FISHING BOATS OF THE WORLD: 2

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Edited by

JAN-OLOF TRAUNG
Chief, Fishing Boat Section, Food and Agriculture Organization of the United Nations, Rome, Italy

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LIST OF CONTRIBUTORS

Page No.

Akasaka, M. 303
President, Akasaka Iron Works Co. Ltd., 3, 1-chome, Ginza, Chuo-ku, Tokyo, Japan.

Alverson, D. L. 101, 128, 133
Chief, North Pacific Fisheries Exploration and Gear Research, U.S. Fish and Wildlife Service, Seattle, Washington, U.S.A.

Arcoulis, E. 249
Managing Director and Project Engineer, Evangelistria Company, Bouboulina 2, Piraeus, Greece.

Bardarson, H. R. . . . 123, 179, 303, 578, 690
Naval Architect and Civil Engineer, Director of Iceland Government Inspection of Shipping, P.O. Box 61, Reykjavik, Iceland.

Beach, D. D. 597
Naval Architect, 3813 South Sheridan Ave., Minneapolis 10, Minnesota, U.S.A.

Beaudoux, E. 97, 308
Directeur Général adjoint, Ateliers et Chantiers de la Manche, rue Charles Bloud, Dieppe (S.M.), France.

Benford, Professor H. 320, 338
Department of Naval Architecture and Marine Engineering, University of Michigan, Ann Arbor, Michigan, U.S.A.

Birkhoff, C. 102, 748, 749
Dipl. Ing., Rickmers Werft, Bremerhaven, Germany.

Boogaard, P. 631
Chief, Shipping Department, Ministry of the Building Industry, Rotterdam, Netherlands.

Bordoli, Dr. Ing. G. 182
Ingegnere Navale e Meccanico, Via Sistina 4, Rome.

Bullis, H. R. 99
Chief, Gulf Fisheries Exploration and Gear Research, U.S. Fish and Wildlife Service, Pascagoula, Mississippi, U.S.A.

Cambiano, A. 609
Architetto Navale, Instituto Nautico, Palermo, Sicily, Italy.

Cardoso, J. C. E. 123, 182
Merchant Marine Inspector General, Ministry of Marine, "Boa Esperanza", Rua 9 de Abril, S. Pedro do Estoril, Portugal.

Carver, Dr. E., Jr. 541
Naval Architect, Ocean Resources Institute Inc., Woods Hole, Massachusetts, U.S.A.

Page No.

Catasta, L. 198
Costruttore Navale, Monte S. Michele, S. Benedetto del Tronto, Italy.

Chapelle, H. I. . 96, 167, 169, 460, 516, 519, 566, 671, 682, 736
Curator, Division of Transportation, Smithsonian Institution, U.S. National Museum, Washington 25, D.C., U.S.A.

Chardome, A. 289, 317
Civil Engineer and Manager, Beliard, Crighton and Co., Ostend, Belgium.

Chardome, P. 525
Managing Director, Chantier Naval de Rupelmonde, Rupelmonde, Belgium.

Chigusa, S. 234
Director, Nissin Kogyo Co. Ltd., Asahi Building, 3, 3-chome, Nakanoshima, Kita-ku, Osaka, Japan.

Claveau, J-M. 97, 98
Directeur, Chantiers Navals Krebs, Concarneau (Finistère), France.

Colvin, T. E. 64
Naval Architect, 1303 North Sheridan Road, Waukegan, Illinois, U.S.A.

Corlett, E. C. B., Ph.D. . . . 627, 695, 698
Managing Director, Burness, Corlett and Partners Ltd., Naval Architects and Marine Consultants, Worthing and London, England, U.K.

Costa, Capitano W. 253
Società Genepesca—Ufficio Tecnico, Viale L. da Vinci 45, Leghorn, Italy.

Crewe, P. R. 540
Chief Engineer (Hydrodynamics), Saunders-Roe Ltd., Head Offices, Osborne, East Cowes, Isle of Wight, England, U.K.

Cristiani, L. 578
Ingegnere Navale, 23 Via Francesco Crispi, Rome.

Crosio, E. 197
Vice-Direttore Tecnologico, Pirelli S.p.A., Viale Abruzzi no. 94, Milan, Italy.

Csupor, Dr. Ing. D. 531
Maierform S.A., 29 rue du Rhône, Geneva, Switzerland.

de Laszlo, P. D. 188, 198
Director, Halmatic Ltd., 10 Upper Berkeley St., London, W.1.

LIST OF CONTRIBUTORS

Page No.

DE WIT, J. G. . . . 56, 95, 96, 123, 197, 581
Deputy Inspector of Shipping, 23 Dokweg, Ijmuiden, Netherlands.

DICKSON, W. 96, 388, 561
Senior Scientific Officer, Marine Laboratory, Aberdeen, Scotland, U.K.

DILNOT, P. F. 741
Stone Marine Engineering Co. Ltd., Woolwich Road, Charlton, London, S.E.7.

DOKE, C. 234
Director, Miho Shipyard Co. Ltd., 7, 3-chome, Yaesu, Chuo-ku, Tokyo, Japan.

DORVILLE, F. 125
MacGregor Comarain S.A. 96 bis, rue du Ranelagh, Paris 16e

DOUST, D. J. . . . 370, 445, 561, 695, 746
Naval Architect, Ship Division, National Physical Laboratory, Feltham, Middlesex, England, U.K.

DREOSTI, DR. G. M. 239, 258
Director, Fishing Industry Research Institute, University of Cape Town, Rondebosch, Cape Town, South Africa.

DU CANE, Commander P. . 541, 542, 547, 576
Managing Director, Vosper Ltd., P.O. Box No. 18, Portsmouth, England, U.K.

DUTRUIT, M. 579
Safety Engineer, 3M Company of St. Paul, Minnesota, 7 Acacias, Prilly, Vaud, Switzerland.

EDDIE, G. C. . . 124, 134, 242, 247, 715, 750, 751
Principal Scientific Officer, Department of Scientific and Industrial Research, Torry Research Station, Aberdeen, Scotland, U.K.

EDGE, Captain, P. F. 134, 556
Manager, Ross Trawlers Ltd., 1 Hutton Road, Grimsby, Lincolnshire, England, U.K.

ESTEVE, V. 99, 124
Arquitecto Naval, Sindicato Nacional de la Pesca, Paseo del Prado, Madrid, Spain.

FEA, E. 196
Ingegnere Navale e Meccanico, Centro Industriale e Navale, Via Ferdinando di Savoia 3, Rome.

FINN, D. B., Ph.D., C.M.G. 21
Director, Fisheries Division, FAO, Rome.

FLINDT, R. I. 304
General Manager, Lister Blackstone Marine Ltd., Long Street, Dursley, Gloucestershire, England, U.K.

FODERÁ, Dr. V. 609
Direttore, Centro Sperimentale Pesca, Palermo, Sicily, Italy.

FUJINAMI, N 536
Naval Architect, Fishing Boat Section, Fisheries Division, FAO, Rome.

GARDNER, J. 515, 557, 673
Technical Editor, *Maine Coast Fisherman*, 33 Glen Park Avenue, Saugus, Mass., U.S.A.

GIANESI, Dott. Ing. G. 249
Ingegnere Refrigerazione, Samifi—Milan, Via Clerici 7, Milan, Italy.

GILLMER, Professor T. C. 341
Department of Marine Engineering, U.S. Naval Academy, Annapolis, Maryland, U.S.A.

GOLDSWORTHY, E. C. 124, 134
Messrs. E. C. Goldsworthy, Estate Buildings, South Road, Weybridge, Surrey, England, U.K.

GOPINATHA PILLAI, Dr. K. 671
Director of Fisheries, Trivandrum, Kerala, India.

GNANADOSS, D. A. S. 171, 672
Assistant Director of Fisheries, B-33, Chidambara Nagar, Tuticorin, India.

GREENHILL, W. A. 303
Managing Director, The Bergius Co. Ltd., 254 Dobbie's Loan, Glasgow, C.4, Scotland, U.K.

GUEROULT, E. R. 654
Architecte Naval, 26 rue Danielle Casanova, Paris 2e.

GURTNER, P. 133, 585, 672
Naval Architect, Fishing Boat Section, Fisheries Division, FAO, Rome.

GUTSCHE, Dr. Ing. F. 522
Löcknitzstrasse 13, Friedrichshagen, Berlin, Germany.

HAMLIN, C. 172, 333
Naval Architect, Manset, Maine, U.S.A.

HANSON, H. C. . . . 101, 137, 167, 185, 332, 574
Naval Architect and Marine Engineer, 102, Pier 52, Seattle 4, Wash., U.S.A.

HANSSON, Captain H. 574, 579
Director, Swedish Sea Rescue Institution, Gothenburg, Sweden

HARDY, Commander A. C., ... 23, 27, 114
39/41 New Broad Street, London, E.C.2.

HARPER GOW, L. M., M.B.E. 126, 748
Shipowner, Chr. Salvesen and Co., 29 Bernard Street, Edinburgh 6, Scotland, U.K.

HEEN, Dr. E. 239
Chief, Technology Branch, Fisheries Division, FAO, Rome.

HEINSOHN, H. . . . 123, 126, 134, 249, 638, 703
Dipl. Ing., Rickmers Werft, Postfach 2066, Bremerhaven 2 Germany.

HENSCHKE, W. 184, 534, 548
Direktor, Schiffbau-Versuchsanstalt, Stühlinger 11, Berlin-Karlshorst, Germany.

LIST OF CONTRIBUTORS

Page No.

HØJSGAARD, J. 96, 307, 580
Chief Engineer, A/S Hundested Motorfabrik, Skansevej, Hundested, Denmark.

HOLT, S. J. 94
Chief, Biology Branch, Fisheries Division, FAO, Rome.

HOPWOOD, G. 274, 315
Chief Engineer, Mirrlees, Bickerton and Day Ltd., Hazel Grove, near Stockport, Cheshire, England, U.K.

HUNTER, A. . 127, 132, 198, 303, 305, 336, 524, 535, 536, 540, 543, 571, 692, 697, 701
Managing Director, Cook, Welton and Gemmell Ltd., Grovehill, Beverley, Yorkshire, England, U.K.

HUSE, H. V. 303
Managing Director, Hydraulik A/S, Brattvag, Norway.

HUTCHINSON, J. G. 582
Administrative Service, Department of Fisheries, Wellington Street, Ottawa, Canada.

INAMURA, K. 295
Chief, Fishing Boat Section, Fisheries Agency; *now* Director, Japan Export Frozen Marine Products Inspectorate Corporation, c/o Kohan Building No. 3, 3-Chome, Kasumigaseki Chiyoda-Ku, Tokyo, Japan.

INKSTER, R. G., M.D. 556
Department of Anatomy, University New Buildings, Teviot Place, Edinburgh, Scotland, U.K.

JABLONSKI, O. 468, 572
Naval Architect, The Maritime Institute, Gdansk, Poland.

JACOBSSON, Professor M. 579
Chairman, Swedish Sea Rescue Institution, Gothenburg, Sweden.

JOHNSSON, N. V. 530, 553
Naval Architect, Nicolovinsgatan 8B, Malmö, Sweden.

JOUDINSTEV, A. F. 572, 750
Engineer, U.S.S.R. Research Institute of Marine Fisheries and Oceanography (VNIRO), Verkhne Krosnoselskaja 17, Moscow, U.S.S.R.

JUL, M. 255, 752
Director, Slagteriernes Forskningsinstitut (The Danish Meat Research Institute), Søndre Ringvej 16, Roskilde, Denmark.

KANASASHI, Y. 73, 97
President, Kanasashi Shipbuilding Co. Ltd., 4010-19, Miho, Shimizu City, Shizuoka Prefecture, Japan.

KLAASSEN, H. 305, 524, 580
Chief Engineer, Lips Propeller Works, Drunen, Netherlands.

KOBAYASHI, T. 146, 348
Naval Architect, Fishing Boat Laboratory, Fisheries Agency, Tsukishima, Chuo-Kui, Tokyo, Japan.

KOSSA, M. 320, 338
Naval Architect, Department of Naval Architecture and Marine Engineering, University of Michigan, Ann Arbor, Michigan, U.S.A.

KREUZER, Dr. R. 239
Chief, Fish Processing Section, Fisheries Division, FAO, Rome.

KRISTJONSSON, H. 94, 97, 101, 128, 133
Chief, Fishing Gear Section, Fisheries Division, FAO, Rome.

KUMMERMAN, H. 748
Président-Directeur Général, MacGregor Comarain S.A., 96 bis, rue du Ranelagh, Paris 16e.

LACHENAL, I. D. 676
President, Inter-Island Deep-Sea Fishing Association, Navotas, Rizal, Philippines.

LACKENBY, H. . 298, 364, 511, 535, 539, 694, 697
Chief Naval Architect, The British Shipbuilding Research Association, 5 Chesterfield Gardens, Curzon Street, London, W.1.

LEROUX, R. 304
Directeur, Société Anonyme des Anciens Chantiers Dubigeon, 1 Boulevard de Chantenay, Nantes (Loire-Inférieure), France.

LEWIS, Professor E. V. 535, 548, 554
Head, Ship Division, Davidson Laboratory, Stevens Institute of Technology, 711 Hudson Street, Hoboken, New Jersey, U.S.A.

LINDBLOM, J. 182
Dipl. Ing., Oy Laivateollisuus Ab, Åbo, Finland.

MACCALLUM, W. A. . . . 197, 208, 242, 258, 750
Research Engineer, Fisheries Research Board of Canada, Technological Station, P.O. Box 429, Halifax, Nova Scotia, Canada.

MCGRUER, E. 179, 196, 557, 671
Boatbuilding Officer, Scottish Country Industries Development Trust, 27 Walker Street, Edinburgh, Scotland, U.K.

MALIG, J. B. 676
Fisheries Technician, Department of Agriculture and Natural Resources, Bureau of Fisheries, Manila, Philippines.

MEWSE, H. V. N. 274
Marine Superintendent, J. Marr and Son Ltd., Fleetwood, Lancashire, England, U.K.

MILLER, W. C. 505
Naval Architect and Marine Engineer, Wm. C. Miller and Associates, 577 Spreckles Building, San Diego 1, California, U.S.A.

MILLER, W. P. 180, 556, 697
Managing Director, James N. Miller and Sons Ltd., East Shore, St. Monance, Fife, Scotland, U.K.

MILNE, G. S. 124, 692, 750
Shipyard General, Manager, John Lewis and Sons Ltd., 186 Albert Quay, Aberdeen, Scotland, U.K.

MINOT, P. 124, 541, 572, 755
Naval Architect, Woods Hole Oceanographic Institution, Woods Hole, Mass., U.S.A.

MITSUI, T. 95, 197, 249, 547
Chief of Hull Designing Section, Shimonoseki Works, Mitsubishi Shipbuilding and Engineering Co. Ltd., Enoura-l, Shimonoseki, Japan.

LIST OF CONTRIBUTORS

Page No.

Möckel, Captain W. 404, 561
Naval Architect, Hamburgische Schiffbau-Versuchsanstalt, Bramfelderstrasse 164 (24), Hamburg 33, Germany.

Muramatsu, S. 84
Chief, Design Section, Yaizu Shipbuilding Co. Ltd., Yaizu City, Shizuoka Prefecture, Japan.

Ninomiya, M. 295
Fishing Boat Laboratory, Fisheries Agency, 1, 2 Kesumigeseki, Chiyoda-Ku, Tokyo, Japan.

Nutku, Professor A. 517, 573, 675
Department of Naval Architecture, Technical University, Istanbul, Turkey.

O Meallain, S. 249, 336, 672, 750
Chairman, Au Bórd Iascaigh Mhara; Inspector and Engineer, Fisheries Division, Department of Lands, 3 Cathal Brugha Street, Dublin.

Orszulok, W. 95, 308, 741, 750
Naval Architect and Main Director, Central Design Office, United Polish Shipyards, Gdansk, Poland.

Osti, O. 253
Ingegnere Refrigerazione, Societa Ing. G. Dell'Orto, Via Merano 18, Milan, Italy.

Otsu, Y. 146, 348, 550, 554
Chief, Fishing Boat Laboratory, Fisheries Agency, 1, 2 Kesumigeseki, Chiyoda-Ku, Tokyo, Japan.

Pain, Commander H. E. H. 114, 134
S. G. Brown Ltd., Shakespeare Street, Watford, Hertfordshire, England, U.K.

Parkes, Sir Fred 95, 123, 249, 303
Chairman and Managing Director, Boston Deep Sea Fisheries Ltd., 238 Dock Street, Fleetwood, Lancashire, England, U.K.

Paul, D. A. 693
Naval Architect, Hall, Russell and Co. Ltd., 16 Carlton Place, Aberdeen, Scotland, U.K.

Paulling, Professor J. R., Jr. . . 489, 574, 577
Department of Naval Architecture and Marine Engineering, University of California, Berkeley 4, California, U.S.A.

Popper, F. E. 337
Chief, Economics Branch, Fisheries Division, FAO, Rome.

Proskie, J. 94, 122, 242, 332, 519
Department of Fisheries, Ottawa, Canada.

Pruchnie, E. 244
Marine Sales Manager, Donald MacPherson and Co. Ltd., 27 Albion Street, Manchester 1, Lancashire, England, U.K.

Qureshi, Dr. M. R. 674
Director, Central Fisheries Department, Saddar, Karachi 3, Pakistan.

Rahola, Professor J. 571
Rector of the Institute of Technology, Helsinki, Finland.

No.

Ranken, Commander M. B. F. 242, 255, 701, 741, 748, 752
J. and E. Hall Ltd., Dartford Ironworks, Dartford, Kent, England, U.K.

Rappini, Dott. Ing. G. 309
Direttore del Laboratorio, Ansaldo S.A., Piazza Carignano, Genoa, Italy.

Rapson, Dr. A. M. . . . .
Division of Fisheries, Department of Agriculture, Stock and Fisheries of the Papua and New Guinea Administration, Port Moresby, Papua, Australia.

Rasalan, S. B. 676
Chief, Division of Marine Fisheries, Bureau of Fisheries, Manila, Philippines.

Reay, Dr. G. A. 200, 258
Director, Department of Scientific and Industrial Research, Torry Research Station, Aberdeen, Scotland, U.K.

Remøy, Captain S. 542, 570, 580, 581
Government School of Fisheries, Florö, Norway.

Reyes Risoto, E. 98
Tecnico Naval, Ave. 33—5603, Apto. 2, e/56 and 58, Marianau, Habana, Cuba.

Rijken, H. 422
Naval Architect, Netherlands Ship Model Basin, Wageningen, Netherlands.

Ringhaver, L. C. 615, 690
President, Diesel Engine Sales Inc., St. Augustine, Florida, U.S.A.

Roden, S. 576
Naval Architect, Department of Naval Architecture, Technical University of Hamburg, Germany.

Roscher, E. K. 528
Dipl. Ing., Kirchenallee 57, Hamburg 1, Germany.

Salomon, H. 308
Manager, Svend s.i.a.s., Via Montevideo 20, Rome.

Santarelli, M. 684
Ingeniere Naval y Mecànico, Hipólito Yrigoyen 723-4° Piso-of. 31, Buenos Aires, Argentina.

Sará, Dott. R. 609
Centro Sperimentale della Pesca, Palermo, Sicily, Italy.

Sato, S. 723
Chief, Design Section, Hitachi Shipbuilding and Engineering Co. Ltd., Innoshima Shipyard, Innoshima, Hiroshima Prefecture, Japan.

Schärfe, Dr. J. 121, 125
Gear Technologist, Fishing Gear Section, Fisheries Division, FAO, Rome.

Schmidt, P. G., Jr. 31, 128
President, Marine Construction and Design Co., 2300 Commodore Way, Seattle 99, Wash., U.S.A.

LIST OF CONTRIBUTORS

Page No.

SEGHERS, V. 309
Constructeur-Armateur, Chantiers et Armement Seghers, Quai du Slipway, 4, Ostend, Belgium.

SEN, B. R. 19
Director-General, FAO, Rome.

SHEWAN, Dr. J. M. 200, 258
Department of Scientific and Industrial Research, Torry Research Station, Aberdeen, Scotland.

SICKLES, Lieut.-Commander C. M. 581
U.S. Coast Guard, O. in C., Merchant Marine Detail, c/o American Consulate General, Naples, Italy.

SILVA, Commodore D. D. 242
Chairman of "Commissão Central das Pescarias", Member of the National FAO Committee, Rua D. Constantine Bracança 10, Lisbon, Portugal.

SIMPSON, D. S. 134, 152, 185, 304, 569, 581, 694, 745
Naval Architect, 200 Summer Street, Boston 10, Massachusetts, U.S.A.

SLAVIN, J. W. . . . 227, 247, 261, 745, 749
Mechanical Engineer, Fishery Technological Laboratory, Division of Industrial Research and Services, U.S. Bureau of Commercial Fisheries, East Boston, Mass., U.S.A.

SMITH, J. D. 688
Joe D. Smith and Associates, Consulting Engineers, 1202 Graycroft Avenue, Madison, Tenn., U.S.A.

SOUBLIN, L. 124, 735
Président de la Fédération des Armateurs à la Pêche de France, Quai Guy de Maupassant, Fécamp (Seine-Maritime), France.

STEEL, H. E., C.B.E. 198, 576
Director, Burness, Corlett and Partners Ltd., 41 St. Mary Axe, London, E.C.3.

STRAKOSH, F. 246
Consulente navale, Via A. Rendano 18, Rome.

STOKKE, I. 261, 313
Head, Department of Internal Combustion Engines, The Technical University of Norway, Trondheim, Norway.

SVENKERUD, H. 17
Naval Architect, Fishing Boat Section, Fisheries Division, FAO, Rome; *now* A/S Nordisk Aluminium Industri, Løkkeveien 9, Oslo, Norway.

SWIECICKI, J. 708
The Maritime Institute, Gdansk, Poland.

SWINFIELD, A. N. 169
Naval Architect, 30 Grosvenor Street, Sydney, N.S.W., Australia.

SÜBERKRÜB, F. 285
Consulting Naval Architect, Chilehaus CVI, Hamburg 1, Germany.

SUTHERLAND, A. 180
Senior Technical Officer, White Fish Authority, 5 Forres Street, Edinburgh, Scotland, U.K.

Page No.

TAKAGI, Professor A. . 96, 175, 475, 576, 577, 754
Department of Naval Architecture, Faculty of Engineering, University of Tokyo, Bunkyo-Ku, Tokyo, Japan.

TAKAHASHI, S. . . . 126, 303, 661, 750
Executive Director, Hayashikane Shipbuilding Co. Ltd., Shimonoseki, Japan.

TANIGUCHI, K. 453
Chief, Nagasaki Experimental Tank Laboratory, Mitsubishi Shipbuilding and Engineering Co. Ltd., Nagasaki, Japan.

THIBERGE, F. 573
Ingénieur, Bureau Veritas, Rue Henri Rochefort 31, Paris 17e.

TITO, J. M. 671
European Representative, Outboard Marine International S.A. of Nassau, Bahamas; Bruges, Belgium.

TODD, Dr. F. H. 304, 542, 543, 548
Superintendent, Ship Division, National Physical Laboratory Feltham, Middlesex, England, U.K.

TOTHILL, J. T. 353, 555, 559
Naval Architect, Ship Laboratory, National Research Council, Ottawa, Canada.

TOWLE, E. L. N. 743
Assistant Chief Engineer, Industrial and Marine Division, Motor Engineering Department, Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, England, U.K.

TRAUNG, J-O. . 98, 133, 167, 183, 196, 428, 546, 562, 575, 582, 673, 690, 755
Chief, Fishing Boat Section, Fisheries Division, FAO, Rome.

TSUCHIYA, T. 542
Naval Architect, Fishing Boat Laboratory, Fisheries Agency, Tsukishima, Chuo-Ku, Tokyo, Japan.

TYRRELL, J. 99, 176, 540, 542, 555
Managing Director, John Tyrrell and Sons Ltd., South Quay, Arklow, Co. Wicklow, Ireland.

VAN MANEN, Dr. J. D. 422, 562
Under-Director, Netherlands Ship Model Basin, Wageningen, Netherlands.

VARRIALE, L. 307
Ingegnere, Società Ansaldo, Genoa, Italy.

VENUS, J. 101, 198, 624, 695, 698
Managing Director, Seawork Ltd., 41 St. Mary Axe, London, E.C.3.

VÖLKER, Professor Dr. Ing. H. 337
Institut für Schiffstechnik der Technischen Hochschule, Gusshausstrasse 25, Vienna IV, Austria.

VON BRANDT, Professor Dr. A. . . 102, 122, 133
Direktor, Institut für Netz- und Materialforschung, Neuer Wall 72, Hamburg 36, Germany.

VOSSERS, G. 393, 422, 555, 561
Head, Seakeeping Laboratory, Netherlands Ship Model Basin, Wageningen, Netherlands.

LIST OF CONTRIBUTORS

Page No.

WEINBLUM, Professor Dr.-Ing. G. P. . . . 515, 535, 540, 547, 567, 569
Head, Department of Naval Architecture, University of Hamburg, Hamburg, Germany.

WENDEL, Professor Dr.-Ing. K. 491, 577
Head, Department of Naval Architecture, Technical University of Hannover, and Professor at the University of Hamburg, Stubbenhuk 10, Hamburg 11, Germany.

YOKOYAMA, N 146, 348
Naval Architect, Fishing Boat Laboratory, Fisheries Agency, Tsukishima, Chuo-Ku, Tokyo, Japan.

ZIENER, P. B. 178, 668, 750
Naval Architect, Tingstuveden 26, Oslo, Norway.

ZIMMER, H. K. 178
Naval Architect, Postboks 1130, Bergen, Norway.

ZWOLSMAN, W. 185, 334, 418, 524
Naval Architect, Holland Launch H.V., Zuiddijk 218, Zaandam, Netherlands.

NOMENCLATURE AND SYMBOLS*

A. TECHNICAL TERMS

A = Lateral area of ship's profile, including erections, exposed to wind

A_b = Blade area, developed (to shaft centre)

A_d = Blade area, developed (outside boss)

A_e = Blade area, expanded

A_m = Midship section area

A_p = Blade area, projected (outside boss)

A_w = Waterplane area

AC = Alternating current

AP = Aft perpendicular

B = Breadth or beam in waterline; Centre of buoyancy

BAR = Blade area ratio (outside boss)

BG = Height, centre of gravity above centre of buoyancy

BHP = Brake horsepower

BM = Height, metacentre above centre of buoyancy

BM_l = Height, longitudinal metacentre above centre of buoyancy

BM_t = Height, transverse metacentre above centre of buoyancy

b = Centre of buoyancy of thin layer of fluid

C_1 = Admiralty constant (Resistance)

C_2 = Admiralty constant (Self-propulsion)

Ⓒ = Resistance constant (Froude's circular C)

C_b = Block coefficient, also δ

C_m = Midship area coefficient, also β

C_p = Prismatic coefficient, also φ

C_r = Residuary resistance coefficient

C_w = Waterplane area coefficient, also α

CB = Centre of buoyancy

CG = Centre of gravity

CN = Cubic number

CP = Controllable-pitch propeller

c = Speed of waves; Chord length of propeller at 0.7 R

D = Depth; Propeller diameter

D_b = Diameter of boss at rake line

DAR = Disc area ratio (to shaft centre)

DC = Direct current

DHP = Delivered horsepower to propeller

d = Draught, also T; Distance between centre of wind pressure and centre of water pressure

EHP = Effective horsepower (tow rope horsepower from resistance tests)

F_p'' = Pitch acceleration at FP

FP = Forward perpendicular

f = Freeboard

G = Centre of gravity; Girth amidships

GM = Height, metacentric

GM_l = Height, longitudinal metacentric

GM_t = Height, transverse metacentric

GZ = Stability lever

GZ_h = Heeling lever

GZ_r = Righting lever

g = Acceleration due to gravity

h = Distance from centre of roll to crew's position; Wave amplitude

h_w = Height of wave

I = Moment of inertia

I_l = Longitudinal moment of inertia of waterplane

I_t = Transverse moment of inertia of waterplane

IHP = Indicated horsepower

J = Advance number

K = Keel, at midship section

Ⓚ = Speed—Displacement constant (Froude's circular K)

K_q = Torque coefficient

K_t = Thrust coefficient

KB = Height, centre of buoyancy above keel

KG = Height, centre of gravity above keel

KG_o = Maximum height of centre of gravity above keel from operational conditions

KG_s = Maximum height of centre of gravity above keel considering stability criteria

KM = Height, metacentre above keel

KM_l = Height, longitudinal metacentre above keel

KM_t = Height, transverse metacentre above keel

k = Radius of gyration; Wave number

k_l = Longitudinal radius of gyration

k_t = Transverse radius of gyration

L = Length in waterline

$\bar{L}$ = Length between perpendiculars, also LBP

L_e = Length of entrance

L_p = Length of parallel middle body

L_r = Length of run

LBP = Length between perpendiculars, also $\bar{L}$

LCB = Longitudinal centre of buoyancy

LCF = Longitudinal centre of flotation

LCG = Longitudinal centre of gravity

LOA = Length overall

l = Any length defined in particular

M = Metacentre

M_h = Heeling moment

M_t = Heeling moment due to centrifugal forces when turning

M_w = Heeling moment due to wind forces

$M\varphi$ = Intersection of line of action of buoyancy and centreline, at an angle of heel φ

MCT1in = Moment to change trim one inch

m = Mass; coefficient

N = Revolutions per minute

n = Revolutions per second

P = Pitch propeller; Trawl pull

P_d = Pitch propeller (boss)

P_e = Pitch propeller, mean effective

P_m = Pitch propeller, mean (face)

P_t = Pitch, propeller tip

PC = Propulsive coefficient

p_e = Mean effective pressure

Q = Torque

QPC = Quasi propulsive coefficient

R = Radius, propeller; Resistance

R_f = Resistance, frictional

R_r = Resistance, residuary

R_t = Resistance, total

S = Surface, wetted

*Compiled by H. Svenkerud.

A. TECHNICAL TERMS—*continued*

Ⓢ	=	Wetted-surface constant (Froude's circular S)
SHP	=	Shaft horse power
T	=	Draught, also d; Thrust; Period; Temperature
T_a	=	Draught at after perpendicular
T_e	=	Period of encounter
T_f	=	Draught at forward perpendicular
T_l	=	Draught, loaded
T_o	=	Draught, light
T_p	=	Period of pitch
T_r	=	Period of roll
T_z	=	Period of heave
TPI	=	Tons per inch immersion
t	=	Thrust deduction fraction; Thickness at shaft axis
t_r	=	Cylindrical thickness at root
U	=	Resultant inflow velocity at 0.7 R
V	=	Speed in knots
V_a	=	Speed of advance of propeller (knots)
V_w	=	Speed, wind
VP	=	Variable pitch propeller
v	=	Speed in ft./sec. (m./sec.)
w_f	=	Wake fraction (Froude)
w_t	=	Wake fraction (Taylor)
y	=	Horizontal shift of centre of gravity of fluid
Z	=	Heave amplitude; Section modulus
z	=	Vertical shift of centre of gravity of fluid
α	=	Waterplane area coefficient, also C_w; Wave direction
α_e	=	Waterplane entrance coefficient
α_i	=	Angle of nozzle profile relative to shaft line
$\frac{1}{2}\alpha_e$	=	Half angle of entrance
β	=	Midship area coefficient, also C_m
∇	=	Displacement, volume of in cubic metres
∇_s	=	Displacement, volume of in cubic feet
Δ	=	Displacement, weight of in metric ton; Small increment (e.g. Δ SHP)
Δ_s	=	Displacement, weight of in long tons
ΔK_t	=	Thrust increase coefficient
ΔT	=	Thrust increase
δ	=	Block coefficient, also C_b
ε	=	Phase angle
ζ_w	=	Wind pressure coefficient
η	=	Efficiency
η_b	=	Efficiency, propeller behind ship
η_h	=	Efficiency, hull
η_o	=	Efficiency, propeller in open
η_p	=	Efficiency, propulsive
η_r	=	Efficiency, relative rotative
η_{rest}	=	Efficiency, rest
η_t	=	Efficiency, trawling
ϑ	=	Wave direction
Λ	=	Tuning factor
Λ_p	=	Tuning factor, pitch
Λ_z	=	Tuning factor, heave
λ	=	Wave length; Coefficient of heat conductivity
μ	=	Wave frequency
ν_m	=	Maximum wave slope
ρ	=	Density (mass per unit volume)
ρ_a	=	Density of air
φ	=	Prismatic coefficient, also C_p; Angle of roll
φ_e	=	Prismatic coefficient, entrance
φ_r	=	Prismatic coefficient run; Range of angles of heel giving positive righting levers
φ_s	=	Angle of heel of maximum righting lever
χ	=	Yawing
ψ	=	Angle of pitch
ω	=	Angular velocity; frequency
ω_r	=	Natural frequency

B. MEASUREMENTS

A	=	Ampere(s)
BTU	=	British thermal unit(s)
°C	=	Degree(s) Centigrade
cal.	=	Calorie(s)
cm.	=	Centimetre(s)
c.p.m.	=	Cycles per minute
c.p.s.	=	Cycles per second
cu.	=	Cubic
°F	=	Degree(s) Fahrenheit
fm.	=	Fathom(s)
ft.	=	Foot or Feet
GT	=	Gross tonnage
g.	=	Gramme(s)
gal.	=	U.S. gallon(s)
h.p.	=	Horsepower(s)
hr.	=	Hour(s)
Imp. gal.	=	Imperial gallon(s)
in.	=	Inch(es)
kcal.	=	Kilocalorie(s)
kg.	=	Kilogramme(s)
km.	=	Kilometre(s)
kW	=	Kilowatt(s)
l.	=	Litre(s)
lb.	=	Pound(s), avoirdupois
m.	=	Metre(s)
min.	=	Minute(s)
ml.	=	Millilitre(s)
mm.	=	Millimetre(s)
NT	=	Net tonnage
oz.	=	Ounce(s), avoirdupois
RT	=	Tons of refrigeration
rad.	=	Radian(s)
r.p.m.	=	Revolutions per minute
r.p.s.	=	Revolutions per second
sec.	=	Second(s)
sq.	=	Square
ton	=	Metric ton(s) = 1,000 kg. = 2,204 lb. avoirdupois = 0.984 long ton = 1.102 short ton
tons	=	Long ton(s) (British)
V	=	Volt(s)
W	=	Watt(s)

C. ABBREVIATIONS

cyl.	=	Cylinder(s)
diam.	=	Diameter
fig.	=	Figure(s)
mld.	=	Moulded
p.	=	Page
pp.	=	Pages
vol.	=	Volume
wt.	=	Weight

This list is based on BSRA's Standard Nomenclature and Symbols (1949), but has also been partly influenced by individual usage and ITTC's 1951 recommendations. Under no circumstances must it be interpreted as an official FAO suggestion, as it is hoped that in 1960 the ITTC will achieve international agreement on naval architecture nomenclature.

PREFACE

THE Second FAO World Fishing Boat Congress, held in Rome from 5 to 10 April, 1959, provided an inspiring example of international co-operation, and the generous response in attendance and technical contributions showed clearly the importance now attached by governments to fishing boat design in the wider context of over-all efficiency of the fishing industry, safety of fishermen at sea and advancement of human nutrition.

FAO has been the spearhead of much pioneering work in the improvement of production techniques in agriculture, forestry and fishery, and this Congress was among the most fruitful it has initiated. The Congress illustrated one of the methods FAO uses to secure the exchange of ideas and to disseminate information. It did not come about in an *ad hoc* manner. It was a carefully prepared part of a very much larger plan of attack on one of the most crucial problems that face the world: that of increasing food production, particularly animal protein foods, to meet the demands of a world population which is increasing at a fast rate. The population of the world today is about 2,800 million, and is increasing at the average rate of 1.6 per cent. per annum. According to a recent United Nations survey, it has been estimated that the world population might double itself by the end of this century. This will undoubtedly exert a tremendous strain on the world's food resources. Even to maintain the current unsatisfactory levels of nutrition, special efforts will be needed to increase agricultural and industrial production. One source which may make a notable contribution to world food supplies is the inland water and oceans. These waters cover about seven-tenths of the world's surface, and produce mostly animal protein food, but at the present time not more than 1 per cent. of the food consumed by human beings is derived from this source. The importance of scientific and technical developments to increase man's ability to utilize the resources of the sea can, therefore, be easily realized. Compared with farming, fishing still remains more of a hunting operation. It is not difficult to see that as husbandry gradually takes the place of hunting, the oceans will yield larger harvests of fish, and, in this field, the work of the Fishing Boat Congress made, I am sure, a significant contribution.

The fishing boat constitutes the heaviest part of investment in the fishing industries of highly developed countries, higher than the investment in harbours, canning plants and retail stores. A recent investigation in Canada showed that vessels accounted for 67 per cent. of the total investment of the Canadian fishing industry, as against 45 per cent. in 1917, and 59 per cent. in 1935. This fact underlines the dominant position of fishing vessels in the economics of the fishing industry and how important is the need to increase their efficiency in the effort to catch more fish. Such an increase will not only add to the world's food supplies but will also increase the prosperity of the world's fishing industries, and raise the living standards of the fishermen.

Awareness of the need to increase the efficiency of boats is reflected in the fact that more naval architects are being employed in the design and construction of fishing craft, and that professors of naval architecture and shipbuilding research organizations are starting to work on improving designs of fishing boats. The proceedings of the Congress, which are published in this volume, FISHING BOATS OF THE WORLD: 2, point to the trends and developments arising from this new interest. Technically, the book is both supplementary and complementary to volume No. 1 of the same title, based on the proceedings of the first Congress, and it will be, I feel, equally, if not more widely, welcomed.

The first Congress in 1953 played an important part in drawing the attention of governments to the contribution that naval architects could make to the efficiency and prosperity of fishing industries. Indeed, until a few years ago, government activity in the fishing industry was mainly in the hands of biologists. In 1950, when FAO first employed a naval architect, only the governments of Norway and Japan had established posts for naval architects. The situation has improved since then, and some other governments, such as those of India, Israel, Newfoundland and Turkey, have since employed naval architects. In Canada, France, Germany, U.K. and U.S.A., naval architects have been employed in semi-government research institutions engaged in fishing boat development work, but, on the whole, naval architects are still the exception rather than the rule in national fishery administrations. But several governments are now considering the establishment of fishing boat departments to help promote the development of the fishing industry.

In this respect there is much to encourage the hope that the resources of the seas and oceans, the lakes and rivers and other waters, can yield much more food for human consumption than is at present harvested from them. For example, in recent years experience has shown that pelagic fish, such as the tuna, may be caught over wide areas of the oceans and seas. The Japanese are making substantial catches of such species in the South Atlantic, while French fishermen, operating from Dakar in West Africa, have built up a tuna fishing industry. Again, the Mediterranean is generally regarded as a poor fishing sea and until recently shrimp fishing was of little importance there. But, a few years ago, French fishermen discovered substantial stocks of big, excellent quality shrimp and, as a result, trawlers from Algeria, Egypt, Italy and Turkey are fishing these stocks. Another outstanding example has been the rapid development of the pilchard fishery in South Africa and the ansiovy fishery off Peru. Here are thriving fisheries which have been developed in a few years and have already yielded millions of tons of fish.

I mention these few examples to indicate something of the huge potential of the sea. Marine biologists have concluded that it should be possible to increase the world commercial catch of fish from about 30 to 60 million tons a year from existing known stocks. But, of course, if this is to be done then an essential development, among other things, is an improvement in fishing boat design and performance throughout the world and not only in a few of the more advanced countries. One of the most significant contributions made by the Second FAO World Fishing Boat Congress has been to help spread this knowledge internationally.

While the Second FAO World Fishing Boat Congress was an important milestone, much remains to be done before fishing boat design as a whole reaches the technical level achieved in the design of other types of ships. The application of science and modern techniques to the improvement of agriculture has yielded highly beneficial results, both to the producer and the consumer. The same process could make the fishing boat more efficient, thereby producing more food for the world while bringing to the fishermen a higher standard of living.

B. R. SEN
Director-General of FAO

INTRODUCTION

IT has already been demonstrated how the ingenuity of mankind can reach out to space and the stars, an ingenuity we also need to turn earthwards towards the art of living. Imagination plays a great part in determining what the future holds. Before ever there was a wheel, somebody imagined what a wheel was like; before ever there was a sidewalk or pavement, somebody conceived the idea; before there was a sail or a steam engine, there was a dream on somebody's part, and so ideas always precede things.

My collaborators, besides being practical, hard-headed technicians and scientists, also have this valuable gift of imagination. Some of them have put forward an idea which, at first sight, seems so fanciful as to be impossible—that is to fish from submarines to escape the perils of weather and to increase fish catching efficiency. But progress in fish finding and in the capture of fish is so rapid that the adaptation of these techniques to submarine fishing has become largely a matter of applied engineering. Submarine fishing may seem impossible today, but I should not be at all surprised to see it in practice tomorrow. And perhaps this is another way in which atomic energy may be turned to peaceful uses. The application of ingenuity, founded on proper scientific and technical knowledge, leads to progress.

Since the 1953 First Boat Congress there have been many new developments. Chilled sea water for preserving the catch is being introduced on the Pacific Coast of the Americas. Large powered blocks are being introduced to handle encircling nets. More fishing vessels are being built with transom sterns, and even bulbous bows are now used on large trawlers. Stern trawling is being adopted on large factory trawlers, and there have also been advances in the design of diesel and free piston machinery, as well as in the design of propellers. Wooden hulls, as another example, are still built in different strengths in many countries. Standardization of scantlings and better methods of construction of such ships could lead to substantial economies. New materials, such as plastic, are being introduced and recently there has been much progress in our knowledge of the behaviour of ships in a seaway which could be applied to the design of fishing vessels.

The fishing boat—particularly that below 100 ft. (30 m.)—is a much neglected sector of the fishing industry in spite of the fact that it has such a lot to do with the efficiency of fishing or fishing operations. It was, therefore, an encouraging experience to see that so many professional and technical men from many countries came, at their own expense, and contributed to the Second World Fishing Boat Congress. This fact in itself illustrates the awakening of world interest in fishing boat design, construction and performance.

I would like first of all to thank those from outside FAO who, over the past six years, and more particularly in the last two years, gave unstintingly and freely of their time in organizing the Congress.

It is very seldom that I have had the privilege of following a Congress which has been marked by harder work or such vigorous discussion, and I think that all who shared this experience feel that the meeting was a rewarding success. This can particularly be attributed to the following:

- The amount of preparation that went into the Congress
  Work on it was started in 1957 by the Secretariat, with the assistance of a Committee
- The high level of the papers
- The professional and technical competence of those attending, which was reflected in the discussions
- The very effective leadership of your Chairman, Commander A. C. Hardy (U.K.) and the Vice-Chairmen, Professor A. Takagi (Japan), Professor G. Weinblum (Germany), M. E. R. Gueroult (France) and Mr. H. C. Hanson (U.S.A.). I also want to mention Mr. J. G. de Wit (Netherlands).

INTRODUCTION

I noted at this Congress the emphasis upon the human factor, on the people who have to go to sea. This is a factor of over-riding importance which has sometimes, in the past, been overlooked, but the meeting showed that the designers, engineers and managers of today are taking it fully into account.

There was also the discussion on new materials and the adaptation of skills and of sciences that have been developed in shipbuilding, which showed not only awareness of present day scientific and technical advances but also an example of the use of imagination.

No meeting of this kind can deal adequately with all the subjects in its field and, without doubt, many aspects of fishing boat design, construction and performance should have been treated in more detail. Personally, I feel still more attention should have been focussed on small vessels, craft which are only just beginning to receive attention from naval architects, technicians and engineers. Perhaps the theme of the 1965 Congress should be "Mechanised craft of less than 100 tons".

The vast majority of fishing boats in the world are certainly of less than 100 tons, most of them, indeed, are of only a few tons but it is these numerous fleets of small boats plying their trade off the coasts of all the fishing countries of the world which have, in the past, been most neglected by the naval architect, boat designer and builder and engineer. Yet, paradoxically, these are the boats that are most likely to benefit from the attention of the scientist and engineer and this is one reason why I should like to see them be the centre of interest and attention at our next congress.

To sum up, I think that this Congress pointed to the upward trend of the application of science, technology and engineering to fishing boats. Meetings of this kind are essential in encouraging progress in the world, and I doubt if there will ever come a time when it will not be necessary to exchange knowledge and opinions and exercise our imagination. The action, therefore, of the governing body of FAO in providing for these congresses at intervals of six years or thereabouts is a wise provision.

D. B. Finn
Director, Fisheries Division, FAO

NOTE FROM THE CHAIRMAN

THE fishing boat is not only a large part of the investment in the fishing industry as a whole; we must also realize that each individual boat is costly. £40,000 or $100,000 is not too much money for a medium-sized fishing vessel. A modern British super-trawler costs £300,000, or $1,000,000, today, and most recent factory ships cost some £1,000,000, or $3,000,000.

In view of the many hundreds of thousands of fishing boats in use under different weather conditions, in various areas, it should seem easy to ascertain from fishermen the hull shape to combine best sea behaviour with least resistance. This is, unfortunately, not the case; it is virtually impossible to get reliable information from talking to fishermen because they mostly have too little experience of the sea behaviour of different boat types and sizes and they have a tendency to confuse their observations. The laws of naval architecture often fly in the face of common sense; a longer or a lighter boat will always be better in waves than a shorter one, even if non-dimensionally it is inferior; ballast sometimes makes a boat roll most uncomfortably. The fisherman has not always the knowledge necessary to separate such factors and might conclude that a longer boat is better due to its shape, when perhaps the reason is only the length. Furthermore, during his lifetime a fisherman usually sails only about a dozen boats, mostly from the one port, and of a similar type; so his experience on different boat types is normally very limited in contrast to his experience of catching fish.

Nobody would think—if designing a transatlantic liner—of asking members of a crew to specify the design: this is based on research and a careful study of conditions, analysis of operating conditions and the co-ordination of technical and economic aspects. If fishing boats are to be improved, the same analytical approach is definitely necessary. Science must play as important a part in fishing as it has played in agriculture, forestry and nutrition. I think the time has come for naval architects to realize that if we wish to design better fishing boats we must operate very closely with all disciples of fisheries science. The term "fisheries science" is comparatively new, but it is probably the best way of describing the change from unplanned hunting to the organized utilization of the untapped resources of the sea.

Therefore, at the Second FAO World Fishing Boat Congress we had not only naval architects; we had biologists, we had practical fishermen themselves, who gave their point of view. We also had very distinguished fishing boat owners and builders. And in a long experience of national and international conferences I have never been to one in which there was so much real friendliness. And furthermore, I feel this particularly as Chairman, I have never been to a conference which was harder work, because the speed of discussion was really terrific. The volume of questions was torrential. And in dealing with the matter from the Chair, it was rather like trying to turn off a shower in a bath-tub because you realized that you had only a certain amount of time to give to any particular subject. Some people were good; they talked slowly and deliberately, and they kept to the rules of the length of speaking. But others went on and on. But the trouble was that they weren't just talking. They were talking "good stuff". So how possibly could you extract the maximum from it and let people feel that everybody was satisfied?

However we invited participants and those who had no opportunity to attend to expand their remarks in writing. This invitation has been acted upon to a very great extent and the 225-page discussion in this book probably constitutes somewhat of a record for a four days technical meeting of this kind. Naturally some condensation has been necessary, but I am happy to note, as I did in my introduction to the first fishing boat book that "the opinions are presented as they have been expressed and just as often as they occur. No attempt is made to talk down to the reader or to tell him what he ought to do". This book has the thickness of a very large Bible and indeed, together with the first book, it will be a super-Bible for fishing boat builders and designers for a long time to come.

The Second FAO World Fishing Boat Congress was very worthwhile, and I would like to say quite definitely that nobody could have done this better than the appropriate United Nations body—the

FAO Fisheries Division. In organizing technical meetings one very easily loses one's sense of proportion but because this was an integral part of the activities of the FAO Fisheries Division, it had a very good balance.

At the last Congress we did not dare to take you as far as atomic propulsion, but in the discussion on the 1975 fishing boat Professor A. Takagi from Tokyo made some suggestions along these lines.

Now, it means just this: that if the Japanese are right, and if they can produce these atomic ships, that the factory can stay at sea for maybe two years. Well, you'll say: that's ridiculous. What about the poor crew? I say: That's all right, don't worry about that. Undoubtedly, such a ship would have a flight deck. And every six months, or less, if necessary, crew A would be flown home and crew B would be flown out. And possibly too, the catch, the frozen packaged fillets of fish, would be flown away out of the freezing hold in the ship. So this ship might be fishing up in the north, and within 24 hours a freshly filleted, deep-frozen packaged piece of plaice or sole could be enjoyed by someone in Alice Town in the middle of Australia. This is not a flight of fancy, it is a distinct possibility, and I give it to you as an idea of the tremendous pace of life today. And as this book goes to press we have news of a proposal to use surplus aircraft carriers as mother- and/or factory-ships. The way in which the air is leading us by the nose, the whole tempo of life is being speeded up. It is time we did speed up the tempo of the fishing industry in view of the fact that only a fraction of 1 per cent. of the food we eat comes from the oceans and seas, although they cover more than 70 per cent. of the surface of the world—some 90,000,000 square miles. Old style fishing is not good enough to-day. We have seen something of the new style in the factory ships and, for example, in the way Russia has built up great fishing fleets. We have also seen a new development in fishing in the way the Japanese have set up fishing enterprises in collaboration with governments of many countries, for example Israel, Ceylon and Brazil. All these efforts are directed towards solving one of the continuing problems of to-day, production and distribution of more and better food.

Fishing thought of the world is going through a period of intense change in which we are taking the "maybe" and "could be" out of it, and making it into a hard science, realizing that "world fishing is world feeding".

A. C. HARDY

PART 1

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PRINCIPAL FISHING BOAT TYPES

by

A. C. HARDY

A table giving the world distribution of the important types of fishing boats at a glance is given. It contains 17 basic types operated by 44 fishing nations, catching between them 92.9 per cent. of the world's fish.

LES PRINCIPAUX TYPES DE NAVIRES DE PÊCHE

A cet égard, on a pensé qu'un tableau donnant d'un seul coup d'œil la distribution mondiale des types importants de navires de pêche était utile. Le tableau contient 17 types de base de navires employés par 44 nations pratiquant la pêche et dont les prises représentent 92,9 pour cent des poissons pêchés dans le monde.

PRINCIPALES TIPOS DE BARCOS DE PESCA

Se da una tabla con la distribución mundial de los tipos más importantes de barcos de pesca. Contiene 17 tipos básicos empleados en 44 naciones pesqueras que capturan entre ellas el 92,9% de la pesca mundial.

IT has been judged useful to prepare a basic table giving the principal ship or boat types used in fishing other than those for purely local and off-shore duty. Fig. 1 shows the distribution of the types among 48 different areas and countries. In order to simplify matters, the types have not been rigidly analysed in so far as sub-types are concerned; rather has the basic function been chosen. The top of the table shows a total of 17 individual types. The columns to the left show the principal fishing nations, divided into geographical areas and arranged in alphabetical order within the continental divisions.

Grouping of boat types

The first shown is the whale-catcher, a boat for shooting, usually attached to the whale factory ship, but capable of operating if necessary from shore bases. There are two kinds of factory ships: (1) the mother ship which operates with catchers and is concerned in processing or canning; (2) the fishing stern chute factory, a new type also coming into prominence particularly in the fishing fleets of the U.S.S.R. This type formed the subject of much debate, some of it acrimonious, on the occasion of the 1953 Congress. It is now beginning to reach maturity, and is a completely self-contained type planned for gutting, producing fish meal, extracting liver oil, and for producing frozen fillets in packaged form ready for the consumer market. The port of discharge is not usually a conventional fishing port.

The next group is the trawler family and it is divided into distant water and near-middle water types. Then come its near relations, the Pareja, and Grand Banker trawlers. Seiners, both Danish and Purse, follow; then the large and diversified drift-net family.

The angling boat group consists of trollers, tuna clippers and longliners. The recent arrival in France of the U.S. type tuna clipper as opposed to the sail-driven trolling tunny ship of former years is to be noted; it represents a revolution in an important branch of the French fishing industry. Longliners can be adapted from other types, particularly in northern waters where a longliner can be employed as a trawler and vice-versa; they can also be specially built. In Japan and Canada longliners are one-purpose boats. The dory-type longliner is confined to Portuguese and Canadian ownership. There is a column for the carrier, which sometimes carries fish in tanks with chilled seawater and on others in wells open to the sea. This is followed by research and training ships which are employed by no less than sixteen different nations, and this is an indication of the importance with which the training of fishermen and biological research is regarded.

No attempt has been made to list hospital ships accompanying the fleets at sea; there are a few of these, some acting as store ships too, and some adapted to trawl fishing. They are mainly owned by two nations, namely the Portuguese and the Dutch. There are also fisheries protection ships of the United Kingdom and Germany equipped with hospital facilities.

Variety of types within countries

A study of fig. 1 produces many interesting facts. The catch figures of each national column are in some respect a measure of each nation's reliance on fishing as a means

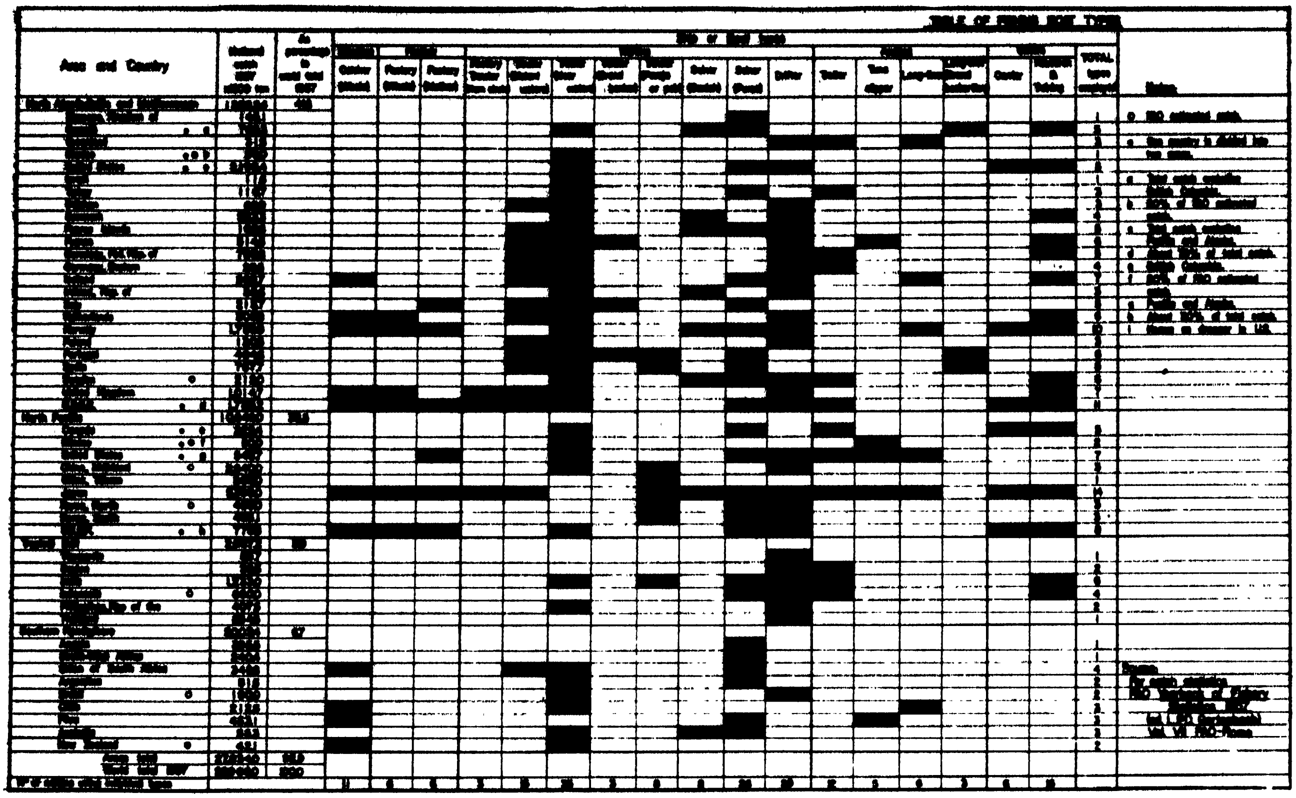


Fig. 1. Table of fishing boat types

of feeding, or for export purposes, or both. In this respect it is natural that Japan should lead in the variety of boats with a total of 14 individual types; followed by the U.S.S.R. with 11 and Norway with 10, though this figure is dependent on the inclusion of factory motherships. In point of fact, Norway was the first country in the world to adapt an ex-tank-landing ship, built during World War II, as a complete herring oil and meal floating factory working in conjunction with a group of catchers; in 1957 this ship was offered for sale. U.S.A. has 9 different types. The United Kingdom, Canada and Iceland list a total of 7 ship types; Portugal, France, Sweden and India, 6 each; the Faroes, Germany, the Netherlands and Italy 5; Denmark, Eastern Germany, Indonesia and the Union of South Africa 4.

A nation's interest in fishing, however, cannot be judged by the number of types it used, this is controlled by such factors as the size of the country and its internal needs, the fishing grounds which are within reasonable distance, and the extent to which fishing is an export industry, i.e. canning, salting, etc., rather than a means of national feeding. On size comparison it is noted that Japan uses 14 types compared with only 11 by the U.S.S.R. Other factors which affect fishing are the size and types of harbours; the size of population willing or able to go to sea in the fishing industry, and their expertness as sailors. The available fishing population is governed in some degree by the way in which other industries intrude, and the extent to which they can absorb labour.

Change in appearance

Seven decades of trawler evolution are outlined in fig. 2, which is a good example of the development of a fishing vessel type. It is a slow and gradual process, for deep-sea fishing is not a business which encourages the taking of unnecessary chances.

The coming of steam for propulsion in the 1880's was perhaps the most important stage. The ever increasing length of voyages, due to fish movements and over-fishing, brought about an increase in size. The advent of oil as a fuel for boilers permitted even longer voyages, although its use was strongly resisted at first, particularly in Great Britain.

The internal combustion engine, just before the outbreak of World War I, probably caused the biggest change which has ever affected shipping. It was not, however, until well after World War II that it began to affect the trawler. Even today steam has not entirely disappeared. The use of electricity for propulsion, and in certain instances for the whole powering of the ship, is however now slowly gaining acceptance.

The growing importance of the bridge as the nerve centre has eliminated outside walkways and increased the

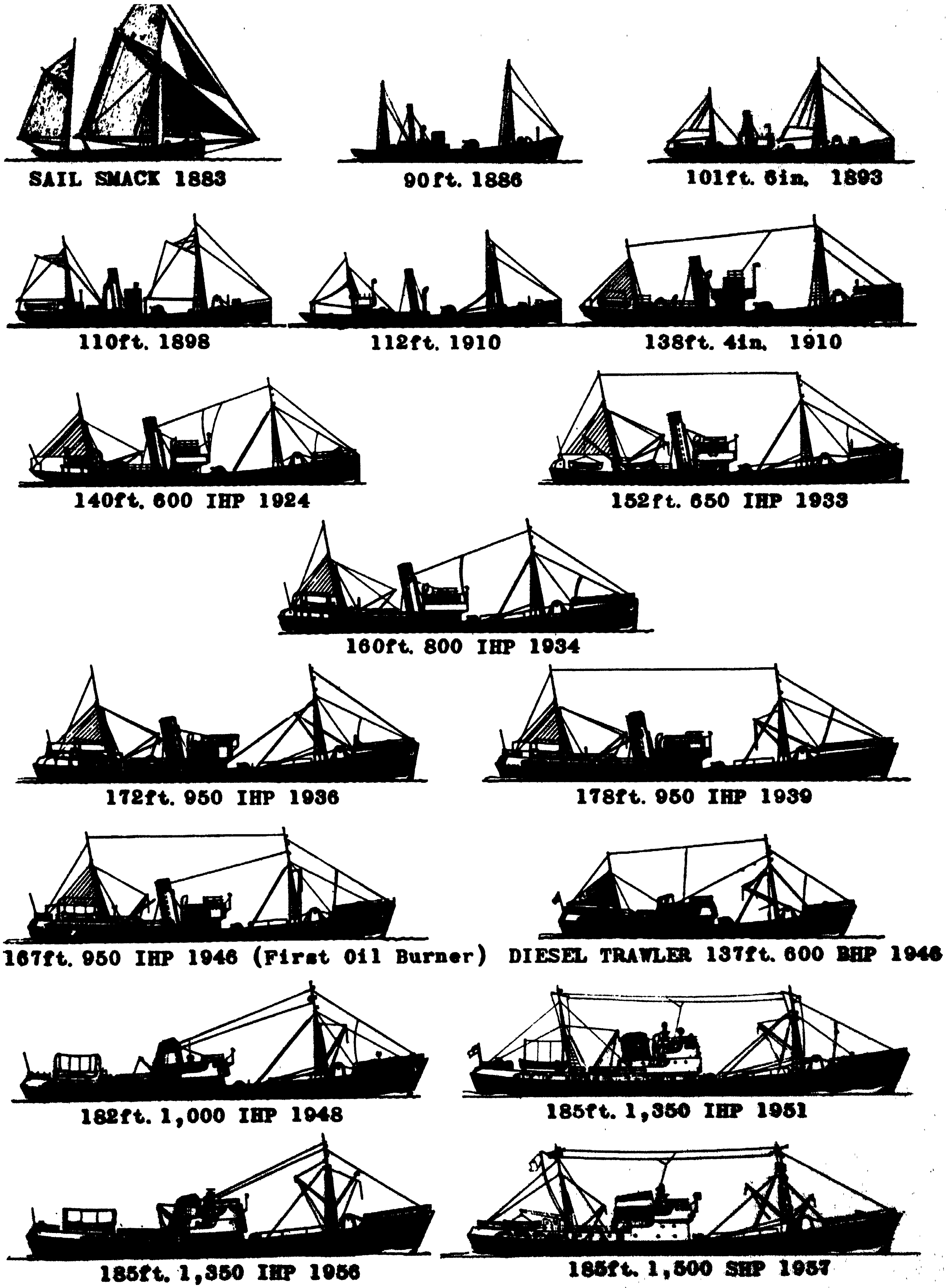


Fig. 2. Seven decades of trawler evolution (compare fig. 96)

size of the structure itself. Alterations in machinery have progressively cut down the size of funnels. An entirely new type of funnel was introduced in 1946, a period which marked the virtual end of the tall stovepipe structure previously necessary to obtain draught for the rather inefficient coal-fired boilers.

Model testing led to a cruiser-conical type of stern about 1933. At the same time there was a tendency up to the outbreak of World War II to increase the sheer forward, rake the stem and build up the fo'c'sle; this, for reasons of seaworthiness, was frequently of turtle-back type. The introduction of the cruiser-conical stern seemed to be the signal to increase the structure aft. This improved comfort, gave extra space for accommodation and reduced the risk of the ship being pooped. Later the mizzen-mast was eliminated, although this is not a common characteristic. The present tendency to fish on the starboard side only enables the superstructure to be extended on the port side, again resulting in more and better accommodation, and better quarters for the crew.

Common types of boat

The figures at the bottom of the columns of fig. 1 show the extent to which various basic fishing boat types are used. It is evident that on present showing, i.e. April 1959, the trawler in one or other of its various forms is the most popular—35 nations use it. Next comes the drifter, which again in one or another of many forms is used by 29 nations. This is followed by the purse seiner employed by 26 nations, compared with the Danish type of seiner employed by only 8. Other high-ranking figures are the troller, shared by 12 nations, and the whale-catcher used by 11—this is employed by 5 nations as shore-based, as apart from the factory-based unit. The Pareja is shared by as many as 8; the research and training ship has a total of 16. The almost universal popularity of the trawler, of near and middle water type, is especially to be noted, and is in fact used by all North Atlantic, Baltic and Mediterranean nations. The Netherlands has specialized in drifter type ships.

The common characteristic, it should be emphasized, is merely one of method of fishing; in size, power, equipment, they vary according to local conditions and local sources of supply, or to the extent to which international sources of supply can be called upon.

It is felt that in the past all these factors for ship types shared by so many nations have been confined to national "watertight boxes". It is the object of this paper to break open the boxes and to let ideas mingle freely. Although there are clearly many points in design which could never be common to all, and perhaps only common to a few, the exchange of ideas cannot but be of benefit for all.

PURSE SEINING: DECK DESIGN AND EQUIPMENT

by

PETER G. SCHMIDT, Jr.

More fish are produced by purse seining, which is the most important form of encircle net fishing, than by any other basic method, and purse seine vessel design has improved rapidly in the last few years. The most important purse seining systems are the two-boat system, as used in the Norwegian herring fishery and the U.S. East Coast menhaden fishery, and the one-boat Western system, as developed on the Pacific Coast of U.S.A. and Canada. The other basic systems are described. The fish can be carried either by the purse seine vessel or by carry-away vessels. This has a major influence on design.

Selection of the size of the purse seiner is described, together with the general requirements for an efficient purse seine system and the important basic design considerations. The most important design consideration is the selection of the fishing method. After the method has been selected, arrangement of work space can be made and proper equipment selected. In most cases, the combination fishing principle shall be taken into account in the design.

The arrangements of fishing vessels, methods of fishing, and mechanization of the fishing process are discussed for the world's most important purse seine fisheries, together with suggested changes.

LA PÊCHE À LA SENNE TOURNANTE

On capture plus de poissons par la pêche au filet coulissant, qui est la plus importante méthode de pêche au filet tournant, que par n'importe quelle autre méthode, et le plan des bateaux pour la pêche à la senne s'est amélioré rapidement pendant les dernières années. Les systèmes les plus importants de pêche à la senne sont le système à deux bateaux, qui est employé par les pêcheurs de harengs norvégiens et par ceux de la côte orientale des Etats-Unis pour la pêche du menhaden, et le système occidental à un bateau employé sur la côte Pacifique des Etats-Unis et du Canada. Une description est donnée des autres systèmes de base. Le poisson peut être transporté soit par le bateau de pêche à la senne, soit par des bateaux de transport. Ceci a une grande influence sur le plan du bateau.

On indique le choix de la grandeur du bateau pour la pêche à la senne tournante ainsi que les exigences requises pour un système efficace de pêche et les considérations primordiales pour le plan du bateau. La méthode de pêche est le point le plus important à considérer pour le plan du bateau. Une fois la méthode choisie, il convient de déterminer l'espace et l'équipement nécessaires pour le travail. Dans la plupart des cas, le plan du bateau devra prévoir une pêche mixte.

L'aménagement des bateaux, les méthodes et la mécanisation des procédés de pêche, sont discutés pour les plus importantes pêcheries à la senne tournante du monde, ainsi que les modifications proposées.

LA PESCA CON REDES DE CERCO

La pesca con redes de cerco, que es la más productiva de todas, y las formas de los barcos que emplean esas redes han mejorado rápidamente en los últimos años. Los sistemas más importantes de pesca con redes de cerco son el de 2 embarcaciones empleado en la pesca del arenque en Noruega y en la de alacha en la costa oriental de los E.U.A., y el de 1 embarcación, practicado en la costa del Pacífico del Canadá y los E.U.A. Se describen ambos sistemas. El pescado lo transporta el barco de pesca al cerco o barcos de transporte. Esto influye mucho en las formas.

Se explican la selección de las dimensiones del barco de pesca con redes de cerco, las condiciones generales que se han de reunir para lograr un buen sistema de pesca con redes de cerco y consideraciones de importancia relacionadas con el proyecto, entre las cuales la más importante es la elección de los métodos de pesca. A continuación se hace la destribución de los espacios donde se realizarán las faenas y se selecciona el equipo. En algunos casos, al preparar el proyecto se han de tener en cuenta las posibilidades de emplear diversos métodos de pesca.

Se estudian: distribución a bordo de los pesqueros, métodos de pesca y mecanización de la pesca en algunas de las pesquerías con redes de cerco más importantes del mundo. Se proponen algunos cambios.

MORE fish are caught by encircling nets than by any other basic type of fishing gear. By far the most important type of encircling net is the purse seine.

Definition: A purse seine is a form of an encircling net having a line at the bottom passing through rings attached to the net, which can be drawn or "pursed". In general, the net is set from a boat or pair of boats around the school of fish. The bottom of the net is pulled closed with the purse line. The net is then pulled aboard the fishing boat, or boats, until the fish are concentrated in the bunt or "fish bag". The fish are then removed from the fish bag aboard the fishing vessel or an accompanying fish-carrying vessel.

In U.S.A., purse seining accounts for over 50 per cent of all fish production. Throughout the world, most of the herring-like fish are caught by this method. The world's great reduction fisheries are all based on purse seining. The fish reduction industry is growing—particularly in many of the relatively undeveloped fishing areas of the world, and along with this purse seining is growing in importance.

In many areas, the more efficient purse seines are replacing other traditional gear. The efficiency of purse seining has increased recently, with the introduction of synthetic nets, mechanization, electronic fish detection and improved vessel design. In the last few years, purse seining has been found to be extremely effective for catching codfish in the Lofoten Islands off Norway, and other applications are being found for sunken purse

There are many variations of the general procedure described above. This paper will describe the design and equipment of modern purse seine vessels, the methods used in many of the important purse seine fisheries of the world and also the traditional types of boats. The reasons behind evolution of the traditional designs are set forth, together with suggested changes in method and design. No attempt has been made to cover all of the types and methods of encircle-net fishing, and the subject has been limited to the more important fisheries.

Purse seining has evolved during the last 60 or 70 years —primarily through the efforts of fishermen, with little attention being paid by naval architects, factory owners, or fisheries technologists. During the last 20 years rapid development has been made in purse seine vessel design and methods on the West Coast of U.S.A. and Canada. In the last 5 years this development has increased in tempo, with the introduction of mechanization of the net-handling process.

In general, purse seining is little known and understood in northern Europe, except in Norway and Iceland. Even there few of the new methods and vessel designs have been tried. As was very evident at the FAO Fishing Gear Congress of 1957, much more work has been done in the development of modern trawling than in the improvement of purse seine methods and vessels. The deep sea trawler had captivated the interest of naval architects and engineers far more than the generally smaller, and less complicated, purse seiner. Very few naval architects have employed themselves in the betterment of the purse seiner outside North America, and in most cases the vessels have been built along the traditional lines of other types of vessels common to the fishing area, with the fishing method adapted to these vessels.

With the increase in mechanization in many parts of the world, it is necessary to improve all phases of the purse seine operation so as to increase the productivity of man and equipment in order to remain competitive. It is possible in most cases to design vessels and equipment and select methods which can increase efficiency well over 100 per cent.

The major purse seine fisheries of the world can be grouped as follows:

- Norwegian and Icelandic herring fishery
- U.S. East Coast and Gulf menhaden fishery
- U.S. Pacific Coast, Alaska, and Canadian salmon, herring, sardine, mackerel and tuna fishery
- Japanese and Korean sardine, mackerel and skipjack fishery
- U.S.S.R. herring fishery
- West Coast of South America anchovy and tuna fishery
- South and South West Africa pilchard and mackerel fishery
- Portuguese, Spanish, French, and North West Africa sardine fishery
- Angola pilchard and mackerel fishery

BASIC PURSE SEINING SYSTEMS

Two-boat system

This is the oldest system of purse seining, and was first developed on the East Coast of U.S.A. in the menhaden fishery. It was introduced into the Icelandic and Norwegian herring fisheries in the early 1900s (Kristjonsson, 1959). In this system, two small seine boats 32 to 36 ft. (9.75 to 11 m.) in length are carried in davits on board a larger vessel, which is called a "steamer" (fig. 3). On reaching the fishing grounds the small boats are launched, each carrying half of the purse seine net. The boats run breasted together until the school of fish is located, and the set begins. The boats, on setting, go in opposite directions, encircling the school of fish and coming together 180 degrees from where they started setting the net. The net is pursed, using a purse winch in one or both of the boats, and the net is then pulled from each end by the crew or power block in the two boats until the fish are sufficiently raised and concentrated for brailing or pumping. The "steamer" then comes alongside and removes the fish from the bunt of the net with either a large brail or a fish pump.

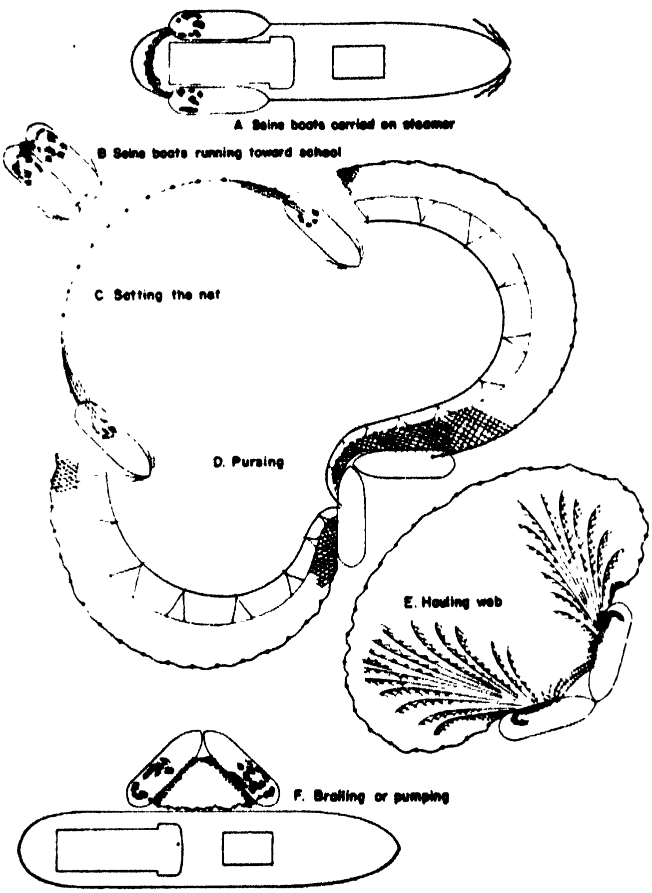


Fig. 3. Two-boat purse seining system

The two-boat system of purse seining evolved in the days before the modern gasoline and diesel engine, when it was necessary to row around the fish. The fish-catching boats were carried out to the fishing grounds on the larger vessel, which was either sail or steam powered, and were small enough to be propelled around the fish by oars. There has been little change in this general method since engines were put in the seine boats.

The two-boat system has the following disadvantages:

- It uses a large number of fishermen. The individual productivity of each fisherman is relatively low. It does not lend itself to mechanization
- Launching and hoisting the smaller boats in rough weather is hazardous, and much fishing time is lost due to the problem of handling the small boats
- The "steamer" must be large enough to carry the small seine boats, which eliminates this system for many species of fish where a large cargo capacity vessel is not required
- The length and depth of net are limited because of limited space in the small seine boats
- The work is extremely back-breaking and hazardous because of the necessarily small and unseaworthy boats which do not provide a good working platform
- Investment per net is very high. Instead of having several nets working per carry-away unit, only one is used

The advantages of the system are:

- Larger carrying vessels can be used, which travel at high speed, complete with their fishing units
- The small seine boats—particularly in Iceland and Norway—compete for the schools of fish, and the large single vessels setting the nets would find it difficult to manoeuvre in such crowded conditions
- With the two small seine boats, it is possible to encircle quickly the school of fish
- The net can be hauled rapidly because it is pulled from both ends simultaneously

Western one-boat system

The Western one-boat system shown in fig. 4 is becoming increasingly popular and is being adopted in many areas where fishing is developing. The net is carried aboard the catcher vessel, and in most cases this vessel also carries the catch back to the factory. A small auxiliary boat is used, called a "skiff". To surround a school of fish, the large vessel releases the "skiff", which is attached to the end of the net. The skiff tows away from the seiner as the seiner is describing a circle around the fish. The seiner joins together with the skiff and purses the net. The net is then pulled aboard the seiner until the fish are sufficiently concentrated to brail into the fish hold of the seiner, or in some cases into a carry-away vessel, which may be working in conjunction with the seiner. The Western purse seiners are arranged with the machinery and deck-house forward, so as to give the maximum working area in the stern of the vessel for handling the net. This system lends itself most favourably to mechanization and high manpower efficiency.

Advantages of the one-boat system are:

- Adaptability to the mechanization of the net hauling process by use of a powered block and highly mechanized handling of rope or wire purse line
- Utilizes a minimum of manpower
- Adaptability to systems capable of fishing in rough weather
- Safety to fishermen and no back-breaking labour
- Ability to carry and handle large nets efficiently
- Flexibility of operation—carries own fish in periods when fish are scarce and works with other vessels to carry away fish during periods when fish are abundant

Disadvantages are:

- Clumsiness of extremely large vessels, which would make them unsuitable for purse seining certain types of fish such as menhaden
- The net is hauled from only one end, which, theoretically, is not as fast as hauling from both ends. This disadvantage is not so great because of the rapidity of hauling using a powered block.

Portuguese system

The Portuguese system, which is used to some degree in France, Spain, and the Northwest coast of Africa, is referred to by many in those countries as the "American system". Evidently this system was derived from the American West Coast system of carrying the entire net aboard the purse seiner, setting it out with a skiff attached to the end.

The bunt, or "fish bag" of the net is in the end, in contrast to the lampara style, with the fish bag in the middle, as used in the Mediterranean. The only basic difference in the Portuguese system from the Western system is that a large amount of manpower is used to haul the nets. On the West Coast of U.S.A., the nets have been historically pulled over power rolls, and strapped with the boom (lifting the net in successive bites, with a single fall from the boom)—now a powered block is generally used.

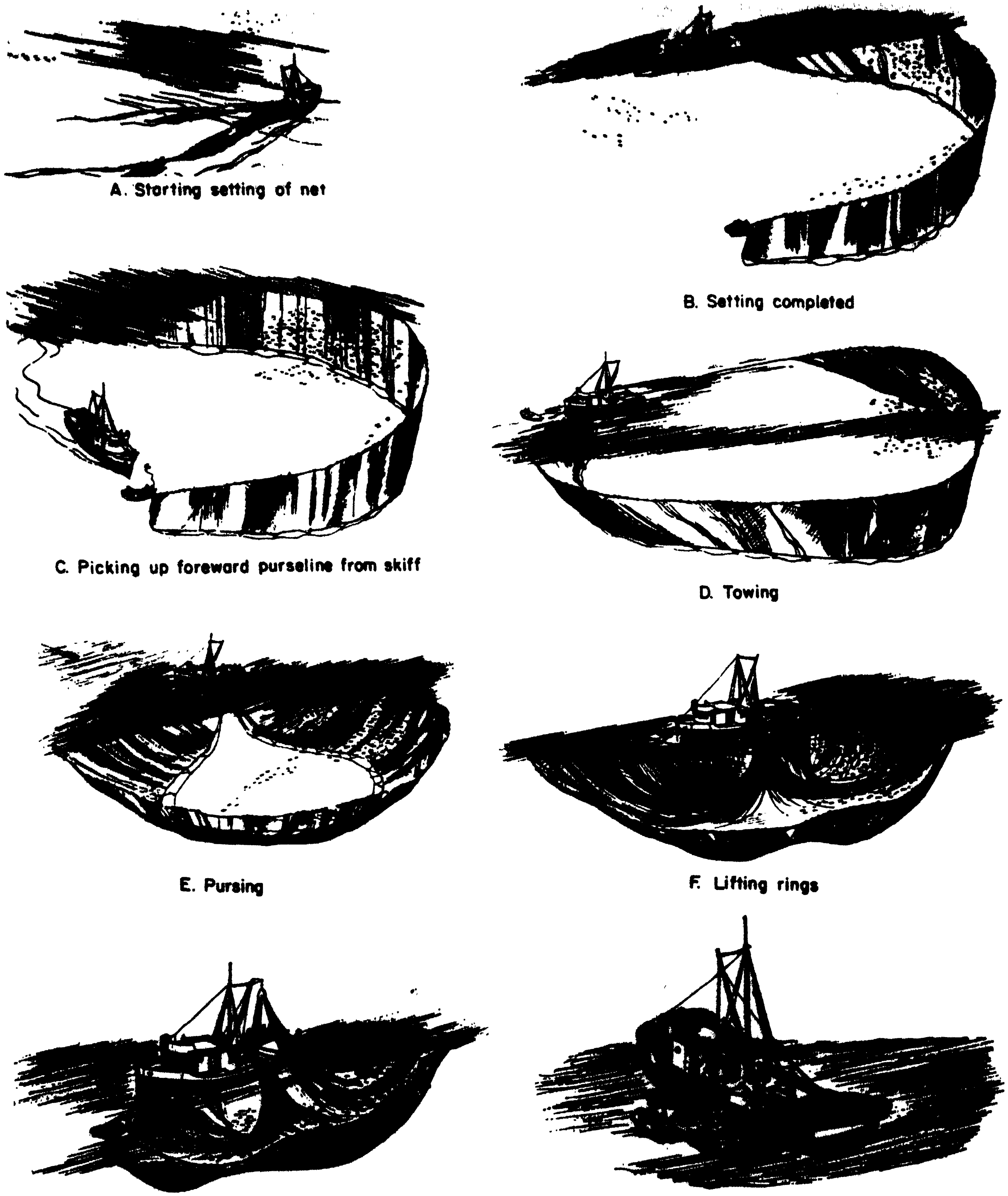
With the Portuguese system, it is not possible to stack the net on the stern of the boat because from 20 to 30 men are lined up along the rail pulling web. From 3 to 5 men coil the cork line on the stern. Several men are used for pulling corks in the bow, and several more for pursing (fig. 32). The body of the net is stacked for about 30 ft. (9 m.) along the side of the vessel. The Portuguese method of setting the net and pursing is generally similar to the Western system.

The arrangement on the Portuguese boats with the deckhouse and machinery amidships does not lend itself readily to convenient handling of the net without modification of the system (fig. 32).

The main disadvantage of the system is that it needs a large amount of manpower. Otherwise it is, in general, similar to the Western system.

South African "lampara" system

In South Africa the net and fish are all carried on one seine boat; however, a modified lampara-style net with



A. Storting setting of net

B. Setting completed

C. Picking up foreward purseline from skiff

D. Towing

E. Pursing

F. Lifting rings

G. Pulling web

H.

Fig. 4. One-boat purse seining system

purse line is used. This system was well described by du Plessis (1959). The South African boats are very similar in arrangement to European "drifters", and the system does not lend itself well to mechanization; however, it is relatively efficient for the small nets used.

Drums were first introduced in 1951 in British Columbia and the Puget Sound areas of the Pacific West Coast. They have been primarily successful in handling relatively shallow salmon seines, and are the fastest, most efficient method yet devised (Smith, 1954; Schmidt, 1953). Unfortunately, there are various problems to be surmounted in using a drum seine, of which gear damage and special methods of handling the net appear to be the most serious. The drum seine lacks flexibility in adapting to the traditional nets that are in use. Prior to the introduction of the powered block, about 30 boats were converted to drum seining, and several new vessels were built. In drum seining, the seine is wound on a large drum mounted on the stern of the vessel. A spooling device, consisting of two vertical rollers moving in a track on the stern of the vessel, is used to spool the net back and forth while it is being wound onto the drum. The entire net from cork line to lead line is bunched together as it goes through the spooler and winds onto the drum. The drums have been mostly hydraulically powered; however, some of them are run mechanically through shafting and gearing. The spoolers have been primarily hydraulically actuated. Some of the drums have been mounted on a rotating carriage in a tub, with spooler mounted on a frame attached to the drum, such that the entire mechanism can be rotated through 180 degrees. This allows picking up the net on the side, similar to the position of pulling the net onto a seine table. The fishing vessel must have a wide, square stern, which in most cases is recessed with a tub, so as to lower the centre of gravity of the drum. The net is set out over the stern of the vessel, allowing the drum to rotate against a brake.

Since the introduction of the powered block during the last three years, only about 6 drum seine vessels have been built or converted. It would appear that the simplicity, low initial cost, and flexibility of the powered block are advantages over the drum. The drum seine method must not be discounted, however, as it can be successfully applied to various types of fishing, and may eventually gain more favour after additional development.

U.S. mackerel and Icelandic herring one-auxiliary boat method

This system is a transition from the two-boat system used in the menhaden and Icelandic herring to a modified one-boat system in which the net is carried in one auxiliary seine boat that is towed by the larger vessel. Obviously, the only justification for this method is that the large boat does not have appropriate space on the stern or alongside the house from which to handle the net. The large boat tows the net-handling boat alongside the quarter, to make the set around the school of fish. In effect the small boat is a floating seine table. The large boat then purses the net and the net is hauled back into the small seine boat. This system is makeshift at best, and should be considered only as a transition to utilize existing equipment where the fishery cannot justify the construction of proper Western-style purse seine vessels.

METHOD OF CARRYING FISH

One-boat carrying its own fish

In the Norwegian herring and menhaden two-boat system the steamer not only carries the two fishing boats to the grounds, but is used to transport the fish back to the factory. Each "steamer" is therefore a complete fishing unit working independently. When the steamer is loaded, it is necessary for it to leave the grounds, with its net, to unload.

In the Western system, the purse seine vessel usually carries its net and fish. On the U.S. West Coast most of the salmon, sardine, and tuna seiners operate in this manner. The salmon seiners, however, are unloaded into tenders (carry-away vessels) each night to transport the fish to the canneries. The California sardine seiners carry their own fish, however, when big sets are obtained many boats of the fleet may load up from one net. The tuna purse seine vessels operating out of Southern California and South America all carry their own fish. In South Africa, Angola, Portugal, Spain, France, and Northwest Africa, most of the purse seiners carry their own catch.

One boat working with carry-away vessel

The best example of this is the Canadian winter herring fishing, where, although the seine boat is a complete fishing unit capable of carrying fish, in most cases these boats work in conjunction with tenders which carry the fish the long distances back to the reduction factory. It is generally only when close to the factory or when all of the carry-away vessels are loaded that the seine boat will load itself and return to the factory. Obviously the advantage of this system is that it allows the fishing unit to stay on the grounds, keeping its net and crew more productive while the carry-away vessels run back and forth to the factory. The consideration of whether the fishing boat should carry its own fish or work in conjunction with carry-away vessels is of prime importance in the selection of the design and arrangement of the fishing vessel.

SIZE OF BOAT

Some of the factors influencing the size of the purse seiner are:

- Governmental regulations
- Distance to fishing grounds
- Maximum daily catch
- Average daily catch
- Stability and adequacy of working platform, together with size and weight of net
- Availability of carry-away boats
- Use of vessel for other methods of fishing

The influence of these factors will be illustrated by the following specific examples:

(1) **Governmental regulation:** In Alaska, protective laws, which are based partially on conservation and partially on protecting the local fishermen, have been passed which limit the lengths of fishing boats. For instance, in Southeastern Alaska, the Alaska limit has been in effect for some time, which prohibits the operation of any fishing vessel of over 50 ft. (15.3 m.) registered length. From this has developed what is known as the Alaska limit combination purse seiner. In other areas in the fishing world, there are regulations which tend to restrict the size and type of vessel. In general, this type of restriction is non-progressive and detrimental to the development of efficient fisheries.

(2) **Distance to fishing grounds:** This criterion has had a major effect on the design of the tuna seiners, inasmuch as they must travel many days, and sometimes as much as three weeks, to the fishing grounds. To make this type of operation profitable, a large fish-carrying capacity is necessary. Tuna seiners are getting larger and larger, and at the present time are up to 150 ft. (45.7 m.) in length and capable of carrying up to 400 tons of frozen tuna.

In many areas, such as the anchovy fishing grounds of Peru and northern Chile, and the fishing grounds of South and South West Africa, the fishing vessels rarely go more than 10 or 20 miles from the factory. In this case, the size of the vessel can be determined primarily by the expected maximum daily catch. At present, in the newer areas, the vessels make two and three trips a day. The trend is to increase the size of the vessel—not because of distance, but because of the expected daily catch.

(3) **Daily catch:** The size of the maximum daily catch and the average daily catch are probably the most important factors influencing size. For instance, most of the menhaden vessels have reached the size (approximately 130 ft. or 40 m.) at which they can handle what would be considered a large day's fishing. These vessels range outward to approximately 100 miles from the factory, generally returning each night with their catch. Recently some vessels of up to 200 ft. (60 m.) in length have been built, and have been refrigerated so that they can stay at sea for up to one week before unloading. It has not as yet been determined whether this is a profitable size of vessel. The South African boats were originally 50 ft. (15.3 m.) in length and carried 80 to 100 tons of fish. Each year they are increasing the length of these boats to a point where they can carry as much as 200 tons of fish. The fishing grounds in South and South West Africa are close to the factories, and it has been common for these boats to make several full-load trips a day. They are now finding that, with improved nets and the echo sounder, bigger and bigger catches are being made; consequently the size of the vessels is increasing. The next step would be the introduction of carry-away boats that would pump the fish out of the nets, carrying them back to the factory, allowing the catcher boats to stay on the ground.

(4) **Working platform:** As mechanization is increasing, the desirability of having a stable vessel with a clear deck area at the stern is becoming more important. A poor working platform is afforded in the small two-seine boats as used in Norway and the U.S. menhaden fisheries. A good working platform is afforded by the large herring, sardine, and tuna seiners on the U.S. West Coast. Complete mechanization is possible aboard these vessels, with the crew exerting practically no physical effort.

(5) **Availability of carry-away boats:** If a system using carry-away boats to take the fish back to the factory is used, the size of the purse seiner can be relatively small. It is the author's opinion that vessels from about 45 to 55 ft. (13.7 to 16.8 m.) can efficiently handle the largest nets, provided they work directly with carry-away vessels that are equipped with pumps. It would be possible with, say, a 50 ft. (15.3 m.) seiner, similar to fig. 27 to handle the largest pilchard, sardine, anchovy, menhaden, and herring nets with not more than six men. These boats can be so mechanized that it would be unnecessary for helper boats, customary in Norway, to be used in drying up the net.

REQUIREMENT FOR AN EFFICIENT PURSE SEINING SYSTEM

The design of a purse seiner should meet the following general requirements:

(1) **Rough weather:** The vessel must be designed to fish in rough, as well as in calm weather. Many of the purse seine vessels and systems being used are ineffective a large part of the time as they cannot be used in high wind and rough seas. It is the author's opinion that a vessel and system can be devised that will fish in much rougher weather than is at present being done in most areas.

(2) **Manpower efficiency:** The system should handle large nets with a minimum amount of manpower—in most cases the modern systems of mechanically handling not only use fewer men, but are more productive, in that more sets can be made during an equivalent fishing period, and the net and fish can be handled faster.

(3) **Safety of fishermen and elimination of hard, back-breaking labour:** As education and the standard of living of the various fishing areas increase, it becomes more and more necessary to improve safety standards and to eliminate unnecessary hard, back-breaking labour, so as to attract better fishermen to the industry.

(4) **Speed of setting and hauling:** It is important that the net should be able to be set out fast, and in many cases the circle made in either direction, to left or right. Likewise, the problem of attack from sharks, which occurs in many areas, is lessened with the speed of hauling.

(5) **Brailing speed:** Efficient brailing systems should be devised to remove the fish from the fish bag as rapidly as possible. Often the hauling speed is very good, but brailing occupies too much time. The fish pump (Burgoon, 1959; Robas, 1959) is being increasingly used. It is at present universally used in the U.S. menhaden fishery, and is being introduced in South America. Whereas rapid

Fig. 5. Pumping menhaden with 10 in. (305 mm.) centrifugal pump

brailing is accomplished in Norway, Canada, and California, the fish pump has advantages in requiring fewer men, less time lost in starting the operation, and allows continuous operation (fig. 5).

(6) **Efficient pursing:** Again, setting, hauling, and brailing can be speeded up, but to little avail if the pursing system is too slow and requires too much manpower. Modern, drum-type winches, using wire cable, are the ultimate answer (fig. 6).

(7) **Night fishing:** The purse seine system should be equally efficient at night as it is during the day. In general, the Western system can be accomplished safely at night. The system using two small seine boats, such as the menhaden and Norwegian herring systems, does not lend itself safely to night fishing.

BASIC DESIGN CONSIDERATIONS

The most important design consideration is selection of the purse seine method. This means selection of the type of net and system of hauling, method of pumping or brailing, and unloading. The next most important consideration is whether the boat is to carry its own fish or whether the fish will be carried in auxiliary vessels. From the above considerations it is possible to block out a general scheme. The design of the hull below the water is less important than the working arrangement and fishability. Of course, good naval architectural practice should be used. There are many considerations, other than resistance, which are of primary importance. It has been found, however, that low resistance vessels can be designed within the more important limitations that go with the fish-catching method.

After the general system is decided, arrangement of working space can be made, and proper equipment can be selected for net hauling, pursing, and fish handling. Stability is of prime importance if mechanical systems of hauling are to be accomplished. Draft is often a consideration—particularly in such areas as the U.S. East Coast menhaden fishery, some areas of the Alaska salmon fishery, and some of the anchovy fisheries of South America. The following outline is suggested in evaluating a design:

- Selection of method of handling net
- Arrangement of working space to best suit this method
- Selection of best possible hull to go with the above, providing adequate stability and low resistance, and meeting draft limitations
- Proper location of fish hold space so that vessel will not trim either by bow or stern when being loaded
- Selection and arrangement of proper equipment:
  (a) Net hauling equipment
  (b) Pursing and purse line-handling equipment
  (c) Fish handling (brailing or pumping)
- Unloading considerations—arrangement of vessel so it can be easily and rapidly unloaded
- Adequate accommodations to attract high quality fishermen.

COMBINATION FISHING

So far, in this discussion, consideration has only been given to purse seining and the purse seine method of fishing. It is becoming more and more apparent that in most fishing areas vessels should be able to accomplish efficiently at least one other type of fishing in the "off season", so as to obtain maximum utilization of the

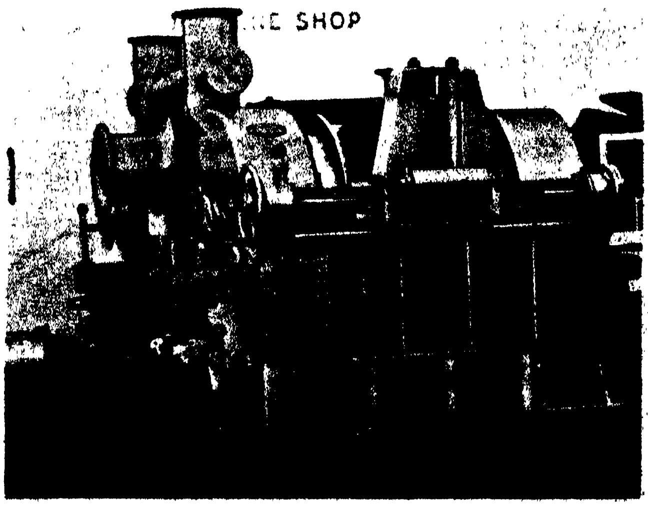


Fig. 6. Hydraulic 3-drum, 5-ton tuna purse winch

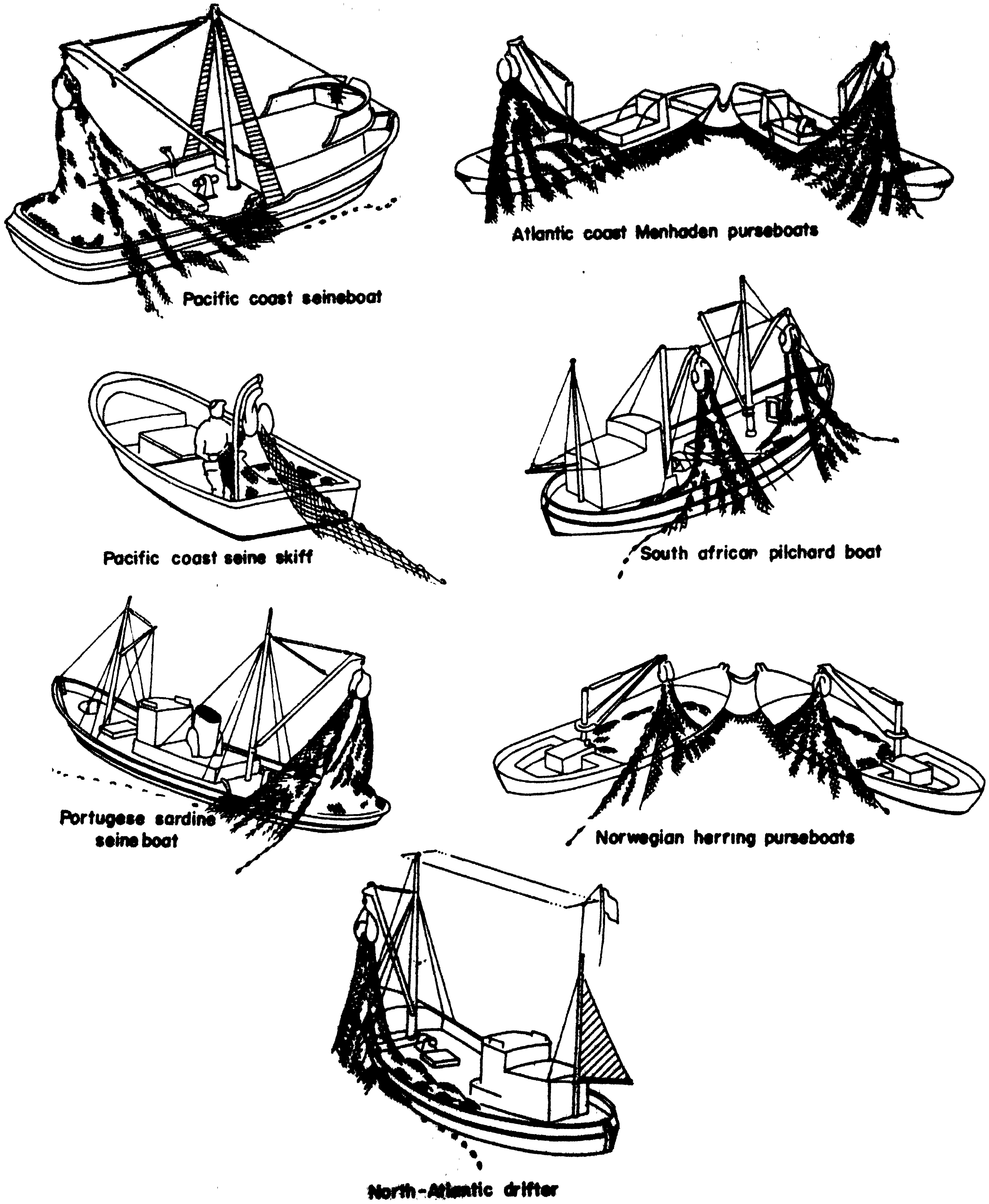


Fig. 7. Application of powered block, showing arrangement on various types of purse seine vessels

vessel throughout the year. Hanson (1955) discusses the combination principle in detail. In Europe most vessels being used for purse seining have evolved from other traditional types. There is a marked resemblance between trawlers, drifters and purse seiners in these areas. In most of the areas, as in Iceland, more consideration has been given to the proper handling of driftnets, long lines, and trawls than to the development of an efficient purse seining system. On the U.S. West Coast and Canada, the vessels have been developed primarily as purse seiners, and have been modified for use as trawlers and long liners. Where the purse seine fishery is the most valuable in terms of monetary return, it is only logical that this approach be used. It is surprising, however, how well the West Coast purse seiner lends itself to stern trawling and long lining. It is the author's opinion that purse seine vessels similar to fig. 20, 21, 24, 27, 28, 29 and 30 not only convert well to trawling, but make superior small stern trawlers with many advantages over the conventional side trawler type. Vessels of this design are also engaged in the North Pacific halibut fishery, and the largest landings in the last few years have been primarily by these vessels, rather than by the traditional schooner type, which is similar in design to the European longliners and drifters. In the conversion of the U.S. West Coast purse seiner to trawling, maximum use is made of the boom in handling the trawl net, as described by Alverson (1959).

EQUIPMENT FOR PURSE SEINING

Powered block

The Puretic Power Block (Schmidt, 1959) and system of hauling nets has in recent years probably done more than any other one thing to revolutionize the purse seine fishery. The powered block is in use by over 1,000 boats on the Pacific East Coast from Alaska to South America. It is gradually being introduced in Norway, Iceland, Korea, and other areas. The U.S. East Coast menhaden fishery is now about 80 per cent. converted to the powered block, even in the small seine boats. In this conversion, twelve men have been eliminated from each net, thereby doubling the labour efficiency. In addition, faster hauls are being made on larger schools of fish. As stated by the author (1959) "The power block is a new concept in net hauling whereby fish nets can be hauled from the sea faster, with fewer men and less toil, with less nět wear than by traditional hand methods". It is not a matter of whether a traditional system can be adapted to the powered block, but whether a system can be developed using the powered block which will increase the productivity of the fishery. In all areas where the powered block has been effectively tried, either a traditional system has been modified or a new system has been successfully developed. Fig. 7 shows applications of the powered block to various traditional boat types and basic methods. In most cases, some redesign or rearrangement of the vessel would eventually follow the introduction of the powered block.

Pursing

Pursing is accomplished usually by pulling the manila, hemp, steel wire or nylon purse line at both ends with the use of a purse winch, with several turns being taken around each one of two winch heads.

In the 1930's a Tacoma shipyard developed a type of wire purse winch for use on the large herring, sardine,

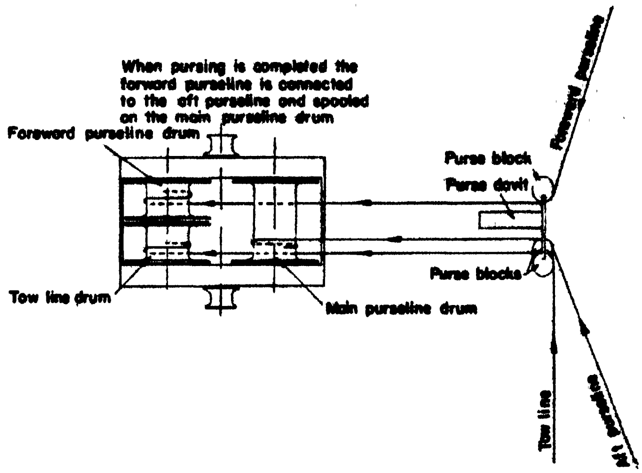


Fig. 8. Pursing with wire purse line on special type 3-drum winch

and tuna seiners on the U.S. West Coast (fig. 8, 9). This type of winch was a decided advancement for the large boats, and allowed them to use wire cable in pursing. Other U.S. Western boats ran the wire from hardened winch heads on the conventional winch to drums, where

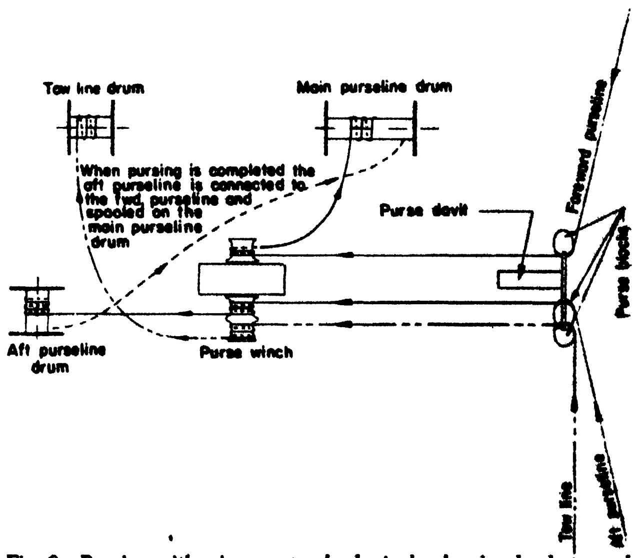


Fig. 9. Pursing with wire on standard winch, showing leads to reels

the wire was wound (fig. 10). Before setting out, all the wire is wound on one drum. In many of the purse seining areas where mechanization is developing, the change to wire purse line is proceeding rapidly.

Fig. 6 shows a new type of hydraulic purse winch for the large tuna bait boats that are converting to purse

Fig. 10. Pursing with wire on standard winch, showing leads to reels

seiners. This all-hydraulic winch has three drums and three gypsies—each with separate controls and hydraulic motor for independent operation. The capacity of the winch is 5 tons, and it is capable of handling a purse line of $\frac{9}{16}$ in. (14.3 mm.) diameter, 800 fm. (1500 m.) long. Sets of up to 300 tons of skipjack have been made with this winch in conjunction with a powered block and nylon tuna seine in Peruvian waters.

Brailing

Brailing using the conventional brailer is well developed in Norway, Iceland, and Canada. The use of pumps is increasing, and will probably supersede brailing in the next few years—particularly where the fish is to be used for reduction. For tuna and salmon the conventional brailing methods will undoubtedly continue. In salmon fishing, when small catches are being made, the fish are rolled aboard with the use of the powered block, by bringing the end of the bunt of the net across to the hatch. This has speeded up the process considerably. Special "brailer blocks", or releases, are used in Norway and Canada. In Norway it is the Haahjem brailer block, and in Canada the Wilfro block. This device holds the bottom of the brailer closed until it is tripped by pulling on the wire.

Miscellaneous equipment

Much hydraulic equipment is being installed on U.S. Western purse seiners and used in conjunction with the hydraulic powered block circuit. Lightweight, compact, high pressure hydraulic mast- and boom-mounted winches have been developed for raising and swinging the boom, and for brailing. Hydraulic anchor winches have also been developed which operate off the powered block circuit. It is very important to have a conveniently operating anchor winch, as it is often necessary to anchor—particularly when operating in the surf. In South America, most of the seine vessels do not yet have anchor winches, but it would be an extreme advantage when fishing anchovies close to the breaker line. Considerable hardware has been developed for handling purse seines such as a special skiff release, purse line release, and snap purse rings. Two types of snap purse rings are used—the Norwegian-Iceland type which the author introduced to the U.S.A. in 1956, and a new type developed in California by Peter Maiorana. The snap purse ring has several advantages—particularly when used in conjunction with the powered block method.

ANALYSIS OF VESSEL TYPES AND METHODS AS APPLIED TO IMPORTANT PURSE SEINE FISHERIES

The following is an analysis of the type and arrangement of fishing vessels, and specific methods, with suggested changes for the more important purse seine fisheries.

UNITED STATES EAST AND GULF COASTS

The U.S. menhaden fishery extends from New England to northern Florida, and from Florida to Texas in the Gulf of Mexico. This is one of the two largest reduction fisheries in the world, and annual production has reached over one million tons of fish. The fishing season lasts nearly six months, and the fish are concentrated in large schools. Most of the fishing vessels are owned by the factories. Robas (1959) describes the general method and type of vessel. The basic system is the two-boat system. The menhaden steamer is from 100 to 200 ft. (30 to 60 m.) long, of relatively shallow draft, and is capable of carrying from 150 to 600 tons of fish. These vessels are highly powered, with speed of up to 15 knots. A number of 138 ft. (42 m.) wooden minesweepers have been converted, and are successfully being used by the industry. Many of these vessels are twin screw, with up to 1,200 h.p. Recently some of the larger vessels have been refrigerated, using a chilled sea-water circulating system.

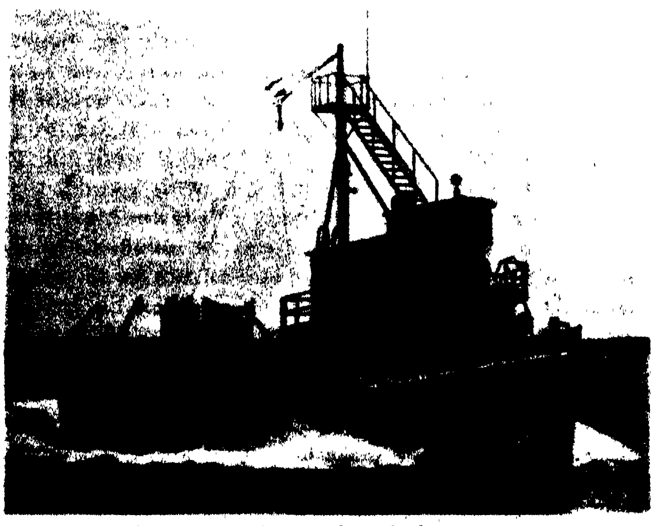


Fig. 11. Modern steel menhaden steamer

Fig. 12. Modern aluminium menhaden boats ready to make set, 36 × 8 ft. 9 in. (11 × 2.7 m.), 100 h.p. gasoline engine and power block

Arrangement: The menhaden steamer (fig. 11) has the engine or engines in the stern, the fish hold amidships, and pilot-house and crew's quarters forward. These vessels take on the general aspect of a tanker. All menhaden steamers are equipped with fish pumps, 10 in. (305 mm.) dia. being the most common size. The fish pump is located in the after part of the forward deckhouse, and is driven by a diesel engine of from 100 to 200 h.p. (fig. 5). The small seine boats, which are called "purse boats" are carried in davits alongside the machinery house aft. A hydraulic system is used for hoisting the boats.

Small seine boats: The "purse boats" are as shown in fig. 12. In 1958 aluminium purse boats were introduced to the industry, made from ¼ and $\frac{3}{16}$ in. (6.35 and 4.8 mm.) aluminium plate, alloys 5083 and 5086. Nearly half of the fleet has now converted to aluminium purse boats. They are 36 ft. long by 8 ft. 9 in. wide (11 by 2.7 m.), and were developed to provide a more stable working platform and more working space for use with the powered block, without increasing the weight. The steel boats which have been replaced were 32 ft. (9.75 m.) long, and it has been found that the larger, lighter aluminium boats, even when used with the powered block, are considerably more stable, buoyant, and seaworthy. The fishermen report that these boats are much drier, and they can be launched, and fished, in rougher weather with the powered block than was possible with the smaller steel boats, fishing by hand. It can be seen from fig. 13 that hauling the net in the overhead position does not cause excessive angle of heel. Actually, the resultant heeling force is about the same as when pulling the net by hand over the gunwhale, the only difference being that the powered block exercises greater force than is possible by hand.

Fig. 13. Hauling menhaden seine with hydraulic power block supported by aluminium block crane (note the easy work of the fishermen)

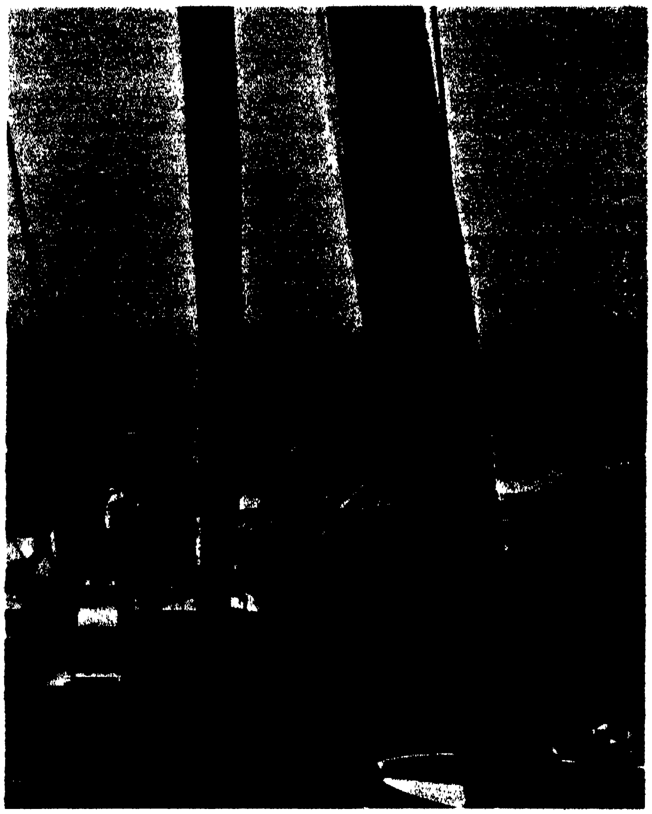


Fig. 14. Modern method of strapping menhaden net with 3-ton hydraulic winch to dry up the fish for pumping (the largest sets can be handled with ease in this manner)

Method of fishing: The method of fishing has been somewhat modified by the use of the powered block, strapping winch, and fish pump. Aeroplanes are universally used in the menhaden industry for spotting fish. Approximately one aeroplane is used for each five boats. Not only does the aeroplane locate the schools of fish,

Fig. 15. Old method of drying up menhaden for pumping (this crew has been reduced by half by the strapping method)

but actually sets the purse boats around the school by the use of radio. Six men are now used in each purse boat with the powered block and strapping system whereas formerly twelve men were needed. By studying fig. 13 and 14 it will be seen that the men do very little physical work. One of the largest operators in the industry has applied electrical attraction, in conjunction with a fish pump, to speed up brailing. This allows pumping before the fish would normally have been sufficiently concentrated, and together with the strapping system has speeded up this part of the operation.

Mechanization: In 1958 and 1959 nearly 80 per cent of the menhaden industry converted to the use of the powered block in the purse boats. The powered block is supported by a specially developed hydraulic crane (fig. 13; Schmidt, 1959). Hydraulic reels for spooling the purse line have also been introduced into the new purse boats. In 1958 the system of strapping the net to dry up and concentrate the fish for pumping was finally adopted. Fig. 14 shows the strapping operation in which the net is lifted by hydraulic winch, using two single falls to the gaff on the mast of the steamer. A two-drum, 3-ton, high pressure hydraulic winch was developed for this purpose. Each drum is on an independent hydraulic circuit, using hydraulic power for both raising and lowering to ensure positive control. The power block cut down the manpower required while pulling in the net much more rapidly, and the strapping system made it possible for this small crew to dry up the net without additional help. This system works with a minimum of manpower, even on the largest schools of fish. It also allows fishing in considerably rougher weather than was possible before.

Suggested changes: It is the author's opinion that the menhaden system has developed about as far as the basic system will allow, with the use of these modern aids: aeroplanes for spotting, powered blocks, strapping winches, electrical attraction, the fish pump, and greatly improved aluminium purse boats. A minor improvement is suggested in fig. 16, which shows an improved purse boat as designed by the author. This design is a further refinement to allow more convenient operation with the powered block, and to give the boat captain better visibility and control of the boat.

Any major increase in efficiency must come from a change in basic method. At present experiments are being made using one-boat systems in the menhaden fishery.

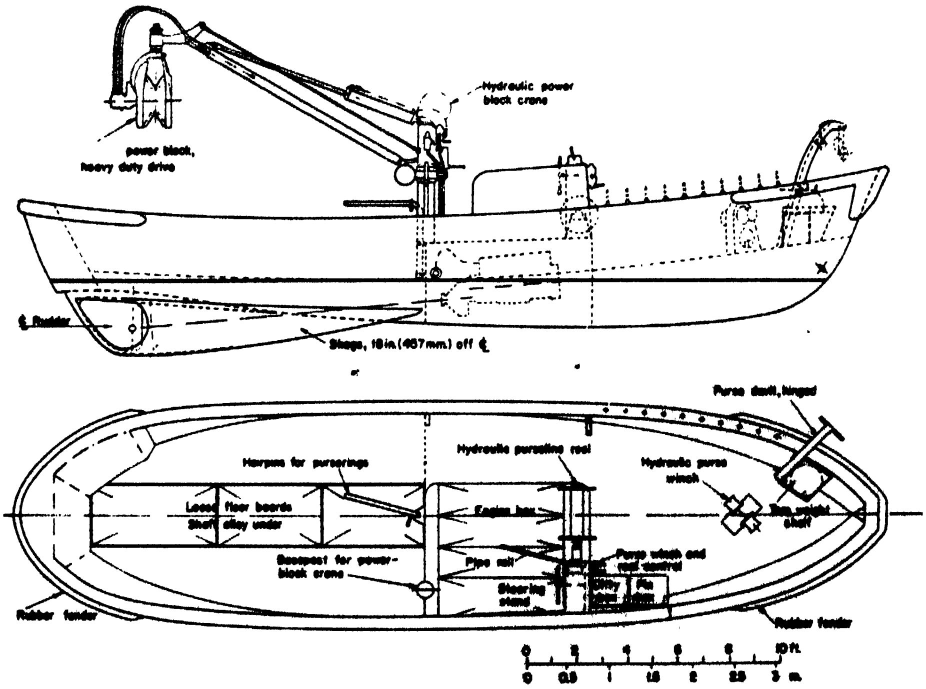


Fig. 16. Improved design for menhaden p

Further experimentation of this type should be conducted to determine whether some form of one-boat system would not be superior to the present two-boat system. A design similar to fig. 22 would be capable of handling the menhaden net with only six, rather than twelve, men needed in the purse boats. A boat of this type with powered block working with a carry-away vessel and employing the strapping system for drying up would be able to handle large schools of fish rapidly with increase in manpower efficiency and ability to fish in rough water.

NORWAY

Herring

The Norwegian herring fishing method has already been described. Fig. 17 shows a Norwegian vessel drying up a large catch of herring.

Arrangement: The type of vessel is similar to the menhaden steamer, but is wider and deeper. This is because there are no draft limitations as in the menhaden fishery. The machinery and deckhouse are all astern, similar to

Fig. 17. Norwegian herring seiner and seine boats with helpers drying up herring for brailling

the schooner or cutter design from which they evolved. The two purse boats are carried in davits aft.

Seine boats: Norwegian seine boats are now being built primarily of steel. A number of aluminium seine boats were built without too much success, primarily because they were of light gauge, riveted construction. With the newer aluminium alloys and welding techniques, aluminium seine boats should have the same advantages as observed in the menhaden industry. The Norwegian seine boats are arranged with the engine in the stern, and the net handling in the bow. They are of whale boat type about 32 by 8 ft. (9.75 by 2.44 m.). There is considerable difference of opinion as to whether this is a more satisfactory arrangement than that used in the menhaden seine boats where the engine is in the bow.

Method of fishing: The echo sounder is used to locate the fish, which are very rarely visible on the surface. The two purse boats encircle the fish, and when large sets are made additional helper boats are called in to help dry up the catch (fig. 17). These boats are out on the grounds, being towed by small drifter-longliners. The fishermen in the helper boats share in the catch that they help to dry up. The boats towing the helper boats are used to tow the "steamer" during hauling and brailing operation.

Mechanization: The net-handling procedure is little mechanized except for some use of powered rollers mounted on the gunwhale. The powered block has not been tried, and drying up of the fish is done by the use of a large amount of manpower in the seine boats and helper boats, rather than by the strapping method. The fish pump, although it has been tried, is not being employed. The method of brailing, using the conventional brailer, is well worked out, and good brailing speed is achieved. The large and modern "steamers" (seiners) are very fine ships, well designed for the system being used.

Suggested changes: The methods developed in the menhaden industry, including the fish pump, strapping, and powered block, can be adapted to the Norwegian herring boats with very little change in basic system. It should be possible to handle the largest sets with the above recommended mechanization. Aluminium purse boats of the design in fig. 16 are recommended for support of the powered block if mechanization is attempted.

Much further experimentation should be made with a one-boat system, working in conjunction with carry-away vessels. There is no reason why this system, properly applied, should not be successful in the Norwegian herring fishery and particularly fishing in the rough weather which has plagued this industry. The only two arguments against adopting the one-boat system are:

- It may be hard for one boat to compete in setting in the congested areas where there is so much competition for a school of fish
- Unsuccessful experiments have been made in Norway with U.S. Western one-boat systems. It is the author's opinion that these experiments were inconclusive, inasmuch as the boats were not adequate; nor were the personnel properly trained. Considerable improvement has since been made in the U.S. Western technique. A seiner of the design of fig. 22 is capable of mechanization, and also can set in congested areas. A vessel of this type can operate in much rougher weather than the open seine boats now used. It would travel to the fishing grounds under its own power, or could be towed, winched tight to the stern of the carry-away vessel

Cod and saithe fishery

A few years ago purse seining was introduced in Lofoten in northern Norway for codfish. Sunken nets were used, similar to the U.S. Western purse seining system. These nets were handled on the stern of drift-net and longline vessels which were not designed for, and were very inconvenient for use with, this system. Purse seining of cod in Lofoten, which was found to be very effective, has now been banned by legislation due to conflict with the fishermen using traditional methods.

An experimental powered block was introduced into that fishery in 1958, and proved an immediate success.

Suggested changes: It is suggested that new vessels have the deckhouse moved forward, such that the net can be efficiently handled using the powered block. The vessels now being used are exceedingly inconvenient for purse seining. The U.S. Western-style combination purse seiners might be ideal for the cod and saithe purse seine fishery, and they can also be used for trawling and long-lining at other times of the year.

UNITED STATES WEST COAST, ALASKA AND CANADA

The types of vessels used have been exceedingly well described by Hanson (1955). These vessels are used for purse seining salmon, herring, sardines, anchovies, mackerel, and tuna.

Arrangement: The general arrangement places the engine in the bow, with a forecastle for the crew in the smaller vessels just forward of the engine room. The deckhouse is forward, and is either of the 1- or 2-level type. This leaves the large deck area at the stern available for handling the net—both in setting and hauling. The larger boats have all of the crew accommodations in the lower deckhouse on the main deck. These quarters are spacious compared to European standards, and are very comfortable, even in a seaway. The boats are equipped with a large mast and boom, and all operations requiring physical effort are handled by power, with much use of the boom—and in some case, booms.

In this design, a horseshoe, or transom, stern is used, with the deck being kept very wide aft, to give a maximum amount of stability, working space, and flotation. The wide deck aft is very important. The fish hold is placed with its centre of gravity on the centre of flotation such that the vessel does not trim by the bow or stern when loaded. The rudder is kept underneath the counter, to keep the net from fouling. The seagoing characteristics of these boats are good, and pitching is very small because, with the wide stern, the tendency to "hobby-horse" is minimized. The tanks are placed in the stern and engine room. The forefoot is fairly deep, which keeps the bow from drifting unduly. This gives an added advantage, in manoeuvring as the stern pivots about the bow, which is very convenient—particularly when this type of boat is being used for longlining.

Method of fishing: The method of fishing has already been described in this paper and, whereas the size of vessel and details of the net vary considerably for different types of fish, the general system is the same for all of the types of fish mentioned above. Specific differences will be listed below.

Mechanization: In general, the U.S. Pacific Coast boats are mechanized, with the use of the powered block and increasing use of wire drum winches for handling the purse line. The fish pump is little used as yet, because it is not applicable to pumping salmon or tuna, which have been the primary source of income in this area. Maximum

Fig. 18. Salmon purse seining on the U.S. Pacific coast—setting the net

use is being made of hydraulic topping lift winches for the boom, boom vanging winches, and other mechanical aids. Very little physical effort is required by the fishermen.

Suggested changes: Since the powered block is generally used in this area, the requirement for the seine table, as shown in fig. 20, and by Hanson (1955), has been eliminated. Many of the boats are now removing the seine tables, and new vessels are being built without them. Since web pulling is no longer done by hand, it is suggested that the boats be designed with higher freeboard and more sheer up in the stern. With the use of the seine table, it was necessary to keep the sheer very flat so as not to cock the table unduly, and to keep it from being excessively high. Increased mechanization of the boom should be used, together with more use of auxiliary booms for brailing. Further improvement should be made in methods and equipment for handling wire purse line. The use of aluminium should be adopted in seine skiffs. The trend toward excessive beam should be stopped. The Alaska limit law, limiting the length of

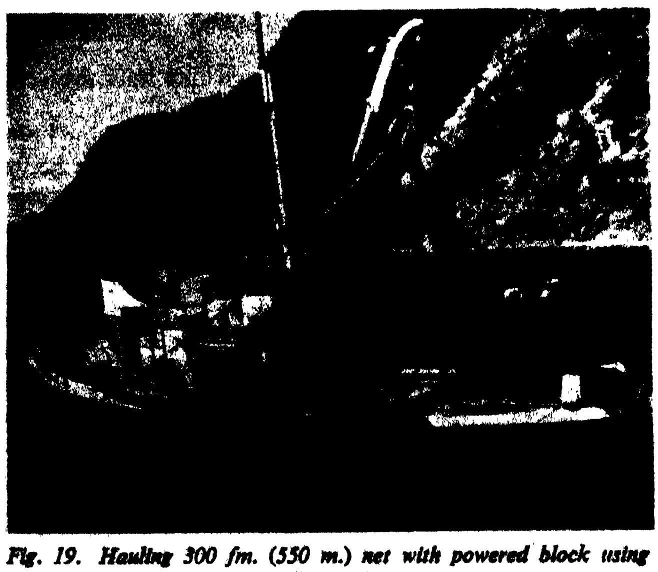
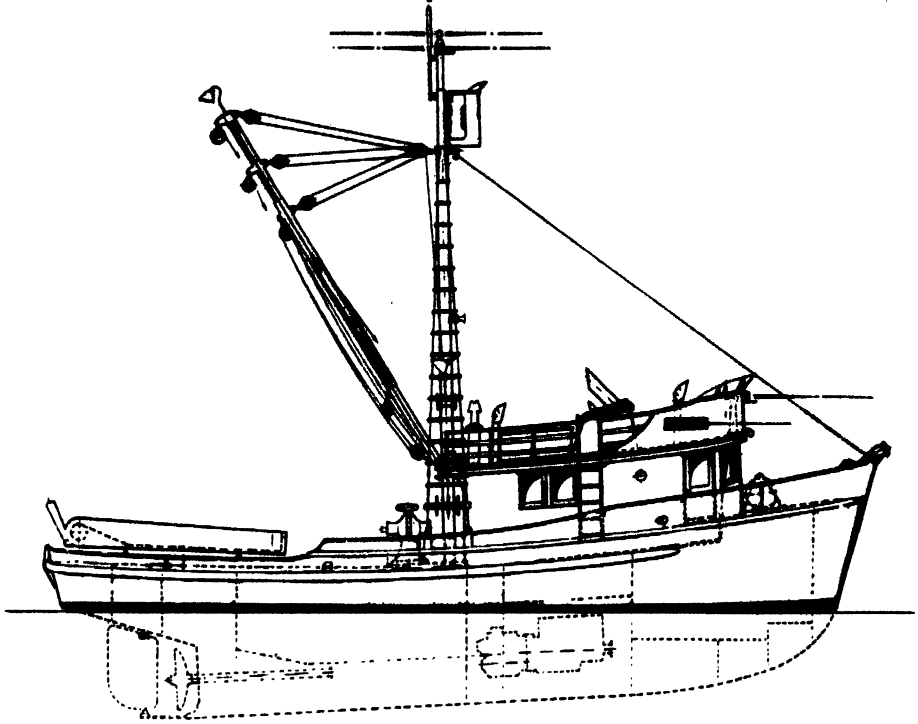
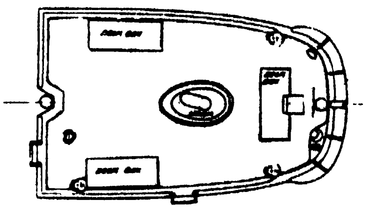


Fig. 19. Hauling 300 fm. (550 m.) net with powered block using seven men



Main particulars

LOA	57.83 ft.(17.65m.)
L	54 – ft.(16.76m.)
Length registered	49.92 ft.(15.19m.)
B	17.33 ft.(5.28m.)
Beam over guards	17.92 ft.(5.46m.)
T	7.75 ft.(2.36m)
T, fully loaded	9.50 ft. (2.90m.)
Fuel oil capacity	6000gal.(22680 l.)
Fresh water capacity	1200gal.(4530l)
Main engine	260 h.p.(Continous)



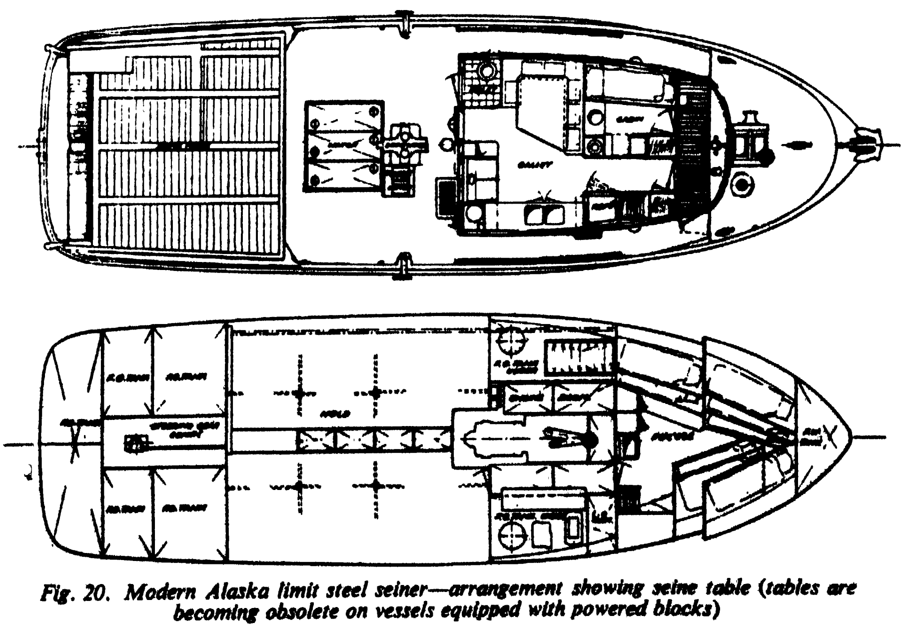


Fig. 20. Modern Alaska limit steel seiner—arrangement showing seine table (tables are becoming obsolete on vessels equipped with powered blocks)

vessels to 50 ft. (15.3 m.) has caused designers to build wider and wider vessels. It has been found that beams in excess of 17 ft. (5.2 m.) on a 50 ft. (15.3 m.) registered length cause excessive steering problems when driven at high speed-length ratios. It is suggested that lower deadrise be used with the resultant increase in midship coefficient and decrease in prismatic coefficient. The tendency in the past has been toward excessive deadrise and high prismatic coefficients, which give high resistance per ton of displacement.

Salmon

Fig. 18 shows a typical Alaska limit salmon seiner making a set. Fig. 20 shows the arrangement of living quarters, working space, winch, and hold. In 1958 this vessel

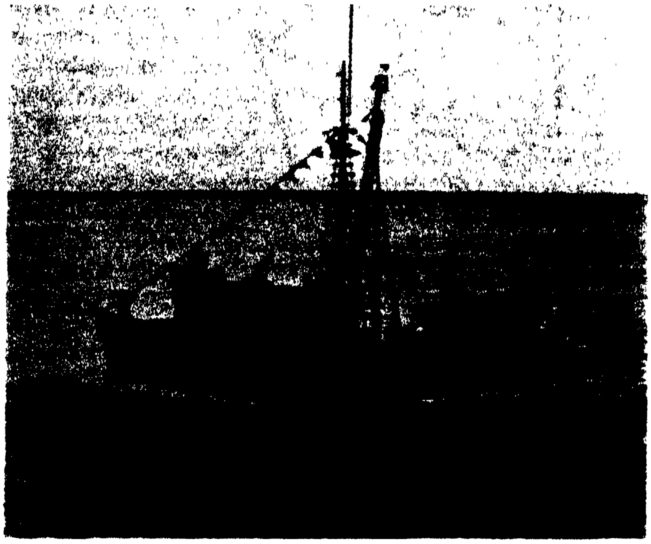


Fig. 21. Alaska limit salmon seiner

covered 17,000 miles in its quest for salmon and sardines —from the Bering Sea to southern California. The Alaska limit design has developed an exceedingly high displacement-length ratio vessel, which provides a very stable working platform. These are big vessels for their length, being designed to make the most of the length limitation. The seine skiff will be noted in fig. 18. These skiffs are from 16 to 18 ft. (4.9 to 5.5 m.) in length, and powered with engines of from 100 to 165 h.p. Their primary purpose is to tow the end of the net while the net is being set out, tow the vessel away from the net during the pursing and hauling operation, and tie off to the cork line during brailing. There are probably nearly 1,000 boats of this general style on the West Coast, including British Columbia. Fig. 22 shows a small, shallow draught "beach" seiner. From 400 to 500 of these vessels operate in the Kodiak Island and Prince William Sound areas of Alaska. A vessel of this type carries a crew of four, who live aboard. The dimensions are 39×14×2 ft. (11.9×4.3×0.6 m.) draft. In Canada and on Puget Sound larger purse seine vessels are also used, because there is no limit on length. The design and

Fig. 22. 39×14 ft. (11.9×4.3 m.) shallow-draught steel salmon seiner, powered with 150 h.p. diesel. Several hundreds of these vessels fish the shallow areas of Alaska

arrangement are similar to the smaller vessels, as shown by Hanson (1955).

The salmon purse seiners have converted generally to the powered block, with the exception of some 30 vessels equipped with drums. Pursing is done, in most cases, by a purse winch with two winch heads, using manila or nylon purse line. Wire purse line is being used increasingly by the bigger boats, using drum type winches.

Fig. 23. Canadian herring seiner hauling 400×45 fm. (732×82 m.) net. Large sets of up to 500 tons can be dried up with the small crew and a powered block. Normal crew is eight

Fig. 24. Californian sardine seiner, loaded

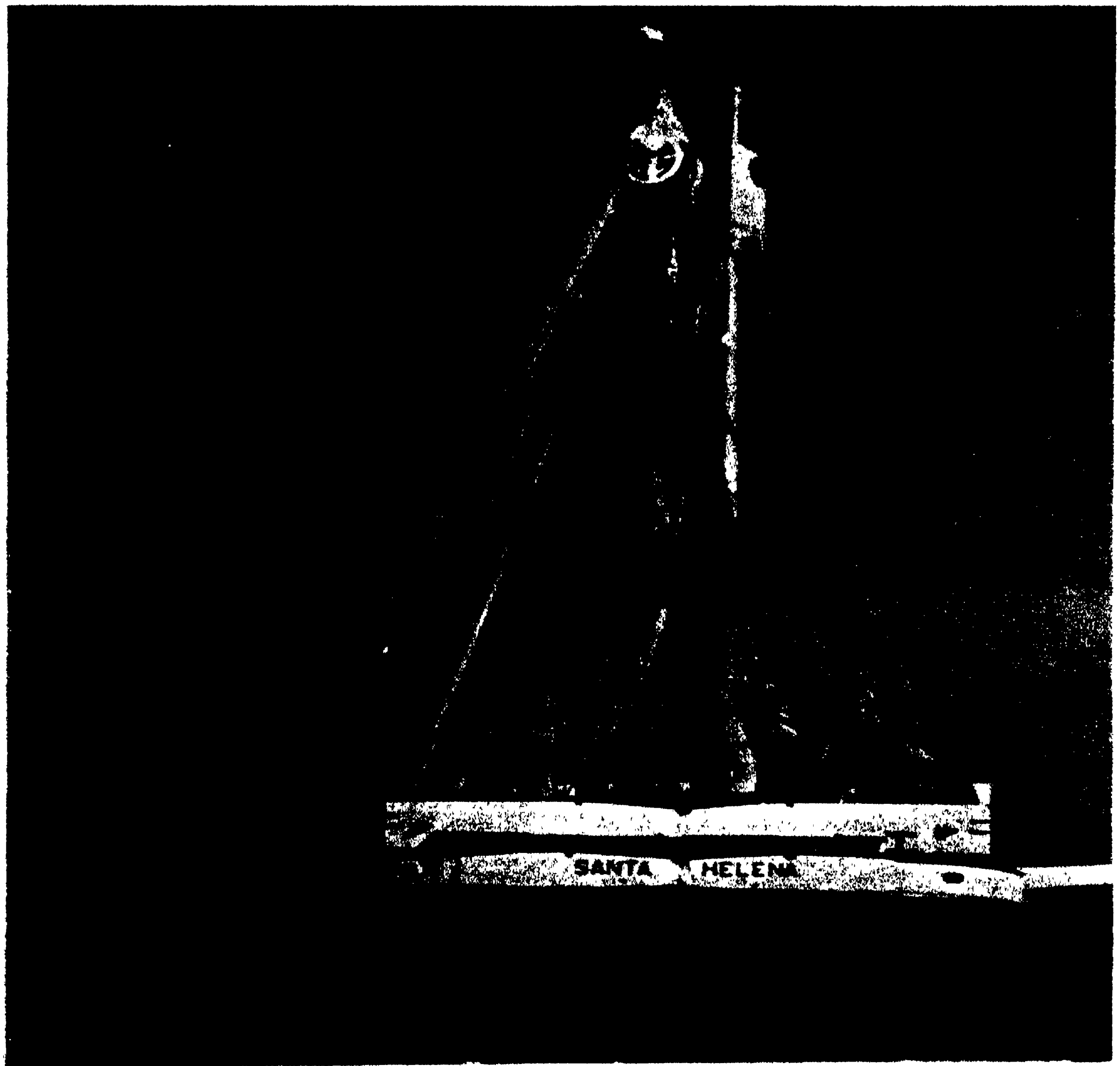


Fig. 25. Tuna seiner converted from Californian bait boats, hauling 450 × 50 fm. (825 × 92 m.) tuna seines with total crew of 12 men. These vessels are from 110 to 150 ft. (33.5 to 45.7 m.) in length. This is currently the most productive U.S. method of producing tuna. Stern view of Santa Helena, *136 × 30½ × 14 ft. (41.4 × 9.3 × 4.3 m.) tuna seiner of 350-ton capacity, hauling giant net with powered block*

Herring

Fig. 23 shows a herring vessel. These vessels also fish salmon during the periods of the big runs. The herring vessels in general are larger—from 75 to 95 ft. (23 to 29 m.) in length. The characteristics of the Pacific herring are very similar to that of the herring in Norway. The big herring fishery is in British Columbia in the middle of the winter. The Canadian herring seiners are completely mechanized, using wire purse line and power blocks. Sets as large as 500 tons can be handled, drying up the fish with the powered block. This has been a big improvement in the method of drying up the set. A crew of eight men is used, including the captain and man in the skiff. Echo sounders in small boats are used to locate the herring schools as in Norway.

Tuna

Tuna seiners are getting larger with the conversion of the bait boats to seining. *Pacific Fisherman*, June 1959, describes the economic reasons for the change from pole fishing to purse seining. Of primary importance has been the Puretic power block and the nylon seine. The tuna seines are up to 450 by 50 fm. (825 by 92 m.) and are exceedingly bulky. Cotton tuna seines seldcm last more than a year. The life of nylon is not known as yet, but is probably in excess of four years. The old method of strapping the net was slow and tedious. With the conversion to nylon, powered block, and other hydraulic equipment for handling purse lines and boom, the efficiency of the tuna seiner has nearly doubled. Fig. 25 and 26 show these large purse seine vessels. It is necessary to handle all phases of this operation by power equipment, otherwise the system would not be feasible.

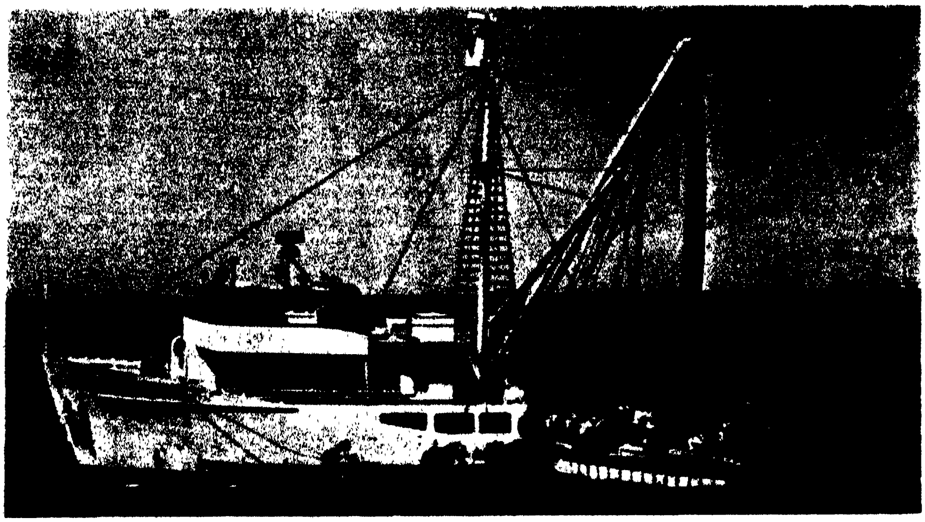


Fig. 26. Side view of Sun King *completing brailing*

WEST COAST OF SOUTH AMERICA

Purse seining on the West Coast of South America has been increasing rapidly. The types of fish obtained are anchovies in Peru and northern Chile, bonito in Equador, Peru and Chile and skipjack and yellowfin tuna along most of the coast. There are now about 500 purse seiners in Peru, which has developed its fishing industry most rapidly. Purse seining for anchovies in that country may reach one million tons in this coming year. The design of vessels was originally based on plans by H. C. Hanson, and in general follows designs of the Northeast Pacific Coast. In the last three or four years, as the industry has matured, there has been evolution developing distinct local characteristics. In the last two years, the quality of construction has improved, and the size of the vessels is gradually increasing. Those vessels catching skipjack tuna are primarily U.S. built.

Arrangement: Fig. 28 shows a design by the author's Company of an anchovy-bonito seiner, typical of modern contruction in Peru. The arrangement is in general similar to that of the Pacific Northeast boats; however, the vessels are designed with much greater freeboard and carrying capacity for their length. The accommodations and rigging of these vessels is very simple.

Fig. 27 shows a boat designed by the author's Company for combination fishing for hake (merluzza) and sardines on the West Coast of South America. The deckhouse is considerably smaller than would be used in North America, and simplicity throughout has been the requirement. Carrying capacity is exceedingly important, and it can be seen that the fish holds are proportionately much larger than those currently being used in Europe or in North America. It will be noted that the seine table, which has been common in the Pacific Northeast, has been eliminated from these designs, as it is not necessary with the powered block. It is, therefore, possible to use more sheer in the stern of the boat, which gives the afterdeck ample freeboard when the vessel is loaded, assuring safety and stability.

Method of fishing: The general method of fishing is similar to that used on the U.S. West Coast and Canada. Distances to the grounds are very short, and in most cases the vessels return before dark. Anchovy, the main species fished, is very easy to catch.

Mechanization: The only mechanization is the powered block, although a few boats have converted to wire purse line, and the fish pump is receiving its initial installation.

Suggested changes: The size of the vessels will increase, probably until they have a hold capacity of about 80 to 90 tons. Increased use of wire purse line, and the powered block, is recommended, in addition to the use of fish pumps. In certain areas where the fish are very plentiful, carry-away vessels should be adopted, and then the size of the seine boat can be held at from 50 to 60 ft. (15.3 to 18.3 m.) in overall length. Catch per man in Peru is higher than in any other purse seine fishery, even though the industry is only eight years old.

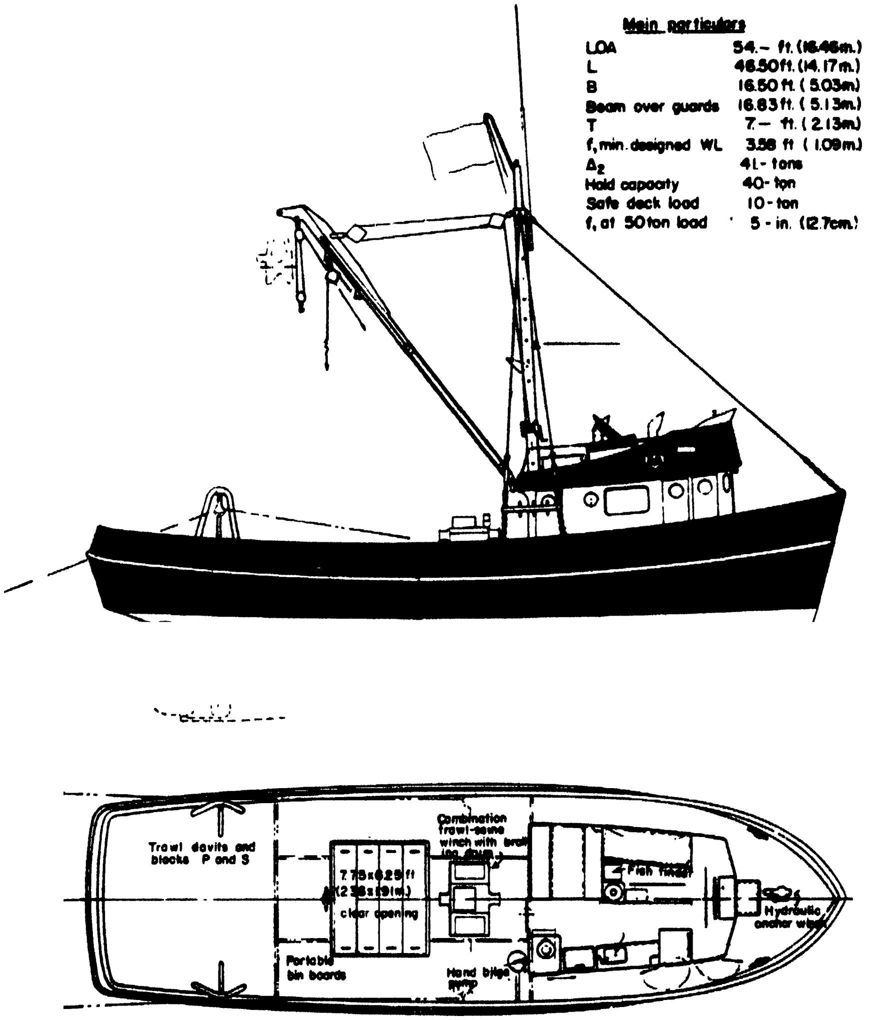


Fig. 27. 54 ft. (16.5 m.) steel combination trawler-seiner for West Coast of South America, designed for trawling hake and seining sardine

ICELAND

Arrangement, method and mechanization: The Icelandic purse seine fishery is for herring. Originally the system was identical to that used in Norway. The method of purse seining in Iceland is undergoing change, as described above. Recently, because of manpower shortage, the one auxiliary seine boat method is being used, towing the single net boat alongside the larger vessel.

Suggested changes: There is interest in vessels which can fish the large schools of herring which have been found in the winter close to Reykjavik. New vessels can be developed to accomplish this fishery. Fig. 29 and 30 give designs of two such vessels proposed by the author. In addition to being efficient purse seiners, the raised deck vessel (fig. 29) would be an exceedingly able stern trawler. The compromise design (fig. 30), places the deckhouse and machinery amidships. This was done to allow working space forward for handling longlines and drift-nets. A modified design is proposed similar to fig. 30, but with the deckhouse located off centre, allowing 8 ft. (2½ m.) of working space adjacent to the amidships deckhouse. This would be convenient for handling drift-nets. The space aft of the deckhouse on this design is ample for efficient handling of a purse seine. The drum-type purse

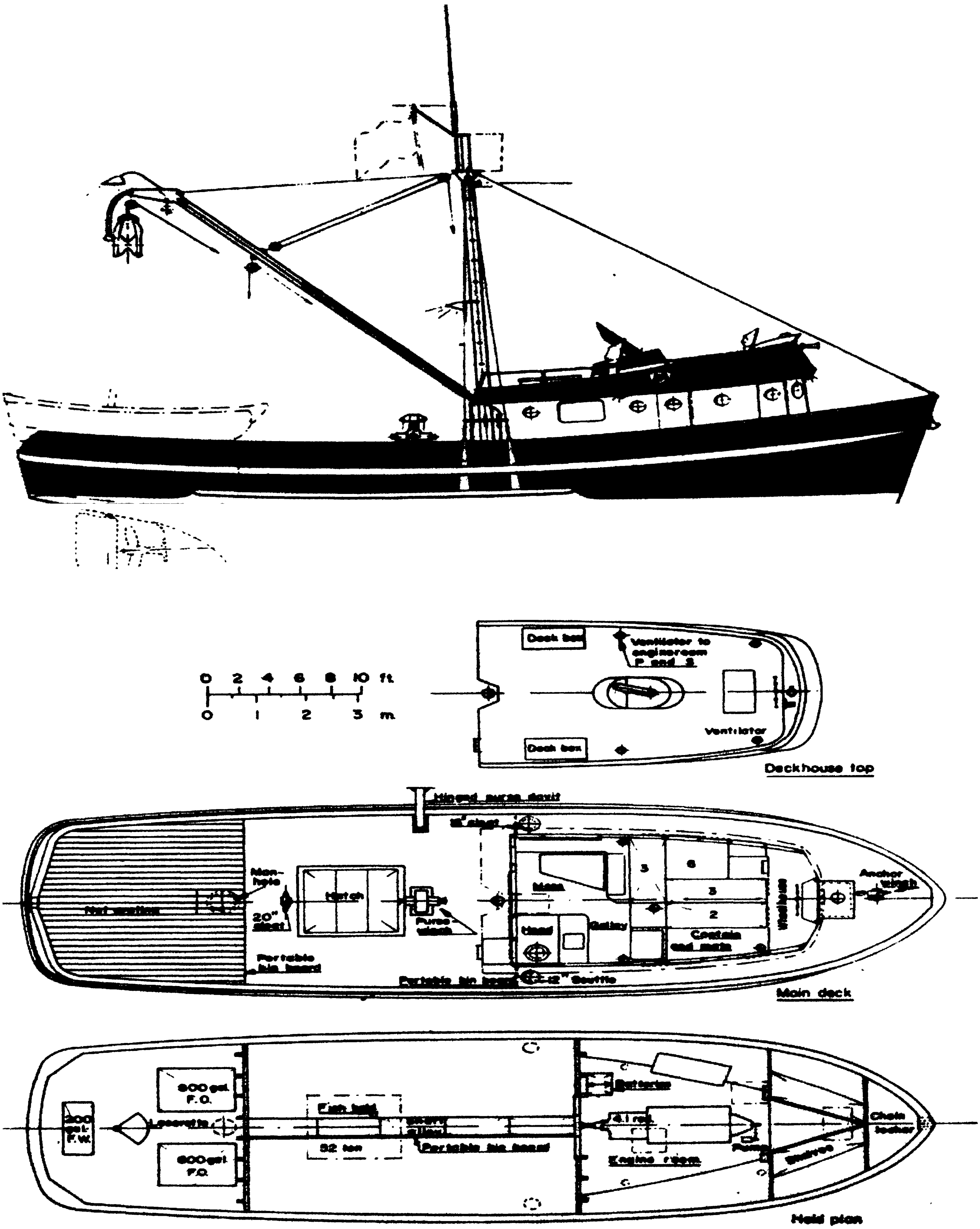


Fig. 28. 60 ft. (18.3 m.) anchovy-bonito purse seiner for West Coast of South America

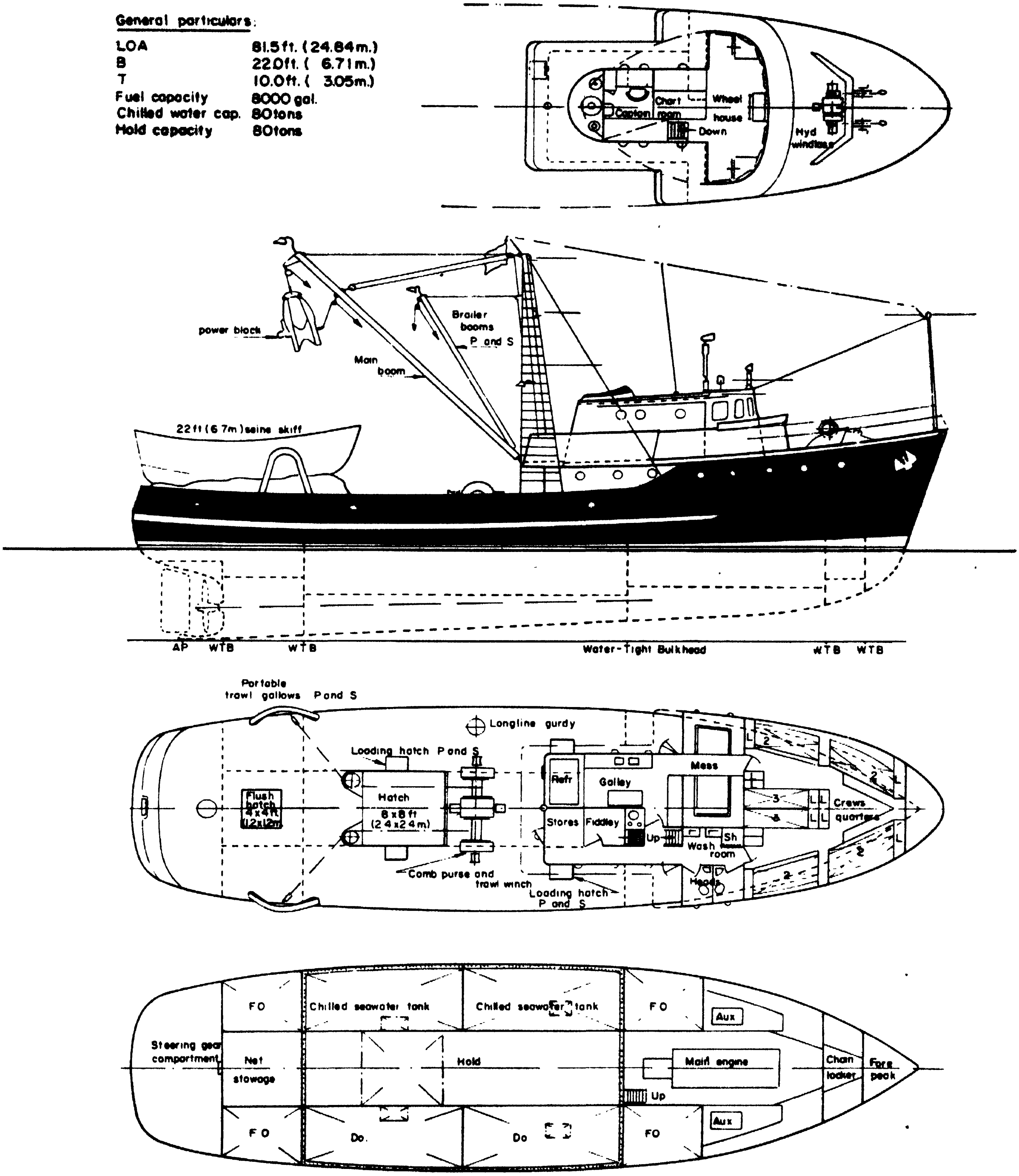


Fig. 29. Proposed combination vessel for Iceland. 140 ton capacity raised deck combination trawler-purse seiner

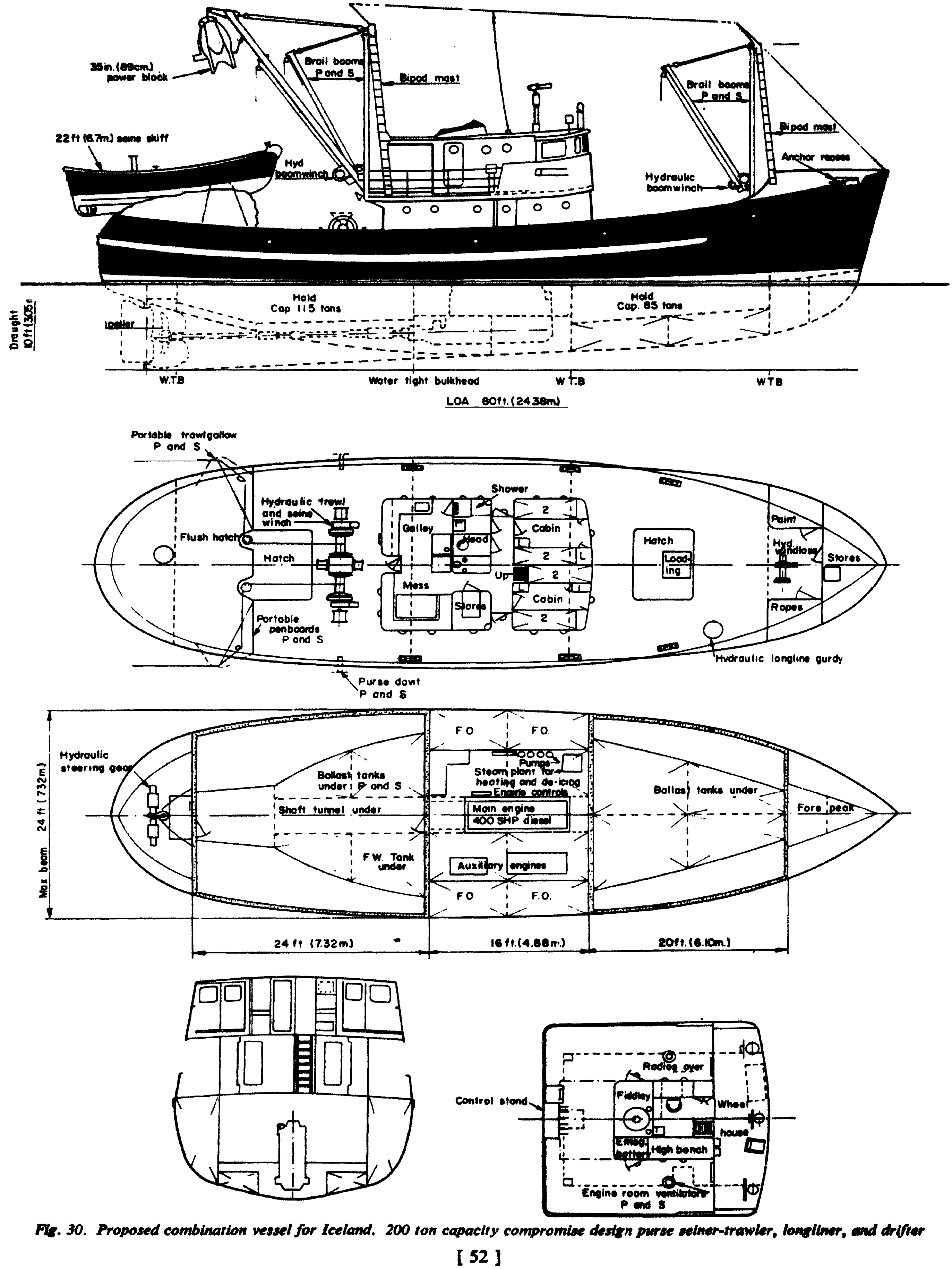


Fig. 30. Proposed combination vessel for Iceland. 200 ton capacity compromise design purse seiner-trawler, longliner, and drifter

winch is also designed to handle the trawl cables, so that one winch suffices for both operations. Maximum use of compact, high-pressure hydraulic winches is made on the booms. Fish pumps would be used for unloading the net, which would allow extremely rough weather fishing.

SOUTH AFRICA AND SOUTH WEST AFRICA

In Walvis Bay of South West Africa, and St. Helena Bay of South Africa, exist two of the most fabulous purse seine fisheries in the world. These fisheries are limited by quota to a total of 500,000 tons fish production per year. This is accomplished with high tonnage per man efficiency.

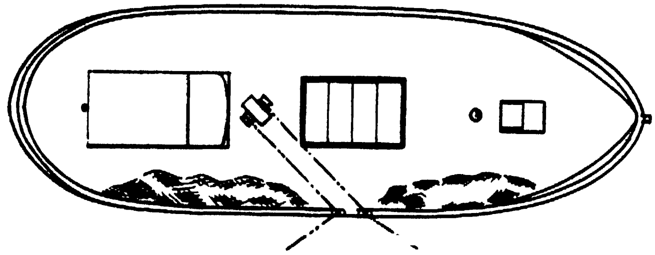


Fig. 31. Typical deck arrangement, South African lampara seiner

This is partially due to the large concentration of available fish, and partially to the unique system used. Fig. 31 shows the arrangement of South African-type vessels. The vessels have evolved from the European drifter type; however, they are being built with much more freeboard and beam than is common in Europe. A South African vessel of 60 ft. (18.3 m.) in length will carry, with deck load, well over 100 tons. No other fishing vessels have been built which will safely carry as large a load for a given length. The arrangement of the vessel is satisfactory for the small lampara net used. If the nets were larger, the location of the deckhouse in the stern would be a handicap.

Arrangement: The engine is in the extreme stern of the vessel, with a huge fish hold forward. The purse winch is located just forward of the main deckhouse, and on an angle. Rollers are used on the gunwhale, over which the purse line leads. These rollers cause an undue amount of wear, and should be improved.

Method of fishing: The lampara net described by du Plessis (1959) is handled very rapidly by from eight to ten men. The vessel sets with a small skiff tied to the end of the net, and on completion of the set pursing starts immediately, and the wings are also pulled in partially while pursing is in process. This is possible because the purse line takes the strain, and allows easy hauling of the wings. The echo sounder is in general use in South Africa, and in the last two years large quantities of fish have been found at times and in areas where there was no previous fishing.

Suggested changes: As yet, the powered block has not achieved much success; however, proper experiments have not been made. Fig. 7 suggests a method of using the block. With the use of the powered block and snap purse rings, possibly two men could be eliminated from the crew, and the work made easier and faster. Further experimentation should be made, using a net with the bunt at the end, rather than the lampara style with the bunt in the middle. Unsuccessful U.S. Western-style vessels have been built and tried in South Africa. These vessels failed because the design was not correct for the local conditions. It is the author's opinion that a correctly-designed U.S. Western boat could be developed for the South African fishery that would be able to handle larger sets as rapidly as the present boats are handling small sets, with approximately the same number of men. Much criticism is heard in South Africa of the Western-designed boats, which apparently cannot carry as big a load as the South African design. This, obviously, is generally a matter of beam, length, and freeboard in the light condition, and the correct U.S. Western design would be able to pack as much fish as the South African counterpart. The present South African design and hand method of hauling cause severe limitations on the depth of the net, as well as the length. With the echo sounder, more and more fish have been found at depths for which the present lampara is not efficient. Considerably more experimentation in basic systems would be desirable.

The addition of fish pumps on carry-away vessels could increase the productivity of the catcher vessels. This would allow greater production, with fewer catcher vessels and fewer fishermen on the grounds, because it would eliminate the waste time of running to and from the factory and waiting for unloading. The catcher vessels could be mechanized for handling larger sets, which would be aided by the fish pump.

PORTUGAL, FRANCE, SPAIN AND NORTHWEST AFRICA

Sardines

Sardines are the primary fish purse seined in these areas. Arrangement of the boats is shown in fig. 32. As the fish are not schooled up very heavily, large nets are used and the catch per set is small. The vessels have a very small fish hold space, and generally the small catch is carried on deck. The arrangement of the vessels is only satisfactory for hand hauling, with the use of a large amount of manpower (25 to 40 men).

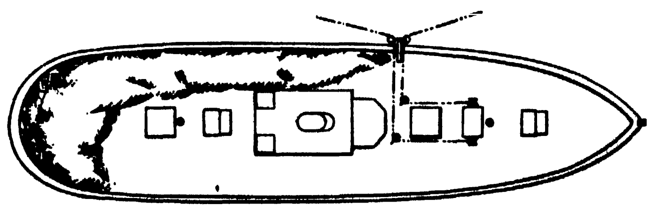


Fig. 32. Typical deck arrangement, Portuguese sardine boat

Method: The general method was described at the beginning of this paper. The boats are well built and seaworthy, and the nets are relatively long and deep.

Mechanization: The use of the fish finder is highly developed, and has increased the productivity of the fishery, allowing the boats to fish in the daytime, as well as at night, and on schools of fish that are not ordinarily visible. This is the only mechanization in the fishery.

Suggested changes: Manpower efficiency is very low, and pay for the crew is small. In the author's opinion, a U.S. Western-style purse seiner of equivalent size could catch an equal amount of fish with one-fourth of the crew presently used.

The general system is good, and Portuguese fishermen are extremely hardworking. Mechanization would increase their efficiency.

Tuna

There is an increasing interest in purse seining tuna in France, Spain, Portugal, and Northwest Africa. This is partially based on the success of this method in southern California. The California vessel design is recommended. There is now considerable bait fishing in these areas, using modified California techniques.

ANGOLA

The methods of fishing in Angola are the same as in Portugal, but the concentrations of fish are much larger. This is a major purse seine fishery, and reduction industry. The principal catch is mackerel and pilchard.

Suggested changes: There is far more reason to change the design of boats than in Portugal, because of the large amount of fish that are handled. Likewise, there is a shortage of trained crews, and the use of more mechanization, including the powered block, wire purse line, and fish pump would increase productivity. It is interesting to note that the Angola fishery, which is very close to the South West African fishery, uses the U.S. style net, rather than the lampara. More experimentation should be done to determine the relative efficiencies of these two systems, and to develop better deck arrangements and vessel designs in order to mechanize the best system for the type of fish available.

JAPAN

Purse seining in Japan is one of the major types of fishing methods. The publication, *Illustration of Japanese Fishing Boat and Fishing Gear* (1959), portrays pictorially the types of seine boats and gear used in Japan. Purse seiners are used primarily for mackerel, sardines, and skipjack. Japanese boats are of the following types:

Two-boat seiner

These are wooden boats of 20 to 50 gross tons, operating in pairs. The engine room is amidships, with hold forward and crew's quarters in the stern. Deckhouse with upper pilot house and flying bridge on top are located amidships. Purse winch is located forward of deckhouse. The net is stacked on the stern.

These boats work in pairs—separating to set the net around the fish. A V-sheave manually operated net hauler is located on the stern. The net is pursed in the normal manner, and half the net is hauled aboard the stern of each vessel.

The vessels are diesel powered and are equipped with fish and direction finders, wireless telegraph, and equipment for determining seawater temperature. Brailing is with conventional brailer.

These vessels are gradually being converted into one-boat seiners.

Two-boat "Aguri" seiner

These are small, Japanese-style vessels of 10 to 50 tons, of historic design. Although these boats were very numerous in the past, they are being replaced by more modern vessels.

One-boat seiner

These are boats, mostly built of wood, from 60 to 85 tons capacity. The trend is to steel construction. Engine room is amidships, with hold in the bow. Crew space is in the stern. These vessels are of modern design and construction.

The method is similar to the U.S. Western purse seine technique, with the net stacked on the stern. Pursing is done with a winch, just forward of the deckhouse. The crew consists of about 30 men, and net hauling is aided by the use of a hand-powered net puller mounted on the stern. The powered block has not yet been introduced. Pursing is mechanized, using wire purse line and net reels, similar to the system illustrated in fig. 8. The vessels are diesel powered, equipped with wireless, telegraph, and fish and direction finders.

The one-boat seiner resembles the two-boat seiner, although it is generally of more modern construction and equipment. The one-boat seine fishery is carried on with the help of a fleet of 5 or 6 boats: one or two lighting boats, one fish finder boat, one skiff, and one or two fish carriers. In this respect, this is an operation of fishing vessel with separate carry-away vessels; therefore, the fish hold in the catcher boats is relatively small.

American-style purse ____

American-style purse seiners were introduced into Japan immediately after the war. Although the general arrangement is very similar to the traditional one-boat seiner boat of Japan, the details of U.S. construction and arrangement were not well accepted and this general arrangement is not at present being built. The basic difference seems to be that even though the Japanese use a partially mechanized system, approximately 30 men are needed, resulting in extremely large crew quarters and correspondingly small fish hold. The U.S. vessels introduced were designed for the small U.S. crew, and the crew quarters are inadequate for the larger Japanese crew.

KOREA

Modern purse seine vessels in Korea are very similar to the Japanese one-boat system. Very large and deep nets are used in fishing mackerel in Korea. Recently powered blocks have been introduced on the Korean boats, with much success, in conjunction with the U.S. International Cooperation Administration program.

U.S.S.R

A Russian publication (Anonymous, 1958) gives an excellent pictorial representation of Russian fishing vessels. This publication shows purse seiners of types similar to the U.S. Western style, complete with seine table, showing methods of handling the nets similar to the Western technique. The two-boat system for catching herring is also used.

CONCLUSION

The percentage of fish caught by the purse seine method in world fisheries is increasing rapidly. Great improvement has been made in some areas in the last few years in both method and vessel design. Unless superseded by some completely new system such as electrical fishing, it is anticipated that purse seining will be applied to more and more species of fish in more of the areas of the world, and will continue to account for a larger percentage of the total fish production. Nylon nets and mechanization of the entire procedure have resulted in large increases in man productivity. In many areas the traditional designs of vessels should be re-analysed in the light of these recent developments. It is most important to design the vessel to suit an efficient method rather than adapt a method to suit existing designs.

Acknowledgments

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DRIFT-NETTING: DECK DESIGN AND EQUIPMENT

by

J. G. DE WIT

Drift-netting has the advantage that it can be done by boats that have engines with an output as low as 80 h.p. but drifters are normally equipped with 150 to 180 h.p. to provide reasonably free running speed. The disadvantages are the rather passive character of the fishing method, the high cost of the gear and its upkeep in shore establishments, and the limited duration of the season—about eight months a year.

There are two types of arrangement for the drift-net: shallow-water and deep-water. In the former the net is above the warp, whereas deep-water nets lie below the warp. Every fleet of nets consists of 100 to 120 separate nets, each 69 to 87 ft. (21 to 26.5 m.) long, making the total length about 1.13 to 1.43 nautical miles (2,100 to 2,650 m.). Setting is somewhat different for the two types but hauling is almost the same.

The design of a boat is mainly determined by the methods of setting the nets and hauling and processing the catch. About 118 ft. (36 m.) LBP is considered as the upper limit for a drifter. The prospects for drifting are uncertain due to the disadvantages mentioned and the poor results obtained in recent years. The solution for these difficulties may be a combined type of "drifter-trawler".

ÉQUIPEMENT DE PONT POUR LA PÊCHE AUX FILETS DÉRIVANTS

La pêche aux filets dérivants offre l'avantage de pouvoir être pratiquée par des bateaux dont la puissance des moteurs n'est que de 80 c.v., mais normalement les drifters sont munis d'un moteur de 150 à 180 c.v. pour assurer une vitesse de route raisonnable. Les inconvénients sont le caractère assez passif de la méthode de pêche, le coût élevé de l'engin et son entretien dans les établissements à terre, et la durée limitée de la saison de pêche—environ huit mois par an.

Il y a deux types de disposition des filets dérivants: en eau peu profonde et en eau profonde. Dans le premier cas, le filet est au-dessus de l'aussière alors que les filets pêchant en eau profonde pendent au-dessous d'elle. Chaque jeu de filets se compose de 100 à 120 filets séparés, mesurant chacun 69 à 87 pi. (21 à 26,5 m.) de long et ayant une longueur totale d'environ 1,13 à 1,43 mille marin (2.100 à 2.650 m.). La mise à l'eau est quelque peu différente pour les deux types mais le relevage est presque le même.

Le dessin d'un bateau est déterminé surtout par les méthodes de mise à l'eau et de relevage des filets et de traitement du poisson. Pour un drifter, on considère que 118 pi. (36 m.) Le.pp. est la limite supérieure. Les perspectives d'avenir pour la pêche aux filets dérivants sont incertaines à cause des inconvénients mentionnés et des médiocres résultats obtenus ces dernières années. Un type combiné de drifter-chalutier pourrait permettre de résoudre ces difficultés.

PESCA A LA DERIVA: EQUIPO Y FORMA DE LA CUBIERTA

La pesca a la deriva tiene la ventaja de que la pueden practicar embarcaciones con motores pequeños de un rendimiento tan bajo como 30 c.v., pero normalmente esas embarcaciones cuentan con motores de 150 a 180 c.v. que les dan suficiente velocidad en ruta. Los inconvenientes son el carácter bastante pasivo del método de pesca, el elevado precio del equipo y de su mantenimiento en los establecimientos de tierra y la duración limitada de la campaña: unos ocho meses al año.

Hay dos maneras de calar la red de deriva: en agua somera y en agua profunda. En el primer caso la red está encima del cable, mientras que en el segundo está debajo. Cada andana consta de 100 a 120 paños separados, cada uno de ellos de 69 a 87 pies (21 a 26.5 m.) de longitud, que le dan una longitud total de 1,13 a 1,43 millas náuticas (2.100 a 2.650 m.). El calamento es algo diferente en los dos tipos de pesca, pero el halado es casi idéntico.

La forma del barco la determina principalmente el método de calamento y halado de las redes y el de elaboración de la captura. Unos 118 pies (36 m.) de eslora entre perpendiculares se considera el límite superior para los pesqueros a la deriva. Las perspectivas de esta clase de pesca son inciertas debido a los inconvenientes mencionados y a los malos resultados obtenidos en los ultimos años. La solución de estas dificultades podría ser un tipo combinado de barco de pesca al arrastre y a la deriva.

HERRING fishing carried out by drifters in the Netherlands was of considerable importance in the years just after World War II. Now, due to increasingly bad seasons and the disadvantages of drifters, there seems to be no future for it. When catches improve, drift-netting is expected to continue for some years.

The conditions and circumstances are apt to change completely in a very short time, and it is difficult to say what will happen next, but the advantages must be weighed against the disadvantages. Shipbuilding is only one of the factors to be considered; others are in the fields of biology, technology and economics.

Although electronics help drift-net fishermen to locate the shoals of herring, drift-netting remains a passive fishing method, in that the vessel after setting the nets has to wait for the fish to swim into them.

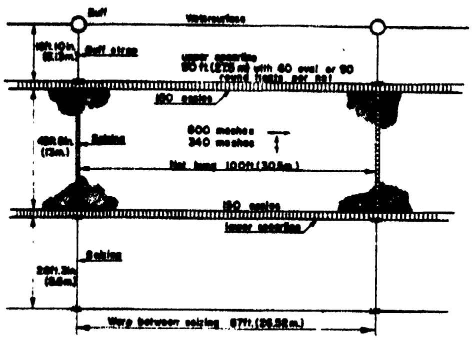


Fig. 33. Shallow water type drift nets or Scottish nets, hung above the warp, are supported by cork floats connected to the upper spearline and the buoys or buffs. Suitable when the herring are near the surface

The main advantages of drift-netting are:

- Herring which swim too high for trawling can be caught
- Engine power can be as low as 80 h.p., which means small capital investment and low fuel consumption

The main disadvantages are:

- The passive character of the operation makes it impossible to "hunt" for fish
- The fishing gear is expensive
- Vessels with small engines of, say, 240 h.p., cannot be used for other fishing during the off-season—approximately, from January until the second half of May

Fishing gear

There are two types of arrangement for the drift-nets, namely, the shallow-water (fig. 33) and the deep-water (fig. 34).

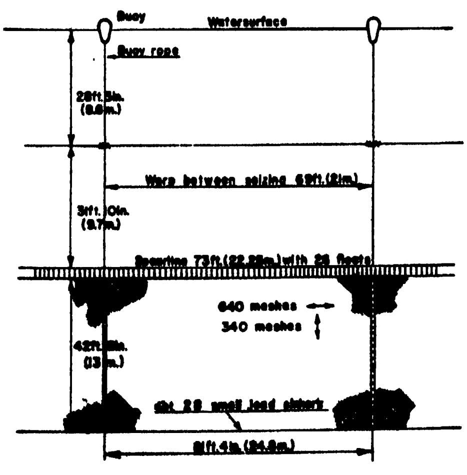


Fig. 34. Deep-water type drift nets, hung below the cable, suspended from the warp and supported by cork floats. Floats are connected to the spearline and by buoys. Used for deeper shoals

A fleet of nets consists of 100 to 120 separate nets, all connected to a warp. The fleet is shot some hours before sunset and the drifter is connected to it by a net-swing. Hauling begins in the early morning, usually just before dawn.

The deep-water nets are generally used for herring in the English Channel and on the Dogger Bank and are made of No. 30/15 American or Egyptian cotton; whereas the shallow-water nets are of No. 30/12 or 36/12 cotton. The seizings are generally of manilla, ⅝ in. (16 mm.) diam. The manilla warp varies from 330 to 375 lb. (150 to 170 kg.) per 120 fm. (220 m.).

The net-swing must be heavier than the warp because it has to absorb the forces acting on the fleet, caused by the movements of the vessel. Made of manilla, about 450 lb.

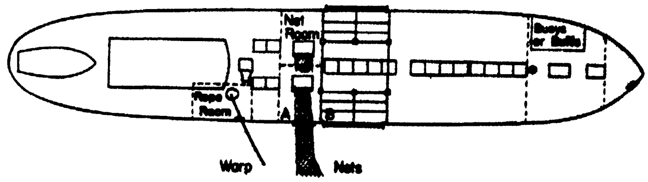


Fig. 35. Setting of Scottish nets. Fisherman 'A' connects the seizing to the warp and fisherman 'B' the buffs to the spearline

(200 kg.) per 120 fm. (220 m.), the net-swing is about 75 fm. (137 m.) long in strong winds, but may be less when the weather is fine.

Setting the nets

Setting a fleet of 100 nets takes 1 to 1¼ hrs. With shallow-water nets, the warp from the rope room runs over a fairlead on the starboard bulwark as it passes overboard, as shown in fig. 35 and 36. Fisherman A connects the seizings to the net at the marked places. Fisherman B connects the buffs to the buff strops on the float-line, the buffs being brought by a boy from the buff store forward.

The warp of the deep-water nets is carried forward from the rope room over the deck and passed overboard just behind the forecastle, as shown in fig. 37. At the same time the nets are run out over the rollers fitted on the starboard bulwark just abreast of the net hold. While the boat steams very slowly astern, steered with a bow rudder, fisherman A passes the seizings to B, who takes them forward to C, and he in turn connects them and the buffs to the warp.

When the setting is finished, the net-swing is led through a deep fairlead just abreast of the stem and fastened to a bollard, located between the foremast and the hawse. This fairlead is usually made of cast iron and has sufficient depth to prevent the net-swing from slipping when the vessel pitches.

Circular hawses are used on vessels with an open forecastle. To keep the space under the forecastle as dry as possible, the hawses are closed with a plate when sailing.

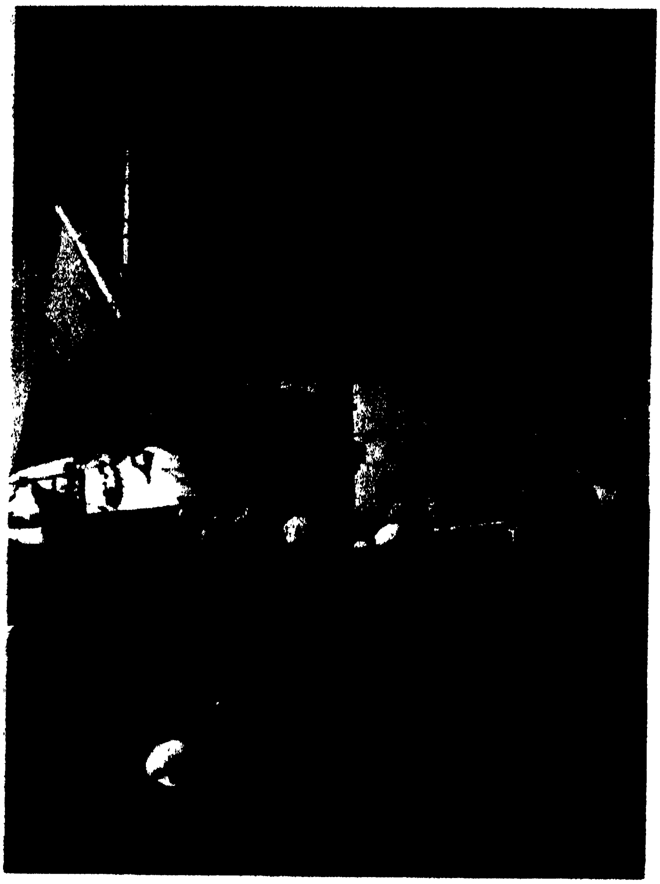


Fig. 36. Setting of Scottish nets abreast the net room. The warp runs from the fairlead on the bulwark forward to the waterline. The buffs are in the pond, ready to be connected to the upper spearline. The skipper, on the bridge, overlooks the operations, while manoeuvring his vessel slowly astern downwind.
(*Courtesy N. Parlevliet Jr., Katwijk an Zee*)

The mizzen sail keeps the bow of the vessel to the wind when drifting with the nets set out. The wind pressure on the vessel is normally enough to keep the warp stretched. In strong winds the main engine is put "slow ahead" to relieve the strain on the net-swing. A controllable-pitch propeller is better for this operation, because it allows the engine to run at optimum and constant speed.

Hauling the nets

The warp is hauled in by the winch. Hauling causes the ship to move slowly in the direction of the fleet. To relieve the strain in strong winds the engine is run "slow ahead". With shallow-water nets, the fisherman at F in fig. 38 disconnects the net seizings from the warp, and the outboard hanging nets, with the buffs are taken aft to the net roller. The man at L disconnects the buffs from the strops as the nets come over the roller, while G clears the seizings as they come in.

The nets are hauled by the men at A, B, C, D and E, who shake them up and down at the same time to empty out the herring. The fish fall into the pond H to starboard and into the space between the two ponds, stow boards being used to prevent them from scattering over the deck.

Hauling a fleet of deep-water nets differs only in that the buoys are disconnected at G. This is not difficult on ships which have no forecastle. When there is a forecastle, the circular warp hawse pipe is usually not wide enough to take the buoys, so the buoy ropes are disconnected from the warp at F and fastened to an endless rope, running through the hawse and around the back of the forecastle.

The hauling gear is shown in fig. 39 and 40. Until some years ago the nets were hand-hauled, but now

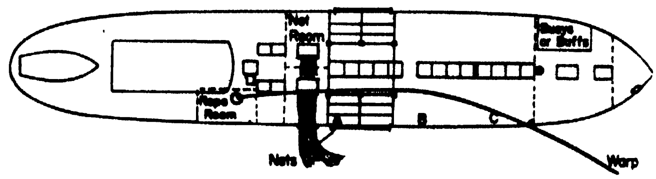


Fig. 37. Setting of deep-water type drift nets. The warp goes overboard almost abreast of the fore mast. The nets are abreast of the net room. The seizings are taken to 'C' by fishermen 'A' and 'B'. The buff strops or buoy ropes and the seizings are connected to the warp at 'C'

power rollers are used. These power rollers cause problems regarding the safety of the deck-hand at M. This deck-hand, who controls the hauling speed of the warp, is a boy of 14 or 15 years, usually the youngest on board. There is an historical reason for entrusting this work to a boy; when the warp was hauled by a hand-driven capstan, it was a boy's job to haul off the warp from the capstan while the crew "walked" around. Differences in hauling speeds of nets and warp were adjusted by slower hauling of whichever was ahead. When the steam capstan was introduced, the hauling speed was controlled by the boy, or the skipper on the bridge, by regulating the steam flow to the winch.

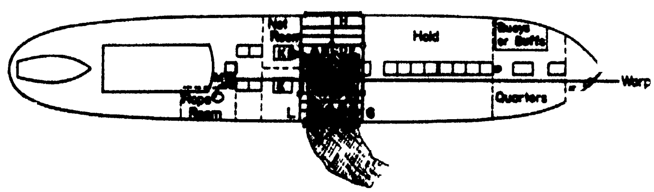


Fig. 38. Hauling. The warp rests in the hawser abreast of the stem. The propeller turns at a very low r.p.m. to maintain a balance between a sufficiently tight warp and too strong a pull. The seizings are disconnected at 'F' and the buffs or buoys at 'L' or 'G'. Fishermen 'A' to 'E' are pulling in the net and shaking the herring into the pond 'H'. The nets disappear into the hatches 'K'

Although modern belt-driven winches are more complicated and harder to handle, the job is still done by boys. Power-driven net rollers, introduced a few years ago, have made their work even more difficult. These rollers are belt driven by the winch shaft. The hauling speeds of the warp and the nets are theoretically the same, but that of the warp is greater, due to the slip of the nets over the roller. At intervals this inequality has to be corrected. This can be done by stopping the winch and slipping the necessary length of warp. This is not very dangerous for

Fig. 39. Hauling and shaking. Fishermen are leaning against the port pond. Lower left, the fishermen in the net room are hauling the nets to the hatch. The nets are led over a roller between the two ponds. Buffs are seen in the foreground.
(Courtesy N. Parlevliet Jr., Katwijk an Zee)

the deck-hand at M, but stopping the winch also means stopping the net rollers: the crew generally object and the boy is strongly urged to slip the warp without stopping the net rollers, i.e., without stopping the winch. This is very difficult for a youngster to do on the deck of a rolling and pitching vessel, and some fatal accidents to boys have resulted. In the Netherlands it is obligatory that the net roller drive is independent of the winch drive, so the deck-hand at M can stop the winch to slip the warp, and the powered net rollers continue without interruption.

The nets pass from the fishermen A to E over an athwartships roller, aft of the ponds, through the hatches K, into the net room, where they are spread evenly over the whole floor. As the nets are easily torn if they catch on protruding objects, constant care must be taken to avoid such mishaps.

Processing the catch on board
The herring are gutted on board and salted in barrels, which are then closed and stored as shown in fig. 41. If the catch is too large it is salted in an ungutted state, to be processed as smoked herring.

Gutting is done on a bench, forward of the winch, which runs from bulwark to bulwark. About ten men gut, the herring being brought to them from the ponds by another gang, who also take the gutted herring to the two men who salt them.

The barrels have to stand for hours and be topped up at intervals, before they can be closed, to allow the contents to settle. When closed they are lowered into the hold which is divided into compartments having a width to accommodate the barrels lengthwise. In loading a fresh compartment all empty barrels have to be brought on deck. If each compartment has a central partition, 26 to 30 barrels are stowed on deck, but when there are no such partitions, the deck has to accommodate about 60 barrels. Therefore a drifter must have ample deck space forward of the ponds to accommodate the filled but not yet closed barrels and the empty barrels, yet leave enough working space.

Deck gear
When setting, the nets are led over rollers on the hatch coamings and from there over the shooting rollers on the starboard bulwark, and then overboard. The hatch rollers are removed when setting is finished.

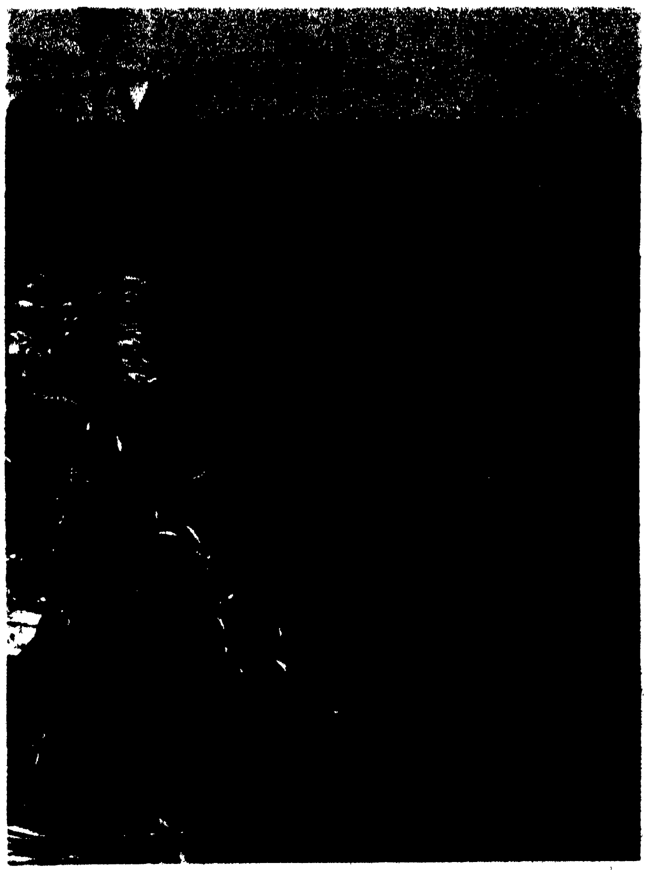


Fig. 40. Hauling. The train of buffs can be seen lying in the water. The fishermen upper left disconnects the seizings. The fisherman forward of the pond is holding the upper spearline and keeping the loose seizings clear from the roller. The open barrels contain the previous day's catch. The gallow indicates that this vessel is also suitable for trawling.
(Courtesy N. Parlevliet Jr., Katwijk an Zee)

Fig. 41. After being gutted and mixed with salt, the herring are put into the barrels, which have to stand open for many hours to allow the contents to settle. The barrels are topped up several times before they are closed. The day's catch is in the pond. The previous day's catch is in closed barrels which will be lowered into the hold and empty barrels brought on deck. Drift-net fishing requires ample deck space for processing the catch

At one time the side rollers for hauling had a diameter of about 6 in. (15 cm.), but some years ago it was increased to about 16 in. (40 cm.) with the introduction of the mechanical drive. These rollers are driven by the winch shaft running from the front of the engine skylight or the superstructure. A pulley is fixed on this winch shaft for a belt drive to the rollers. The winches are of a simple type and belt-driven from the main or an auxiliary engine. The best way to drive the power rollers is an arrangement that allows the skipper in the wheelhouse to regulate the speed of the net rollers, and to even the differences of the hauling speeds of nets and warp. For this, the electric or hydraulic drive appears to be the best solution. The long power rollers usually extend beyond the ship's side and are likely to be damaged in harbour. To avoid this, the rollers are often hinged at a point near the deck to allow them to be moved inboard.

The ponds are nearly the same height as the bulwarks. They must be easily removable, especially on vessels which trawl during the winter months. Each pond is divided into two or three compartments by longitudinal boards, which prevent the fish moving about too much—and thus losing condition when the ship rolls.

Hauling is preferably done over the starboard side, but a shifting wind may make this difficult and bring the nets along the stem or even under the keel. In such circumstances the nets are hauled on the port side.

Bow

Because a drifter sets its fleet while steaming slowly astern, a bow rudder is required. This is constructed to fit well into the form of the hull, as shown in fig. 42. The rudder can be settled in the central position by a fixing rod while steaming. This rod is located in a pipe and can be easily disengaged on deck. The rudder head is carried up to a tiller on deck.

Another type consists of a rudder head resting in a heel pot rivetted to the stem as far below the waterline as possible. The lower part of the rudder head is square; the upper part is kept in position by a bearing. The tiller remains outside the bulwark and is operated from the deck by two tackles. The rudder plate has two arms which fit to the square on the rudder head. A rudder davit on the bow enables the rudder plate to be moved up and down. Before setting, the rudder plate, pointing forward, is lowered. When sailing it is hoisted and fixed against the bulwark, pointing aft.

A mizzen is used to keep the vessel's bow to the wind when heaving-to, riding at the fleet and hauling.

The position of the foremast is determined by the loading and unloading gear (de Wit, 1955). There are considerable difficulties in stowing and in loading barrels forward of the foremast and, for this reason, the best

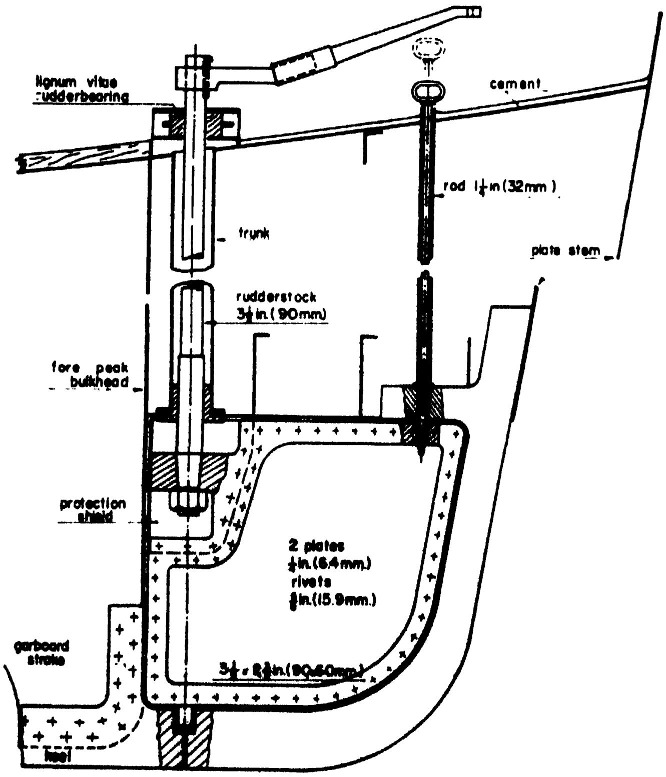


Fig. 42. Bow rudder. Its design can be made to fit into the waterlines having a rather sharp entrance angle

place for the foremast is on, or just aft of, the forward hold bulkhead.

Under deck arrangement

In subdividing the hold, the size of the barrels is taken into account. The height of the barrels determines the distance of the wooden partitions between the rows of barrels.

A Dutch barrel has a height of 2.4 ft. (73 cm.), whereas a Scottish barrel is 2.54 ft. (77 cm.) high. Allowing 2.5 ft. (76 cm.) between the partitions for a Dutch barrel and 4 in. (10 cm.) on one side for the thickness of the partition planks with clamps, the neck-to-neck distance between the partitions amounts to 2.85 ft. (86 cm.). These partitions are preferably arranged in steel channels, welded to the reverse frames, so that the distance between frames is ruled by the distance between the wooden partitions or, for Dutch barrels, 17 in. (43 cm.).

The net room has a length equal to at least five frames, namely 7 ft. 1 in. (2.15 m.). The frames are covered with wood to prevent the treated nets coming into contact with the hull. The location of the net room hatches is determined by the location of the aft bulkheads of the ponds. The rope room is aft of the winch, with a capacity of at least 320 cu. ft. (9 cu. m.) and a floor space large enough for coiling down the warp. Lath sheathing is normally used on the hull and the bulkheads.

It is possible to use a double barrel compartment as a rope room, in which case its width must be about half the breadth of the vessel. As a height of about 8 ft. 3 in. (2.5 m.) is sufficient, a fuel oil tank can be installed under such a rope room.

Sometimes the rope room is built into the engine room, but this is not recommended because it cramps the engine room space. A circular hatch of 2 ft. (60 cm.) diam. and a minimum height of 1 ft. (30 cm.) gives entrance to the rope room. The hatch is closed with a steel lid or a hood of ¼ in. (6 mm.) plate.

The crew's quarters in older drifters are arranged both forward of the hold and aft of the engine room. The forward quarter provides room for twelve men and the aft quarter for three or four. In modern vessels all crew's quarters are located aft of the engine room. The after part of the vessel has a deckhouse which, at least to port, reaches to the side.

Hull form

For good manoeuvrability when sailing astern, a drifter should not have too much trim by the stern. If it does, the ship will only respond slowly to the bow rudder.

When riding to the fleet the forefoot must not be of too shallow draught, otherwise the bow will be "thrown away" by the swell and the nets may be damaged.

Dutch drifters of 82 to 98 ft. (25 to 30 m.) LBP have the following draughts:

Forward .	6 ft. 7 in. to 7 ft. 3 in. (2.0 to 2.2 m.)
Aft . .	9 ft. 2 in. to 9 ft. 10 in. (2.8 to 3.0 m.)

The bow must not be too high because net damage can result from the wind blowing away the bow; nor should the warp hawse be too high above water. These requirements result in a very moderate sheer forward, which also provides a good working platform forward.

Before 1940 there was a trend to increase the length of new ships from 90 to about 105 ft. (27 to 32 m.) LOA. After 1945 this trend continued until vessels were about 118 ft. (36 m.) long, which for drift-net fishing, must be considered as the maximum. It is commonly considered that the sea qualities necessary for drift-netting would be lost if this length is exceeded. Experience has shown that more net damage occurs when vessels are longer.

The beam of the older boats is about 21 ft. 3 in. (6.5 m.). Just after World War II a drift-netter of 105 ft. (32 m.) LBP was built with a beam of 22 ft. 4 in. (6.8 m.). The trawler-drifters of about 115 ft. (35 m.) LBP, in which the emphasis is on trawling rather than drifting, usually have beams of 25 ft. 1 in. (7.6 m.), but it is felt that they have excessive beam with a correspondingly large GM which makes them too stiff. If the GM is too large the period of roll will be too short and the barrels on deck will be upset. When a ship is built primarily for drifting its beam should not be larger than about 23 ft. (7.0 m.).

The depth of a drifter is generally 10 ft. 4 in. (3.15 m.) but sometimes as much as 11 ft. 6 in. (3.5 m.). The depth is determined by the number of barrels that can be stowed on top of each other without damaging those at the bottom: if there is too much pressure the lower barrels may spring leaks, especially when the vessel pitches and rolls.

Six layers of deal barrels can be stowed without danger to the bottom layer, such stowage requiring a depth of 10 ft. 4 in. (3.15 m.). With oak barrels, seven layers can be stowed and they need a depth of 11 ft. 6 in. (3.5 m.).

According to Roorda (1957) the coefficients of drifters should be $\delta=0.52$ to 0.54, $\beta=0.73$ to 0.80, $\varphi=0.65$ to 0.74, $\alpha=0.83$ to 0.86. The floor should rise 3 ft. 3 in. to 4 ft. (1 to 1.2 m.) and the bilge should have a radius of about 3 ft. 7 in. (1.1 m.). The hull form must be such as to dampen pitching and heaving and the wind profile should be kept as small as possible, especially forward.

The old drifters, which were very good vessels for drifting, had a vertical stem with V-frames forward, almost without flare, and fine waterlines in which the bow rudder fitted well. The raking stem now used has not been an improvement.

Propulsion machinery

When drift-netting, a ship must be able to steam astern for a long time, and when hauling much manoeuvring is necessary. To do all this a mechanical or an hydraulic reversing gear is much better than a direct reversible engine. For the same reason it is desirable to have a controllable-pitch propeller.

The coupling of the engine to the propeller shaft usually has no reduction gear. The engines have a maximum speed of about 350 r.p.m., but must be able to work for hours at their lowest speed. If the speed is too high and the propeller is engaged when the ship is hauling there is a great risk that she will suddenly gain too much speed. When that happens the warp will slacken and the foreship may easily run over the nets.

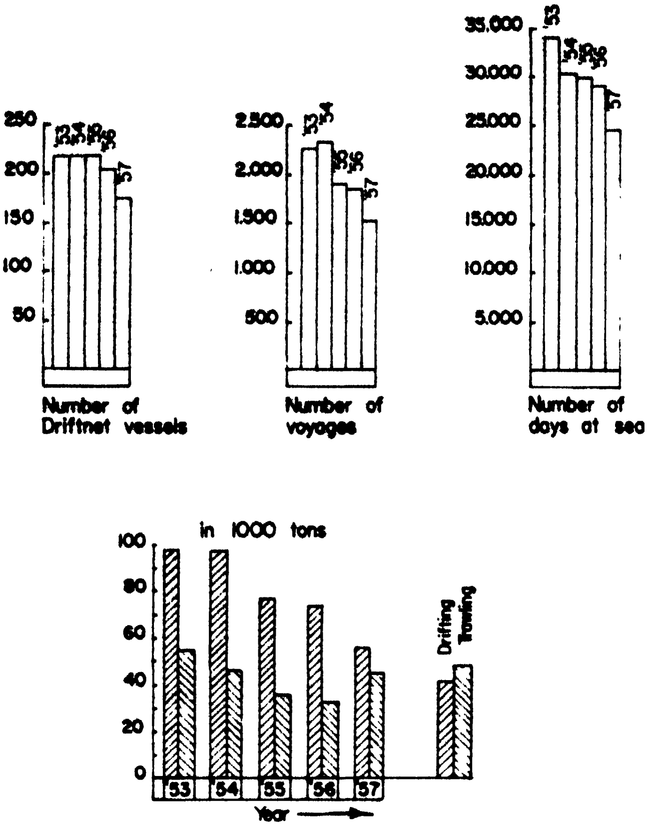


Fig. 43. Trends in drift-net herring fishing. During recent years the number of vessels, voyages and days at sea have all decreased; so have catches. Catches by trawling are increasing

The control of the engine and the reversing gear must be from the bridge where the skipper can see the whole scene. Although one qualified engineer is carried when the vessel has an engine of 150 to 225 h.p., and two when the engine is more than 225 h.p., it is difficult to keep them in the engine room during fishing operations.

Prospects

As previously stated, the results of drifting in the Netherlands have not been encouraging in recent years, as shown in fig. 43 (Jaarcijfers . . . 1954 to 1958), although there was an improvement in the first part of the 1958 season. Drifters are cheap to operate, but they can only be used from May until the end of December. This creates a social and economic problem because most of the crews often remain as idle as their ships. In an attempt to solve their problems, engines with higher power than is necessary for drifting have been installed, thus bringing into being the combined type of "drifter-trawler".

In recent years, when some drifters have been scrapped, the question has been asked: What kind of ships should be built in their place to maintain the fishery? That is very difficult to determine. Trawlers are increasingly supplying the market with sea-gutted, sea-salted and sea-packed herring, formerly the function of drifters, and a trawler can be used all the year round.

Again, the fishing gear for drifting is very expensive, and a costly shore establishment is needed to maintain it, as shown in fig. 44 and 45. Indeed, the cost can seldom be borne by owners of only one to three vessels; so the trend has been for such owners to sell their ships to larger concerns.

While many factors point towards a disappearance of the drifter, herring can usually be caught by drifting when bottom trawls produce little or nothing. For this reason there is some hesitation in giving a plain answer to the question posed above. The trend so far has been to replace drifters by small trawlers of 118 to 125 ft. (36 to 38 m.) LBP, with engine outputs of 600 to 800 h.p. Most of these vessels are doing very well. There is also the trend to combine drifting and trawling, which is not a new idea. It has been tried in Germany with the aid of the "propeller-rudder". When drifting, this "propeller-rudder" only is used, but for trawling or steaming the main engine is brought into action. A Dutch shipyard is following another method and is constructing a vessel of 126 ft. (38.5 m.) LBP, with a twin engine installation (2 × 500 h.p./650 r.p.m.) working on one propeller shaft

Fig. 44. The shore establishment for the upkeep of fishing gear is costly. The fleets of nets can be seen in the background, and large quantities of prepared ropes, etc., are shown hanging from the ceiling

through a 3 : 1 reduction gear. For drifting, only one engine is used, but both for steaming and trawling.

The requirements of a drifter and those of a trawler are contradictory in many respects. The modern tendency is to give the crew better protection against the weather and the sea. This naturally improves the working conditions and it also increases the efficiency of operation and the quality of the product. All these developments and improvements might result in a new type of fishing vessel. Fig. 46 is a sketch resulting from some thinking about such a new type.

Trawling is done over the stern. This brings the deckhouse more forward and gives a reasonable length between the slipway and the electric winch. Drifting takes place more forward than is usual in Dutch vessels. The net room (5) and the rope room (6) are located forward of the fish holds (3) and (4). The fish ponds (15) and the capstan (16) are located on the 'tween deck. In this way net damage caused by the pitching and heaving while hauling can be greatly reduced. Over the ponds (15) there is a double deck height for nearly the full breadth of the vessel. When the nets are shaken so that the herring can fall clear of them, there should be sufficient deck space alongside.

The 'tween deck at the ponds is built about 2 ft. (0.6 m.) higher, and the bottoms of the ponds are sloped. This slope causes the fish in the ponds to slide astern to sluices in the forward bulkheads of the working space, and from these sluices they pass to the working space (13) and (14), where they are processed.

Fig. 45. Much labour is involved to get the gear ready and in good condition before the season starts. Damaged nets are prepared by the fishermen's wives while the vessels are at sea. The nets are loaded on carriages, seen in the background, laid out to dry, thoroughly inspected, and repaired on the spot

The crew is accommodated in the forward part of the ship but the engineers have their quarters near the engine room.

The power units may comprise a main engine of about 600 h.p. and an auxiliary engine of about 200 h.p. The

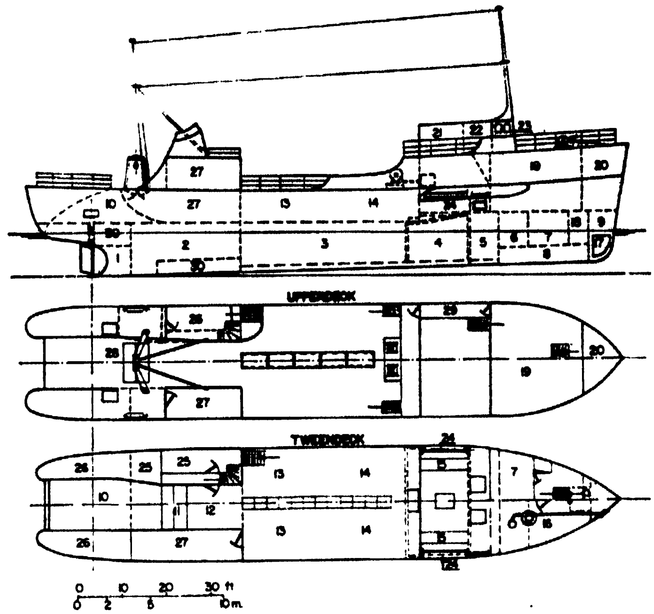


Fig. 46. Sketch of a trawler-drifter affording more shelter for the crew. Explanation of the figures:

1. After peak
2. Engine room
3. Hold for about 700 barrels
4. Insulated fish hold
5. Net room
6. Rope room
7. Crew's quarters
8. Drinking water
9. Fore peak
10. Hydraulic steering gear
11. Fish pond for trawling
12. Sorting place
13. Gutting and salting
14. Filling and closing the barrels
15. Ponds for drifting
16. Hydraulic or electric capstan
17. Hydraulically-operated bow rudder
18. Chain locker
19. Galley and messroom
20. Cook's store
21. Starboard: Captain; Port: Mate
22. Chart room
23. Wheelhouse
24. Hydraulically-operated net rollers
25. Engineers' cabins
26. Boatswain's store
27. Engine casing
28. Hydraulically-operated hatch covers
29. Passage
30. Fuel oil

auxiliary engine drives a generator which supplies current to the motor of the electric winch and also to a motor mounted on the propeller shaft. The auxiliary engine thus serves a triple function:

- It operates the winch
- Through the propeller shaft motor its power can be added to that of the main engine for propulsion when trawling
- Alone it can drive the ship when drifting, the main engine being stopped

With about 200 h.p. and suitable electrical wiring this auxiliary engine should give the vessel good manoeuvrability for drift-netting operations.

A vessel like that outlined in fig. 46 might have the following main dimensions:

LBP	=118 ft. (36 m.)
B	=26 ft. 3 in. (8.0 m.)
D ('tween deck)	=10 ft. 6 in. (3.2 m.)
D (shelter deck)	=17 ft. 6 in. (5.3 m.)

Due to the rather high superstructure forward, a mizzen sail will be necessary to keep the vessel in the wind.

GILLNET FISHING: DECK DESIGN AND EQUIPMENT

by

THOMAS E. COLVIN

The Great Lakes (U.S.A.) gillnetter is distinguished by the extensive superstructure which covers the full length of the hull. Climatic conditions on the Lakes make this superstructure necessary, which, in turn greatly influences hull design. Hull developments has progressed and been refined from early tugboat designs. While the early boats were of wood, the majority of all new construction is of steel. The V-bottom has been found to be the most economical method of constructing a steel hull for the Great Lakes. Nets are set from the stern and picked or lifted from the bow. These vessels must possess many of the capabilities of the ordinary icebreaker because of wintertime operation. Engines today are primarily high or low-speed diesels; formerly, steam and gasoline engines were popular. Air-cooled diesels show promise. There is a possible future development of small gillnetters for perch, and they would be about one-half the size of the existing gillnetters. Wood, in all probability, would be used for these smaller boats.

The fishing industry has declined sharply due to the infiltration of the lamprey eel into the Great Lakes. It has completely destroyed trout in Lakes Erie, Huron and Michigan. Because of the lamprey, catches of fish are down from one-forth to one-tenth of what they were 15 years ago. Part-time fishermen require smaller boats, as the existing boats are too large for present catches.

EQUIPEMENT DE PONT POUR LA PECHE AUX FILETS MAILLANTS

Le bateau de pêche aux fillets maillants des Grands Lacs (E.-U.) se distingue par ses superstructures étendues, qui couvrent toute la longueur de la coque. Les conditions climatiques sur les Lacs rendent ces superstructures nécessaires, et à leur tour elles ont une grande influence sur le dessin de la coque. Le développement de la coque a progressé, et elle a été affinée à partir des formes primitives de remorqueur. Alors que les premiers bateaux étaient de bois, la majorité de toutes les constructions nouvelles est en acier. On a trouvé que le fond en V est la méthode la plus économique de construction d'une coque d'acier pour les Grands Lacs. Les filets sont mis à l'eau par l'arrière et ramassés ou relevés par l'avant. Ces bateaux doivent avoir la plupart des capacités du brise-glace ordinaire à cause de la pêche en hiver. Les moteurs actuels sont surtout des diesels rapides ou lents; auparavant, les moteurs à vapeur et à essence étaient très répandus. Les diesels refroidis par air offrent des possibilités. Il sera possible de procéder au développement des petits bateaux pêchant la perche aux filets maillants, et leurs dimensions seraient environ la moitié de celles des bateaux existants, pêchant aux filets maillants. Selon toutes probabilités, on utiliserait le bois pour ces petits bateaux.

L'industrie de la pêche a nettement décliné par suite de l'infiltration de la lamproie dans les Grands Lacs. A cause de la lamproie, les pêches de poisson ont baissé d'un quart à un dixième de ce qu'elles étaient il y a 15 ans. Les pêcheurs ne s'adonnant pas exclusivement à la pêche ont besoin de bateaux plus petits car les bateaux existants sont trop grands pour les pêches actuelles.

LA PESCA CON REDES DE ENMALLE: FORMA DE LA CUBIERTA Y EQUIPO

El barco de pesca con redes de enmalle de los grandes lagos de los E.U.A. se caracteriza por su amplia superstructura, que comprende toda la eslora del casco. A emplear estas superestructuras, que influyen mucho en la forma del casco, obligan las condiciones climatológicas de los lagos. Estos cascos son un perfeccionamiento de los antiguos de los remolcadores. Aunque los primeros barcos eran de madera, todos los nuevos se construyen de acero. El fondo en V ha demonstrado ser el método más económico de construir un casco de acero para navegar en los grandes lagos. Los artes se calan por la popa y se recogen por la proa. Estos barcos tienen que reunir muchas de las características de los rompehielos corrientes a causa de pescar en el invierno. Los motores empleados en la actualidad son principalmente Diesels de alta o baja velocidad; antiguamente eran populares las máquinas de vapor y los motores de gasolina. El motor Diesel enfriado por aire ofrece posibilidades. La pesca de la perca es un posible campo de actividades futuras para barcos pequeños que emplean redes de enmallo, pero los barcos tendrian que ser un 50% más pequeños que los actuales. Es muy probable que se usase madera en la construcción de estos barcos más pequeños.

La industria pesquera ha decaido mucho debido a la llegada de la lamprea a los grandes lagos. Debido a los estragos causados por la lamprea, las capturas de pescado han disminuido a entre la cuarta y la décima parte de lo que eran hace 15 años. Los pescadores que no dedican todo su tiempo a la pesca necesitan embarcaciones más pequeñas, porque las que tienen actualmente son demasiado grandes para las capturas que logran.

THE Great Lakes (U.S.A.) gillnetter is distinctive in appearance due to its rather high superstructure, shown in fig. 47 and 48. This superstructure has greatly influenced the design of the hull and is the result of coping with climatic conditions on the lakes. The gillnetter is used on all five of the Great Lakes, but is most popular and numerous on Lakes Michigan, Huron and Superior. Almost every harbour on these three lakes on both the Canadian and U.S.A. sides, has a small fleet of gillnetters which were originally designed to fish trout, perch, chub, whitefish, smelt, salmon, suckers, herring, and other species of fresh-water fish. These vessels range in length from about 33 to 60 ft. (10 to 18 m.); and the most common length is between 40 and 45 ft. (12 and 14 m.), and these are usually two-man boats.

The long superstructure was necessitated by the extremely cold weather of 0°F (−18°C). There are

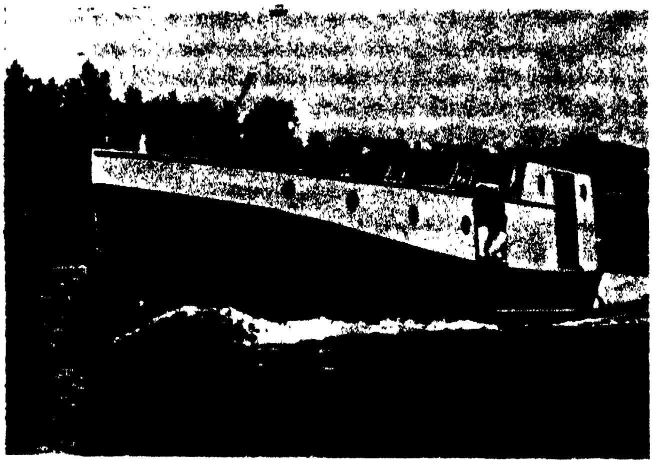


Fig. 47 and 48. Great Lakes gillnetters with high superstructure to protect the crew

relatively few days during the winter when the temperature is much above freezing point. The entire interior of the vessel is kept warm during the winter by a coal or oil burning stove. This prevents the nets from freezing and also keeps them dry prior to being set. The fishermen are reasonably warm except when actually hauling.

During the early days, some of the gillnetters had split superstructures and occasionally only a forward or after deckhouse. Net boxes were carried on deck, as were the fish. In the winter it was not uncommon to have a large accumulation of ice on the decks, in the nets, and in the fish, which caused a severe stability condition, so there was always the danger of loss of life and gear due to capsizing, even with careful handling. Since these boats are also called upon to break ice to get to and from the fishing grounds, as shown in fig. 49, conditions were aggravated by this accumulation of ice and the weight of nets and fish so high above the waterline, especially when the hull rode up on an ice floe prior to crushing the ice. Also, it is often desirable while going through the ice to rock the hull in order to break an even larger channel to allow backing, manoeuvring, and gaining speed to continue to break ice ahead of the hull.

The early boats were constructed of wood, and, for the most part, were based on the tugboat hull, the only difference being in the superstructure. The hulls were sheathed with galvanized iron from slightly above to well below the waterline. They were propelled by steam at first, but the Great Lakes gillnetters adopted gasoline engines very early in the twentieth century. In those days, when the fishing fleet was primarily of wood construction, the addition of the full-length deckhouse often lightened the hulls rather than made them heavier through the elimination of the main deck. Superstructure framing was widely spaced and lightly sheathed with tongue-and-groove ceiling of $\frac{3}{8}$ to $\frac{3}{4}$ in. (9.5 to 19 mm.). Actually, the only requirement of the deckhouse is that it be weatherproof and watertight, and that it supports the weight of a man and some light buoys, anchors, and, occasionally, some newly-treated nets which would present a fire hazard if stowed inside before being set the first time. With these deckhouse changes, the net boxes were lowered to a working flat. With the introduction of adequate heaters to warm the whole interior of the hull, the nets that had been hauled remained warm and did not freeze. With the lowering of the centre of gravity, the boats became safer: the fishermen worked lower in the boat and were better supported, as well as remaining reasonably dry and protected not only from the winter cold but from rain and the hot sun of summer.

Other types of fishing vessels are used on the Great Lakes, the design being entirely different from the gillnetter. These include the pound-net and trap-net boats, which are very popular on Lake Erie, and an occasional handliner for trout.

Fig. 49. Great Lakes gillnetter in ice

Fishing gear

The gillnets of the Great Lakes are normally set on the bottom, and vary in length from 1,000 to 30,000 ft. (305 to 9,150 m.). The lengths are made up into boxes, each box containing from 1,000 to 2,000 ft. (305 to 610 m.) of nets, with corks and leads. The nets vary in width from 5 to 6 ft. (1.5 to 1.8 m.). Along the upper portion of the net are placed aluminium or plastic floats. The floats are approximately 4 in. (102 mm.) in length by 2 in. (51 mm.) in diameter and are spaced from 7 to 9 ft.

(2.1 to 2.7 m.) apart. Opposite each float is a lead of approximately 6 oz. (170 g.), which is of sufficient weight to sink the net and the floats to the bottom. The leads are of cylindrical shape about 4 in. (102 mm.) in length, with a hollow centre, and are so tied as to permit them not only to revolve but to move slightly back and forth so that there is no binding while being pulled around the lifting drum. The mesh is about 2.5 in. (64 mm.), although this differs greatly from State to State. The nets are of nylon. The seaming twine is of cotton. The float and lead lines are of linen or cotton, and occasionally nylon thread consisting of three or more strands, specially treated by dipping in a preservation made of gasoline and oils mixed. Newly-treated nets are never carried inside the superstructure because of their volatility, which is dissipated after the first setting.

Location of nets

The depth at which the nets are set varies not only with the season and species but with the locality. The rather shallow waters are from 6 to 20 fm. (11 to 37 m.), and the deeper between 35 and 50 fm. (64 to 91 m.). Nets are often set in the summer to as great a depth as 115 to 130 fm. (210 to 238 m.). Modern boats, with their lifting gear, have reduced the labour of deep-water fishing. Two men with a mechanical lifter can haul nets from over 30 fm. (55 m.), whereas it used to require from three to five men to do the same work by hand.

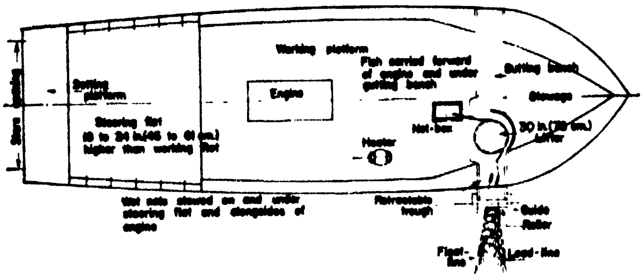


Fig 50. Deck arrangement of gillnetter with hauling equipment in the fore end of the vessel

Packing the nets

The nets are stretched on a drying reel, and from this drying reel they are stowed in boxes with the leads arranged and stacked in tiers along the right-hand side of the box. The floats are then stowed in tiers throughout the remainder of the box. Great care is taken to ensure that each float corresponds to its lead, and to be certain that everything runs free when setting. The belly of the net is allowed to overhang the edge of the box, and when the reel is emptied—that is, from 1,000 to 2,000 ft. (305 to 610 m.)—the belling is folded over the float and leads. The ends of the float and lead lines hang from the box. When all the boxes are packed, they are loaded into the after or raised platform of the boat. The number of boxes to be set in any one day depends not only on locality but on the individual fisherman; from 10 to 30 boxes is the usual number. Ideally, the width of the hull just forward of the setting platform will be that of a given number of boxes to prevent any movement due to rolling. If a vessel, is, say, 8 boxes in width and is to set 32 boxes, it will have two rows of 8 boxes each on the bottom and a second tier of two rows of 8 boxes. Net boxes are seldom stowed more than two high because of the weight and the inconvenience of handling and stowing them.

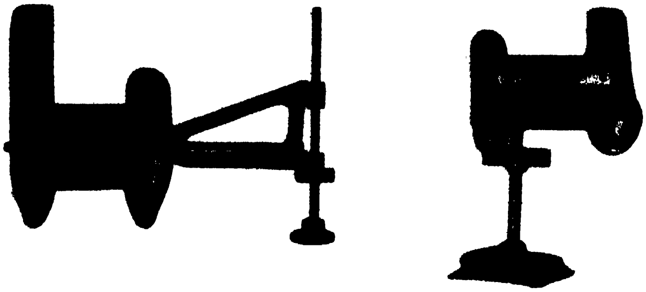


Fig. 51. Trough and roller equipment extending about 30 in. (76 cm.) over the side

Setting the nets

When the fishing grounds are reached, a buoy anchor and buoy line are made ready. These are often carried on the housetop, but sometimes inside. The buoy and its anchor are then dropped with a suitable length of bridle which varies according to the depth of the water. When the buoy is in place and anchored, the vessel moves ahead at a speed of 3 to 5 knots, depending on the weather and the skill of the men setting the nets. Each man setting picks up a lead and a float from the box and throws them clear of the stern. When the box is almost empty, a third man, if there is one, moves box No. 2 into place and makes fast the ends so that its contents are

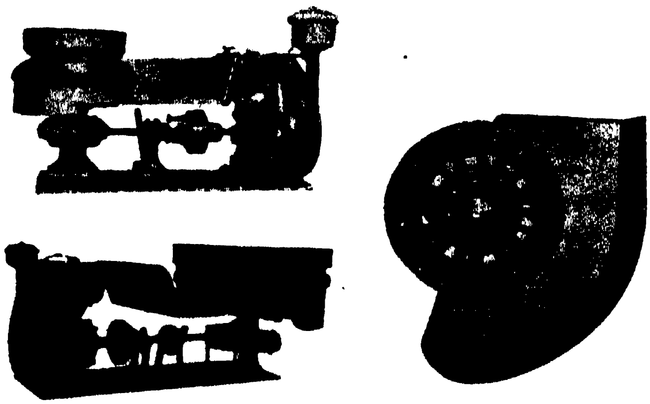


Fig. 52. Net hauler drums ranging from 10 to 30 in. (25 to 76 cm.) in diameter

ready to be set when the first box is empty. On a two-man boat, the last few leads and floats are thrown by one man, the second man moving the next box into position. Occasionally when a man and a boy work the boat, the boy steers and moves the boxes into place, and the man throws the floats and leads. This can be dangerous as it is possible for the man to become entangled in the nets and be pulled overboard. When the desired length of net is in the water, a second bridle is made fast and attached to a second buoy and anchor.

Hauling the nets

The reverse process is used when hauling, but this is always done forward, as shown in fig. 50. The location of the forward opening varies from boat to boat. A trough and a roller, shown in fig. 51, extend over the side of the hull for approximately 30 in. (760 mm.). Large guides on the ends of the roller prevent the net from slipping off as it passes to a hauling drum via the trough. Drums, shown in fig. 52, range from about 10 to 30 in. (254 to 760 mm.) in diameter, the last being the most common size. The hauler is so designed as to catch the leads, and the floats, being opposite the leads, are pulled evenly with them. The net, with the catch, sags between the float and the lead lines. Thus, as the nets pass the drum, the float and lead lines are, together with the fish, dispersed in the belly of the net. If the net is heavily loaded with fish, it is common, especially on two-man boats, to allow the fish to remain in the nets and to stow them in boxes; but with light catches the fish are picked from the nets as they come aboard. During hauling, the speed of the vessel is very slow and only sufficient power is maintained to ease the load on the hauler as much as possible. The filled boxes are stowed as directed by the skipper, while the wet nets are placed in another part of the vessel. In the winter the boat is kept as closed as possible because it is essential that the inside of the vessel remains warm, usually around 60°F (16°C), to prevent the nets freezing.

After the haul is made, the vessel proceeds to the next set of nets to be hauled, and during this run some of the crew either pick the nets just hauled or, if they were picked during hauling, gut the fish. Hauling is normally done only after all the dry nets have been set. In port, the wet nets are wound on to drying reels, picked of debris, and stretched for drying, ready for repacking.

The methods of handling the nets on mechanized boats differ little from those on unmechanized craft. The mechanical hauler of course, reduces labour. The continuous superstructure was in general use long before the mechanical hauler. The modern hauler is very small, takes very little space, and can be adapted to any type of hull. It is very efficient and needs but little maintenance. The drive is from the main engine through a shaft. The haulers are always operated from one side of the boat only, either port or starboard.

Future development will be in the boats themselves, followed by improvements in fishing methods.

Other methods have been tried for setting gillnets. One of these is the drum setter, similar to that used on the West Coast, but it has not be successful.

Deck openings for gear

The configuration of the superstructure varies according to the preference of the fisherman, builder or designer. The nets are always set from the stern, which can be open the entire width of the hull, and is the only universal feature in the superstructure. The large double doors on the sides of the superstructure aft are for loading and unloading the nets on the dock. The smaller boats all have a raised deck aft which is the steering flat and the net-setting flat and which is seldom less than 8 or 10 ft. (2.44 or 3.05 m.) in length fore and aft. All the boats, regardless of size, have double doors on the sides aft, and here, again, personal preference dictates their width and the manner in which they swing. Some open vertically, while others open horizontally. Advantages of horizontal hinging are that there is better control of the open area and it is reasonably watertight when running on a quartering sea or in rainy weather. The net-hauling doors are arranged over a great portion of the forward length. Generally, they are placed well forward to permit better control of the boat while hauling the nets, and the mechanical net haulers are usually located forward. A second door is often found in the hull, about half way between the forward and aft openings, used for picking when the net is to remain without resetting.

Location of wheelhouse

It is very difficult to manoeuvre from the aft steering flat as visibility directly ahead is restricted at close quarters. So a hatch is often fitted in the cabin roof, permitting the helmsman to stand with at least his shoulders above the housetop. He steers with his feet on the wheel, the engine controls being within easy reach while in this position. A large window is fitted in the sides of the hull on some boats to give the helmsman better visibility, but he is still blind on the opposite side. There is often a large stack in the housetop for the exhaust pipe, which further restricts visibility. The larger boats of 55 ft. (16.8 m.) or more in length, usually have the pilot house amidships, with a separate steering flat above, and this gives very good visibility, especially as the engine exhaust is always aft.

Height of superstructure

The headroom is usually about 7 ft. (2.1 m.) in the working flat, although there is no apparent reason for this excessive height. The most efficient boats are those in which all openings are low to the water, or the working flat is raised to a point where it is convenient to lean out. During hauling, especially with mechanical haulers, height is not as objectionable as it once was. Nevertheless, height in the stern is still disliked because the nets have a tendency to fly off to leeward when being set. The superstructure across the stern, therefore, is usually carried just high enough along the bottom to allow it to be flush with the tops of the fish boxes.

The only fittings normally seen on superstructures are: a mooring bit forward, grab rails just forward of the break into the pilot house, running lights atop the pilot house with a horn, and grab rails on the raised deck aft.

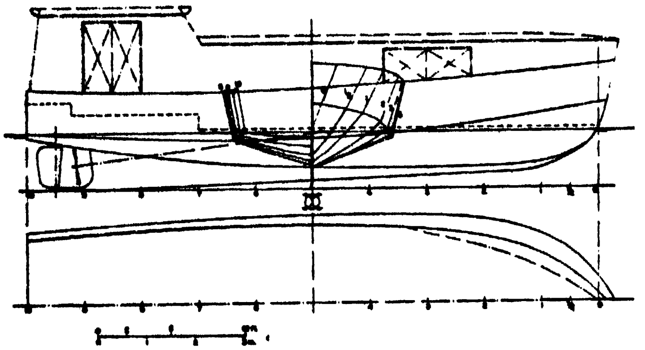


Fig. 53. Gillnetter, Boat A, where the entire bottom is developed on a series of cones

The minimum equipment required by law, such as fire extinguishers, etc. is all that is carried. For the most part, gillnetters have no accommodation for the fishermen.

Main

Although there are no fixed types of boats for gillnetting, the main specifications of some Great Lakes gillnetters are given in table 1.

Fig. 53. This is the lines plan of Boat A in table 1, which is also shown in fig. 47. In this vessel the entire bottom was developed on a series of cones, with the primary apex just forward of station O and in line

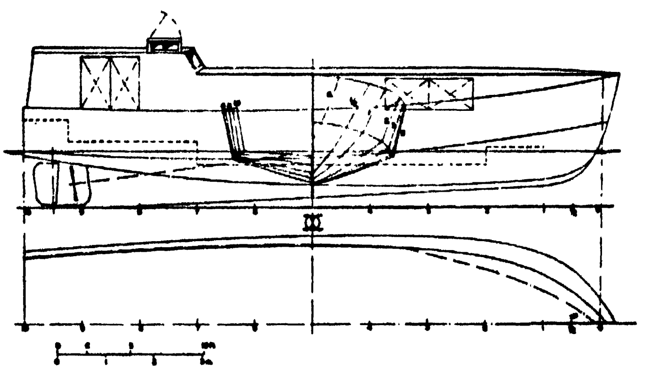


Fig. 54. Gillnetter, Boat B, being a design study and modified version of the previous figure, with a reduced height of superstructure

with the fairbody extended from stations 2 and 3. The superstructure heights are normal for the average gillnetter as are the locations of the openings. The working flat is above the design waterline and, considering the beam, results in a very spacious platform. This is a standard hull design and built by the Kargard Company of Marinette, Wisconsin.

Fig. 54 is a design study and modified version of the vessel shown in fig. 53, namely Boat B in table 1. Here there is a drastic reduction in superstructure height, which is not only weight-saving, but also permits a reduction of ballast as well as displacement. Development on this hull is conical in the forward sections (0 to 3) breaking into cylindrical at stations 3 to 5, and the afterbody sections are then straight lines between the fairbody and the chines. It is normal on gillnetters to have as much outside keel or deadwood as is shown. This could be drastically reduced and is, for the most part, a carry-over from the wooden hulls. Although reduction in wetted surface would be small, improvement in manoeuvrability would be great and well worth the reduction. This vessel has not been built.

Fig. 55. More and more men, having steady employment ashore, fish only part time and that mostly only during the spring, summer and fall, and fishing is limited to perch and some chub. Boat C in table 1 was designed

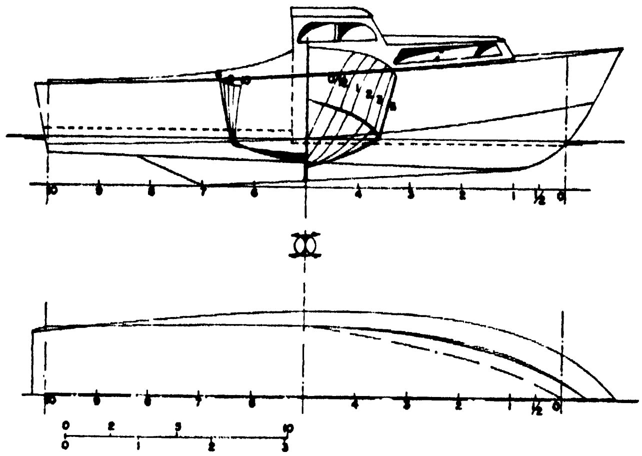


Fig. 55. Gillnetter, Boat C, constructed of aluminium alloy and designed for high speed, with accommodation for two

by the author originally for this purpose. The pilot hull, however, was converted to a handliner and is to fish as a gillnetter in the North during the summer, and as a handliner along the Gulf Coast during the winter. Constructed of aluminium alloy and welded throughout, it was designed for high speeds in rough water and to do some ice breaking. Her light weight, however, will not permit operation in thick ice. The beam was limited to 8 ft (2.44 m.) so the boat could be carried on a trailer. There is limited accommodation for two, and the engine is aft, operating through a V-drive unit.

Several vessels, in the near future, will be built from the same general plan but the hulls will be of steel. The complete boat will not cost more than about $4,000 (£1,430). If the vessel is to be operated from one port only, cabin accommodation will be omitted, a self-draining cockpit fitted in lieu of the foredeck, a bow roller installed, and the cabin used to stow nets and fish, during the haul, which will be moved to adjust trim while preparing for the next haul.

Fig. 56 is the Boat D in table 1. This is the result of a preliminary investigation of a high-speed gillnetter. This vessel has the ability to break ice up to, say, 6 in. (15 cm.) in thickness. The short superstructure reduces

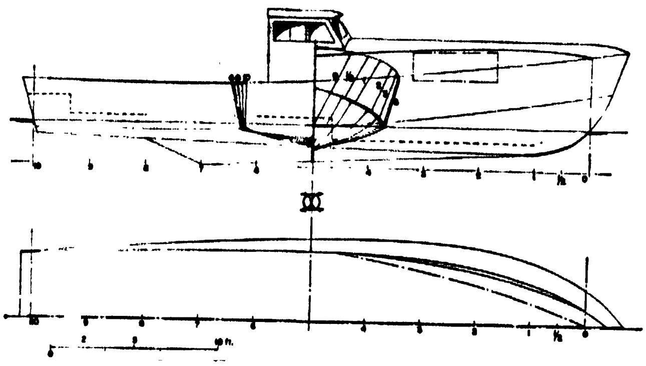


Fig. 56. Gillnetter, Boat D, being the result of a preliminary investigation for a high-speed craft

the weight considerably, and is still of sufficient length to warrant the hauling of nets from inside. Setting would be from the stern, and during bad weather a lifeboat spray hood could be erected to advantage. The stowage of nets, whether for setting or after they are hauled, would be below decks on a fore and aft roller conveyor that passes port and starboard of the engine. This boat would cost between $2,500 and $3,500 (£890 to £1,250), not including engine and equipment.

Table 2 shows the sectional area of these four vessels, and table 3 their power requirements.

TABLE 1

Principal particulars of hulls of Great Lake gillnetters

		Boat A	*Boat B*	*Boat C*	*Boat D*
Length overall, LOA	ft.	40.42	40.17	26.33	36.0
	m.	12.32	12.24	8.03	10.97
Length in waterline, L	ft.	38.87	38.67	23.58	33.0
	m.	11.85	11.79	7.19	10.06
Length between perpendicular, LBP	ft.	39.0	39.0	23.25	33.0
	m.	11.89	11.89	7.09	10.06
Breadth, mld. at sheer, B	ft.	12.50	12.50	7.96	10.0
	m.	3.81	3.81	2.43	3.05
Breadth, mld. at chine	ft.	10.83	10.83	6.67	8.50
	m.	3.30	3.30	2.03	2.59
Draught, T	ft.	3.92	3.92	2.25	2.50
	m.	1.19	1.19	0.69	0.76
Displacement, Δ_s	tons	11.98	11.02	2.50	4.99
Δ	ton	12.17	11.20	2.54	5.07
LCB from FP in % of LBP		0.514	0.508	0.560	0.567
Water plane area, A_w	sq. ft.	356	354	127	225
	sq. m.	33.07	32.89	11.80	20.90
Tons per in.		0.824	0.819	0.294	0.522
„ „ cm.		0.329	0.328	0.117	0.208
LCF from FP in % of LBP		0.555	0.557	0.579	0.582
Displacement per in. (cm.) trim by stern	lb.	102	104	53	96
	kg.	18.40	18.60	9.48	17.15
$\frac{1}{2}\alpha_e$		35°	39°	27°	22½°
Wetted surface, S	sq. ft.	487	477	168	281
	sq. m.	45.24	44.31	15.61	26.10
Profile above water, A	sq. ft.	291	245	101	153
	sq. m.	27.03	22.76	9.38	14.21
BM_t	ft.	6.93	7.26	4.43	6.37
	m.	2.11	2.21	1.35	1.94
BM_l	ft.	81.28	87.48	49.21	84.71
	m.	24.77	26.66	15.00	25.82
Moment to change trim/in. (cm.)	ft.tons	2.08	2.06	0.45	1.07
	m.ton	0.254	0.251	0.055	0.131

TABLE 2

Sectional area of each station in percentage of the

Station	*Boat A*	*Boat B*	*Boat C*	*Boat D*
0	—	—	0.0084	—
½	0.1600	0.1421	0.2000	0.1444
1	0.3300	0.2970	0.3891	0.3000
2	0.6500	0.5787	0.6695	0.5555
3	0.8575	0.8122	0.8410	0.7667
4	0.9700	0.9543	0.9456	0.9222
5	1.0000	1.0000	0.9874	1.0000
6	0.9750	0.9442	1.0000	0.9889
7	0.8750	0.8046	0.9707	0.9444
8	0.7000	0.6015	0.9247	0.8778
9	0.4400	0.3604	0.8787	0.8028
10	0.1250	0.1015	0.8201	0.7222

Construction

With the depletion of good shipbuilding timber and a constant increase in costs, coupled with the ever-declining number of skilled shipwrights, the introduction of the steel gillnetter was inevitable. The early steel hulls followed very closely the shape of the wooden hull—that is, the tugboat hull. It was soon found that these hulls were, in many cases, at least as heavy if not heavier than their wooden counterparts. The use of the long super-

TABLE 3

Horsepower, coefficients and displacement-length ratio

	Boat A	*Boat B*	*Boat C*	*Boat D*
Designed speed (trial condition)	11	11.5	22	20
h.p.	150	150	105	150
Type of engine	Diesel	Diesel	Petrol	Petrol/Diesel
$\frac{\Delta}{(LBP/100)^3}$	202	186	199	139
$LBP/\Delta^{1/3}$	5.21	5.36	5.24	5.90
$\frac{V}{\sqrt{LBP}}$	1.76	1.84	4.56	3.48
$\frac{v}{\sqrt{g.LBP}}$	0.524	0.548	1.36	1.04
φ	0.6923	0.6454	0.8435	0.7881
δ	0.4090	0.4032	0.5500	0.4938
β	0.5908	0.6247	0.6521	0.6266
α	0.8428	0.8372	0.8170	0.7902

TABLE 4

Scantlings for the hulls

		Boats A and B	*Boat C*	*Boat D*
Keel plate	in. mm.	$\frac{3}{4}$ 19	$\frac{3}{4}$ 19	$\frac{5}{8}$ 15.9
Stem bar	in. mm.	$\frac{3}{4}\times 5$ 19×127	$\frac{3}{4}\times 4$ 19×102	$\frac{5}{8}\times 4$ bulb plate 15.9×102 „ „
Longitudinal stringers	in. mm.	—	$1\frac{1}{4}\times\frac{3}{16}$ flat bar 32×4.8 „ „	$1\frac{1}{2}\times\frac{3}{16}$ flat bar 38×4.8 „ „
Longitudinal spacing	in. cm.	—	9 22.9	11 28
Chine bar	in. mm. in. mm.	$\frac{3}{4}$ round bar 19 „ „ —	$\frac{1}{2}$ round bar aft 12.7 $\frac{1}{4}$ plate forward 6.35	$\frac{5}{8}$ round bar aft 15.9 $\frac{3}{16}$ flat bar forward 4.8
Gunwhale bar	in.	2 51	$1\frac{1}{2}$ 38	$1\frac{1}{2}$ 38
Frames	in. mm.	$\frac{1}{4}\times 2\frac{1}{2}$ 6.35×63.5	$1\frac{1}{4}\times 2\frac{1}{2}\times\frac{1}{4}$ angle $32\times 63.5\times 6.35$	$\frac{3}{16}\times 2\frac{1}{2}$ 4.8×63.5
Frame spacing	in. cm. in. cm. in. cm.	15 forward $\frac{1}{4}$L 38 19 midship $\frac{1}{2}$L 48.3 24 aft $\frac{1}{4}$L 61	14 forward $\frac{1}{4}$L 36 28 elsewhere 71 —	15 forward $\frac{1}{4}$L 38 30 elsewhere 76 —
Bottom shell	in. mm.	$\frac{3}{16}$ 4.8	$\frac{1}{8}$ 3.2	$\frac{1}{8}$ 3.2
Side shell	in. mm.	$\frac{3}{16}$ 4.8	$\frac{1}{8}$ 3.2	$\frac{1}{8}$ 3.2
Working flat	in. mm.	$1\frac{1}{2}\times 6$ fir 38×152	$\frac{7}{8}\times 3$ fir 22×76	$\frac{7}{8}\times 3$ fir 22×76
Superstructure	in. mm.	$\frac{1}{8}$ 3.2	$\frac{1}{8}$ 3.2	$\frac{1}{8}$ 3.2
Superstructure, deck	in. mm.	$\frac{1}{8}$ 3.2	$\frac{3}{8}$ plywood 9.5	$\frac{3}{8}$ plywood 9.5
Superstructure, deck beams	in. mm.	$1\frac{1}{4}\times 3\times\frac{3}{16}$ angles $32\times 76\times 4.8$	$1\times 1\frac{5}{8}$ laminated spruce and fir 25.4×41.3	$1\times 2\frac{1}{2}$ laminated white oak 25.4×63.5
Main deck beams	in. mm.	—	$2\frac{1}{2}\times 1\frac{1}{4}\times\frac{1}{4}$ angle $63.5\times 32\times 6.35$	$\frac{1}{8}\times 2\frac{1}{2}$ 3.2×63.5

Note. Boats A, B and D are mild steel; Boat C is aluminium alloy 6061T-6, with a nominal chemical composition of 1% magnesium, 0.6% silicon, 0.25% chromium, and 0.25% copper.

structure in steel construction again caused a stability problem, since it was not possible to build as light a structure which could be walked on without extensive framing. This, in turn, increased the cost out of all proportion. To counteract the effects of the increased weight and the raising of the centre of gravity, the vessels were heavily ballasted. Some of the newer hulls began to increase beam to offset the superstructure weight and ballast. For a number of years this was the major improvement; but as the propulsion plants became lighter, the hulls became wider, again the V-bottom was introduced to further reduce the initial cost. This came only after welding was in general use. The riveting of a V-bottom hull has never been economical.

Most new gillnetters are of steel. The steel hull is easier to maintain, does not leak, and can be worked through the ice fields with little or no danger of puncturing or opening up. The Great Lakes, on the whole, are surrounded by metal working plants; therefore, metal-working skill is common. Numerous small plants have the necessary equipment as well as a plentiful supply of skilled metal workers so that they can economically build boats either as a full-time or part-time business.

The use of aluminium alloys for gillnetter construction on the Lakes is not warranted at the present time: it is too costly and the corrosion rate of fresh water steel vessels is very small. Lighter weight, by itself, is of no importance, in fact the greater weight of a steel gillnetter is an advantage in winter when it is used as an ice breaker.

There has been an increasing tendency to copy the yacht hull form up to the sheer line in both round and V-bottom hulls. While it is true that plate development does reduce the cost of labour in plating, the extreme to which it is occasionally carried increases the cost of framing and requires more horsepower than is installed to achieve the maximum hull efficiency. Unless the desired speed is in excess of 15 knots, there is very little to be gained in carrying the plate development all the way to the transom.

Table 4 gives the scantlings for both steel and aluminium gillnetter hulls.

Engines

With the increasing cost of fuel, the most popular engine is still the diesel, even for smaller boats. The air-cooled diesel promises to become popular in the smaller perch boats. It is felt by the author that the most economical engine will be between 5 and 25 h.p.

Engine power varies widely in gillnetters. In the past, engines of low power were common, but due to their lighter weight and lower cost per h.p., the higher powered engines are preferable today. An increase in horsepower makes it desirable to have a hull capable of higher speeds. Unfortunately, higher speeds require a flatter and wider transom which, in turn, necessitates a fuller bow to prevent running under. The excessive beam necessary because of the vast amount of superstructure causes the half angle of entrance to become very full if any of the developed plating methods are used.

Problems affecting the industry

Perhaps the greatest menace to fishing on the Great Lakes has been the lamprey eel. During the war years, the lamprey spread through Lake Huron and throughout the entire length of Lake Michigan. The average annual catch of trout between 1812 and 1945 was over 2,500 tons, whereas today there are none in Lakes Michigan, Huron and Erie. Unfortunately, the fight to control the lamprey eel came only after it had destroyed the trout in Lakes Michigan and Huron and had begun to spread into Lake Superior.

The lower Lakes fishermen now concentrate on perch, chub, smelt, whitefish, herring, suckers, some carp, etc., but the catch does not meet the demand. Trout are still caught in Lake Superior, but they are small and of a recent stock. The only solution is the eradication of the lamprey, or at least its control, and the restocking of trout throughout the Lakes.

Poaching in the Great Lakes is quite common, and although there are laws against it they are very lenient and the fines so small that the commercial fisherman has little protection against poachers.

The Lakes fishermen are somewhat concerned that the opening of the St. Lawrence Seaway may encourage migrations of certain species of trash fish which will not improve the Great Lakes fishing.

Some other problems are: (1) pollution of water by industrial plants; (2) restocking the Lakes with trout and other compatible species; (3) the expected population increase which will utilize the Lakes to their fullest; and (4) educating the population of the Lakes States to eat more fresh-water fish, rather than to import salt-water fish.

Unless these problems are solved, gillnet fishing could ultimately be destroyed. When the catches amounted to upwards of a ton per day, the large gillnetter with great beam was a necessity. Today, however, the average catch is more in the range of 400 or 500 lb. (180 or 230 kg.) or even less per day, so that large boats are not economical to own and operate. It would be possible in a period of, say, 20 years to stock the Lakes with trout and many other species of food fish, thus strengthening the fishing industry which, in turn, would then warrant extensive research and development of not only hull design and performance, but of fishing methods themselves.

Future developments

There are two possibilities for future development in Great Lakes fishing vessels. One is the one-man perch boat, with a hull of between 18 and 25 ft. (5.5 and 7.6 m.), all open or at most with a small cuddy or wind break. The cost would be small, and the nets would be limited to three or four boxes. The other possibility is the introduction of the trawler, which would be not more than 36 to 45 ft. (11 to 14 m.) and would be operated by two or three men. It would be used primarily to catch trash fish for fertilizer or mink feeding, and would sort out marketable species if market conditions warranted.

Just recently there have been some developments in the field of welding thin material—0.015 to 0.125 in. (0.381 to 3.17 mm.)—at high production speeds, using the inert-gas-consumable electrode. This development will be a boon to designers as well as to builders, as the rule of thumb has always dictated that the minimum economical thickness of welded material is 0.125 in. (3.17 mm.) or greater. To weld thinner material than this, highly skilled men were required and, even then, there was excessive burn-through and distortion due to the slow welding speeds necessitated by the thin plate. The use of thinner material will allow large reductions in superstructure weight, thereby permitting many refinements in hull design. This lighter material will also be feasible in the construction of very small perch boats which would have been too heavy if constructed of 0.125 in. (3.17 mm.) steel. Heretofore, builders have been reluctant to attempt the smaller and lighter steel hulls and, when forced to build them, increased the weight of the materials to a point where the performance was unsatisfactory, or they increased the cost of construction to such a degree that it was no longer economical to use steel.

In the future, the building of small perch boats will also encourage the revival of the wooden hull. Many of the boats will no doubt be built by the fishermen themselves to save money. While some are skilled in boatbuilding, the majority are not; therefore, the hull design and construction will have to be kept simple. There is every possibility that the cross-planked hull of the Chesapeake Bay could be reintroduced to the Lakes. The system was never popular on the Lakes, which was mainly due to not understanding the method of construction and to the attempt to lighten backbone and bottom planking. This method of planking a hull could result in some very practical hull designs that would be easy to build and would not require a great deal of knowledge as far as lofting or carpentry is concerned. By the elimination of bottom framing, it would be more economical to build than a longitudinally planked V-bottom hull, and the increased weight by cross planking would be beneficial rather than detrimental to the development of the perch boats.

LONGLINE FISHING: DECK DESIGN AND EQUIPMENT

by

YOSHIAKI KANASASHI

Characteristics of tuna longliners are large fish rooms and fuel oil capacity. Electric welding, light alloys and new insulating materials have reduced ships' weights considerably, and engine room arrangements have been improved.

Accurate navigation instruments are used to ensure safe voyages and economic operation. Excellent insulation materials and refrigeration equipment are used to preserve the freshness of the catch.

As fishing operations are carried out in tropical waters, improvements in the living quarters are constantly sought. Overseas bases have recently been established for vessels fishing far-distant grounds.

EQUIPEMENT DE PONT POUR LA PÊCHE AUX PALANGRES

Les thoniers-palangriers sont caractérisés par un grand espace réservé à la cale et une grande capacité pour le carburant. La soudure électrique, les alliages légers et les matériaux isolants ont considérablement réduit le poids des navires, et les dispositions de la salle des machines ont été améliorées.

Pour assurer des voyages sûrs et un fonctionnement économique, on utilise des instruments de navigation précis. Pour préserver la fraicheur de la pêche on utilise d'excellents matériaux isolants et des installations frigorifiques et de conditionnement de l'air.

Comme les opérations de pêche ont lieu dans des mers tropicales, on recherche constamment des améliorations à apporter aux emménagements pour le logement. Récemment, on a établi des bases outre-mer pour les navires pêchant sur des lieux très éloignés.

LA PESCA CON PALANGRES: EQUIPO Y FORMA DE LA CUBIERTA

Los atuneros se caracterizan por la gran capacidad de sus bodegas y de sus tanques de combustible. La soldadura eléctrica, las aleaciones ligeras, y los materiales aislantes han reducido considerablemente el peso de los barcos y se ha mejorado la distributión de la maquinaria en la sala de máquinas.

Se emplean instrumentos de navegación de precisión para asegurar que los viajes se harán sin novedad y que el funcionamiento será económico. Se emplean excelentes materiales aislantes, equipo de refrigeración y de acondicionamiento de aire para mantener las frescura de la pesca.

Como la pesca se realiza en aguas tórridas, se trata constantemente de mejorar los alojamientos. Ultimamente se han establecido bases lejos del Japón para los barcos que pescan en caladeros muy distantes.

JAPANESE tuna fishing has moved from coastal waters to the deep sea, the size of the ships has increased, and the equipment has been much improved, although more improvement is still desirable.

The largest tuna longliner in 1941 was 150 GT, with a maximum cruising range of 5,000 sea miles, but the ships today range up to 1,900 GT, capable of voyages of 23,000 sea miles.

Tuna are caught mainly by two types of vessel, namely, longliners and combination boats. Longliners are built of wood or steel, most boats of 100 to 1,900 GT being of steel. Combination boats are suitable for both longline and pole-line fishing; the pole-line season for tuna being short, this type of boat is limited to 300 GT.

There are three types of operation: single boat, group, and from a base abroad. Mostly it is single boat, but group operation was started about 1950 on distant grounds, using a mothership to service the catcher boats.

For the third type of fishing, there are shore bases near the fishing grounds.

A longline fishing trip lasts three to four months, so the boats must be very seaworthy, of good stability, and provide comfortable accommodation for the crew. And, of course, keeping the catch fresh is of prime importance.

FISHING GEAR

Longlining is the best method for catching tuna at a depth of 260 to 525 ft. (80 to 160 m.). Large catches can be made at low cost, and it can be carried out on any scale, according to the capital invested.

Layout and construction of the fishing gear is shown in fig. 57, 58, and 59. The principal items are main lines (cotton or nylon yarn), branch lines (cotton or nylon yarn) and hooks. Auxiliary tools are buoy lines, buoys (glass balls), bamboo rods and lamp buoys. A set of unit line is 650 to 1,300 ft. (200 to 400 m.) long, with branch lines about 100 ft. (30 m.) long, all coiled and stacked in a basket when not in use. The number of branch lines per unit line varies according to the species of fish to be caught: 5 to 6 for bluefin tuna, and 12 to 13 for albacore. A longline consists of 350 to 400 sets of unit lines, giving the main line an overall length of 50 to 75 miles (80 to 120 km.). The depth of hooks is adjusted by the buoy line to meet the swimming shoals, and is about 35 to

120 ft. (11 to 37 m.) for bluefin tuna and 180 ft. (55 m.) for albacore. Some fishermen now use radio buoys to prevent longlines from being snapped or carried away.

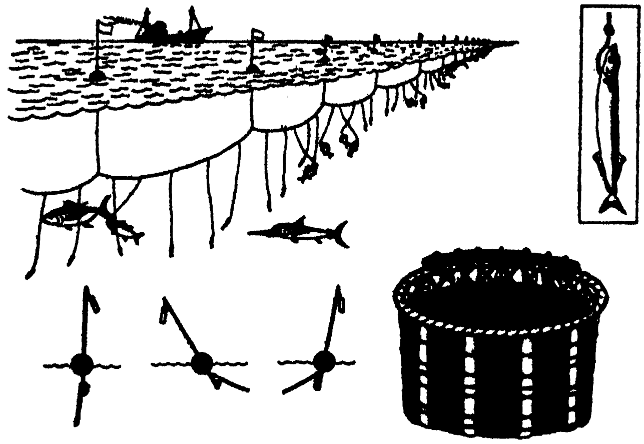


Fig. 57. Longline layout

Before departure the owners of longliners collect as much data as possible concerning the fishing grounds, mainly by radio from other boats at sea, and the longliner master is given an approximate target area. The boats as they approach the area indicated begin to measure the sea water temperature, because tuna live in definite temperatures, and in particular near the current rip where warm and cold currents meet and plankton are produced. Every morning at dawn the unit lines are joined with metal couplings, the hooks are baited with frozen sauries, and the sets are cast into the sea from the stern at 8 to 9 a.m., the speed of the boat being about 8 knots. The line is

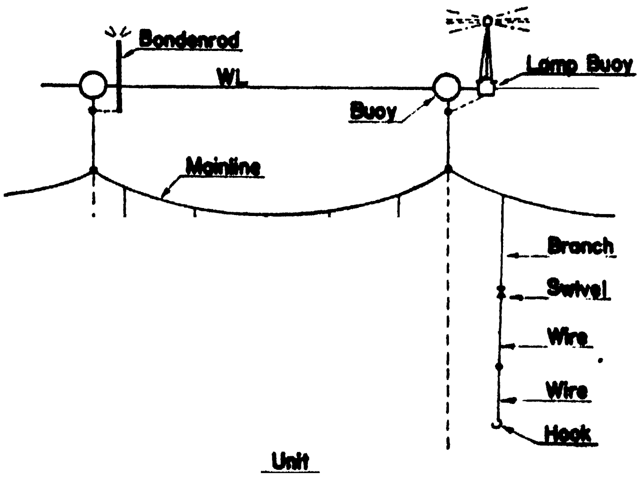


Fig. 58. Longline construction

cast at a rate of about 100 sets of unit lines an hour. The boat drifts until about 11 a.m., when it comes around to the end of the line which was first thrown out and starts to haul with the line hauler. The fish come up through an opening in the bulwark to the deck, where they are gutted, washed and prepared for freezing or ice storage.

The longlines are then carried by a conveyor to the port side and stowed in a housing on the poop deck, and the day's work is finished.

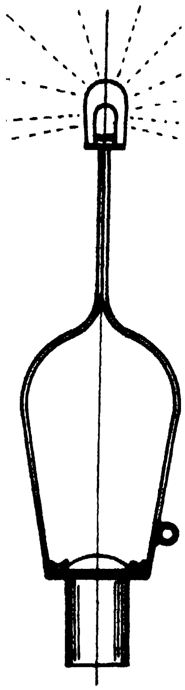


Fig. 59. Lamp buoy

GENERAL ARRANGEMENT

Larger boats are not necessarily more profitable but, because catches have declined in the pre-war fishing areas, larger boats have been built to increase the cruising range and they have been provided with more refrigerating capacity.

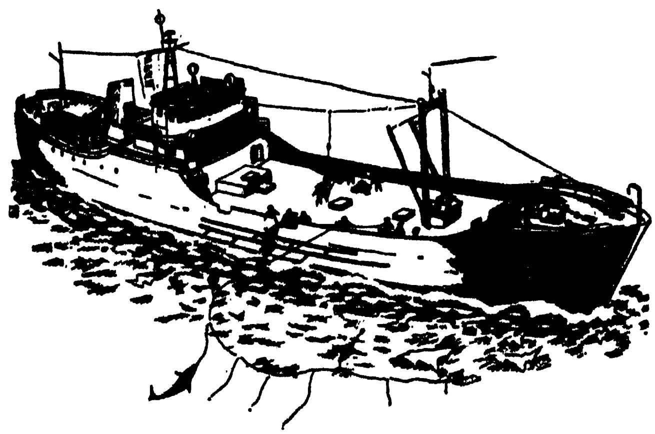


Fig. 60. Longline fishing boat

To economize in the time spent sailing to and from the grounds, and to keep the catch fresh, a mothership system has been introduced. Fig. 60 is a sketch of a fishing boat, and the general layouts of 250 and 1,000 GT boats are shown in fig. 61 and 62. The 250 GT vessel

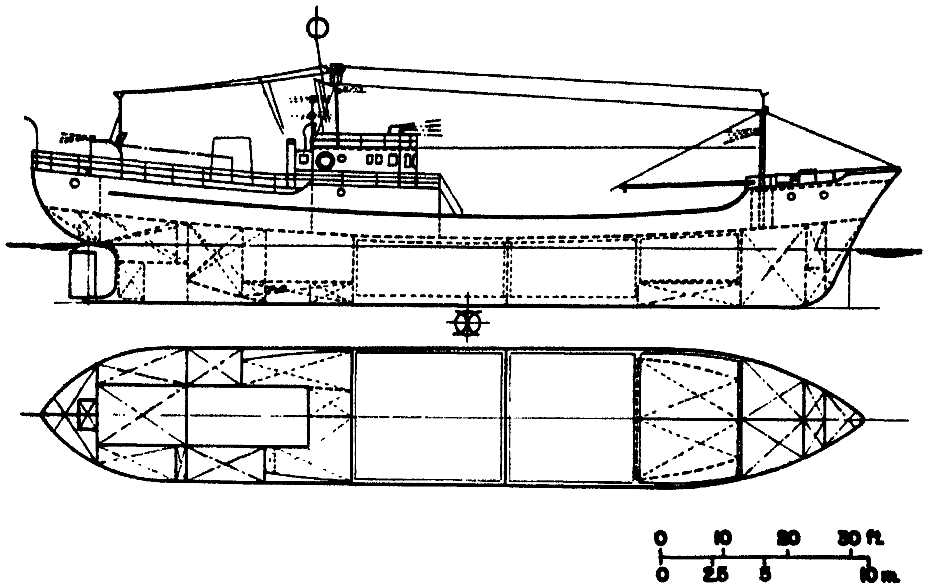


Fig. 61. General arrangement of 250 GT tuna longliner

has a waterline length of 122.5 ft. (37.34 m.), breadth of 22.31 ft. (6.8 m.) and depth of 10.99 ft. (3.35 m.) and is powered by a 550 h.p. engine. The 1,000 GT vessel has a waterline length of 196.6 ft. (59.9 m.), breadth of 36.1 ft. (11 m.) and depth of 17.39 ft. (5.30 m.) and is powered by a 1,500 h.p. engine.

Holds

Holds are divided into 3 to 5 compartments. In a boat with small refrigerating capacity, such as the combination craft, the hold is divided into 6 to 12 small compartments for crushed ice storage, and a large compartment for fish storage, each cubic foot of which can hold about 34.3 lb. of tuna fish (0.55 ton/cu. m.). In flush-deck boats, the hold is sometimes located aft of the engine room. Two longitudinal partition boards and one or two shelves are inserted into each fish hold. A bilge well and suction pipe are fitted in each hold, the bilge being emptied by a pump in the engine room, or by a hand pump on the deck. The ice needed is 0.5 tons per ton of fish to be

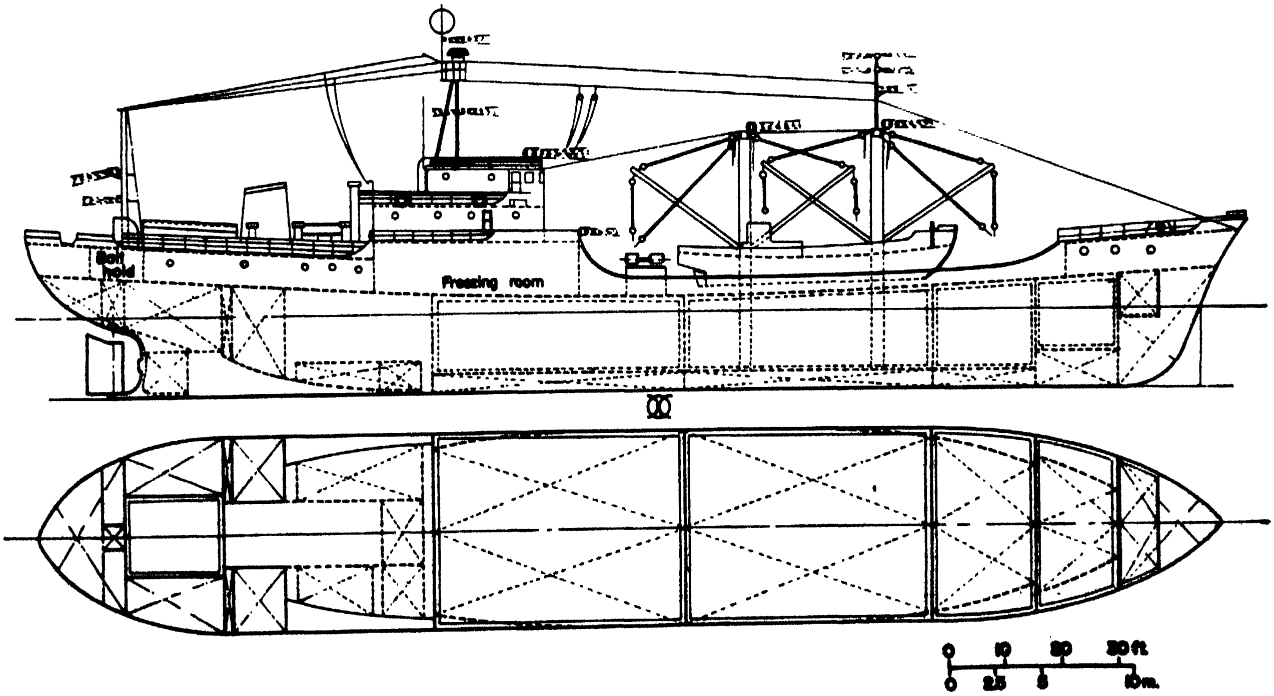


Fig. 62. General arrangement of 1,000 GT tuna longliner

cooled. The bait is saury and squid. Details of freezing facilities are given in the paper "Tuna freezing" on page 234.

Deck equipment

Friction multi-plate line haulers are most widely used, but some fishermen prefer the hydraulic coupling type. Two sets of line haulers are placed in tandem forward on the starboard side, with motors aft of the forecastle. There are side rollers on the bulwarks so that the hooked

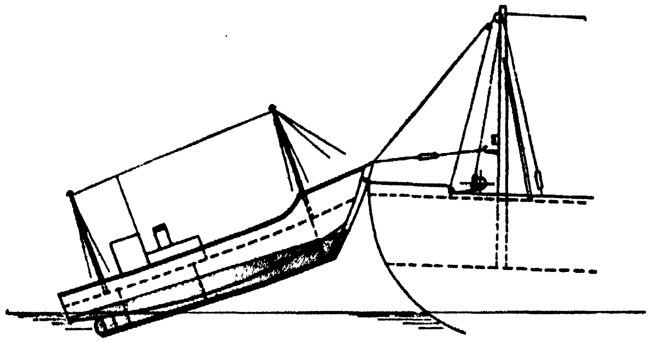


Fig. 63. Schematic towing arrangement for a catcher boat on a mothership of less than 1,000 GT

fish can be pulled up to the deck. Lines are stored on the boat deck or aft of the poop deck. The gear is carried by conveyor belt to its storage place aft. Motherships store equipment used in the catcher boats (Yagi, 1955).

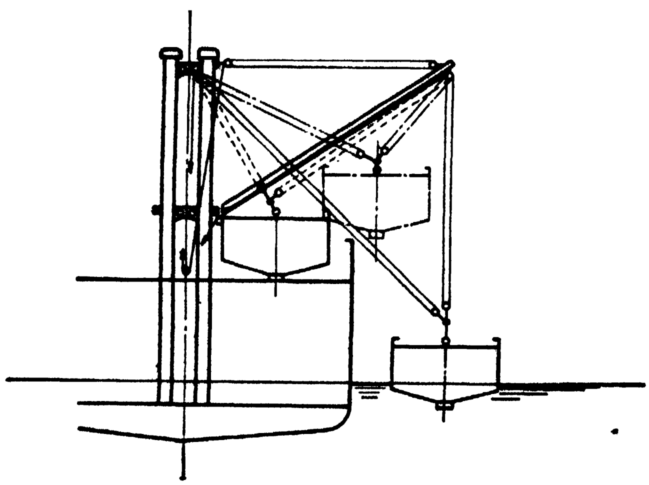


Fig. 64. Lifting arrangement for a catcher boat on a mothership of more than 1,000 GT

Foremast booms and detachable davits are used for loading and unloading on both longliners and combination boats. Another method is to run three strands of wire, with triangular rings, from the foremast through hatchways, and to use a block and tackle at the warping end of the windlass.

TABLE 5

Number of crews for

Longliners		*Combination boats*	
Gross tons GT	*Crew*	*Gross tons GT*	*Crew*
250	30	150	50
350	34 to 37	180	55
700	45 to 47	220	60
1,000	65 to 80	300	70
1,500	90	—	—

One or two sets of derrick posts are erected on deck, the loads being hauled by winches with drum-wound ropes.

Conveyors are used to carry both gear and catch.

Accommodation

Large crews are carried, especially on combination boats, and accommodation is inadequate, but designers are paying more attention to this problem. Table 5 gives the number of crew for various sizes of boats.

Air conditioning is desirable for men working in tropical waters, but not many boats are so equipped. Mechanical ventilation is common on large longliners, (ceiling heights are limited to 6.2 to 6.9 ft. or 1.9 to 2.1 m. to lower the centre of gravity) and air conditioning and other facilities are beginning to be installed on many smaller boats.

Boats for single operation

These are mostly in the 250 to 350 GT class and appear to be most economical and efficient for the time being. Ships under 300 GT are all of the flush-deck type, while those over 350 GT often have a long poop deck. Every boat has a freezing chamber located forward of the deck

TABLE 6

Principal particulars of wood and aluminium catchers

	Aluminium	*Wood*
Length, L	46.5 ft. (14.20 m.)	52.5 ft. (16.00 m.)
Breadth, B	11.8 ft. (3.60 m.)	12.1 ft. (3.70 m.)
Depth, D	5.25 ft. (1.60 m.)	5.4 ft. (1.65 m.)
Gross tonnage, GT	19.80	19.50
Main engine	75 h.p. diesel	90 h.p. diesel
Air compressor	3 h.p. hot bulb	3 h.p. hot bulb
Generator	3 kW	3 kW
Line hauler	Small type	Small type
Wireless equipment	10 W short wave wireless phone	10 W short wave wireless phone
Speed, light, at 110% engine load, knots, V	9.08	9.42
Speed, loaded, at 100% engine load, knots, V	7.40	8.01
Light weight, ton	16.40	16.10
Fish hold capacity	530 cu. ft. (15.0 cu.m.)	360 cu. ft. (10.3 cu.m.)

house or the poop, but the refrigerating capacity of the flush-deck type is kept below 4 tons per day because of the limited space.

Mothership operation

Boats smaller than 1,000 GT have no deck space to carry a catcher boat, but it is towed as shown in fig. 63. Derrick post booms and a winch are installed aft, and the stern is strengthened. Boats larger than 1,000 GT carry one or more catcher boats on each side of the deck as shown in fig. 64. This type of boat has two rigid derrick booms and four units of 3 to 5 ton winches, so that catcher boats are hauled with drum-wound ropes, the deck being reinforced and provided with rigid rope-winding equipment.

All motherships have long poops and engines aft, with a freezing room forward of the poop. Crew accommodation is aft of the poop and the deckhouse.

Catcher boats must be seaworthy. To ensure easy operation without sacrificing stability, many difficult problems confront naval architects: the rolling period should be long; the speed should be more than 8 knots at full load condition, and it should be possible to handle 200 to 250 sets of lines. The weight of catchers should also be reduced. At present, they are built of wood or light alloy, but study of this problem may lead to lighter boats. Table 6 compares the wood and light alloy types.

Comparison of longliners and combination boats

These boats have different functions and it is difficult to compare their merits and disadvantages. The general arrangement plan of a 216 GT combination boat is shown in fig. 65, having the below principal particulars:

L = 108.3 ft. (33 m.)
B = 21.65 ft. (6.6 m.)
D = 11 ft. (3.35 m.)
Engine 650 h.p.

The hold space of longliners is 20 to 40 per cent. larger, as it is not divided into small compartments.

Half the number of crew is needed, and living quarters can be provided on the upper deck.

Some 30 to 40 per cent. more fuel can be carried, which extends the cruising range.

Larger boats of this type can be built so that freezing equipment can be installed and longer voyages made.

Table 7 compares boats of nearly equal dimensions.

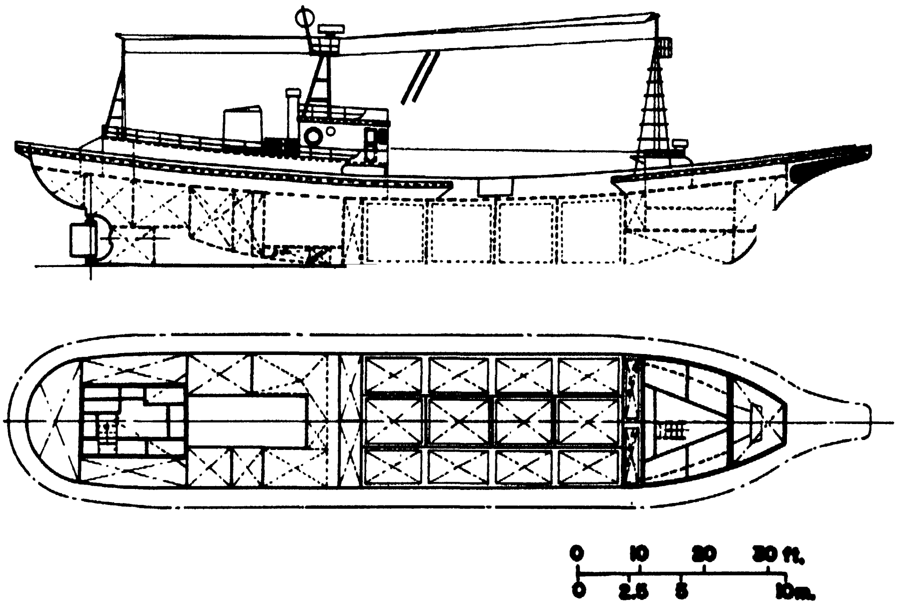


Fig. 65. General arrangement of a combination tuna longliner and skipjack pole and line fishing boat

MAIN SPECIFICATIONS AND CONSTRUCTION

The Japanese Government issues fishing licences for certain fixed GT, so that shipowners tend to build the largest ships possible within the GT allocated to them, based on maximum loading capacity, cruising range and speed.

Relations between gross tonnage (GT), cubic number (CN) and length (LBP)

The relations between GT–CN and GT–LBP are shown in fig. 66 and 67 respectively. The relation between GT–CN can be expressed by the following equations:

Longliner, poop-deck type

GT=(0.00906 to 0.00920)×CN(cu. ft.)
=(0.32 to 0.325)×CN (cu. m.)

TABLE 7

ith nearly equal dimensions

Type		Longliner		Combination boat	
Gross tonnage, GT		309.54	239.24	299.00	215.59
Year built		1958	1958	1955	1958
Length, LBP	ft.	130	115	124	109
	m.	40.00	35.00	37.80	33.20
Breadth, mld., B	ft.	24.6	22.3	23.6	21.6
	m.	7.50	6.80	7.20	6.60
Depth, mld., D	ft.	12	11	11.8	11
	m.	3.70	3.35	3.60	3.35
GT/LBP×B×D		0.278	0.300	0.305	0.290
Capacity:					
Fish hold (a)	cu. ft.	11,050	7,800	7,560	5,400
	cu. m.	313	221	214	153
Fuel oil tank (b)	cu. ft.	5,890	4,250	4,010	3,200
	cu. m.	167	120	113.5	91
Freshwater tank (c)	cu. ft.	911	530	985	826
	cu. m.	25.8	15	27.9	23.4
	cu. ft./GT	57.9	52.6	42.0	43.8
	cu. m./GT	1.64	1.49	1.19	1.24
Main engine, h.p.		650	500	650	650
Refrigerating machinery	Japanese RT	58.5	30	14.0	13.5
	kcal.	177,000	91,000	42,000	41,000
Freezing capacity.	ton/day	6.5	1.9	—	—
Cruising range	nautical miles	19,800	14,920	11,950	9,120
Navigation days		75	71	51	41
Weight of catch, ton		170	116	105	69
Weight of catch/GT		0.55	0.48	0.35	0.32
Cruising speed in knots, V		11.01	10.32	10.71	10.23
Max. trial speed, in knots, V.		12.09	11.39	11.68	11.27
Crew: deck		21	16	64	45
engine		8	11	10	8
clerk		2	1	2	2
Total		31	28	76	55

Longliner, flush-deck type

$$GT = 0.00850 \times CN \text{ (cu. ft.)}$$
$$= 0.30 \times CN \text{ (cu. m.)}$$

Combination boat

$$GT = 0.00734 \times CN \text{ (cu. ft.)}$$
$$= 0.295 \times CN \text{ (cu. m.)}$$

The relation between GT and LBP can be expressed by the following equations:

Longliner, poop-deck type

300 to 600 GT

$$LBP \text{ (ft.)} = (18.37 \text{ to } 19.03) \times \sqrt[3]{GT}$$
$$\text{(m.)} = (5.60 \text{ to } 5.80) \times \sqrt[3]{GT}$$

600 to 2,000 GT

$$LBP \text{ (ft.)} = (19.36 \text{ to } 19.52) \times \sqrt[3]{GT}$$
$$\text{(m.)} = (5.90 \text{ to } 5.95) \times \sqrt[3]{GT}$$

Longliner, flush-deck type

Below 600 GT

$$LBP \text{ (ft.)} = (19.03 \text{ to } 19.52) \times \sqrt[3]{GT}$$
$$\text{(m.)} = (5.80 \text{ to } 5.95) \times \sqrt[3]{GT}$$

Combination boat

Below 300 GT

$$LBP \text{ (ft.)} = (17.39 \text{ to } 18.37) \times \sqrt[3]{GT}$$
$$\text{(m.)} = (5.30 \text{ to } 5.60) \times \sqrt[3]{GT}$$

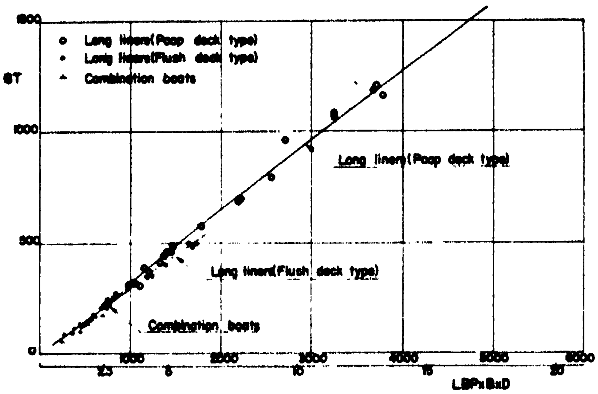


Fig. 66. Relation between gross tonnage and cubic number for longliners and combination boats

Relations between depth (D), beam (B), draught (T) and LBP

For motherships, carrying one or more catcher boats, allowance must also be made for catchers and the stability when lifting them. The location of freezing rooms must, also be considered. With the recent trend towards increasing the weight of fittings, the value of KG has been gradually enlarged, making the breadth correspondingly larger.

Fig. 68 shows the values of beam (B) and depth (D) against LBP, which can be expressed by the following equations:

LBP ≦ 164 ft. (50 m.) (about 600 GT)

$$B \text{ (ft.)} = 0.11\, LBP + (10.17 \text{ to } 9.51)$$
$$\text{(m.)} = 0.11\, LBP + (3.1 \text{ to } 2.9)$$

LBP > 164 ft. (50 m.)

$$B \text{ (ft.)} = 0.20\, LBP - 3.61$$
$$\text{(m.)} = 0.20\, LBP - 1.10$$

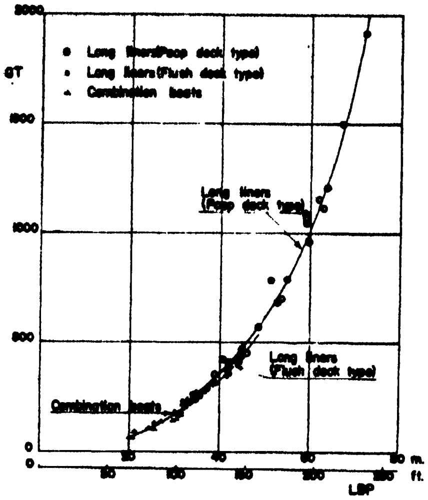


Fig. 67. Relation between gross tonnage and length for longliners and combination boats

LBP ≦ 164 ft. (50 m.)
D (ft.) = 0.068 LBP + (3.61 to 2.95)
(m.) = 0.068 LBP + (1.1 to 0.90)

LBP > 164 ft. (50 m.)
D (ft.) = 0.080 LBP + (1.64 to 1.31)
(m.) = 0.080 LBP + (0.50 to 0.40)

Values of B/D range between 1.95 and 2.30, usually between 2.0 and 2.1. In the standard design, draught is equal to 85 per cent. of depth, the block coefficients being about 0.66 to 0.70.

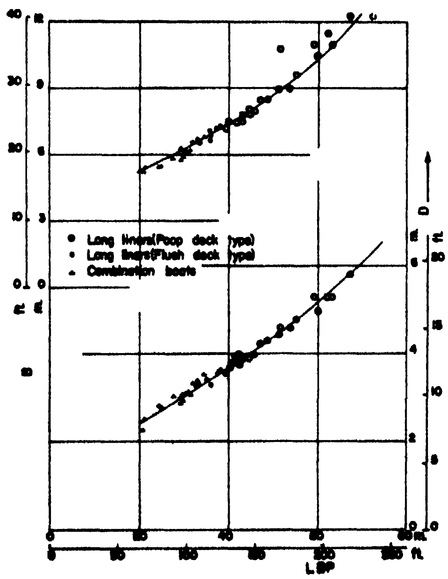


Fig. 68. Relation between breadth and depth and length for longliners and combination boats

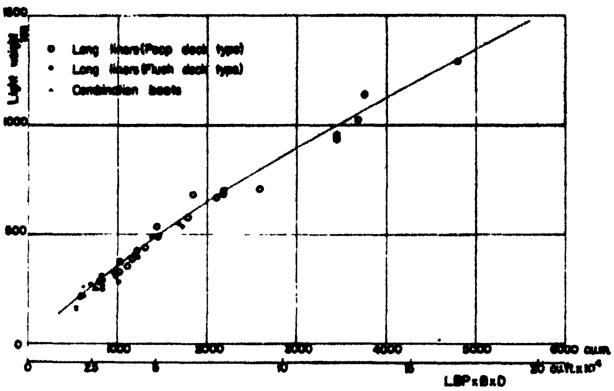


Fig. 69. Relation between light weight and cubic number for longliners and combination boats

Weights and longitudinal centre of gravity (LCG)

Light weights are shown against CN, in fig. 69, and hull weights in fig. 70.

CN ≦ 63,600 cu. ft. (1,800 cu. m.) (about 600 GT)
Light weight (ton) = (0.0102 to 0.0093) × CN (cu. ft.)
= (0.36 to 0.33) × CN (cu. m.)

CN > 63,600 cu. ft. (1,800 cu. m.)
Light weight (ton) = (0.0093 to 0.0076) × CN (cu. ft.)
= (0.33 to 0.27) × CN (cu. m.)

CN ≦ 63,600 cu. ft. (1,800 cu. m.)
Steel hull weight = (0.0051 to 0.0038) × CN (cu. ft.)
= (0.18 to 0.135) × CN (cu. m.)

CN > 63,600 cu. ft. (1,800 cu. m.)
Steel hull weight = (0.0038 to 0.0037) × CN (cu. ft.)
(ton) = (0.135 to 0.130) × CN (cu. m.)

Weights of steel hulls, deck planks, insulation, equipment and fittings, and machinery are given in table 8 in the form of percentages of the light weight.

The longitudinal centre of gravity in light condition is aft of midship, due to the position of the engines. It was

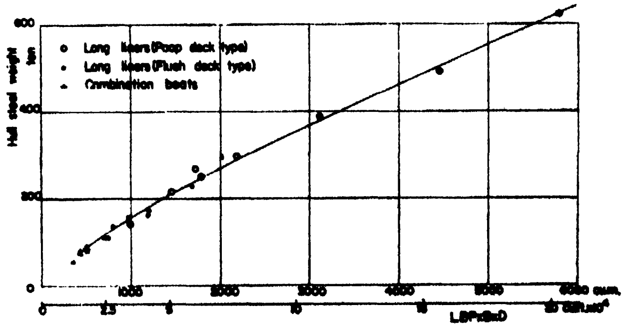


Fig. 70. Relation between hull steel weight and cubic number for longliners and combination boats

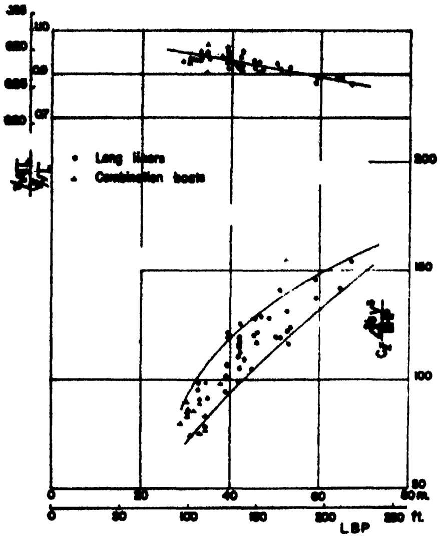


Fig. 71. Admiralty constant and Froude number versus length for longliners and combination boats

3 per cent. LBP aft of midships in the immediate post-war boats. The longitudinal centre of gravity is now 7 to 8 per cent. LBP aft of midships owing to the increased weight of machinery in the engine room, weight of general outfit in living quarters and a decrease in the weight of heat insulating materials. The increased weight of the machinery and outfit means that the value KG/D is raised to 0.87 to 0.89 against a previous value of 0.80 to 0.82.

The maximum displacement of small boats is on the outward cruise, and of large boats over 500 GT on the homeward cruise. The centre of gravity varies according to the load in the holds. At full load it is higher than in light condition, and when the fuel oil in the double-bottom tank is consumed, counter-measures should be taken, such as using water ballast, to get better stability.

Metacentre

The height of the metacentre varies according to the type

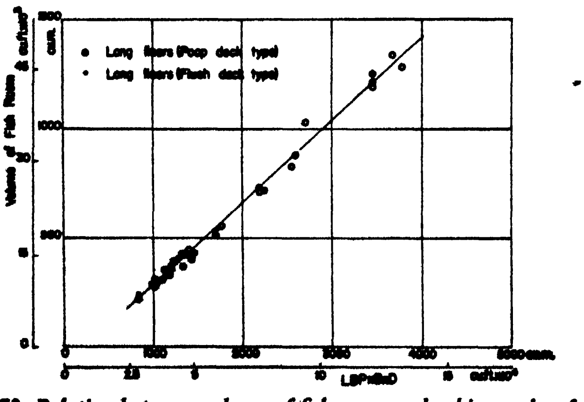


Fig. 72. Relation between volume of fish room and cubic number for longliners and combination boats

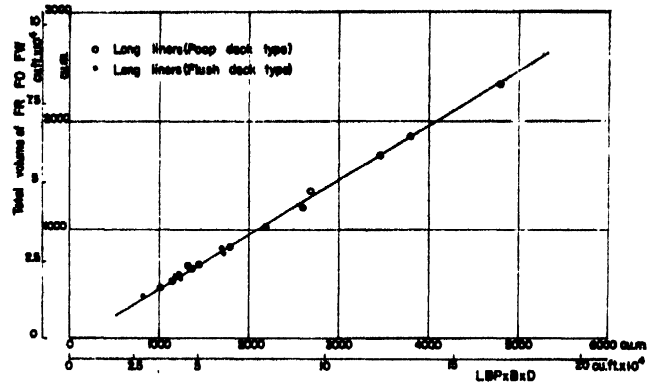


Fig. 73. Relation between volume of fish room, fuel oil and fresh water and cubic number for longliners

of boat but, in general, the following equations are valid where T is the mean draught of the boat:

KB=(0.55 to 0.56) T

BM, light condition=(0.085 to 0.090)B^2/T

BM, full load condition=(0.090 to 0.095)B^2/T

With 250 to 350 GT ships, every effort should be made to maintain a GM of 1.31 to 1.64 ft. (0.40 to 0.50 m.) in the most unfavourable conditions. With larger boats, the difficulty is lessened by their breadth.

Speed, etc

The main engines should be large to give a high speed, so that fish can be landed fresh and command better prices. But, with the development of refrigerating facilities, the question of sailing speed needs to be re-examined.

Fig. 71 shows the maximum values of $V/\sqrt{L}$ and $\Delta^{2/3} V^3/BHP$ against LBP at the time of trials.

Fish room capacities

The relation between CN and the total hold volume of fish holds, fuel oil and fresh water tanks as shown in fig. 72 may be expressed as follows:

Total volume (cu. ft)=0.50 CN−1,766

(cu.m.)=0.50 CN−50

TABLE 8

Percentage weight of main items on a longliner and combination boat

Item	Longliner Below 600 GT	Longliner Over 600 GT	Combination boat
Steel hull, %	43 to 46	43 to 46	46 to 50
Deck planking, %	2.5 to 3.4	2.2 to 2.5	5 to 5.5
Insulation, %			
Cork only	16 to 17	17 to 18	15 to 22
Cork and alfiex	10 to 11	11 to 12	
Equipment and fittings, %	15 to 19	19 to 22	15 to 18
Machinery, %	13 to 15	11 to 13	13 to 15

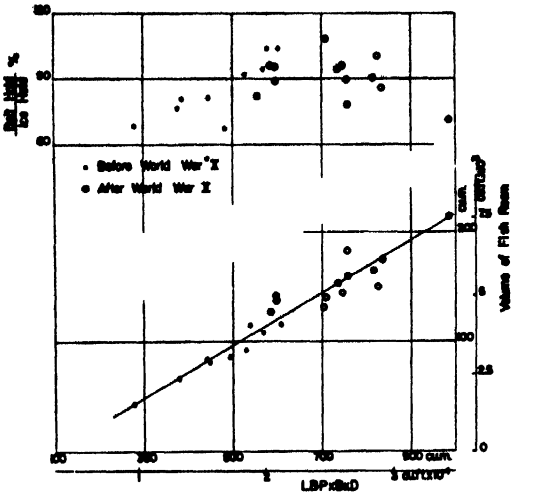


Fig. 74. Relation between ratio bait hold/ice hold and cubic number for combination boats before and after World War II

Fig. 73 shows the relation between CN and the fish hold capacity of *longliners* which may be computed from the following equation:

CN ≦ 123,600 cu. ft. (3,500 cu. m.) (about 1,200 GT):
Fish room (cu. ft.) = 0.375 CN − 3,531
(cu. m.) = 0.375 CN − 100

CN > 123,600 cu. ft. (3,500 cu. m.)
Fish room (cu. ft.) = 0.13 CN + 31,070
(cu. m.) = 0.13 CN + 880

Refrigerating facilities are installed and limit the space for the fish hold.

Fig. 74 shows the relation between the hold capacity (bait and ice holds) and CN, and also the ratio of the bait hold capacity to the ice hold capacity and CN for *combination boats*. The hold capacity may be expressed as follows:

Fish room (cu. ft.) = 0.24 CN − 8,823
(cu. m.) = 0.24 CN − 25

TABLE 9

Radius of action for various sizes of vessels

Type	*Gross tonnage GT*	*Radius of action Sea-miles*
Longliner . . .	200 to 250	12,000 to 15,000
	350	15,000 to 20,000
	Over 700	20,000 to 25,000
Combination boat .	150 to 180	8,000 to 10,000
	200 to 300	11,000 to 13,000

Ratios of bait tanks to ice hold were 0.6 to 0.8 before World War II, when no refrigerating equipment was provided, but nowadays most boats have such equipment, and hold space is reduced so that the ratio is about 0.8 to 1.0. Fig. 75 shows the capacity of the bait hold and ice hold space against gross tonnages.

Tank capacities

Fig. 76 shows the freshwater and fuel oil tank capacities in relation to gross tonnages. The amount of freshwater varies according to the number of crew and navigation days, but in general,

Water (cu. ft.) = (1.94 to 3.00) × GT
(cu. m.) = (0.055 to 0.085) × GT

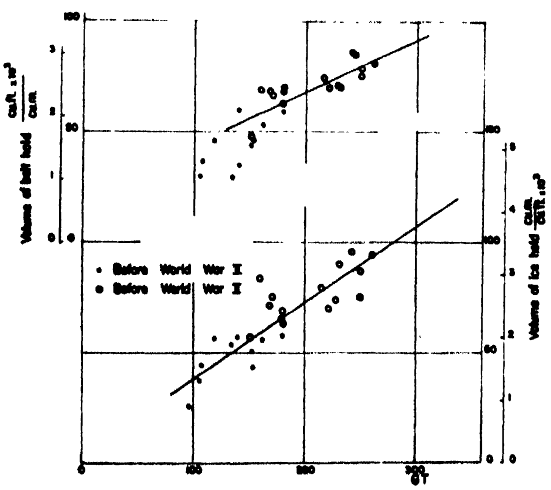


Fig. 75. Relation between volume of bait hold and gross tonnage for combination boats before and after World War II

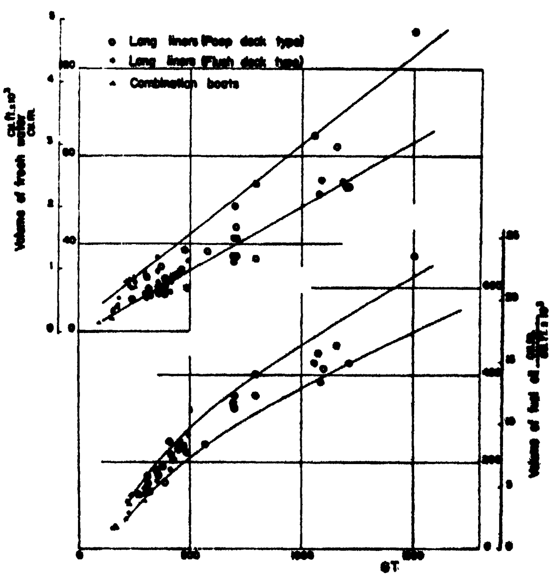


Fig. 76. Relation between volume of freshwater and gross tonnage for longliners and combination boats

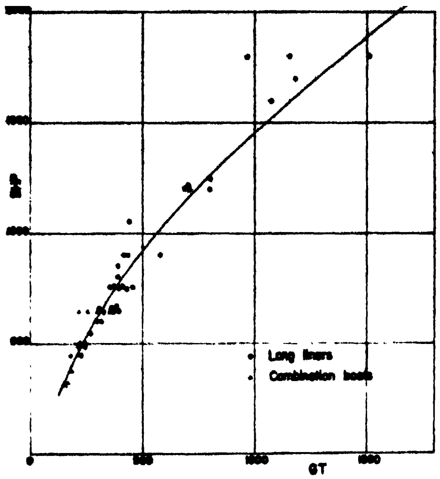


Fig. 77. Main engine output of longliners

There is a tendency towards an increase in these figures.

Fuel oil (cu. ft.)=(12.36 to 15.89)×GT
(cu. m.)=(0.35 to 0.45)×GT

The main engine output of longliners is shown in fig. 77, and the radius of action is given in table 9.

Construction

Electric welding is generally used, riveting being employed only for the seams of bilge plates and deck stringer angles, etc. Section building is being widely adopted and construction time has been shortened remarkably.

Slamming in the aft engine type of boat is a serious problem, and engineers are strengthening various parts more than specified in the regulations, although further studies are necessary.

Longliners often cannot be docked for six months or longer, and their shell plating is badly fouled, so the sand-blast vinyl coating process was introduced to protect the hull.

MACHINERY

Main engines

Main engines are 4-stroke, airless injection diesels. The power of the engines has recently been increased by 30 to 50 per cent. by the use of superchargers, with the result that, without sacrificing hold space, higher speed and longer voyages have become possible. The relations of gross tonnage to main engine power are shown in table 10.

TABLE 10

Normal main engine output for various sizes of boats

Gross tonnages GT	*Main engine h.p.*
250	500
350	650
700	1,200
1,000	1,500
1,500	1,800

Engines are expected to run at full speed when a shoal of tuna is found, but at only 4 knots when hauling lines. Very low revolutions are kept for a long time, with clutches in and out. The engines must have the durability to stand continuous running for six months without overhauls.

The majority of screws are of the 4-blade, fixed-blade type and made of manganese bronze. Controllable-pitch propellers are operated from the wheel house by electric, hydraulic or rod systems.

Main engines are controlled from the bridge on some large longliners. With controllable-pitch propellers, remote control is believed to contribute much towards safety, high speed and accuracy of operation.

TABLE 11

Normal auxiliary engine output for sizes of boats

Gross tons GT	*Total h.p.*
250	150
350	200
700	400
1,000	500
1,500	1,000

Auxiliary engines

After World War II, the power of auxiliary engines increased because of the adoption of freezing systems and the increase in cargo capacity. Three generators are installed, running in parallel, to supply electric power on ships exceeding 1,000 GT.

Alternating current has been adopted to meet increased demands, and it has resulted in reduced costs, more flexibility of voltage, ability to take power from shore supplies, and easier maintenance.

Table 11 shows the relation between gross tonnage and total horsepower of auxiliary engines.

Other apparatus

Wireless. Communication with the land and with other ships is necessary to ensure safety, detect shoals of fish, and to obtain information about fluctuations in fish prices, etc. Particulars are given in table 12. For communication between mother and catcher boats, 2-MC 10 W wireless telephones are installed.

Radar. With automatic position finders and gyro-compasses it is functioning well.

Echo sounders (fish finders). These operate very satisfactorily.

TABLE 12

Item	*Before War*	*After War*
Transmitter		
Type	Self-exciting	Pre-tuned crystal control system
Power × units	100 to 300W × 1	100 to 500W × 1
Auxiliary transmitter		
Power × units	None	25 to 50W × 1
Receiving set		
Short wave	4-valve autodyne × 1	8- to 16-valve superheterodyne or double super × 1
Long and medium wave	Ditto × 1	Ditto × 1
Emergency	None	4-valve autodyne × 1, or 8-valve super set × 1, or All-wave set × 1

Thermometers. Tube and electric thermometers are installed in each hold to maintain the proper temperature, and indicators in the engine room enable the engineers to regulate the temperature by means of expansion valves.

Steering devices. Steering angles are large and manoeuvring is frequent when tuna boats are fishing. The electro-hydraulic system is used on most ships. Magnetic compass pilots and remote controls are used in navigation for longer voyages.

Table 13 shows the relation between gross tonnage and steering engine power.

TABLE 13

Normal steering engine output for various sizes of boats

Gross tons GT	*Steering engine power, h.p.*
250	1.5
350	1.5 to 2
700	3
1,000	5
1,500	7.5

Anemometers, logs, helm indicators, tachometers, exhaust air thermometers and other electrical measuring instruments are used on tuna boats.

Lifeboats or liferafts for ten persons were at one time required, irrespective of the number of the crew, but today the law stipulates that fishing boats must have sufficient lifeboats or rafts for the entire crew. As there is little space for lifesaving appliances, liferafts of the self-expansion type are generally used.

POLE AND LINE FISHING: DECK DESIGN AND EQUIPMENT

by

SHOGO MURAMATSU

One of the important fishing methods in Japan is by pole and line. The boats differ in construction, equipment and installation depending on the species they catch: skipjack, mackerel and squid.

This paper deals with particular features of these boats, i.e. the fishing method and the resultant deck design, especially the water-sprinkling device, bait tank, electric equipment, steering arrangements and fish hold.

EQUIPEMENT DE PONT POUR LA PECHE A LA LIGNE AVEC UNE CANNE

La pêche à la ligne avec une canne est une des principales méthodes utilisées au Japon. Les navires diffèrent dans leur construction, leur équipement et leur installation selon les espèces pêchées: bonite à ventre rayé, maquereau et calmar.

Cette communication traite des caractéristiques particulières de ces navires, c'est-à-dire la méthode de pêche et l'équipement de pont qui en découle, spécialement le dispositif de projection d'eau, le vivier à appât, l'équipement électrique, les dispositifs pour gouverner et la cale à poisson.

LA PESCA CON CAÑA Y LIÑA: EQUIPO Y FORMA DE LA CUBIERTA

La pesca con la caña y liña reviste gran importancia en el Japón. La forma de las embarcaciones, el equipo y la instalación varían según se pesque barrilete, caballa o calamar.

Trata esta ponencia de características determinadas de las embarcaciones, por ejemplo: el método de pesca y las formas que hay que dar a las cubiertas para practicarlo, especialmente el sisterma de chorrillos de agua, los viveros, el equipo eléctrico, los sistemas de gobierno y la bodega de pescado.

SKIPJACK* fishing in Japan goes back thousands of years, bones of skipjack being found in shell mounds of the Stone Age. It is thought that in those days they were caught with the bare hands when a fish school swam towards the shore. Later they were caught with bone hooks, or with horn or bone spears. Up to the Edo era (1603 to 1868), the skipjack came very near to the shore and fishing was done from conventional sail or row fishing boats of small size. In the Meiji era, from 1868 to 1912, skipjack migrated more offshore, so larger boats were required. Mechanisation began in 1903.

Modern boats have a fishing platform all around the bulwarks, and a huge bow platform. More than one-third of the hold has no buoyancy when used for bait, because it is open to the sea through the bottom.

The skipjack fishing fleet, including boats for tuna longline and skipjack pole and line fishing numbered, at the end of 1954, 1,263 vessels of over 20 GT, the total gross tonnage being 142,892 and the average 113 GT. The average power was 233 h.p. The total catches of the fleet amounted to 114,000 ton.

The trips last, according to the size of the boats, from 5, 10 to 12 days for fishing craft of 20, 50 and over 100 GT, respectively, with 2, 4 and 6 days fishing respectively. The duration of the trips also depends, of course, on the distance to and from the fishing ground, and necessary provisions—fuel, fresh water, ice, bait, etc.—must be carried accordingly. The quantities of ice vary according to the degree of insulation of the fish hold and size of the refrigeration plant.

Some attempts have been made to reduce the heavy work of angling from fishing platforms and also to decrease the large crew. The purse seine was assumed to be the best alternative method, and more than ten boats were constructed with a large space aft, the engine forward, and without the fishing platforms. These purse seiners all proved a failure, however, and were converted into the traditional type.

FISHING METHOD

Before leaving port all possible information is gathered on the presence of the fish schools. A sharp look-out is kept at sea, the temperature and colour of the water are examined, and trolling tests made to detect the schools. The best time for finding fish is about sunrise, and they seem to bite best in the morning. In general, more fish are caught in cloudy weather than in fine, and there are more chances of detecting them during a change of weather and after the passage of small cyclones.

*Skipjacks: *Katsuwonus pelamis* (Linné), *Euthynnus affinis yaito* (Kishinouye), *Sarda orientalis* (Temminick at Schlegel), and *Auxis* (Kishinouye).

Fish are apt to come to the surface when the wind drops, and biting fish are usually found in clear, tidal waters.

Upon detecting fish, the boat sails in the direction of the school, its formation and movement being assessed by trolling. If it is satisfactory, live bait is chummed while sailing slowly ahead. When the school rises to the bait, the boat stops with its fishing side to leeward.

Angling

Fishing to leeward gives the forward fishing lines more range, the constant tension in the lines preventing their entanglement. When the fish are abundant and biting well, the fishing platforms on both sides of the boat can be used. The crew are assigned duties as anglers, chummers and bait carriers. The chummers are experienced and skilled fishermen who throw bait into the sea from boxes at the bow, stern and midship to attract the fish towards the boat and keep them there. Less experienced fishermen distribute live bait from the bait tanks to the bait boxes for the chummers. Skilled young anglers are posted at the bow, and older anglers at the stern, as shown in fig. 78.

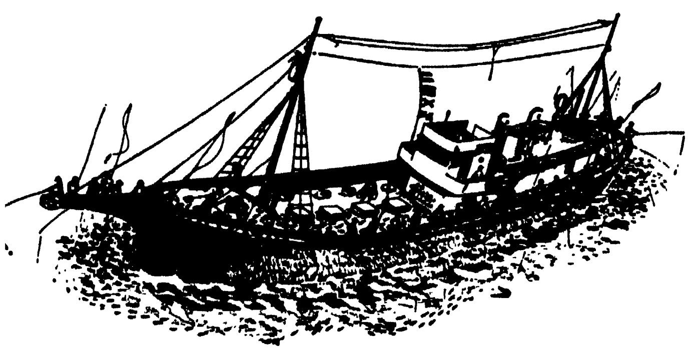


Fig. 78. Skipjack pole and line fishing with skilled young anglers posted at the bow and older anglers at the stern

To conceal the shadows of the boat and crew and to increase the effect of baiting, sea water is sprayed with sprinklers over the sea where the live bait has been chummed, so as to make the surface seem alive with small fish.

Each angler has a fishing rod, with live or artificial bait, and he fishes either standing or sitting. Sitting gives a good balance to the body but restricts action, so that, except when the boat is rolling heavily, the standing position is usually assumed. The angler holds the rod, set in a rod-holder attached to his waist, and the moment he feels a bite he jerks it up and catches the fish under his left arm to remove the hook. Some men swing the fish on board and by a whipping motion of the lines release the hook with a snatch as the fish lands on deck. The latter method is used mainly with artificial bait.

Fishing efficiency can be greatly improved with artificial bait, which can be used when the skipjack are biting very freely. Enough live bait must be thrown out to keep the school from dispersing. When the biting becomes less active, live instead of artificial bait is used.

When hooking, every possible care is taken not to impair the vitality of the live bait. Sardines are usually hooked in the collar-bone, but other fish in the back, neck, nose or eye, according to species and size. The rod is operated to permit the bait to swim freely in the water. When the school disperses, fishing is abandoned and a new school sought. A school normally gives from 10 min. to 2 hr. fishing, and in a few exceptional cases it can last for a whole day.

Fishing gear

This is quite simple, being merely a bamboo pole, 15 to 20 ft. (4.5 to 6 m.) long, fitted with a hemp or cotton line 1 to 1.5 ft. (0.3 to 0.45 m.) shorter than the pole. The bait hook is 1 to 2.5 in. (25 to 65 mm.) long, and has no barb because a large number of fish are caught in a short time and have to be rapidly released from the hook. The centre of the jig hook is made of horn, or whale bone, and wrapped with a feather.

Handling the catch on board

The best and the most generally adopted way of storing skipjack during a 10 days' trip is to keep them in a light brine at about 32°F (0°C), which prevents drying and damage by pressure. The catches piled up on deck should be stored immediately, to avoid exposure to the sun. When quick storing is not possible, constant sprinkling with sea water as well as protection from the sun are necessary. The bait carriers, when they are not carrying bait, kill the live skipjack and wash them with sea water. When the bait tanks are emptied they are cleaned and used as fish holds. The holds are partitioned off so that fish can be stored by size. After all catches have been stored, they are covered with rough hemp or cotton cloth, bamboo hurdles, and cement weights, to avoid damage by the rolling of the vessel.

Albacore fishing

The pole and line fishing season for albacore in Japan starts at the end of July. This is normally combined with skipjack fishing because the two species are generally found in the same areas. Therefore, skipjack vessels during the albacore season make preparations to catch both, because albacore are very valuable for the export market. The gear used for albacore is stronger than for skipjack, particularly the pole and line.

For albacore two anglers work together, each with a pole having joined lines. The hooked fish is lifted on board between the two anglers. Otherwise the method is practically the same as for skipjack. The maximum size of fish which can be lifted by a single angler is about 24 lb. (11 kg.), whereas two anglers can handle 42 lb. (19 kg.). Bigger fish have to be lifted on board with a gaff hook.

GENERAL ARRANGEMENT

Fishing operations for skipjacks and albacore take place far out in deep water and often in a high swell, so the hulls must be strong and seaworthy. Moreover, as the crew often fish on one side of the vessel, it must have good stability. The majority of the wooden skipjack boats range from 30 to 150 GT. Steel vessels are mostly of the 150 to 180 GT class.

Since most of the skipjack fishing boats are also used for tuna in its season (spring and summer) they must have a good cruising range and a speed of 9 to 10 knots to operate all the year round in far distant fishing grounds and facilitate a large number of voyages.

The hold is divided into 9 to 12 compartments, with the ice holds on both sides and bait tanks in the centre. Each compartment has a deck hatch.

No special fishing deck gear is required, except piping and the fishing platforms.

Fishing platforms

Their effective width is about 21.7 in. (55 cm.) and they have 17.8 in. (45 cm.) high benches. Since the bow is

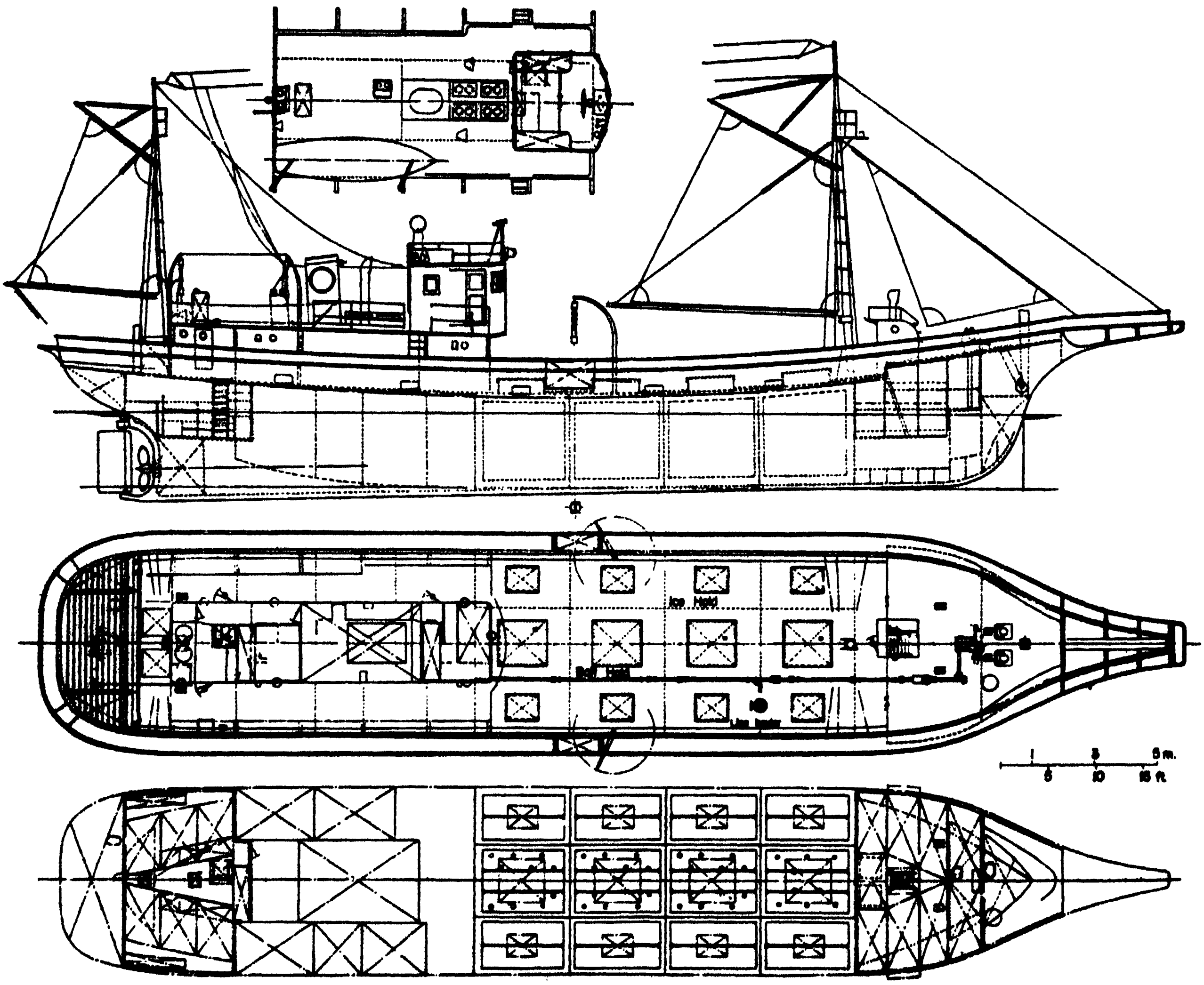


Fig. 79. General arrangement of skipjack and tuna clipper where no special fishing deck gear is required

most suitable for fishing, the platforms in this area are designed to accommodate as many fishermen as possible, to withstand heavy waves, to enable the anglers to keep in contact with those on the other side, and to allow the fish to slide to the deck.

Because of the limited angling time, it is essential to have a large crew for whom accommodation must be provided. Boats of 20 to 50 GT carry on an average a crew of 30; 50 to 100 GT boats 45; and boats of over 100 GT, about 55 fishermen.

As shown in fig. 79, the boats usually have the engine aft, hold forward, and the deck house above the engine room. A large number of the crew are accommodated in two cabins—one forward, and the other aft of the engine room.

Turbine pumps, belt-driven from the main or auxiliary engine, are used for the water sprinkling system. The diameter of the pump discharge pipe is 5 in. (127 mm.) on large boats; 4 in. (102 mm.) on vessels of medium size and 1.3 in. (33 mm.) for those of smaller size. The sprinkler pipe is usually laid over two-thirds of the length of the boat, the diameter decreasing towards the stern. The distance between the sprinkler nozzles is approximately 13.8 in. (350 mm.) at the bow, 15.8 in. (400 mm.) at the stern and 19.6 to 35.5 in. (500 to 900 mm.) midships. On some vessels the pump is controlled from the bridge.

Fig. 80 shows a section of fishing platform and fig. 81 the water sprinkler machinery.

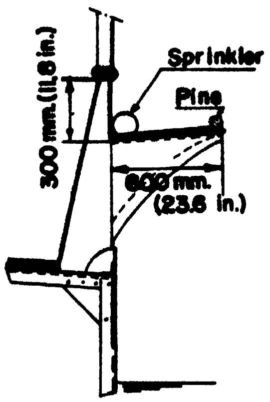


Fig. 80. Fishing platform

Sea water circulates through the bait tank on deck, supplied by a turbine or centrifugal pump in the engine room. The diameter of the supply pipes is 3 in. (76 mm.) for large, 2½ in. (63 mm.) for medium and 2 in. (51 mm.) for small boats. The same pump is also used for washing the deck. The capacities of pumps used on skipjack boats are shown in table 14.

Main :

A few typical specifications are given in table 15. The hold capacity is huge and the GM is not very small, but the freeboard at full load is amazingly small. This last characteristic is not conducive to safety. Another outstanding feature is the number of crew required and consequently accommodation is a difficult problem.

A 5 kW generator supplied electricity for deck and cabin lights, navigation and flood lights. A second 5 kW generator is installed for battery-charging equipment, radio, direction finders, Loran and fish finders.

Hold design

The main hold is divided into many small compartments. There are two longitudinal bulkheads to give one row along each side for the ice containers and a centre one for the bait tanks, as shown in fig. 79. On the outward voyage the containers are filled with block or crushed ice and the tanks with live bait; whereas on the homeward voyage all are used to hold fish.

The capacity, type and location of live bait tanks have an important influence on fishing operations. The tanks are generally partitioned to keep the bait quiet and to prevent excessive water movement. The sea water in the tanks is circulated by power or naturally. Power circulation requires large pumps, costly piping and an auxiliary power unit; so this method is rarely used. With natural circulation, the sea water enters freely through valves in the bottom of the ship. These valves are plugged

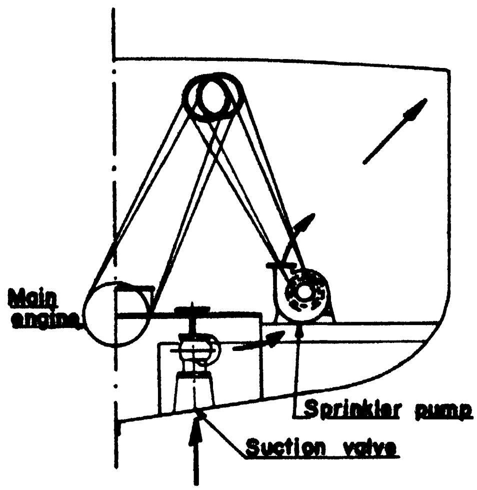


Fig. 81. Arrangement of sprinkler machinery

TABLE 14

Capacity of bait tank pumps

Type	*Diameter*		*Dimensions (excluding piping)* *Length*		*Breadth*		*Height*		*r.p.m.*	*h.p.*	*Discharge (ton per hr.)*	*Head*	
	in.	*mm.*	*in.*	*mm.*	*in.*	*mm.*	*in.*	*mm.*				*ft.*	*m.*
Turbine	2	51	21.6	550	12.4	315	15.9	405	1,700	2	15	52.5	16
”	2½	63	26.0	660	14.2	360	18.1	460	”	3	22	59.1	18
”	3	76	29.1	740	14.7	373	18.9	480	”	5	35	65.7	20
”	4	102	31.3	795	15.9	405	21.8	555	”	7.5	65	65.7	20
”	5	127	36.4	925	22.4	569	24.4	620	”	13	95	65.7	20
Rotary	3	76	30.9	785	11.0	280	13.4	340	260	6.8	35	65.7	20
”	4	102	39.4	1,000	13.4	340	19.1	485	”	12.5	60	65.7	20
”	5	127	45.8	1,165	18.3	465	22.4	570	”	17.8	80	65.7	20

TABLE 15

of skipjack fishing

Ship's name		*Myojyo Maru No. 3*	*Kotoshiro Maru No. 3*	*Kaio Maru No. 11*	*Choei Maru No. 11*	*Koryo Maru No. 2*
Type of construction		Steel	Wood	Wood	Wood	Wood
Year launched		1948	1951	1949	1950	1951
Shipyard		Kanasashi	Goriki	Nishii	Koyanagi	Yaizu
Principal dimensions						
L	ft. (m.)	101.38 (30.90)	97.77 (29.80)	81.36 (24.80)	74.80 (22.80)	68.24 (20.80)
B	ft. (m.)	19.68 (6.00)	20.01 (6.10)	18.04 (5.50)	16.73 (5.10)	14.93 (4.55)
D	ft. (m.)	10.17 (3.10)	10.33 (3.15)	9.19 (2.80)	8.04 (2.45)	7.61 (2.32)
GT		159.85	153.19	97.93	78.04	61.03
Main engine (diesel)	h.p.	320	430	210	210	160
Wireless antenna power	W	125	125	125	50	50
Number of crew		65	70	57	50	40
Capacities						
Fish hold	cu. ft. (cu. m.)	5,141 (145.6)	5,552 (157.2)	3,581 (101.4)	3,147 (89.1)	1,886 (53.4)
Fuel oil tank	cu. ft. (cu. m.)	1,639 (46.4)	1,519 (43.0)	816 (23.1)	619 (17.5)	297 (8.4)
Fresh water tank	cu. ft. (cu. m.)	364 (10.3)	219 (6.2)	258 (7.3)	102 (2.9)	138 (3.9)
Light condition						
T	ft. (m.)	5.61 (1.71)	7.38 (2.25)	6.14 (1.87)	4.92 (1.50)	5.15 (1.57)
Trim by stern	ft. (m.)	5.18 (1.58)	6.66 (2.03)	6.14 (1.87)	4.92 (1.50)	5.18 (1.58)
Δ	ton	183.76	218.89	130.91	91.34	73.99
δ		0.59	0.59	0.59	0.54	0.57
φ		0.65	0.63	0.63	0.63	0.66
α		0.76	0.76	0.77	0.74	0.75
GM	ft. (m.)	1.34 (0.41)	1.77 (0.54)	1.61 (0.49)	1.77 (0.54)	1.54 (0.47)
KG/D		0.80	0.77	0.82	0.88	0.85
LCG aft ½L	ft. (m.)	1.77 (0.54)	5.97 (1.82)	5.25 (1.60)	4.72 (1.44)	3.18 (0.97)
Full load condition						
T	ft. (m.)	9.42 (2.87)	10.50 (3.20)	8.07 (2.46)	7.81 (2.38)	6.63 (2.02)
Trim by stern	ft. (m.)	3.15 (0.96)	4.27 (1.30)	5.51 (1.68)	3.15 (0.96)	4.89 (1.49)
Δ	ton	366.68	360.95	200.82	171.15	108.75
δ		0.69	0.67	0.65	0.64	0.65
φ		0.73	0.70	0.69	0.70	0.72
α		0.89	0.84	0.83	0.86	0.83
GM	ft. (m.)	2.23 (0.68)	2.20 (0.67)	1.57 (0.48)	1.64 (0.50)	2.30 (0.70)
KG/D		0.70	0.70	0.77	0.87	0.63
LCG aft ½L	ft. (m.)	−1.77 (−0.54)	3.25 (0.99)	4.49 (1.37)	3.41 (1.04)	2.46 (0.75)
Trial result						
T	ft. (m.)	5.61 (1.71)	7.48 (2.28)	6.07 (1.85)	5.09 (1.55)	5.38 (1.64)
Trim by stern	ft. (m.)	5.91 (1.80)	6.30 (1.92)	2.62 (0.80)	5.91 (1.80)	6.30 (1.92)
Δ	ton	134.00	218.00	123.20	85.20	78.6
V/100% h.p.		9.66/320	10.11/430	8.63/210	9.70/210	8.67/160
V/Max. h.p.		10.05/384	10.61/516	8.76/282	9.77/250	8.90/192

with lead or glass spigots when carrying fish. The disadvantage of natural circulation is that the tanks cannot hold a large quantity of bait, and the boat cannot anchor in muddy waters when she carries live bait. Fig. 82 and 83 show a bait tank valve as used on large boats with ceiling. The total area of the valves is usually $\frac{1}{15}$th of the bottom area of the tank. When the bait tank is to be used to store the catch, the water is ejected with a rotary pump through a hose with strainer. The pump can also be used, in an emergency, for emptying other compartments.

The fish holds must withstand a large water head, both when they are used for bait and for fish stored in a mixture of crushed ice and sea water. The ceiling is made from cedar or pine planks of the same length as the hold, 1 to 1.5 ft. (0.3 to 0.45 m.) wide, and 2 to 3 in. (50 to 75 mm.) thick. Skill is needed to make the seams and butts completely watertight. There is a recent tendency to use plywood—covered with a binding agent—as a lining for fish holds, because of its water-resistant qualities. Refrigeration equipment now commonly installed in large vessels maintain the temperatures in the hold at about 32°F (0°C) and thermometers are installed having recording dials in the wheelhouse.

MACKEREL

The history of Japanese mackerel* fishing can be traced back to very remote times and it has developed remarkably since the Edo era, when mackerel were caught by

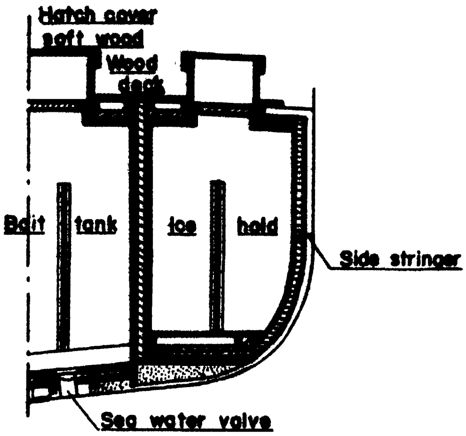


Fig. 82. Section through bait and ice hold

handlining or with nets. Handlining in those days was done at night, using lights, as well as in the daytime. In recent years pole and line fishing has been introduced. Until about 1948 small boats of under 20 GT were used, from September to February, the operation being subsidiary to fishing for skipjack. Since 1951 pole and line

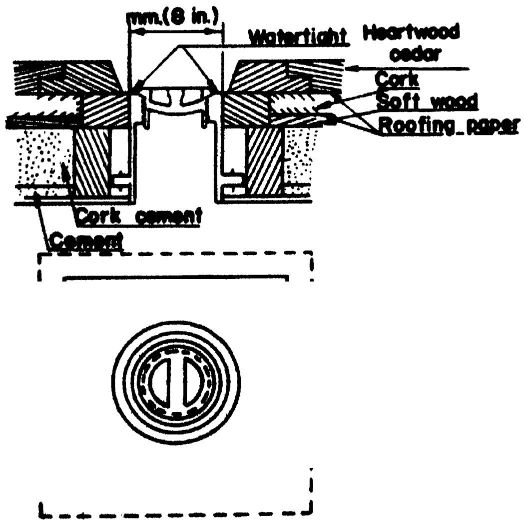


Fig. 83. Sea water valve, the total area of the valves being about one-fifteenth of the bottom area of the tank

fishing has been conducted all the year round with 35 to 60 GT vessels. In the southern part of Japan, boats of 100 to 135 GT are now often used.

*Mackerel: *Pneumatophorus japonicus* (Houttuya), *Pneumatophorus* r (Bleeker).

FISHING METHOD

Catching mackerel with pole and line is similar to skipjack fishing, except that the trips are shorter and a larger crew is required for mackerel. Further, the bait consists mainly of frozen sardine, saury or herring, packed in 34 lb. (15 kg.) cases. The quantity of the bait is 10 per cent. of the weight of the catch expected with it.

Mackerel is caught by night, and boats go to the fishing grounds in the evening to investigate the movement of the schools with echo sounders. At the same time fish-luring lamps are hung over the side, and frozen bait is chopped and distributed to the bait boxes of each angler. The fish, attracted by the lights, come to the surface and try to bite the bait, when the fishermen, with a quick swing of the pole, hooks it indiscriminately and hauls it up.

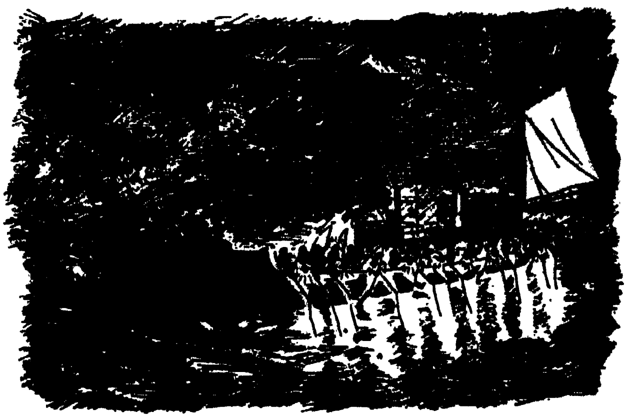


Fig. 84. Mackerel pole and line fishing boat

When fish are found in deep waters, the anglers first use hand lines and shorten them as the fish gradually come up to the surface (fig. 84). Immediately this occurs, the anglers change to pole and line, while bait is chummed, or scattered, on the surface. Young anglers are seated in the bow with veterans aft, on both sides, facing astern. The pole is held in the outboard hand and a dipper in the other, and as the angler scatters chum with the dipper, he moves the hook back and forth through the water, inducing the fish to bite. While keeping the boat to the wind, the master adjusts the speed so that the boat stays with the scattered bait. When the school is very dense all anglers fish on one side of the boat standing up. Bait chumming is of major importance in this type of operation. The bait is brought to the anglers when they are fishing by four or five bait carriers on each side of the boat, and the anglers scatter it as evenly as possible.

Fishing gear

This consists of pole, line and hook. The pole is about 3.3 to 6.6 ft. (1 to 2 m.) long; the line is made of synthetic fibre of almost the same length as the pole, with one ordinary barbed hook. Because mackerel fishing is done at night, some lighting equipment is also necessary.

TABLE 16

bait choppers

Width of blade	*Length*	*Width*	*Height*		*r.p.m.*	*h.p.*	*Discharge port*
2 in.	21.4	12.8	13.2	in.	200 to	4.5	0.2 to 0.28 in.
51 mm.	545	325	335	mm.	250		5 to 7 mm.
3 in.	29.5	15.3	16.3	in.	150 to	7.5	0.28 to 0.36 in.
76 mm.	750	390	415	mm.	200		7 to 9 mm.

The electrical installation does not differ much from that of skipjack pole and line craft. However, a rather powerful generator is necessary to supply the fish-luring lamps, since one such lamp is required for every two anglers. Normally 20 kW generators are installed for this purpose on the large boats, a 15 kW generator on medium, and one of 10 kW on a small boat.

Handling the catch on board

Three methods are used to preserve the catch namely (i) ice; (ii) chilled water and (iii) salt. With ice about 35 mackerels are packed in boxes and covered with crushed ice. In small boats, where the capacity of the hold is limited, the catch is usually preserved in chilled water; the hold being filled with sea water and having its temperature lowered by adding crushed ice before putting in the mackerel. Mackerel in ice or chilled sea water will

TABLE 17

Main specifications of mackerel fishing boats

Ship's name		*Kyowa Maru No. 8*	*Kyowa Maru No. 5*	*Kyowa Maru No. 3*	*Toyokuni Maru*	*Shomba Maru*
Type of construction		Wood	Wood	Wood	Wood	Wood
Year launched		1958	1956	1952	1950	1948
Shipyard		Yaizu	Yaizu	Yaizu	Yaizu	Showa
L	ft. (m.)	88.19 (26.88)	80.38 (24.50)	68.14 (20.77)	64.63 (19.70)	54.89 (16.73)
B	ft. (m.)	19.03 (5.80)	17.72 (5.40)	15.16 (4.62)	13.98 (4.26)	11.02 (3.36)
D	ft. (m.)	9.88 (3.01)	9.02 (2.75)	7.58 (2.31)	6.17 (1.88)	5.31 (1.62)
GT		132.21	96.94	64.04	37.48	19.50
Main engine (diesel)	h.p.	380	350	180	120	75
Wireless antenna power	W	80	50	75	40	20
Number of crew		60	60	45	32	29
Capacities						
Fish hold	cu. ft. (cu. m.)	3,740 (105.9)	2,861 (81.0)	1,614 (45.7)	1,052 (29.8)	795 (22.5)
Fuel oil tank	cu. ft. (cu. m.)	1,052 (29.8)	1,022 (28.95)	356 (10.1)	215 (6.1)	117 (3.3)
Fresh water tank	cu. ft. (cu. m.)	251 (7.1)	201 (5.7)	124 (3.5)	989 (2.8)	71 (2.0)
Light condition						
T	ft. (m.)	6.82 (2.08)	6.43 (1.96)	4.59 (1.40)	4.72 (1.44)	3.64 (1.11)
Trim by stern	ft. (m.)	8.60 (2.62)	6.56 (2.00)	5.31 (1.62)	5.91 (1.80)	3.44 (1.05)
Δ	ton	182.24	141.91	70.36	60.66	33.97
δ		0.61	0.59	0.55	0.56	0.64
φ		0.67	0.66	0.64	0.68	0.68
α		0.80	0.82	0.74	0.73	0.78
GM	ft. (m.)	1.97 (0.60)	1.71 (0.52)	2.07 (0.63)	1.05 (0.32)	0.72 (0.22)
KG/D		0.805	0.82	0.76	0.90	0.84
LCG aft ½L	ft. (m.)	7.12 (2.17)	6.92 (2.11)	—	4.23 (1.29)	4.99 (1.53)
Full load condition						
T	ft. (m.)	8.58 (2.62)	8.66 (2.64)	6.56 (2.00)	5.91 (1.80)	5.31 (1.62)
Trim by stern	ft. (m.)	3.25 (0.99)	4.13 (1.26)	2.46 (0.75)	2.76 (0.84)	0.33 (0.10)
Δ	ton	261.33	225.28	116.3	84.61	58.86
δ		0.66	0.66	0.65	0.61	0.70
φ		0.71	0.72	0.70	0.70	0.73
α		0.87	0.91	0.83	0.78	0.84
GM	ft. (m.)	1.87 (0.57)	1.87 (0.57)	1.67 (0.51)	1.18 (0.36)	0.79 (0.24)
KG/D		0.765	0.75	0.71	0.81	0.74
LCG aft ½L	ft. (m.)	6.30 (1.92)	3.87 (1.18)	—	1.51 (0.46)	1.25 (0.38)
Trial result						
T	ft. (m.)	7.48 (2.28)	6.27 (1.91)	5.41 (1.65)	4.99 (1.	4.59 (1.40)
Trim by stern	ft. (m.)	8.01 (2.44)	5.84 (1.78)	5.58 (1.70)	5.02 (1.	2.62 (0.80)
Δ	ton	205.50	135.8	86.20	64.60	46.20
V/100% h.p.		10.11/380	10.27/350	8.90/180	8.09/120	7.44/75
V/Max. h.p.		10.40/456	10.90/420	9.11/216	8.26/142	7.59/90

not keep for very long periods; therefore on long trips the fish is salted. This method, however, requires a large deck space.

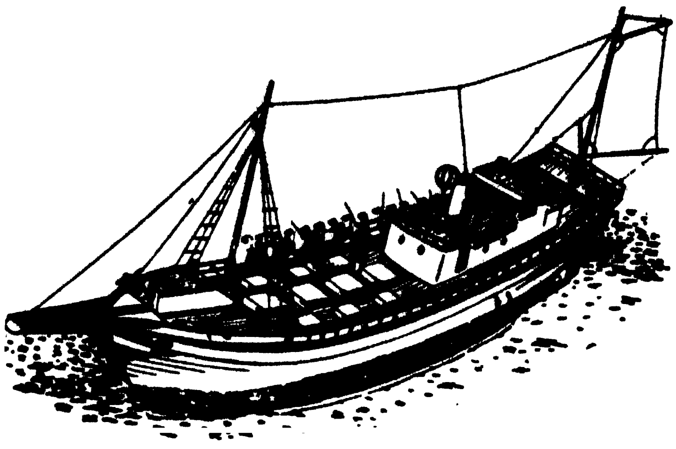


Fig. 85. Mackerel pole and line fishing boat with wheelhouse aft for control of operation. The vessel is also fitted with a spanker sail

GENERAL ARRANGEMENT

Most of the small mackerel boats, up to 30 GT, are of modified Japanese type incorporating foreign ideas. The boats have straight sides and bottom with a chine, providing a streamlined water flow from stem to stern. As shown in fig. 85, the wheelhouse is placed at the stern to enable the skipper to control the whole operation and see both the crew and the effect of the chumming at the same time. The wheelhouse aft also helps to keep the bow into the wind.

During the fishing operation the catch is collected on deck amidships. To prevent it from sliding astern, the deck has an upward sheer from midships to aft. Such sheering is, however, impracticable on larger vessels, so these have pond boards to stop the fish from moving on the deck.

Fishing platforms

These are more or less the same as in skipjack boats. The anglers generally fish in a standing position, but when the schools are not very dense they sit on fishing seats on either side of the boat, facing towards the stern. Each seat has a board which can be set up as a shelter, both from the wind and also from the bait that is being scattered by the forward anglers. The seats for mackerel fishing are, therefore, slightly different from those used on skipjack boats.

With mackerel pole and line fishing, it is not necessary to sprinkle the sea with water, nor are bait tank circulation and draining needed; so pumps are only required for deck-washing and bilges. In some of the large mackerel boats, however, motor pumps have recently been installed to unload the catch by pumping.

Spanker sail

The vessel must be kept head to the wind without drifting too much to leeward. To facilitate this, the vessel normally carries two large spankers, as shown in fig. 85, on the mizzen mast, which prevent the rather high bow from yawing. The size of the spanker in large vessels is about one-third of the wind profile. Sometimes it is also necessary for the same reason to reduce the the freeboard forward by filling the forward fish holds with water.

In order to have full control of the rudder movements, the connection between rudder and wheel is by direct shaft. Some boats have recently been fitted with hydraulic steering gear.

Bait chopper

Mackerel vessels are also fitted with a chopper driven by belt or chain from the main or auxiliary engine with characteristics according to table 16.

Main specifications

A few typical examples of mackerel boats are shown in table 17.

Hold design

This is practically the same as in skipjack pole and line fishing boats, the only difference being that mackerel boats have no sea water valves because live bait is not necessary for mackerel.

SQUID

Squid is one of the most popular fish in Japan. They are caught in all the coastal waters, especially on the Pacific side, and constitute about 10 per cent. of the Japanese fish catch. The pole and line boats used for squid are mostly 6 to 20 GT, with motors ranging from 10 to 30 h.p. They are of the Japanese type, and are equipped with fish-luring lights, three such lamps being fitted on each side of the vessel. A crew of about 15 is carried. Squid fishing is also conducted in-shore from small open boats with one or two anglers.

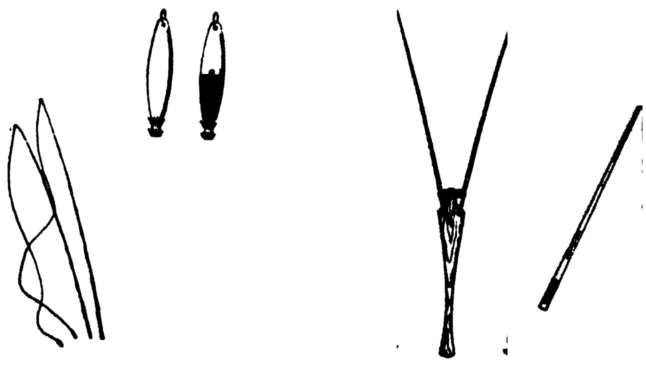


Fig. 86. Squid hand lines, with different arrangements of hooks, with a mackerel pole and line shown extreme right

In peak seasons various small craft, normally used for other purposes join the squid fishing fleet.

FISHING METHOD

Good fishing grounds for squid are generally found in waters 2 to 4 miles from the coast at a depth of about 20 to 75 fm. (35 to 135 m.). The squid swims nearer the surface in the summer than in winter, and it also goes to shallower water in warm weather. The fishing operation itself is very simple: on arrival at the ground, the vessel stops and fishing starts and goes on for 1 to 3 hours. Dawn and dusk seem to be the best time for squid. The handlines are moved up and down at various depths until a "biting" depth is found. The squid is then lured to the surface by gradually shortening the lines, after which shorter handlines are used, which increase the angling activity. Skilled fishermen can handle two or more sets of this gear at one time, and one man can catch about 1,000 to 1,500 squids in a night.

Fishing gear

Squid is mostly caught in the evening and before daybreak with the aid of lights. Three kinds of gear are used, namely (i) *hanegu*; (ii) *tombo* and (iii) *yamade*. The *hanegu* gear is used for squid swimming near the surface, the *tombo* for those in mid water, and the *yamade* for those in very deep water. The *hanegu* gear used in Hokkaido consists of three parts, the hook, the synthetic line and the pole, as shown on the right in fig. 86. The hook itself consists of about 10 brass hooks arranged in the form of a small parasol, fastened to the line and baited

TABLE 18

Main specifications of squid fishing boats

Type of construction		Wood	Wood	Wood
Principal dimensions				
L	ft. (m.)	68.86 (20.99)	62.76 (19.13)	51.97 (15.84)
B	ft. (m.)	14.11 (4.30)	13.25 (4.04)	11.68 (3.56)
D	ft. (m.)	7.15 (2.18)	6.40 (1.95)	5.64 (1.72)
GT		48.88	32.27	19.97
Main engine	h.p.	115	115	50
Type of main engine		semi-diesel	semi-diesel	semi-diesel
Wireless antenna power	W	35	—	—
Capacities				
Fish hold	cu. ft. (cu. m.)	1,861 (52.7)	1,342 (38.0)	600 (17.0)
Fuel oil tank	cu. ft. (cu. m.)	233 (6.6)	120 (3.4)	64 (1.8)
Fresh water tank	cu. ft. (cu. m.)	53 (1.5)	32 (0.9)	7 (0.2)
Light load condition				
T	ft. (m.)	4.89 (1.49)	4.53 (1.38)	4.10 (1.25)
Trim by stern	ft. (m.)	3.48 (1.06)	4.33 (1.32)	2.69 (0.82)
Δ	ton	64.91	51.64	24.89
δ		0.54	0.56	0.50
φ		0.63	0.62	0.58
α		0.74	0.77	0.73
GM	ft. (m.)	1.77 (0.54)	1.71 (0.52)	1.15 (0.35)
KG/D		0.76	0.80	0.90
LCG aft ½L	ft. (m.)	3.84 (1.17)	4.79 (1.46)	1.84 (0.56)
Full load condition				
T	ft. (m.)	6.85 (2.09)	5.58 (1.70)	5.38 (1.64)
Trim by stern	ft. (m.)	2.43 (0.74)	1.64 (0.50)	1.18 (0.36)
Δ	ton	113.12	73.02	41.24
δ		0.63	0.61	0.54
φ		0.70	0.67	0.61
α		0.84	0.83	0.80
GM	ft. (m.)	1.18 (0.36)	1.35 (0.41)	1.44 (0.44)
KG/D		2.53 (0.77)	2.56 (0.78)	2.53 (0.77)
LCG aft ½L	ft. (m.)	2.53 (0.77)	1.57 (0.48)	0.33 (0.10)
Trial result				
T	ft. (m.)	5.34 (1.63)	4.63 (1.41)	
Trim by stern	ft. (m.)	5.71 (1.74)	4.20 (1.28)	—
Δ	ton	76.2	53.76	—
V/100% h.p.		8.10/115	8.14/115	7.10/50
V/Max. h.p.		8.30/125	8.31/125	7.35/60

with slices of squid. In the other two types of gears, the hooks are fashioned as shown on the left in fig. 86.

GENERAL ARRANGEMENT

The boats have the engine aft, a small fish hold forward and the crew quarters aft, as shown in fig. 87. The hold immediately in front of the engine room is often used for crew accommodation, being fitted with a removable entrance. The fishing platform is built on the bulwark around the rear half of the boat, and on the fishing ground a removable platform is rigged around the bow. The fish boxes are piled on deck on the outward voyage.

About eight fish-luring lamps, each of 1 kW, are hung from the spar slung between the fore and mizzen mast. The main engine is stopped when fishing, and a sea anchor is dropped.

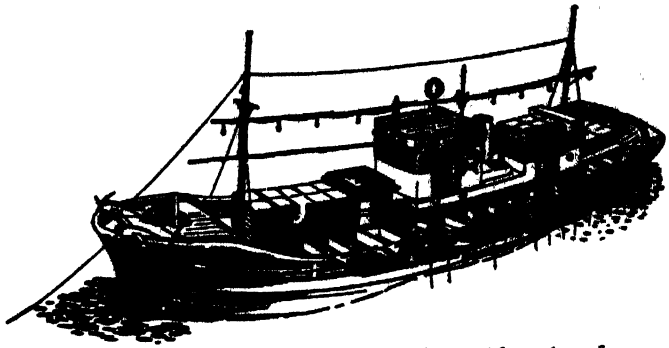


Fig. 87. Squid pole and line fishing boat with engine aft

Main specifications

A few typical examples of squid fishing boats are given in table 18.

NON-TRAWLING FISHING METHODS — DISCUSSION

Boat types

MR. S. J. HOLT (FAO): Turkey has one research trawler and two small vessels carrying on experimental work; Belgium has trawlers; Eastern Germany has several research vessels; so has Poland; research in Portugal is carried out from the *Gil Eanes*, the hospital ship of the dory fleet; Spain has a small vessel; the U.S.A. has several research vessels operating in the North Pacific. The Chinese Peoples Republic is conducting oceanographic studies and probably has one or more research vessels; India, on the other hand, does not yet have a research vessel; the Union of South Africa has several such as the *Afrikana*; Australia has a small vessel for experimental work.

The *rastrelliger* fishery in the Gulf of Thailand is carried out with the aid of a large *carrier* fleet possessed by Thailand.

MR. JOHN PROSKIE (Canada): Hardy's paper is interesting and stimulating. There are, however, several omissions of important Canadian fishing boats in fig. 1. For example, the following important existing types have been omitted: On the Atlantic coast, the whale catcher, the trawler (Grand Banker), longliners and sardine and herring carriers.

Of the boats listed in Hardy's paper, the Grand Banker dory schooner (longliner) is now relatively unimportant and is on the way out. In 1957 only 18 of these boats operated out of the Canadian Atlantic ports and accounted for less than 4 per cent. of the total groundfish landings in that year. On the other hand, the modern longliners (which do not use dories) in 1957 accounted for nearly 7 per cent. of the total groundfish landings (except halibut), 65 per cent. of the swordfish and 40 per cent. of the halibut landings.

In Canada the modern longliners are not one-purpose boats—besides fishing for groundfish by longline technique, these boats are also used for swordfishing (where longline gear is not used) and also for mackerel seining. Another recent development is the "trapper-longliner" which uses trapping and longline technique for capturing fish. These boats have been developed in the province of Newfoundland.

The sardine and herring carriers (packers) are important in the Bay of Fundy fishery and play a dominant role in the weir fishery of the area.

On the Pacific Coast the important fishing boat types omitted from Hardy's table are the whale catcher, drifter and longliner. Drifters are important salmon boats and the longliners play a dominant role in the halibut fishery.

Non-trawling fishing

MR. H. KRISTJONSSON (FAO, Rapporteur): The advent of nylon in the last few years has given a new impetus to gillnet fishing in many countries where it was waning before, and due to this gillnets are now frequently used on big boats, up to over 100 GT. The big boats fish in rough weather and this makes it more important to locate the power gurdies for hauling the nets and longlines near the point of minimum movement due to pitching and heaving of the ship. This is more critical in the rough Northern seas than it is on the tuna longline vessels operating mainly in equatorial waters, and this is indeed to some extent reflected in present day practices. The Japanese tuna longline vessels normally have the line haulers fairly far forward, while the tendency in Scandinavian boats, fishing with bottom-set cod gillnets and longlines, is to locate the net and line haulers near midships. Power gurdies for hauling gillnets and longlines are sometimes placed far forward on the assumption that the boat is pulled towards the gear. This is a fallacy. Even when fishing with small motorboats it is important to manoeuvre the ship under power in such a manner that the nets or lines are lifted nearly vertically up from the bottom. From the wheelhouse the skipper must naturally have a clear view of the hauling operation and be able to see the direction of the gear coming up.

Gillnetting and the other methods of fishing mentioned above are very often carried out from combination boats, due to the short seasons for each gear. This means that certain compromises have to be made as to deck arrangement and also the ways and means of providing shelter for the people hauling the gear. On the American Great Lakes gillnet boats the deck is totally covered, and de Wit has suggested in his paper a rather radical design that also provides full shelter for the men while hauling drift-nets. Other more improvized shelters can no doubt be provided on many of the one-purpose or combination boats. It is becoming ever more important to give attention not only to labour saving, but also to labour easing—to make work on the boats more attractive. In many countries where industry offers steady and comfortable employment on land the fishing operators find it increasingly difficult to attract people to work on their boats, unprotected on the open deck.

It should be easy to give much more shelter than is done today. There is no need for this hardiness that is expected of the fishermen, and furthermore it is wasteful from the point of view of efficiency as the men tire less and work better in shelter than when wet and cold and encumbered by heavy and stiff seaclothes.

More fish is caught by purse seining than by trawling or any other single method of fishing. As long as the net is operated from auxiliary purse seine dories, as in the U.S. menhaden fishing, the New England mackerel fishery and the Norwegian and Icelandic herring fisheries, any type of boat can be used as the main or carrier vessel. The boats in Norway and Iceland are multi-purpose boats. The Icelandic ones (Tomasson, 1955) fish with longlines, bottom-set gillnets, drift-nets for herring, purse seines and trawls. Cargo vessels of up to 7,000 tons have been used as purse seine ships, carrying in davits several pairs of mechanized net dories about 30 ft. (9.15 m.) long.

When the net is operated from the main boat special demands are, however, made on design and deck arrangement. This has been carried to its most rational conclusion on the U.S. Pacific Coast (Hanson, 1955).

Schmidt's paper on purse seining arrived too late to be presented at the Congress. This was most unfortunate as it would no doubt have helped to stimulate very useful discussion on purse seiners which have not yet received the attention from naval architects which these boats merit as the biggest fish producers.

When purse seines are hauled by hand, 12 to 20 men are needed. This waste of man power is now becoming critical even in countries where wage levels are not yet up to American or Scandinavian standards. It is therefore essential to introduce mechanical labour saving devices and to modify the boats accordingly.

The latest innovation for handling purse seines is the powered block, which has come into prominence since 1953. Schmidt (1959) has also proposed ways and means of modifying several conventional boat types (with the wheelhouse aft or midships) for use with the powered block. The powered block is indeed a revolutionary labour saving and labour easing device, which makes it an easy task for 6 or 7 men to handle a big net.

Purse seining seasons are often short so combination boats are usually called for. One advantage of the powered block method is that it can even be applied in the net dories, thus leaving the main boat unaffected. This is mainly an advantage when mechanizing net handlings on existing boats with too small deck space aft. It is however often desirable not having to operate with net dories but to handle the net directly from the main boat. This can only be done conveniently where there is ample free deck space aft or on the quarter for stacking the big net. There are many other strong arguments in favour of free deck space aft. This is the driest and most sheltered part of the ship and the stablest working platform; apart from purse seining, the gillnet, drift-net, and longline boats operate ever greater quantities of gear which should preferably be stacked on the after deck for setting at high speed over the stern.

A great deal more thought must be given to evolving more rational deck layouts and this must go hand in hand with work studies on board the boats during fishing operations.

Drift-net and gillnet fishing

Mr. J. G. de Wit (Netherlands): The Netherlands have specialized in drifters. In former days the drifters were sailing vessels and in the twenties the whole fleet became motorized. The engines were mostly of the hot bulb type of 60 to 80 h.p. The vessels were only used during the herring season from May to December. In the remaining months, the ships were idle. From 1940 there was a growing tendency to use the vessels all the year round. This could be done by trawling in the winter months. The only objection was that engines of 60 to 80 h.p. were too small. From that time engine power has increased steadily to about 1,000 h.p.

The compromise engine for trawling and drift-netting would be of about 400 h.p. If the output is higher, it is better to trawl only, also during the herring season. If the output is lower than 400 h.p. it is possible to drift during the herring season and to trawl during the winter months.

It became clear that a 141.1 ft. (43 m.) vessel is not the right vessel for drift-netting and trawling. These vessels equipped with engines from 600 to 1,000 h.p., operate in the North Sea, the Channel, and recently, south of Ireland. It is this type of vessel that might be called the Netherlands near and middle-water trawler.

There are two types of nets used in drifters. They require a little different handling, though the arrangement on board the ships can be the same for both methods. In case the herring is expected to swim high the fishermen use nets above the warp. If they swim deep, the nets are suspended from the warp. The length of a fleet of nets is about 8,200 ft. (2,500 m.)

Most of the drifters are about 40 years old, and much thought is given to their replacement. Up to now replacement meant scrapping the drifter and building a middle-water trawler. Therefore the drifters and consequently drift-netting will gradually disappear.

Still there are people believing in the construction of new drifters. If they are built, they shall always have to be able to trawl and to drift; this combination will be inevitable. He felt that it will be possible to trawl over the stern on vessels of the drifter type and so he tried to combine drift-netting and stern trawling. He was fully aware that this point is open to discussion.

Mr. W. Orszulak (Poland): de Wit stated that the upper limit of a drifter was considered to be about 118 ft. (36 m.). Studying the problem of the future Polish fishing fleet, three main types of ships had been found to meet the requirements of bringing fish to the market in the needed amount and quality. They were:

- Processing and freezer trawlers of about 1,000 to 2,000 tons d.w.
- Freezer trawlers of about 1,000 tons d.w.
- Deep-sea drifter-trawlers for salted herring (about 350 tons d.w.)

The size of the last mentioned ship (length overall about 165 ft. or 50 m.) has been discussed with Polish fishermen, and they found it possible to operate a drifter of this length.

He would appreciate it if de Wit could give him a more detailed explanation about the elements limiting the size of drifters to the said length. He mentioned that it was proposed in Poland to install diesel-electric drive and a bow rudder based on the water jet principles.

The sketch of the proposed drifter-trawler in de Wit's paper seems to have as main disadvantage the proportion of the profile areas. The size of the mizzen sail to keep the ship against the wind will probably be too large for efficient handling.

Sir Fred Parkes (U.K.): He was also interested in drifting. One of his vessels had won the Prunier trophy twice and he found it interesting to note that the vessel which won the prize five or six years ago, had twice the herring catch of the one that brought home the trophy last season. Why, he wondered, was herring scarce in the North Sea? Why the reduced catches? Herring drifters were hardly built any more because of scarcity of fish, and many of the old ones were being converted for various other tasks. What could be done to preserve the herring as food for human beings?

Mr. T. Mitsui (Japan): de Wit is of the opinion that the qualities necessary for drift-netting would be lost if the length of the boat is over 118 ft. (36 m.) approximately. The seakeeping qualities would of course be improved as the size of the boat becomes larger and the duration of the operation could become longer. In his opinion the manoeuvrability could be improved by using a controllable-pitch propeller, bow rudder, propeller rudder, etc. He would very much appreciate if de Wit would elaborate on these details from his experience.

MR. W. DICKSON (U.K.): Drift-netting is done by Scottish boats in deep water as well as shallow water, with strops between the top of the net and the buoys. The limit for the net is about 20 fm. (36 m.) between the buoys and the float line.

Drifter-trawlers are not the only possibility for dual purpose vessels. Drifter-seiners and drifter-longliners also offer possibilities. Seining in this context means Danish seining, fly dragging style. The biggest drifter-seiners are about 75 ft. (23 m.) long with 150 h.p. engines. Although these boats were intended to be dual purpose, the tendency has been for them to remain on one job or the other because of crewing difficulties. The other possibility is drifter-longliners of 75 to 90 ft. (23 to 27 m.) length with 150 to 300 h.p. engines. The drift-netting arrangement is the usual one, but some of these boats are rigged for both types of fishing at once. They shoot the nets and if the fishing is good they return to port; if not, they lay the longlines and then continue fishing until a good catch is obtained.

A few 75 ft. (23 m.) boats are now converting to trawl and the usual deck arrangement is to have the trawl winch forward. This is the easiest form of conversion to make, but not the most satisfactory because of the inconvenience in handling the gear from a trawl winch up at the bow.

Another combination boat suggested is the seiner-trawler with the winch aft of the casing with clear deck space aft. This, however, is not quite satisfactory for drift-netting.

A 73 ft. (22.3 m.) research vessel of this style is now in operation in Scotland. Trawling can be done from the side or from the stern, and seining is done from the stern. This type has no arrangements for handling heavy gear over the stern, so that only light gear is worked over the stern; heavy gear is worked over the side. It is quicker to shoot and haul the net over the stern, but in rough weather it is easier to handle from the side. When operating from aft, the crew space has been shifted forward, which is not satisfactory to the crew; this is a real problem.

PROFESSOR A. TAKAGI (Japan): Drift-netting for herring is not practised much in Japan, but drifters of 66 to 82 ft. (20 to 25 m.) long, with 250 to 340 h.p. engines, are used to a large extent for salmon and trout. About 30 tons of synthetic fibre net are shot from the stern, and hauled forward. Only small boats are used in Japan, for economic reasons. Salmon and trout drift-netting may not be common in other countries but this type of boat could be used for other purposes.

MR. J. G. DE WIT (Netherlands): He considered the bow rudder an essential part of the equipment of a drifter. The controllable-pitch propeller and the propeller rudder are very helpful but not essential.

If the vessel gets longer, the absolute forces on such vessels due to the wind and waves become also of great magnitude. There must be balance between these forces and the strength of the gear. Drift-nets are very tender. With the materials now in use, the Dutch fishermen are of the opinion that vessels exceeding 118 ft. (36 m.) LBP will increase the net damage.

As he pointed out in his paper, one of the Dutch builders is going to build a 126 ft. (38.5 m.) LBP vessel. In giving the vessel a suitable form, in diminishing the wind area, by building the vessel light and by using modern and stronger materials, one can pass this limit. The main objection against his proposal is the large wind area, requiring a very large mizzen sail if it is not possible to use water jet bow rudder for instance, as Orszulak suggested.

He would like to say that diesel-electric drive is ideal from a technical point of view also for drifters. But he is convinced that it is too expensive for this type of vessel with decreasing catches, as Sir Fred Parkes pointed out.

Kristjonsson touched the problem of offering more shelter to the fishermen and better accommodation because there is a growing difficulty to recruit people for the industry. It is his impression that more shelter while working means poorer quality of the sleeping accommodation in many cases. The quarters will be in the foreship while the best place is aft.

Regarding the Scottish type nets mentioned by Dickson, he thinks the main reason for using them is not fishing in shallow waters, but catching the herring swimming nearer to the surface.

MR. H. I. CHAPELLE (U.S.A.): The use of a deckhouse covering the whole deck of a fishing boat as described by Colvin is unusual. This is not practical in all fisheries carried on in cold weather, for reasons of gear used. Nevertheless the ark-type deckhouse would have advantages in some instances; some New England fishermen found the last winter sufficient excuse to consider additional shelter for the crew working on deck.

The deck-layout of these gillnet boats seems to give the maximum working space, considering the average size and deck machinery required. The windage of the ark-type deckhouse is important. As shown in fig. 54, a reduction is possible by lowering the working deck to the greatest possible degree; considering the form of body in V-bottoms, placing the deck below the chine elevation sharply reduces the working platform width. Ballast is necessary in these boats because of the limitation just mentioned. As Colvin has indicated, the Great Lakes fisheries are in process of change, and so are the boats used. It is probable, therefore, that the boats of the designs shown in fig. 53 and 54 with ark-deckhouses will be replaced by types somewhat similar to fig. 55 and 56.

The replacement of the round-bottom with the V-bottom, in the types represented by fig. 53 and 54 does not appear to have resulted in any improvement in hull-form resistance-wise. The proposal to employ a fast planing hull in a fishery should be of interest. Obviously, the practicality of this is yet to be proven, so far as economic operation is concerned. Let us hope we may have a report on this matter in due time.

So little has been published on the Great Lake gillnet boats that they are almost unknown outside their area of use. Colvin's paper is therefore most useful, particularly as it gives an adequate description of a highly individualistic type of U.S. fishing boat.

MR. J. HØJSGAARD (Denmark): An interesting gillnet hauling winch is shown in Colvin's paper. This Crossley-type net hauler is more automatic than the conventional ones used, for instance, in Scandinavia. The net is gripped by finger-like clamps actuated by an eccentric. No man is therefore needed to haul the net off the gurdy as is the case with an ordinary vertical net hauler with pressure-groove sheave. He understood that these net haulers are used extensively in the American Great Lakes gillnet fishery but not to any great extent elsewhere, except that he had heard that some of the

Russian herring drift-net vessels operating in the North Atlantic are now equipped with such, or similar, winches. In U.S.A. these winches are normally driven by a separate small engine but a hydraulic drive could also be used as security against pulling too hard on the net. Even though these net haulers are rather costly, about £400 (about $1,100), they should be tested in European waters and, if found suitable, their use should be economic if they save one man.

MR. E. BEAUDOUX (France): He asked five questions:

- Are the Japanese health and safety regulations for refrigeration apparatus on board tuna longliners the same as those of other countries?
- Direct expansion system of ammonia in the fish storage holds seems to be authorized in Japan, whereas it is prohibited in France. Is this procedure more widely used in Japan than brine circulation?
- The installation of compressors in the engine-room makes more space available, but is prohibited in France for safety reasons. A separate room is required in France. Is it permitted to have refrigeration machinery in the engine-room in Japan?
- Are there any longliners equipped with propulsion motor rating between 750 and 1,500 r.p.m.?
- Are there any longliners equipped with air-blast refrigeration holds? What is the opinion as to this system?

MR. Y. KANASASHI (Japan): The answers to Beaudoux's questions are:

- Spaces, fittings, etc. for the crew's accommodation are completely regulated by the Ships' Security Law of the Japanese Government
- Ammonia is permitted and widely used as the refrigerant for the cooling coils in the fish hold, and the piping materials, scantlings, etc. are also regulated by the same law. Brine circulation is not so common
- The ammonia compressor is in the engine room to economize space and it is permitted
- Low-speed engines are considered better for frequent changes of speed during fishing operations.
- There are no longliners equipped with air-blast in refrigeration holds or in freezing rooms because of the limited space where big quantity of the catch to be frozen at one time. Therefore, semi-air blast is more suitable for longliners

MR. J-M. CLAVEAU (France): French shipowners consider the cost and maintenance expenses of tuna clippers using live bait too high; they are greatly interested in the method of fishing tropical tuna fish with longlines as used in Japan. They are anxious to know whether the Japanese designers would be willing to supply information about their refrigerated tuna longliners. The following basic data concerning the use of these boats would be of particular interest:

- The size of the crew required for tuna longlining must be one of the essential economical factors. It would be interesting to have full particulars regarding the manner and percentage of the distribution among the shipowners and crews of the proceeds from the sales of the fish. What approximately are the monthly earnings of a skipper and a seaman of a tuna longliner in Japan?
- Have the Japanese tuna shipowners experimented with the U.S. tub method, which aims at reducing the number of the crew required for setting the longlines in the water? Have these experiments proved satisfactory?
- What, in order of preference, are the live bait species used by the Japanese tuna longliners?
- What are the species of tuna caught by the high sea longliners, and in what percentage?
- What is the approximate sale price of these species in Japan?

MR. Y. KANASASHI (Japan): Answering Claveau he gave examples from a fisheries company where he is the president.

- The distribution of the income among the owners and crew is as follows:
  - (a) Fishing boat from 300 to 500 GT:
    owner (the income from the sales of the fish − expenses) × 65%
    crew (the income from the sales of the fish − expenses) × 35%
  - (b) Fishing boat above 500 GT:
    owner (the income from the sales of the fish − expenses) × 70%
    crew (the income from the sales of the fish − expenses) × 30%
  - (c) The monthly earnings of the captain, skipper and seaman are approximately as follows:
    Captain: £61 to 79 (U.S.$170 to 220)
    Skipper: £75 to 93 (U.S.$210 to 260)
    Seaman: £32 to 43 (U.S.$ 90 to 120)
- The Japanese tuna shipowners have no experience with the U.S. tub method for the baiting
- The bait for skipjack or bonito pole and line fishing is entirely different from that for tuna longline fishing. Live fish bait is used for the former, while the bait used by the tuna longliners are frozen saury pikes. Both of these baits are easily obtained in the market and it is a waste of time for the fishing boats to catch them by themselves
- The species of tuna caught by the deep sea longliners are as following:

Species	*Percentage*	*Sale price per 2,240 lb. (1,000 kg.)*
Yellow fin tuna	50%	£286 to 325 (U.S.$800 to 910)
Big eyed tuna	5%	£239 to 286 (U.S.$670 to 800)
Albacore	5%	£304 to 429 (U.S.$850 to 1,200)
Striped marine	10%	£257 to 314 (U.S.$720 to 880)
Black marine	20%	£304 to 378 (U.S.$850 to 1,060)
White marine	5%	£268 to 304 (U.S.$750 to 850)
Broadbill sword fish	2%	£378 to 572 (U.S.$1,060 to 1,600)
Others	3%	£143 to 239 (U.S.$400 to 670)

Pole and line fishing

MR. H. KRISTJONSSON (FAO): At the first Fishing Boat Congress the U.S. pole and line tuna fishing boats were described in detail and the Japanese bonito boats are described now. There are, however, at least two other types of pole fishing boats that have not been described yet in these two Boat Congresses: one is the rather simple type bonito boat used in Cuba. The other development in recent years, mostly since the first Boat Congress, is the creation of a pole and line tuna fishery out of Dakar, where nearly 100 tuna clippers operate now. These boats resemble the American tuna clippers, but there are some significant modifications; the bait tanks, for instance, are not on deck but flush in the hull. He hoped that someone from France would give a description of these boats.

Mr. J-M. Claveau (France): Three types of French tuna vessels are presently in use:

- The 65 to 82 ft. (20 to 25 m.) wooden trawler-tuna clipper, engaged in albacore fishing from June to November off the coast of France, and in trawling from December to June
- The 72 to 85 ft. (22 to 26 m.) baby tuna clipper, equipped with a 300 to 350 h.p. motor and two auxiliary 20 h.p. motors for driving the pumps of the 4 bait wells. The profile is similar to that of the Californian tuna clipper. It has 4 fish-wells with a total capacity of 6,750 to 11,200 Imp. Gal. (30,000 to 50,000 l.) of water for keeping the live bait. It has no freezing apparatus, but only low-powered refrigerator for storing at 32 to 28°F (0 to —2°C) tuna in ice, so that it can land 20 to 30 tons of tuna fish. This type is used in the summer tuna fishing season off the coasts of France, and then in the six-month yellowfin tuna season off the coasts of West Africa. It is manned by a crew of 13 to 15 men
- Freezer tuna clipper. This is a steel ship of very recent construction in France: 2 series are now in use:

  (a) The 89 ft. (27 m.) clipper, equipped with a 400 h.p. motor and two auxiliary 60 h.p. motors for driving the pumps to the 6 bait wells and with ammonia refrigeration compressors at 100,000 BTU (25,000 kcal.). Its general profile is that of the Californian tuna clippers, but it differs from the latter by reason of smaller superstructures and the considerably reduced volume of the bait tanks situated on the deck. This ship is equipped with small fishing racks in the calm waters off the coast of Africa. It has no dry fish hold, all its tanks being used first for storing the live bait and then for freezing the tuna in brine and storing it. It can land about 35 tons of tuna fish. This type of ship is essentially intended for fishing tropical tuna off the coasts of Africa, where it can navigate the whole year round. It is manned by a crew of 15 men

  (b) The 118 ft. (36 m.) clipper, equipped with a 600 h.p. motor and 2 auxiliary 120 h.p. motors. It has 3 refrigeration compressors at 200,000 BTU (50,000 kcal.). Its profile and deck equipment are similar to those of the previous ship. Its wider cruising range allows it to remain at sea for 1 month and to land about 150 tons of frozen tuna fish. It is manned by a crew of 17 men and is used for fishing tropical tuna

Mr. J-O. Traung (FAO): The French use longer poles than the Californians, and have a line and a number of tackles from a wire between the masts to help to take the fish on board. It would be useful to know the main considerations behind these fishing techniques.

Mr. E. Reyes Risoto (Cuba): Cuba has kept to traditional fishing gear and methods. Both construction and types of boats are rather antiquated; there is hardly any difference between the boats that were built on the island at the end of the last century and today's boats. This situation is due to the lack of specialized technicians such as draughtsmen, fishing boat builders etc. Recently the visit of an FAO fisheries economist stimulated interest in the modernization of the fishing fleet, or more exactly, its creation, because the present fleet cannot be modernized or even improved.

There are two main types of fishing boats: the bonito boats, which measure from 40 to 70 ft. (12.2 to 21.3 m.) LOA, and the lobster boats, 30 to 40 ft. (9.15 to 12.2 m.) long. They are both made of wood and are mostly of the schooner type with sail propulsion; recently they have been motorized, thus converting them into sailing vessels with auxiliary engines.

Their layout is not functional: 2 or 3 of the 7 crew members can sleep in the forecastle on the lobster boats, though not very comfortably. This compartment has little depth as the boat has a very low freeboard. Aft of this compartment is the fish hold that will take 20,000 to 30,000 lb. (9 to 13.5 tons) of fish with ice. Next comes the live well, in which the live bait ("majúa"—variety of sardine) is kept. This well is a tank with several orifices to allow the seawater to enter through pipes. A slow-going boat and a tank with small orifices will not allow free circulation nor proper oxygenation of the seawater, and consequently the "majúa" bait can be kept alive for 24 or 48 hours at the very most. Towards the stern there is another small compartment, just as inconvenient as the first, where the rest of the crew sleeps.

The motorized boats have their engines placed between the live well and the stern cabin. The drinking water is kept in barrels on deck; a small charcoal stove serves for cooking; a small canvas shields from the sun both the fish lying on deck and the men while they fish and clean their catch. The compass and helm are also under the canvas.

Bonito are fished with rod and live bait. Cuban fishermen are undeniable highly skilled in this type of fishing.

The boats used for catching spiny lobsters are smaller, shorter and have no normal fish hold. There is a live well in the centre of the boats, similar to that used by the bonito boats for live bait, in which the lobster are put. The live wells will hold 300 to 600 lb. (135 to 270 kg.) of lobster. The gear used is the "chapingorro", namely a rod, that together with a glass-bottomed bucket, can be used to fish at depths of not more than 6 fm.

In Cuban bonito and lobster boats, the longitudinal lines are very curved at the stern; consequently the boats are slow. There is considerable suction resistance due to these lines, but the boats have inherent stability since a large part of the total displacement lies low. The frames, keel, stem and clamp and structural parts are extremely thick, and the timbers used are heavier than water. In addition, the boats have a wide beam, approximately a third of their length, which contributes still further to their stability.

Being unacquainted with the principles of hydrodynamics, the skippers and owners use too much power. In most cases, with half to one third of the power, the boats would sail at the same speed and consume much less fuel. In addition, there is incorrect choice of propeller revolutions, that is too high r.p.m. Further, the owners install propellers of too large diameter, and as a result a proper pitch-diameter ratio is by no means attained.

Obviously all this is due to ignorance. Some time ago when inspecting launches of the Navy in various fishing ports of the island, he was able to see the defects noted above. He forthwith became very keen on the idea of designing fishing boats

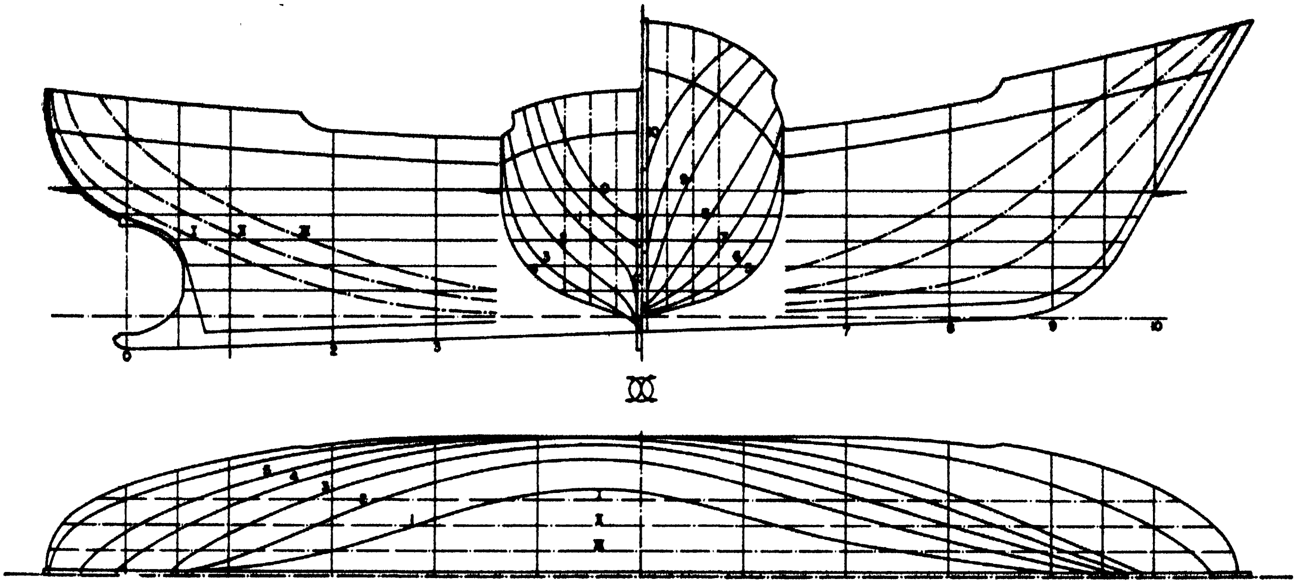


Fig. 88. Lines of Spanish tuna bait fishing vessel

for modern skippers and suitable for the Cuban coasts, and for that purpose he studied the FAO projects and publications. Further, on several occasions he got the skippers and fishermen together, and boarded their boats with them to learn at close hand their shipboard needs. In this way he was able to analyse and ascertain what would be the most suitable type of boat for the kind of fishing practised in Cuba. There is a great interest among most Cuban shipowners and fishermen with regard to creating a new fishing fleet suitable for their coasts, which are fairly broken and where allowance must always be made for the shallow draught.

Mr. H. R. Bullis (U.S.A.): An article on the Cuban tuna fisheries published in the "Commercial Fisherman's Review" five years ago gave the sizes of vessels, number of crew and the fishing technique. The vessels fish for their own bait using a beach-seine.

Mr. V. Esteve (Spain): One very typical fishing boat on the northern coast of Spain is that from which bonito is fished with rods. These small boats, 59 to 72 ft. (18 to 22 m.) in length, are made of various timbers; the keel, the stern, the stern post and the frames are made of oak, the keelson of eucalyptus and the rest of the hull of pine. These are strong, seaworthy boats, very good for navigating in the Atlantic and the Bay of Biscay. Lines and general arrangement is shown in fig. 88 and 89.

The propulsion equipment generally consists of a diesel engine of from 150 to 250 h.p. at 300 to 600 r.p.m., coupled by a clutch to a fixed-blade propeller. The engine room is usually located in the centre of the boat in order to give good trim under any possible load. Usually the auxiliary machinery consists of two sets of mechanical pumps of from 20 to 30 h.p. that circulate water through the live bait tanks. Either of these pumps can take care of all these tanks while the other is out of use. In addition, each set works another pump of greater discharge pressure, that produces artificial rain to attract the fish, and is also used as a fire extinguisher. One of these sets has an air compressor to start the propulsion motor and the other a dynamo of about 5 kW to provide electric current when the boat is in port. When the boat is at sea, electric power is supplied by a dynamo coupled to the shaft.

The compartments in the hull are as follows: the chain locker; the forecastle that will hold 10 to 12 fishermen; an insulated fish hold; the engine room with live bait tanks, one toward the bow and one toward the stern, and with fuel tanks on the sides; a room for the two enginemen and finally a storeroom for fishing gear.

The front bulkhead of the engine-room and the wheel-house are usually made of steel plates and the galley and food stores are located in the superstructure. The holds are insulated mainly with sheets of pressed cork, glass fibre or asphalt products. The insulation material is covered with an inside planking of wood over which cement mortar is applied.

The live bait tanks are made of sheets of galvanized steel or else an aluminium alloy resistant to seawater corrosion. Salt water is introduced into these tanks through pumps from the auxiliary units, and passes out through the discharge funnels on the top portion of the tanks, thus producing the continuous circulation of seawater necessary to keep the bait alive. The inside of these tanks is properly lighted. These boats usually have three wood or steel masts with booms.

Combination fishing

Mr. J. Tyrrell (Ireland): In Ireland they are not concerned with drift-net fishing, which has, with few exceptions, been discontinued for many years, due to uncertainty of catches and expense of gear. They have therefore developed multi-purpose vessels in sizes from 50 to 80 ft. (15 to 25 m.), for operating herring ring net, otter trawl, Danish seine and lately the floating trawl. The chief fishing methods have been bottom trawling and Danish seining, for which the individual catches were relatively small.

The traditional deck and internal layout, with cabin, engine-room and wheelhouse aft, and a combined Danish seine-trawl winch on the foredeck has been found satisfactory for these operations. Modern gear developments, particularly the herring ring net and the mid-water trawl, have, however, produced much increased individual hauls, and in the light of this development, an improved deck arrangement is clearly becoming necessary.

He noted the Pacific Coast deck arrangement with particular interest, since his company had quite independently been making experiments and came to similar conclusions; although no actual vessel of this layout has yet been built, they had made designs and models which are presently being discussed with Irish fishermen.

The vessel will be about 75 ft. (23 m.) long with 20 ft. (6 m.) beam, the crew accommodated forward, followed by the

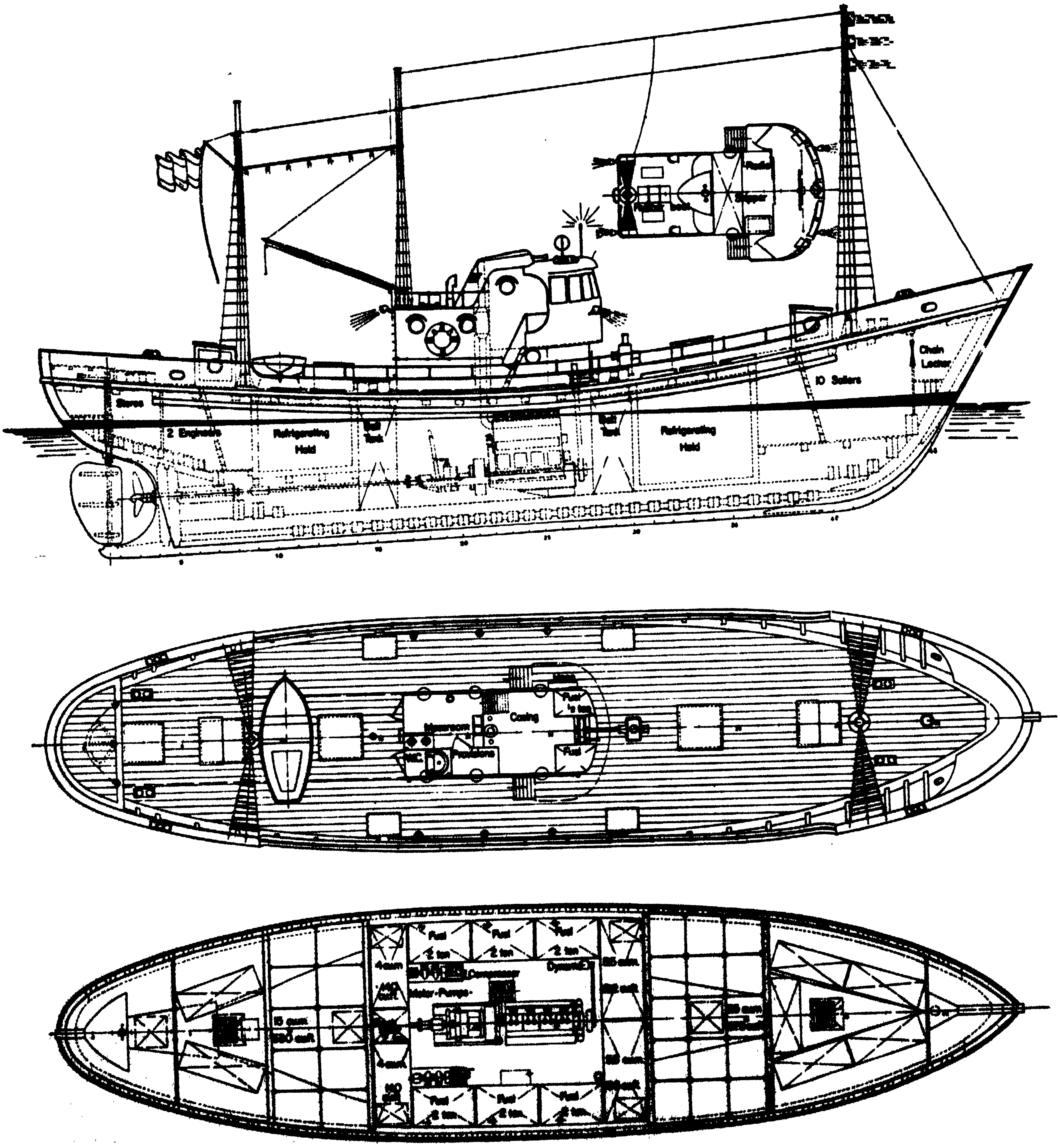


Fig. 89. General arrangement of Spanish tuna bait fishing vessel

engine room and the fish hold aft. The wheelhouse would be located forward of amidships, with the winch, of the combined Danish seine and trawl type, at about mid-length.

A transom stern seems most desirable for this layout, and care must be taken to preserve trim, with a heavy load located considerably aft of midships.

The chief objections are:

- The crew dislike living forward
- The engine installation requires a relatively long shaft running below the fish hold
- The crew are doubtful about the safety of working on a wide exposed aft deck

He felt these objections could be overcome without much trouble, except possibly the first, which goes against all traditional practice. He should like to hear from Hanson or Kristjonsson whether they have met with similar difficulties with vessels of the proposed arrangement, and how these were overcome.

MR. H. C. HANSON (U.S.A.): He had witnessed a fast transition in fishing boat types in the Western U.S.A. and in Alaska. The first step from the rowing boat came with the bow-pickers, with the engine aft. The West Coast was at that time a new country without heritage or tradition, and consequently with little prejudice, which meant quick changes. Purse seining started about 1914 and brought about the change from bow fishing to stern fishing. The boats developed from the flat bottomed seine boats and the trolling vessels to the combination boat as it is known now. Seine fishing, trolling, lining and trawling are all done by these boats developed within the last 20 years. Large tuna vessels often operate for up to three months at sea.

Practically all vessels on the West Coast are now fishing over the stern. Tuna vessels are being stripped of their bait tanks and are converted to purse seining. A net table is still used in combination with the powered block.

He expected that in the near future West Coast fishermen would go further out to sea, and it might well be that they will then adopt smaller types of stern trawlers, such as are now operating in the North Atlantic.

MR. D. L. ALVERSON (U.S.A.): According to Hanson, the change-over to multi-purpose fishing boats has come about in a short time, and this has been advantageous to the fishing industry. Up to now fishing has been done close inshore and the methods used have been trawling and purse seining. In future, fishing for extended periods might be done in distant waters like the Gulf of Alaska and the Bering Sea, and a new type of vessel may be considered.

Regarding the changes in the tuna fleets, there has been a tendency in recent years to remove the bait tanks and equip the vessels for purse seining. This change has been mainly due to the distribution and schooling patterns of tuna, which make it more profitable to catch them with a purse seine. The introduction of nylon nets has made it possible to use larger and stronger seines.

Regarding changes in deck arrangement of small gillnet vessels, aluminium construction has been indicated. One of the advantages of this material is the lighter weight of the vessel and the consequently greater payload.

MR. H. KRISTJONSSON (FAO): When he was as a young student on the U.S. West coast during World War II, he got for the first time acquainted with the Pacific type boats with the wheelhouse forward. He had, as a youngster, worked on the Scandinavian boats in Iceland and it was immediately obvious to him that the Pacific type had many important advantages, for instance, in regard to purse seining. He had, however, the same misgivings about their seaworthiness as expressed by Tyrrell. To test their performance in rough weather, he worked his way to Alaska, mainly with the objective of testing the performance of this boat type under rough weather conditions somewhat similar to those in the North Atlantic. He returned to Seattle on a 78 ft. (23.8 m.) purse seiner, an 11 days' voyage, and, luckily for him, they got a full gale in the Gulf of Alaska lasting for two days. After this he was quite confident that he could recommend the Icelanders to test this type. He wrote an article in an Icelandic newspaper which came at the right moment. The people at home were optimistic and asked him to go ahead and have a boat built of the new type to be tested in Iceland. The Icelandic Skippers' Union sent over an experienced purse seine skipper who familiarized himself with the Pacific purse seining gear and method and sailed the boat home. Unfortunately this boat, an 84 ft. (25.6 m.) purse seiner, came a little bit too late to Iceland due to late delivery and missed the herring season in 1945. This meant that this design had not been tested when a big-scale rebuilding of the boats was decided immediately after the war, mainly in Sweden. This Pacific type boat has been operating in Icelandic waters since 1945. It has been found to be eminently seaworthy. As a matter of fact, it is used during most winter seasons to aid the cod fishing boats and to tow them in when they have engine trouble. That is not necessarily because it is the best and most seaworthy boat, but it is seaworthy enough for this tough service. There is still a prejudice against using it for any fishing method where the gear is handled forward of amidships because of imaginary or real difficulties which are anticipated due to windage on the wheelhouse, lack of deck space forward etc. This has however not been tested in Iceland yet after all these years, and this in spite of the fact that such boats are used successfully in the Pacific halibut longline fishery in the stormy Gulf of Alaska.

MR. J. VENUS (U.K.): His firm had built orthodox trawlers for middle distance trawling. The efficiency of the design had not been questioned. However, accommodating the crew forward may have an adverse effect on the willingness of the crew to go to sea, because of the heavy motion in high seas.

MR. H. C. HANSON (U.S.A.): As regards living quarters forward on the combination type boat, this seems to be all right as 95 per cent. of the owners prefer it this way. The only difficulty is probably the over-icing occurring in the North Atlantic, but there is also risk for icing in the Pacific and no difficulties seem to arise.

TRAWLING: DECK DESIGN AND EQUIPMENT

by

A. VON BRANDT and C. BIRKHOFF

In several countries, such as Belgium, United Kingdom, Federal Republic of Germany, France, 75 to 100 per cent. of all landings from the sea are obtained by trawls. The trawl thus is an important gear to gather the protein resources of the sea.

Its development is closely connected with the fishing vessels which represent approximately 80 per cent. of the capital invested in fisheries. The efforts to catch more with larger nets, to extend operations into deeper waters, and to reduce manual work by mechanization requires a corresponding development of trawlers with the necessary deck equipment. The investment is considerable in the most modern stage of development.

The beam trawl is the most primitive type used in power trawling. Unless very large, it is light and handy and needs relatively little special deck equipment. Its height and width are limited by the beam.

The introduction of otter boards decisively influenced developments and extended the range of fishing. Winches were needed for the longer and stronger warps as well as the gallows to lower and haul the boards.

The methods of towing, handling the net and hauling the catch distinguish a "side trawler" from a "stern trawler", the latter with or without a ramp.

Although the stern trawler has certain advantages in handling the trawl, side trawlers are still dominating in the North Atlantic. On stern trawlers without a ramp the net is hauled over a broad stern roller; the codend with the catch, however, must be hauled over the vessel's side, and this takes time. The arrangement of the deck machinery varies greatly, because trawlers are often also used for other fishing methods.

The stern trawler with a ramp developed from the desire to process the fish on board, in order to extend the fishing trips. It is important that the sailing time to and from the fishing grounds and the stay in port be as short as possible so that actual fishing days can be the maximum. This also applies to the time to shoot and haul the nets. Stern trawlers with a ramp have a number of advantages over other types. These include the time saved in handling the trawl and catch, thus preserving the quality of the fish, less damage to the nets, better working conditions for the crew, a more seaworthy vessel, easier conversion to other types of gear, as for instance pelagic trawls, and more favourable use of the space on board.

Two-vessel trawling can lead to greater yields than when each vessel operates by herself, and two small vessels can use a larger net.

Pelagic trawling has mainly been done with two boats, but the size of the vessels is limited and fishing is difficult in bad weather or at night. Therefore work is being carried out to develop a pelagic one-boat trawler. The stern trawler appears to be the better type of vessel for this operation.

EQUIPEMENT DE PONT POUR LE CHALUTAGE

Dans plusieurs pays, tels que la Belgique, le Royaume-Uni, la République fédérale allemande et la France, 75 à 100 pour cent de toutes les quantités débarquées d'origine marine sont pêchés au chalut. Le chalut est donc un engin important pour récolter les ressources protéiques de la mer.

Son développement est en relation étroite avec les bateaux de pêche qui representent approximativement 80 pour cent du capital investi dans les pêches. Les efforts pour pêcher plus avec de plus grands filets, pour étendre les opérations de pêche à des eaux plus profondes et pour réduire le travail manuel par la mécanisation nécessitent un développement correspondant des chalutiers possédant l'équipement de pont nécessaire. L'investissement est considérable dans les stades les plus récents du développement.

Le chalut à perche est le type le plus primitif utilisé dans le chalutage avec des bateaux mécanisés. A moins qu'ill soit très grand, il est léger et manoeuvrable et nécessite relativement peu d'équipement de pont spécial. Sa hauteur et sa largeur sont limitées par la perche.

L'introduction des plateaux de chalut a exercé une influence décisive sur les développements et a augmenté la portée de la pêche. Il a fallu des treuils, des funes plus longues et plus fortes ainsi que des potences pour mettre à l'eau et embarquer les plateaux. Les méthodes de remorquage, de manoeuvre du filet et d'embarquement de la pêche distinguent le "chalutage sur le côté" du "chalutage par l'arrière", ce dernier étant pratiqué avec ou sans rampe.

Les chalutiers pêchant sur le côté sont utilisés surtout dans l'Atlantique nord, bien que les chalutiers pêchant par l'arrière présentent certains avantages dans la manoeuvre du chalut. Sur les chalutiers sans rampe, le filet est hissé à bord sur un large rouleau placé à l'arrière; cependant, le cul-de-chalut renfermant les poissons doit être hissé à bord sur le côté du navire, et cela prend du temps. La disposition de l'équipement de pont varie beaucoup parce que les chalutiers sont souvent utilisés pour d'autres méthodes de pêche.

L'idée du chalutier muni d'une rampe provient du désir de traiter le poisson à bord afin d'augmenter le rayon d'action des navires. Il est important que le temps passé pour aller sur les lieux de pêche et en revenir et le séjour au port soient aussi courts que possible afin que le nombre de jours de pêche réelle puisse être maximum. Les chalutiers pêchant par l'arrière, munis d'une rampe, présentent un certain nombre d'avantages par rapport aux autres types. Ces avantages comprennent: l'économie de temps pour manipuler le chalut et le poisson, préservant ainsi la qualité du poisson; moins de dégâts provoqués au filet; de meilleures conditions de travail pour l'équipage; une meilleure tenue à la mer du navire; plus de facilités pour transformer le navire pour l'utilisation d'autres types d'engins, comme par exemple les chaluts flottants; et une utilisation plus favorable de l'espace à bord.

Le chalutage à deux navires peut donner des rendements plus élevés que lorsque chaque navire opère seul, et deux petits navires peuvent utiliser un plus grand filet.

Le chalutage pélagique est surtout effectué avec deux navires, mais la taille des navires est limitée et la pêche est difficile par mauvais temps ou de nuit. On travaille donc à mettre au point un chalut flottant à un navire. Le chalutier pêchant par l'arrière paraît être le type de navire le meilleur pour cette opération.

EQUIPO PARA LA CUBIERTA DE LOS ARRASTEROS

En varios países, entre ellos Bélgica, el Reino Unido, la República Federal Alemana y Francia, del 75 al 100 por ciento de toda la pesca marina desembarcada se captura con artes de arrastre. El arte de arrastre constituye, pues, un importante medio para recoger los recursos de proteínas del mar.

Su perfeccionamiento está estrechamente relacionado con el de los barcos de pesca, que representan, aprox., el 80 por ciento del capital invertido en la industria pesquera. Los esfuerzos encaminados a pescar más con redes mayores, a extender la pesca a aguas más profundas y a reducir el trabajo manual mediante la mecanización, exigen mejoras correspondientes en los arrastreros y en el material de cubierta necesario. En la fase más moderna de perfeccionamiento la inversión de capital es considerable.

El arte de vara es el tipo más primitivo empleado en la pesca de arrastre con barcos mecánicos. A menos que sea muy grande, es ligero, maniobrable y necessita relativamente poco equipo de cubierta especial. Su altura y su anchura están limitadas por la vara.

La introducción de las puertas influyó de manera decisiva en el perfeccionamiento y permitió ampliar el alcance de la pesca. Se necesitaron maquinillas para los cables de arrastre más pesados, así como pescantes para izar y arriar las puertas.

En los métodos de arrastre, de maniobrar el arte y de embarcar la captura se distinguen el arrastre por el costado y el arrastre por la popa; este último con rampa o sin ella.

Los arrastreros que pescan por el costado se emplean principalmente en el Atlántico norte, aunque el arrastrero que pesca por la popa reúne ciertas ventajas en cuanto a la maniobra de arte. En arrastreros sin rampa el arte se iza a bordo sobre un gran rodillo instalado en la popa, pero el saco con la captura se tiene que izar por el costado y ésta es una faena larga. La distribución del equipo de cubierta varía mucho porque los arrastreros se suelen emplear para otros métodos de pesca.

La idea del arrastrero con rampa se debe al deseo de elaborar el pescado a bordo a fin de aumentar el radio de acción de los barcos. Es importante reducir en todo lo posible la duración de los viajes de ida y vuelta a los caladeros y la permanencia en puerto, a fin de que el número de días hábiles de pesca sea el máximo. Esto es también de aplicación al tiempo dedicado a largar y virar el arte. Los arrastreros con rampa a popa tienen varias ventajas sobre los otros tipos ,entre las que están el tiempo ahorrado en la maniobra del arte y la manipulación de la captura, que contribuyen a mantener la calidad del pescado, perjudican menos a las redes, la tripulación trabaja en mejores condiciones, el barco tiene más resistencia a los efectos del tiempo, es más fácil convertirlo para emplear otras clases de arte y el espacio a bordo está distribuído más favorablemente.

La pesca al arrastre con dos barcos puede producir mayores rendimientos que cuando cada barco opera por sí solo, y dos barcos pequeños pueden emplear un arte grande.

El arrastre pelágico se ha efectuado principalmente con parejas, pero el tamaño de los barcos es limitado y la pesca resulta difícil en mar gruesa y de noche. Por estas razones se estudia la manera de perfeccionar un arte pelágico para una sola embarcación. El arrastrero que pesca por la popa parece ser el mejor para esta operación.

THE trawl, the most important gear for demersal fish in sea fisheries, is used at all fishing depths, from the shallow off-shore waters to the deepest fishing grounds known today. Although trawls have been used since the invention of nets, they have only attained their present importance in recent times. This importance depends on, and has grown with, the development of suitable vessels, their propulsion and deck equipment. Fig. 90 and table 19 show the magnitude of trawling compared with other fishing methods.

The trawls were developed to:

- Catch more fish by increasing the volume and efficiency of the fishing gear
- Fish in deeper waters off shore
- Reduce manual work by mechanization
- Be suitable for many species of fish
- Catch fish not only on the bottom but also in mid-water
- Be suitable for bad weather operations

Fish and other marine animals must be in certain concentrations to be trawled. If not, such gear as hand lines, longlines, fixed bottom set gillnets, trammel nets or traps are used. The encircling net only, in size of catch, can be compared with the trawl, although the encircling net is only used for pelagic fishing.

The trawl plays little part in inland water fisheries although smaller types of trawl are still used in some lakes and rivers, such as the large lakes of South-east Europe, the Caspian Sea and the large African lakes.

The trawl is closely correlated to the vessel in which it is used, and no other gear has had such a great influence on the design of fishing vessels.

The development of fishing vessels from the open rowing boat to the factory ship has been accompanied by the development of larger nets requiring greater towing power; thus the development of the trawl is closely connected with that of propulsive power. The influence of the net was apparent in the sailing trawlers which had to be fitted with special sails to increase their towing power. With the development of special vessels and deck equipment, trawling has become a fishing method calling for considerable capital investment. Consequently, it is changing from a single owner and small business basis into a large enterprise. Although the trawl requires a smaller crew and less working time than several other methods used for bottom fish, the total expenditure for the equipment is high and continues to increase.

TABLE 19

Bottom trawl catches expressed as percentages of the total catch of the country

Belgium	100
England	91
Germany (Federal Republic)	91
France*	78
Iceland	61
Canada: Atlantic coast†	42
Pacific coast	5
Phillipines	39
Portugal	35
Scotland	35
Union of South Africa (excluding South West Africa)	32
U.S.A.‡	25
Japan	22
Norway	4

*Data for 1955

†By trawlers under 70 ft. LOA 12%
By trawlers over 90 ft. LOA 30%
42%

‡Data for 1949

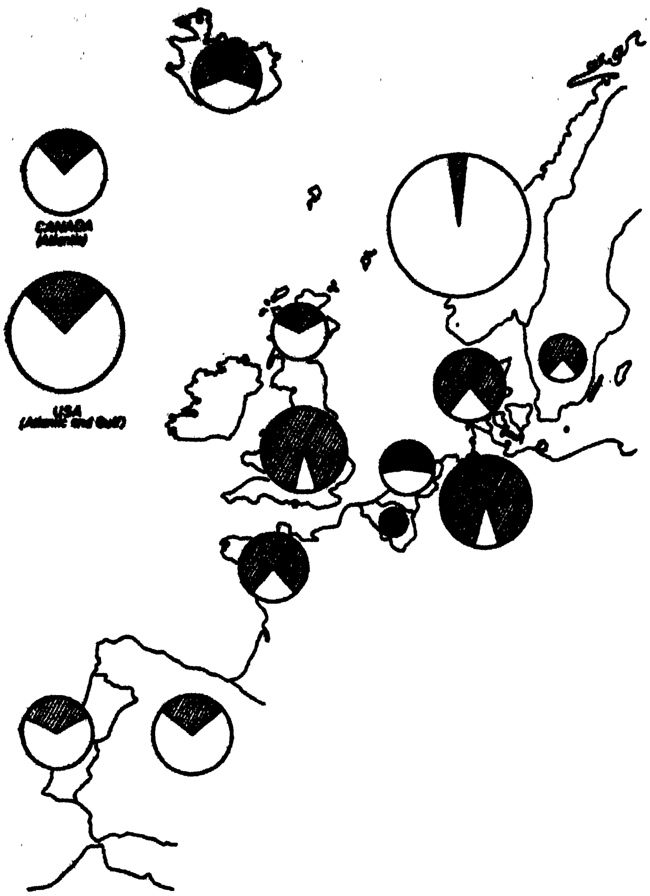


Fig. 90. Contribution of bottom trawl catches to total catches in the North Atlantic area

GENERAL DESCRIPTION OF FISHING GEAR

Net

The size and design of the trawl is governed by the species to be caught, and by the available towing power. Until recently, ideas about the behaviour of the trawl nets in action were only hypothetical, but nowadays direct or indirect underwater observations have made it possible to understand better how the net behaves in action and to determine its relation to the vessel.

Various designs have been evolved to achieve good filtration of water and to avoid a swirl before the net which would repel the entering fish. The material, composition and shape of the parts, mesh size, etc., of the net scarcely influence deck equipment and need not be mentioned.

Accessories

Fig. 91 and 92 give examples of modern trawl designs, which are no longer simple net bags but include accessories that are of essential, if not decisive, importance for obtaining good catches. The largest possible width and/or height of the net opening is essential for effective operation. When the net is towed by one vessel, the horizontal width can be obtained with booms or beams or otter boards. Booms were first used by sailing boats, as shown in fig. 93. It is much easier to get the desired width of opening by towing with two boats. Two-boat trawling, therefore, is widely practised. Vertical spread is partly achieved with net floats or sheering equipment or kites, and partly by design.

The size of the net and the opening is also influenced by the length of the lines (groundrope and headline). To ensure smooth running of the groundrope over a rough bottom, wooden bobbins and hollow iron balls weighing, in total, as much as 1.5 tons are attached to the rope. Handling calls for special deck equipment.

Handling of fishing gear

The time taken for one haul depends on the bottom and on the abundance of the fish and may vary from a few minutes to several hours. The trawling speed depends on the net type and species of fish to be caught. Large trawlers work at 3 to 5 knots for most species of fish. Small vessels, however, fish at lower speeds. Low speeds are especially important in trawling for some flat fish.

Shooting and hauling require special equipment, particularly for handling the lines and accessory gear. It is important to bring the codend on deck without damaging the fish.

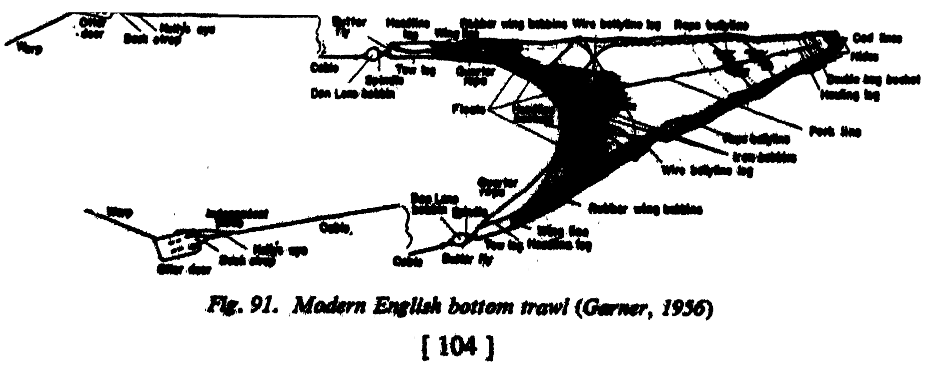


Fig. 91. Modern English bottom trawl (Garner, 1956)

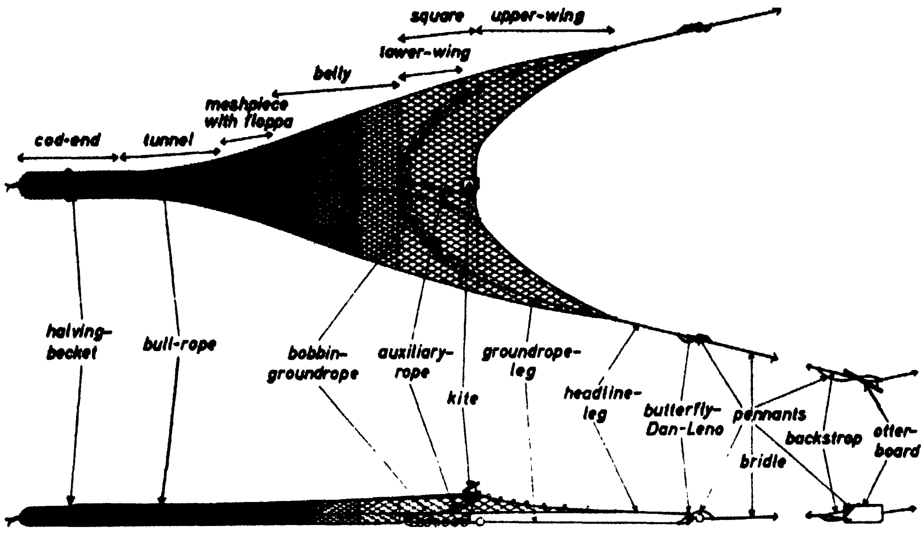


Fig. 92. Modern German round-fish trawl (Schärfe, 1957)

BOTTOM TRAWLING WITH ONE BOAT

General description

To keep the trawl open horizontally from only one boat, booms are attached to the bow and stern to which the warps are fastened, as shown in fig. 93. This method, however, was mainly developed for sailing boats, and has been practised since ancient times in Europe and in Asia. Another well-known method is to open the trawl horizontally with a stick or beam and to trawl with one warp and bridles as shown in fig. 94 (beam trawl). With the low towing power of sailing boats, small trawls can only be used and they are lowered and hauled by hand.

The width of the net opening of the beam trawl is determined by the length of the beam, which varies from 25 to 45 ft. (8 to 14 m.), and sometimes skids attached to each end of the beam hold the mouth vertically. The beam and skids give the opening a certain rigidity. In large sizes, however, the long and heavy beam makes it much more wieldy than the otter trawl (Morgan, 1956). It is really a gear for small inshore fishing craft and is used in European, Asiatic, African and American coastal waters.

Otter boards were first used at the end of the last century, although the idea is old. Line fishermen used—and still use—a similar device to control the direction of lines in running water or when towing from a boat.

The otter board for trawlers was used in Ireland about 1870 but was first reported from England. Originally the otter trawl, like the beam trawl, was towed with one warp and bridles but a second warp was soon added. The introduction of otter boards encouraged the manufacture of larger nets for use at greater depths. Fig. 95 shows such a German trawl. Concurrently with the development of larger trawls, more powerful vessels were designed (fig. 96), which extended the fishing time and distance from home ports. Longer and stronger warps led to powered winches, and the invention of the gallows enabled the boards to be handled.

Methods of trawling and handling the net determine whether the vessel is a "side trawler" or a "stern trawler".

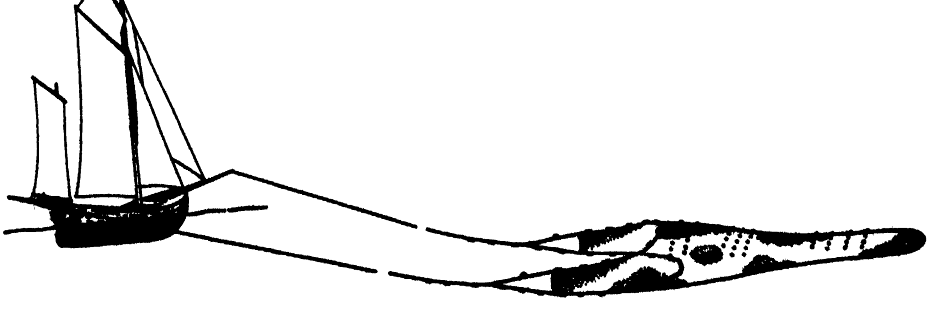


Fig. 93. Towing by a boat sailing athwart, the horizontal opening of the trawl being obtained by booms fore and aft of the boat

In the first type, the two warps run asymmetrically because the net is shot and hauled on one side. In the stern trawler, however, the warps run symmetrically. The codend is hauled over one side of the vessel or over the stern.

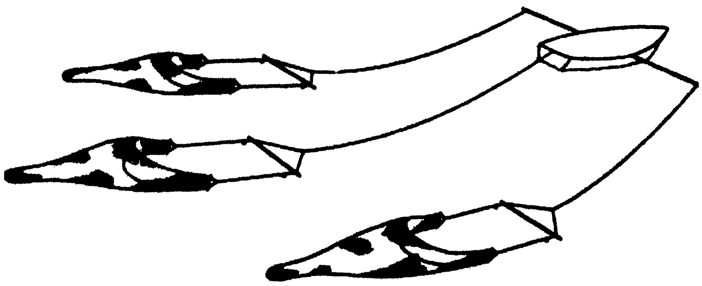


Fig. 94. Japanese beam trawls

SIDE TRAWLER

Origin

The side trawler is the most familiar type of vessel in the North Atlantic deep sea fishing industry and it has been developed over a longer period than other types. In the days of sailing trawlers, the trawl was handled on one side, and this arrangement was inherited by mechanized vessels. Indeed, modern side trawlers still make use of the wind, heaving to so that the net can be shot and hauled from the weatherside to prevent the vessel being driven over it, and to help stream it out.

The equipment of side trawlers has become more or less standardized internationally. There are two gallows for the otter boards and a derrick for the bobbin wire in front of the after gallow. There is also a derrick at the foremast for shooting and there may be a third derrick near the mast. Between the hatches and the deckhouse there is a winch from which the warps run forward and are guided over the centre and wing bollards to the gallows. Aft at the bulwark there is a messenger, with sheave and slip hook or slip block (also called a towing block) or other equipment for connecting the two warps when fishing. Quarter rope- and bridge tackle-sheaves at the deckhouse haul the net, and the tackle at the foremast lifts the filled codend on deck, as shown in fig. 97. Sometimes, on smaller inshore trawlers, the winch is placed before the hatches, or between two hatches. This requires corresponding fairlead bollards.

The fish hold is normally in front of the engine room which is in the aft part of the vessel. The crew's quarters today are usually located near the messrooms aft, to avoid unnecessary walking over the open deck. The trawlers have a forecastle to improve seaworthiness and to protect the crew working on the open foredeck where working rooms and net and cable rooms are located.

Trawlers have hatches over the fish holds and these are arranged at regular distances, so that several groups of 11 to 14 men can work simultaneously when unloading. The superstructure is located aft of the hatches.

As only one side, generally the starboard, is required for handling the net, the portside superstructure on modern vessels is usually closed. A working passage runs to starboard, and this also accommodates the bulky bobbins of the ground rope. Arranged on the free working deck forward of the superstructure are the fish ponds, where the catch is gutted, washed and sorted.

STERN TRAWLER WITHOUT A RAMP

Origin

This type of vessel was developed in fair weather regions, such as the Pacific coast of U.S.A. and in the Mediterranean, and has only come into use as a near-distance trawler in recent years. In order to utilize drifters,

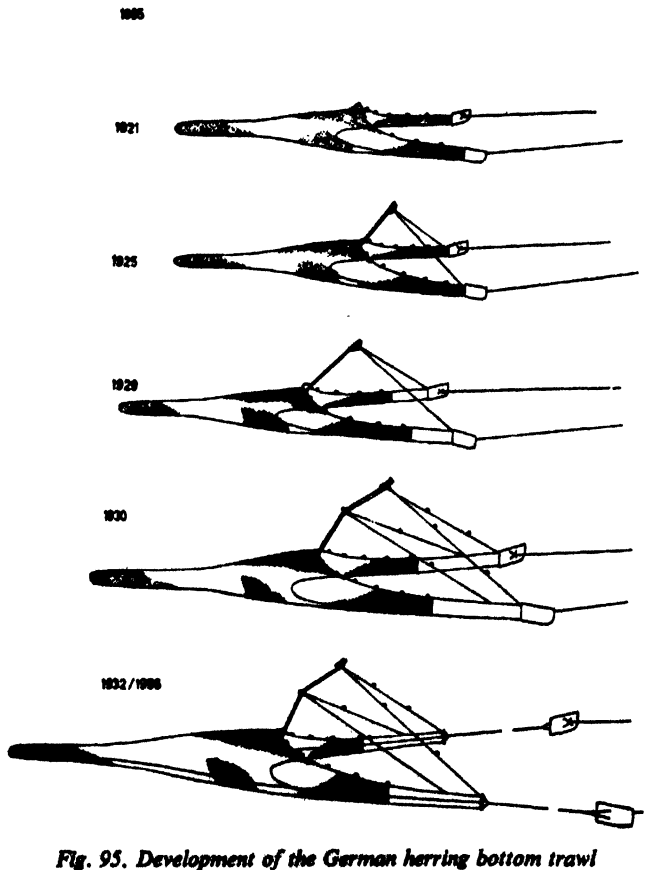


Fig. 95. Development of the German herring bottom trawl (von Brandt, 1957)

seiners, longliners, tuna clippers and, possibly, trollers, throughout the year, it was necessary to equip them for an alternative fishing method, such as trawling. And as the other fishing gear—with the exception of most of the drift-nets—was handled over the stern, it followed that the trawl was also handled over the stern. The gallows

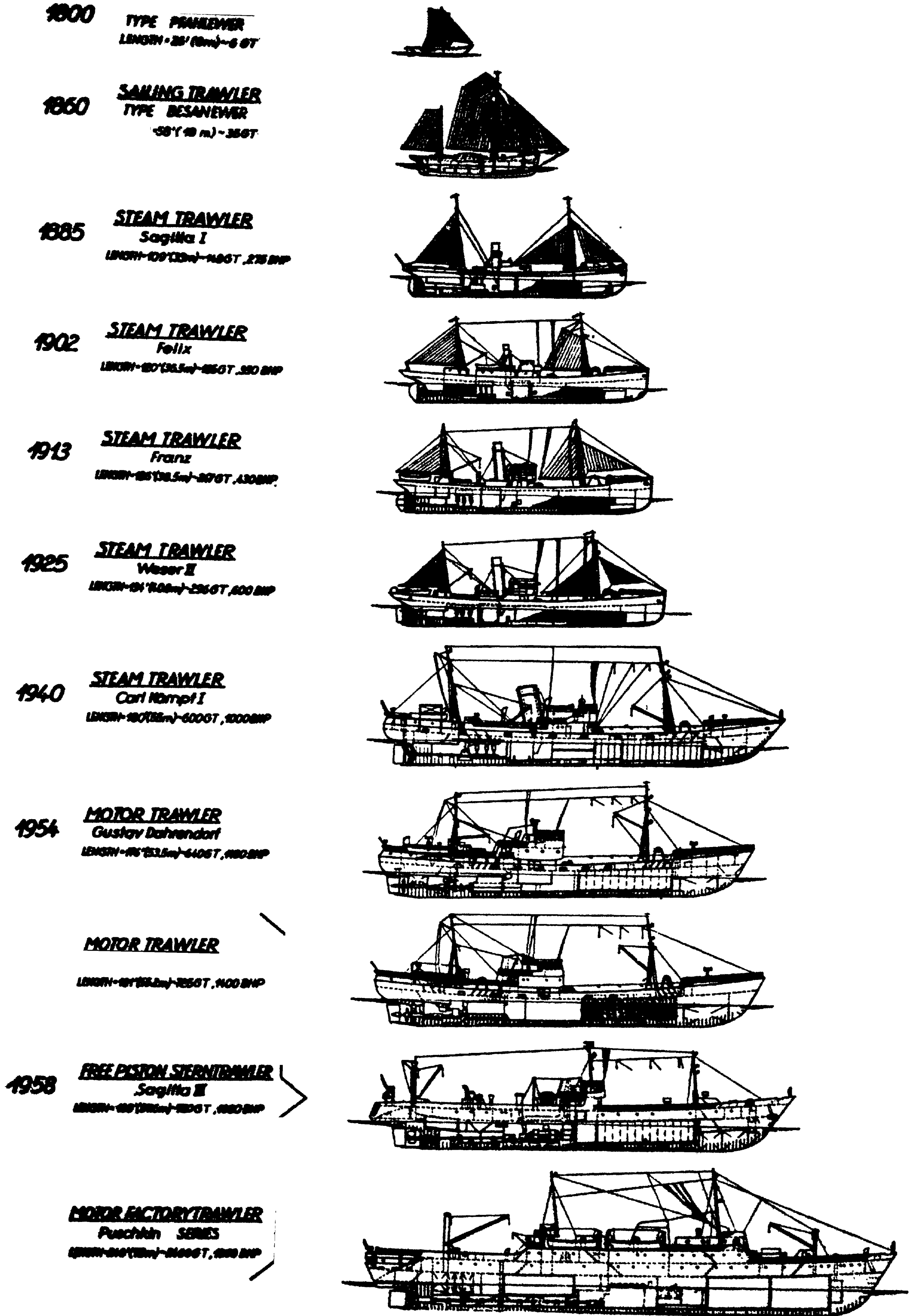


Fig. 96. Development of the European trawler (compare also fig. 2)

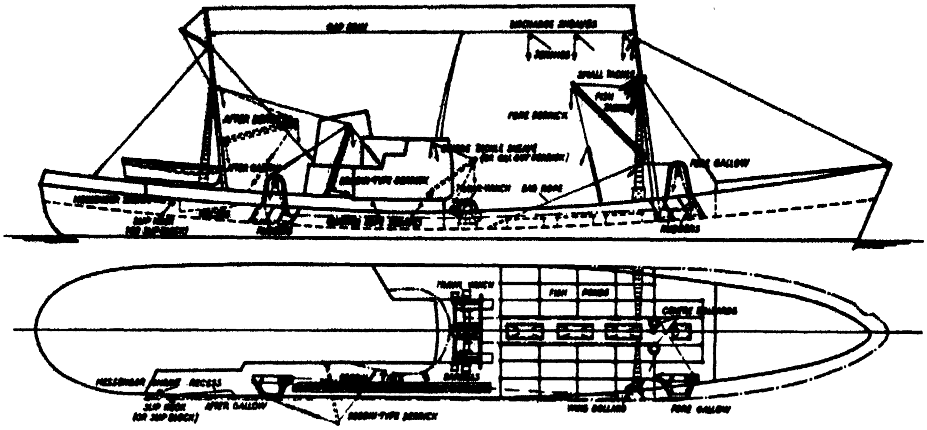


Fig. 97. Deck arrangement and leading of warps on side trawlers

were symmetrically arranged at the sides near the stern. A stern-roller is often used for shooting and hauling the trawl, and the catch is sometimes hauled over the side as the existing derrick can best be used as the "cod-end derrick", while the heavy tackle at the mast serves as the "fish tackle".

The deck equipment of these vessels varies, often depending on the original fishing method, and even the most modern vessels remain typical of their original character.

Arrangement

The vessels have two movable side-gallows, either reversed U-shaped or davit, situated approximately 10 to 16 ft. (3 to 5 m.) forward of the broad stern, which is often a transom stern. This latter is best for the large net-roller and it provides a good working space for shooting and hauling the nets.

The vessels have a mast, aft of the deckhouse, with a large derrick to serve the hold and fishing gear hatches and the aft working place. A heavier tackle for hoisting the codend over the side is often attached to the middle of the large derrick. There may be another small derrick at the mast for this purpose and also for hoisting the lifeboat.

There are various arrangements of the winch and the fairlead bollards, differing in types and sizes from the small shallow-water winch with a twin drum, transversely set, to the deep-sea winch with two separated drums placed in a longitudinal direction. The fairlead bollards are arranged according to the working direction, so that there are either centre bollards between the gallows or two wing bollards. Modern winch drums are aligned towards the gallows by using a cardan shaft, and rotatable davit-gallows are fitted. Vessels with larger trawl winches working in a longitudinal direction sometimes also have a small seine-double-capstan or two additional drums as shown in fig. 98, which may be advantageous for pelagic fishing. This type of vessel is very profitable in fair weather areas, as it can be adjusted to the best fishing method for existing conditions. With the addition of a trawl, such a vessel is capable of working throughout the year. As it costs relatively little to build and operate, this type of vessel has a great future in fisheries where favourable weather prevails.

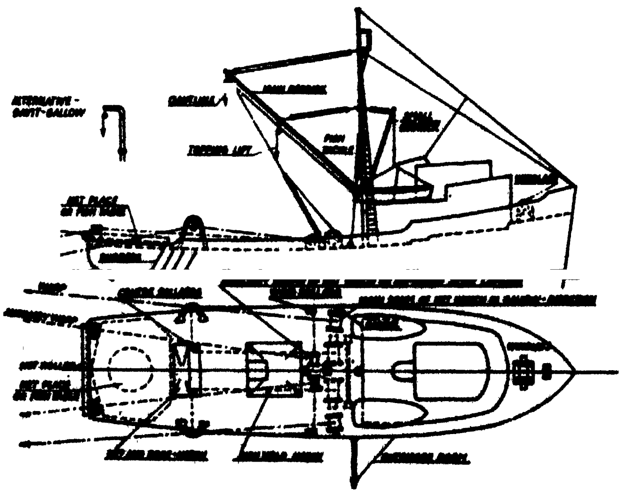


Fig. 98. Deck arrangement and leading of warps on stern trawlers without ramp

STERN TRAWLER WITH A RAMP

Origin

The idea of processing fish on board to facilitate voyages to remote fishing grounds has led to this type. The processing machinery required a large space, and the shelter deck was the obvious place for it. The beam wind position on the side trawler when handling the trawl was very inconvenient. The height of the shelter deck made the handling of the trawl difficult, and heavy rolling had to be avoided because of its effects on the processing machinery and conveyor belts. The answer to these problems was to operate over a stern ramp which, as was soon proved, does not impair the quality of the fish.

type

At first, there were some difficulties in handling the trawl over the stern. Additional sweepline-gilsons were used in the British stern trawlers. These drew the sweeplines from the trawldoors to the ramp, simultaneously slacking the warps. The arrangement of the trawl winch, fairlead bollards and gallows has a slight resemblance to that of the smaller stern trawlers without a ramp.

Warp roller trollies type

A different arrangement was used on German built vessels. The large factory trawlers built for Russia used warp roller trollies running on rails along the stern ramp which, although expensive, can be handled quickly. This arrangement has been given up in new Russian vessels where use is made of two conventional gallows aft on each side of the deck.

gear in line with the inclination of the ramp. This arrangement allows the wet net, with the exception of the full codend, to be kept clear of the ramp and thus reduces friction.

Other equipment includes a derrick at the portal-gallows for lowering the codend; a bipod mast over the loading hatch, designed to allow the codend to be emptied without being lifted; coamings and bobbin tracks along the deck for safety when the vessel rolls, two short lifting lines which make it easy to fasten the warps to the otter boards, and two veering lines for the heavy bobbin wire. With this method of handling the gear, the flush fish hatch with a chute leading into the large buffer store should be located just in front of the

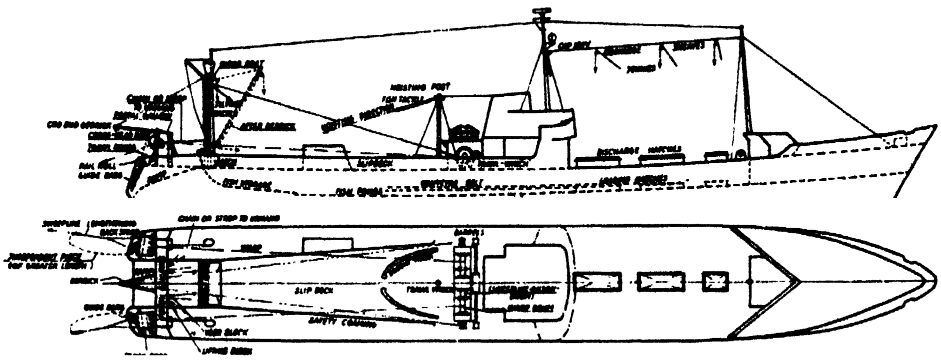


Fig. 99. Deck arrangement and leading of warps on stern trawlers with ramp

ramp as shown in fig. 99. By unloading the catch from the codend immediately below deck the fish ponds can be installed on the 'tweendeck in front of the gutting places.

A free deck space over the fish hold and uniformly distributed hatches are needed for unloading fresh fish; therefore the superstructure is restricted in size. A larger superstructure can be accommodated on a factory trawler because the frozen fish can be unloaded in containers through a central hatch.

Gallows type

A relatively simple solution was found for trawlers of conventional size and without a raised upper deck. Gallows based on the gallow-sheave principle were installed near the stern, turned aft, beside the ramp. The transom surfaces were bent inward to guide the otter boards to the stern with guide bars. Cross-head bows on the gallows heads assured a firm three-point position of the otter boards flush with the transom. Two rail rollers prevented the warps touching the bulwark when hoisting. In most cases, the gallows are single portal shaped—extending over the whole width of the vessel—with two fixed warp-sheaves (fig. 99). An alternative version of this system, which is adopted by one German company, is fitted with two movable warp-sheaves. In this case the transverse part of the gallow allows for a transverse shifting of the warp-sheaves during operation. When separate warps or special sweepline-gilsons, slightly elongated back strops and pennants (independent piece) adjusted to the ramp are used, the net can be handled over the stern without transverse or longitudinal movable warp-sheaves.

Other items

Another typical deck arrangement in these large stern trawlers is a hoisting post with the tackle for hoisting the

Advantages of stern trawlers with ramps

The cost of building such a stern trawler is about 10 to 15 per cent. higher than that of a comparable side trawler, but the stern trawler can fish longer, which might result in better annual returns.

Crews quickly adapt themselves to the stern trawler and its deck equipment, and the better working conditions are appreciated. The advantages of the stern trawler can be summarized as follows:

(1) Longer fishing time because there is

- No turn round for hauling and shooting. Ship need not be laid athwart to sea
- Generally free choice of the direction of hauling, independent of current and wind—a special advantage when fishing on steep banks

- Higher hauling speeds are possible than those obtained on side trawlers, because the warp pull is in line with the ship
- Mechanical hauling of the net by the trawl winch only, instead of pulling by hands as on side trawlers
- No necessity to split the codend
- No necessity to lift the codend, which is only tilted and emptied

(2) More successful fishing because there is

- Better manoeuvrability when hauling, shooting and towing as the warps leave the stern symmetrically without influencing the ship motions. Therefore fishing on steep banks, especially in heavy athwartship seas, is easier than on side trawlers
- The possibility of varying the length of towing warp to the different depths of sea without damaging the warps in the towing block
- No fouling of the gear when shooting as this is cleared into the water when the ship is under way and all parts are carried away by the flow in the proper sequence. Doors immediately start to sheer away
- No unequal elongation of trawl-warps due to the symmetrical arrangement of bollards (if any) and rollers. Therefore control and readjustment of length-marks on warps is not necessary.

(3) More careful handling of the catch due to

- Shorter death-struggle in the codend lengthening piece when splitting the catch because the codend is brought to the deck in one pull, this not being the case on side trawlers (experience proves that up to now the quality of the fish has apparently been better)
- Smoother unloading of the codend onto the gutting deck immediately after hauling (consequently earlier protection of the catch from heat, light and weather)
- The use of processing and stowing conveyor belts, thus reducing fish handling to a minimum

These points give considerably better quality fish than is the case with the conventional trawler. At the fish market in Bremerhaven only less than ½ per cent. of stern trawler catches have been unfit for sale, although mostly the ships had made longer trips.

(4) More careful handling of the fishing gear by

- Better guiding of lines
- Few changes in the direction of pull
- Avoiding uneven load on the warps
- Keeping the warps clear of the ship's hull

(5) Better working conditions for the crew by

- Saving the long, dangerous and heavy work in hauling the net
- Reducing the work of handling
- Having the ramp deck—especially the trawl winch—protected by the superstructure
- The working deck being completely enclosed
- Having the gutting room in the after part of the ship which is not so much affected by pitching as the foreship. The same applies for pitching at the ramp which is less than at the forward gallow of side trawlers

(6) Adverse weather effects reduced by

- Linear direction of hauling
- The net being handled only by the winch
- Having the ramp deck and the winch protected
- The working deck being completely protected

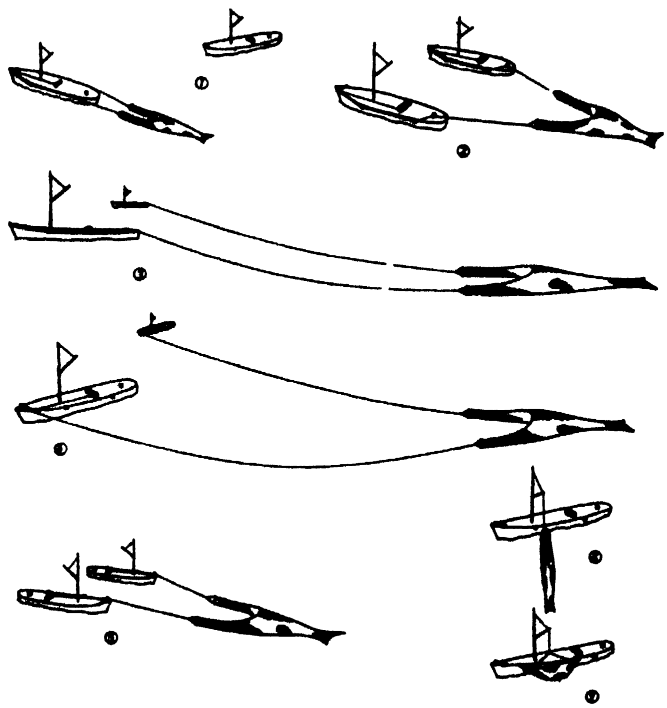


Fig. 100. Operation of two-boat trawlers

(7) Danger of icing up in "black frost" is lessened due to higher freeboard (on side trawlers water shipped on the open foredeck may not drain away, as freezing ports are frozen up).

(8) More space for processing machines and their arrangement in a continuous processing line (e.g. the effective long washing machine) is given by

- The long, completely enclosed working deck
- The location of the codend unloading hatch and the storing hold hatches at the opposite ends of the working deck

Drawbacks

There are only a few drawbacks against the above advantages

(1) Methods for dealing with very big catches or splitting them are still to be developed. Up to now

about 25 ton have been handled safely. However, further improvements seem possible.

(2) Codends and lengthening pieces must be made particularly strong by using expensive materials such as Perlon etc. Therefore the loss of a net is very expensive.

(3) Some difficulties arise by using the conventional herring trawl with the second kite. Only time and money is needed to solve this problem.

(4) First costs of stern trawlers are higher than those of side trawlers, the difference being bigger on small trawlers and diminishing with size. At a length of about 200 ft. (61 m.) LBP, the difference disappears.

(5) There is a loss of speed of about 5 per cent. because of the broad aft end of the ship with ramp.

completing the haul, to close without endangering the vessels, as shown in fig. 100.

Psychological reasons often hamper successful two-boat fishing, as captains and crews must be able to work in harmony. It is easier to find two equivalent boats, than to find two captains who can work in effective agreement.

Pareja trawler

The Pareja vessels operate a large trawl at slow speed. The boat requires an aft platform for the net and a special compartment for the lines. A snatch block hanging overboard is used on either side of the stern. In addition to the centre and wing bollards on the fore deck, the Pareja trawler has wing bollards on the bulwark behind the snatch blocks and the towing block amidship at the deck house. Although the net is shot over the stern, it is hauled over the bow, where there is another pair of rollers; on either side of the latter, modern vessels have in addition two protective rollers. Vessels with whale backs have yet other protective rollers at the rear end, as shown in fig. 101.

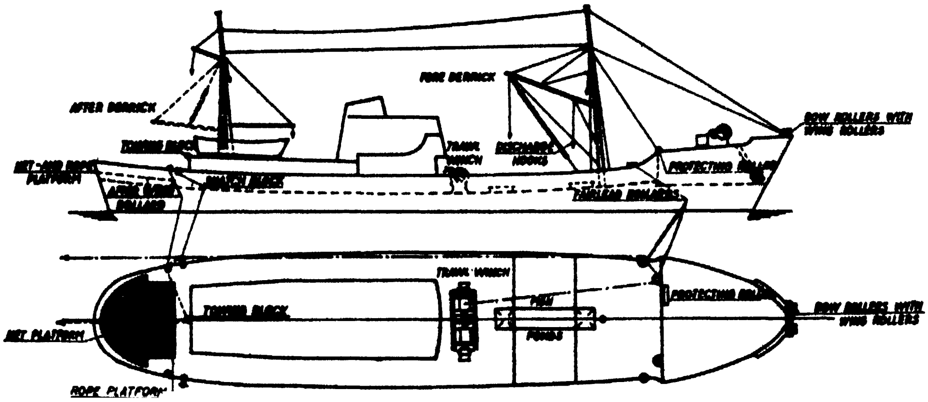


Fig. 101. Deck arrangement and leading of warps on Pareja trawlers with protecting rollers in the aft end the forecastle

The many more advantages indicate that the stern trawler may well have the greater future. The technical details given above only indicate present possibilities. In the distant future, stern trawling might be further developed to operate almost automatically.

BOTTOM TRAWLING WITH TWO BOATS

Two boats can be used to spread a trawl horizontally, as in the Spanish "Pareja", the Japanese "Teguri", the Italian "Paranzella", and the German "Tuckzeesen" fisheries.

Advantages and disadvantages

Two small vessels with low engine power are able to tow relatively large trawls, no otter boards being required. As vessels and warps are remote from the entering fish, the catches are larger — sometimes twice as large as those caught by the one-boat net; so it might be profitable to use two vessels with two crews. This applies in the Pareja fishery for vessels of up to 400 GT.

There are, however, disadvantages in trawling with two boats at night and in bad weather. It is often difficult to maintain a constant distance between the vessels and, in

The full codend is brailed until it can be hoisted by the fore derrick. The Pareja trawler cannot be used as a single trawler.

Teguri trawler

The Teguri trawlers are small boats operating in the East China Sea and the Yellow Sea. The engine room and deck house are aft, while the fish holds are arranged in the foreship. The shooting operation is carried out by the two boats but the net is hauled aboard over the stern of one boat. The warps are hauled by two drums on either side of the deckhouse and thereafter wound on reels behind the forecastle. The trawl winch is driven by the main or auxiliary engines through a countershaft. Most of the vessels shown in fig. 102 are 50 to 130 GT, of steel or wooden construction. Smaller boats of traditional type as shown in fig. 103 are also used. The average trip lasts three weeks and the crew numbers 12 or 13 men.

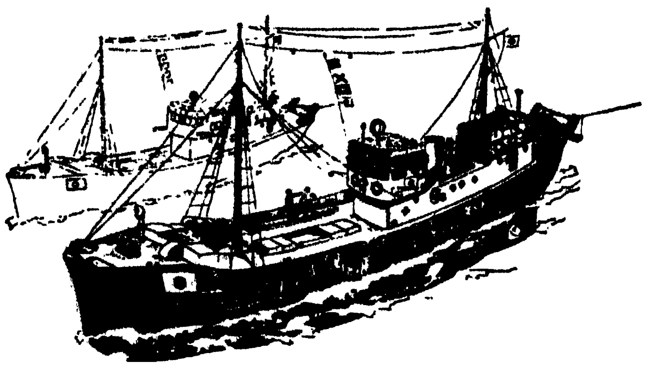


Fig. 102. Japanese Teguri steel or wooden two-boat trawler of 50 to 130 GT

Tuckzeesen trawler

The Tuckzeesen trawlers operate with equipment used in one-boat trawling. An inshore trawler or "trawl smack", well known in North European waters, is used, with deck equipment similar to that of the large side trawler. There are two small gallows but sometimes only one forward gallow with two rollers for two warps. The wheelhouse is placed aft and the net is only handled on the working deck forward of the wheelhouse. Trawl winch, guiding rollers, foremast and hatches are arranged as on large trawlers. Shooting and hauling is done by one boat, towing by both. The crew of the shooting boat has in some cases to be bigger due to this reason.

MIDWATER TRAWLER

While the trawl is considered the most important gear for catching fish on or close to the bottom, it can also be

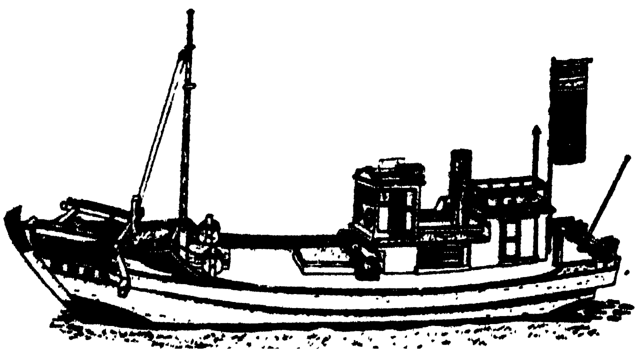


Fig. 103. Small Teguri trawler having a crew of 12 or 13 men

operated away from the bottom. But, until the invention of fish-detection instruments, it was not possible to ascertain the depth at which the fish were swimming. There are still problems to be solved before success in pelagic trawl fishing can be assured. In particular, there is a need to acquire biological knowledge of the behaviour of the fish, especially herring and similar species.

There is also a need for instruments to control continuously the depth of the net. Special equipment is wanted to transmit the data from the depth measuring device to the bridge. This might be wireless or by a cable from the net. If it is done by cable, then an additional cable drum or winch would have to be installed.

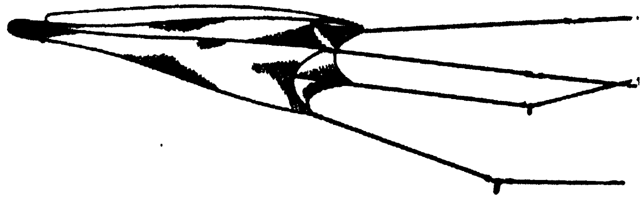


Fig 104. Danish two-boat pelagic trawl (Larsen type)

Two-boat type

As in two-boat bottom trawling, there is no frightening effect on the fish, and the trawling speed is sometimes greater. These advantages have contributed to the success of the Danish net shown in fig. 104, which was invented by Robert Larsen.

Two-boat fishing limits the size of the vessels, and operations are difficult in bad weather, from wind force Beaufort 4; and for larger vessels, 6.

One-boat type

Fishing with one vessel is less dependent on the weather. The disadvantages are that the lines of the net cross the

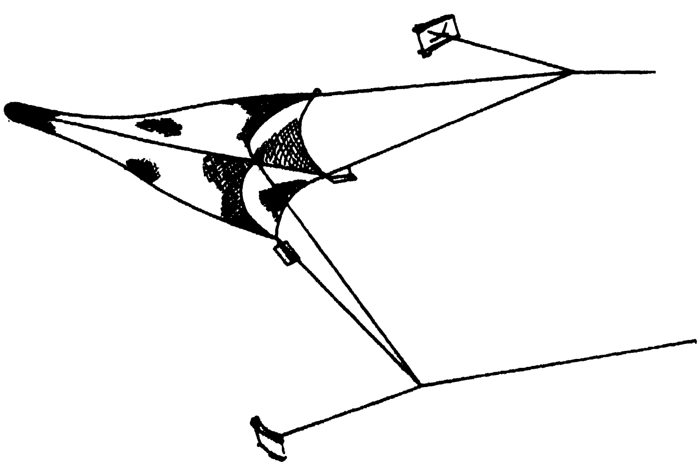


Fig. 105. One-boat pelagic trawl of British Columbia

fish shoal, and the otter boards may also cause disturbance. Moreover, if the vessel sails over the shoal the fish, if high in the water, may be frightened. These difficulties may explain why this kind of fishing has not been very successful until recently.

At least two types of pelagic one-boat trawls have become well known: the Canadian net, operated over the stern, as shown in fig. 105 and 106, and the Swedish net, designed by K. H. Larsson, operated over the side: the latter system is shown in fig. 107. The deck equipment is the same as used for bottom trawl nets. The codend of the Canadian trawl is opened at the side and brailed. This enables finer net material to be used but some additional deck equipment is necessary for brailing as shown in fig. 106.

Recently, indications from an echo sounder transducer placed on the headrope of pelagic trawls could be transmitted by cable to the echo sounder recorder in the wheelhouse. Because the depth of the trawl can be adjusted by altering the ship's speed, the depth can be adjusted to that of fish shoals, indicated by the ship's echo sounder. As a result of this technique very large catches were made by both small and large German trawlers.

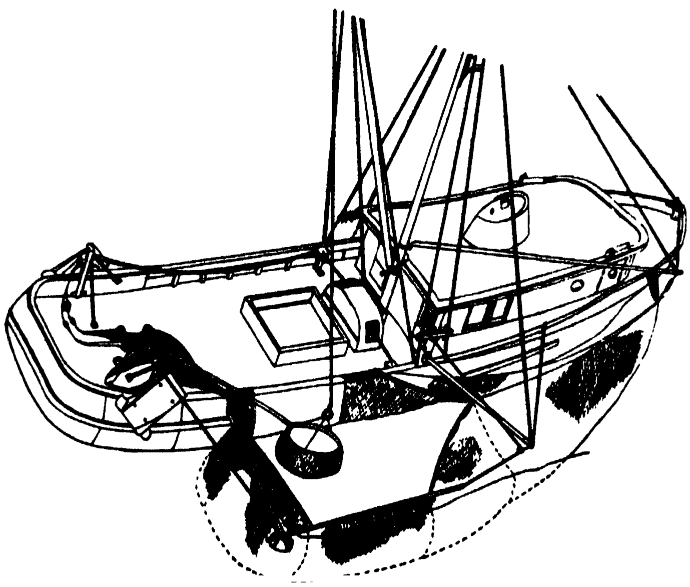


Fig. 106. Brailing of a Canadian pelagic trawl net (Barraclough and Johnson, 1955)

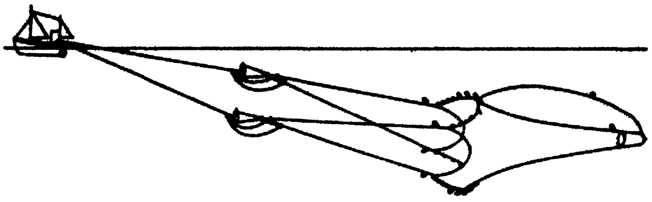


Fig. 107. Swedish one-boat pelagic trawl (Larsson type)

FUTURE PROSPECTS

Future deck arrangement and the method of handling the gear will depend to a large extent on trends in catching, handling, processing and transport of fish. There is a trend towards the larger trawler with more store room and greater engine power, but the limitations in fishing techniques and other factors tend to restrict this development.

The need to cut down travel time between port and fishing ground calls for vessels of improved design and/or with greater power. They must also be able to fish in rougher weather and thereby increase the fishing time.

The operational method of stern trawling permits building a vessel of approximately 300 ft. (90 m.) in length, which is larger than the present side trawlers, and suggests a development of the stern trawler towards a large combined fishing, transport and processing vessel.

The advantages of the existing stern trawlers with a ramp suggest the development of a smaller craft of this type, also with a ramp. Design studies and experience suggest that a vessel of 100 to 120 ft. (30 to 35 m.) in length may have a future. It might become a new type of "distant water trawler" without transport functions, seaworthy and efficient. A stern trawler of less than 100 ft. (30 m.) in length, with a wide net roller instead of a ramp, also seems to have a useful future.

CENTRALIZED CONTROL OF TRAWLERS

by

A. C. HARDY and H. E. H. PAIN

The appearance and interior of trawlers have altered much over the years, mainly due to the advent of mechanical propulsion, the application of model test results, and the development of navigation and fishing instruments and equipment. To accommodate the added apparatus and to give centralized control, the bridge has increased in size. It is becoming the nerve centre of the vessel. The paper describes this progress and explains the basic requirements for centralized control. A few examples of bridge layouts are given.

LES COMMANDES CENTRALISÉES A BORD DES CHALUTIERS

L'aspect et l'intérieur des chalutiers ont beaucoup changé au cours des années, surtout à la suite de l'avènement de la propulsion mécanique, de l'application des résultats d'essais de modèles et du développement des instruments et de l'équipement de navigation et de pêche. Pour loger les appareils ajoutés et centraliser les commandes, la passerelle a été agrandie. Elle devient le cerveau du navire. L'article décrit ce développement et expose les exigences fondamentales d'une centralisation des commandes. Les auteurs donnent quelques exemples de disposition de la passerelle.

CENTRALIZACION DE LOS MANDOS EN LOS ARRASTREROS

Con el transcurso de los años han cambiado mucho el aspecto y la distribución interior de los arrastreros, debido principalmente al advenimiento de la propulsión mecánica, la aplicación de los resultados de ensayos de modelos y el perfeccionamiento de los instrumentos y material de navegación y pesca. Para que albergase todos estos aparatos y centralizar los mandos del barco, se ha tenido que aumentar el tamaño del puente, que se ha convertido en el centro neurálgico de la embarcación. En la ponencia se describen estos adelantos y se las necesidades fundamentales para centralizar los mandos. Los autores dan algunos ejemplos de distribución de puentes.

THE trawler of today is an expensive and intricate piece of fishing mechanism. It is expensive largely because it is intricate, and it is intricate because of the devices and equipment it carries; yet no trawler carries anything other than of a severely utilitarian nature. Rapid advances in technology have affected the shape, altered the profile and improved the interior of the trawler.

In the profile, not the least important portion is the bridge. In fact, the bridge of today is the nerve centre from which every function of a trawler's operation—other than cooking—is controlled. In the 80's, the bridge was merely an open space above the engine room with a steering wheel, a compass, and a voice pipe to the engine room. The masts were still fitted in the same position they had occupied when the trawler was propelled by sails. Indeed, sails were often used in trawlers on the mainmast up to the outbreak of World War II.

Today from the bridge or nerve centre the speed and direction of the ship is controlled, the fish are detected, the trawl winch is operated and ship-shore communication is maintained. Instruments give the skipper exact information about his vessel's trim and stability, and the speed of the various machines, and he has a "broadcast" weather map showing the approach of bad weather, so that he can avoid it. Electronics now play an important part in the trawler's nerve centre, and automation is increasingly being adopted.

Instrumentation and automation have increased the size of the bridge and altered its appearance. The more or less open launch of the 1880's is developing into the totally enclosed ship of the 1980's.

Idea of centralized control

As more aids to control the trawler from the bridge come into use, they are installed at positions most convenient for the user and to meet many individual requirements, but in general the arrangement follows the same broad pattern.

Fig. 108 shows the general layout in plan and front elevation of a modern deep-water trawler's bridge, and it also illustrates the basic requirements in terms of functional instrumentation.

In aircraft, control is concentrated in the pilot's cockpit. Here the essential control requirements in terms of functional instrumentation have increased to the point where it is hardly possible to find space for a single extra instrument or information dial. Fig. 109 shows the cockpit in a modern commercial aircraft. All the information sources cannot be studied at once, nor do they need to be, but their grouping, logically placed with preference given to the most vital, is an excellent example of centralized control and information services.

Similarly, in ships, the grouping is basically universal: Centrally placed steering position, engine control telegraphs at each side of the bridge, duplicate steering control in certain classes of trawler, with winch and other controls conveniently positioned, together with radar and echo-sounding or fish-finding displays.

Fig. 108 shows the common information services and functional controls. The arrangement is wasteful of space and all units cannot be said to be conveniently placed to meet all situations. The illustration is a good example of conventional equipment. It will be noted that a gyro compass steering repeater is fitted.

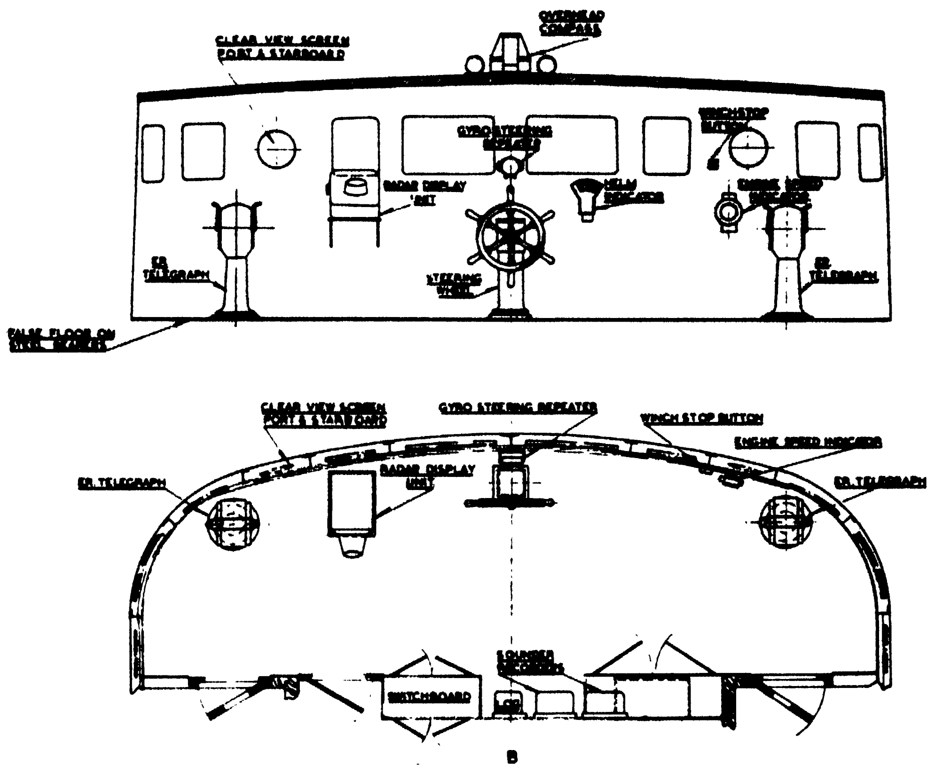


Fig. 108. Conventional wheelhouse of a modern middle-water or deep-sea trawler illustrating the basic information and control services

BASIC COMPONENTS FOR CENTRALIZED CONTROL

Hydraulic and electro-hydraulic steering engines are still the most suitable for large fishing vessels. In the interests of safety at least one magnetic compass must be carried in all types of vessel.

Gyroscopic auto steering

The electric gyroscopic north-seeking compass has been generally adopted in ocean-going vessels. Its advantages are the absence of errors due to variation and deviation, accuracy in polar latitudes and also reliability. Modern gyroscopic compasses are small and robust and present no siting problem. Compass information can be provided anywhere in the vessel by means of electric repeaters.

More than 30 years of use has proved the considerable fuel saving with automatic steering. In addition, steering engine wear is reduced and the human helmsman is released.

Most automatic steering systems using a gyroscopic compass as datum also have electric hand steering. Its reliability has also been proved. Very much less manual effort is required to steer, the course is more accurate, and fuel and time are saved.

It is of interest that a helmsman using the hitherto conventional telemotor steering control, but having a gyroscopic compass as course indicator, can maintain a more accurate course than he can with a magnetic compass. This particularly applies in heavy seas and high winds. Again there is a saving in fuel. A telemotor transmitter control can be replaced by electric steering control with complete safety and increased efficiency. As a safety precaution, the necessary wiring to the steering engine should be duplicated, as should also, and separately, the connection to the steering engine. With electric control, duplicate steering positions are simple additions; they can, of course, be remote from the bridge.

Hitherto, the conventional wheel has been almost

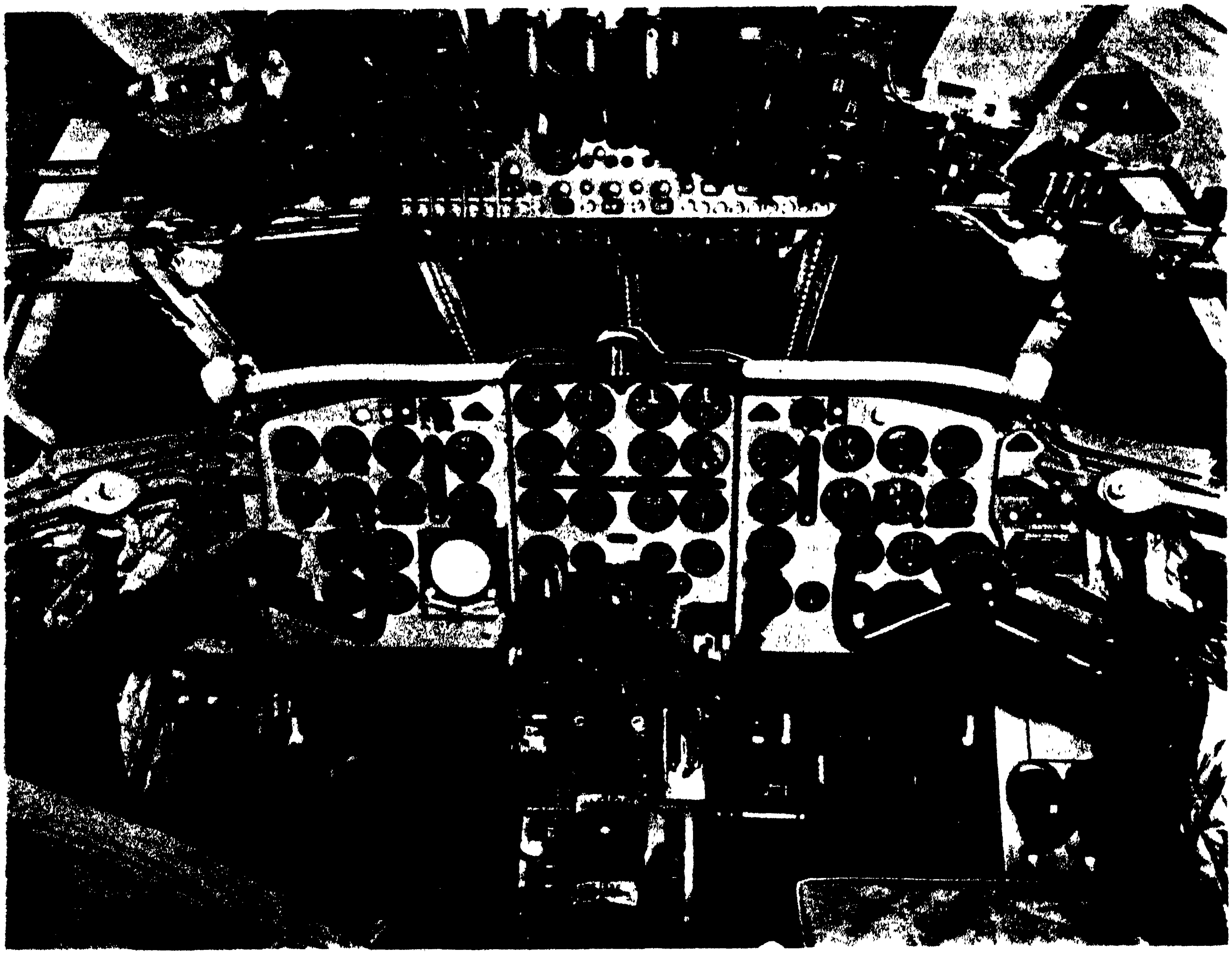


Fig. 109. Cockpit of a modern airliner illustrating centralization and concentration of information and control services

universally used to actuate the rudder. With electric control, a complete wheel is unnecessary and can even be omitted entirely.

Magnetic auto steering

A magnetic compass as datum can also be used for automatic steering. It cannot give as accurate a course, but is efficient and by comparison inexpensive. It is, in general, more suitable for the smaller vessels. Here also, remote control can be provided.

Magnetic compasses, with remote repeaters, are available and may have advantages in terms of cost, where the extreme accuracy and other services provided by a gyroscopic compass are not required.

The remote repeaters of transmitting compasses can give inputs to the radio direction finding indicator. With gyro input it is of evident advantage to read off true bearings.

Radar

In the latest development of radar, sometimes called "true motion", the gyro input has made it possible for the radar console to provide azimuth stabilized true motion display: off-centred relative motion display; true motion display using log speed input, and true motion display using manual speed input.

In effect, the officer-in-charge can be given a picture showing the positions, movements and tracks of all ships within range in true perspective to his own ship.

Rudder angle indicator

Many types of electric rudder angle indicators are available. With direct-acting electric steering control can readily be incorporated the rudder angle indicator.

Log

The most modern logs transmit information electrically and, as has been said, can supply one of the automatic inputs to "true motion" radar. Distance travelled can also be displayed.

Echo sounder

Many types are now available to meet two basic requirements—navigation and fish location. For accurate and speedy detection, and identification of fish, a combination of recorder and visual display, similar to the conventional radar presentation, represents a considerable advance. The recorder will give an indication of the presence of fish and a certain measure of quantitative information. For detailed examination the cathode-ray tube enables extremely accurate and rapid assessment to be made. An aural system can give notice that fish echoes have been detected.

r.p.m., and propeller-pitch, with provision to stop the engines, and also discontinue the automatic speed control to obtain full-engine revolutions when necessary. A second lever alters the relationship between pitch and power.

Further advances enable complete control to be exercised from a single lever. This regulates fuel supply and shaft speed, and at the same time controls pitch to meet any change in ship condition.

Such systems can also provide a second or "slave" control position in addition to that from the engine room.

Propeller-pitch and engine revolution indicators

These are ancillary to main engine controls and are positioned at the control position.

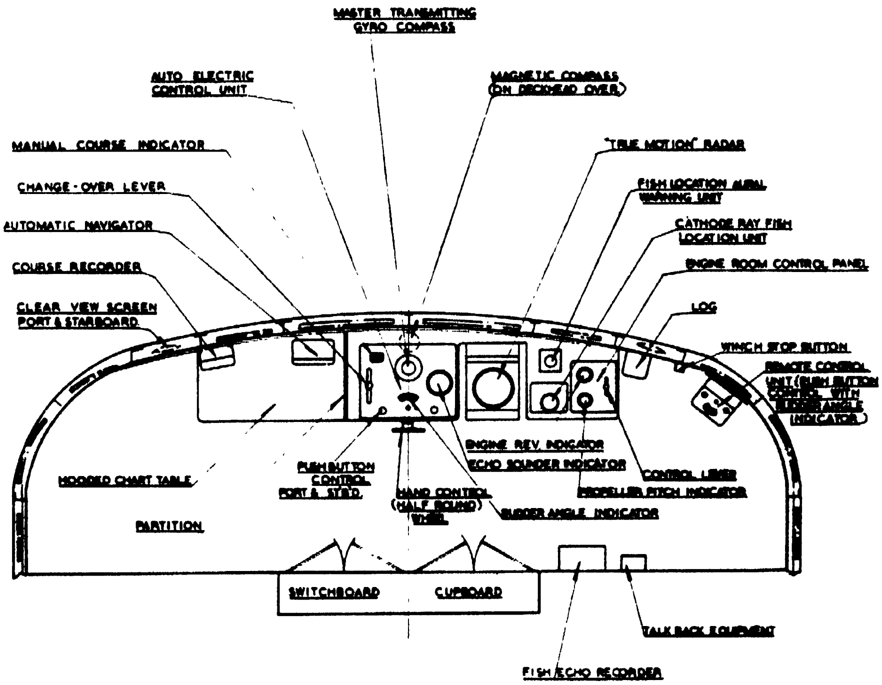


Fig. 110. Wheelhouse of a middle-water or deep-sea trawler illustrating a concept of centralized information and control services to provide maximum economy of space and manpower

As an ancillary to the fish detecting devices, which it must be remembered only indicate when fish have been found and not how to find them, it is required to know accurately the depth at which the trawl is towing. The trawl can then be adjusted to the known depth of fish.

Engine and propeller control

Where the main propulsion machinery is internal combustion or electrical and also where controllable-pitch propellers are used, complete remote control can be exercised from the wheelhouse as well as from the engine room. A single lever can select both engine

Engine room telegraph

The conventional engine room telegraph has been developed into indicating telegraphs and control levers which can be desk-mounted in juxtaposition with other controls.

Closed circuit television

For stern trawling, closed circuit television, to observe operations that would otherwise not be visible, may be considered. Provision can be made for its incorporation in any scheme of centralized control.

TYPICAL LAYOUTS OF CENTRALIZED CONTROL

Three main classes of fishing vessels are chosen as representatives of the vessels where centralized control would show the greatest saving in construction cost, top hamper, weight and operating expenditure:

- The "middle-distance" and "deep-water" trawler
- The fish factory trawler with or without stern trawl facilities
- The fish factory parent ship or other large vessel.

engine controls are at hand, as are also the winch button and log.

For normal control while on passage the information sources are placed around the main steering position. The master transmitting gyro compass is used as the steering repeater. An indicating echo-sounder unit is also placed where most easily seen when navigating in confined waters. The radar unit is placed to give maximum accessibility without in any way interfering with either of the two steering positions.

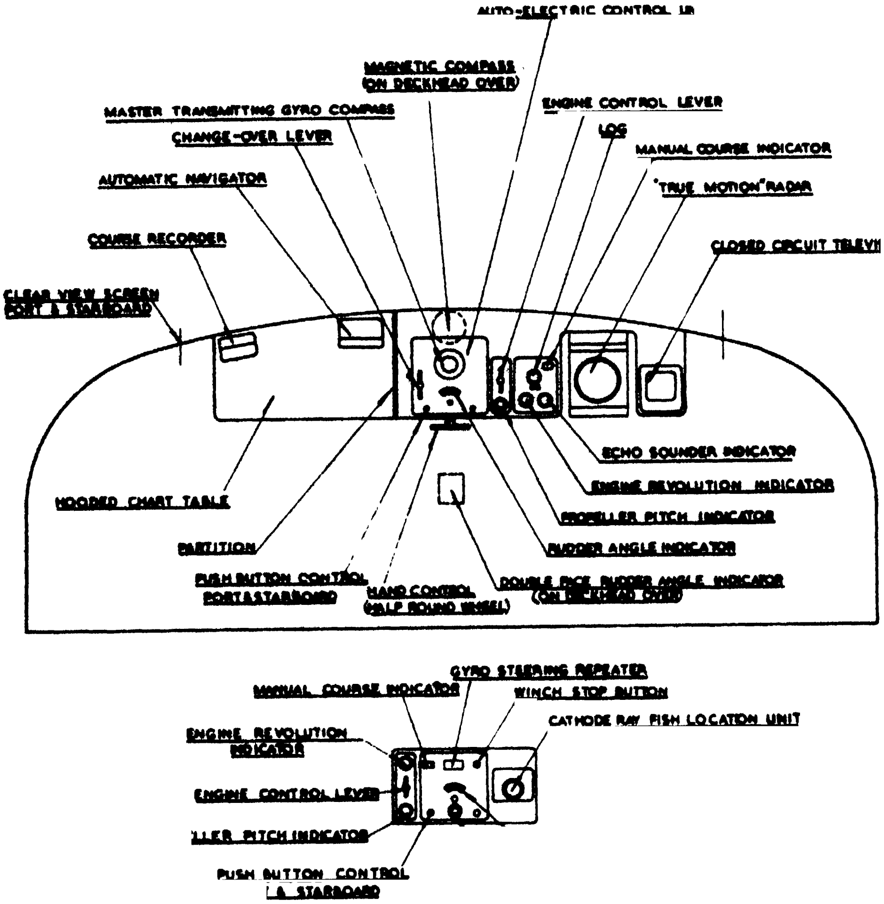


Fig. 111. Centralized command control in the wheelhouse (above) and remote control at the stern trawl position (below) in a fish factory trawler

Fig. 110 shows a centralized layout suitable for a middle-distance or deep-water trawler with starboard control of fishing. Although the vessel can remain in automatic steering, the "push-button" controls at the starboard wing can over-ride automatic steering and direct the vessel as necessary.

The "fish indicating" recorder, while not obstructing direct vision, can be kept under constant observation while the ancillary cathode-ray display unit is also immediately accessible. Engine room telegraphs or

Fish factory trawler

Fig. 111 illustrates a control layout applicable to the fish factory trawler with stern trawl and the stern control position. The starboard wing control position is not required. Provision is made for closed circuit television display to provide immediate visual information about operations astern.

A control console for the after position is shown. This includes push-button steering together with rudder angle indicator, main engine controls and a cathode-ray display for examination of fish echoes.

At both the wheelhouse and stern control positions, engine room telegraphs could be substituted for the main engine controls, if required.

Large vessel

Fig. 112 and 113 shows the centralized command concept for the largest type of vessel, including the fish factory and mother ship.

Two schemes are shown. Both include a deck-head mounted, double-faced rudder angle indicator, visible from anywhere in the wheelhouse or wings of the bridge. Both also show the reflector type magnetic steering compass.

engine room is considered more practicable in larger types of vessel.

This provides an opportunity to emphasize the safety factors incorporated where auto-electric control is used. If wiring and, separately, the connection to the main steering engine is duplicated, it is then possible to have hand electric control and automatic steering available through one set of connections with push-button control via the other set at standby.

Using auto-electric control, change-over to any of the three methods of steering can be accomplished in seconds. Further, the complete cycle of change-over is duplicated.

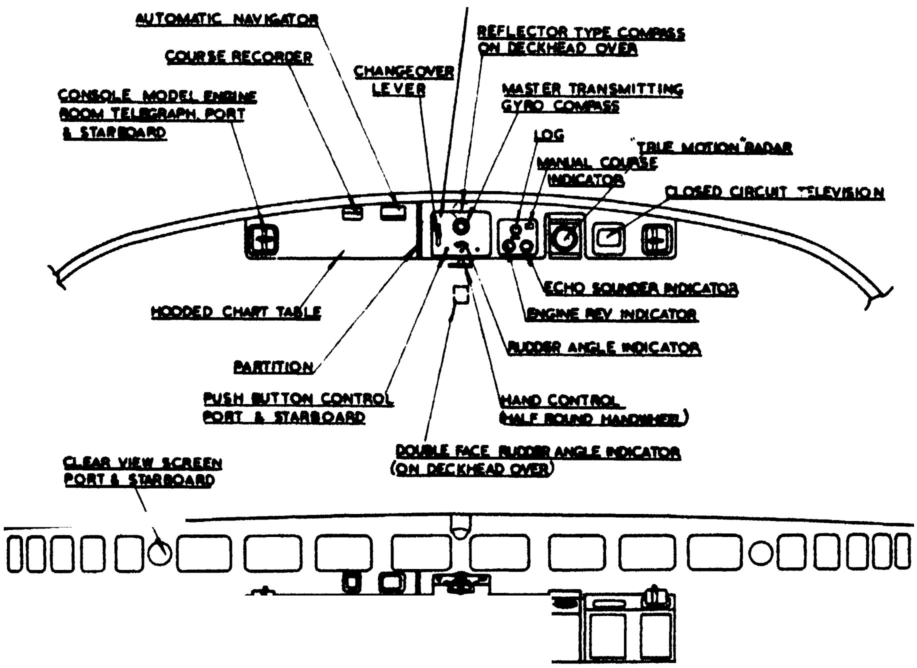


Fig. 112. Centralized control in a fish factory or large mother ship

Fig. 112 shows the main steering position embodied in central control. The command position is placed immediately to starboard with the engine revolution indicator, log and echo-sounder indicator conveniently displayed.

Fig. 113 shows the main steering to the rear of the central control. Although shown amidships, there is no technical reason why this main steering position should not be elsewhere in the wheelhouse if desired. Push-button steering is included in the main console. While in automatic steering, the officer-in-charge can take immediate over-riding steering control whenever required.

Control positions remote from the wheelhouse could be provided if necessary. Control of main engines is replaced by engine room telegraphs because at the present stage, control of main propulsion machinery from the

All these proposals of centralized control have the common feature of leaving much of the port side clear of obstructions. Larger ocean-going vessels have a trend towards combining the chartroom and wheelhouse. By careful attention to lighting and screening, the port side of the wheelhouse could be used as a chart table and for the automatic navigator, electric course recorder, weather map display or other instruments concerned in navigation. Where the size of the wheelhouse does not permit this, the space can still be used for a chart table.

Other instruments, particularly internal and radio telephones, could very easily be incorporated in the control consoles. Such units, as loudspeakers and switch boards could be sited conveniently on the after bulkhead.

The instruments illustrated are not comprehensive and are only representative of the many available.

The design of centralized control must be flexible and adaptable to meet individual requirements. Easy access to the various instruments is required for servicing and can be achieved by removable panels or components.

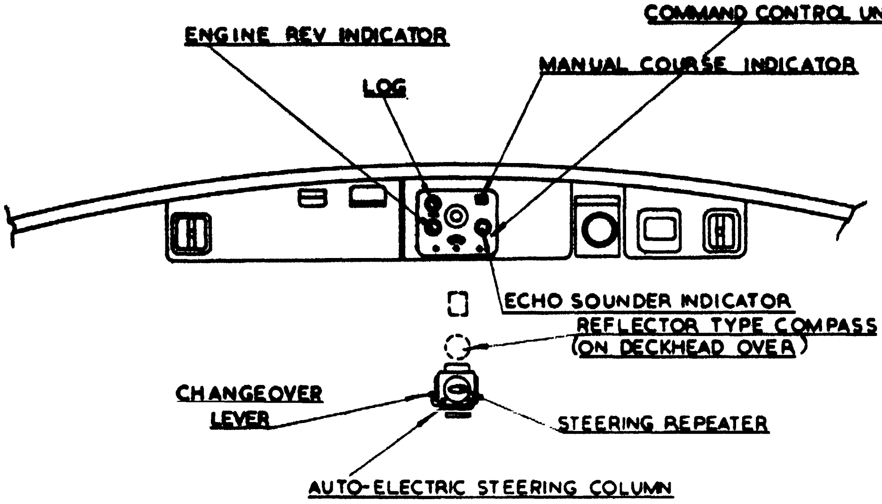


Fig. 113. Alternative arrangement to fig. 112 with separate steering position

Smaller vessels

A degree of centralized control can also be achieved, with resultant saving, in smaller classes of fishing vessel than those mentioned. For instance, the systems using a magnetic compass as datum and providing automatic, hand electric and remote control of steering as an addition to the normal system, are considered particularly useful in drifters, seiners and line fishing boats.

As well as the physical relief afforded by automatic steering, the remote steering facility can be particularly valuable in saving manpower, always provided due regard is paid to lookout.

Conclusions

All of the designs shown are entirely practical and are intended to show how to achieve greater efficiency and economy in control.

An early decision by the owner to take advantage of centralized control would enable the naval architect to prepare the most economical wheelhouse design leading to a change in the size and shape of the bridge and a saving in weight and cost. Installation problems would be modified and streamlined. An economy in manpower would be achieved with, at the same time, reduction in fatigue and increase in operating efficiency.

DESIGN OF TRAWLERS — DISCUSSION

Review of related papers

DR. J. SCHARFE (FAO, Rapporteur): Apart from von Brandt and Birkhoff's background paper, information on specific trawler deck design is given, for instance, by Ringhaver who describes the Gulf shrimp trawler in Florida. The forward position of the deckhouse of these boats is said to go back to the old times of hand hauling the gear. The ample working space aft although very welcome is not essential for the power handling of the gear. Instructive drawings are given, illustrating the recent radical change from the conventional one-net to the modern two-net method which demanded a considerable change of the rig. The new method for which two 40 ft. (12 m.) otter trawls are towed simultaneously from strong outriggers, as many other subjects to be mentioned later have also been described from the gear point of view in *Modern Fishing Gear of the World* (Kristjonsson, 1959). The operation can be taken as rather well mechanized. A similar two-trawl method of shrimp trawling is common in the Netherlands and Germany with the difference that beam trawls, instead of otter trawls, are used. A sketch of the rigging of such a boat is given by Boogaard (fig. 695 and 696). It may be mentioned that considerable risk can be attached to such outrigger trawling in case one of the trawls gets caught at the bottom. When towing with a strong tide, only a very quick action, namely releasing the respective warp, can prevent the boat capsizing. An automatic device for effecting this release in proper correlation with the pull of the remaining warp would be a great help.

Boogaard also touches the question of winch drive by giving details of construction, performance and wire capacity of the trawl winches of four conventional types of Dutch craft. The smaller boats have belt drive from the main engine. The bigger trawler-drifters use an auxiliary diesel of 100 h.p. and the still bigger trawlers of 132 ft. (40.25 m.) LOA have hydraulic drive.

The pro and contra of electric and hydraulic winch drive for big deep sea trawlers is discussed by Stokke (p. 26). The somewhat smaller efficiency of the hydraulic drive is said to be compensated by its smaller size, which not only can save engine room space but also allows for direct attachment of the oil motor to the winch. The considerable space otherwise needed for the winch motor can be used, for instance, for crews' accommodation. This is an advantage particularly for smaller craft.

Hauling trials described by Dickson provide information on the relation of hauling speed and power output of the winch at different warp loads for two typical U.K. trawlers. Dickson furthermore stresses the need for considering the stability when converting for instance Danish seiners into trawlers. The well known stiffness of the Swedish motor cutters enables them even to tow with both warps at the top of the aft gallows. They, therefore, need no sliphook and avoid the working of the warps in the sliphook which Dickson mentioned as result of too short a distance between aft gallow and towing block. More tender boats might come in a dangerous position when heaving with conventional equipment broadside in bad weather and a strong tide with the gear caught at the bottom.

Seakindliness has a bearing on the present subject in so far as it affects the working conditions on deck. Möckel collected data of the metacentric height (GM) of five commercial trawlers. He found that a GM between 2.3 and 2.6 ft. (0.7 and 0.8 m.) is a reasonable compromise for those vessels and is most agreeable for the crew. Lower values give the feeling of insecurity. High values result in too much stiffness. In both cases, particularly in the latter one, the vessel ships much water in bad weather interfering with the ability and safety of the crew working on deck. Such vessels consequently have to stop fishing earlier. Zwolsman states the average metacentric height for modern standard Dutch fishing boats of about 72 ft. (22 m.) LOA to be 2.56 ft. (0.78 m.) fully equipped but without ice. The crew are said to consider these boats as very seakindly.

Besides the operation of the gear, often a greater part of the crew's work on deck is devoted to the care of the catch. Reay and Shewan (p. 200) point out that the fish quality and the time it can be kept in good condition on ice, depends very much on the time which elapses before it can be cooled down. The process of gutting, cleaning and stowing should, therefore, be accelerated as much as possible. Mechanical washing machines and chutes to direct the fish into the fishroom have already considerably contributed to diminish delays. But there is still a wide field for improved mechanization of fish handling on the conventional trawlers with respective changes and additions in the deck designs.

De Wit states that herring drift-netting in the North Sea is declining. Consequently in Holland drifters often are replaced by small trawlers. Existing drifters with sufficient engine power are fitted with gallows and trawl winch to serve as combined drifter-trawlers and also new combination vessels have been designed. In Germany the same tendency can be observed. Until now these combined vessels trawl over the side which still is the most common method in northern European countries. De Wit now proposes a revolutionary design combining stern trawling with a stern chute with drift-netting from a sheltered 'tween deck.

This leads to the most recent development, namely stern trawling, particularly with a stern chute. The conversion from side trawling to stern trawling with a stern chute has strongly affected the traditional deck design and brought forward a good deal of new ideas and improvements in favour of the so badly wanted mechanization of trawl operation. Heinsohn gives a comprehensive description of the three German stern trawlers in operation to date, comparing and discussing also their different deck design and equipment. Ordinary trawl winches should serve the purpose but for convenience an additional pair of drums or capstans have been installed in two vessels. Electric drive, installed in two boats, seems to have advantages over hydraulic drive because of its better flexibility and the easier possibility of using the winch generator as additional propulsion power. A long distance between the winch and the upper edge of the stern chute is advantageous for hauling in the about 183 ft. (56 m.) long net with the catch. The distance should not be less than about 70 ft. (21 m.). On *Heinrich Meins* it is even 97 ft. (30 m.). So with two additional pulls the catch can be brought on deck. For the last pull for heaving the loaded codend, now a tackle is used in line with the slope of the stern chute. This eases the pressure and wear on the codend and lengthening piece. With nylon codends having special strengthening, more than 25 tons are said to have safely been brought on deck in a single operation. This means a considerable saving in time compared with the splitting of the catch of side trawlers. The average time taken on a commercial trip of *Sagitta* was 24 min. for the otter boards to be out of the water. Of this time 14 min. were spent in average for net repair and removing gilled fish and only 10 min. for clipping and unclipping the otter boards, hauling the trawl on deck, emptying the codend and shooting again. The crew is released from all heavy work such as hauling in the net and it works well protected and in safety. The fish is gutted or further processed under deck, washed by a machine and carried to the hold by means of conveyor belts. This most promising development should most carefully be considered for application to different fishing conditions. It seems well suited to solve quite a few trawling problems. A standard deck design, as, for instance, is found in side trawling, has not been established yet so that exchange of practical experiences with the different systems would be most fruitful. Ease and speed of operation is one of the main points of this method. There are, however, some doubts regarding the quality of the fish hauled in a big bulk, which should be discussed.

One aspect of the ideas on centralized control of trawlers put forward by Hardy (p. 114) might shortly be mentioned already now. It regards full winch control from the bridge which at the moment is still wishful thinking. A partly control, namely the release of the warps from the bridge in case of the gear being caught at the bottom, has been installed for instance in some new German vessels. But there are strong points in regard to efficiency, labour saving and safety which make a full central winch control during the whole gear operation desirable. This is a problem worthwhile to be taken up by marine engineers. The present trawl winches might not be suitable for such central control. So new designs, eventually with separate drive systems for the warp drums and capstans and suitable brakes, could easily lead to a complete change of winch arrangement and warp conduct and consequently to a thorough redesign of the deck equipment of certain trawler types in favour of improved mechanization.

Professor A. von Brandt (Germany): The importance of trawling is underlined in Hardy's first paper. For the North-western part of Europe, for instance, the trawl is the most important gear for harvesting the sea. Trawling as we know it now, however, is a comparatively new method and there are still old skippers who have participated in it from its beginning.

It is not surprising that, for instance in Europe and East Asia, very old types of trawling gear are being used side by side with the most progressive gear from one and the same port; there are beam trawls and otter trawls, and there are bottom trawls and floating trawls.

Trawling is made from a very wide range of sizes and types of craft; there are small sailing boats and high-powered trawlers, there are inshore and deep sea vessels, and the towing speed might vary between 0.5 and 5 knots.

There, naturally, is a close correlation between the type of the gear and the type and equipment of the boat; the gear influences the boat and the boat might eventually influence the gear. The introduction of power propulsion was indispensable for the development of modern trawling. The exploitation of the deep sea required bigger and bigger craft, these, on the other hand, allowed for bigger gear.

This shows that, *first*, boat and power must be a sound unit: this is underlined by the several contributions dealing with propulsion problems. The solution is important not only for the big trawlers but perhaps even more for the small ones which usually are treated as less interesting for rational approach, and, therefore, are almost forgotten.

There must *secondly* be a close correlation between the boat and power unit on one hand and the fishing gear on the other hand. Coming from a Gear Research Institute, Professor von Brandt felt quite clearly the wide gap between the present state and the effective solution aimed at. A great deal of improvement is needed before the powered boat together with the gear will become a very efficient unit, and this demands efforts from the naval architects, the fishermen and the gear technologists working in close collaboration.

Until now, only technical matters have been mentioned, i.e. the boat, the power and the gear, which should be a proper unit. But besides this there is a further very important point which has to be taken into consideration: the crew. There are model tests with boats and with gear, but until now the fishermen seem to have been neglected. In this respect he was not thinking of better accommodations for living and sleeping on board or safety at sea. A lot has recently been done in this field in different countries. He was thinking of working physiology.

If a farmer's wife wants a new kitchen, she can rely on extensive studies concerned with the right placing of table, water tap, and even to avoid unnecessary steps. If a farmer needs a new spade, lots of tests have been made about the best shape and length of the handle to obtain highest efficiency. But looking at a trawler's crew working, it is quite obvious that nobody has ever seriously cared how their operation could be improved. There is a wide field for extensive time and motion studies, on proper deck design and equipment and its optimal placing. Until now it obviously made not much difference to the designer if a basket had to be lifted 3 ft. (1 m.) high or only 1½ ft. (½m.) or if it had to be used at all. The fishery is in this respect in the same position as all industry with the difference that on land this demand has long been realized. In the fisheries of highly developed countries with a high standard of living and the consequently growing difficulties to find trawler crews for the difficult job of handling the gear to a great extent with their own hands, the demand for rational mechanization becomes more and more pressing.

Fortunately there is now a promising indication that the trawl fishery gradually becomes conscious of this need. The development of the big Northern European stern trawlers, for instance, is one first and very important step in this direction. It is to be hoped that the great interest caused by this development will stimulate similar efforts in other trawl fisheries too.

Mr. J. Proskie (Canada): Since the trawl has been specifically developed for groundfishing (all species except halibut) the impact of this type of gear on total catches of groundfish shows some interesting results for the Canadian Atlantic coast.

An estimate of contribution to total landings of groundfish in 1957 by trawlers was as follows:

Percentage contribution to total groundfish landings
By trawlers under 70 ft. (21.4 m.) LOA—12 per cent.
By trawlers over 90 ft. (27.4 m.) LOA—30 per cent.

The small trawlers were developed under the fleet modernization programme for the Atlantic coast and are fishermen owned. The large trawlers for the most part are company owned.

Brandt and Birkhoff in their paper also suggest the development of stern trawlers of less than 100 ft. (30.5 m.). Three such craft were developed on the Atlantic coast by the Department of Fisheries of Prince Edward Island. These trawlers were 50 ft. (15.2 m.) LOA powered by a 76 h.p. diesel engine. Although these craft proved to be suitable for scallop dragging, they were found to be unsuitable for groundfish fishing for the time being.

Stern handling versus side handling

MR. H. R. BARDARSON (Iceland): Stern trawling is a remarkable new development from the usual side trawling. However, this new type of handling the gear seems to have more advantages when adopted on big factory ships than on the small sea-going trawlers of 600 to 850 GT. Icelandic trawlers come almost entirely within these tonnage limits and none of them trawl over the stern. In Iceland, they have up to now no experience with stern trawlers, but they have been considering very carefully whether this type of ship would be a step forward for their trawling industry.

Iceland is not basing the fishing industry on factory ships, as there are freezing plants on land all around the coast, and the task of the fishing vessels is to bring first rate fresh fish to the harbours. The freezing plants are much closer to the fishing grounds than in many other countries. The big type of factory trawler with freezing plant on board is very expensive, not the least owing to the large crew it must carry. Although mechanization can be used on board for preparing the catch and freezing, the crew have to be paid all the time they are on board, whereas on land workers are only paid for actual working hours. Owing to the difficult crew situation in Iceland at present, with a need for more fishermen, the factory ship would be a big problem to solve.

The question is then whether the stern trawler would still have many advantages over other types of trawlers in the size group of 600 to 850 GT for iced or cooled fish only. He felt that the crew would have better working space and the bigger freeboard might also result in less icing. These are important advantages.

The motions on the aft end of a vessel are not so comfortable as in the midship region. He considered that it would be possible to fish in worse weather with the conventional ships rather than with the new ones, considering the size of ship. Iceland is following with interest the results of the first stern trawlers. It had been said that stern trawling still results in difficulties in handling a completely filled codend, as the whole net is hauled at once. He had also heard that this has caused damage to fish in the lower part of the net through pressure when the net is hauled up the ramp.

Although stern trawlers are very interesting, he felt that some alterations would be necessary for Icelandic conditions, and he considered this type of trawler to be still in the experimental stage.

MR. A. HUNTER (U.K.): The characteristics of modern side fishing trawlers permit high economical speed and provide a safe platform for fishing in bad weather up to force 7/8 on the Beaufort scale. More knowlege of the reaction of a trawler form to varying sea energy spectra and the best routing based on more use of weather prediction may enable quicker voyages to be made. This is important from the aspect of fuel costs where the fisheries are remote. Stern trawling must nevertheless always attract the attention of owners and builders. Were such vessels comparable in resistance? Model experiments carried out with a good trawler speed form modified for a stern ramp showed that with the lower portion of the ramp immersed the resistance increased by 20 per cent. On this basis 20 per cent. more fuel would be consumed. If fish processing were done on board speed was of less consequence, but generally larger ships were involved. In Britain it had been stated that factory ships of the *Fairtry* type caught in one year about the equivalent of two orthodox trawlers, while the cost was said to be as much as that of three or four orthodox trawlers. In these ships commercial considerations could not ignore the sociological effect on larger crews required to spend considerably more time at sea, often in bad weather conditions. There may therefore be a place in the fishing economy for the normal size of trawler bulk freezing part of the catch at sea. This did not mean that builders were opposed to stern trawling and they would always undertake the construction of vessels which owners considered best for their purpose.

MR. J. C. E. CARDOSO (Portugal): Although no big stern trawlers are at present operating in Portugal, he believed that stern trawling has great possibilities and shows advantages over the traditional method. It is, however, difficult to convince fishermen to take up a new fishing method. At present the Government is building a research ship of 190 ft. (58 m.) length which will be equipped for stern trawling. This vessel should serve the purpose of convincing owners and fishermen of the advantages to be derived from the adoption of stern trawling.

MR. J. G. DE WIT (Netherlands): Stern trawling results in an arrangement in which the crew's quarters are in the forward part of the vessel. This is of no advantage to the crew. All new vessels in the Netherlands have crew quarters aft. He would ask as to what the advocates of stern trawling have to say about this question.

SIR FRED PARKES (U.K.) felt that German trawler owners did not favour stern trawling for their normal size vessels, a method which seemed to be of advantage mainly for large vessels.

Distant water trawlers were very costly, about £300,000 ($840,000) apiece. One should strive to evolve a vessel that brought fish to port in larger quantity and in good quality at lower costs. His company had ordered six small vessels of 100 ft. (30.5 m.) length, with controllable-pitch propellers. This was a new venture for home water fishing.

MR. H. HEINSOHN (Germany) said that his company was designing stern trawlers of the size of ordinary side trawlers, and three had already been operating successfully for two to three years. Although there was at the moment still a wide field for improvement, because stern trawling with deep sea trawlers was a new venture, the evidence offered by practical operation should not be ignored and should have more weight than theoretical conclusions.

For example, the quality of the catch was doubted because of the big pressure in the codend. However, landing statistics and reports from fish merchants showed definitely that this was *not* the case. On the contrary, there were indications that the average quality was better, especially on long trips. One of the reasons might be that the fully packed codend is lifted on board quickly, and there is a shorter death struggle than with side trawling when the bag has to be split when a large catch is made. The fact that the fish before gutting are stowed below deck and protected from the light may also mean improved quality, as well as the mechanical handling, washing and quick transport to the holds after gutting.

It has been said that stern trawling, especially in smaller vessels, was impossible in bad weather and that a stern ramp would only be suitable on big factory vessels. Here actual experience, too, proved this statement to be wrong. The stern ramp should follow the movement of the waves as closely as possible, which seems more likely to happen with smaller vessels provided the most suitable course during hauling and shooting operations is maintained (i.e. with the sea, or with the sea on the beam) so as to avoid heavy pitching. Stern trawlers are able to fish longer in bad weather than side trawlers because the crew is in safe and dry positions to operate the gear. In respect of icing up, experience has shown better performance with stern trawlers due to shipping less spray and water because of the higher freeboard than with side trawlers where the freeing ports and the trawl winches ice up. Regarding seaworthiness, the stern trawler is as good, and perhaps even better, than a side trawler of the same size.

What happens when the codend is completely full? This is still a problem, which probably arises only once a year. A catch of 25 tons has been brought on deck safely in severe weather conditions without creating undue problems, and it should be borne in mind that for 60 years fishermen have constantly been improving details of the gear of side trawlers. Stern trawlers at present operate with side trawling gear, but it is likely that this is not a good proposition. Stern trawlers should have their own gear which fishermen should start improving.

Greiss (owner of a stern trawler) found that in the rare cases when the net was full, the fore part had to be cut to release the weight, and if the net was on the deck, to get the catch out more easily.

Hunter has said that transom stern trawlers have 20 per cent. higher resistance. Model tests, which have been made with stern trawlers, have been very encouraging and the resistance is found to be just slightly more than for ordinary side trawlers of the same size. The reason for Hunter's statement may be that a type of transom stern was used which was too deeply immersed in water and therefore not advantageous at the speeds at which these ships operate. A cruiser stern would probably be slightly better but would never result in a 20 per cent. difference.

MR. G. S. MILNE (U.K.) agreed with Heinsohn that a stern trawler need not show much extra resistance over the traditional cruiser stern trawlers. He felt however, that the principle did not show to advantage for vessels below 180 ft. (55 m.) LBP operating in North Atlantic waters.

MR. G. C. EDDIE (U.K.) suggested that the reason for any apparent difference in the quality of fish between stern trawling and side trawling is that stern trawlers are distant water trawlers making long voyages. The dominant factors are time and temperature; other factors, like the length of the death struggle and high pressure for a few minutes, were not important in this type of ship but might be of more importance in the smaller stern trawlers which have been suggested for the North-East Pacific.

MR. F. MINOT (U.S.A.) believed that stern trawlers would develop greatly in the future and would prove their exceptional seaworthiness. The question of the difference in resistance between a stern trawler and a cruiser stern side trawler did not seem to be due to the stern shape but rather to the ramp.

MR. E. C. GOLDSWORTHY (U.K.) said that fish brought by stern trawlers could easily be more than eight days old. Fish meal would be the result unless distant fishing were done by factory ships. Recent developments had shown that side trawling was on the way out, and fishermen still being suspicious of the new method should be invited to come on board stern trawlers, to see for themselves that these vessels were as good as the side trawlers. Stern trawling most certainly safeguarded the fisherman and made his life more comfortable. For these reasons alone it seemed inevitable that stern trawling would be the method of the future. The problem of pitching and heaving referred to by other participants should be easy to deal with.

MR. V. ESTEVE (Spain): It is no easy matter to decide which trawling method is best as regards ease of net handling, volume of catch and quality of fish. In Spain, all fishermen on the northern coast without exception trawl over the side of their ships, while most of those on the eastern coast trawl over the stern. The catch by either method is about the same and so is the quality of the fish. The boats from which trawling is done over the side normally have gallows on either side. Those using the stern trawling system have large-diameter net rollers, a guide rollers or gallows depending on the shipmaster. Both types of ship use the same sort of winch.

MR. L. SOUBLIN (France): His opinion was that the stern trawler factory ship is satisfactory from the technical standpoint, but that the principle is open to question.

There is no reason to fear that the fish caught by stern trawlers is inferior in quality to that obtained by side trawling. On the contrary, the filleting and freezing of fish that have just been caught result in a high quality product. The trawl can be hauled in rapidly and efficiently in one operation. Trawling in bad weather is made much easier. The crew working on the lower deck is well protected in very comfortable conditions.

These points, and many others, indicate that the stern factory trawlers are highly satisfactory from the technical standpoint. Nevertheless, they have three important requirements with regard to:

- Weight (winch and various gear on the upper deck)
- Length (82 ft. or 25 m. clearance are required between the winch and the aftermost hatchway; hence at least 100 ft. or 30 m. between the winch and the after end of the ramp)
- Beam (because the deck admiships must be cleared for shooting the trawl, it is necessary to provide for additional fish ponds on each side to store fish temporarily)

These three requirements necessitate very large trawlers. Thus, stern trawling must be associated with very large factory trawlers. This very principle, he found, was open to

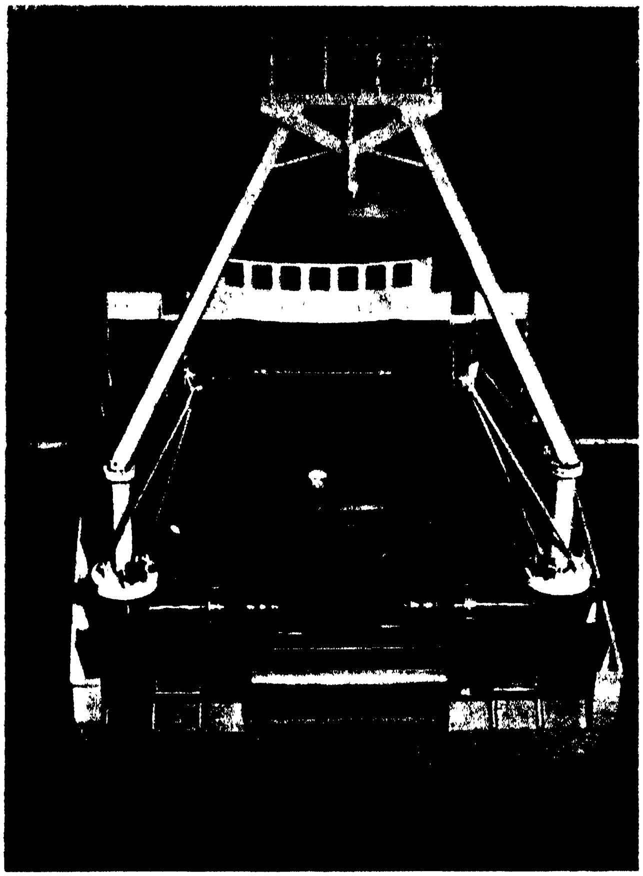


Fig. 114. Proposed stern trawling arrangement without ramp

question because some national fish markets cannot accept the large production from this type of ship.

The stocks in the sea are not inexhaustible; for some species, they seem to be already decreasing. There is moreover real depletion, such as, for instance, the inordinate catching—which should be frankly denounced and courageously discussed—of one- and two-year-old herrings in some coastal areas of the North Sea, which constitutes a veritable *genocide*. He feared that these large trawlers, in view of the need to fill their holds, will gradually go in for overfishing and thus contribute toward the progressive depletion of the resources of the sea. In this sense one can say that this type of ship, which is very satisfactory from the technical standpoint, is a design the principle behind which is open to question.

MR. F. DORVILLE (France): Deep-sea trawlers are developing very rapidly and will in all probability evolve into self-contained factory ships. Important progress has been made with regard to hull construction, speed, and crew comfort. Electronic devices are increasingly used. Yet, on the other hand, means of handling the gear and the catch have changed but little over the past years. Means of hoisting the net are still missing on trawlers of the classical type. The present system, consisting of mast, derrick and fishing winch, cannot be considered as an efficient solution, in spite of the skilful use made of it by the fishermen. On new factory ships, derricks and winches have become more and more numerous, bringing about a real complication of gear.

Fishing methods have been widely tested over a very long period, during which the basic principles underlying the methods have withstood any attempt at modification. This must not apply also for the future, especially in the case of the trawl, which, in spite of all recent improvements, must always be kept alongside the ship, borne by its own buoyancy, and emptied into the fish ponds on the deck to prevent damage.

With the above ideas in mind, Mr. Dorville's firm, in association with fishing experts and with one well known winch maker, has developed a new way of operating the trawl from the stern of a large trawler by centralizing the mechanism for the gear operation at the aft end of the ship, though keeping the method of lifting the net now used in side fishing (fig. 114).

The new stern trawling unit consists of a shroudless bipod mast and two symmetrically arranged groups of mechanism for shooting, controlling and handling the trawl. Each group consists of a revolving crane with 3 ton and 16 ft. (4.5 m.) range, and an electric fishing winch with brake and warp-guiding gear. Two separate motors and control gears are provided for the operation of the associated winches and cranes. Elimination of the gallows system, with the warping fairleads and bollards, allows the warp to have direct way. A watertight steel folding flush hatch tightly covers the hatch space under the mast. It is fitted in a frame and forms a hinged ramp enabling the fish to slide easily and quickly to the 'tween-decks.

Trawling operations are performed as follows:

Shooting.—The codend is picked up by one of the two revolving cranes, pulled back, lowered astern and dropped in the ship's wake. By its resistance in the water it pulls the whole trawl over the transverse roller on the bulwark into the water. After the bridles have been paid out from the winches the veering is stopped for unhooking the otter boards. Then the necessary amount of warps is paid out, the winches are braked, and trawling starts.

Hauling.—The warps are hauled in on the drums of the two winches, then the otter boards are hooked up, disengaged from warps and bridles, and the bridles hauled in the conventional way until the wings appear. The ends of the foot rope are then seized by one crane each, and in one single operation by both cranes the whole trawl mouth is first raised and then lowered on to the deck at the aft end of the ship. The codend is then attached in the customary way and lifted by one crane, either over the stern if the catch is normal, or over the sheltered side of the ship if the catch is large, and is discharged into the hold by hauling over the hatch cover ramp. Thus the codend is hoisted directly from the sea and brought over the movable ramp without contacting either the hull or the deck, thus avoiding any damage to the fish or nets.

The design of this stern trawling unit allows valuable deck space to be gained, owing to concentration of the gears aft, which enables the crew to work with increased safety on the whole deck area. The output increases, although there is a reduction in the number of the crew, and the whole operation is accelerated. All operations are mechanically controlled from the bridge.

Due to growing difficulties to find qualified crews for the very hard job of handling the gear on side fishing trawlers, the demand for rational mechanization is becoming more and more urgent. The answer to this fundamental problem might be this stern trawling unit with a remote control equipment.

DR. J. SCHARFE (FAO): Dorville's statement that there is no progress in trawl hauling is not quite justified. Besides some small improvements on conventional side trawlers, as, for instance, the "bang up" method of dealing with the heavy bobbin groundrope and the mechanical hoisting of the body of the net, there has also been the development of the British, Russian and German stern trawlers with chute. Their equipment for fully mechanized hoisting of the net, which is used on a commercial scale with satisfactory results is carefully described and discussed in this book.

The use of separate winches for each warp, which has already been considered in the past, should contribute to decreasing the wear on the warps and to increasing the safety of the crew working on deck. However, it seems that the price of such an arrangement as against that of the conventional trawl winch has acted as a deterrent to its introduction.

Large super trawlers are now fishing in weather up to Beaufort 8 to 9. The operation of the proposed system with revolving cranes which, with only a 3 ton capacity, seem somewhat small, might become difficult. The hoisting of a bag filled with about 3 tons of fish—which is the common weight for a splitting bag—" . . . without contacting either the hull or the deck . . ." would hardly be possible when the vessel is rolling and pitching in a rough sea.

Deck space can certainly be gained by omitting a stern chute. But this factor is not of importance to ships with a 'tween deck for processing the catch. It is not quite clear how the operation can be greatly accelerated with the proposed arrangement, particularly as the method of dealing with big catches (more than 3 tons) is not described.

MR. Y. TAKAHASHI (Japan): The first Japanese commercial stern trawler of 1,500 gross tons, 1,800 h.p. was built in 1958. This boat is a combination freezer vessel. The length of the slipway, or stern chute, is too short. Operating results have not been altogether successful, mainly because of the long time needed for lifting the net, and there is some belief that a side trawler might be better. The defect mentioned might be overcome by lengthening the distance between the chute and the winch. Another weak point of this boat is the square stern which often causes entanglement of the net. Round sterns only will be built in the future.

With regard to the trawl winch power, this in Japan is usually from 60 to 90 h.p., but in France it is almost 120 h.p. and in some other countries it is as high as 200 to 250 h.p. It would be much appreciated if an explanation could be given for these big differences. Incidentally, Japanese trawlers are operating to depths of 2,000 ft. (800 m.).

MR. L. M. HARPER GOW (U.K.): He spoke as a ship manager and not as a technician of his experience since 1953. At that time, they had carried out some experiments with the *Fairfree* to investigate possibilities of stern trawling and freezing at sea. At the time they had under construction the *Fairtry*, which started operating in 1954.

Fairtry I completed 18 operational trips in 4½ years (4 trips per year) which was approximately what was planned. In 1955 and 1956, the last being a particularly good year for distant-water fishing, the results were satisfactory enough to make them decide to construct two more vessels, following the lines of *Fairtry I*, but with such improvements as found necessary and advisable. See fig. 115 for the general arrangement drawings of *Fairtry II* and *III*. The main controversial points of this type of vessel are: 1. Stern trawling; 2. Production at sea; 3. Personnel problems.

1. There was little change in general design in the two new vessels. They had improved the layout in design to allow the gear to flow more freely and come in more easily, and altered the arrangement to prevent the danger of the trawl net coming into the propeller. There is a danger in the first vessel, but it has only happened once. On that occasion the vessel nearly had to call for a salvage vessel but she managed to clear it herself. The Russians have probably had the same experience in heavy seas with strong winds.

In 18 voyages the gear had been shot about 10,000 times. Therefore it would be clear that the crew would not continue to do this unless it went smoothly. It could therefore be said that this is no longer an experimental method of handling trawling gear but a perfectly normal one. It is not the only method but it happens to suit the large factory trawlers with a 'tween deck.

2. He wanted to discuss the question of production at sea later (see Part IV—discussion).

3. Regarding the personnel problem, which occurred in many places, particularly among the Americans, he did not feel that any troubles were present, although it was anticipated by the trawler industry and might have turned out very differently if they had not had the full support of the trade unions and the services of a somewhat outstanding skipper who was able in the early days to hold the crew together. He admitted that in the first two or three voyages, it was a difficult problem to get the men accustomed to remaining at sea for two to three months. That difficulty had largely been overcome. They could have attracted men from the start by very high rates of earnings, but obviously with a crew of 80 men or more, they wished to keep the earnings on a fair basis, not an extravagant one, and they tried to increase their earnings by increasing production. The crew receive at least 50 per cent. of their earnings on production and therefore if one can get them to increase the production or the value of it, the pay automatically improves. There is probably some room in Britain for further increase in pay, should that be necessary. Earnings still were below those of the deep-sea trawlers working out of Humber.

Reverting to stern trawling, he agreed that the problem of getting a heavy catch up the slip does exist, and that methods had to be improved to overcome this problem. The problem is however in acceptable proportions. The amount of fish lost by the odd heavy bag brought up the slip is very low in relation to the total catch.

He firmly believed that this type of vessel would increase and develop. It has been proved to work in a practical way and it is a logical way of utilizing the catch fully. It would take a long time, and he doubted whether factory vessels would ever do more than supplement the normal standard fishing vessel.

MR. H. HEINSOHN (Germany): He made some explanatory comments on the horsepower of the trawl winches used on stern trawlers. He is using basically the same type of winch as is used on side trawlers and he had found that the output for the trawl winch has something to do with the output of the main engine. According to the experience of the German and British skippers, the engine is at full speed ahead while hauling, the intention being to haul the net up quickly. There might be some sound reason behind this, but what matters in his opinion is the speed of the net through the water, which is a result of the ship's speed and the hauling speed. Now if the ship's speed is increased the pull on the winch must be much heavier than if the speed is reduced, so for trawlers with a high horsepower with engines running full speed ahead one must have a much stronger trawl winch. He has tried to explain to skippers that what matters is the speed of the net through the water and that if they reduce the speed of the vessel the speed of the trawl winch goes up simultaneously.

Regarding the output, the first trawler had 180 h.p. and the power gradually was increased to 250. The tendency now is to go up to 300 h.p. or more.

MR. A. HUNTER (U.K.): He supported Heinsohn's remarks about trawl winches. It appeared from the methods employed

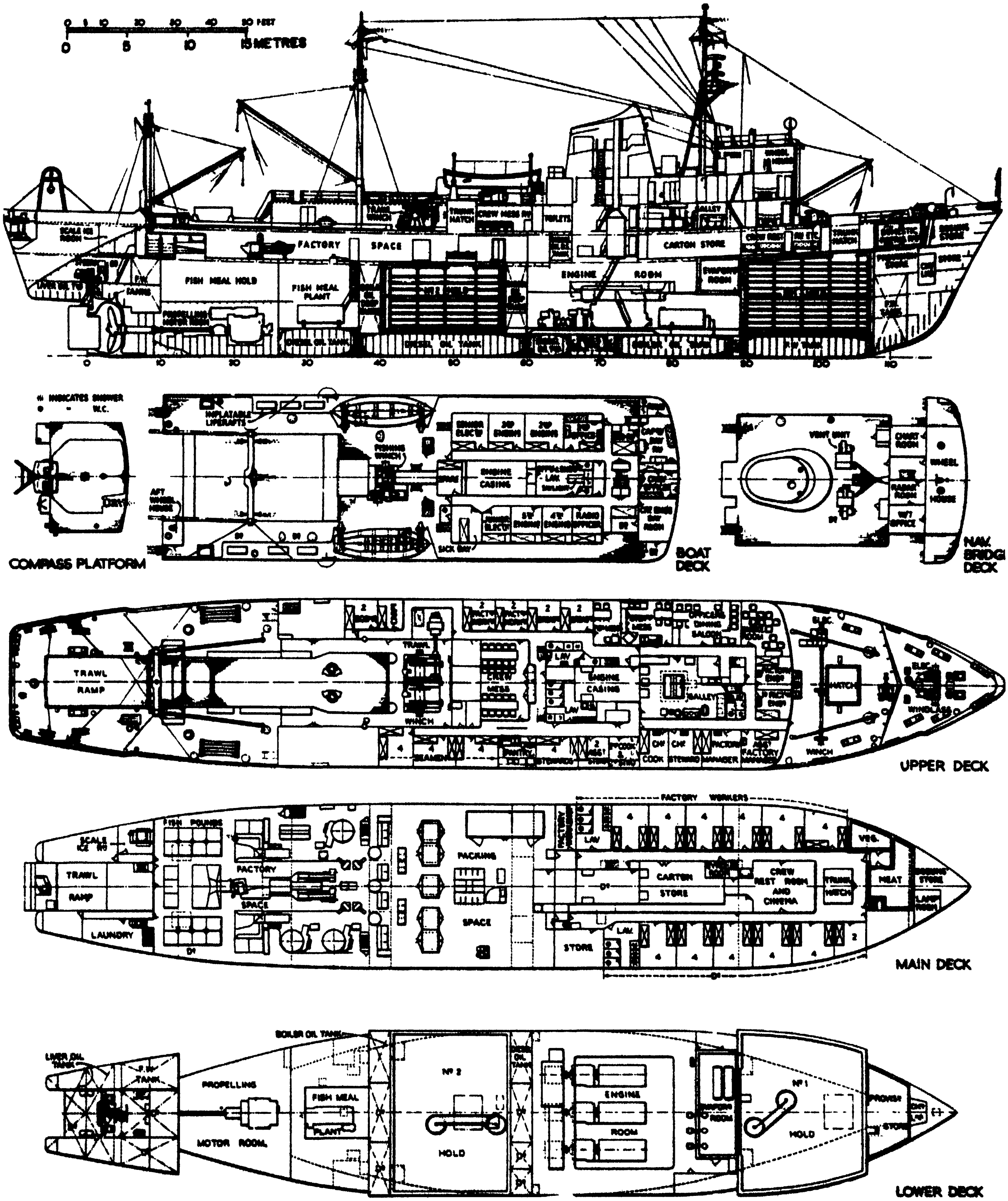


Fig. 115. General arrangement of Fairtry II *and* III

by some skippers as if the trawl winch should have the same power as the main engine so that they could fight it out. British ships with 1,500 to 1,700 h.p. engines usually have winch motors of 300 h.p. The normal trawling speed is 3½ knots and the winch can haul from the mean barrel position at roughly the same speed, viz: 250 ft. (75 m.) per minute. It was therefore difficult to understand why when the order for hauling up the net is given the main engine telegraph should immediately be rung to "Full speed ahead" as is sometimes done. It is understandable that the gear should lift off the bottom quickly, but surely in the end it is the question of the speed through the water which counts in preventing the fish escaping from the net,

There seems great room for education in this matter. The trawl winch with its actuating machinery is an expensive item of equipment in a large trawler and the whole success of the voyage depends upon it. Yet when the trawl gear is shot these mechanisms are subject to the most primitive usage.

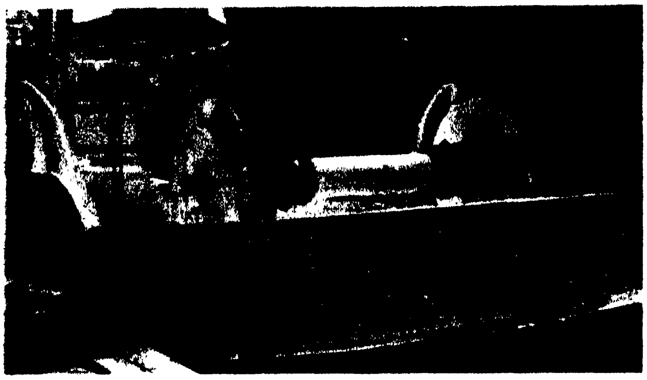


Fig. 116. Stern view of a trawler rigged with a drum for handling the net

Sometimes when shooting the ship steams at 6 to 8 knots and the warps are paid out with the winch brakes almost full on with sparks flying all over the place. There would appear to be room for improvement in practice and perhaps also in design.

MR. H. KRISTJONSSON (FAO): Heinsohn and Hunter have mentioned the habit of trawler skippers of increasing towing speed when beginning to haul up the trawl and it sometimes calls for rather critical power requirements, and the question was posed: "Why do the skippers do this, and is it necessary to increase the towing speed so much at this point?" Obviously the need for accelerating the towing speed when beginning to haul up depends largely on the species fished, how fast swimming and active they are, the trawling speed of the vessel prior to hauling, the construction of the net, etc. In many fisheries there is, of course, no such speeding up at the beginning of hauling. On the contrary, it is common practice, for instance in the Mediterranean, to leave the net practically stationary on the bottom, the vessel coasting backwards while hauling in the warps. In some Scandinavian fisheries the vessel even doubles on its track, steaming towards the net while hauling in the warps.

The fact remains, however, that under certain conditions it is essential to increase the hauling speed when beginning to haul up. Mr. Kristjonsson thought that perhaps the most convincing proof would be found through underwater television observations, such as those started some years ago by the U.S. Fish and Wildlife Service. A most interesting film taken by an underwater camera placed in the codend of a trawl, first facing aft and later facing forward, was shown in 1957 at the FAO International Fishing Gear Congress in Hamburg. At that time underwater research on the behaviour of fish in front of and inside a trawl had not quite reached a conclusive stage, yet it was fascinating to watch the fish swim just in front of the footrope—sometimes for a considerable time—then maybe relax and be carried aft into the belly, feeling themselves trapped when coming into the codend and then perhaps trying to escape out of the mouth of the net.

Smaller stern trawlers

MESSRS. DAYTON L. ALVERSON and PETER G. SCHMIDT JR. (U.S.A.): Purse seiner type vessels ranging from about 50 to 75 ft. (15.2 to 22.8 m.) in length constitute the bulk of fishing craft trawling from Puget Sound, Washington, U.S.A. ports. A typical multi-purpose vessel of this type was described by Hanson (1955). Combination purse seiners have become popular because of their versatility in other fisheries, such as salmon and herring seining, tuna trolling, and gillnetting. When rigged for trawling, either of two types of winches are used to handle the trawl warp. The centre winch, which houses both drums in one unit, leads toward the guard rail and the wire is led around heavy blocks aft to the davits. Divided single-drum winches with a common drive shaft are also extensively used. These are set to feed directly aft to the davits.

As Pacific trawlers employ relatively small crews, say 3 to 5, handling the net is facilitated by hauling in the wings, body, intermediate and codend of the net in successive lifts, using the boom and winch. This method is relatively safe during average weather conditions as no bobbins are used, but not in squalls when it may result in loss of fishing time. This handicap has been partially overcome with the advent of the drum trawler shown in fig. 116. These vessels (Alverson, 1959) are fitted with power drums to haul in the wings and body of the trawl. Successive lifts of the net are not necessary as only the codend is lifted aboard.

Although small boats have generally been satisfactory for most coastal fishing, they have some disadvantages for Puget Sound trawling. These vessels generally make longer trips than those operating from coastal ports. The expansion of the fishery to northern Vancouver Island and Hecate Strait, British Columbia, has resulted in trips averaging from 8 to 11 days each and runs up to 500 miles. Fishing in Hecate Strait has been possible because increased yield per fishing effort has exceeded increased operating costs. The small size and relatively small capacity of these vessels, coupled with slow sailing speeds of about 9 knots have, however, reduced their ability to obtain maximum benefits from the more productive distant grounds.

A factor which may further reduce their effectiveness is the recent development of territorial rights. Territorial extension would exclude Puget Sound trawlers from fishing grounds from which a large percentage of their catch is currently derived.

To compensate for the loss of such areas, fishing vessels would either have to intensify exploitation of the species in the deeper waters along the outer continental shelf or to fish further afield perhaps in the Gulf of Alaska, where some large unexploited banks exist between Cape Spencer and Kodiak Island. Although the smaller vessels now fishing in the Pacific Northeast would be suitable, but perhaps not

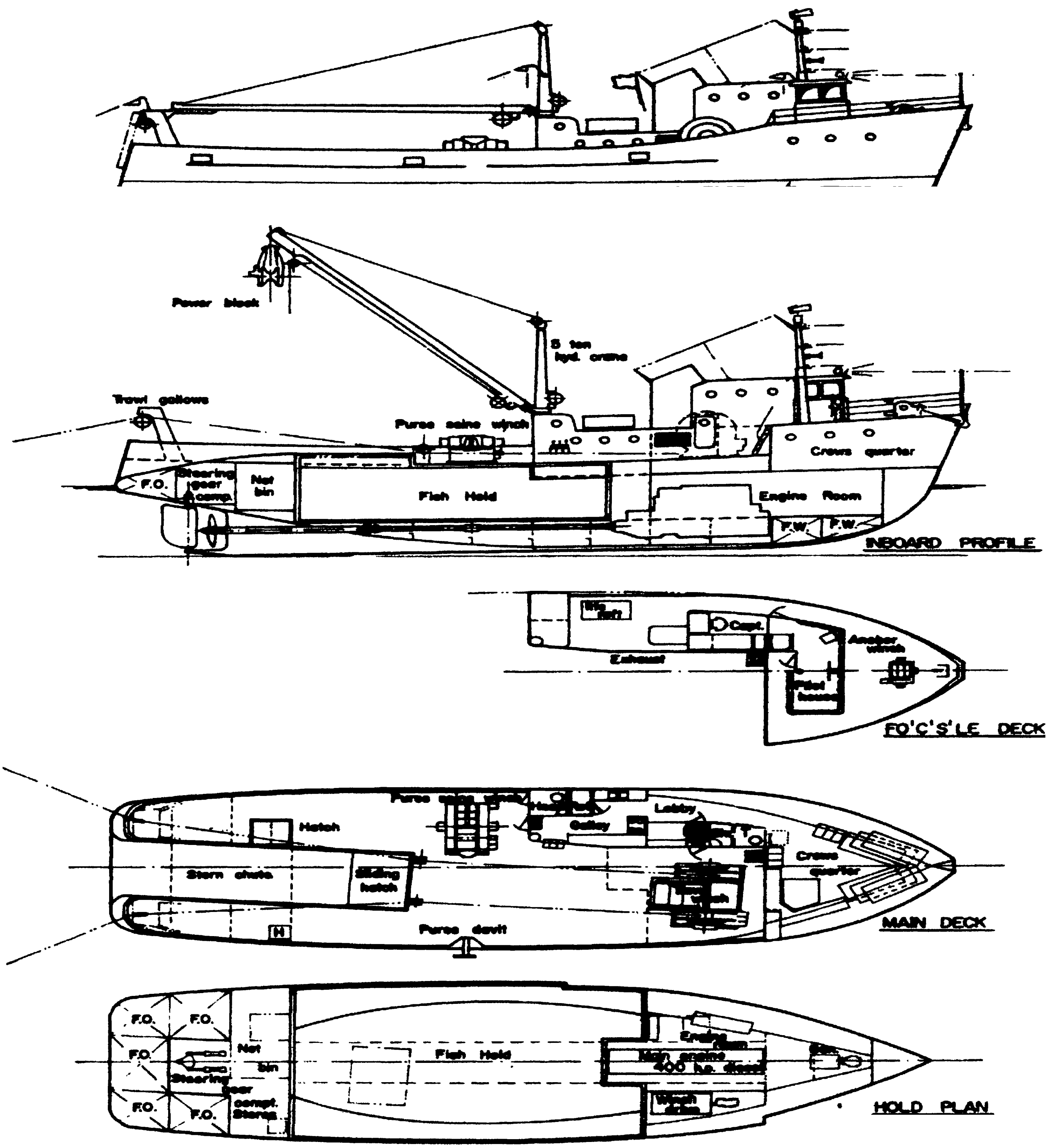


Fig. 117. Proposed 84 ft. (25.6 m.) stern chute trawler

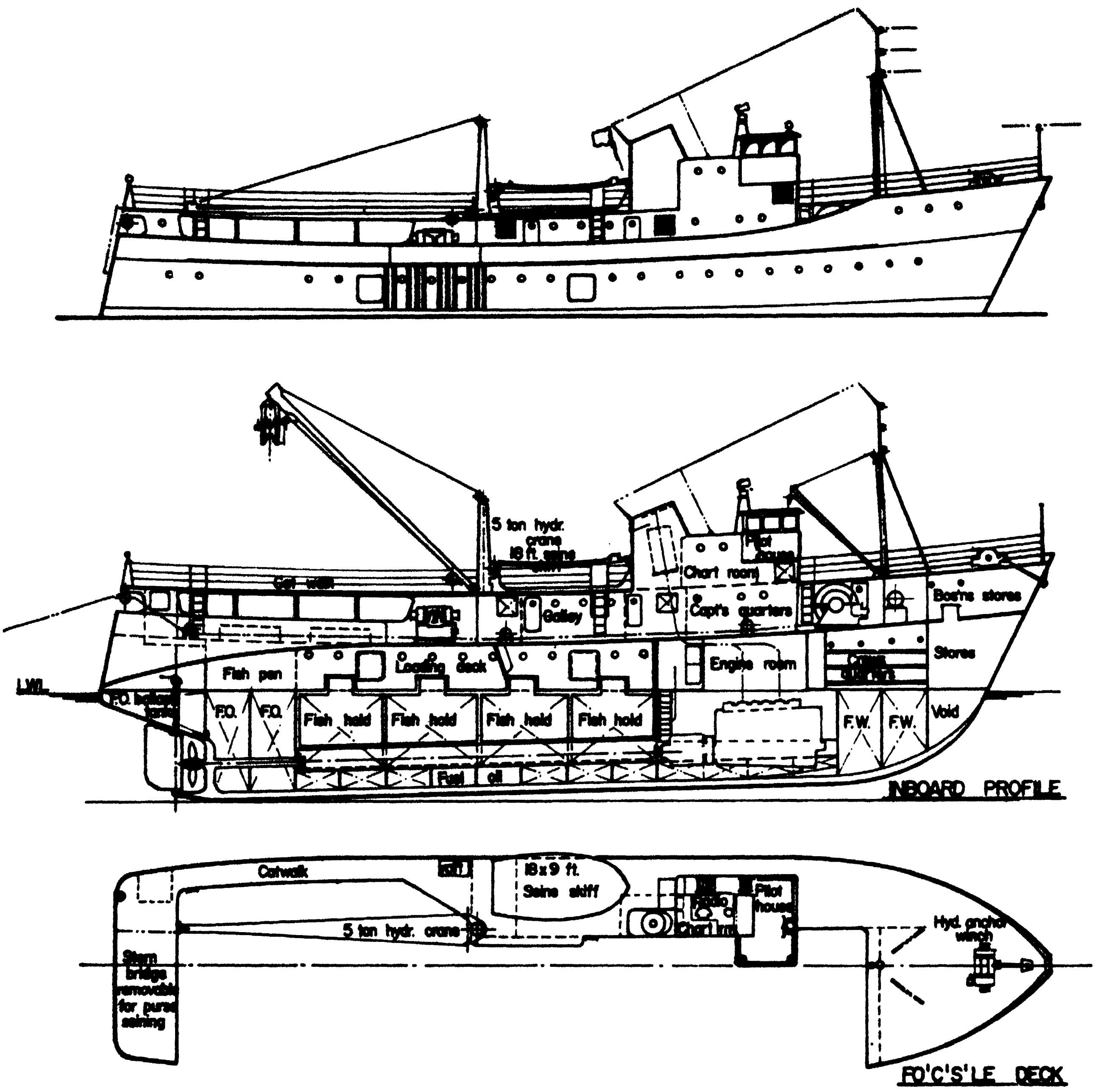


Fig. 118. Proposed 127 ft. (38.8 m.) shelter deck stern trawler (see also overleaf)

efficient in the deeper waters, they would not be capable of distant trawling in the Gulf of Alaska.

Two trawler designs should be considered: (1) a vessel capable of operating efficiently in grounds currently fished, and (2) one able to trawl in the Gulf of Alaska and the Bering Sea. If future trawling leads to greater offshore operation, the "sea-ability" and ability to fish in relatively rough seas will be of considerable importance. For the local fishery, alteration of deck design and equipment may be sufficient. It would be advisable to utilize the drum trawl and stern chute. This method could be improved by shifting the drum forward, which would aid in handling the net and would avoid, in most instances, having to lift the heavy codend over the side. With a larger vessel a shelter deck could be provided.

Drawings of an 84 ft. (25.5 m.) combination trawler for the local Pacific Northeast fishery are given in fig. 117. Major departures from the current seiner-trawler include an offset deckhouse, a stern ramp, and a combination offset trawl winch. The deck plan offers a number of advantages: (1) the offset deckhouse provides extremely good visibility from the pilot house (approximately 315°) which allows the skipper to observe the handling of fishing gear on deck, (2) the winch operator, protected by the raised forecastle, can see the trawl warps at all times, (3) a large clear work area is available, (4) a hydraulically controlled boom or crane is free to swing 300°, and (5) the stern ramp and drum winch combination

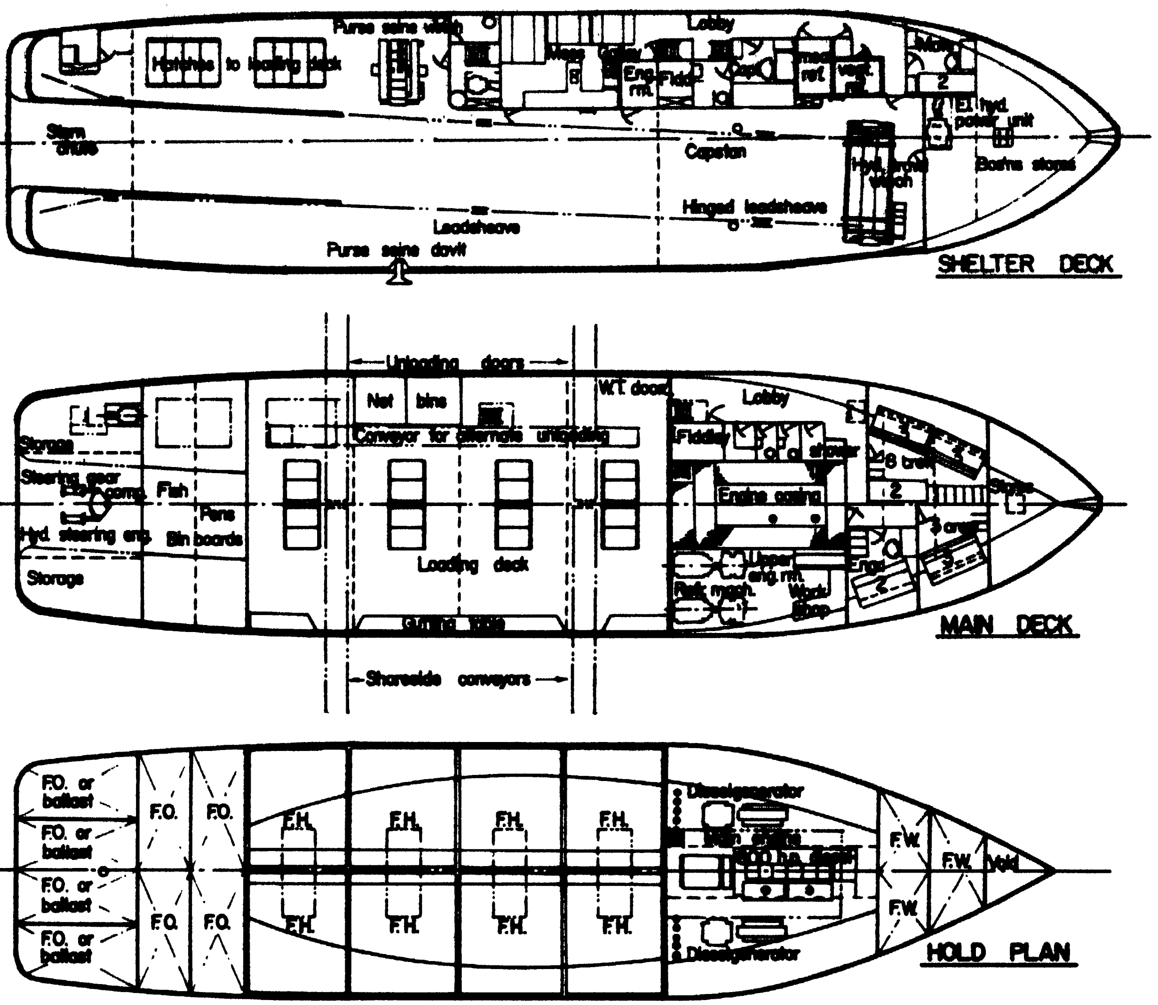


Fig. 118 continued

brings the codend aboard in two hauls. If "splitting" is necessary this can be done in the normal way. The advantages of the stern chute trawler have been discussed by Birkhoff (1959).

The hold is designed to provide ice storage with auxiliary refrigeration, or to contain chilled seawater. The vessel has an estimated fish capacity of 120,000 lb. (54.5 ton) of iced fish or 129,000 lb. (58.5 ton) of fish carried in chilled seawater.

The vessel can be easily converted for purse seining or for longlining. In addition to bottom trawling, the vessel can be used in the Alaska king crab or shrimp fisheries.

This smaller trawler is proposed for operation in areas from the Columbia River to Northern Hecate Strait. Maximum running distance would not exceed 500 miles, although the operational capabilities are much greater. South-east storms are frequent in these waters for much of the year and small trawlers lose close to 35 per cent. of the available fishing time because of adverse weather. The stern chute should allow fishing in relatively heavy seas. If one additional fishing day per trip could be attained, the average catch per trip could be increased 15 to 20 per cent. Reduction in hauling and setting time should also add to the general fishing efficiency.

The main details are:

LOA	84 ft. (25.6 m.)
B, moulded	23 ft. (7.01 m.)
D, moulded	12 ft. (3.66 m.)
GT	146
Hold capacity	90 ton at 40 cu. ft./ton
Fuel oil capacity	25 ton
Freshwater capacity	3 ton
Engine output	360 h.p. at 375 r.p.m.
Approximate speed (light)	10½ knots
Approximate range	4,000 miles

Plans for a 127 ft. (38.8 m.) medium-distance trawler are shown in fig. 118. As with the smaller vessel, an offset house, stern chute, and forward-placed drum winch are suggested. The advantages of this arrangement are similar to those given for the smaller boat. The added length allows for bringing the net aboard in one haul. In addition, a shelter deck is provided to handle or process the catch. Processing equipment, if desired, can be installed on the shelter deck. The catch is hauled to the work deck, spilled through a loading hatch, separated into fish bins, and then loaded into the fish hold. Doors are provided on the side shelter deck for fast unloading. If dock facilities are not adequate for handling side unloading, then the unloading hatch can be used. Hold capacity is about 400,000 lb. (185 ton) for iced fish and 430,000 lb. (200 ton) when carried in chilled seawater.

The vessel also can be used in the purse seine fisheries for herring, sardines, or tuna, as well as for king crab or shrimp.

This suggested trawler could fish all the present areas, as well as the extensive Gulf of Alaska banks. Maximum operating range without processing equipment would be about 1,400 miles. Operating conditions would be more severe than those encountered on present grounds, as gales are common during a large part of the year. The large "single-haul" through the stern chute would improve the fishing ability, and the shelter deck would provide protection for the crew. The trawl grounds of the Gulf have been reported to contain large concentrations of unfished Pacific Ocean perch, similar to the red-fish of the Atlantic, which should provide high yields for distant trawlers. The growth of future markets, coupled with possible changes in territorial seas, could provide the incentive to initiate trawling on the more distant grounds.

The main details are:

LOA	127 ft. (38.8 m.)
B, moulded	30 ft. (9.15 m.)
D, moulded	14 ft. (4.27 m.)
GT	500
Hold capacity	250 ton at 40 cu. ft./ton
Fuel oil capacity .	115 ton
Freshwater capacity	14 ton
Engine output	800 h.p. at 310 r.p.m.
Approximate speed (light) .	12½ knots
Approximate range . .	8,000 miles

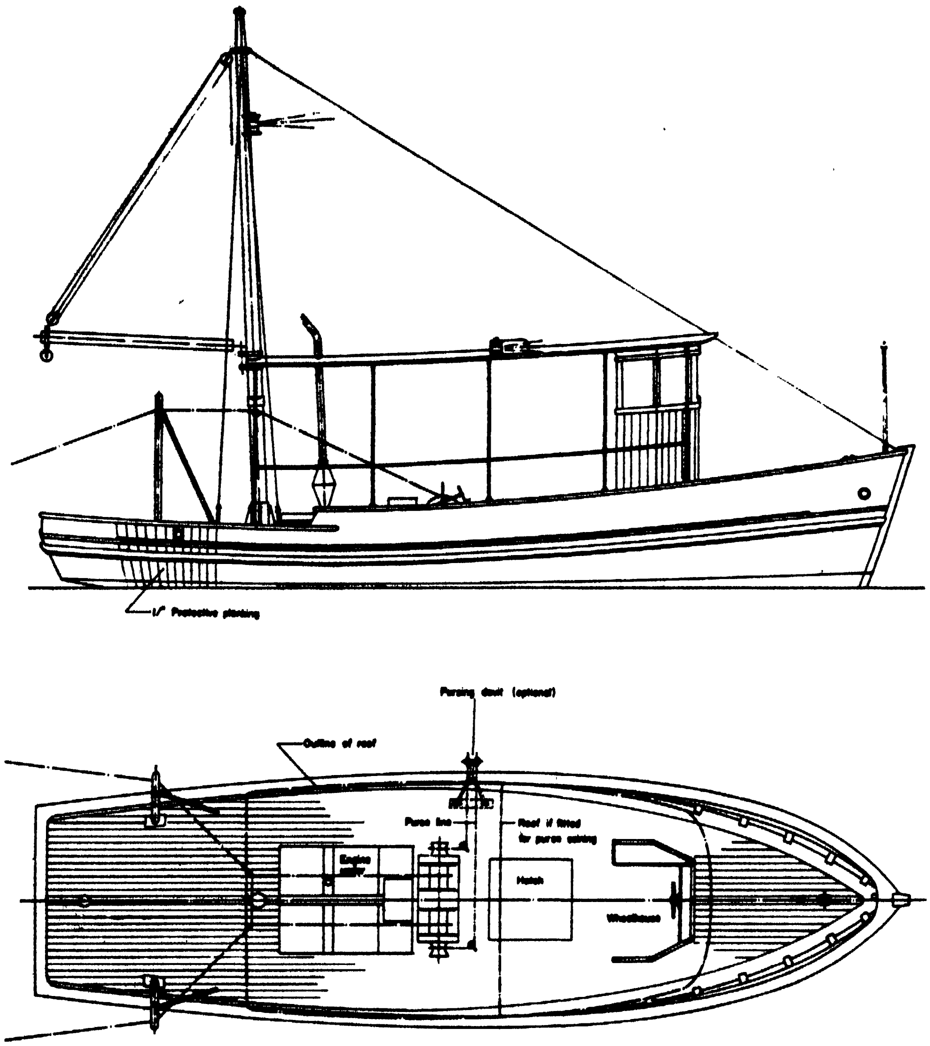


Fig. 119. 32 ft. (9.75 m.) multi-purpose fishing boat with layout for trawling

MR. A. HUNTER (U.K.): In the smaller size of stern trawlers such as proposed by Alverson, he asked if sufficient experience had been gained regarding the safety of the stern ramp arrangement in a following sea. There could be conditions where the sea could flood the deck by coming up the ramp. It was noticeable that this design considerably restricted the crew's accommodation and the arrangements shown by Alverson would not be acceptable in Britain where the sleeping accommodation has to be placed at least 5 per cent. of the ship's length abaft the forward perpendicular. Moreover three beds in the height would not comply with British law. Care also would be required in balancing athwartship weights without undue weight of compensating ballast always more difficult in the smaller ship.

MR. D. L. ALVERSON (U.S.A.): There is no restriction in crew's quarters in Schmidt's and his design. On purse seiner type vessels the crew is always put up in restricted quarters far forward. In the U.S.A. they do not have to put up with the regulation mentioned by Hunter. He is of the opinion that the broad stern is no problem, not even in a following sea.

Recruitment of fishermen is very difficult and hence as much as possible should be done to improve working and living conditions on board the ships. In the U.S.A., in line fishing, the average age of the fishermen is over fifty years. The trawling fleet shows a somewhat lower average age which might be due to the shorter trips these trawlers undertake.

MR. P. GURTNER (FAO) mentioned that stern trawling had been introduced in India for some time now even for very small boats ranging from 25 to 32 ft. (7.5 to 9.75 m.). The smaller boats do not normally have a winch, but the net is hauled by hand and towed from one or two samson posts at the extreme aft end. Bigger boats are now generally rigged as shown in fig. 119. Some criticism was heard from fishermen against having trawl davits at the extreme aft end of the boat, when bad manoeuvrability was experienced. Trawl davits are now fitted about ¼ LOA forward of the transom and much improved manoeuvrability is expected. Fig. 119 shows a 32 ft. (9.75 m.) trawler.

Future development

MR. H. KRISTJONSSON (FAO): It must be regretted that the discussion on stern trawling had dwelt too exclusively on trawling over a ramp or stern chute, while little mention had been made of the old and conventional stern trawling arrangements, such as the Mediterranean one, where there is certainly also scope for improvement. On Mediterranean trawl boats it is customary to place the winch rather far forward so that fewer strapping operations are needed when taking in the net. This method could, however, be further improved, but the main question is: Is it practical to take on board such lightweight trawl nets as the Mediterranean ones with their small catches, or can time and labour be saved by adopting the mode of operation used in the Gulf of Mexico shrimp fishing and on some stern trawlers on the U.S. West Coast, where the stern of the vessel is swung around slightly to bring the codend up to the side, leaving wings and belly in the sea? This is one example of the scope of efficiency studies which are urgently needed on board fishing vessels. But such work studies must not be limited to finding out how to save labour in the handling of the vessel and gear, but should also cover handling of the catch. For instance, the small Mediterranean trawl boats carry crews of six to nine men—not mainly for handling the gear but for sorting the small species in the catch meticulously into little boxes for icing. Similarly, up to 40 people are sometimes carried on Icelandic long-distance trawlers, mainly for gutting the fish when working on exceptionally rich grounds.

The big problem of saving manpower is generally very closely tied up with handling and preservation of the fish on board. Factory ships staying at sea for a couple of months, operating in distant grounds more than 1,000 miles from the home port, are obliged to carry large crews and complicated machinery for processing the fish. Such elaboration of the catch at sea is inherently expensive. On vessels staying out for a shorter time, i.e., less than 20 days after catching the first fish, there is bound to be an increasing trend to save labour by minimizing elaboration of the catch and streamline this through mechanical handling and automation to be able to operate with very small crews. Provided with good accommodation and labour easing, as well as labour saving appliances, the crew members should work long hours while at sea and rather enjoy their leisure time at home by staying on shore once in a while by rotation. This would make fishing a more attractive employment.

An ideal fishing boat would then resemble a tanker where the fish is dumped into a tank with chilled brine or sea water, or preserved by other simple means where laborious gutting, bleeding, and other handling is avoided. Mr. Kristjonsson was curious to hear the opinion of the fish processing people about such possibilities. He was afraid that research on keeping fresh fish in chilled brine or sea water so far had been done mainly in countries which fish in cold waters where was relatively little difference between the chilling temperatures and the temperature at which the fish live—and also the bacteria on the fish. This method of preserving fish in fresh condition is, however, much more hopeful when fishing in warm waters where there is a drop of maybe 35 to 55° F (20 to 30° C.) from the sea temperature down to chilling temperatures. Such drastic chilling of the fish immediately when it comes out of the sea should effectively arrest spoilage and might quite likely result in improved quality and increased keeping time—with an absolute minimum of handling.

Progress in this direction would obviously have a very profound effect on fishing vessel design and on the economics of fishing operations, as drastic savings might be achieved in labour—which is universally and increasingly the biggest cost item in fish production.

PROFESSOR A. VON BRANDT (Germany): Most of the discussion was concentrated on stern versus side trawling, their advantages and disadvantages, fish quality problems and crew problems. It seems to him these questions were answered as far as it was possible. There was only one question regarding the gear itself: should a new type of gear for stern trawling be developed.

Knowledge of the conventional types of trawls is still restricted. For gear research, not the bottom trawl but the floating trawl is now in the centre of attention. It seems necessary to say that in future there will have to be more interest in floating trawls in connection with biological and economical problems. This could influence the deck arrangements a great deal and naval architects should watch this development carefully.

Command of operation

MR. J-O. TRAUNG (FAO, Rapporteur): Two reasons have prompted the subject:

- To transmit the intentions of the skipper as fast as possible
- To transmit the brain impulses of the skipper to the reaction of the vessel

Hardy and Pain have attempted the task of putting forth their ideas on the subject. Sülberkrüb's, Chardome's and Heinsohn's papers also deal with this subject. Heinsohn's paper gives a very vivid account of what is possible for a skipper from the bridge of a modern vessel.

MR. G. C. EDDIE (U.K.): The concept of the flight deck of an aeroplane in the bridge of a modern fishing boat is not a correct one. The skipper's automatic navigator is to be placed at one end of the bridge and the echo-sounder at the other end, so that the skipper gets enough exercise and is relieved of his mental anxiety which is very often the cause of mishaps.

He doubted the extent to which automation could be carried out in a fishing boat. Such centralization tends to increase the anxiety and strain on the skipper and he would recommend that the equipment on the bridge be restricted to what is absolutely necessary. As automation is the rule of the day, it has to be accepted.

MR. E. C. GOLDSWORTHY (U.K.): If one cannot get the trawler skipper to think in terms of a speed of 2½ or 3½ knots in conducting his fishing operations, he wondered how it is possible to make him understand anything else in fishing. It is a question of education. It is problematical if the advent of gyro compass, echo sounders, radar and all modern equipment has brought about any additional safety.

However, the fishermen have the equipment and they tend to grow more and more automation minded.

MR. H. HEINSOHN (Germany) said that a feature of modern German trawlers is a revolving chair for the skipper on the starboard side, around which the naval architect has arranged various devices. The arrangements shown in Hardy's and Pain's drawings would not be favoured because of the absence of the revolving chair.

Due to lack of space, the radar screen or screens are normally arranged on the port side. In the starboard bridge wing is a second helm control and the engine telegraph and/or propeller bridge control, which should be within reach of the skipper from his revolving chair.

In certain vessels some controls are purposely put out of reach of the skipper's chair, so that another person must also remain on the bridge. Automation means that the man may be in sole control, which is against German law and there is a consequent risk of mishaps.

CAPTAIN P. F. EDGE (U.K.) said that while fitting out a new ship, he found it rather difficult to place all the gadgets. He noted that old skippers tended to find all these gadgets in the wheelhouse very disturbing, but in the case of younger skippers acquainted with automation and electronics, great benefits might result from centralized control positions.

MR. A. HUNTER (U.K.) quoted the old Navy saying "Though the instrument may be perfect there are limitations to the man". He felt that these proposals rather reversed this. While the proposals were imaginative they perhaps tended to imitate too much the control of a modern aircraft. Full reliability of rudder control was essential, and the function of the steering gear was not only to control the rudder angle but also to hold the ship against the action of the sea. Robust steering gear was therefore essential. Visibility forward and aft is of the utmost importance to the trawler skipper, and the size of the control console proposed would prevent access to some of the wheelhouse windows. Moreover, such controls had to take into account the activities of the skipper when fishing. These operations enforced quick action between the doors at the bridge wings, a weather eye forward and a quick use of engine and steering controls. It was hardly likely he would respond readily to delegating some of these responsibilities to a close television circuit.

MR. DWIGHT S. SIMPSON (U.S.A.) agreed with Hardy and Pain and said that there were two main requirements for successful centralized control—a pilot house from which the skipper could see all the ship operations without going outside, and a diesel equipped engine room. Perhaps a third should be mentioned—a well trained skipper.

He believed that the starting of the engine should be omitted from the pilot house and left to the engineer, who could see what he was doing. Probably this also applied to the manoeuvring of a reversing engine, although in the smaller engines that can be easily arranged for the pilot house too. These installations would pay for themselves by releasing the engineer for maintenance work.

COMMANDER H. E. H. PAIN (U.K.) agreed with Hunter as to the aids necessary for navigation. He however added that nothing could replace the need for good seamanship.

An arrangement which would cut off fuel oil supply in case of over-heating of the engine was feasible and desirable. He would not suggest an elaborate system but would prefer the very flexible system of electric steering control of the conventional electro-hydraulic steering engine.

The problem of older skippers who were not accustomed to automation would eventually disappear. The skippers of the future would be better educated and well versed in handling the equipment. The proposals might appear to be looking too much into the future, but most of the things which had been suggested were already in use in one way or another in many fishing boats.

He suggested that the analogy of the flight deck of an aeroplane and the bridge of a modern fishing vessel was valid. Centralized control aims at increasing the efficiency of the vessel as a fish catching machine, at reducing the burden of the skipper thereby and also at reducing hazards and increasing safety.

STEEL AND WOOD SCANTLING TABLES (West Coast of U.S.A.)

by

H. C. HANSON

Figures and scantling tables are given for small fishing vessels not covered by bodies such as Lloyds and the American Bureau of Shipping. They are for wooden boats of from 30 to 90 ft. (9.15 to 27.4 m.) with bent-frame construction and for those of from 30 to 125 ft. (9.15 to 38.1 m.) with sawn frames. They also cover V-bottom wooden boats of from 30 to 90 ft. (9.15 to 27.4 m.) and welded steel vessels of from 30 to 130 ft. (9.15 to 39.6 m.) in length overall.

TABLES D'ÉCHANTILLONS POUR L'ACIER ET LE BOIS (CÔTE OCCIDENTALE DES E.-U.)

L'auteur donne des figures et des tableaux d'échantillons pour des petits navires de pêche n'étant pas couverts par des organismes tels que le Lloyds et l'American Bureau of Shipping. Ils sont destinés aux navires de bois de 30 à 90 pi. (9,15 à 27.4 m.) construits avec des membrures courbées et aux navires de 30 à 125 pi. (9,15 à 38,1 m.) à membrures sciées. Ils couvrent aussi les navires de bois à fond en V de 30 à 90 pi. et les navires d'acier soudés de 30 à 130 pi. (9,15 à 39,6 m.) de longueur hors-tout.

TABLAS DE ESCANTILLONES PARA EL ACERO Y LA MADERA (COSTA OCCIDENTAL DE LOS E.U.A.)

El autor da figuras y tablas de escantillones para los pequeños barcos de pesca que no están asegu-rados por organizaciones como la Lloyds y el American Bureau of Shipping. Se destinan a los barcos de madera de 30 a 90 pies (9,15 a 27,4 m.) de eslora construídos con cuadernas aserradas. También comprende los barcos de madera de fondo en V de 30 a 90 pies y los barcos de acero soldado de 30 a 130 pies (9,15 a 39,6 m.) de eslora total.

VIEWS were expressed at FAO's Fishing Boat Congress in 1953 that there was a need for information on scantlings for smaller vessels not covered by bodies such as Lloyds and the American Bureau of Shipping (ABS). The author has collected data pertaining to such types built on the West Coast of the U.S.A. for both wood and steel fishing boats.

Wooden construction

Bent frames comprise 90 per cent. of wooden boat construction. Fig. 120 to 124 show typical sections and some profiles of boats built on this system. Table 20 recommends scantlings which represent common practice for vessels of bent-frame construction. The bent-frame in this case is white oak, if obtainable. This material has now become very scarce, so red oak, while it is not the best, is used to a large extent. It is not, however, very rot resistant, and to give it a reasonable life, it is cut to the proper sizes, the edges rounded slightly and then pressure-treated with preservative.

Typical bent-frame boats have keelsons and keel bolted together, the frame is dapped into the keelsons, with hard-wood floors over the keelsons and frame, the frame, backbone and floors all being well bolted together. In smaller vessels, such as beach seiners and gill-netters, deep floors are used instead of keelsons, thus differing from the midship section shown.

Sawn-frame construction is not used to any great extent nowadays, but boats so built range from 80 to 125 ft. (24 to 38 m.) and are used for tuna fishing, but they are expensive to build due to high wages and lack of skilled shipwrights. Table 21 gives scantlings proved by practice. The midship section and profile, fig. 125 and 126, is of an 80×22 ft. (24.4×6.7 m.) wooden sawn-frame round-bottom combination vessel used primarily for tuna fishing, this particular one in Africa.

The midship section shows two types of construction. The one to the left is a development from the bent-frame construction with single keel and keelsons bolted together forming an integral backbone. The framing can be sound if done properly by tenoning the cants into the keelson for about ½ in. (12.7 mm.); by having solid deep floors bolted to each frame as it is set, and with the floor sided to within 1 in. (25 mm.) of the width of the bay; and by filling the anchor stock floor over the top of the frame to the depth of the floor itself; all being well fastened. Failure to follow this method of construction could lead to disaster if the vessel sustains any heavy blow.

Table 22 shows the scantlings for V-bottom vessels up to 90 ft. (27.4 m.) in length and it is based upon common usage for a great many years. The fishermen on the U.S. West Coast had an aversion to using V-bottom types, probably because they have been able to afford

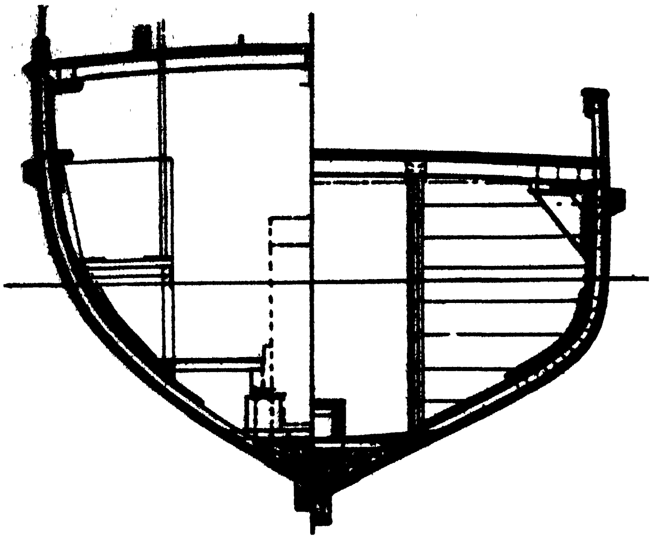


Fig. 120. Bent-frame construction of U.S. West Coast oak boats

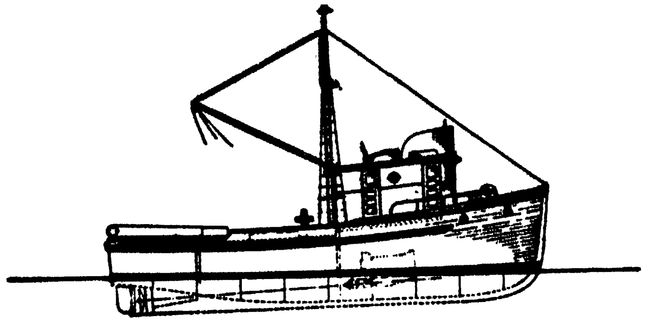


Fig. 123. Wood beach seiner, 45 × 14.5 ft. (13.72 × 4.42 m.) with 4 ft. (1.22 m.) draught

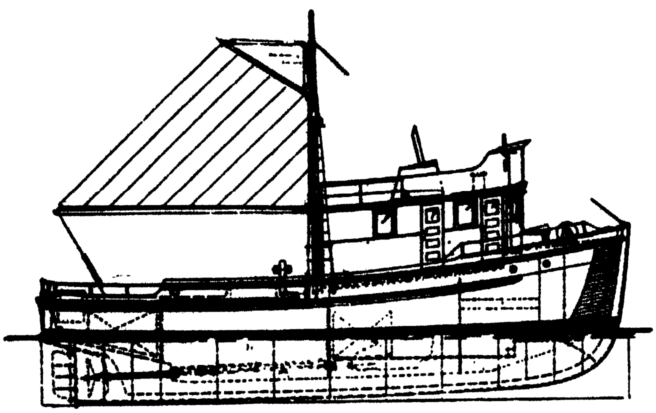


Fig. 121. Wood constructed combination vessel, 44.5 × 14 ft. (13.6 × 4.3 m.). Suitable 165 h.p.

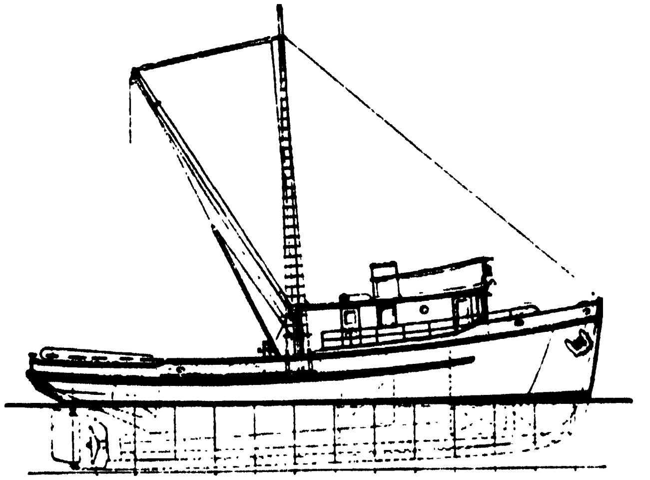


Fig. 124. 67 × 17 × 9.5 ft. (20.4 × 5.2 × 2.9 m.) combination boat designed for seining, otter trawling and trolling

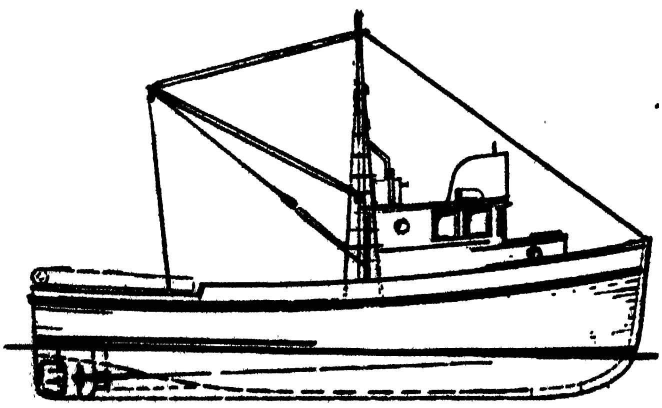


Fig. 122. Wooden seiner, 38 × 12 ft. (11.6 × 3.65 m.) with 3 ft. (0.91 m.) draught

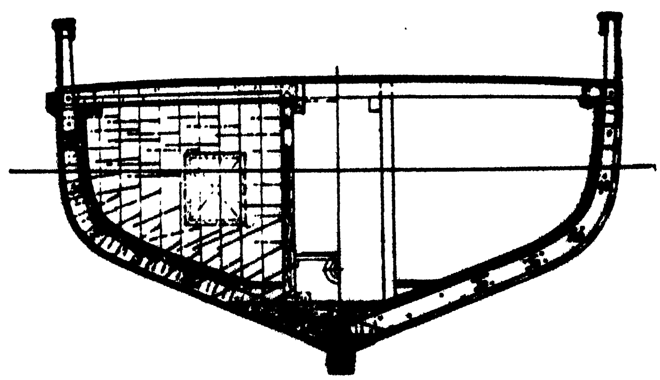


Fig. 125. Midship section showing sawn-frame construction of a vessel of 80 × 22 ft. (24.4 × 6.7 m.)

TABLE 20

of the U.S. Pacific Coast to 90 ft. (27.4 m.)
All sizes given rough and to be surfaced

LOA	ft.	30	45	50	57	65	75	85	90
	m.	9.1	13.7	15.2	17.4	19.8	22.9	25.9	27.4
Keel	in.	6×8	8×8	8×8	10×10	12×12	12×12	12×14	12×14
Stem (Hdwd.)	in.	6	8	8	10	12	12	12	12
Stern post (Hdwd.)	in.	6	8×12	8×12	10×16	12×16	14×18	14	14
Keelson	in.	8×8	8×10	12×12	14×14	14×14	14×14	14×14	14×14
Sister Keelson	in.	6×6	8×8	8×8	8×8	8×8	10×10	10×14	10×14
Floors (white oak)	in.	2×3	2×3	2×3	3×4	3×4	4×4	4×4	4×4
Floors in place of keelsons (Hdwd.)		2×8	3×8	3×9	3×10	4×12	4×12	4½×14	4½×14
Deadwoods	in.	8	8	8	10	12	12	12	12
Shaft logs	in.	8	10×12	10×12	12×12	14	16	16	16
Horn timber	in.	8	12	12	12	14	14	16	16
Gripe (Hdwd.)	in.	8	8	8	10	12	12	12	12
Frames (white oak)	in.	1½×2	2×2½	2×3	2½×4	3×4	3×4	3½×4	4×5
Frame spacing	in.	9 and 10	10	10	10	12	12	12	16
After cants (S.W.)	in.	2 Dbl.	3 Dbl.	3 Dbl.	3 Dbl.	4 Dbl.	4 Dbl.	4½ Dbl.	4½ Dbl.
Beams, sided	in.	3 to 6	4 to 8	4 to 8	4½ to 9½	5½ to 10	5½ to 12	5½ to 12	5½ to 12
Beams, moulded	in.	3	3½	3½	4	4½	4½	5	
Beam spacing	in.	18	24	24	24	27	27	27	27
Bilge stringers	in.	2×6	3×6	3×6	3×6	4×6	4×8	4×8	4×8
Number of strakes		4	5	5	6	6	7	8	8
Clamp, main deck	in.	2×6	3×8	3×8	3×10	3×12	4×12	4×12	4×12
Shelf, main deck	in.	2×6	3×8	3×10	3×12	3×12	3×12	4×12	4×12
Ceiling, main deck	in.	1 (n)	1½	1½	2	2	2	2	2
Clamp, raised deck	in.	2×6	3×8	3×8	3×12	3×12	3×12	3×12	3×12
Shelf, raised deck	in.	2×6	3×6	3×6	2×12	2×12	3×12	3×12	3×12
Ceiling, raised deck	in.	1 (n)	1½	1½	2	2	2	2	2
Garboard	in.	1½ (n)	2×10	2×12	2½	2½	2½	3	3
Sheer strake	in.	1 (n)	2×10	2×10	2	2	2	2½	2½
Planking	in.	1 (n)	1½ (n)	1½ (n)	2	2	2	2½	2½
Broad strake	in.	1½	1½×10	1½×10	2½	2½	2½	2½	2½
Guard (Hdwd.)	in.	2×3	2×6	2×8	2	2	2	2	2
Sponson		None	2×8	3×8	4×9½	4×12	4×12	5×12	5×12
Shoe (Hdwd.)	in.	1½	1½	2	2	2	2	2½	2½
Decking	in.	1½×2	2×3	2×3	2×4	2×4	2½×4	2½×4	2½×4
Waterway	in.	1½×6	2×12	2×12	2×12	2×12	2½×12	2½×12	2½×12
Rim timbers	in.	—	8	10	12	12	12	12	14
Quickwork	in.	—	4	4	6	6	6	6	6
Sag in keel	in.	½	¾	⅞	1	1 1/16	1¼	1⅜	1½

Deck camber ¼ in. per ft., Hdwd. = hard wood, S.W. = soft wood, (n) = nominal, e.g. surfaced

the more expensive fully-shaped boat. Now, they are becoming aware of the merits of this method of construction which, experience has shown, can reasonably be expected to last from 20 to 50 years.

Table 22 refers to soft woods, such as firs and cedars. Yellow cedar is recommended because it has practically the same strength as West Coast firs but is slightly lighter in weight. The best grades of this are used for such members as the frames, floors, navels, fillers, beams, keelsons and keel. Clears are used for the planking, vertical grain above water, slash grain below water. It is realized that vertical grain is difficult to obtain, but in warm countries it would greatly reduce maintenance costs. If hardwoods are used, scantling sizes can be reduced considerably below those given, which are for soft wood. All flitch used must be close-grained, select, structural, without sap, wane, rot or loose knots, all well bolted. A typical 57×16 ft. (17.4×4.9 m.) V-bottom boat is shown in fig. 127 and 128. The bays between the frames are filled in solid from keel to deck in the cargo hold. This provides insulation by the wood itself and makes a solid backing for the ceiling to resist the impact

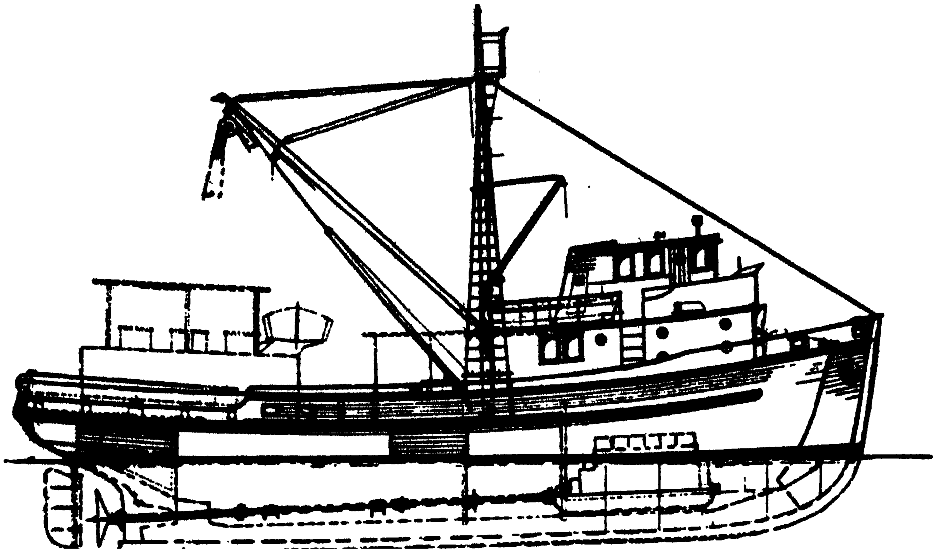


Fig. 126. 80 × 22 × 9 ft. (24.4 × 6.7 × 2.7 m.) wood constructed tuna boat designed for service in South African fisheries. Suitable for both seine and bait fishing. 300 h.p.

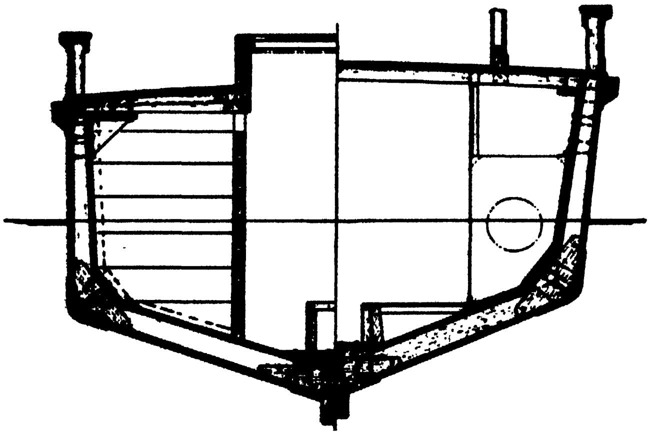


Fig. 127. Midship section showing V-bottom construction of a vessel of 57 × 16 ft. (17.4 × 4.9 m.)

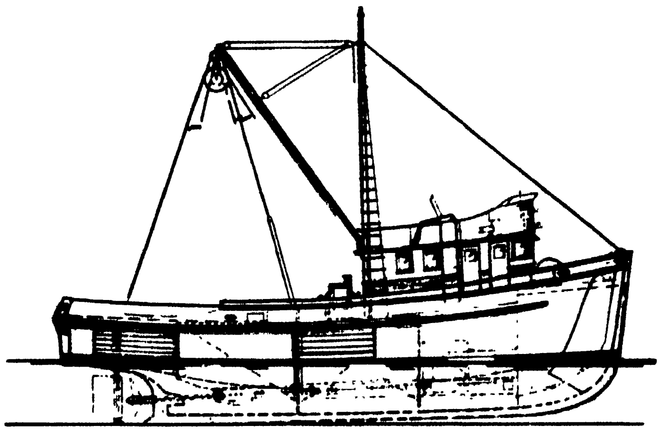


Fig. 128. 57 × 16 ft. (17.4 × 4.9 m.) wooden V-type combination boat for Alaska seining and for crabbing. Suitable for 240 h.p. diesel and with two brine cooling tanks forward. Economical construction

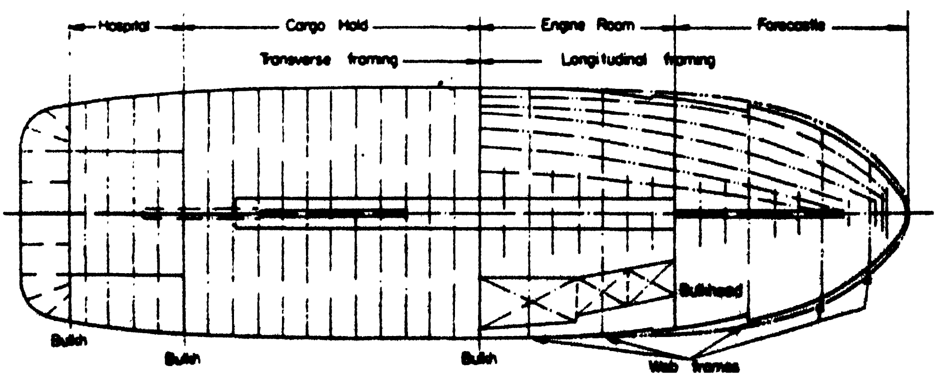


Fig. 129. Framing used in smaller steel vessels from 45 to 75 ft. (13.7 to 22.9 m.) length, with transverse framing aft and longitudinal forward

TABLE 21

_ of wooden sawn-frame fishing vessels of the U.S. Pacific Coast to 125 ft. (38.1 m.)
Minimum requirements. All sizes given rough and to be (

LOA	ft.	30	45	50	57	65	75	85	100	112	125
	m.	9.1	13.7	15.2	17.4	19.8	22.9	25.9	30.5	34.2	38.1
Keel	in.	6×8	8×8	8×8	10×10	12×12	12×12	12×14	14×14	14×16	16×16
Stem (Hdwd.)	in.	6	8	8	10	12	12	12	14	14	16
Stern post (Hdwd.)	in.	6	8×12	8×12	10×16	12×16	14×18	14	16	16	18×18
Keelson	in.	8×6	6×8	8×8	10×10	12×10	14×12	12×16	14×16	14×18	16×18
Sister keelson	in.	6×6	6×6	8×8	8×10	10×10	12×12	10×14	12×14	12×14	16×18
Deadwoods	in.	8	8	8	10	12	12	12	14	14	16
Shaft logs	in.	8	10×12	10×12	12×12	14	16	16	18	20	24
Horn timber	in.	8	12	12	12	14	14	16	18	20	20
Gripe (Hdwd.)	in.	8	8	8	10	12	12	12	14	14	16
Frame spacing	in.	12	12	12	14	16	16	18	21	22	22
Frame taper	in.	6 to 3	7 to 3	7 to 3½	8 to 4	8 to 4	9 to 4½	10 to 5	11 to 5½	12 to 6	12 to 6
Flitch	in.	2	3	3	3½	4	4	4½	6	6	6
Beams, sided	in.	3 to 6	4 to 8	4 to 8	4½ to 9½	5½ to 10	5½ to 12	5½ to 12	6 to 12	6 to 12	6 to 12
Beams, moulded	in.	3	3½	3½	4	4½	4½	5			
Beam spacing	in.	18	24	24	24	27	27	27	27	30	30
Bilge stringers	in.	2×6	3×6	3×6	3×6	4×6	4×8	4×8	4×10	6×10	6×10
Number of strakes		4	5	5	6	6	7	8	8	7	8
Clamp, main deck	in.	2×6	3×8	3×8	3×10	3×12	4×12	4×12	4×14	4×14	6×14
Shelf, main deck	in.	2×6	3×8	3×10	3×12	3×12	3×12	4×12	4×10 (2)	4×10 (2)	6×10 (2)
Ceiling, main deck	in.	1 (n)	1½	1½	2	2	2	2	3	4	4
Clamp, raised deck	in.	2×6	3×8	3×8	3×12	3×12	3×12	3×12	4×12	4×12	4×12
Shelf, raised deck	in.	2×6	3×6	3×6	2×12	2×12	3×12	3×12	4×12	4×12	4×12
Ceiling, raised deck	in.	1 (n)	1½	1½	2	2	2	2	2	2	2
Garboard	in.	1½ (n)	2×10	2×12	2½	2½	2½	3	4×12	5×12	6×16
Sheer strake	in.	1 (n)	2×10	2×10	2	2	2	2½	2½	3 (n)	3 (n)
Planking	in.	1 (n)	1½ (n)	1½ (n)	2	2	2	2½	2½	3 (n)	3 (n)
Broad strake	in.	1½	1½×10	1½×10	2½	2½	2½	2½	3½	4	4
Guard (Hdwd.)	in.	2×3	2×6	2×8	2	2	2	2	2½	2½	3
Sponson	in.	None	2×8	3×8	4×9½	4×12	4×12	5×12	5½×14	5½×14	6×14
Shoe (Hdwd.)	in.	1½	1½	2	2	2	2	2½	3	3	3
Decking	in.	1½×2	2×3	2×3	2×4	2×4	2½×4	2½×4	2½×4	3×4	3×4
Waterway	in.	1½×6	2×12	2×12	2×12	2×12	2½×12	2½×12	2½×12	3×14	3×14
Rim timbers	in.	—	8	10	12	12	12	12	14	14	14
Quickwork	in.	—	4	4	6	6	6	6	6	6	8
Sag in keel	in.	½	¾	⅞	1	1 1/16	1¼	1⅜	1½	1⅞	2

Deck camber ¼ in. per ft., Hdwd. = hard wood, (n) = nominal e.g. surfaced

of the free water, and does away with the possibility of loose water in the bilges. This is a typical fishing boat commonly called an Alaska limit combination boat, being designed for heavy liquid cargo in both holds: for carrying crabs, the water circulates and flows over the top of the hatch continuously.

Steel construction

Scantlings for round- and V-bottom construction in sizes from small gillnetters up to larger boats, 130 ft. (39.6 m.) long, are given in table 23. Compromises have been made with existing methods of construction by using both transverse and longitudinal framing for the same hull. Experience has shown this to be most practical and efficient, especially where light-weight plating is used. Plate skegs with apertures are introduced for better handling, and so are heavy horn plates to eliminate struts and reverse framing to a large extent. These have all been proved and are recommended.

Fig. 129 shows the framing used in smaller steel vessels, from 45 to 75 ft. (13.7 to 22.9 m.). Transverse framing is

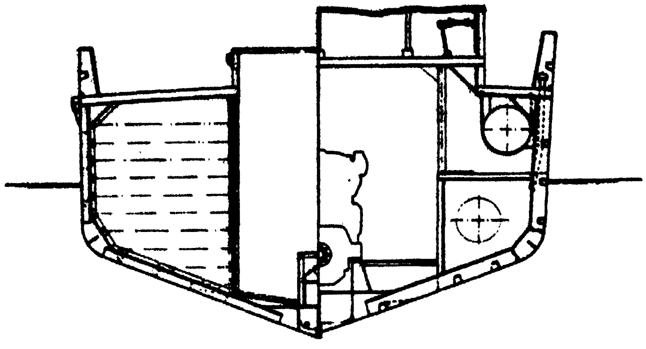


Fig. 130. Midship section of welded steel construction in a 65 × 18 ft. (19.8 × 5.5 m.) combination vessel

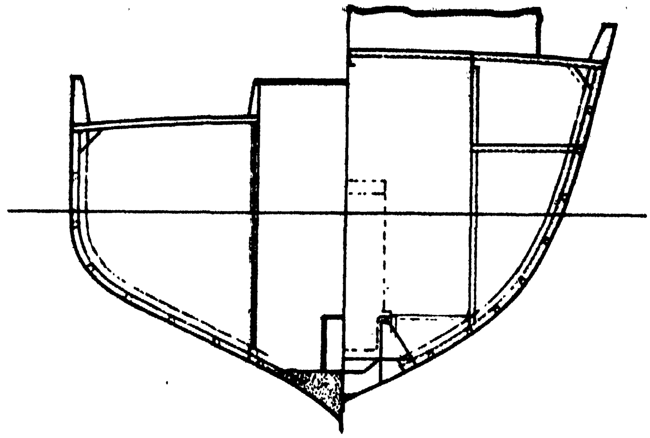


Fig. 132. 83 × 22 ft. (25.3 × 6.7 m.) welded steel round-bottom combination vessel

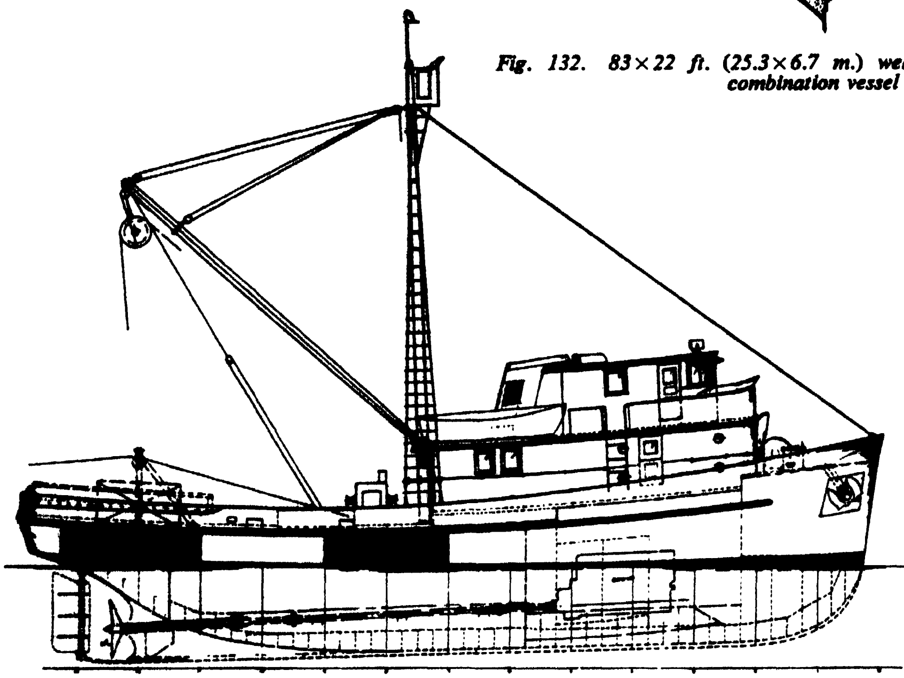


Fig. 133. 83 × 22 ft. (25.3 × 6.7 m.) welded steel round-bottom combination vessel

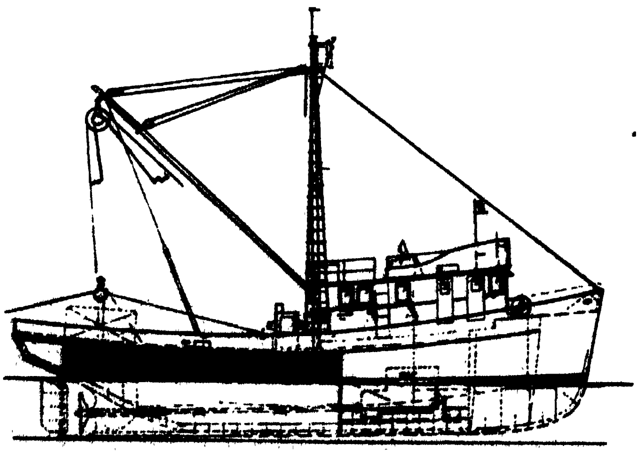


Fig. 131. 65 × 18 ft. (19.8 × 5.5 m.) welded steel V-bottom combination vessel capable of carrying 55 tons, 275 h.p. diesel, suitable for two brine tanks

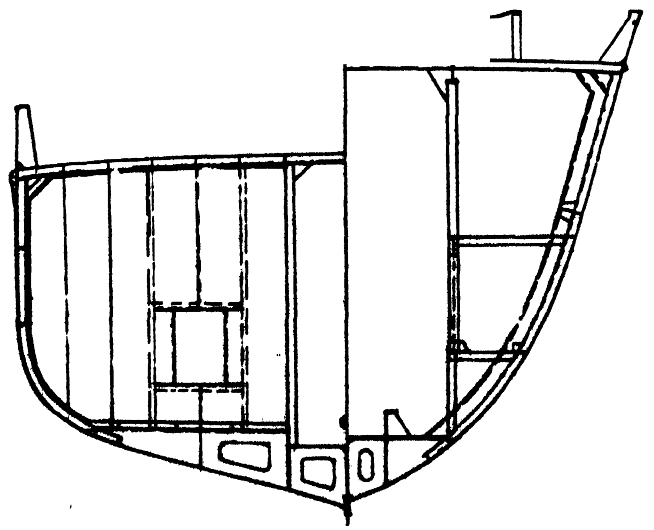


Fig. 134. 100 × 26 × 13.75 ft. (30.5 × 7.9 × 4.2 m.) all-welded steel combination trawler and tuna fishing vessel

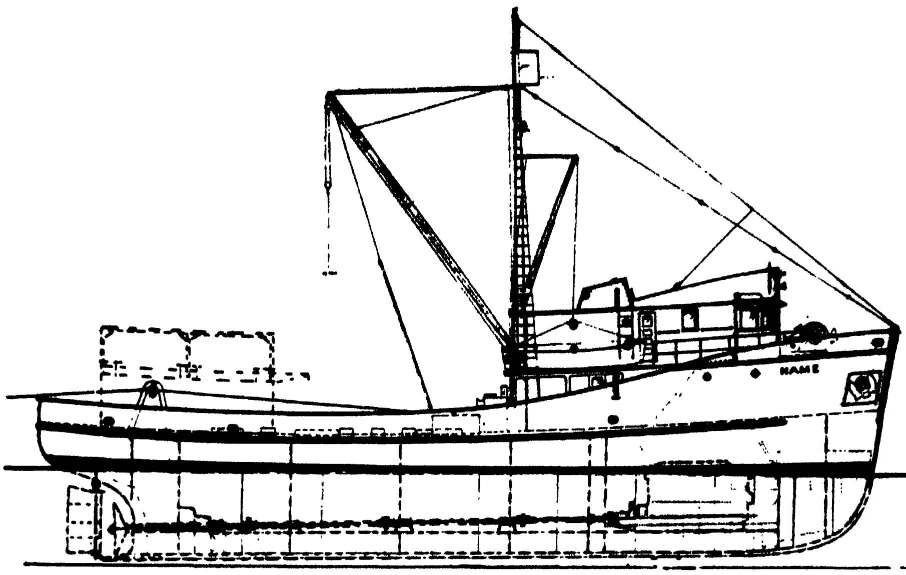


Fig. 135. 100×26×13.75 ft. (30.5×7.9×4.2 m.) all welded steel combination trawler and tuna fishing vessel with portable bait tanks

used aft of the engine room bulkhead, with longitudinal framing forward. Since the plating recommended for the 45 ft. (13.7 m.) vessel is 3/16 in. (4.75 mm.) thick, the framing is spaced more closely than the ordinary rules require. This is done to eliminate the washboard effect. To this end care must be taken not to over-weld plating to the frames.

Fig. 130 and 131 show a 65×18 ft. (19.8×5.5 m.) welded steel V-bottom combination vessel with typical sections showing transverse framing aft of the engine room bulkhead with longitudinal framing forward. This type of construction is typical of all lengths of boat from 45 to 75 ft. (13.7 to 22.9 m.). Since the arrangements, in the lengths under 35 ft. (10.7 m.) depart from standard and use lighter weight steel, complete longitudinal construction in these smaller sizes is recommended.

Fig. 132 and 133 show an 83×22 ft. (25.3×6.7 m.) welded steel round-bottom combination vessel. This uses 5/16 in. (7.9 mm.) plating, so transverse framing can be used without much trouble from washboard effects. The midship section shows framing built either transversely or longitudinally. Plate must be pressed over the entire hull surface, which is more costly than the V-bottom type. There is more space to work with here, therefore this added cost is not so important.

Fig. 134 and 135 is a 100×26×13 ft. 9 in. (30.5×7.9×4.2 m.) all-welded steel combination fishing vessel with portable bait tanks for tuna fishing. With the tanks removed the vessel is used for seining and longlining. The steel weights comply closely with the ABS or Lloyds rules with the exception that the framing is more closely spaced for welding. The heavy shaded areas on the profiles of vessels indicate where heavy chafing plates are usually installed. The use of 1/16 in. (1.6 mm.) heavier gunwale plate is recommended in all cases, thereby eliminating the extra cost of installing doublers in the trawl and seine lofts.

Forward, where webs are used, intermediate floors between webs are recommended at the same spacing as

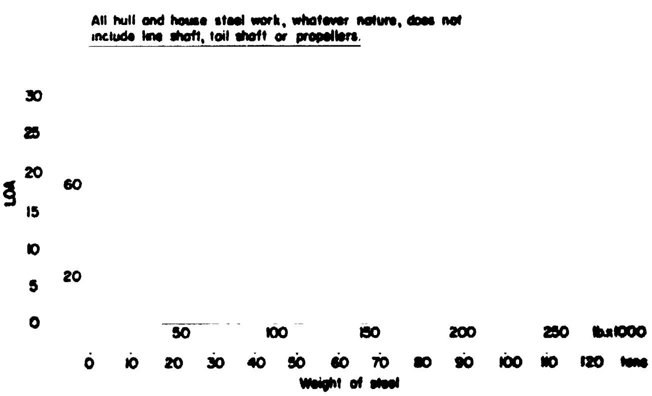


Fig. 136. Steel weights in combination and tuna fishing vessels of lengths overall up to 114 ft. (34.8 m.)

the transverse framing, not only for increased strength but to help to eliminate vibrations in the hull. In some cases angled cants are used where there is a heavy flare.

Where engine beds and shaft alley bulkheads are welded to the plating they act as vertical strength members, and regular vertical centre keelsons can be eliminated. However, at the ends of the vessel they can be used to advantage. Aft, where the weld line rises to the stern with plate margin line, the heavy skeg plate should be brought forward inside the hull to form a vertical centre keelson in this area.

Fig. 136 shows steel weight in relation to length.

TABLE 22

of V-bottom type wooden fishing vessels of U.S. Pacific Coast from 30 to 90 ft. (9.1 to 27.4 m.)
All sizes given rough and to be

LOA	ft.	30	45	50	57	65	75	85	90
	m.	9.1	13.7	15.2	17.4	19.8	22.9	25.9	27.4
Keel	in.	6×8	8×8	8×8	10×10	12×12	12×12	12×14	12×14
Stem (Hdwd.)	in.	6	8	8	10	12	12	12	12
Stern post (Hdwd.)	in.	6	8×12	8×12	10×16	12×16	14×18	14	14
Keelson	in.	3×8	4×10	4×10	6×12	8×12	8×12	10×14	10×14
Sister keelson	in.	3×6	4×8	4×10	6×12	8×12	8×12	10×14	10×14
Floors (Hdwd.)	in.	2×6	3×8	3×9	3×10	4×12	4×12	4½×14	4½×14
Deadwoods	in.	8	8	8	10	12	12	12	12
Shaft logs	in.	8	10×12	10×12	12×12	14	16	16	16
Horn timber	in.	8	12	12	12	14	14	16	16
Gripe	in.	8	8	8	10	12	12	12	12
Frames	in.	2	3	3	3	4	4	6	6
Frame taper	in.	6 to 3	7 to 3½	8 to 3½	8 to 4	9 to 4½	9 to 4½	10 to 5	11 to 5½
Frame spacing	in.	12	12	12	12	12	12	12	12
Cants (S.W.)	in.	2 Dbl.	3 Dbl.	3 Dbl.	3 Dbl.	4 Dbl.	4 Dbl.	4 Dbl.	4 Dbl.
Navel pieces at bilge	in.	2×8	3×8	3×10	3×12	4×12	4×12	4×14	4×14
Beams, sided	in.	3 to 6	4 to 8	4 to 8	4½ to 9½	5½ to 10	5½ to 12	5½ to 12	5½ to 12
Beams, moulded	in.	3	3½	3½	4	4½	4½	5	—
Beam spacing	in.	18	24	24	24	27	27	27	27
Bilge stringers	in.	2×6	3×6	3×6	3×6	4×6	4×8	4×8	4×8
Number of strakes		4	5	5	6	6	7	8	8
Clamp, main deck	in.	2×6	3×8	3×8	3×10	3×12	4×12	4×12	4×12
Shelf, main deck	in.	2×6	3×8	3×10	3×12	3×12	3×12	4×12	4×12
Ceiling, main deck	in.	1 (n)	1½	1½	2	2	2	2	2
Chine (Hdwd.)	in.	3×6	3×8	3½×8	4×8	5×9½	6×10	6×10	6×10
Chine clamp	in.	2×8	3×10	3×10	3×10	3×12	4×12	6×12	6×12
Clamp, raised deck	in.	2×6	3×8	3×8	3×12	3×12	3×12	3×12	3×12
Shelf, raised deck	in.	2×6	3×6	3×6	2×12	2×12	2×12	3×12	3×12
Ceiling, raised deck	in.	1 (n)	1½	1½	2	2	2	2	2
Garboard	in.	1½ (n)	2×10	2×12	2½	2½	2½	3	3
Sheer strake	in.	1 (n)	2×10	2×10	2	2	2	2½	2½
Planking	in.	1 (n)	1½ (n)	1½ (n)	2	2	2	2½	2½
Broad strake	in.	1½	1½×10	1½×10	2½	2½	2½	2½	2½
Guard (Hdwd.)	in.	2×3	2×6	2×8	2	2	2	2	2
Sponson	in.	None	2×8	3×8	4×9½	4×12	4×12	5×12	5×12
Shoe (Hdwd.)	in.	1½	1½	2	2	2	2	2½	2½
Decking	in.	1½×2	2×3	2×3	2×4	2×4	2½×4	2½×4	2½×4
Waterway	in.	1½×6	2×12	2×12	2×12	2×12	2½×12	2½×12	2½×12
Rim timbers	in.	—	8	10	12	12	12	12	14
Quickwork	in.	—	4	4	6	6	6	6	6
Sag in keel	in.	½	¾	⅞	1	1⅛	1¼	1⅜	1½

Deck camber ¼ in. per ft., Hdwd. = hard wood, S.W. = soft wood, (n) = nominal, e.g. surfaced

TABLE 23

of the U.S. Pacific Coast from 30 to 130 ft. (9.1 to 39.6 m.)

LOA	ft.	30	45	50	57	65	75	85	100	112	130
	m.	9.1	13.7	15.2	17.4	19.8	22.9	25.9	30.5	34.2	39.6
Stem bar	in.	1/2×6 to 3	3/4×6	7/8×6	1×6	1×6	1 1/8×6	1 3/8×6	1 3/8×6	1 1/2×6	1 1/2×6
Keel	in.	1/2×6	3/4×6	1×6	1 1/4×6	1 1/4×6	1 3/8×6	1 3/8×6	1 3/8×6	1 1/2×6	1 1/2×6
Stern post	in.	1/2	3/4	3/4	3/4	7/8	7/8	1 1/4	1 1/4×6	1 1/2×8	1 1/2×8
Skeg	in.	1/2	5/8	5/8	5/8	5/8	5/8	7/8	1	1 1/4	1 1/4
Horn plate	in.	1/2	5/8	5/8	5/8	3/4	7/8	1	1 1/4	1 3/8	1 1/2
Gudgeon plate	in.	1/2×3	1 1/4×6	1 1/4×6	1 1/4×6	1 1/4×6	1 3/8×6	1 1/2×8	2 1/2×8	3×9	5×10
Rudder	in.	3/8	1/4	1/4	5/16	5/16	3/8	3/8	7/16	3/8 (streamlined side plates)	
Rolled stem plate	in.	1/8	1/4	1/4	1/4	1/4	5/16	5/16	5/16	3/8	3/8
Rolled stern plate	in.	1/8	3/16	1/4	1/4	1/4	1/4	1/4	5/16	5/16	5/16
Stern stiffeners	in.	1 3/4×1 1/4×1/8	2 1/2×1 1/2×1/4	3×2×1/4	3×2×1/4	3×2×1/4	3 1/2×2 1/2×1/4	3 1/2×2 1/2×1/4	4×3 1/2×5/16	4×3 1/2×5/16	5×3 1/2×5/16
Centre keelson	in.	None	3/16	3/16	1/4	1/4	1/4	1/4	5/16	5/16	5/16
Engine bed, vert.	in.	1/4	1/4	1/4	1/4	1/4	5/16	5/16	5/16	3/8	3/8
Engine bed, top	in.	1/2	5/8	5/8	3/4	7/8	1	1	1 1/4	1 1/4	1 1/4
Shaft alley, vert.	in.	None	1/4	1/4	1/4	1/4	1/4	1/4	5/16	5/16	5/16
Frames, transverse	in.	None	2 1/2×1 1/2×1/4	3×2×1/4	3×2×1/4	3×2×1/4	3 1/2×2 1/2×1/4	3 1/2×2 1/2×1/4	4×3×5/16	4×3×5/16	5×3 1/2×5/16
Trans. frame spacing	in.	None	15	15	15	18	20	21	22	23	24
Web frames	in.	3/16×3	5×2×1/4T	6×3×1/4T	6×3×1/4T	6×3×1/4T	7×3×5/16T	} Transversely framed			None
Web frame spacing	in.	30	45	45	45	54	60				None
Frames, longitudinal	in.	1 3/4×1 1/4×3/16	2 1/2×1 1/2×3/16	3×2×1/4	3×2×1/4	3×2×1/4	3 1/2×2 1/2×1/4	side stringers 10×1/2 (2 required)			None
Long. frame spacing	in.	12	15–18	18	18	18	18				None
Floors, plate	in.	3/16	1/4	1/4	1/4	1/4	1/4	1/4	5/16	5/16	5/16
Floors, flange	in.	2	1 1/2	2	2	2	2 1/2	2 1/2	3	3	3 1/2
Floors spacing	in.	15	15	15	15	18	18	21	22	23	24
Bulkheads, lower pl.	in.	1/8	3/16	1/4	1/4	1/4	1/4	1/4	1/4	5/16	5/16
Bulkheads, upper pl.	in.	1/8	3/16	3/16	3/16	3/16	3/16	1/4	1/4	1/4	1/4
Bulkhead stiffeners	in.	1 3/4×1 1/4×3/16	2 1/2×1 1/2×1/4	3×2×1/4	3×2×1/4	3×2×1/4	3 1/2×2 1/2×1/4	3 1/2×2 1/2×1/4	4×3×1/4	4×3×1/4	4×3×1/4
Beams	in.	1 3/4×1 1/4×3/16	2 1/2×1 1/2×1/4	3×2×1/4	3×2×1/4	3×2×1/4	3 1/2×2 1/2×1/4	3 1/2×2 1/2×1/4	4×3×1/4	4×3×1/4	5×3 1/2×5/16
Beam spacing	in.	15	15	15	15	18	21	21	22	23	24
Deck plating	in.	1/8	3/16	3/16	3/16	1/4	1/4	1/4	1/4	5/16	5/16
Shell plating	in.	1/8	3/16	3/16	1/4	1/4	1/4	1/4 to 5/16	5/16	5/16	5/16
Bilge plate	in.	1/8	1/4	1/4	1/4	3/8	3/8	None	None	None	None

Plates and shapes to have a minimum tensile strength of 58,000 to 68,000 p.s.i.

STRUCTURAL TESTING OF SMALL CRAFT

by

YOSHINORI OTSU, NOBUTATSU YOKOYAMA and TSUTOMU KOBAYASHI

Traditional Japanese coastal fishing boats are simple and inexpensive to construct. The hull has wide wood planking and its nail-jointed seams are much stronger than expected. The longitudinal members have a large safety factor. Transverse deformation may be caused unless the hull is fixed by beams suitably spaced.

L'ESSAI DE PETITS BATEAUX EN VRAIE GRANDEUR

Les bateaux de pêche côtiers traditionnels japonais sont de construction simple et peu coûteuse. La coque a de larges éléments de bordé et ses coutures clouées sont beaucoup plus fortes qu'on ne la pensait. Les membrures longitudinales ont un grand facteur de sécurité. Il peut y avoir une déformation transversale, à moins que la coque soit fixée par des barrots convenablement espacés.

ENSAYOS DE BARCOS PEQUEÑOS A TODA ESCALA

Las embarcaciones tradicionales japonesas dedicadas a la pesca costera son sencillas y baratas de construir. El casco es de planchas de madera de mucha anchura y la clavazón resulta mucho màs fuerte de lo que se podría suponer. Los miembros longitudinales tienen un gran factor de seguridad. Puede ocasionarse una deformación transversal a menos que el casco se asegure mediante baos bien espaciados.

THERE are more than 130,000 small unique fishing craft from 1 to 5 GT along the open and sheltered coasts of Japan, most of them are operated as small individual enterprises. The boats are built up of wide wooden planks without a complete frame system as shown in fig. 137 and 138, called the *Yamato* type.

The example in fig. 137 has the following principal dimensions:

LBP = 21.5 ft. (6.55 m.)
B = 4.43 ft. (1.35 m.)
D = 1.80 ft. (0.55 m.)
GT = 0.95

They are said to have been developed from a primitive 15th century dug-out vessel. The Yamato boats are used for net fishing, pole fishing, lining, shore seining, etc. They are now mostly mechanized with small kerosene, semi-diesel or diesel engines but the sail and the rowing scull peculiar to the region are still used, although more as auxiliary power during fishing than for emergency propulsion.

The building cost of the Yamato boat is about half that of the round-bottom type. It is easy and economical to maintain and has a good performance when riding on the surf and beaching. The weak point is the transverse strength, because of the incomplete framing. The length is thus limited to about 50 ft. (15 m.). Larger boats with frames are constructed and are called improved Yamato or the compromise Japanese type.

Constructional knowledge and experience have been passed on from individual boatbuilders to their apprentices, without any drawings or calculations so, naturally, there are many variations in the details of the hull form. Nevertheless, there is a fair amount of standardization, and the common constructional features can be summarized.

GENERAL DESCRIPTION

The hull is made of five flat or slightly bent wide wooden planks and a transom, as illustrated in fig. 139. The planks are cut to complete developed shapes and nailed up while being pressed into place by props or stays. The bottom and side planks are often neither caulked nor filled with a sealing compound; they are merely nailed after the joints are fitted by sawing, when they are in position.

Transverse members

The sides and the bottom planks are transversely reinforced with wooden knee-brackets of naturally shaped timber, usually spaced about 3.3 or 6.6 ft. (1 or 2 m.) apart. Floor timbers are placed from chine to chine at the brackets, or sometimes in between. The floor timbers are nailed or bolted to the hull planks. The transom is a thick plank fitted a little forward from the stern to form a recess for the rudder and the lifted propeller. Mechanized boats are strengthened by bulkheads for and aft of the engine.

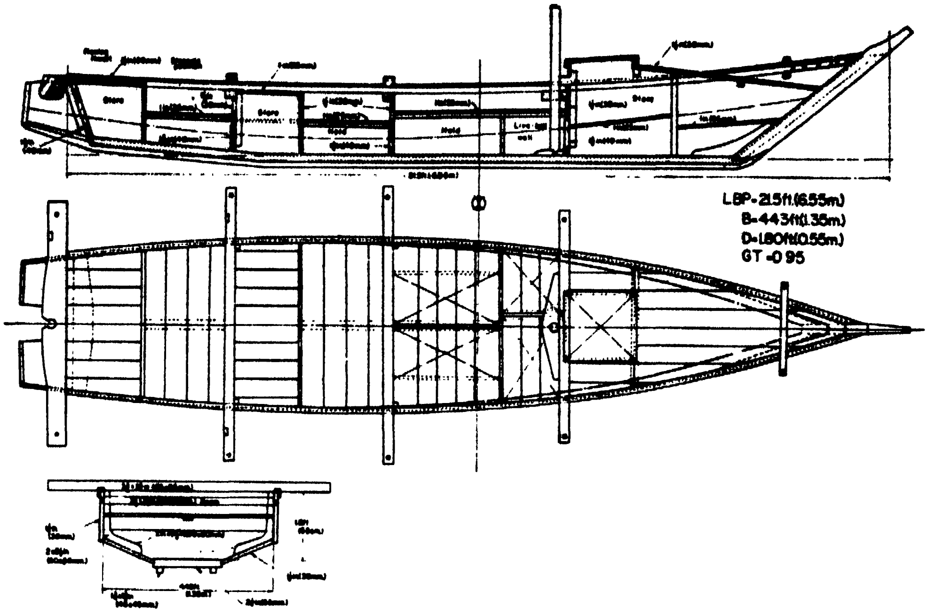


Fig. 137. Construction plan of Yamato type, built of wide wooden planks, without a complete frame system

Longitudinal strength

This is obtained from the hull planking only, except for the guard and rail. There is no deadwood, keelson and bilge strake as found in normal round-bottom boats.

Usually there is a rowing thwart and a steering place aft, an engine trunk just forward, and an open space for fishing operations between the engine bulkhead and the short bow deck, with a wave breaker. The boats often have beams passing through both sides to hold additional rowlocks and/or to lay masts and long poles.

Fittings and equipment

Two or three masts for single square sails with yards are used when the boats are fishing, as shown in fig. 140, and sometimes for sailing. The rowing sculls are operated at the stern or the side in a unique manner. Usually a man stands on the stern thwart and with a single scull placed on a pivot on the transom, stirs the water behind the boat with a regular, rocking motion of pulling and pushing athwart the handle of the oar. The scull blade has an ogival section to produce a propelling action, as shown in fig. 141.

Dimensions

Some representative boats are listed in table 24. The most popular size is between 15 and 40 ft. (4.6 and 12.2 m.) in length, with a beam of 3.6 to 8.5 ft. (1.1 to 2.6 m.). The L/B ratio ranges from 4 to 5. Yamato boats are normally under 50 ft. (15.24 m.). Boats from 40 to 60 ft. (12.2 to 18.3 m.) are normally a combination of the traditional and modern type. Larger boats are usually of round-bottom design.

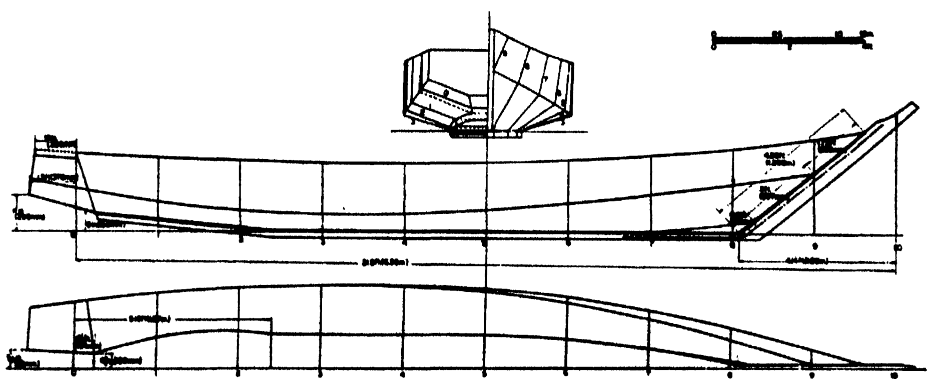


Fig. 138. Lines of the Yamato type

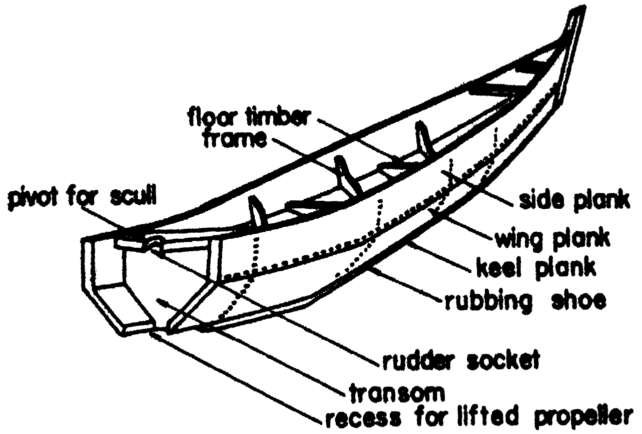


Fig. 139. The Yamato boat, which is made of five flat or slightly bent planks

Power

The majority have recently been converted into power boats, using small kerosene engines with electric ignition, semi-diesels, or small diesels from 1 to 50 h.p. The speed range is from 6 to 7 knots. These engines are easily maintained, spare parts and skilled labour being readily available in any village. As the propeller shaft is made to be lifted when landing or rowing in shallow water, a square slotted timber is fixed aft above the keel to provide a recess for the lifted shaft. A description of the system is given on p. 295.

STRUCTURE TEST

The methods for calculating the longitudinal strength of steel ships are so far as is known never used on wooden ships, and to ascertain if steel ship calculations are suitable for wooden boats, a preliminary test of the structural deflection was made with an improved Yamato boat, the *Akatsuki* of the Fishing Boat Laboratory of the Japanese Fisheries Agency. This boat has the typical wide planking but a frame system, as shown in fig. 142.

The boat was placed on two keel blocks, 24 ft. (7.3 m.) apart, and loaded amidship with weights from 980 to 4,750 lb. (445 to 2,159 kg.). The deflection was measured by piano wire stretched between the bow and the stern. Dial gauges were placed under the keel and optical measurement made by mirror, telescope and cathetometer. The results were:

(1) There is a linear relation between load and deflection in a wooden ship, even in such severe conditions that the maximum shearing force is 4.16 times the calculated sagging force for the 1/15 wave, the greatest bending moment being 4.33 times that estimated for the same wave.

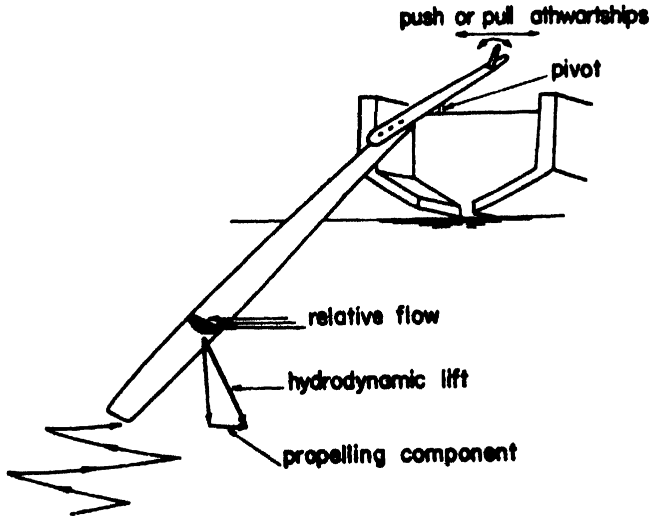


Fig. 141. Rowing scull having an ogival section to produce a propelling action

(2) Modulus of elasticity can, therefore, be assumed and the usual method for beam calculations applied. This test indicated the equivalent Young's modulus of elasticity E=197,000 lb./sq. in. (13,850 kg./sq. cm.). One of the test results is shown in fig. 143, where the computed deflection, assuming E=2,276,000 lb./sq. in. (160,000 kg./sq. cm.), is represented by broken lines.

(3) When the load was removed there was not complete recovery. The reason was not clear but it might have been permanent strains or slip in the timber and the nails.

(4) The transverse deformation at the open hold was far greater than expected, as shown in fig. 144. Transverse members, such as beams, floor timbers and bulkheads, should be carefully arranged during construction.

(5) The longitudinal deflection was only 0.4 in. (10 mm.) even though the applied stress was severer

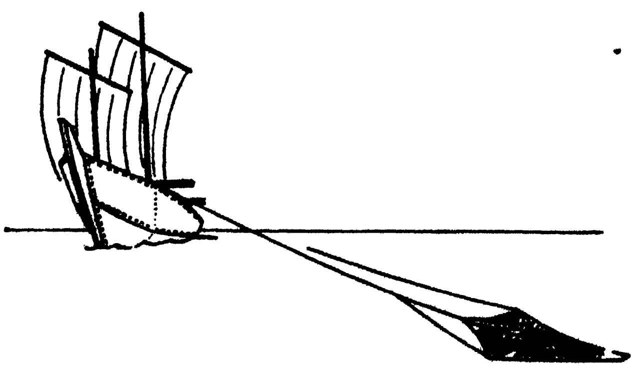


Fig. 140. Single square sails are fitted on two or three masts in the Yamato boat

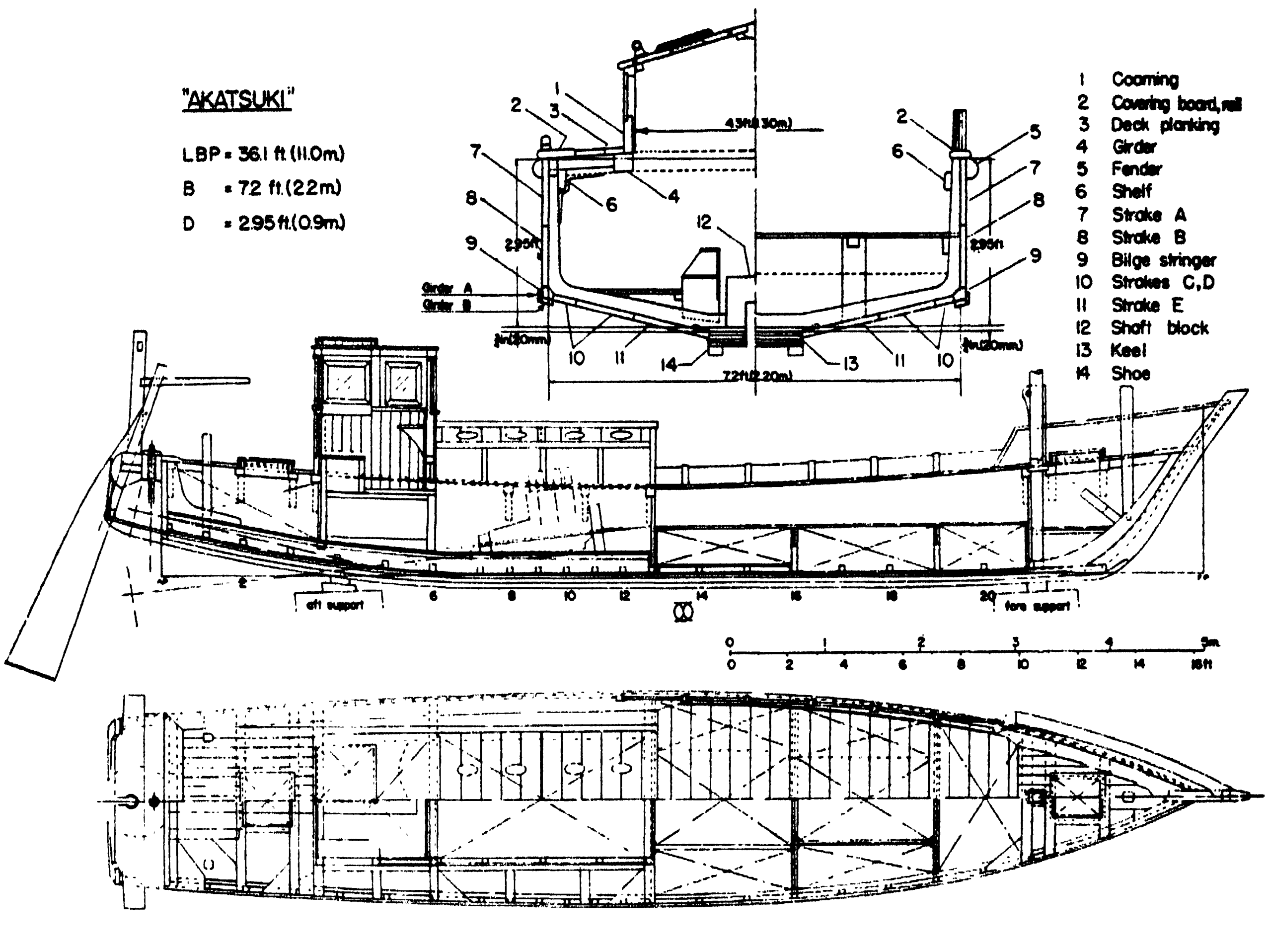


Fig. 142. General arrangement of an improved Yamato type, the Akatsuki, *with typical wide planking*

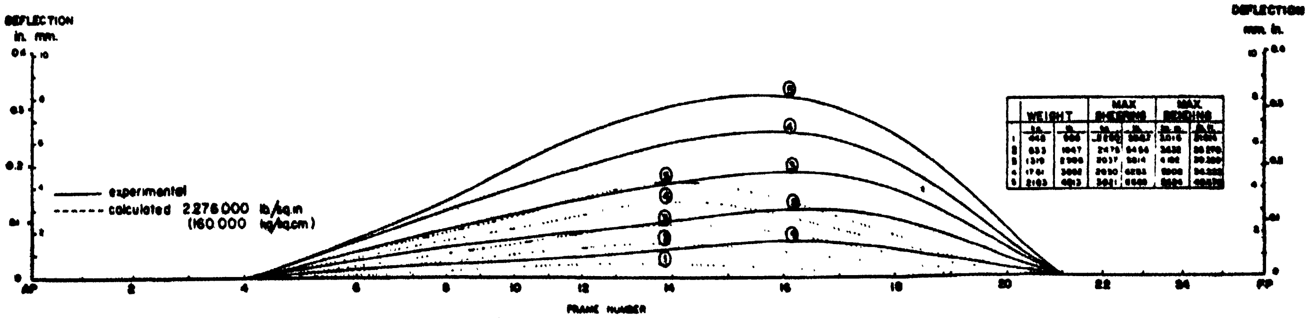


Fig. 143. Longitudinal deflection of Akatsuki

TABLE 24

Main particulars of typical Japanese small crafts

Type of boat		*Length (L)*	*Beam (B)*	*Depth (D)*	*Engine (h.p).*
Pole line fishing (skip-jack)	ft. m.	50 15.24	9 2.74	4.0 to 4.5 1.22 to 1.37	s. 30 to 50
Sailing trawler	ft. m.	45 13.72	8.5 2.59	3.5 1.07	k.d. 8 to 10
Net fishing (sardine)	ft. m.	40 12.19	5 to 9 1.52 to 2.74	4.5 to 5 1.37 to 1.52	s. 25 to 30
Small trawler	ft. m.	35 to 36 10.67 to 10.97	6.2 to 7.0 1.89 to 2.13	2.4 to 2.5 0.73 to 0.76	k. 6.5 to 8 d. 15
Sailing trawler (shrimp)	ft. m.	27 to 36 8.23 to 10.98	7 to 9 2.13 to 2.74	3.0 to 3.5 0.91 to 1.07	k. 8 d. 6 to 10 s. 10 to 15
Pole fishing (miscellaneous)	ft. m.	23 to 25 7.01 to 7.62	5.2 to 5.3 1.58 to 1.62	1.7 0.52	
Pole fishing (miscellaneous)	ft. m.	18.0 to 22.5 5.49 to 6.86	4.5 to 5.5 1.37 to 1.68	2.0 to 2.5 0.61 to 0.76	k. 5 to 6

Abbreviations: k. kerosene engine
d. diesel engine
s. semi-diesel engine

TABLE 25

Stresses in various construction members

Number in fig. 142	*Member*	*Material*	*Bending stress lb./sq.in. (kg./sq.cm.)*
2	Covering board	Zelkova	217 (15.27)
5	Fender	Cypress	197 (13.81)
6	Shelf	Zelkova	189 (13.28)
7	Strake A	Cedar	203 (14.29)
8	Strake B	Cedar	83 (5.83)
	Girder A	Cedar	62 (4.29)
	Girder B	Cedar	46 (3.20)
9	Bilge stringer	Cypress	35 (2.47)
10	Strake C	Cedar	70 (2.84)
10	Strake D	Cedar	72 (5.05)
11	Strake E	Cedar	110 (7.71)
13	Keel	Zelkova, Cypress	126 (8.87)
14	Keel shoe	Cypress	142 (9.95)

Number in fig. 142	*Member*	*Material*	*Shearing stress lb./sq.in. (kg./sq. cm.)*
1	Coaming	Zelkova	37.1 (2.61)
2	Covering board	Zelkova	5.5 (0.39)
3	Deck	Cedar	3.3 (0.23)
4	Girder	Zelkova	21.6 (1.52)
5	Fender	Cypress	21.6 (1.52)
6	Shelf	Zelkova	21.6 (1.52)
7	Strake A	Cedar	41.0 (2.87)
8	Strake B	Cedar	44.9 (3.16)
9	Bilge stringer	Cypress	21.3 (1.49)
10	Strake C	Cedar	5.1 (0.36)
10	Strake D	Cedar	11.5 (0.81)
11	Strake E	Cedar	22.6 (1.58)
12	Shaft block	Zelkova	37.0 (2.60)
13	Keel	Zelkova, Cypress	21.6 (1.52)
14	Keel shoe	Cypress	8.1 (0.57)

than would occur at sea. This seems to be due to the wide side planks and the nails along the chine.

(6) The calculated stress on each member in the severest test is shown in table 25.

The safety factors were 35 for compression, 88 for tension and 16.5 for shear. These results suggest that the structure of the Yamato type is much stronger than previously estimated and the scantlings might possibly be decreased to save hull weight. However, there must always be a margin for deterioration and easy repair.

The longitudinal strength of the type was proved to be more than sufficient, but transverse strength should be increased, preferably by means of beams or thwarts closer spaced than 6 ft. (2 m.). The easy construction will save much labour and material, but skill is needed for caulking, nailing, planking, etc.

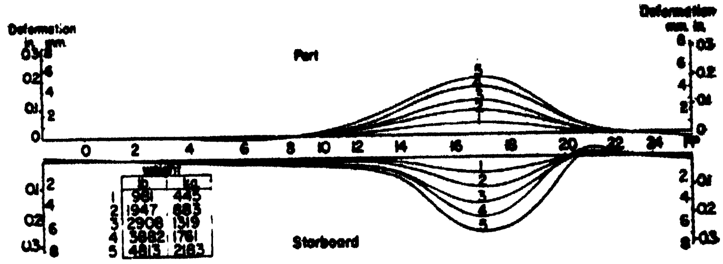


Fig. 144. Transverse deformation of Akatsuki

SUGGESTED STANDARD SCANTLINGS

by

DWIGHT S. SIMPSON

The scantlings of 22 successful fishing vessels from 50 to 150 ft. (15 to 43 m.) were investigated. As length, beam and depth are known at the beginning of construction, and final displacement and gross tonnage are more difficult to estimate, the unit load was formulated: $N = \sqrt[3]{(LOA \times B \times D/100)}$ in feet, and $N = \sqrt[3]{(LOA \times B \times D/2.83)}$ in the metric system. Due to the small variation in block and prismatic coefficients, it was considered that any difference in scantlings due to the sharpness of the vessel could be neglected. It was also assumed that the section modulus of the frames will vary as the unit load and as the square of the frame length. The frame length is related to $F = [(B+D)/2]^2$ in feet, or $F = 2.69\ (B+D)^2$ in the metric system.

Diagrams are given from which the frame sections and frame spacings can be determined from the numerals. A table recommends the plank thickness in relation to unit load and frame spacing. Similar diagrams are given for the determination of deck beams. The scantlings for keel, stem, keelsons, garboard strakes and other longitudinal members are determined in relation to the plank thickness.

A wooden ship is no better than its fastenings, and an over-fastened one is equally bad. A hole is still just a hole and subtracts from the strength of the timber. Common fastenings are discussed and formulas given for permissible loads in various types of timbers. Correct pre-boring is important. Round fastenings give better holding power than square ones, weighing 33 per cent. more. On a weight basis small fastenings have greater holding power than large ones, and they are less liable to split the wood. Hot dip galvanizing gives ferrous fastenings amazing life. Timber connectors might increase the holding power in sheer of a fastening about five times. Recommendations are given, expressing the diameter of the fastening as a fraction of the member it is to connect.

SUGGESTIONS POUR DES ÉCHANTILLONS STANDARDISÉS

On a fait des recherches sur les échantillons de 22 navires de pêche mesurant de 50 à 150 pi. (15 à 43 m.) et donnant toute satisfaction. Comme la longueur (Lht), la largeur (B) et le creux (D) sont connus au début de la construction et que le déplacement final et la jauge brute sont d'une estimation plus difficile, on a établi la formule suivante donnant la charge spécifique: $N = \sqrt[3]{(Lht \times B \times D/100)}$ dans le système d'unités anglaises, et $N = \sqrt[3]{(Lht \times B \times D/2{,}83)}$ dans le système métrique. A cause de la faible variation des coefficients parallélipipédique et prismatique, on a considéré qu'il était possible de négliger toute différence dans les échantillons due à la finesse du navire. On a aussi admis que le module de flexion des membrures varie comme la charge spécifique et comme le carré de la longueur de la membrure. La longueur de la membrure est en relation avec $F = [(B+D)/2]^2$ dans le système d'unités anglaises ou $F = 2{,}69\ (B+D)^2$ dans le système métrique.

Il est donné des diagrammes à partir desquels on peut déterminer les sections des membrures et leur espacement d'après $N \times F$. Une table recommande l'épaisseur du bordé en relation avec la charge spécifique et l'espacement des membrures. Des diagrammes similaires servent à la détermination des barrots de pont. Les échantillons pour la quille, l'étrave, les carlingues, les virures de gabord, et autres pièces longitudinales sont déterminées en relation avec l'épaisseur du bordé.

Un navire de bois vaut ce que valent les assemblages de ses différentes parties, et un excès de liaisons est également mauvais. Un trou n'est qu'un trou et retire de la résistance à la pièce de bois. Les assemblages courants sont examinés, et l'auteur donne des formules pour les charges pouvant être autorisées pour divers types de pièces de bois. Le forage des avant-trous est important. Les pièces d'assemblage rondes (clous, boulons, etc.) remplissent mieux leur fonction que les pièces carrées, qui pèsent 33% de plus. Sur la base du poids, de petites pièces d'assemblage ont une meilleure action de liaison que de grandes pièces et sont moins susceptibles de faire éclater le bois. La galvanisation par trempage à chaud assure aux liaisons de fer une durée étonnante. Les rondelles munies de dents peuvent augmenter de cinq fois environ la résistance au cisaillement d'un assemblage. L'auteur donne des recommandations exprimant le diamètre des pièces d'assemblage comme une fraction de l'élément à lier.

SUGESTIONES PARA ESCANTILLONES NORMALIZADOS

Se investigaron los escantillones de 22 barcos de pesca que medían de 50 a 150 pies (15 a 23 m.) y que habían dado resultados muy satisfactorios. Como la eslora (LOA), la manga (B) y el puntal (D), se conocen al comienzo de la construcción y como el desplazamiento final y el tonelaje bruto son más difíciles de calcular, se estableció la siguiente fórmula que da la carga específica: $N = \sqrt[3]{(LOA \times B \times D/100)}$ en el sistema de medidas británicas y $N = \sqrt[3]{(LOA \times B \times D/2{,}83)}$ en el sistema métrico. Debido a lo pequeñas que son las variaciones de los coeficientes de bloque y prismático, se creyó que se podría hacer caso omiso de cualquier diferencia en los escantillones debida a la finura del barco. También se supuso que el módulo de flexión de las cuadernas variaría como la carga específica y como el cuadrado de la longitud de la cuaderna. La longitud de la cuaderna está en relación con $F = [(B+D)/2]^2$ en el sistema de medidas británicas o $F = 2{,}69\ (B+D)^2$ en el sistema métrico.

Se dan diagramas con los cuales se pueden determinar las secciones de las cuadernas y su espaciado con $N \times F$. Una tabla recomienda el espesor de las planchas con relación a la carga específica y el espaciado de las cuadernas. Se dan diagramas análogos para la determinación de los baos de la cubierta. Los escantillones para la quilla, contraquilla, tablones de aparadura y otras piezas longitudinales se determinan con relación al espesor de las planchas.

El valor del barco de madera lo da la clavazón; una clavazón excesiva es perjudicial. Un agujero no es nada más que un agujero y hace perder resistencia al trozo de madera. Se examinan las clavazones corrientes y se dan fórmulas para las cargas autorizadas para diversas clases de madera. El barrenado exacto es muy importante. El material de clavazón (clavos, pernos, etc.) redondo es major que el cuadrado, que pesa 33% mas. Basándose en el peso, las clavazones pequeñas sujetan mejor que las grandes y la madera está menos expuesta a agrietarse. La galvanización en caliente da a la clavazón de hierro una extraordinaria duración. Las arandelas dentadas pueden aumentar hasta cinco veces la resistencia de la clavazón. Se hacen recomendaciones en las que se expresa el diámetro de la clavazón como una fracción del miembro que tiene que conectar.

WHAT reasons are there for establishing minimum standards of construction? Who benefits? The answer is: all concerned with fishing boats.

The owner can rest assured that his vessel is soundly built in accordance with the best experience, and able to withstand the hazards of her trade for a reasonable number of years with no undue maintenance costs.

The builder knows that he and his rivals are bidding on approximately the same construction, a sort of "fair practice" arrangement that should put him on his mettle to improve his workmanship as well as to watch his management and his buying methods.

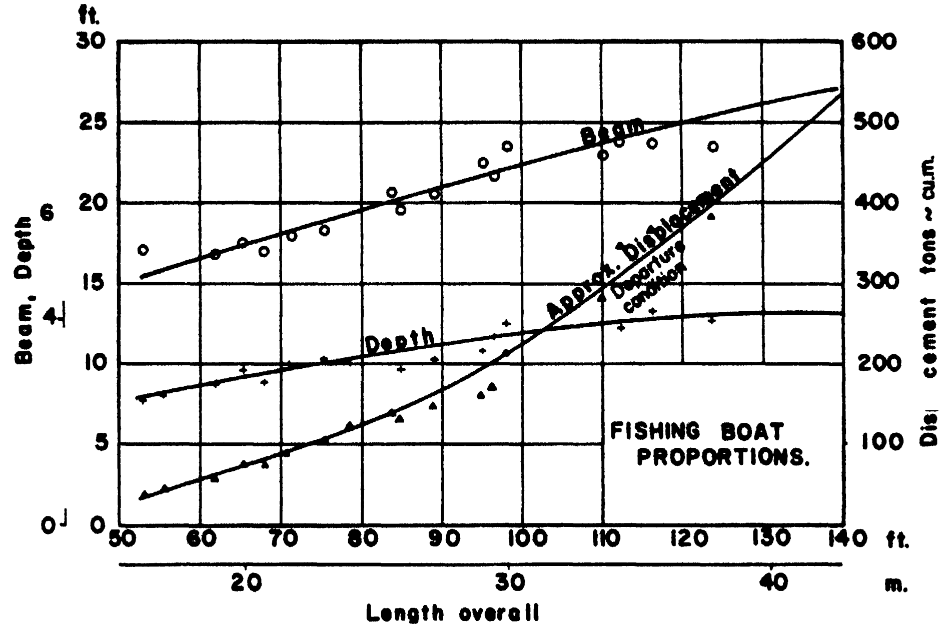


Fig. 145. Relationship between displacement, length overall, beam and depth of U.S. East coast fishing boats

The insurance companies would have more confidence in rule-built vessels and, if properly powered and equipped, such vessels should enjoy lower insurance premiums.

These ideas were brought out at a 1954 meeting of the Western Hemisphere Committee appointed by the 1953 FAO International Fishing Boat Congress in Miami. The Committee found there were so many variations in methods and countries that it decided to "start from scratch" with an investigation of a number of satisfactory fishing boats in service.

The scantlings of 22 fishing vessels, built in New England and Nova Scotia, which vary in age from 5 to 18 years and have stood up to year-around fishing from Georges to the Grand Banks, about as hard service as fishing vessels find, were selected as a base.

The designs of these "specimen" vessels represent the work of six well-known naval architects and builder-designers. Three of them are classed with the American Bureau of Shipping, three were approved by the Canadian Steamship Inspection Service, and the rest represent merely the individual designer's or builder's customary practice. They vary in length from 50 to 140 ft. (15 to 43 m.) and in proportions as in table 26.

The lowest freeboard in ready-for-sea condition varies from .32D to .45D. The higher percentage generally pertains to the smaller vessels, although the newer large vessels are approaching .4D. These relationships are shown graphically in fig. 145.

With few exceptions, keels, frames, stems, sternposts, planking and beams are of oak. Keelsons and other longitudinal members are generally of fir, with some of oak, and decks and bulkhead sheathing of pine or fir. All have ice sheathing along the forward two-thirds of the waterline and extended to the rail in way of the trawl gallows, usually 1 in. (2.5 cm.) thick of oak, but sometimes of greenheart. For typical midship section, arrangement of fastenings and nomenclature, see fig. 146.

The original analysis of this data followed closely the method used by Smith (1950) for smaller craft based on displacement. Spots were widely scattered on all methods of plotting. It was found that the displacement figures were not reliable. Many lines drawings were not available, and accurate flotation lines were almost impossible to get. Displacement figures given by designers or

TABLE 26

Proportions of investigated vessels

LOA/B	from	3.12	to	5.26	with	an	average of	4.23
LOA/D	„	6.75	„	11.06	„	„	„	„ 8.55
B/D	„	1.76	„	2.18	„	„	„	„ 1.93

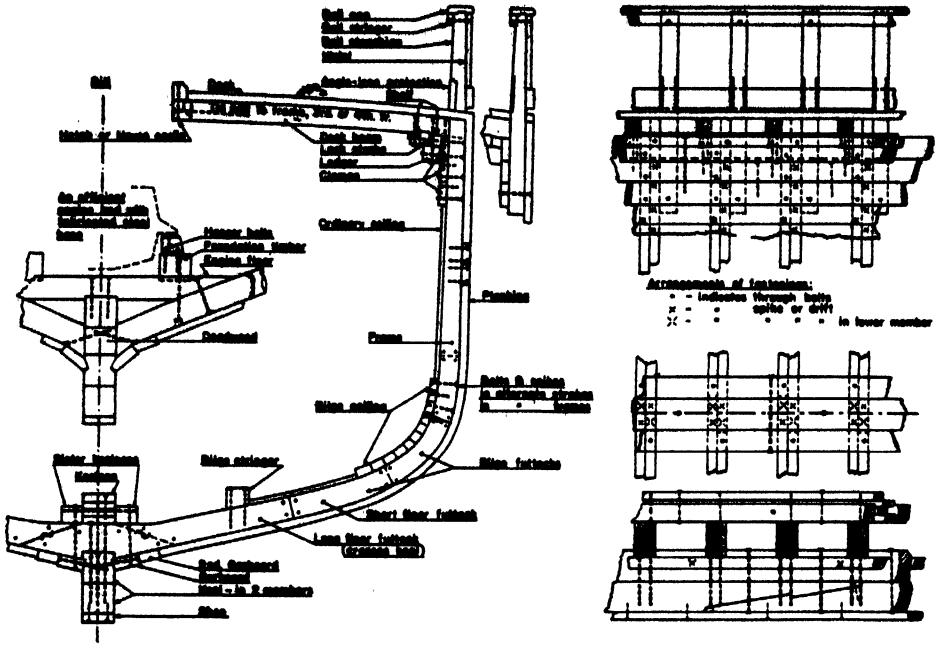


Fig. 146. Typical midship section of wooden trawler showing fastenings and nomenclature

builders differed from light to loaded and are not comparable. The use of under deck tonnage would be a sound base, but the tonnage is not likely to be known until the vessel is approaching completion; therefore it seems as difficult for the builder to use as displacement. Some other criterion had to be found.

HULL TIMBERS

Numerals

To quote Smith: "The values for frame spacing and hull plank thickness have been developed on the assumption that the primary (structural) function of the planking is to present a certain degree of resistance to lateral deflection and if sufficient to provide this stiffness, it will be more than ample to sustain its function as a principal member of the longitudinal hull girder." To which may be added the further assumption that, since this analysis is based on satisfactory existing vessels, frames and planking should be of sufficient size to withstand all the hazards of the service.

It has been suggested that frame moulding should be sufficient so that planking and ceiling, considered together, constitute a trusslike structure. Perhaps usage and survival have already developed this system. The combination of planking, bilge ceiling and frame moulding produced herein have a high stiffness factor.

Length, beam and depth are known at the beginning of construction. A cubic number based on LOA×B×D seems to be as good if not a better indication of vessel size than displacement, and has been used in this analysis.

It is recognized that a wide variation in the block or prismatic coefficients would require a modification of the scantlings, but fishing vessels in the size under investigation vary only from .420 to .500 in block and from .575 to .645 in prismatic. Within these limits scantling differences can be neglected.

Smith again proposed that "the section modulus of the

TABLE 27

Comparison of vessel factors

Line	Item	Vessel No. 6		Vessel No. 12		Vessel No. 20	
		ft.	*m.*	*ft.*	*m.*	*ft.*	*m.*
1	LOA	68.0	20.75	85.0	25.9	115.86	35.3
2	B	17.0	5.18	19.58	5.96	23.75	7.25
3	D	8.83	2.69	9.58	2.92	14.25	4.35
4	Δ_s ready for sea	78.5		125.0		367.0*	
5	LOA/B	4.0		4.35		4.87	
6	LOA/D	7.7		8.86		8.14	
7	B/D	1.93		2.10		1.66	
8	φ	0.589		0.636		0.628	
9	$\sqrt[3]{\Delta_s}$	4.27		5.00		7.17	
10	N	4.68		5.51		7.26	
11	Line 9/Line 10	0.910		0.908		0.985	
		ft.	*m.*	*ft.*	*m.*	*ft.*	*m.*
12	$\frac{1}{2}G$	14.8	4.52	17.33	5.3	22.5	6.86.
			sq. m.	*sq. ft.*	*sq. m.*	*sq. ft.*	*sq. m*
13	$(\frac{1}{2}G)^2$	———	20.4	300.0	28.7	508.0	47.2
14	B^2	289.0	26.8	383.0	35.5	562.0	52.2
15	F	167.0		212.5		363.0	
16	Line 13/Line 14	0.764		0.785		0.905	
17	Line 13/Line 15	1.32		1.41		1.41	

*Estimated

Note: It will be seen that the average of the percentages in line 16 gives a variation of −6.6 to +10.6 per cent., whereas the difference shown in line 17 is between −4.3 and +2.2 per cent. Since this holds closely throughout the list of vessels, (B+D)/2 has been used as more closely approaching the half-girth figures. Similarly, line 11 indicates only minor differences between lines 9 and 10.

frame, Z, per unit length of vessel will vary as the unit load and as the square of the frame length. The unit load can be shown to vary about as the cube root of the displacement" [for which the writer has substituted the more readily obtainable $N=\sqrt[3]{(LOA \times B \times D/100)}$ feet or $\sqrt[3]{(LOA \times B \times D/2.83)}$ metres].

Smith assumed that in smaller vessels the proportion of beam to depth remains about constant and substitutes B^2 for the square of the frame length. This would appear to put a double penalty on beam, possibly leading to narrow fishing vessels; therefore in this proposal, frame length has been related to $F=[(B+D)/2]^2$ feet, or $F=2.69\ (B+D)^2$ metric. Table 27 gives some data of vessels selected from 22 base vessels which seems to justify this assumption.

Thus, the section modulus of the frame, Z, has been determined to be $Z=0.15 \times N \times F$. This is shown graphically in fig. 147.

The frame, Z, is measured at the turn of the bilge and is considered for only one futtock of the double frame. The proportion of frame siding to moulding used is the average of the "specimens" and is very close theoretically to the section most economical in material.

Fig. 148 gives nomograms with which one can determine the frame dimension and frame spacing in feet and metres respectively from the section modulus per foot of ship's length (Z). Further, fig. 149 gives the moulding at deck and keel for a given moulding at bilge and the same siding.

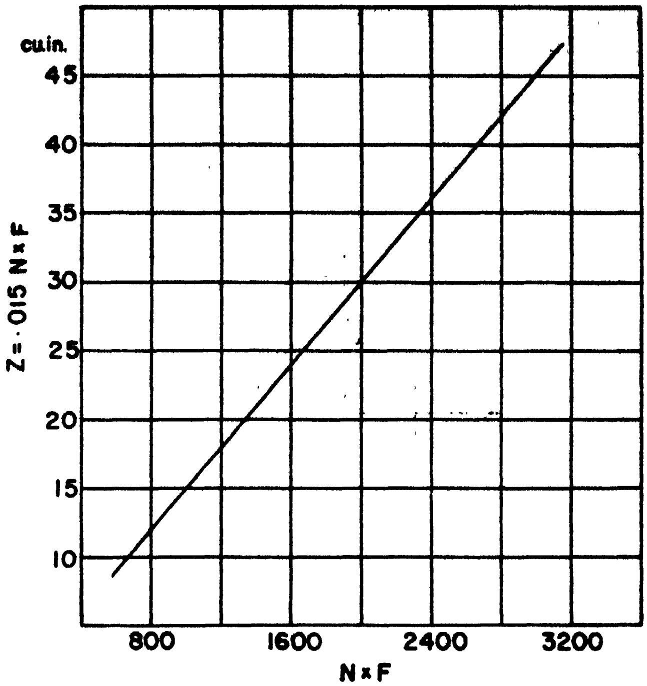


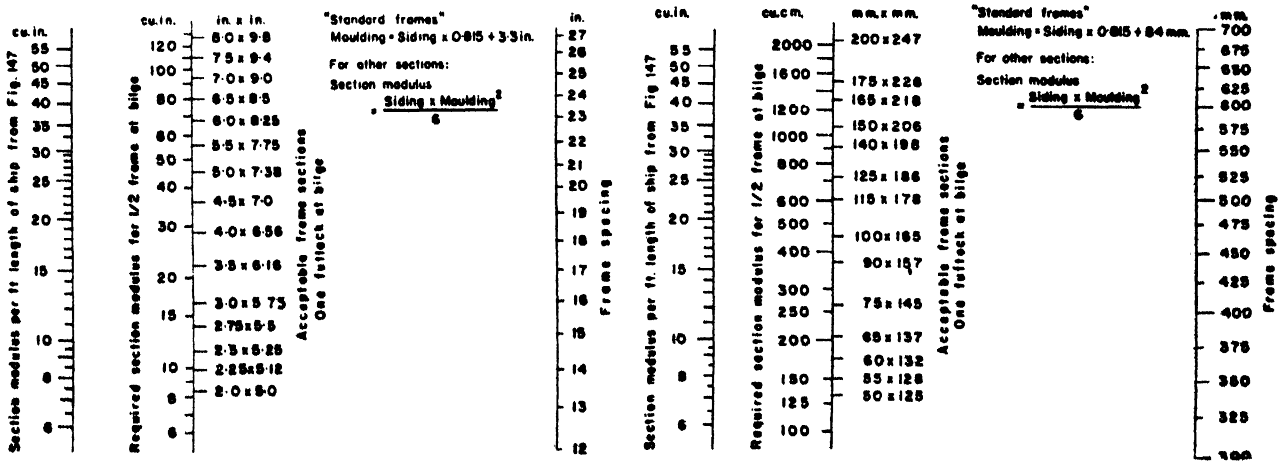
Fig. 147. Section modulii of frames

Bent frames

Too few vessels over 50 ft. (15.25 m.) with bent frames were investigated to warrant definite conclusions. The indications are that Z for a complete bent frame may be about the same as Z for a single futtock of the sawed frame. Plank thickness may also be about the same as for sawn frame construction, but frame spacing must be closer so as to leave about the same space between frames as resulted by standard sawn frames. Up to 3 or 3½ in. (76 or 89 mm.) thick frames may be bent in a single stick and should be sided and moulded the same. If a greater Z is required, the frame should be in two or more parts laid on top of each other, with the total moulding about 1.5 times the siding.

Planking

Smith developed his plank thickness, t, on the theory that deflection is constant and that load varies as the planking area, s. By simplification, $(t/s)^3$ varies as $\sqrt[3]{\Delta}$. While this is sound theory, in practice the fact remains that no New England or Nova Scotia trawler has planking more



(A). *Scantlings of frames (inch units)*

Fig. 148

(B). *Scantlings of frames (metric units)*

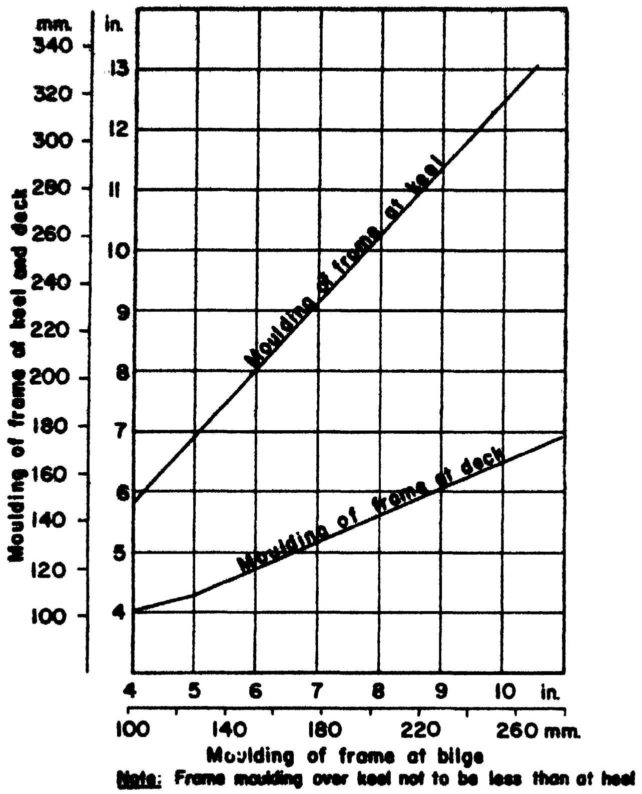


Fig. 149. Moulding of frame at deck and keel in relation to its moulding at the bilge

than 3 in. (76 mm.) nor less than 1½ in. (38 mm.) thick. Examination of the examples shows that the space between frames (frame bay) varies only between 9 and 12 in. (229 to 305 mm.). In other words, the actual support of the plank depends very little on the size of the ship. However, the larger vessels obviously subject a greater load on the planking and its fastenings and it is therefore assumed that plank thickness varies as the N.

There are a number of vessels between 110 and 120 ft. (33.5 and 36.5 m.) with 2¾ or 3 in. (70 or 76 mm.) planking, and it is assumed that 3 in. (76 mm.) is the correct thickness for the median 115 ft. (32 m.) boat corresponding to N of 7.00. Another group of about 70 footers (21 m.) average 2 in. (51 mm.) planking for N of about 5.00.

Table 28 has been developed on this assumption and shows, in addition, the standard frame spacing associated with any N and plank thickness.

It should be noted that all U.S. East Coast fishing vessels have their planking reinforced at the critical areas. A narrow belt of 1 in. (25 mm.) sheathing of oak or greenheart is carried along the waterline from the stem to the aft trawl gallows and it is extended clear to the rail below the trawl gallows. Further protection is provided at the gallows by half oval strips or ⅛ in. (3.2 mm.) steel sheets. This sheathing is easily replaced when necessary and protects the planking from damage by ice, trawl doors, etc.

Deck beams

Fig. 150 and 151 give scantlings for the deck beams, based on a similar analysis as described for the frames. Spacing is generally the same as for the frames and this is assumed in determining the deck thickness factor.

Deck camber can be considerably greater than usually designed. For several years the writer has used a camber of between 0.4 and 0.5 in. per ft. (33 and 41 mm. per m.) with satisfaction to the crews.

Bulkheads

There are two construction types:

(a) double diagonal sheathing, with painted or treated fabric between the two layers and stiffeners on one side;

(b) two thicknesses of tongue and groove planking, with the stiffeners (and insulation) between

In very few cases is there any real attempt to make the bulkhead-skin connection watertight. Experience proves that it can be done, although at considerable expense. Vessels would undoubtedly be safer with bulkheads better than "reasonably watertight". It is doubtful if any wooden vessels would float for very long if seriously damaged, but to make them watertight in even a one-compartment class standard would, except in the very large ships, impair their fishing efficiency.

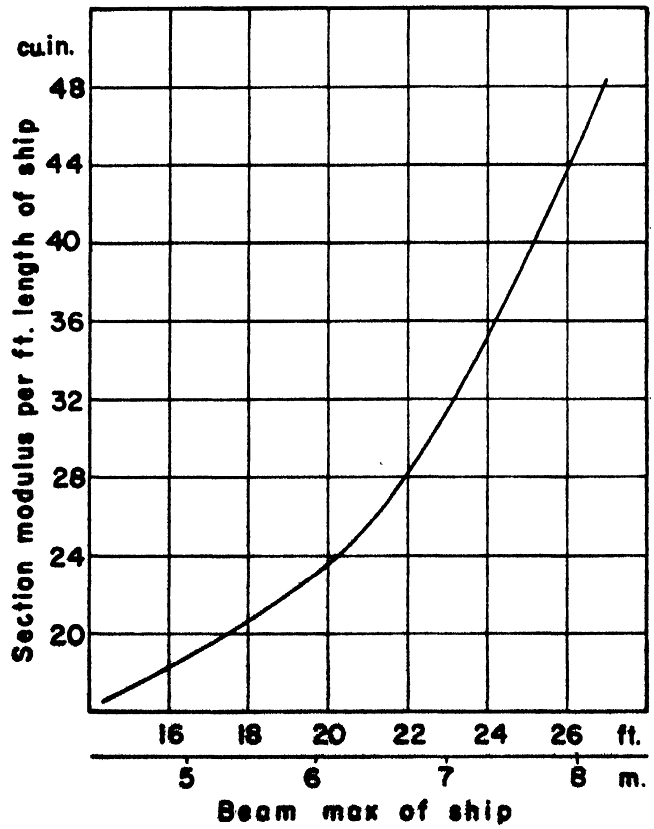
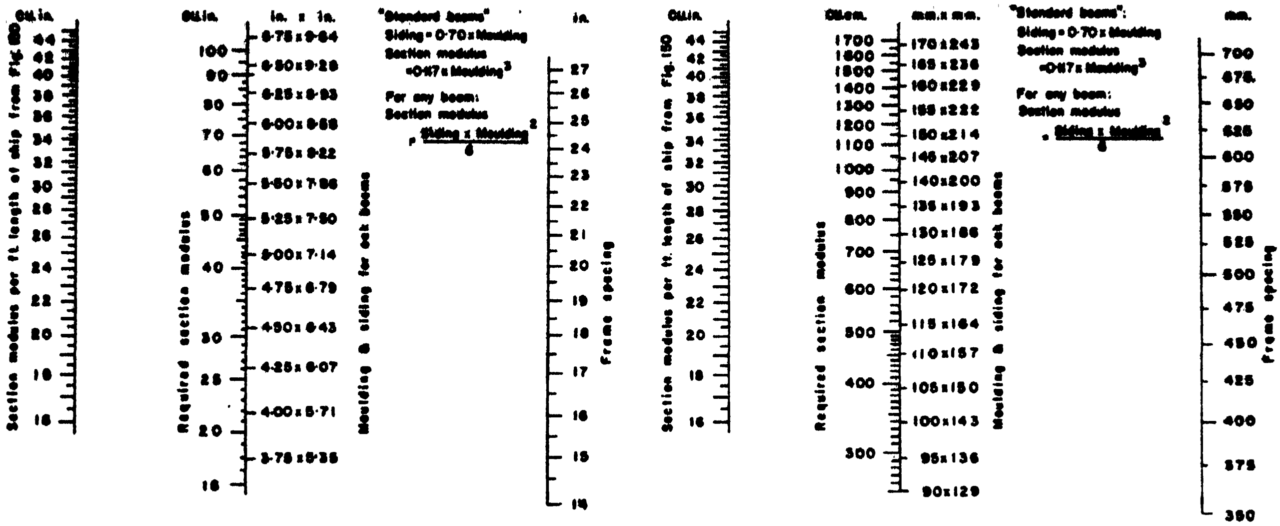


Fig. 150. Section moduli of deck beams



(A). *Scantlings of deck beams (inch units)*

(B). *Scantlings of deck beams (metric units)*

Fig. 151

To make the bulkhead tight at the planking, stop-waters are required in all the butts of the frame futtocks; stop-waters in all the longitudinal joints on both sides of the bulkhead and caulking between the stop-waters; gaskets between planking and frame, and between ceiling and frame; and caulking of the bulkhead chine log.

Keels, stringers and other longitudinals

The suggested scantlings are based on mathematical averages worked from the "specimen" vessels and on the principal longitudinal member—the planking. The siding and moulding of the keel are determined as follows:

- Keel siding is based on practice over many years
- Keel moulding is based on plank thickness, which varies as $\sqrt[3]{\Delta}$, which again varies in relation to length
- In addition to contributing to the longitudinal strength, the keel is the chief contributor to drift resistance (when hauling in the net, for instance). Steel boats, even with a relatively small bar keel, do not handle nets as well as wooden boats with their relatively deep keels (Simpson, 1951)

For details see heading: Determination of scantlings.

Laminated construction

Since World War II, glued laminated timber construction has advanced enormously and vessels up to 165 ft. (50 m.) in length have been completely laminated, and with a great saving in weight for, perhaps, greater strength. However, it is an expensive method and still rarely used except in military vessels. It is the author's opinion that material specifications are much more stringent than necessary (a laminated vessel requires more basic timber than a normal sawn construction ship), but even if much less material were used, the labour costs would be too high for fishing vessel construction.

TABLE 28

Standard frame spacing and plank thickness

	Frame spacing		*Plank thickness*	
N	*in.*	*mm.*	*in.*	*mm.*
4.00	12	305	1½	38
4.25	13	330	1⅝	41
4.50	14	356	1¾	44
4.75	15	380	1⅞	48
5.00	16	406	2	51
5.25	17	432	2⅛	54
5.50	18	457	2¼	57
5.75	18	457	2⅜	60
6.00	19	483	2½	64
6.25	20	508	2⅝	67
6.50	21	533	2¾	70
6.75	22	559	2⅞	73
7.00	22	559	3	76
7.25	23	584	3⅛	79
7.50	24	610	3¼	83
7.75	25	635	3⅜	86
8.00	26	686	3½	89

Timber grading

There are numerous lumber association specifications for various species of timber, and each has its own grade specification covering the requirements for "select", "structural", "No. 1 common", "No. 2 common", and so on. The skilled shipwright will ignore most of these, knowing that in any given pile of timber of any species or any grade he can find both suitable and unsuitable ship timber. A crooked log that the millwright would pass over with scorn might be exactly the thing that would save the shipwright many hours of labour, as well as material, rather than produce an inferior item from straight stock.

To quote from a memorandum prepared during World War II: "The *actual piece of timber* to be used must be

TABLE 29

Some properties of shipbuilding woods in order of preference

Resistance to rot
1 Live oak
2 Greenheart
3 Juniper
4 Cypress
5 Cedar, white, yellow
6 White oak
7 Yellow bark oak
8 Mahogany
9 Grey oak
10 Yellow pine (dense)
11 Douglas fir (dense)
12 White pine (Eastern)
13 Sweet gum
14 Hackmatack
15 Mahogany (Philippine)
16 Douglas fir (average)
17 Larch (Western)
18 White pine (Western)
19 Beech
20 Ash (white)
21 Elm
22 Red oak
23 Maple, birch
24 Spruce

Ability to hold fastenings
1 Beech
2 Sugar maple
3 White ash
4 Yellow birch
5 Teak
6 Iron bark
7 Live oak
8 Greenheart
9 White oak
10 Yellow bark oak
11 Grey oak
12 Red oak
13 Sweet gum
14 Elm
15 Larch (Western)
16 Yellow pine (dense)
17 Douglas fir (dense)
18 Cypress
19 White pine
20 Port Orford cedar
21 Spruce

Paintability
1 Mahogany
2 Mahogany (Philippine)
3 Cedar
4 Oak
5 Cypress
6 White pine
7 Spruce
8 Teak
9 Fir
10 Yellow pine

Steam bending
1 Ash (white)
2 White oak
3 Red oak
4 Elm
5 Beech
6 Birch
7 Yellow pine
8 Cedar

Glueability
1 White pine
2 Sitka spruce
3 Mahogany
4 Douglas fir
5 White oak
6 Red oak
7 Yellow pine

satisfactory for the purpose intended and the specific inspection is more important than the general approval of any species or grade of lumber".

All recommendations in this paper are based on the timbers in use in New England and Maritime vessels—oak, fir and pine. There has not been time to relate these, in variable terms, to other timber more readily available in other regions. Table 29 might make comparisons easier.

Plywoods

Plywoods of the marine waterproof type have been used in bulkhead sheathing, in crew quarters and in deckhouse construction. The builder should be cautioned that the weak point in all plywood is the edges, which should be well painted just before being secured in place.

There are many excellent formulae for plywood construction but, in practice, three thicknesses seem to be sufficient—$\frac{3}{8}$ in. (9.5 mm.) for interior sheathing; $\frac{3}{4}$ in. (19 mm.) for bulkheads and house tops, and $\frac{3}{4}$ in. or 1 in. (19 or 25 mm.) for deckhouse exteriors. Fig. 152 shows a practical stiffener spacing.

Wood preservatives

While not contributing to the immediate life or safety of the vessel, experience has proved that, when used in strategic places, a preservative of some sort greatly prolongs the life of the structure. Creosote and tar derivatives should not be used as they seem to affect the quality of the fish. Even brush coatings of copper naphthanates, and probably others, have been successful over a number of years. Needless to say, the coating should be applied after the final fitting and just before securing the members. Faying surfaces of frames, scarphs, heads and heels of frames, deadwoods and the upper surfaces of beams are especially benefited.

DETERMINATION OF SCANTLINGS

For a new vessel, it is only necessary to know the basic dimensions—length, breadth and depth, as previously defined.

1. *Numerals:* ● feet system

$$N = \sqrt[3]{\frac{LOA \times B \times D}{100}} \quad = ?$$

$$F = \left[\frac{B+D}{2}\right]^2 \quad = ?$$

● metric system

$$N = \sqrt[3]{\frac{LOA \times B \times D}{2.83}} \quad = ?$$

$$F = 2.69(B+D)^2 \quad = ?$$

▶ $$N \times F \quad = ?$$

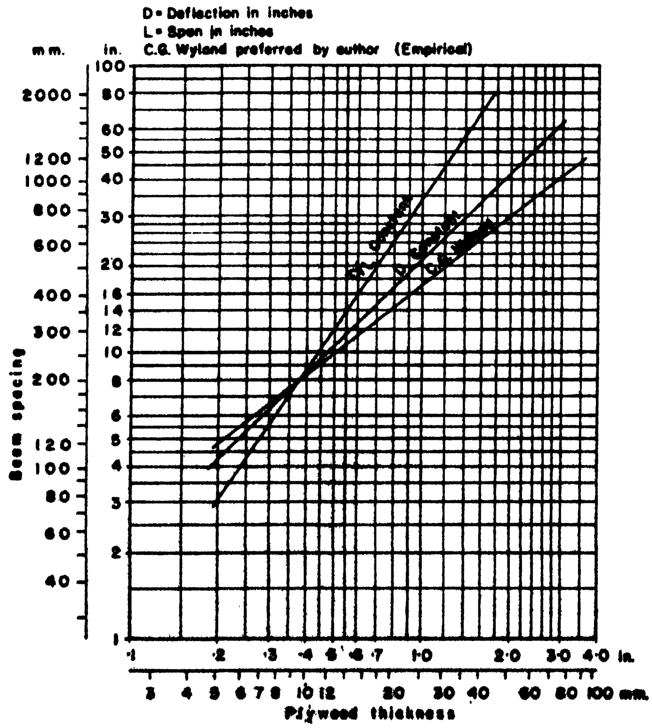


Fig. 152. Practical spacing of stiffeners

2. *Frame spacing and plank thickness:* Select the standard frame spacing (to the nearest ½ in. = 12.7 mm.) and plank thickness (to the nearest ⅛ in. = 3 mm.) from table 28.

3. *Frame dimensions:* (a) Take out Z = section modulus of frame futtock for the calculated N × F from fig. 147.

(b) Connect Z with standard frame spacing on fig. 148 for feet or metres respectively and read dimensions for standard frame. Interpolate if necessary. If slightly thicker or thinner frame stock is more readably available, shift index line to suit and read new frame spacing. Return to table 28 and select plank thickness to suit.

(c) Take out frame moulding at head and heel for selected frame moulding at bilge from fig. 149.

4. *Deck beams:* (a) Take out section modulus per foot of ship's length for given B from fig. 150.

(b) Proceed as in operation 3, using selected frame spacing on fig. 151. In theory, the moulding of beams can be reduced as much as 20 per cent. at their ends. Siding can be reduced when beam length is less than ¾B. Increase siding 40 per cent. for hatches, partners, breaks, etc.

5. *Other scantlings:* Are related to the thickness, t, of the standard planking.

Keel, stem and deadwood: Sided 4 × t. Moulded 8 × t. For very full deckline, the upper part of stem may require an apron piece to give sufficient rabbet width.

Keel shoe: 2½ to 4 in. (63 to 102 mm.) depending upon the length of the vessel.

Keelsons: Sided and moulded 4 × t.

Sister keelsons: Sided 3.2 × t. Moulded 0.8 × siding or 2.56 × t. Not used—in vessels shorter than 90 to 95 ft. (20 to 29 m.) LOA.

Stern post and shaft log: 1.8 × keel siding, or 7.2 × t; not less than 3 × shaft diameter.

Garboard strake: 1.5 × t; 3 to 4 × t in width.

Second garboard (when fitted): 1.2 × t.

Clamps: Sided 1.25 × t. Moulded 6.75 × siding (moulding in 2 or 3 strakes).

Shelf: Moulded 1.82 × t. Sided 2.5 × moulding.

Lock strake: One of shelf members ¾ in. (19 mm.) deeper.

Lodger: Sided and moulded 2 × t (fitted in vessels longer than 90 ft. or 27 m.).

Bilge ceiling: Sided 1.25 × t. Total moulding 13 × siding, should overlap butts of short futtocks at turn of bilge.

Decking: White pine, generally same thickness as planking but not less than 2 in. (51 mm.).

Rough deck: Spruce, ¾ in. (19 mm.) in all vessels. Laid on working deck to protect structural deck (fastened with short nails).

Bulkhead sheathing: Pine or fir, same total thickness as t of planking, laid in two layers.

Bulkhead stiffeners: $D^2/10$ × spacing gives a reasonable figure for Z. Moulding = $\sqrt[3]{0.8Z}$, siding = 0.6 M.

Where D is depth of hull as before in feet
Z is section modulus
S is siding
M is moulding
Spacing in feet.

Rail or bulwark stanchions: Sided and moulded same as frame at head; buried to lower edge of clamps. (About half the "specimen" vessels have one frame futtock extended through the deck to form a stanchion. Better practice is to make the stanchion entirely separate as above, secure it by two bolts extending through planking and ceiling. Such stanchions can be replaced without damage to the frame and the head of the frame is protected from leaks in the deck caulking.)

Following this recommendation, the scantlings of the three vessels in table 27 as built and as recommended have been listed in table 30.

FASTENINGS

Fastenings are more difficult to handle than the wood members, as definite mechanical stresses on ship joints are impossible to calculate. Again one must rely on what has proved sufficient. In addition, basic knowledge of the mechanical properties of various types of fastenings will be of help in developing reliable standards. A wooden ship is no better than its fastenings, and it is well to remember that an over-fastened structure is as bad as an under-fastened one—and more expensive. A hole bored for a fastening is still just a hole, and subtracts just that much from the area of the timber, hence from its section modulus, etc. Fastenings placed too close together may, therefore, actually weaken the structure, as will too large fastenings.

The proposed scantlings unquestionably allow for deterioration over the life of the vessel, and fastenings which may be weaker than the timbers connected will then be sufficient for the deteriorated timber of some future date.

Scarphs and fishplates

Originally end joints were merely butted, then strengthened by overlapping pieces known as fishplates. In many places, the fishplate could not be used and the scarph was developed, and is still essential in longitudinal members of fishing vessels—keels, keelsons, clamps and shelves—and sometimes in topside planking and bilge ceiling, although it is of doubtful value there, in relation to expense.

The standard scarph is of the nib-ended hook type, fig. 146, with a length of 5 to 6 times the depth of the timber and with all faying surfaces snugly fitted. Where keelsons, sister keelsons and shelves are built of several relatively thin members, a plain scarph may be used in the individual members. In many existing vessels these joints are simply butted, but this is not good practice.

Metal fishplates are still used to reinforce the joint between keel and sternpost heel and in similar conditions. Here they are usually of the double fishtail pattern, set flush into the wood.

Treenails

Treenails, throughnails or "trunnels", which are various names for wooden dowels, used for all ship fastenings

30

Vessel No.		6		12		20	
			m.	*ft.*	*m.*	*ft.*	*m.*
LOA			20.75	85.0	25.9	115.86	35.3
B		17.0	5.18	19.58	5.96	23.75	7.25
D		8.83	2.69	9.58	2.92	14.25	4.35
N		4.68		5.51		7.26	
F		167		212.5		363	
N × F		783		1,170		2,635	
Z for frames		11.50		17.5		39.3	
Z for beams		19.4		22.8		34.3	
Z for bulkhead stiffeners		11.65		13.8		30.8	
Scantlings		*As built*	*Proposed*	*As built*	*Proposed*	*As built*	*Proposed*
Plank thickness	in.	2½	1⅞	2¼	2¼	3	3⅛
	mm.	63	48	57	57	76	79
Frame spacing	in.	16	15	18	18	20	23
	mm.	405	380	455	455	507	583
Frame, sided	in.	3	2⅞	3½	3¾	5	6¼
	mm.	76	73	89	95	127	159
Frame, moulded head	in.	4¼	4¼	5	4¾	5½	5¾
	mm.	108	108	127	120	140	146
Frame, moulded bilge	in.	5¾	5½	7½	6¼	7½	8½
	mm.	146	140	191	159	191	216
Frame, moulded heel	in.	7	7½	9	8¼	10	1
	mm.	178	190	228	210	254	–
Beam, space	in.	18	15	18	18	20	23
	mm.	457	381	457	457	508	585
Beam, moulded	in.	5½	5¾	6½	6½	8	
	mm.	140	146	165	165	203	21
Beam, sided	in.	4	4	4½	4½	5	5¾
	mm.	101	101	114	114	127	146
Keel	in.	9 × 18	7½ × 15	9 × 20	9 × 18	12 × 24	12½ × 25
	mm.	228 × 457	190 × 381	228 × 507	228 × 457	305 × 610	318 × 635
Keel shoe	in.	3	2½	3½	3	4	4
	mm.	76	63	89	76	101	101
Keelson	in.	8 × 10	7½ × 7½	10 × 8	9 × 9	12 × 12	12½ × 1
	mm.	203 × 254	190 × 190	254 × 203	228 × 228	305 × 305	318 × 31
Sister keelsons	in.	—	—	—	—	7 × 7	10 × 8
	mm.	—	—	—	—	178 × 178	254 × 203
Sternpost and log	in.	17	13	—	16¼	22	22
	mm.	432	330	—	413	560	560
Garboard strake	in.	2½	2 15/16	3	3⅜	4	4⅝
	mm.	63	74	76	85	101	117
Second garboard	in.	—	—	—	—	—	3⅞
	mm.	—	—	—	—	—	99
Clamps	in.	2½ × 16	2⅜ × 13½	2½ × 16	2⅞ × 19½	4 × 24	3⅞ × 26
	mm.	63 × 407	60 × 343	63 × 407	73 × 495	101 × 610	98 × 660
Shelf	in.	4 × 9	3⅞ × 8½	4 × 7	4⅛ × 10	4 × 12	5¾ × 14
	mm.	101 × 228	98 × 216	101 × 178	105 × 254	101 × 305	146 × 355
Lock strake	in.	3 × 5	2½ × 4½	—	2½ × 5	4 × 5	4 × 6¼
	mm.	76 × 127	63 × 114	—	63 × 127	101 × 127	101 × 159
Lodger	in.	—	—	—	—	6 × 6	6¼ × 6¼
	mm.	—	—	—	—	152 × 152	159 × 159
Bilge ceiling	in.	2½ × 30	2⅜ × 32	2½ × 48	2⅞ × 38	3 × 48	3⅞ × 50
	mm.	63 × 762	60 × 812	63 × 1,218	73 × 965	76 × 1,218	98 × 1,270
Decking	in.	2¼	2	2¼	2¼	3	3
		57	51	57	57	76	76
	in.	—	⅞	—	1⅛	1½	1½
			22	—	29	38	38
	in.	—	2¾ × 4½	—	2¾ × 4¾	—	3¾ × 6¼
	mm.	—	70 × 114	—	70 × 121	—	95 × 159

long before metal fastenings were developed, are occasionally still used, but it is believed that they have no place in modern, high-powered vessels.

Metal fastenings

There have been many experiments to determine the holding power of various types of fastenings, such as wood screws and lag screws, cut nails and wire nails, spikes and drifts, both round and square, bolts, patent fastening aids, glues, etc. The following is a brief review of the results.

A load may be applied laterally to the fastening, tending to break down the wood fibre and/or bend the fastening; or it may be applied lengthwise of the fastening, tending to draw it out of the wood. Most ship fastenings must resist a combination of the two loadings.

TABLE 31

Working loads for fastenings

Type of fastening	*Lateral loading*	*Loading in withdrawal*
Nails and spikes	$P_n = K_n D^{3/2}$	$P = 1{,}380\ G^{5/2} D$
Screws	$P_s = K_s D^2$	$P = 2{,}850\ G^2 D$
Lag screws	$P_1 = K_1 D^2$	$P = 1{,}800\ G^{3/2} D^{3/4}$

Where P gives safe working loads in lb. (to obtain kg. divide by 2.2)
G is the specific gravity of timber
K is a coefficient based on specific gravity of timber
D is the diameter of the fastening in inches (to obtain mm. multiply by 25.4)

The basic factors that determine the holding power of any fastening are: the specific gravity of the wood and its moisture content; the diameter and penetration of the fastening; its relation to the grain of the wood (whether driven parallel or perpendicular to the grain), its fit and, of course, the type and material of the fastening.

The common design formulae for the various fastenings are given in table 31. Table 32 shows the required figures for the more common woods used in American shipbuilding.

Preboring for fastenings

For anything but the smallest nails, preboring reduces the tendency to split the wood and adds somewhat to the holding power. Boring should be done with a sharp tool, preferably of the twist drill type. A dull bit leaves a rough hole, reducing the contact surface and, therefore, the holding power. In heavy timber, holes are generally bored $\frac{1}{16}$ in. (1.6 mm.) smaller than the fastening. Better practice would vary the holes to suit the type of timber and the size and type of fastening. A bolt, for instance, needs only a slip fit, while a spike or drift requires a tighter fit as its holding power depends entirely on friction.

For screws in lateral resistance, the holes in soft woods should be 85 per cent. of the diameter of the shank and root of the thread. In hardwoods, the ratio is 100 per cent. In withdrawal, the holes for the thread should be about 75 per cent. of the root diameter and about 90 per cent. of the shank diameter. Lubrication slightly increases the holding power of screws and lags, but has the reverse effect on nails, spikes and drifts.

Plank fastenings

The author made a series of tests in 1933. All fastenings were galvanized and sized as near as possible to a No. 14 screw. They were driven into Maine oak frame stock, using the same size holes as if planking a vessel. They were all 2¼ in. (57 mm.) long and driven into the oak 1⅝ in. (41 mm.).

They were first pulled to the giving point; then an attempt was made to determine what holding power was

TABLE 32

Specific gravities and coefficients of woods

Group	*Species*	*G*	K_n	K_s	K_1	G^2	$G^{3/2}$	$G^{5/2}$
1	Cedar, white .	0.32				0.102	0.181	0.058
	Pine, white . .	0.37	1,040	2,520	1,800	0.137	0.225	0.084
	Spruce, Sitka .	0.42				0.176	0.272	0.114
2	Cedar, Alaska .	0.44				0.194	0.292	0.128
	Cedar, Port Orford	0.44	1,350	3,240	2,040	0.194	0.292	0.128
	Cypress . .	0.48				0.230	0.333	0.160
	Hackmatack . .	0.56				0.314	0.419	0.235
3	Fir, Douglas .	0.51				0.260	0.364	0.186
	Larch, Western .	0.59	1,650	3,960	2,280	0.348	0.453	0.267
	Pine, yellow .	0.64				0.409	0.512	0.327
	Beech .	0.64				0.409	0.512	0.327
	Birch .	0.66				0.435	0.536	0.354
	Oak, red	0.66	2,040	4,800	2,640	0.435	0.536	0.354
	Oak, white	0.71				0.504	0.598	0.425
	Locust .	0.71				0.504	0.598	0.425

$P_n = K_n D^{3/2}$ based on depth of penetration not less than ⅔ length of nail or spike in soft woods and ½ in hardwoods
$P_s = K_s D^2$ based on penetration of not less than 7 × diam. of shank of screw
$P_1 = K_1 D^2$ based on penetration of 11 × diam. of lag screw shank in Group 1; 9½ × diam. in Group 2; 8½ × diam. in Group 3 and 7 × diam. in Group 4 woods.

The figures are based on prebored holes and with the fastenings driven perpendicular to the grain of the wood. When driven parallel to the grain, use 75 per cent. of P for screws and lags and 60 per cent. of P for nails, spikes and drifts.

Nails, spikes, drifts and screws should not be used in withdrawal condition in end grain. Lags may be so used, taking P at 60 per cent.

These figures are based on dry timber and bright steel fastenings. Fastenings driven into green timber have less holding power after the timber has seasoned.

Composition nails and spikes have less holding power than formula and should not be used unless clenched or made with grooved shanks. Galvanized fastenings have somewhat less holding power when first driven but, in moist timber as found in shipbuilding, after two or three months, the holding power is somewhat better than formulae.

left after the fastenings had been drawn 1/4 in. (6.4 mm.).

Boat nails gave suddenly at widely different values: 400, 500, 675 and 800 lb. (180, 225, 310 and 360 kg.) and held very little; 0 to 200 lb. (0 to 90 kg.) at 1/4 in. (6.4 mm.) exit.

Hatch nails started quite uniformly at 625 lb. (280 kg.), gave gradually and held about a uniform 225 lb. (102 kg.) at 1/4 in. (6.4 mm.) exit.

No. 14 screws started at 1,200 to 1,350 lb. (545 to 610 kg.), gave gradually and held 450 to 500 lb. (204 to 226 kg.) at 1/4 in. (6.4 mm.) exit.

Later some composition nails with a variety of corrugations were tested under the same conditions and showed about twice the resistance as hatch nails—in other words, about the same as screws of the same size. Still later, tests on bronze drift bolts of 3/4 in. (19 mm.) diam., with ratchet type grooves, showed the same excellent results.

Another result of these tests was to confirm the repairman's practice of replacing a fastening, once drawn, with a new fastening of slightly larger size.

Round v. square fastenings

Table 33 is taken from one of the many test reports concerning the holding power, in withdrawal, of round and square drift bolts. Note that the round and square rods of the same dimension (diameter or face), each in its own most efficient bored hole, have practically the same holding power. However, the square rod weighs 33 per cent. more than the round rod and it is, therefore, more economical to use the round rod. The author's own tests showed the same thing, i.e., round fastenings are better and cheaper.

Large v. small fastenings

It is sometimes overlooked that, on a weight basis, small fastenings have greater holding power than large ones, whether they be nails, drifts, screws or lags. This property is especially valuable where the length of fastening is limited. Also several small fastenings may be less liable to split the wood than, say, two large ones of the same holding power.

Galvanized v. non-ferrous fastenings

The advantages or disadvantages are frequently discussed. It is well known, of course, that a copper nail has little holding power unless the end is "clenched". However, bronze screws have many devotees who speak vilely of galvanized fastenings.

In theory, the non-ferrous metal is less subject to corrosion than galvanized metal and a good bronze screw can be driven harder than a galvanized one with less danger of breaking. However, non-ferrous metals are often chosen unwisely and two slightly differing compositions can be spoiled by electrolysis.

The life of hot dip galvanizing is sometimes amazing. The author has a planking spike, removed from an eighteen-year-old vessel with a yellow pine planking and oak frame. The plank was soft but the spike was hard to draw and, although its galvanizing is a bit discoloured, it is perfectly fit to be used again. Even much older fastenings are known to be in good condition.

The galvanized fastening cements itself into the wood after a few months, and its holding power, in withdrawal, is then considerably greater than the formulae figures. Conversely, for a month or two, as the wood seasons, the strength is somewhat lower. In an explosion, in which some planking was blown off the top-sides of a vessel, it was noted that most of the planking spikes were still firmly planted in the oak frames. Their heads had been pulled through the mahogany planking. This also calls attention to another advantage of the hatch nail: its head is much larger than that of boat spikes.

TABLE 33

Ultimate holding power per inch [25.4 mm.] penetration

1 in. [25.4 mm.] diam. round bolt

Diam. bored hole	in.	15/16	14/16	13/16 20.6	12/16 19.05	*Penetration*
Yellow pine parallel to grain	lb. kg.	200 91	280 127	344 156	222 101	14 in. (356 mm.)
Yellow pine perpendicular to grain	lb. kg.	375 170	633 288	788 358	400 181	14 in. (356 mm.)
White oak parallel to grain	lb. kg.	617 280	817 370	1,033 469	867 393	11 in. (279 mm.)
White oak perpendicular to grain	lb. kg.	1,200 543	1,778 810	2,500 1,135	1,133 514	11 in. (279 mm.)
		1 in. [25.4 mm.] [illegible]				
Yellow pine perpendicular to grain	lb. kg.	710 322	777 352	675 306	—	

Note that the round bolt in its most efficient bored hole, 13/16 in. (20.6 mm.), has practically the same holding power as the square bolt in its most efficient hole, 14/16 in. (22.2 mm.), yet the round bolt has only two-thirds the weight of the square one.

The obvious economy in using round drifts applies also to round hatch nails for planking and decking.

TABLE 34

Standard wood screws, practical gauge, length limits

Practical length:
← 1½ in. (38 mm.) — (gauges 5 to 11)
← 2 in. (51 mm.) — (gauges 7 to 11)
← 2½ in. (63 mm.) — (gauges 9 to 11)

		5	6	7	8	9	10	11
Gauge		5	6	7	8	9	10	11
Diameter D	in.	0.125	0.138	0.151	0.164	0.177	0.180	0.203
	mm.	3.2	3.5	3.8	4.2	4.5	4.6	5.2
D^2	sq. in.	0.0156	0.0190	0.0228	0.0269	0.0313	0.0325	0.0412
	sq. mm.	10.1	12.3	14.7	17.4	20.1	21.0	26.5
Root diam.	in.	0.098	0.105	0.115	0.121	0.129	0.141	0.151
	mm.	2.5	2.7	2.9	3.1	3.3	3.6	3.8
Head diam.	in.	0.2421	0.2684	0.2947	0.3210	0.3474	0.3737	0.400
	mm.	6.2	6.8	7.5	8.1	8.8	9.5	10.2

Practical length:
— 1½ in. (38 mm.) → (gauges 12 to 14)
— 2 in. (51 mm.) → (gauges 12 to 16)
— 2½ in. (63 mm.) → (gauges 12 to 18)
← 3 in. (76 mm.) → (gauges 12 to 20)
← 3½ in. (89 mm.) → (gauges 14 to 20)
← 4 in. (102 mm.) → (gauges 18 to 24)

		12	14	16	18	20	24
Gauge		12	14	16	18	20	24
Diam. D	in.	0.216	0.242	0.268	0.294	0.320	0.372
	mm.	5.5	6.2	6.8	7.5	8.1	9.5
D^2	sq. in.	0.0467	0.0586	0.0718	0.0864	0.1024	0.1384
	sq. mm.	30.1	37.8	46.3	55.7	66.2	89.5
Root diam.	in.	0.161	0.178	0.200	0.226	0.245	0.270
	mm.	4.1	4.5	5.1	5.7	6.2	6.9
Head diam.	in.	0.4263	0.4790	0.5316	0.5842	0.6368	0.7421
	mm.	10.8	12.2	13.5	14.8	16.2	18.8

About two-thirds of the screw length is threaded. For best results the shank of the screw should be started into the foundation member. Lubrication makes easier driving with no effect on holding power.

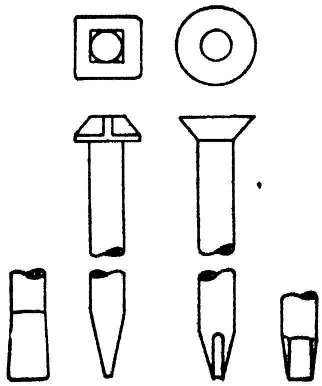
Resistance to withdrawal in the direction of driving

Drifts have the least resistance to withdrawal in the direction that they were driven, some tests giving about 60 per cent. of the resistance shown in retraction. Fortunately, the head formed on long drifts during the process of driving greatly counteracts this difference. Short drifts should have small heads formed before driving. Spikes and drifts should be driven at least twice the thickness of the fastened member into the foundation member.

In practice, when drifting tiers of members such as keelsons, through floors to keels, and edge fastening of ceiling, clamps etc., the fastening is driven through the fastened member, the adjacent member and at least two-thirds of the depth into the third member. The hole bored through the fastened member should be little tighter than a slip fit.

Type of fastening point

The author's tests confirm the general experience that the pointed end of spikes and drifts should be in the form of short tapered cones, with the end little smaller than the bored hole, see fig. 153. A long taper, either in a cone or chisel point, is likely to split the wood, and the length of the point has no holding power. The tests covered long chisel-pointed square spikes, and it was found that in



A B

Fig. 153. A: ship spike, B: hatch nail. A and B have the same holding power per unit length of penetration, however galvanized hatch nails B weigh about 70 per cent. of the galvanized spike. The bearing area of the head of A is only 65 per cent. of that of B. The blunt double tapered point of B is less apt to split the wood or to be turned by hard grain than the chisel point of A

yellow pine, particularly, the long taper would catch against the hard grain, carrying the spike so far to one side that an arc of the bored hole was untouched. This not only destroys holding power, but could be a source of leaks.

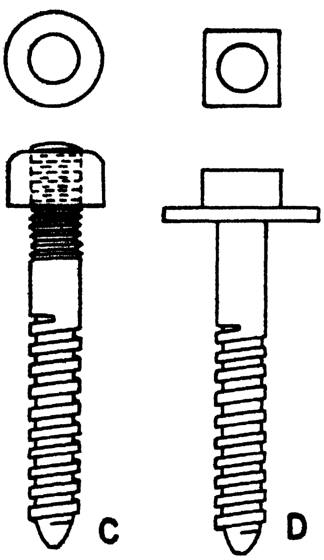


Fig. 154. C: hanger bolt, D: lag screw. While the holding power of D is much greater than that of either A or B, the bearing area of the head of D is 79 per cent. of A and only 40 per cent. of B. A washer must be used under the head when bearing on wood. D should not be used when its frequent removal is foreseen. C should be used for holding metal to wood where adjustment or replacement is foreseen

A short chisel point is the next best to the blunt cone. It should be driven with the chisel edge across the grain of the member most likely to be split.

Wood screws

Table 34 shows the practical limits of gauges and lengths, particularly for hard woods and with properly sized prebored holes. Nickel-bronze screws of larger size can be used without danger of breaking. Screws should not be started with a hammer and should not be over driven. Power screw drivers are prone to this error unless in very skilful hands. While screws are often used to draw members together, this is bad practice—clamps do a better job.

Screws should be driven to full depth of the thread into the foundation member for best results in withdrawal, and slightly more for lateral strength.

Screws are said to damage the wood slightly for a short distance and should, therefore, in soft wood be spaced not less than ½ in. (12.7 mm.) across the grain, nor less than 1 in. (25.4 mm.) along the grain, when driven perpendicular to the grain. For No. 10 and larger screws, these figures should be doubled, and for hard wood another ½ in. should be added to all figures. A slightly smaller spacing may be used when driven parallel to the fibres. Spacing from the edge should be not less than 3 diameters.

Lag screws

Lag screws, generally, may be treated as large wood screws, fig. 154D. Preboring should provide a hole for the shank of the same diameter and depth as the shank. For the threaded portion the hole should be equal to the length of the threaded portion. The guiding figures are:

In oak or similar hard woods—65 per cent. to 85 per cent. of the shank diameter

In Douglas fir or Southern pine—60 per cent. to 75 per cent. of the shank diameter

In pine, cedar or spruce—40 per cent. to 70 per cent. of the shank diameter

The larger percentages apply to the larger sizes.

If the use of lag screws in end grain is unavoidable, then 60 per cent. of the values for P should be used.

Lags should not be driven nor even started with a hammer.

Where it is possible that a fastening may be removed, such as in realigning an engine or replacing a damaged fitting, hanger-bolts should be used instead of lags, fig. 154C. Once withdrawn, a lag should be replaced with a larger size.

Bolts

Through fastenings may be made by riveting over clinch rings or by threaded nuts—the latter being much the better method. Bolts should be galvanized after the

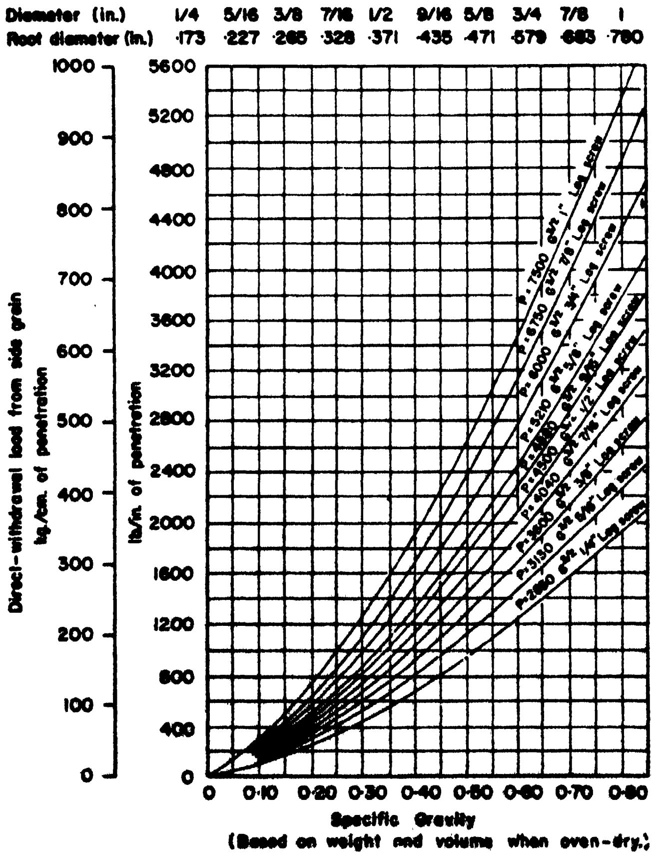


Fig. 155. Holding power of lag screws

threads are cut, and due allowance should be made for this when cutting the threads. The threaded nut, particularly when fitted over a heavy washer, can be used to draw the members together and to take up the slack due to inevitable shrinkage. Clinch rings can do neither very well, and a loose clinch ring has no value.

Bolts should be of the carriage or T head type, with a square under the head to prevent turning.

The bored holes should provide an easy driving fit.

Where fittings are bolt fastened, the washer should be in one plate, taking all the bolts wherever possible. This makes the fitting almost one with the wood to which it is fastened.

There are many tables giving strength values for bolts in various conditions, and it is not a subject to deal with in detail in this paper. Generally, by using heavy and large washers, bolts can be stressed to the safe values of the metal and the thread root diameter.

Fittings and foundations

Chainplates, cleats, pad eyes and machinery should be secured by through bolts wherever possible. Wherever lags or screws must be used, they should have the maximum length, and the values of P in the formulae for lateral resistance can be increased by 25 per cent. when the fastening is parallel to the grain.

Timber connectors

Timber connectors in a variety of shapes and patents and much used in land structures, greatly increase the lateral strength of timber joints. The author made extensive use of them during World War II to join members of keels, keelsons, shelves and frames of a hundred or more salvage vessels, subject to extraordinary stresses in their day's work. Some of these vessels, almost unstrained, survived experiences that broke up vessels of normal construction.

Connectors of the split ring type have been used in keel and keelson members of some of the larger U.S. wooden trawlers. However, the double assembly required makes their use rather costly and probably unwarranted for smaller fishing vessels. Further information can be found in the literature. The holding power in shear of a 4 in. (102 mm.) split ring connector in conjunction with its ¾ in. (19 mm.) diam. bolt is about 5 times that of the bolt alone.

TABLE 35

Fastenings

Tack bolts for keel and keelson members, scarphs, etc.:	Keel siding × 0.085
Frames to keel (2 drift bolts):	Siding of frame member × 0.175
Keelson, through frames to keel (2 drifts):	Siding of frame member × 0.216
Sister keelsons through keelson; sister keelsons through frame to garboard:	Moulding × 0.1
Garboard to keel (alternate frame bays); garboard to frames:	Thickness of garboard × 0.171
Clamps to frames (1 bolt, 1 spike):	Siding of frame × 0.142
Ceiling to frames (1 bolt, 1 spike):	Siding of frame × 0.135
Lodgers; to frames and beams:	Largest dimension × 0.15
Beams to clamps:	Siding of clamp × 0.25
Planking to frames (2 hatch nails to frame):	t (plank) × 0.18 Length = 2.4t if bunged, 3t if flush
Deck to beams:	Diam. = t × 0.125 Length = 2t
Ice sheathing to planks:	Long enough to penetrate ½ to ¾ main planking

[measurements in inches]

Notes

All fastenings should be galvanized, preferably by hot dip.

Round plank fastenings (hatch nails) are much more effective than square spikes.

Bolts should have washers under both head and nut wherever possible. Heavy drop forged washers are more effective than thin punched washers.

When it is necessary to draw a fastening, the replacement should be 1/16 to ⅛ in. (1.6 to 3.2 mm.) larger.

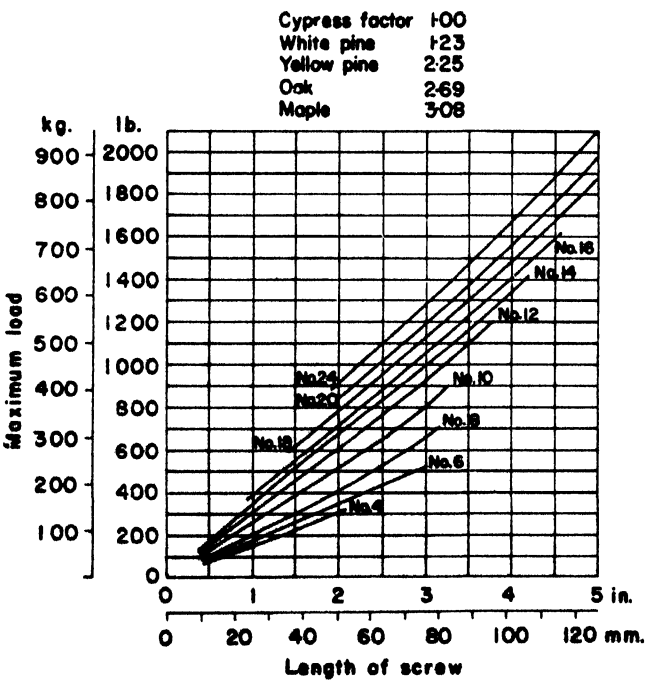


Fig. 156. Holding power of wood screws

Glue joints

The use of laminated wood and glue fastening in vessel construction is rapidly advancing in many countries, having started about the end of World War II. Glues in numerous varieties, and with almost unbelievable properties, are available. Even metal surfaces can be "stuck" together with ultimate tensile strength of upwards of 5,000 lb./sq. in. (350 kg./sq. cm.).

The method had its inception, ostensibly, in an effort to conserve the ever-increasing scarcity of timber. However, material specifications are so stringent that 165 ft. (50 m.) non-magnetic mine-sweepers built for the U.S. Navy, although very successful vessels, are said to require some 20 per cent. more standing timber than if built in the orthodox manner.

The equipment for satisfactory gluing is extensive and expensive and labour costs are rather high, so that this type of construction is as yet not economic for commercial production. Nevertheless, the progressive builder will do well to keep informed of developments in this field.

Determination of fastenings

From the vessels listed, plus other partially complete data available, the mathematical "average" has been established and "standards of practice" proposed in table 35.

SCANTLINGS — DISCUSSION

MR. J-O. TRAUNG (FAO, Rapporteur): The relevant papers concerned with scantlings were Gurtner's paper on surf boats, Beach's on small outboard motor craft, and Ringhaver's on mass production of shrimp trawlers.

Gurtner adopted bent frames in a small boat which is subjected to great stresses when landing on a beach because bent frames for that purpose give stronger construction for a given weight. Beach's paper is interesting in that it shows how boats can be made today with marine plywood, especially in countries where the cost of labour is high. Ringhaver's paper on shrimp trawlers shows bent frame construction but much lighter scantlings than given in Simpson's recommendations. This shows that when weather conditions are less severe the boats can be built lighter.

Good boatbuilding practices

MR. H. I. CHAPELLE (U.S.A.): Bent frames were now more economical and the sizes and types of North American fishing boats made this type of frames highly desirable.

It was his belief that bent frames should be thin and wide, rather than square in cross section, to avoid damage to the grain in bending or over steaming and resulting brittleness and breakage. Red oak had proved reasonably satisfactory. Green or nearly green stock seemed to be effective, steaming and caulking apparently preventing rot.

Floors ought to be placed on top of bent frames. Floors should have two long arms made of sawn plank on top of the frame, bolted at keel centre-line and joined by a common plank floor timber. They should be spaced every third or fourth frame and common short plank floors, if necessary, fitted on top of the intermediate frames. Experience had shown that this produced a strong and rigid bottom.

Hard bends in the frames require lamination, or splitting the frame. Split frames to be secured by the plank fastenings.

Stiffening of the topsides should be done by the use of deep shelves at least in the midbody and by hanging knees at central points of support. Locking knees might also be used occasionally.

Frame spacing of the wide, thin bent frames may be greater than with square frames of the same cross-section. The wide frame gives better planking support by its greater bearing surface.

He considered square fastenings, boatnails and spikes, superior to round ones, but they require great care in boring and driving.

Rot was an important problem. Formerly, impregnation with creosote or copper naphthalate was recommended but now a simple brush treatment was used to sterilize the timber and this seemed to destroy fungi and add 5 to 7 years of life at small cost. Salt was a very useful preservative, placed outside the clamp on stops inserted between frames. This could prevent mould and fungi for a very long period, 10 to 15 years. Experience suggests that it is best to build boats of timber native to the area in which a boat will be used, as native timber appears to have some greater resistance to local fungi, compared to imported stock.

Ventilation was very important but very difficult to accomplish. Deckwood should be formed to avoid pockets, creosoted if possible, and openings in bulkheads left for ventilation. Openings in ceiling and framework for this purpose were necessary.

Painting the bilge area should never be done in a wooden boat, it encourages rot in the vicinity of frames, floors and even in the planking.

Rail stanchions should never be part of or joined to the frames. It is practically impossible to prevent breakage of stanchions sooner or later. They should be placed between the frames and fastened to the clamps from inside the hull. This makes replacement easy and prevents or delays rots in topside timbers or framing.

The use of steel engine bedcaps is desirable, particularly with a heavy engine. Strapping and fish plates are useful. To prevent condensation forming and rot resulting these should be bedded in tar or asphalt and tarred felt or paper.

U.S.A. rules and experience

MR. H. C. HANSON (U.S.A.): Loadline scantling rules were established primarily for large cargo ships of steel construction. Most of these vessels have a full square midship section and a parallel mid body. The U.S. Coast Guard and ABS rules state that: "Where the frame obtains additional strength from the form of the vessel, due allowance is to be made to the value of the coefficient." So some thought was given to the shape of the hull when the rules were written, but no consideration is given in actual practice. Therefore, such rules work to the disadvantage of vessels other than of the square section type.

Applied to smaller wooden vessels, such rules become very unfair as most wooden vessels, especially those with smaller dimensions, gain their greatest strength through their deadrise, which makes the lines of the vessel fore and aft fairer, rising quickly towards the ends. There are seldom more than two to four identical frames. Such a hull shape is much stronger than one with a flat bottom. He had obtained measurements of the hog in the keels of various vessels, which showed that the flat bottom craft invariably hogs, whereas the vessels with a deadrise remain straight for many years. One vessel operating now is 60 years old and had retained her original shape. Any rule that does not take into consideration the hull shape is not correct according to his experience and judgement.

Other construction features are necessary for the wooden vessel to keep its shape for years. The steel vessel relies on its shell plating for its longitudinal strength; on its floors for its transverse. The wooden vessel for cargo purposes and for really heavy weather relies for its fore and aft strength on strength members, such as the bilge ceiling, side ceiling, clamps and shelves and bulkheads. It does not depend on its planking, although the planking, if properly fitted, will give considerable longitudinal strength when new. The planking to give strength must fit wood to wood, and to do this small caulking seams must be used.

During World War I much timber was wasted by improper use in the tremendous wooden ship building programme. Some seemed to believe that merely by putting timber into the vessel strength would be added. If a little more time and thought had been spent during design, much of the natural resources would have been saved and wooden ships would have had a better standing. This was also true during World War II, but to a much lesser extent because there were not so many large wooden vessels built.

At the end of World War I, some designers used double diagonal planking inside the regular planking to provide greater longitudinal strength. However, nothing came of it. During World War II, the Navy used this system in the wooden minesweepers. These vessels were not designed for carrying cargo and had no inside strength. They were of bent oak frame construction; they had deadrise and good shape, but were not strong enough for carrying cargo. Once these vessels are recaulked in the customary method, they will gradually lose their original strength and are not to be compared with orthodox methods of wood construction with the strength built into the ceiling.

One of the older vessels built along this order was the *Roosevelt*, built especially for Arctic exploratory work. The hull had curvature all ways, fore and aft and transversely. The construction was by the double planked fore and aft method and the vessel was apparently designed for bruising against the ice rather than for great longitudinal strength. Nominal ceiling was used, but the vessel held her shape to the very end of her career, due undoubtedly to the hull shape. She was about 35 years old when wrecked.

The tuna vessels built on the Pacific coast are an example of the vessels holding their shape due to hull design, in spite of the fact that many were not properly built in terms of good ship construction. They could be called satisfactory as most of them did not hog at all. As long as they were used for tuna work and retained their many watertight bulkheads, they were satisfactory, but without bulkheads they could not be called good vessels. Only in rare instances were they built with heavy long floors.

Good lumber necessary

It is very important when building a wooden vessel to be careful when selecting lumber. With rot-resistant woods, such as yellow cedar, few troubles will arise. If one is unable to obtain rot-resistant wood in quantities to build all the upper part of the vessel, then it should be used in those members where rot mostly occurs, so that if a repair job is necessary, the main frame can be saved and repairs be made economically. The important members that are usually subject to decay are the frame heads, the rim timbers, covering boards around the frame heads, and above the rims. In fact, wherever fresh water leaks occur, rot will commence. Deck planking is easily replaceable so it is not so important to have rot-proof woods there, but the house coamings are susceptible.

Years ago fir was easily obtainable near the salt water, so cutting in winter was easily done. However, in later years, say, since World War I, cutting of timber spread away from the sea and is now largely done in the summer. This means that the logs are never stored in salt water but only in fresh water, for some period. If they do, they will have a good start towards decay even before being cut into lumber. Also, since the logs are cut in the summer, the sap is up: winter is the best time for cutting trees.

Yellow cedar grows at the snow line and its annular grain set-up is very narrow, showing its fight to live. So in the selection of lumber for boat building, it is always best to use the logs with the very narrow annual rings. Second growth timber should be avoided as much as possible as this has not attained mature growth, usually having the wide rings.

All lumber used should be free from large knots, sap, pitch pockets, decay or other imperfections that would render it unsuitable for the wood building purposes. All lumber should be air-seasoned. As a minimum, the keel, keelsons, deadwoods and frame timbers should be seasoned for from 30 to 60 days; the ceiling, beams, bilge stringers, shelves and clamps, waterways for from 60 to 90 days; the topside planking, beams, coamings and the like from 90 to 120 days. Spacing sticks should be used so that air can circulate all around timbers and the ends protected so that they are not sun or air checked.

Usually it is best to use ironbark for the stem, gripe, forefoot, stern post and the like, and in case of a cruiser stern, the lower rim should be of ironbark.

Oak is by its very nature full of moisture and it takes a long time to dry, so it is very difficult to determine the life of this wood. If oak comes in contact with other woods, it induces decay through the moisture from it. Mr. Hanson had had success with steam-bent frames, by painting the frame with preservative such as cuprilignum before steaming, but the oak was fairly dry when used and did dry after being bent to shape. This type of frame was used for minesweepers.

Preservatives should be used on all faying surfaces, between the ceiling edges, the back of ceiling facing the frame, face of frame when dubbed, faying surfaces between frames, back of planking, and so on. Preservatives should coat the outside of the wood as well as penetrate it. Any preservative, such as creosote, that is placed over the wood forming a coating, is harmful as moisture will collect under this coating and rot will occur.

Caulking

One important aspect in the construction of wooden vessels that is guided by the "hand-me-down" system is in the caulking of the vessel. Reference can always be found in the old publications and writings relative to the use of "hawsing beetles". This is a large wooden maul with a handle about 3 ft. (0.9 m.) long. The Navy Wooden Boat Manual 250-336 includes it as recently as 1948 as a guide. After the regular caulking has been done by hand, the seams are then gone over by two men, one with a hawsing iron and the other with powerful blows to set the caulking up. Mr. Hanson long ago had come to the conclusion that wherever possible the use of this hawsing beetle should be prevented. It has been his creed to see that in all the vessels that he had to deal with, whether in the design or the building, the seams should be made as small as possible and only hand caulking used. The reason for this is that the caulker has better "feel" and co-ordination with the smaller caulking mallet and, because of that, can place the oakum and cotton in the seams more evenly, throughout the length of the seam. This is very important because when driving with the large beetle this simply cannot be regulated. All blows by this method are different: one may be 50 lb. (23 kg.), the next 60 lb. (27 kg.), and then one may be

75 lb. (39 kg.), and wherever the heaviest blow is made, it spoils the work done before and the stage is set for seepage into the seams. This would not be so bad under water, in salt water, but on deck where fresh water comes and goes, it will not be long before rot starts. This is one of the main causes for maintenance costs in wooden vessels. He had seen the caulkers at the drydocks immediately take this beetle and start on the stern posts and exposed deadwoods. They will drive the hawsing iron up to the hilt into the seams and spread the seams sometimes as much as ¾ in. (19 mm.) wide: this, in a seam that was wood to wood when built, just naturally destroys the vessel in time.

Mr. Hanson for years had insisted that the seams in any boat of his design be made as small as possible, and on hand caulking only, making the planking wood to wood at least half the depth. This he had adhered to, and vessels such as the *Penguin*, *Brown Bear*, *Lester Jones*, *Patron*, *Northwestern*, and many others, never had to be caulked. The only reason that they finally came to the caulking phase was because of the "beetling" process commonly used in the drydocks. This creates additional work for the drydocks, but he thought that this method was used only because that is the way they have seen it done and continue to do it.

Further U.S.A. practice

MR. H. I. CHAPELLE (U.S.A.): He agreed with Hanson in practically all matters, particularly so where deadrise affects strength. Longitudinal strength is lacking in many wooden boats today. Improper construction design causes this. Diagonal planking, or diagonal strapping of the hull, are rarely seen and are considered costly and, with the introduction of steam bent frames in large fishing boats in the East coast of U.S.A. thought was given to the design of structure particularly in this matter of longitudinal strength. With regard to the *Roosevelt* he believed she originally had longitudinal strength members that were removed after her usefulness in Arctic work was ended. She was very carefully designed by experienced shipbuilders, he was informed.

The Woods Products Laboratory, U.S. Department of Agriculture, had informed him that excessive steaming or boiling of steam-bent oak frames produces brittleness in some degree and that use of wood preservative before steaming is not recommended. To avoid the first it is necessary to use young and not thoroughly seasoned oak, apparently.

Over caulking is very common in repair yards. A new vessel ought to have little or no driven caulking but U.S. yards seem to have lost the skill in fitting required, to a steadily increasing degree.

A great deal of Western Fir has been used in the East of U.S.A. since the beginning of World War II. It is a strange thing reconsidering the good record of this timber on the West Coast that Western Fir has gained a poor reputation in the East. Extensive and rapid rotting has occurred, obviously far more destructively in East coast boats than in Western craft. There was much trouble with Eastern built fir vessels in the Army and there has also been so in more recently built Eastern boats in spite of the use of preservatives. A similar situation has been found in boats built of materials of the Canadian Maritime Provinces when Canadian built boats are brought to Southern New England and to the Middle Atlantic States. These boats were of superior workmanship and material was carefully selected, but rot was both rapid and far-reaching. Mr. Chapelle therefore agreed with the Department of Agriculture suggestion that there are advantages in employing timber native to the area in which a boat is used.

Australian practice

MR. ARTHUR N. SWINFIELD (Australia): From what he could gather, overseas construction does vary quite a deal from usual Australian ideas of construction; but so does the type and species of timber, along with climatic conditions. These last two factors dictate the builder's approach to building commercial vessels—hence no doubt the difference in design.

Almost every wooden commercial vessel in Australia is built of hardwood, with the possible exception of planking and decking; these could be of Oregon, but in many cases are of medium hardwoods. The term "hardwood" relates to many approved types of eucalyptus, most of which weigh in the vicinity of 55 to 65 lb./cu. ft. (880 to 1,040 kg./cu. m.) at 12 per cent. moisture content. These timbers are naturally heavy to handle, hard to work, and hard to bore for fastening. However, they "take" steam well, do not crush under fastenings, and produce very strong and durable frame work.

For many years steam-bent frames have been used exclusively—so that it is unusual to see a sawn frame vessel at any time—regardless of dimensions. Laminating becomes accepted practice in any frame over 1⅜ in. (35 mm.) thick, depending, of course, upon the sectional shape of the vessel.

Boat builders prefer bent frames of flatter section to those used overseas. His personal conclusions are that, from a practical angle:

- A wider timber (frame) gives more room for reeling or staggering of fastenings
- In spite of the fact that its modulus is reduced (by its very shape) it loses less strength from boring of fastenings than would a narrow, thicker frame
- Collapse and fracture are not so prevalent at significant points of stress
- Lamination is always reverted to as required and presents no problem

Referring to the general construction of a wooden vessel, drift bolts are seldom (if ever) used in any vessel; screw bolts are always preferred: bilge ceiling as known overseas is not used; bulkheads are regarded with seemingly greater importance; edge fastening of garboards is rarely used; planking is thinner; bent frames are closer spaced; all fastenings are copper and are through fastened.

Stringers occur at "floor" tops, bilge, and half way between bilge and clamp—always "on their flat" and through fastened with copper screw bolts through planking and bent timbers.

It is in the last remark that he found a most significant detail when considering flat sectioned frames—as against a deep or square sectioned bent frame. So often does one find a bent frame practically cut in halves by the very fastenings that go through or into it—so that unless the frame is made wide enough to take the actual fastenings (stringers or plank fastenings), all talk of modulus becomes mere theory.

How often does the repair man lift a stringer (particularly in the way of the bilge) only to find the bent frames fractured just where they are most needed, and this very often is due to the very fastenings themselves. True enough, a vessel is as strong as her fastenings, but fastenings can in truth, by their very size, prove weak links, particularly in deep sections.

All plank fastenings are copper through fastenings, either riveted (rooved) or turned over. A combination of both is sometimes used. Square copper nails are used exclusively, and all nails are driven through bored holes.

Another aspect of design, deserving special consideration, is that relating to the fastening of the covering board which to his way of thinking is always a possible source of trouble. So often one notices the top strake used as the "chopping block"

TABLE 36

Cubic content of timber for wooden fishing boats as compared with Simpson's
Volumes in cu. m. for 1 m. (3.28 ft.) length midship section

Boat No.	Timber	Simpson's proposal	New England trawlers (no regulations): As built	New England trawlers: Percentage of difference from Simpson's	Bureau Veritas (France): As built	Bureau Veritas: Percentage of difference from Simpson's	Danish Regulations: As built	Danish Regulations: Percentage of difference from Simpson's	Swedish Regulations: As built	Swedish Regulations: Percentage of difference from Simpson's	Newfoundland Rules: As built	Newfoundland Rules: Percentage of difference from Simpson's	Hanson's Scantlings: As built	Hanson's Scantlings: Percentage of difference from Simpson's
6 20.75 m.	Oak	1.120	1.250	+ 11.6	1.376	+22.8	1.570	+40.0	1.470	+31.2	1.368	+22.01	1.314	−17.45
	Pine	0.260	0.294	+ 13.1	0.340	+30.8	0.352	+35.4	0.336	+29.2	0.293	+12.7	0.260	Nil
	Oak and pine conv. to oak	1.336	1.495	+ 11.9	1.659	+24.2	1.863	+39.5	1.750	+30.09	1.612	+20.7	1.531	−14.6
12 25.9 m.	Oak	1.564	1.556	− 5.1	1.960	+25.6	2.242	+43.7	1.970	+26.3	2.122	+36.0	1.910	−22.2
	Pine	0.334	0.334	Nil	0.456	+36.6	0.388	+16.2	0.450	+34.8	0.364	+ 9.0	0.374	−11.4
	Oak and pine conv. to oak	1.842	1.834	− 0.4	2.340	+27.6	2.565	+39.5	2.345	+27.6	2.425	+31.9	2.222	−20.6
20 35.3 m.	Oak	2.810	2.644	− 5.9	2.810	Nil	—	—	—	—	3.460	+23.1	3.280	−16.7
	Pine	0.556	0.556	Nil	0.586	+ 5.4	—	—	—	—	0.443	−23.4	0.553	Nil
	Oak and pine conv. to oak	3.273	3.107	− 5.0	3.300	+ 0.8	—	—	—	—	3.830	+17.0	3.746	−14.4

Note: Pine to oak conversion factor . . 0.833

for the covering board fastenings, with dire results, and he referred to light plywood decking as well as to that used on the more solidly constructed vessel.

He suggested that every commercial vessel should be fitted with a doubling over the topstrake, and clear of the caulking seam. This strake could be through-bolted as required, for easy removal if ever such became necessary. The covering board then goes over the topstrake, but fastens only to the doubling strake. This protects the topstrake and reduces the ever present hazard of dry rot, caused by the leakage of fresh water around and under the edge of the covering board, thence on to the top edge of the top strake and down into the

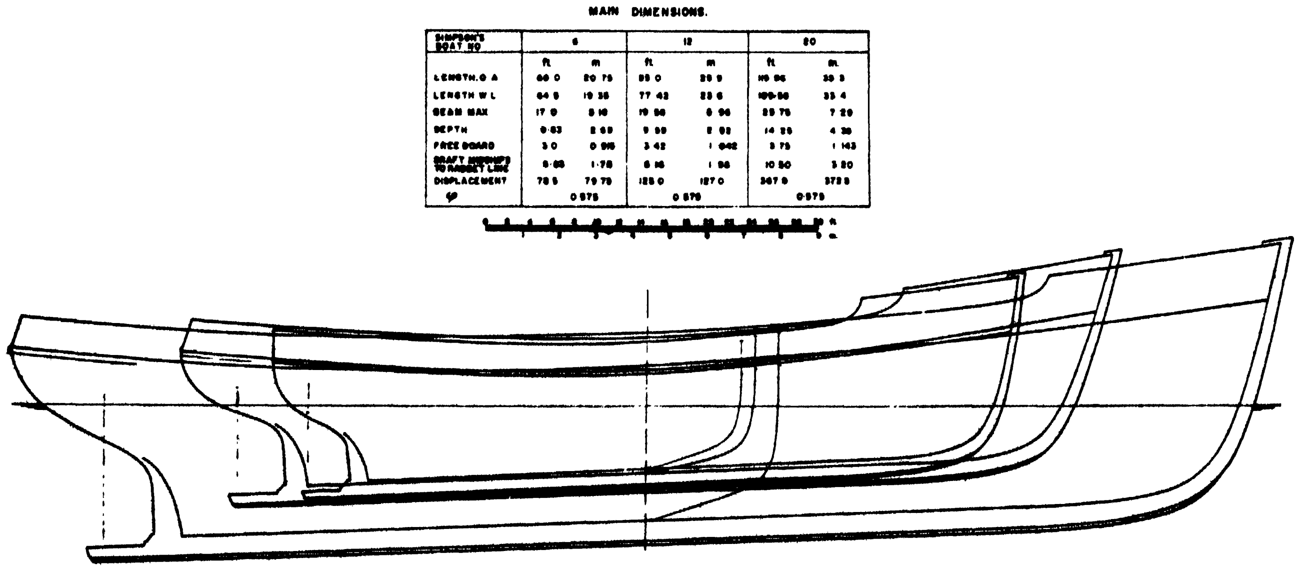


Fig. 157. Reconstruction of profile and midship sections of Simpson's three example trawlers

TABLE 37

Cubic content of timber for wooden fishing boats as compared with Simpson's proposal
Volumes in cu. ft. for 3 ft.(0.917 m.) length midship section

		CLASSIFICATION												
Boat No.	*Timber*	*Simpson's proposal*	*New England trawlers (no regulations)*		*Bureau Veritas (France)*		*Danish Regulations*		*Swedish Regulations*		*Newfoundland Rules*		*Hanson's Scantlings*	
			As built	*Percentage of difference from Simpson's*	*As built*	*Percentage of difference from Simpson's*	*As built*	*Percentage of difference from Simpson's*	*As built*	*Percentage of difference from Simpson's*	*As built*	*Percentage of difference from Simpson's*	*As built*	*Percentage of difference from Simpson's*
6 68 ft.	Oak	36.10	40.40	+11.6	44.37	+22.8	50.40	+40.0	47.30	+31.2	44.15	+22.1	42.40	+17.45
	Pine	8.40	9.40	+13.1	11.00	+30.8	11.36	+35.4	10.85	+29.2	9.47	+12.7	8.40	Nil
	Oak and pine conv. to oak	43.10	48.30	+11.9	53.55	+24.2	59.75	+39.5	56.35	+30.09	52.02	+20.7	49.40	+14.6
12 85 ft.	Oak	50.44	50.18	− 5.1	63.30	+25.6	72.40	+43.7	63.65	+26.3	68.6	+36.0	61.60	+22.2
	Pine	10.55	10.55	Nil	14.60	+36.6	12.26	+16.2	14.27	+34.8	11.45	+ 9.0	11.75	+11.4
	Oak and pine conv. to oak	59.24	58.98	− 0.4	75.60	+27.6	82.60	+39.5	75.55	+27.6	78.20	+31.9	71.40	+20.6
20 115.85ft.	Oak	90.80	85.45	− 5.9	90.80	Nil	—	—	—	—	112.0	+23.1	106.00	+16.7
	Pine	17.80	17.80	Nil	18.75	+ 5.4	—	—	—	—	13.82	−23.4	17.83	Nil
	Oak and pine conv. to oak	105.63	100.28	− 5.0	106.48	+ 0.8	—	—	—	—	123.5	+17.0	120.85	+14.4

Note: Pine to oak conversion factor . . . 0.833

topstrake through the innumerable splits caused by the driven covering board fastenings.

This, of course, could happen to the doubling piece, but in such an event the repair cost would be ever so much cheaper. This method was adopted with marked success in Australia during World War II, even with double diagonally built vessels, and it is now, of course, on record just how badly, most double diagonally planked vessels suffered from dry rot, particularly at the junction of the decks and hull planking. It is most important that the faying surfaces of both planks should be well painted as well as the top edges.

Some important strength details of select Australian hardwoods may be of interest to naval architects.

Modulus of rupture	*Modulus of elasticity*	*Crushing strength*
lb./sq. in.	lb./sq. in.	lb./sq. in.
(kg./sq. cm.)	(kg./sq. cm.)	(kg./sq. cm.)
15,000–24,000	2,400,000–3,000,000	7,500–12,000
(1,050–1,700)	(170,000–210,000)	(525–840)

The first figure in each case is for green timber, whilst the second is for timber seasoned to 12 per cent. moisture content. Their highly durable hardwoods, such as ironbark, tallowwood, jarrah, etc., have a useful life in wooden shipbuilding of up to 40 years, and in many instances they have commercial vessels of over this age still in good order. The rest of their shipbuilding timbers would easily give a good life of 25 years.

COMPARISON OF WOODEN SCANTLING REGULATIONS

MR. D. A. S. GNANADOSS (India): The papers by Simpson and Hanson deal with a subject which is fundamental for good boatbuilding and they will be much appreciated by all those concerned with wooden boat designing and construction. He made a comparative study of the scantling regulations for wooden boats according to the Bureau Veritas, the Danish, the Swedish and the Newfoundland regulations. The main object of the study was to determine how these regulations compared with Simpson's suggested standard scantlings.

To facilitate the study the profiles and the midship section of the special boats selected by Simpson (boats 6, 12 and 20) were drawn up to the given principal dimensions, assuming their prismatic coefficient to be 0.575, see fig. 157.

One metre length (3.28 ft.) of the boat at midship was taken as the unit, and the cubic content of timber under the different classifications was worked out. The timbers used for the calculation are pine for decking and oak for the rest. However, for easier comparison, the pine has been converted to oak, using a factor of 0.833. The data obtained are given in tables 36 and 37, and indicate that,

- The small and medium boats are much more heavily built than would appear necessary according to Simpson
- The boats built to the Danish regulations are the heaviest in the categories analysed
- The Newfoundland rules lay down that where timber other than Newfoundland timber is used it may be sided and moulded ½ in. (12.7 mm.) smaller if the construction is entirely of hardwood. This reduction does not appear sufficient in the larger boats
- It might be possible to evolve unit weights for different categories of boats, which may also form a basis for estimating the total weight of the hull

TABLE 38

Principal dimensions	*Simpson's proposal*	*Bureau Veritas (France)*	*Danish regulations*	*Swedish regulations*	*Newfoundland rules*
LENGTH	From fore part of stem to the aft of the stern	From fore part of the stem to the aft of the rudder post	From the aft side of the stem to the middle of the rudder post	On the summer waterline, from the fore side of the stem to the centre of the rudder post or 96 per cent. of the length at the summer waterline, whichever is lower	From forward part of the stem to the aft part of the stern
BEAM	Extreme breadth outside the planking	Widest part of the vessel outside the frames	Extreme breadth outside the frames	Extreme breadth outside the planking	Extreme breadth at deck line inside the ceiling
DEPTH	From the top of the deck at side amidship to the lower edge of the keel rabbet	From the top of the upper deck beam at side amidships to the lower edge of the keel rabbet	From the top of the deck beam at side to the inner edge of the keel rabbet	From the under side of the decking at side to the lower edge of the keel rabbet	From the top of the beam at the centre-line to the top of the ceiling on a flat bottom
SCANTLING NUMERAL	$N = 3\sqrt{\frac{LOA \times B \times D}{100}}$ in foot system $3\sqrt{\frac{LOA \times B \times D}{2.83}}$ in metric system $F = \left(\frac{B+D}{2}\right)^2$ in foot system $2.69\ (B+D)^2$ in metric system $C = N \times F$	$L \times B \times D$	$L \times B \times D$	Transversal $B+2D-R$ where R is the shortest distance from the intersection of the base line plane and the vertical plane from the extreme beam outside planking to the turn of the bilge Longitudinal $L \times$ Transversal	$\frac{L \times B \times D \times 0.75}{100}$
When the numeral is not in the Table	—	Select the lower of the numbers	Use the nearest (lower or higher) scantling numeral	—	—

- The possibility of gathering further information to cover small boats, to compare the existing scantlings and to suggest more judicious and rational use of timbers
- They form a basis for comparing scantling regulations in several other countries and to eventually formulate uniform regulations
- Simpson's proposals appear a fair basis for determining the scantlings and are a fine blend of scientific knowledge with practical experience

It is, however, likely that the suggested standard scantlings of Simpson may not be acceptable to the countries whose regulations have been taken up for comparison, because of the considerably lighter construction indicated which requires much departure from the existing practices. These regulations are the results of age-old practices and do not rest on a scientific basis. The sea conditions, the timbers used, and the types of fishing necessitate different methods of construction and strengthening. Hence, naturally, they vary from country to country, and in many cases even inside the same country. Some of the main variations in classifying the vessels for scantlings are given in table 38.

In recent years there has been considerable interest in wooden fishing vessels. Many studies have been made on the performance, power and resistance and the like, but the actual timbers that go into building the boat itself are still mainly determined on the basis of past experiences. As yet no method has been developed to determine the stresses and strains on wooden fishing boats.

The unique feature of Simpson's proposals is that he has evolved an acceptable system of calculating minimum standard scantlings for wooden fishing boats of the U.S. East Coast. This system is naturally limited in its applicability to other countries because of local conditions, but it is reasonable to expect that with Simpson's proposals as a basis, suitable standards for minimum scantlings could be worked out under the various regulations. It is hoped that further research work will be done on this important subject, which, as Simpson observes, would benefit all concerned with fishing boats.

New type of construction

MR. C. HAMLIN (U.S.A.): Simpson was to be congratulated on his paper suggesting standard scantlings. For over ten years Mr. Hamlin has been designing, almost exclusively, yachts of glued-strip construction, i.e. the hull is built up of square longitudinal strips of wood glued and edge-nailed together, with framing largely omitted. Since this new and different concept of construction had no previous data upon which to base scantlings, it became necessary to create some standards of his own. Fig. 158 is a graph he used with success when selecting cedar planking for sailing yachts with displacements of from ½ to 10 tons. It would be noted that his longitudinal number took into account only displacement and effective length, defined as (LOA+2×L)/3. This curve has served well for a particular type of boat within the range of displacements given above.

Most scantling rules with which he is familiar ignore displacement. With this omission, it would seem that any attempt to match the planking and other structural members to the loads they will be called upon to sustain will be erroneous. For instance, a pilot boat and a sardine carrier may both have

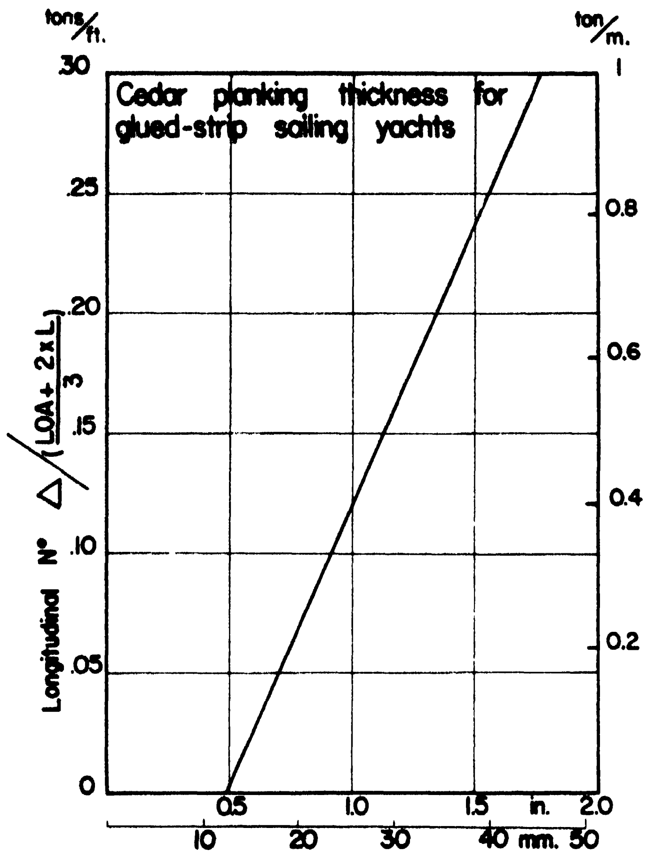


Fig. 158. Hamlin's graph for cedar planking thickness for sailing yachts from 0.5 to 16 tons

the same overall dimensions and hence call for the same scantlings under most rules, but the loaded sardine carrier will have about twice the displacement of the pilot boat.

It is his belief that a system of scantling numerals could be devised which would apply to any size and type of vessel. He suggested that the system takes into account displacement and effective length, and possibly includes depth and speed length ratio in a minor role. There should be in addition a set of coefficients established which would allow for varying strengths of materials, arduousness of vessel function, etc. With such a universal set of scantling formulae, any boatbuilder anywhere could safely select material for any type of boat.

In fig. 159 are plotted both the actual and recommended planking thicknesses for the 22 examples of fishing vessels cited in the paper, but using, instead of Simpson's longitudinal number, Mr. Hamlin's which was defined as follows: displacement in tons divided by the effective length, (LOA+2×L)/3.

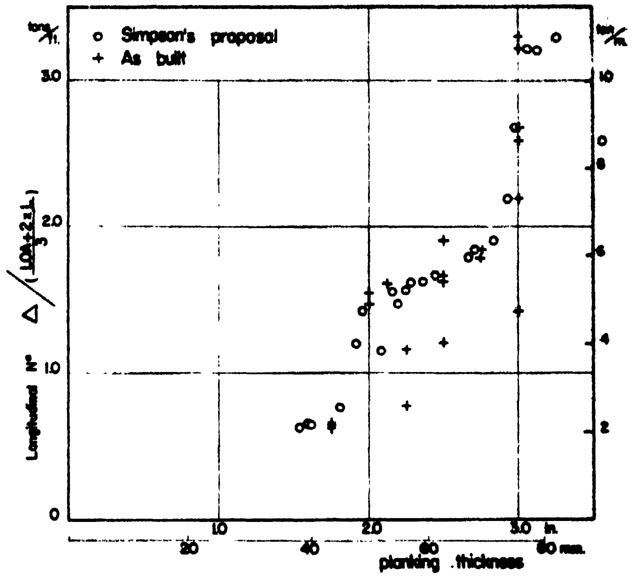


Fig. 159. Planking thickness from Simpson's examples as built and as recommended by Simpson plotted over Hamlin's longitudinal number

It would be seen that Simpson's recommended spots fall in line fairly well, and much better than the actual spots.

In fig. 160 the Simpson's recommended spots are plotted together with several points representing planking thickness according to Lloyd's rule for sailing yachts applied to some of Simpson's examples, as well as to some very light displacement sailing yachts. The linear fall of the points would indicate the possibility of a longitudinal number such as suggested, containing displacement, having universal application for all types of vessels.

The justification for using displacement divided by length as the longitudinal number undoubtedly lies in the fact that it expresses the approximate loading per unit of length.

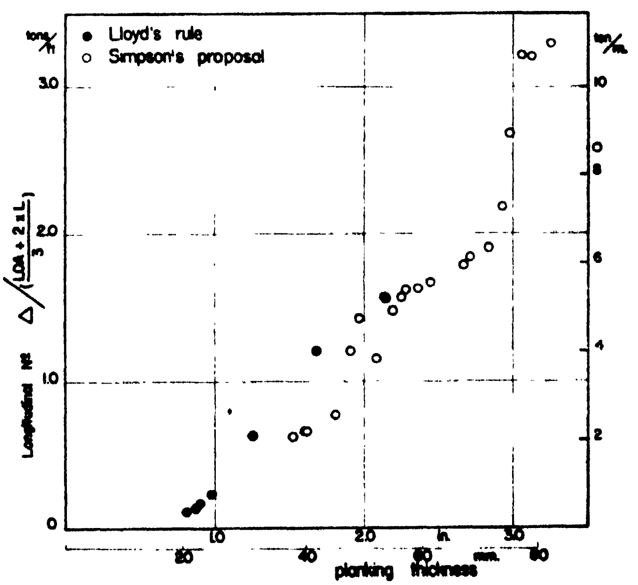


Fig. 160. Simpson's recommended plank thickness for sailing yachts compared with Lloyds' rules

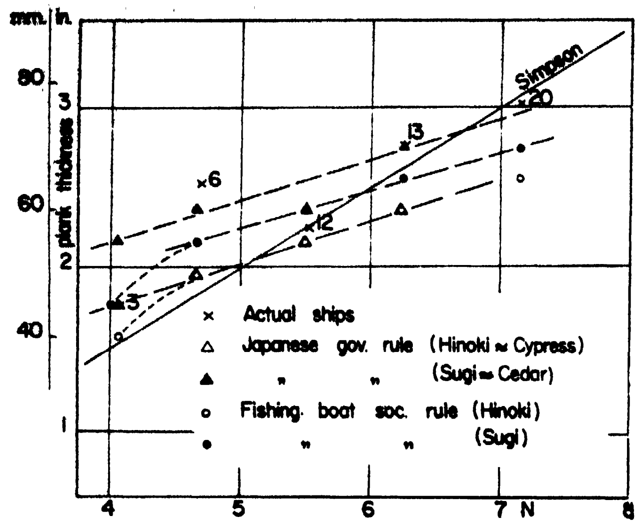


Fig. 161. Simpson's recommendations for planking compared with Japanese standards

Although considerable data exist regarding the stresses imposed upon a vessel at sea, there are relatively few regarding the strength of vessels' hulls; the scatter of Simpson's "as built" points demonstrates better than anything else the lack of science in this area. It seemed to him that an experimental model investigation of ship strengths could be carried out profitably and inexpensively.

He proposed that a simplified standard parallel mid-section be adopted as the basic test section. It might be semicircular

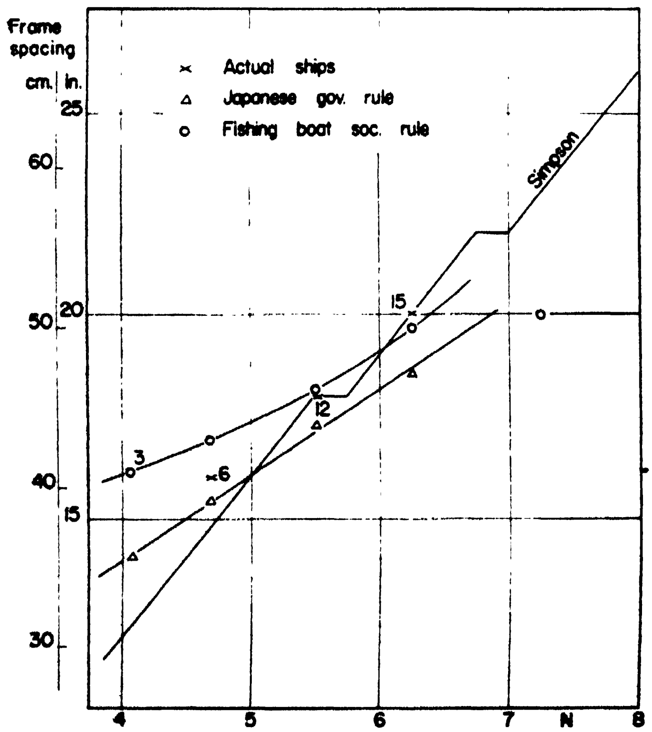


Fig. 162. Japanese frame-spacing, indicating that these are larger for small boats and shorter for large boats than those proposed by Simpson

in section, with a length equal to twice the beam, thus approaching the maximum unstiffened length of hull probably encountered in practice. For simplicity, there would preferably be no deck crown. All construction details would be exact scale representations of the full-size vessels. For variations of beam/depth ratio the sections would become semi-elliptical. Being prisms, the "hull" could be built in long lengths inexpensively, allowing uniform testing of several different factors.

Forces encountered by a ship's hull could be reproduced approximately by cantilevering the test section out from a rigid base and acting on the free end with various machines.

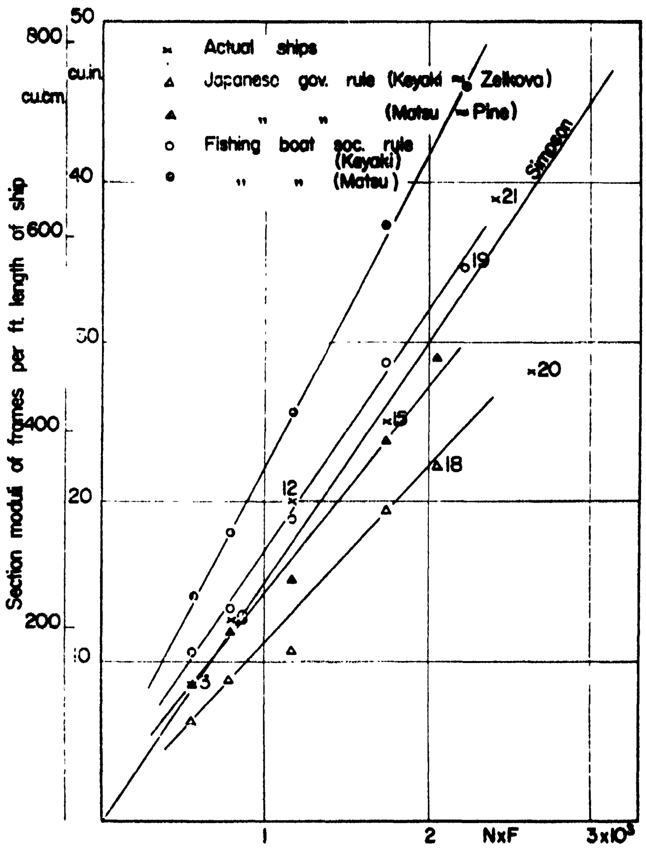


Fig. 163. Simpson's recommended figures for section moduli of frames falls between the two Japanese standards

The major effects to be exerted by the machines would be hogging, sagging, a combination of the two in flexure, and torsion.

Standardization of test procedures and measurements, etc. would be necessary to insure the fullest usefulness of such a programme. The basic hull section should be tested in various constructions, such as conventional wood with moulded and bent frames, fibreglass, glued-strip, moulded plywood, aluminium, steel, etc. The construction method, materials and scantlings should be carefully defined, preferably by formula, to permit reproductibility. The principle of the Standard Series should be adhered to in all variations from the basic tests. The results should undoubtedly be given in terms of yield strength. Perhaps an experimental engineer could help avoid the pitfalls of scale effect in materials testing.

Mr. Hamlin urged that as much attention be given to the small fishing vessels as to the large. He rather regretted that Simpson did not extend his studies down into the lower limit of size, i.e. perhaps to 20 ft. (6 m.). In making damage surveys for insurance companies, his experience with fishing vessels under about 50 ft. (15 m.) LOA has been that usually the cost of repairing damage is much higher than the severity of the accident warrants. This invariably results from inconsistent and unbalanced scantlings. The establishment of universal scantling standards would benefit insurance companies by reducing the settlement load, benefit the fisherman by reducing his insurance cost and increasing confidence in his boat and benefit the builder by materially advancing the art.

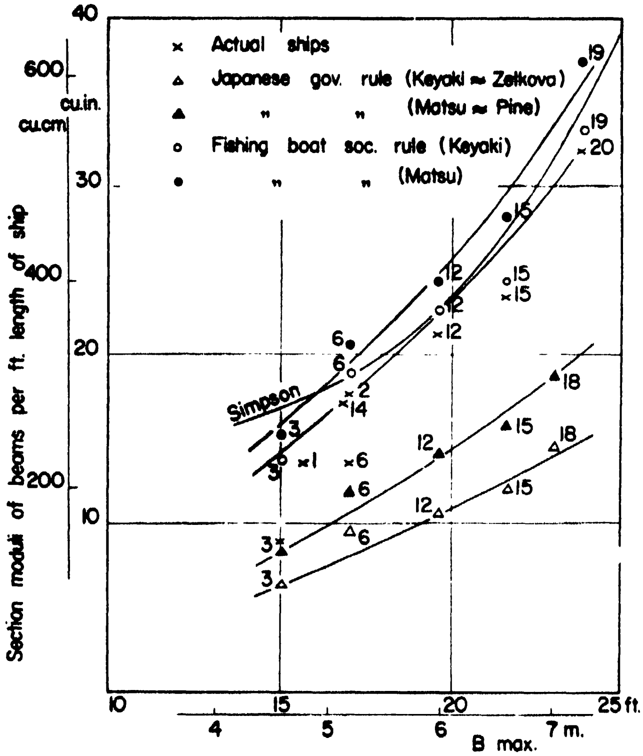


Fig. 164. Simpson's section moduli of deck beams compared with the two Japanese standards

Standards in Japan

PROFESSOR A. TAKAGI (Japan): In Japan there are about 1,000,000 gross tons of wooden fishing boats. Simpson's paper, giving new standards of scantlings and fastenings for wooden boats, is very useful. Japan uses two standards for wooden boat construction, namely the Government's Wooden Boat Construction Rules, and that to be issued by the Fishing Boat Association of Japan, which is still in draft form. Some comparisons have been made between these two standards and those put forward by Simpson. See fig. 161 to 166 and table 39. The results are as follows:

Member	*Simpson's Numeral N*	*Comparison*
Planking	4 to 5	Japanese is thicker
	Over 6	Japanese is thinner
Frame space	Below 6	Japanese is larger
	Over 6	Japanese is smaller

Section modulus of frame: Simpson's figure falls between two Japanese Government standards for wooden fishing boats and general wooden boats.

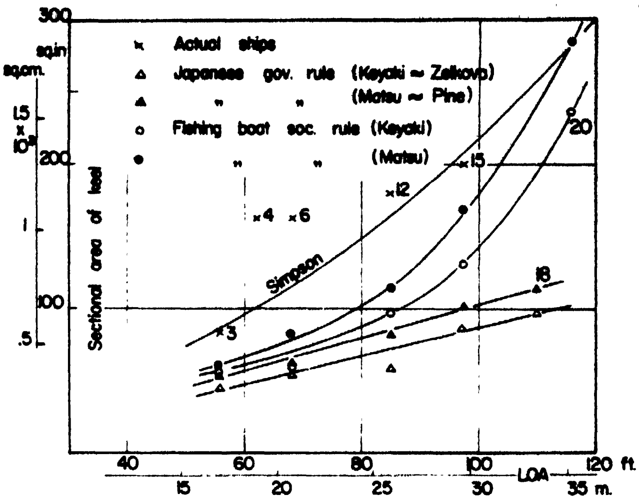


Fig. 165. Simpson's proposals for keels compared with the much smaller required by Japanese rules

Keel based on L: Simpson's suggestion is much larger than the Japanese standards but the same if the keelson is included.

He would be glad to have some points clarified:

- The minimum thickness of the planking when N is very small, especially regarding the minimum necessary thickness of planks for caulking and fastening with nails
- Generally speaking, the keelson is larger than the keel in Western wooden boats, but in Japan the keelson is always smaller than the keel, and so it is in Simpson's paper. Is there any reason for the Western countries' practice?

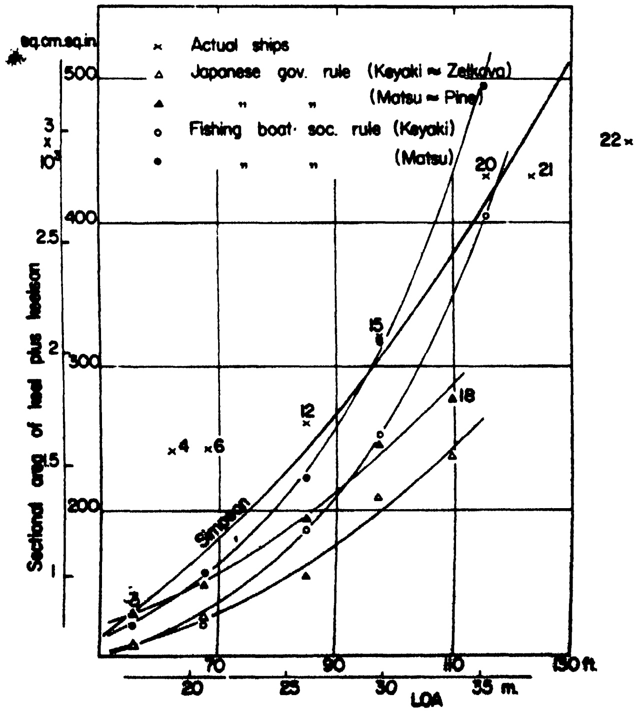


Fig. 166. Simpson's proposals for keels and keelsons being similar to the Japanese rules

TABLE 39

Comparison of Simpson's proposal with the Japanese rules

	Ship No.		3	4	6	12	15
			ft. in. m.	ft. in. m.	ft. in. m.	ft. in. m.	ft. in. m.
	LOA		55 10 17.02	62 0 18.9	68 0 20.75	85 0 25.9	97 7 29.44
	L=.92LOA		15.66	—	19.09	23.83	27.08
	B		15 0 4.57	16 10 5.13	17 0 5.18	19 7 5.96	21 7 6.58
	B–2t		4.48	—	5.05	5.85	6.44
	D		8 0 2.44	8 8 2.64	8 10 2.69	9 7 2.92	11 9 3.58
	N		4.06	4.49	4.68	5.51	6.26
	F		135	163	167	212.5	277.9
	N×F		548	—	783	1,170	1,740
	B/2+D		4.68	—	5.22	5.85	6.80
			in. cm.	in. cm.	in. cm.	in. cm.	in. cm.
Fig. 161	Plank thickness	A	—	—	2⅛	2¼	2⅜
		S	—	—	1⅞	2¼	2⅝ 6.7
		J Hinoki	4.5	—	5	5.5	6
		J Sugi	5.5	—	6	6	7
		F Hinoki	4		5	5.5	6
		F Sugi	4.5	—	5.5	6	6.5
			in. cm.	in. cm.	in. cm.	in. cm.	in. cm.
Fig. 162	Frame spacing	A	10	16	16	18	20
		S	—	—	15	18	—
		J	35.7	—	39.1	43.8	47.1
		F	41	—	43	46	50
			cu. in./ft.	cu. in./ft.	cu. in./ft.	cu. in./ft.	cu. in./ft.
Fig. 163	Section modulus of frames (bilge part)	A	8.5	—	12.62	20.0	24.9
		S	8.2	—	11.50	17.5	26.1
		J Keyaki	6.17	—	8.95	10.5	19.5
		J Matsu	8.45	—	11.73	15.1	23.8
		F Keyaki	10.5	—	13.3	18.8	28.6
		F Matsu	14.0	—	18.0	25.5	37.2
			cu. in./ft.	cu. in./ft.	cu. in./ft.	cu. in./ft.	cu. in. /ft.
Fig. 164	Section modulus of deck beams (ordinary)	A	8.8	—	13.5	21.1	23.3
		S	—	—	19.4	22.8	—
		J Keyaki	6.42	—	9.50	10.5	11.9
		J Matsu	8.25	—	11.75	14.1	15.7
		F Keyaki	13.7	—	18.8	22.5	24.1
		F Matsu	15.1	—	20.5	24.3	27.9
			sq. in.	sq. in.	sq. in.	sq. in.	sq. in.
Fig. 165	Sectional area of keel	A	84	162	162	180	200
		S	85	98	113	162	213
		J Keyaki	45	—	53	58	86
		J Matsu	53	—	62	82	101
		F Keyaki	56	—	58	97	130
		F Matsu	58	—	82	113	168
			sq. in.	sq. in.	sq. in.	sq. in.	sq. in.
Fig. 166	Sectional area of keelson	A	—	80	80	80	120
		S	43	49	57	81	111
		J Keyaki	107	—	125	155	208
		J Matsu	128	—	148	195	245
		F Keyaki	106	—	120	186	252
		F Matsu	120	—	157	222	317

A = Actual ship data
S = Simpson's paper
J = Japanese Government's Wooden Ship Construction Rule (1958)
F = Wooden Fishing Boat Construction Rule (1958) of the Fishing Boat Association of Japan

- How was the relationship between the section modulus per foot length of the ship and the maximum beam obtained?
- Japan has Steel Fishing Boat Rules, and standards for wooden fishing boats are being drawn up. Are there any similar standards for fishing boats in other countries?

MR. J. TYRRELL (Ireland): Simpson's proposals should be of considerable value for new vessels of the types and in the districts he has investigated.

Equally satisfactory vessels of quite different scantlings and construction methods have been developed independently in other parts of the world, and to these research similar to that carried out by Simpson might profitably be applied, so that different standard specifications could be arrived at. He felt

TABLE 39 (*continued*)

Comparison of Simpson's proposal with the Japanese Rules

	Ship No.		18	19	20	21	22
			ft. in. / m.	ft. in. / m.	ft. in. / m.	ft. in. / m.	ft. in. / m.
	LOA		110 0 / 33.53	112 0 / 34.14	115 10 / 35.3	123 6 / 37.64	140 0 / 42.67
	L=.92 LOA		30.85	—	32.48	—	—
	B		23 0 / 7.01	23 9 / 7.24	23 9 / 7.25	23 9 / 7.24	27 3 / 8.31
	Bm-2t		6.86	7.09	7.14	—	—
	D		12 6 / 3.81	12 3 / 3.73	14 3 / 4.35	12 8 / 3.86	12 7 / 3.84
	N		6.75	6.90	7.26	7.17	7.86
	F		306	325	363	336	399
	N×F		2,063	2,240	2,635	2,405	3,135
	B/2+D		7.24	7.28	7.92	—	—
Fig. 161	Plank thickness		in. / cm.	in. / cm.	in. / cm.	in. / cm.	in. / cm.
		A	—	—	3	—	—
		S	—	—	3⅛	—	—
		J Hinoki	[illegible]	—	—	—	—
		J Sugi	—	—	—	—	—
		F Hinoki	—	—	—	—	—
		F Sugi	—	—	—	—	—
Fig. 162	Frame spacing		in. / cm.	in. / cm.	in. / cm.	in. / cm.	in. / cm.
		A	21	24	20	21	24
		S	—	—	23	—	—
		J	50.9		—		—
		F	51	52	—	—	—
Fig. 163	Section modulus of frames (bilge part)		cu. in./ft.	cu. in./ft.	cu. in./ft.	cu. in./ft.	cu. in./ft.
		A	—	—	28.1	38.9	47.3
		S	—	—	39.3	36.1	47.0
		J Keyaki	22.1	—	—	—	—
		J Matsu	29.1	—	—	—	—
		F Keyaki	—	34.6	—	—	—
		F Matsu	—	46.0	—	—	—
Fig. 164	Section modulus of deck beams (ordinary)		cu. in./ft.	cu. in./ft.	cu. in./ft.	cu. in./ft.	cu. in./ft.
		A	—	—	32.1	—	—
		S	—	—	34.3	—	—
		J Keyaki	14.5	—	—	—	—
		J Matsu	18.7	—	—	—	—
		F Keyaki	—	33.1	—	—	—
		F Matsu	—	37.7	—	—	—
Fig. 165	Sectional area of keel		sq. in.	sq. in.	sq. in.	sq. in.	sq. in.
		A	—	—	288	288	—
		S	—	—	314	288	—
		J Keyaki	97	—	—	—	—
		J Matsu	113	—	—	—	—
		F Keyaki	—	—	236	—	—
		F Matsu	—	—	286	—	—
Fig. 166	Sectional area of keelson		sq. in.	sq. in.	sq. in.	sq. in.	sq. in.
		A	—	—	144	144	168
		S	—	—	157	144	196
		J Keyaki	237	—	—	—	—
		J Matsu	277	—	—	—	—
		F Keyaki	—	—	405	—	—
		F Matsu	—	—	495	—	—

A = Actual ship data
S = Simpson's paper
J = Japanese Government's Wooden Ship Construction Rule (1958)
F = Wooden Fishing Boat Construction Rule (1958) of the Fishing Boat Association of Japan

that such investigations should be sponsored by the Fishery Departments of the countries concerned, since it would be unreasonable to expect naval architects or builders to conduct so much research at their own cost.

His firm's standard multi-purpose vessel, 56×17×8 ft. (17.1×5.2×2.4 m.), with 44 tons displacement when ready for sea, compared for framing and planking as follows:

	Simpson	*Tyrrell*
Frame spacing	13 in. (330 mm.)	16 in. (406 mm.)
Plank thickness	1⅝ in. (41 mm.)	1¾ in. (44.5 mm.)
Frame section at bilge	2.25×5.12 in. (57×130 mm.)	3.25×5.5 in. (82.5×140 mm.)

It is surprising to find larch given such a low classification in table 29. This is the Irish standard material for planking, and is a most reliable timber, very resistant to rot, and of excellent steam bending properties. There must be a considerable difference in the U.S. and Irish varieties.

Galvanised mild steel plank spikes are first-class in lasting and holding power. He thought those shown in Simpson's fig. 153 were quite unsuitable for planking or in other positions of stress.

Their standard spike had a rose head, and taking the 5 in. (12.5 cm.) as an example, had a section of $\frac{3}{8} \times \frac{1}{4}$ in. (9.5 × 6.35 mm.) under head, tapering to $\frac{5}{16} \times \frac{1}{8}$ in. (7.8 × 3.2 mm.) at the point. These were driven with the point at right angles to the grain of the frame, prebored by $\frac{5}{16}$ in. (7.8 mm.) drill through the plank and about $\frac{3}{4}$ in. (19 mm.) into the frame.

Lag screws were not reliable in any position subject to stress.

In fig. 146 (mid-section) the topside planking was shown of a standard thickness. The Irish current practice in the vessel referred to above, was to fit three $7 \times 2\frac{1}{2}$ in. (178 × 63 mm.) top wales. It was noted that through fastenings are fitted before planking. They consider this in Ireland as bad practice and fit all such bolts through outer planking.

Bent frames would not at all do in his area. In shallow harbour entrances the boats were subject to heavy knocking on the bar when entering port. He strongly advocated well-prepared plank seams, tight inside, and judicious application of caulking. Lock scarves were made in keels and rails in his yard. He felt the best fastenings to be bolt and nut, although drift bolts could be satisfactory.

Scandinavian practices

MR. H. K. ZIMMER (Norway): Standard scantlings for wooden fishing vessels are not a new thing. Apart from the classification societies, Lloyds Register of Shipping "Rules for Wood and Composite Vessels 1929" and Det Norske Veritas' (Norwegian Veritas): "Regler for bygging og klassifikasjon av treskip—1955" (in Norwegian only), there are the Danish: "Bekendtgörelse angaende Forskrifter om Bygning og Ombygning m.v. af Fiskefartöyer—1947" and the Swedish "Regler för byggandet av fiskefartyg av trä—1952".

These rules are based on local practices like the proposed standard, but the discrepancy of practice may be considerable. For instance: the Swedish practice of making keelson and floors of a reinforced concrete construction.

The Danish rules, which are the simplest, are based on a Numeral: (L × B × D) and cover the range of 33 to 84 ft. (10 to 25.5 m.). The Swedish rules are based on a transverse Numeral: (B + 2D − R) and a longitudinal Numeral, L(B + 2D − R), R being the distance from the bilge to the lower corner of square B × D.

The different standards seem to give similar results although there are some points worth taking note of.

Scantlings of deck beams are based on B alone in Scandinavian rules, and the dimensions are heavier and the spacing correspondingly larger. These rules give adequate strength and render a cheap hull.

The keel is the backbone of the hull, and one of the most apparent and common defects of wooden hulls is the hogging of the keel and often the complete hull. The siding of Simpson's proposed scantlings is decidedly smaller than Scandinavian practice. His experience called for increased strength in the keel and the keelson (hog). It is most essential that longitudinal members like the keel, keelsons, bilge stringers, clamps, lodgers (shelf) and waterways are joined by scarphs to enable them to take up longitudinal strain (tension) efficiently.

The butts of the planking should be well staggered and butts of deck planking must be kept well away from hatch corners to avoid leakage there and also to increase longitudinal strength.

Looking at the keel construction alone, i.e. the keel with garboards and keelsons, the main strain will be compression in the keel and garboard, and tension of the keelsons, scarphs are therefore most essential in the keelsons. He experienced good results when strengthening existing, weak vessels by fitting a channel steel section upside down over the centre keelson with secure fastenings at the ends. The Swedish type reinforced concrete keelson is another solution that may be of advantage in small seagoing vessels that call for extra weight stability.

Hanging knees and riders of steel were not mentioned in the proposal. The knees may not be required due to the suggested small beam spacing but the riders certainly have a mission to avoid hogging. Ceilings of double diagonal construction between the bilge stringers and clamps would also help to resist hogging.

Simpson remarked in his paper that the basic vessels would have ice protection, Mr. Zimmer presumed that the scantlings were not intended for navigation in ice. Scantlings for vessels like sealers might be considered separately.

One of the main drawbacks of wooden vessels is their tendency to rot. Copper naphthanates etc. might be useful as preventive measures, but there is nothing like salting of the space between the ceiling and the skin planking from the bilges to the clamps, combined with adequate ventilation of the space above. It was perhaps this tendency to rot which helped the advent of steel hulls. Today there are hardly any wooden hulls longer than 80 ft. (24 m.) being built in Norway. The upper range of the proposed scantlings seems to be outside future trends, whereas the lower range is not covered by the proposed standards.

He recommended that FAO should continue the research done by Simpson with the aim to produce more simplified standards that could be of international use. Cooperation with the leading classification societies in this work might be an advantage.

MR. P. ZIENER (Norway): Simpson's suggested scantlings are for a specific area. The question arises whether they could be used for similar boats in other regions in the form they now appear. In his opinion this would not be recommendable, because operational conditions, building woods and convenient construction modifications would in most cases demand scantlings and fastenings quite different from those arrived at by the proposed numerals.

For instance, the resulting dimensions are far too heavy for most fishing boats operating in tropical waters, not considering the extensive use of hardwood in those regions which would require further substantial reductions.

For near-Arctic waters where wooden fishing boats are seasonally employed in seal catching and Arctic hunting, the scantlings would result in hulls too weak even if prescribed ice reinforcements were added.

A standardization as proposed is undoubtedly valuable if strictly limited to defined areas, and might well include machinery and certain equipment. Operational demands, materials and construction techniques vary so widely throughout the world that the suggested principle of standardization hardly could be universal.

Saw-mill standards for cutting

MR. E. MCGRUER (U.K.): The numeral system is already used by the Classification Societies and recent yacht scantling rules is based on it. He hoped that people versed in construction methods would join a boatbuilders' forum and develop Simpson's proposals.

In Scotland frames have greater moulding at the turn of the bilge, and he thought a better section could be had by not having a mass of material in the inner ceiling so near to the neutral axis as indicated in fig. 146.

Referring to the fastenings of a wooden ship, he thought that those who encouraged the use of nature's bounty for boats were entitled to say that a steel ship was no better than its welding, and a fibre glass hull no better than the unskilled labour that is claimed could build it. Nor was the laminated boat better than the glue.

As the inventor of an early laminated hollow spar, he felt entitled to glue parts of a boat, combined with early ship's carpentry methods, proper riveting and dovetails and interlockings, so that in the event of a glue-line failure, the structure would not fall apart.

He thought the Belgian fluted, square-section nail was excellent. It had a greater and more effective bearing surface, was easy to drive and was as light as a round fastening, because each side of the square section was concave. As a general principle, boat nails should be square. He referred also to the ringed nickel alloy nail for use as a non-corrodible spike.

In the Museum at Lake Nemi, Italy, can be seen wrought square nails of various lengths up to 24 in. (610 mm.), all nicely tapered from about ¾ to ¼ in. (20 to 6 mm.) and with such neat heads and finely worked points for plying-over. These long nails could not be driven. Rather were they lacings tying one hull member to another. The Romans would find it easier to work a square tapered nail than a round one—and this is perhaps the primary reason for the square section. But there can be no doubt the tapering square would fill the drilled pilot hole better where water might have ingress.

Preference for the square nail is based on its greater resistance to shearing stresses between the members fastened, and not on axial pull.

The constructional design of a good draughtsman should use the old shipbuilder's term "room and space" to represent the distance between the molded edge or face of the frames; siding is in the space and the room is the space left between the frames. Sidings vary with the different builders.

He should like to help in the question of how a boat design specification should be presented to the boatbuilder, the owner and the Classification Society.

He felt the methods of sawing the tree for scantlings, particularly for planking, should be reconsidered. He suggested the boatbuilders should revert to the early sawer's method of quartering the tree before culling the planks. This quartered wood had much less shrinkage than the tangential wood, which was common now. It was necessary to make quite certain that the materials used were properly sawn.

He suggested slightly lower rise of floor, but advocated the use of a hollow garboard to add considerably to the strength of the hull. Regarding the keelson, he suggested this—with intercostals between the frames—should be treated as a part of the keel itself to get a good section modulus.

Established rules in Iceland

MR. H. R. BARDARSON (Iceland): He discussed Hanson's and Simpson's papers together. In Iceland they have had rules for wooden vessel construction for several years. They were based on the experience of the hardest use any fishing vessel could suffer: North Atlantic service during the winter season.

They were always putting bigger and bigger main engines into these ships. A 71 ft. (21.6 m.) long vessel (about 90 GT) would have a main engine of about 400 h.p. Normally, small fishing harbours in Iceland were open to the sea; often five or more vessels were tied up side by side, bumping against each other and the harbour walls during rough weather. For some harbours it was even necessary to have a U-shaped steel piece on the bottom of the keel and up the stem to ride over the rocky bottom when entering port at low tide. Almost all wooden ships over 46 ft. (14 m.) in length (about 20 GT) were built of oak with sawn frames. Bent frames were only used for the very small ships. Keels, keelsons, frames, stems, stern posts, planking, deck beams and other main strength members were of oak. Decks, bulkheads were of fir or pine and ceilings in fish hold of oak or fir.

Owing to the Icelandic rules for the construction of fishing vessels, boatbuilders and boatyards in other countries building for Iceland never had to do any guesswork, and no builder could tell the owner that his ships were stronger than those of another builder. He was well aware of the fact that they used more timber (oak) and possibly more galvanized bolts, than would be used for similar size vessels in other countries. He believed that a strong and seaworthy ship was required above all, even if it were somewhat heavy.

The Icelandic rules were based on tables for scantlings, the main scantling numerals being:

the athwart ship numeral:	$B+D+G/2$
the longitudinal numeral:	$L(B+D+G/2)$
the breadth numeral:	B

L was the length of the ship between forward end of stem to after the end of stern, measured on deck, B the greatest moulded breadth, D the depth amidships from top of keel to lower edge of deck at side and G the girth amidships.

In order to compare the amount of timber needed for a ship according to the Icelandic rules, with the ships mentioned in Simpson's paper and Gnanadoss' comments, he had calculated the oak and fir needed in cubic metres of timber for one metre length amidships, for the usual Icelandic type of vessels and according to their rules. This cubic figure was based only on the section in the fish hold. The material for stem, stern frame, engine seatings etc., was not included. For a 55 GT vessel with the dimensions of $77\times17.7\times8.5$ ft. ($23.4\times5.4\times2.6$ m.) they needed 70.5 cu. ft. oak and 20 cu. ft. fir for 3 ft. length midships (2.183 cu. m. oak and .616 cu. m. fir for one metre). For a 75 GT vessel $80\times18.2\times9.2$ ft. ($24.34\times5.55\times2.8$ m.) they needed 81 cu. ft. oak and 23.3 cu. ft. fir (2.506 cu. m. of oak and .721 cu. m. fir).

Icelandic ships, down to about 50 GT are now also built of steel, mainly of all-welded construction, owing to the increasing problem of rot in wooden fishing vessels. About half the new Icelandic vessels below 100 GT are still built of oak. Good oak has proved to be the best wood for the building of strong vessels, but it was difficult to find a good preservative, as the known coatings did not penetrate the wood far enough without expensive drying and pressure treatment.

It may be of interest to know that they had very good experience in Iceland with all-welded steel engine settings in wooden ships, bolted with galvanized bolts through the frames and plankings. When auxiliaries were connected to the main engines, the seatings for these and the main engines were the same. These steel engine beds were important additions to the strength of the afterbody of the vessel, strength which was very much needed with high horsepower engines built into these comparatively small ships.

Different specifications needed

MR. W. P. MILLER (U.K.): He felt that uniform specifications would not suit all types of boats in the world. The boatbuilders should evolve a few standard specifications which would suit various types of boats under different conditions. Timbers vary from country to country, and for that reason uniform specifications will not satisfy every boat.

Twelve years ago the Scottish Fishing Boat Builders' Association (SFBBA) issued a catalogue with specifications for several types of wooden fishing boats in the 30 to 80 ft. (10 to 24 m.) length range. Two years ago the White Fish Authority in Scotland took up these specifications and asked for something better—more concise and with wider coverage. The White Fish Authority and the SFBBA have been working on this together for two years now.

In 1958 he had occasion to visit fishing boat yards in many parts of the world and he took the opportunity to show them the catalogue of the Association. People everywhere expressed considerable interest in the publication and felt the necessity for issuing similar publications in their own areas. The customer gets normally very little information from the boatbuilder on the details and specifications of boats. He felt it was necessary that publications, giving all details of boats, should be made available to prospective boat owners so that they could make their best choice.

Before commencing the drawing up of new specifications, the White Fish Authority conducted some preliminary investigations. Information was obtained from the authorities concerned with the Danish regulations and the Icelandic regulations. Bureau Veritas, however, could not furnish the English version of their regulations. He suggested that all standard specifications should be published by FAO.

He felt one of the most vital points in boatbuilding was proper preservation of the timber. His idea was that timber should be permitted to be preserved by the natural element of the air and that all dead air spaces should be avoided. Preserving timber by air should be one of the major points of study by naval architects.

It was his opinion that the practice of fitting a keelson was a relic from the days of sailing boat construction, but boatbuilders were now faced with the problem of accommodating huge, heavy engines. It was necessary to distribute the weight and the vibration of the engine to the whole structure of the boat.

in U.K.

MR. A. SUTHERLAND (U.K.) had read with very great interest Simpson's paper. The Scottish Committee of the U.K. White Fish Authority had been working on a Minimum Standard Specification for Wooden Fishing Vessels since 1956 and the papers are now in preparation for printing.

It would be as well to describe briefly part of the functions of the White Fish Authority in order to explain the Authority's standing in the matter.

By Section 4 (1) (g) of the Sea Fish Industry Act, 1951, the Authority was empowered to give financial assistance by way of loan to meet capital expenditure incurred in providing, acquiring, reconditioning or improving fishing vessels or their gear. The White Fish Industry (Grants for Fishing Vessels and Engines) Scheme, 1953 came into operation under the White Fish and Herring Industries Act, 1953, whereby the Authority were empowered to grant money towards the cost of fishing vessels not exceeding 140 ft. (42.7 m.) in length. Very broadly the assistance for a new vessel now takes the form of a grant of 25 per cent. of the total cost (with a grant ceiling of £30,000 or $84,000) and a loan under favourable rates of interest of up to 60 per cent. of the total cost. In the case of wooden inshore fishing vessels the grant to working owners is 30 per cent. of the cost (grant ceiling £5,000 or $14,000) with a loan of 55 per cent.

As a condition of such assistance the vessels and engines have to be constructed and equipped to the satisfaction of the Authority. This involves the submission of plans, specifications and tenders from any applicant desiring a new fishing vessel and the subsequent examination of the vessel whilst in process of building and during the handing over trial trip.

TABLE 40

Comparison of Scantlings

(as recommended by Simpson and for Scotland)

Simpson's vessel No. 6

Proposed by Dwight S. Simpson			*Proposed for Scotland*
Plank thickness	$1\frac{7}{8}$ in.		$1\frac{7}{8}$ in.
Frame spacing	15 in.		15 in.
Frame sided	$2\frac{7}{8}$ in.		4 in. (clamps 3 in.)
Frame moulded head	$4\frac{1}{2}$ in.		$5\frac{1}{2}$ in.
Frame moulded bilge	$5\frac{1}{2}$ in.		7 in.
Frame moulded keel	$7\frac{1}{2}$ in.		11 in.
Beam space	15 in.		17 in.
Beam moulded	$5\frac{3}{4}$ in.	Main	7 in.
Beam sided	4 in.	beams	6 in., ordinary beams 5 in. × 4 in.
Keel	$7\frac{1}{2} \times 15$ in.		$8\frac{1}{2} \times 12$ in., plus hog 6 in. sided
Keel shoe	$2\frac{1}{2}$ in.		$6 \times \frac{3}{4}$ in. steel convex bar
Keelson	$7\frac{1}{2} \times 7\frac{1}{2}$ in.		6×8 in.
Sternpost and log	13 in.		$8\frac{1}{2}$ in. (swelled in way of tube so that 25 per cent. of thickness remains on each side)
Garboard strake	$2\frac{11}{16}$ in.		$1\frac{7}{8}$ in.
Clamps	$2\frac{5}{8} \times 13\frac{1}{2}$ in.		10×3 in. (beam (stringer)
Shelf	$3\frac{3}{8} \times 8\frac{1}{2}$ in.		$6 \times 3\frac{1}{2}$ in. (beam shelf)
Lock strake	$2\frac{1}{2} \times 4\frac{1}{2}$ in.		4 in., beam knees
Lodger			
Bilge ceiling	$2\frac{5}{8} \times 32$ in.		8×3 in. bilge stringer
Decking	2 in.		2 in.
Bulkhead sheathing	$\frac{7}{8}$ in.		$1\frac{1}{8}$ in.
Bulkhead stiffeners	$2\frac{3}{4} \times 4\frac{1}{2}$ in.		3×4 in.
			2 at 3 in. bilge strake
			4 at 3 in. rubbing strake

The Authority insists that steel trawlers should be built to Lloyds classification. However, there were no recognized rules for classification of wooden fishing vessels and practices varied from port to port in Scotland. The rise in costs of vessels had been causing some concern and it was felt that by standardizing the scantlings of fishing vessels and their equipment boat builders would then submit tenders on similar basis and fishermen would be certain of a well-found boat. There was accordingly set up a working party consisting of three well known Scottish boat builders, a technical consultant, a representative from Lloyds holding a watching brief and the Senior Technical Officer of the White Fish Authority, who eventually produced the Standard Specifications referred to which have now been approved as a condition of Grant and Loan assistance for Scottish vessels.

The majority of the scantlings were fixed by means of previous submission and methods of fastening were carefully studied before the final choice was made. Sizes of rudder stock, chains and rods were estimated by using Lloyds Rules for rudders.

Special attention was given to the methods of ventilation to try and eliminate decay in timbers and to cut down the danger of fire in the engine room. The lining of fishrooms except in special circumstances is forbidden as experience has shown that the entrapping of air leads to rapid decay of the structural members of the vessel.

TABLE 41

Comparison of scantlings
(as recommended by Simpson and for Scotland)

Simpson's vessel No. 12

Proposed by Dwight S. Simpson		*Proposed for Scotland*
Plank thickness	2¼ in.	2½ in.
Frame spacing	18 in.	20 in.
Frame sided	3¾ in.	5 in. double (10 in.)
Frame moulded head	4¾ in.	6 in.
Frame moulded bilge	6¾ in.	8 in.
Frame moulded keel	8¾ in.	12 in.
Beam space	18 in.	20 in.
Beam moulded	6½ in.	Main beams { 8 in.
Beam sided	4½ in.	Main beams { 8 in., ordinary beams 8 × 6 in.
Keel	9 × 18 in.	10 × 14 in., plus hog 8 in. sided
Keel shoe	3 in.	6 × ¾ in. steel bar
Keelson	9 × 9 in.	10 × 11 in.
Side keelsons	—	7 in. sided (engine seats extended full length)
Sternpost and log	16¼ in.	10 in. (swelled in way of tube so that 25 per cent. of thickness remains on each side)
Garboard strake	3⅜ in.	2½ in.
Clamps	2⅞ × 19½ in.	20 × 4 in. plus 10 × 3 in. (beam stringer)
Shelf	4½ × 10 in.	14 × 4 in. (beam shelf)
Lock strake	2½ × 5 in.	} 4½ in. beam knees
Lodger	—	} 4½ in. beam knees
Bilge ceiling	2⅞ × 38 in.	32 × 3 in. bilge stringer
Decking	2¼ in.	2½ in.
Bulkhead sheathing	1½ in.	¼ in. steel
Bulkhead stiffeners	2¾ × 4¾ in.	2½ × 2½ × ¼ in. angle iron

Regulations for life-saving and fire fighting equipment are insisted on by the Ministry of Transport and a close liaison is maintained with that body.

There are of course differences in methods of construction and in general the Scottish type of wooden fishing vessel is broader in the beam and deeper for similar lengths than those described by Simpson.

The Scottish tables are based on a Scantling Numeral obtained by multiplying $L \times B \times D$ where L is the length overall, B the greatest breadth of the vessel and D the distance from the underside of the keel to the top deck beam at side in the middle of the rule length.

These standards have been adopted from tried practice cutting out certain methods of building and fastening which had been found wanting, and substituting these with approved methods. It will be argued that this is not the correct way but the ability of vessels built in this way for generations gave the basis from which to work.

TABLE 42

Cubic content of timber for Scottish wooden fishing boats as compared with Simpson's proposal
For 3 ft. (0.917 m.) length

Boat No.	*Timber*	*Simpson's proposal*	*Scottish Regulations* — *As built*	*Scottish Regulations* — *Percentage of difference from Simpson's*
6 68 ft.	Oak	36.10	39.0	+ 8.0
	Pine	8.40	8.4	Nil
	Oak and pine conv. to oak	43.10	46.0	+ 2.3
12 85 ft.	Oak	50.44	77.0	+52.6
	Pine	10.55	11.5	+ 9.0
	Oak and pine conv. to oak	59.24	86.57	+46.1
20 115.85 ft.	Oak	90.80	—	—
	Pine	17.80	—	—
	Oak and pine conv. to oak	105.63	—	—

Note: Pine to oak conversion factor . . . 0.833

Using the Scottish method of calculating scantling sizes Mr. Sutherland had drawn up tables 40 and 41 of comparison for vessels No. 6 and 12 in table 30 of Simpson's paper. The Scottish Scantling Numeral at present does not go beyond a 90 ft. (27.4 m.) overall vessel. Also attached is a sectional view of the method of construction, fig. 167, used in Scotland and compared with that as shown in Simpson's fig. 146.

Using these comparisons he estimated the amount of wood used in a 3 ft. length of each vessel amidships and the difference in cubic content is as shown in table 42 which is an extension of table 37 by Gnanadoss.

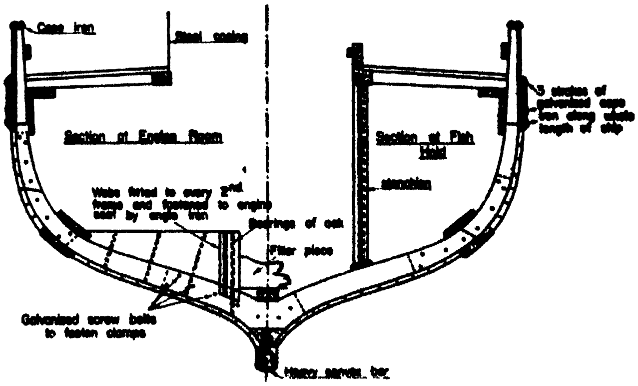


Fig. 167. Typical Scottish wooden ship construction

There are certain differences, the main ones being that the Scottish engine seats are fitted directly on to the frames, checked over each frame and through bolted before planking. The side floors and filler pieces are lugged to the seats with angle irons. In vessels of 80 ft. (24.4 m.) and over the engine seats are continued as far forward as practicable in the form of side keelsons. The garboard strakes are normally the same thickness as the ordinary planking but very much wider and the bilge and rubbing strakes are increased in size as shown in the drawing. The only woods used in the main structure of the vessel are oak and larch, the deck being of pine. The rise of floor is also much more pronounced in the Scottish type.

It will be seen that in the smaller vessels the weight of wood is practically the same as in those proposed by Simpson but with rather striking differences in various members as shown in the sectional drawing attached.

In the case of Vessel 12 however the comparison is very high and is higher than that of any other regulation. This is accounted for by the double framing, and practically all the other scantlings as shown in table 41.

The Scottish method of double framing is different from that of the Danish type as the two frames are bolted together after the inside faces have been treated with preservative. When a Scantling Numeral of 20,000 and over is reached the horse power and weight of the engine necessitates such construction.

In vessels of 80 ft. (24.4 m.) and over it is becoming general practice to fit steel bulkheads and steel beams in way of the engine room with steel engine beds and these can be welded together to form a strong attachment for the engine.

The papers by Simpson and Hanson have, Mr. Sutherland hoped, started a movement that will eventually lead to more discussion and interchange of ideas on this controversial but highly important subject.

In Scotland there is no intention of standardizing the design of vessels, as this would be a retrograde step and a bar to progress. He was happy to add that the step taken was made in consultation with the principal producers' associations and with the fullest co-operation and advice of the builders. Improvements are bound to come and this can be greatly speeded up by the interchange of ideas between naval architects and designers.

MR. J. LINDBLOM (Finland): The scantling proposals suggested by Hanson and Simpson have been needed for a long time. When his shipyard started building, some 15 years ago, no scantling tables were available. The conclusion that laminated construction of frames is expensive, is not true. Frames built for 1,500 boats have been found to be cheaper but this depends on equipment used in the construction. It is preferable to start from raw material, then build up the impregnated material for machining and then build up the frames. As regards fastening, bolts with nuts were first used but later old fashioned clinch bolts 0.71 in. (18 mm.) were introduced. These bolts are driven cold. Soft materials were used and proved to be good. Norwegian pine was used, having good absorbing properties for impregnation. It also has tensile strength.

Portuguese and Italian Practices

MR. J. C. E. CARDOSO (Portugal): In Portugal sawn frames are used throughout. The method of construction in which both frame futtocks are interrupted at and tenoned into the keelson is not practised. Local pine and oak are generally used. They are not usually of very high quality with the exception of wood coming from a few forests. This leads in some cases to the use of increased scantlings.

He has not yet had time to compare fully the scantlings they use in Portugal with those given in the two papers. He would only say that in Portugal they would not go below 30 mm. (1¼ in.) in hull and deck planking and that beams are very seldom placed on the same spacing as frames. Their spacing is regulated by the arrangement of hatches and casings.

Deck camber is generally 1/30 to 1/20 of beam. In some cases regulations limiting size of fishing vessels would penalize the boats with greater camber. In wood construction they use scarphes in keels which agree with the ones indicated by Hanson.

For bulkheads the tongue and groove construction, with one thickness of plank, is quite prevalent. Such bulkheads are not strictly speaking watertight. On the whole their scantlings agree with the "as built" figures given by Simpson and not too well with the ones given by Hanson. Keels are never square in section and keelsons are always practically so. On the matter of caulking, he agreed most certainly with Hanson. On fastenings, scarphes and bent frames, he agreed with Tyrrell.

They use and recommend the bilge stringer construction mentioned by the Scottish participants. They do not use keelsons in their smallest craft and the engine bearers are always extended well forward.

He would point out that standard scantlings, although very desirable, can only be worked out in conjunction with a table of standards of quality and strength of materials and standard methods of construction. Both these standards are now unobtainable on an international basis and in his opinion that makes the two papers even more important.

He liked to think that standards could be used to further evolution and adaptation to local conditions which vary considerably due to service requirements of the vessels and wood working habits. He regretted to say that scantling tables of classification societies had been used as a rigid law in his country. Here was the superiority of Simpson's paper where the underlying working hypothesis was clearly stated and allowed for other basis to be applied.

He felt it was the duty of all participants to provide this kind of information regarding their own local standards as Hanson and Simpson have done.

Regarding Simpson's numeral, he would only disagree with the use of LOA as a parameter, although it seemed a most practical one.

In Portugal both the Veritas rules are generally followed in wood and steel construction and from 130 ft. (40 m.) upwards Lloyds or Veritas in steel construction.

Referring to fig. 120 in Hanson's paper, he presumed that the fastenings were merely generally indicated and that possibly their details would not exactly correspond to what the drawing appears to show. Otherwise he would prefer different arrangements.

DR. G. BORDOLI (Italy): He was pleased to note that from the small amount of information given in the various papers, it was evident that for hulls of the same type and of the same dimensions, the weights of the bare hulls varied quite a bit, if constructed according to traditional local methods or the various government or classification institute regulations. The reasons for these differences, which it certainly would be a good thing to eliminate or at least reduce, are due to the varying importance attributed to the different parts of the hull structure.

In a congress in Ancona in 1955, Italian shipbuilders requested, at his suggestion, that the Registro Italiano Navale (RINA) should modify the regulations for wooden construction. Adopting the same methods as Gnanadoss, he had now been able to conclude that for the construction of a hull of similar dimensions as No. 6 of Simpson, using the regulations of the Bureau Veritas and the RINA, the weights proved to be about 18 and 30 per cent. greater than those foreseen by Simpson's scantlings.

The subject of scantlings is such a vast and complicated one that a separate Congress for that purpose is called for. Regulations had been drawn up according to tradition in different countries, and boats built according to them. It was very complicated to compare various specifications, because they were based on local rules.

He agreed with all participants that standardization was difficult to achieve because of local conditions, availability of timber, labour, etc. The traditions of boat building go back thousands of years: if one went back to these traditions, it might be possible to obtain some comparisons and evolve some standards and then, with suitable coefficients, suggest the best scantlings for the respective areas. He knew that different emphasis had been attached to various structural particulars.

Strength with economy

MR. J-O. Traung (FAO) said that it was evident that some participants disagreed with Simpson because they had different practices. If when comparing two successful boats built differently one type was built with considerably less

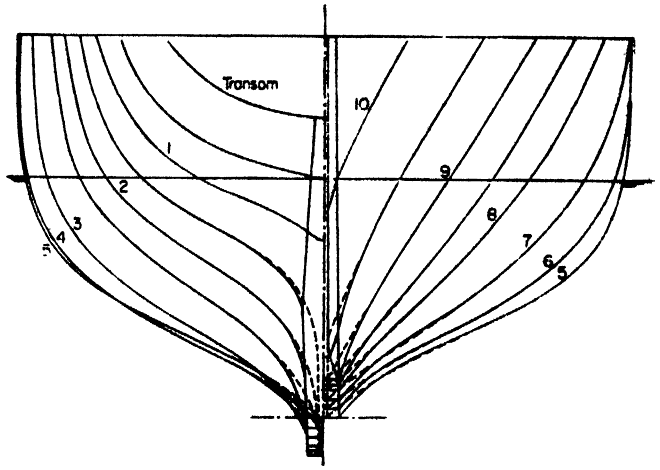


Fig. 168. Body plan of 78.5 ft. (24 m.) fishing boat in both wood and steel version, the steel version having 7 to 9 per cent. lower resistance

material and both had withstood the hazards of the sea for many years, then the lighter one would be the most economical to build. It was important to remember that Simpson's proposals were based only on successful boats. They might be too heavy—but not too light.

Mr. Traung had first seen the possibility of using steam-bent frame construction in large fishing boats when he visited

TABLE 43

EHP values for similar ships made of steel and wood

	Δ=135 ton								
	B=19 ft. (5.8 m.)			B=21 ft. (6.4 m.)			B=22.9 ft. (7.0 m.)		
	M87 Wood	*M106 Steel*	*Improvement*	*M66 Wood*	*M99 Steel*	*Improvement*	*M57 Wood*	*M100 Steel*	*Improvement*
V	*EHP*		*Per cent.*	*EHP*		*Per cent.*	*EHP*		*Per cent.*
6	15.7	13.8	12.1	16.1	15.3	5.0	15.9	14.3	10.1
7	27.6	25.3	8.3	28.5	27.3	4.2	29.1	25.8	11.3
7.5	36.8	33.6	8.7	37.7	35.7	5.3	38.8	34.3	11.6
8	50.2	44.8	10.7	50.0	46.7	6.6	51.9	45.3	12.7
8.5	66.8	60.3	9.7	66.2	61.4	7.3	68.8	60.4	12.2
9	85.6	78.9	7.8	84.5	78.6	7.0	88.0	80.4	8.6
9.5	107.5	100.4	6.6	106.7	99.0	7.2	110.0	104.0	5.5
10	134.7	124.8	7.4	135.0	124.9	7.5	137.9	127.5	7.5
			8.9			6.3			8.0
				Δ=110 ton		8.1			
				Δ=160 ton		7.8			
						7.4			

TABLE 44

steel Dutch fishing cutters from 50 to 100 ft. (15 to 30 m.)

LOA	ft.	49.2	54.0	59.1	62.3	65.6	68.9	73.8	77.8	78.7	82.0	91.8	98.5
	m.	15.00	16.45	18.00	19.00	20.00	21.00	22.50	23.70	24.00	25.00	28.00	30.00
LBP	ft.	43.0	47.7	52.5	55.6	58.1	62.0	63.5	68.7	71.2	73.1	83.4	88.6
	m.	13.20	14.55	16.00	16.97	17.70	18.90	19.35	20.95	21.70	22.27	25.40	27.00
Breadth, moulded	ft.	13.5	15.4	16.7	17.4	17.7	18.4	19.0	19.0	19.7	20.7	21.3	21.7
	m.	4.10	4.70	5.10	5.30	5.40	5.60	5.80	5.80	6.00	6.30	6.50	6.60
Depth, moulded	ft.	6.4	7.1	7.5	8.0	8.2	9.0	9.0	9.0	9.8	10.7	10.7	11.5
	m.	1.95	2.15	2.30	2.45	2.50	2.75	2.75	2.75	3.00	3.25	3.25	3.50
Draught, aft	ft.	5.7	5.9	6.6	7.1	7.2	8.2	8.2	8.2	8.5	9.8	10.2	10.8
	m.	1.75	1.80	2.00	2.15	2.20	2.50	2.50	2.50	2.60	3.00	3.10	3.30
Gross tonnage (74.5 ft. or 23.70 m. and upwards with closed whaleback)		21.40	32.50	42.83	46.34	52.48	63.59	67.14	85.73	91.80	110.67	129.80	155.60
	BHP	50	80	100	120	135	150/180	200/250	250/320	250/320	375	450	500
	r.p.m.	320	350	320	350	350	750/300	750/300	750/300	750/300	750/300	750/300	750/300
Speed	knots	8	8	8½	9	9	9¼	9¼	9½/10	9½/10	10	10½	10½
Stem (bended plate)	mm.	7	8	8	8	8	9	9	9	9	9	9	9
Sternpost	m.	75 × 25	100 × 45	100 × 50	100 × 50	100 × 50	125 × 50	125 × 50	125 × 50	125 × 50	125 × 54	125 × 60	125 × 63
Barkeel (with bulb)	,,	150 × 8	150 × 8	180 × 10	180 × 10	180 × 10	180 × 10	180 × 25	180 × 25	180 × 25	180 × 25	200 × 25	200 × 25
Bilgekeels (with bulb)	,,	150 × 7	150 × 7	180 × 8	180 × 8	180 × 8	180 × 8	180 × 8	180 × 8	180 × 8	180 × 8	200 × 8	200 × 8
Rudderhead	,,	65	80	85	90	90	90	95	100	100	105	115	125
Rudderplates	,,	6	6	6	6	6	6	6	8	8	8	8	8
Keelplate	,,	7	7	7	8	8	8	8	8	9	9	10	10
Sheerstrake	,,	6	7	7	8	8	8	8	8	8	8	10	10
Other shell plates	,,	6	7	7	7	7	7	8	8	8	8	9	9
Bulwark	,,	5	5	5	5	5	6	6	6½	6½	7	8	8
Steel deck	,,	5	6	6	6	6	6	6	6	6	6	6	7
Wooden deck (teak)	,,	60	60	60	60	60	65	65	65	65	65	65	65
Bulkheads	,,	6	6	6	6	6	6	6	6	6	6	7	7
Bulkheads lower plate	,,	6	7	7	7	7	7	7	7½	7½	7½	8	8
Bulkhead stiffeners	,,	65 × 50 × 6	65 × 50 × 6	65 × 50 × 6	65 × 50 × 6	65 × 50 × 6	75 × 50 × 7	75 × 50 × 7	75 × 50 × 7	75 × 50 × 7	75 × 65 × 7	90 × 65 × 7	90 × 65 × 8
Bulkhead stiffeners		700	700	700	700	700	700	700	700	700	700	700	700
Floors		300 × 5	300 × 5	350 × 6	350 × 6	350 × 6	350 × 6	350 × 7	350 × 7½	350 × 7	350 × 7	380 × 8	400 × 8
Frames	,,	50 × 50 × 6	65 × 50 × 6	65 × 50 × 7	65 × 50 × 7	65 × 50 × 7	75 × 50 × 7	75 × 50 × 7	75 × 50 × 7	75 × 50 × 7	75 × 65 × 8	75 × 65 × 8	90 × 65 × 8
Frame spacing	,,	450	450	450	450	450	450	450	450	450	450	450	450
Deckbeams	,,	65 × 50 × 6	75 × 50 × 6	75 × 50 × 7	75 × 50 × 7	75 × 50 × 7	90 × 50 × 7	100 × 50 × 7	100 × 50 × 7	100 × 65 × 7	100 × 65 × 8	100 × 65 × 8	100 × 65 × 8

Hanson in 1948, and learnt that these boats had a lifetime of over 30 years. The boats in his home country, built of sawn frames, did not all last so long. He had come to the conclusion that steam-bent frame construction was superior. Many seemed to think that a frame should have a big section modulus. Mr. Traung felt that a frame should not be regarded as a beam, but rather as a tie rod—something which kept the planking together—and a very flat section of the steam-bent frame as suggested by Chapelle might be suitable. In fact, smaller boats have been built with stainless steel tie rods inside the planking, which thus forms a true arc construction.

Builders of wooden boats were feeling increasing competition from builders of steel ships, the construction of which had been very much simplified during the last few years. Welding, for instance, had developed with the use of covered electrodes and with cheap welding equipment. Mr. Traung felt that the builders of wooden boats should drop their conservative attitudes and study the practices of other countries, with a view to improving their own methods. Only in this way could they hope to produce boats which were cheaper than those constructed of steel.

Scantlings were important, not only to builders and owners of fishing vessels, but also to FAO, for FAO aimed at cheaper fish production, which could be achieved by building cheaper fishing vessels. If there were no competition from steel ships, it would not matter from the wooden boatbuilding point of view whether the vessels were built heavy or not, so long as all builders gave the same quotations, but it made a big difference to both the fisherman and the consumer if there was also unnecessarily heavy initial investment.

RESISTANCE OF WOODEN KEEL, STEM AND STERN POST

MR. W. HENSCHKE (Germany): Hanson showed that it is important to have a strong keel and corresponding stem and stern post to give wooden boats a good strength. He agreed with this but wanted to draw attention to the fact that resistance and propulsion characteristics also have to be considered. In the model tank at Berlin–Potsdam he had made tests with wood and steel 78.5 ft. (24 m.) fishing boats having the same dimensions and shape. The models were made to the scale of 1 to 10. According to fig. 168 the difference consisted only in the type of keel, stem and stern post. In spite of comparatively small differences, the steel boat had, according to table 43, as an average, 7 to 9 per cent. smaller resistance than the wooden boat (these results have also been given in FAO Fishing Boat Tank Tests, Part II). Later resistance and self-propulsion tests were made with a model of scale 1 to 8 and it was found that the propulsive efficiency of the steel boat was some 10 to 20 per cent. higher than that of the wooden boat. He felt that the wooden boatbuilder should consider these results and endeavour to obtain the best combination of strength and resistance such as fairing stem and stern posts.

STEEL SCANTLINGS

MR. W. ZWOLSMAN (Netherlands) referred to Hanson's paper, which gave minimum scantling dimensions of steel boats, and suggested that a further list of scantlings based on many years of actual practice might be useful.

Table 44 indicates scantling dimensions that are also approved by Lloyd's Register of Shipping and Bureau Veritas. All the construction drawings of the fishing craft built by his firm have been approved by one of these classification bureaus or by both. If the boats are to be supplied with a certificate for ice-reinforcement, the shell plates must be .02 to .04 in. (½ to 1 mm.) thicker.

A comparison of this specification with Hanson's shows that the shell plates are somewhat heavier and the frame distance somewhat smaller.

Owing to the heavier shell plates it has never been necessary to apply longitudinal frames. Heavier shell plates also are found to prolong the life of the boats considerably.

As per the prescriptions of the Shipping Inspection or the insurers, the shell plates must be renewed if wear and tear have reduced their thickness to .16 in. (4 mm.), and obviously if shell plates .32 in. (8 mm.) instead of .24 in. (6 mm.) thick are applied, it will be twice as long before the critical limit of .16 in. (4 mm.) is reached. These heavier shell plates have only little influence on the overall cost price of the boat.

REPLIES OF AUTHORS

MR. H. C. HANSON (U.S.A.): His paper suggested a minimum standard scantling table based upon actual usage in thousands of vessels that had been built throughout the world, boats now in operation having been built along these standards as long ago as 60 years. So far as preservatives for wood were concerned, he was of the opinion that anything that penetrates the wood is good, but that anything forming a coating over the wood where moisture is encased is not good, since this forms a rot condition.

Air circulation and the use of salts are recommended. The use of sawn frames fore and aft in a bent oak frame boat are necessitated because the shapes require it, builders will try to bend the frames and they crack, so to overcome this they split the bent frame, which he considered bad practice, because experience shows that rot will occur between the two split members. The use of deep floors is good, not only for the strength they give the vessel, but in smaller vessels the tonnage measurement is reduced which is an advantage in some countries. Chapelle's statements that boats should be built and used only in the areas where the wood itself grows, for longevity, he did not agree with, one has only to see the many wooden vessels built in the Southern parts of U.S.A. from the Northwest firs to refute this statement. He agreed with Chapelle that the use of independent top timbers is good, but more costly; Mr. Hanson had shown the frames extended to form bulwarks because one pays for the oak to bend the frames, and thus he had shown this construction for economical reasons. Iron bark sheathing over soft wood planking is used in the Pacific Northeast, in constrast to the use of solid hardwoods for planking as mentioned for Iceland, and he believed the sheathing method was better and more economical and easier repaired.

Mr. Hanson agreed that the steel engine bed for a wooden vessel is superior construction, he had used steel engine beds for years and had used steel bulkheads in conjunction with them tieing the engine bed to bulkheads at ends of engine room, and he found this reduced vibration and made a better vessel for upkeep costs.

The use of clinch bolts in wooden vessels was discontinued at the end of World War I; they do not do a good job, and as soon as the wood shrinks around them nothing can be done about it. By using screw bolts one is able to cinch them up at any time, and before delivery of any vessel it is common practice now to cinch up on the screw bolts, after wood has dried out while building. Even on vessels several years old one can take up on these screws.

Hook scarphs will do the job all right, but they are costly to make and Mr. Hanson saw no purpose whatsoever in using them, as the many thousands of vessels built from his plans never had any and neither did the 60-year-old vessel above mentioned. Also since there is some pretty heavy weather throughout these Pacific areas, he considered money spent on lock scarphs, lock dowels a waste of time and money. Lock strakes come under the same category of waste.

MR. DWIGHT S. SIMPSON (U.S.A.): Since so many variations of Numerals have been offered with a number of suggestions seeming a bit wide off the mark, Mr. Simpson thought it well to repeat and amplify some of the statements in his paper.

The paper was an attempt to develop by analysis of existing fishing vessels, minimum scantlings for the construction of fishing vessels but not freighters, sailing yachts or motor boats. They were not intended to be used without judgement; however since the prototype vessels serving the analysis have existed for many years in North Atlantic waters from Hatteras to the North of Newfoundland—about as tough an area as can be found anywhere—sound judgement might, of course, increase scantlings for Arctic use or decrease the same for less arduous spots of the world.

It was known that most fishing vessels are still built from models, or even from rule of thumb, with no plans available. Therefore, basic dimensions that required no plans or engineering skill to obtain were chosen.

Length (LOA) was taken as overall length simply because most fishermen and many builders know and talk no other length. Length on the waterline may vary with the loading and trim. Length between perpendiculars is no nearer estimate of the vessels size than length overall, and would have to be explained to many owners and builders.

Breadth (B) over the planking is easy and universal.

Depth (D) amidship from top of deck at side to the rabbet line is easy to obtain and a better measure of size than if taken to top or bottom of keel or top of floors (Hanson mentions the use of deep floors to reduce tonnage measurement, for instance).

Mr. Simpson thought that perhaps not enough had been said about the effect of varying prismatic coefficient. Again remembering that the paper dealt with fishing vessels, the limits of the prismatic appear to be between .58 and .68.

If the 85 ft. (25.9 m.) vessel No. 12 were designed to these limits, maintaining the same displacement she would have midship coefficient between .791 and .680 or areas between 96.4 sq. ft. (8.95 sq. m.) and 82.8 sq. ft. (7.7 sq. m.). These sections give half girths of 15.23 and 16.06 ft. (4.65 and 4.9 m.), a difference of ±.415 ft. (.126 m.) or ±2.66 per cent. from the average of the two. Applying this differential to the calculation of the numeral, the minimum F × N will be 1,079 and the maximum 1,192. Entering the chart, fig. 147, Z minimum will be 16 and Z maximum 17.55 and from fig. 148 the minimum frame section will be 3.65 × 6.28 in. (93 × 160 mm.) and the maximum section 3.82 × 6.57 in. (97 × 167 mm.). Both of these would likely be transformed by the builder into 3¾ × 6¼ in. (95 × 160 mm.), or perhaps 6½ in. (165 mm.).

Again, an examination of 60 vessels from all parts of the world show a minimum midship section coefficient of .641 and a maximum of .900 (both are extreme and rare), which give half girths of 15.21 and 17.86 ft. (4.65 and 5.45 m.) or ±8 per cent. from the median. Applying this differential as before to the F formula gives a minimum section of 3.35 × 6 in. (85 × 152 mm.) and a maximum of 3⅞ × 6½ in. (98 × 165 mm.). These are so close to the 3¾ × 6¼ in. (95 × 160 mm.) obtained from the unmolested rule that it seems not worth while to further complicate the numeral calculations.

While a number of rules use the R or diagonal extension factor, it would appear from the above that it matters little, especially since fishing vessels with large midship sections seem to have small prismatics and vice versa. The American Bureau of Shipping uses a block coefficient at .8 × D which clearly fixes the capacity and, of course, makes it necessary to have a completed lines drawing. The original list of prototype vessels would be greatly reduced owing to lack of lines and a new list established before calculating a new set of graphs, and Mr. Simpson again wondered if the game is worth the candle. If these formulae become so complicated that many would close the book after a partial glance and go on building in their accustomed manner what has been gained?

The paper requested that timbers from other countries be related to those listed. Only Swinfield has complied and it would be valuable if he had included more varieties and more details. Mr. Simpson believed the controlling properties would be specific gravity, resistance to rot, and obtainable size. For vessels of 75 ft. (22.9 m.) and smaller, bending properties would be valuable. Teak was not included in the original list since it is not a fishing vessel timber in the North Americas.

Tyrrell and others question the position allotted to larch, but he is talking of the European larch (*larix decidua*). The U.S. Western (*larix occidentalis*) and Eastern (*larix laricina*) larches are very different and generally yield a brash timber and, except for the roots from which the old "hackmatack" ship knees were hewn, are almost unknown in shipbuilding.

Mr. Simpson was surprised at the universal antagonism shown against the round spike and wondered if a square drift or bolt is in universal use in other parts of the world. He thought it strange that minds able to accept complicated mathematical formulae and model basin tests as criteria for good hull design baulk at equally good mathematics and laboratory tests as criteria for good fastenings. Obviously there is no reason except custom for the feeling. Simply to say that fig. 153A (used almost exclusively in the North America for more than 100 years) or fig. 154D (used by the best boat and shipbuilders for 20 or 25 years) "are unfit for fastenings" or that "the square fastening is to be preferred" is not a satisfactory answer in the face of technical and practical experience to the contrary.

Tyrrell's standard spike was once largely used as a clenche nail but is now largely succeeded by the wood screw. The long life of his sample is, of course, due to the purity of the metal and the excellence of the galvanizing.

McGruer's fluted "Belgian" nail seemed to hold well in withdrawal but appears weak in lateral resistance. It also might be expensive.

With some experience of structural testing, Mr. Simpson was of the opinion that Hamlin has outlined a program so extensive and costly that none but a Government or wealthy Foundation could finance it. The results would have a qualitative value but otherwise might have to wait until some sort of strain measurements were devised and tried on parts of many hulls in service.

Hamlin and others desire the rules to be extended to smaller boats and bent frames. The paper by Smith (1950), already referred to, covers the subject quite well with reference to U.S. West Coast construction.

Experience has shown that, at least up to 75 ft. (22.9 m.) or so, a well-built bent frame vessel is at least the equal of sawn frame construction in ability to stand grief. Glued laminated bent frames have been used in U.S. Navy vessels as large as 165 ft. (50.3 m.), with satisfactory results, but they are not troubled with large and varying loads.

Bardarson, Gnanadoss and Sutherland have laboured mightily in a good cause and their efforts serve well to show the need of further study of the scantling problem.

If Bardarson's 75 GT vessel is compared with Mr. Simpson's slightly larger vessel No. 12 in Gnanadoss's table 36, it is found to be 68.6 per cent. heavier than Mr. Simpson's formulae; 32.8 per cent. heavier than Bureau Veritas; 32.5 per cent. heavier than Swedish; 28.3 per cent. heavier than Newfoundland. Sutherland would rate it 22 per cent. heavier than the White Fish Authority rule. This is indeed a heavy vessel, sacrificing many tons of pay load at some considerable expense. It seems added proof that the subject under discussion is well worth pursuing. Icelandic waters cannot be so severe as to justify such heavy scantlings—if they were so severe, the GM and GZ of the Icelandic vessels could not be as low as they are.

Takagi's graphs are extremely interesting and will be of great assistance in the final analysis. His fig. 161 and question recall the statement in the paper than no New England or Nova Scotia trawler has planking less than 1½ in. (38 mm.) finished thickness and possibly a revision of the figures would develop 3 in. (76 mm.) finished planking for an N of 8 instead of 7. It is interesting to find the Simpson rule in the middle, more or less, of the several proposed Japanese rules.

In Mr. Simpson's opinion the keels of his vessels, both existing and rulewise, are much too heavy structurally. It must be remembered that all these vessels handle their nets from the side and the necessity of holding the vessel against drift while bringing in the net accounts for the depth of keel. He has added box keels of wooden keel dimensions to several steel trawlers, improving their handling of the net immensely, and has just completed a design of a 110 ft. (33.5 m.) steel dragger with such a keel.

Answering Takagi's third question, Mr. Simpson said that the section modulus per foot of ship's length of beams as for frames is simply Z of the beam divided by spacing in inches multiplied by 12. In this connection it should be noted that beams should be spaced to suit bulkheads, hatches and deckhouses but kept as close to standard as possible. If a different spacing is wanted the chart gives it. However, in spite of comments, the closer the beams are spaced the smaller and cheaper they are. Experience shows that with small spacing the expensive knees are not required for long life.

To Zimmer's question, Mr. Simpson stated that U.S. North East coast vessels are sheathed only to protect the planking from surface ice and the banging of the doors. He would like to see details of Zimmer's concrete keelson.

The suggestion that all standard specifications be collected in one volume is good but might make it harder for the novice to make up his mind. He therefore preferred the idea of a world-wide committee to collect and analyse the various rules in an attempt to revise the formulae and suggested variations, other timbers, etc.

He noted that Sutherland's fig. 167 apparently shows single frame futtocks with long butt straps for the smaller vessels but believed that double futtocks of lighter scantlings would be a lighter and stronger frame.

Sutherland's engine bed seemed very deep and subject to vibration. The crossing of the keelson with secondary floors would stiffen the hull under the engine, decrease the size of the engine bed, and minimize vibration.

Mr. Simpson agreed with Chapelle's remarks on bent frames except for the preference for thin frames. Most Nova Scotia small craft are built this way and invariably show many broken frames after short use. Thin frames offer little bury for ordinary spikes; clench nails are unreliable, being subject to rust and breaks at the bend; rivets and screws are expensive. With proper equipment there is no great trouble in bending 3 in. (76 mm.) stock. If thicker is required it could be laminated with added strength.

Mr. Simpson took issue with Traung, believing that it does matter to the trade whether a boat be light or heavy. The lighter vessel saves both timber and labour and carried more load. It should sell for less and easier, and would tend perhaps to more boatbuilding.

He agreed with Traung that frames could be reduced, even perhaps, dispensed with if planking could be made a monolithic unit such as can be achieved by double or triple planking, by glued strips or edge fastening. (He has seen 40 × 8 ft. (12.2 × 2.4 m.) dugouts with no framing). For hundreds of years large Chinese junks have been built with no frames, just intermittent cleats holding three or four planks together plus a unique method of edge fastening the planks. As long as the skin consists largely of individual planks transverse strength must be achieved by frames and under this stress they could be likened to beams.

Mr. Simpson hoped that Swinfield can be persuaded to expand his thoughtful remarks, with more information on Australian scantlings and timbers. He also joined the majority of discussers in the hope that FAO can arrange a further research into the possibility of more uniform basic scantlings.

GLASS REINFORCED PLASTIC HULLS

by

PATRICK D. DE LASZLO

The paper deals with plastic hulls and decks made from cold setting polyester resin reinforced with glass fibre "mat" laid up in a female mould. The chief advantages of plastic hulls are low initial cost and very low maintenance and repair costs. One hull costs no more than an equivalent wooden hull but several hulls from the same mould are cheaper than wooden hulls. Maintenance costs are low because plastic hulls are unaffected by sea water; they cannot warp, rot, or split like wooden hulls. They are dry because they are homogeneous and therefore will not open at the seams or leak. They cannot rust or corrode and they are not subject to galvanic action like aluminium, nor are they attacked by marine borers. They do not absorb water, therefore they cannot be contaminated by fish nor will they add to their own weight by water absorption like a wooden hull when they are launched. Plastic hulls do not have to be painted. The colour is impregnated into the resin at the time of manufacture. The colour can, however, be changed if desired by sanding down and painting with a suitable paint. Plastic hulls can be made fire-resistant. They are stronger than wooden hulls of the same weight and have greater resistance to impact. They are resiliant and do not dent under impact. If a plastic hull is damaged in a collision the damage will be local—that is to say there are no planks to split. A first-aid repair can be carried out in a matter of hours and a full-scale repair takes less than one-tenth of the time required to repair a wooden hull. Plastic is a natural insulator and therefore will not sweat internally like metal. The largest plastic hulls in the world are built under Lloyd's survey, with bulkheads, tanks and engine foundations installed while the hulls are still in their moulds.

LES COQUES DE PLASTIQUE RENFORCE DE FIBRE DE VERRE

La communication traite des coques et ponts de plastique fabriqués avec de la résine de polyester prenant à froid, renforcée par des matelas de fibre de verre étalés dans un moule creux. Les principaux advantages des coques de plastique sont le coût initial bas et les très faibles dépenses d'entretien et de réparations. Une coque de plastique ne coûte pas plus qu'une coque équivalente de bois, mais plusieurs coques sorties du même moule coûtent moins cher que des coques de bois. Les frais d'entretien sont faibles parce que les coques de plastique ne sont pas affectées par l'eau de mer: elles ne peuvent ni gauchir, ni pourrir ou se fendre comme les coques de bois. Elles sont sèches parce qu'elles sont homogènes et ainsi ne s'ouvrent pas aux joints et ne fuient pas. Elles ne peuvent pas rouiller ni se corroder ni être attaquées par les organismes perforants marins, et elles ne sont pas sujettes à l'action galvanique comme l'aluminium. Elles n'absorbent pas l'eau: ainsi elles ne peuvent pas être contaminées par le poisson et leur propre poids ne peut pas être augmenté par absorption d'eau comme une coque de bois quand elles sont lancées. Il n'est pas nécessaire de peindre les coques de plastique. La résine est imprégnée de colorant au moment de la fabrication. Cependant, on peut changer la couleur si on le désire, en sablant la coque et en la peignant ensuite avec une peinture appropriée. Les coques de plastique peuvent être rendues résistantes au feu. Elles sont plus robustes que les coques de bois de même poids et ont une plus grande résistance aux chocs. Elles sont élastiques et ne se bossèlent pas sous le choc. Si une coque de plastique est endommagée dans une collision, les dégâts sont locaux—c'est-à-dire qu'il n'y a pas de planches de bordé qui se fendent. Une réparation urgente peut être effectuée en quelques heures, et une réparation normale prend moins d'un dixième du temps nécessaire pour réparer une coque de bois. Le plastique est un isolant naturel, donc il ne transpire pas à l'intérieur comme le métal. Les plus grandes coques de plastique du monde sont construites sous le contrôle du Lloyd's, les cloisons, les réservoirs et les fondations du moteur étant installés alors que les coques sont encore dans leurs moules.

CASCOS DE MATERIAL PLASTICO REFORZADO CON FIBRA DE VIDRIO

Trata esta ponencia de los cascos y cubiertas de materiales plásticos fabricados con resina de poliéster de fraguada en frío, reforzados con palletes de fibra de vidrio extendidos en un molde hueco. Las principales ventajas de los cascos de plástico son su costo inicial bajo y los pequeños gastos de mantenimiento y reparación. Un casco de plástico no cuesta más que uno equivalente de madera, pero varios cascos hechos con el mismo molde son más baratos que los cascos de madera. Los gastos de mantenimiento son bajos porque a los cascos de plástico no les afecta el agua del mar: no se pueden alabear, ni pudrir, ni rajarse como los cascos de madera. Son secos porque son homogéneos y, por tanto, no se abren en las juntas ni se hacen vías de agua. No se pueden oxidar ni corroer y no están sometidos a la acción galvánica, como el aluminio, ni pueden ser atacados por los taladradores marinos. Como no absorben agua, no los puede contaminar el pescado ni aumentará su propio peso por absorción de agua como aumenta el de un casco de madera cuando se bota. No hay que pintar los cascos de plástico. La resina se impregna de colorante en el momento de la fabricación, pero si se desea cambiar el color, se puede hacer raspando el casco con arena y pintándolo con una pintura apropiada. Se puede hacer que los cascos de plástico resistan el fuego. Son más robustos que los cascos de madera del mismo peso y tienen mayor resistencia a los choques. Son elásticos y no se abollan al chocar. Si un casco de plástico sufre averías en una colisión, los daños son locales, es decir, no hay planchas que se puedan romper. Una reparación urgente se puede hacer en unas pocas horas y una reparación normal tarda menos de la décima parte del tiempo necesario para reparar un casco de madera. El plástico es un aislante natural que no transpira en el interior como el metal. Los mayores cascos plásticos del mundo se construyen bajo la inspección de la Lloyd's y los mamparos, los tanques y las bases del motor se instalan mientras los cascos están todavía en los moldes.

GLASS reinforced plastic can be used for making the hulls and decks of all vessels—and in particular fishing vessels—up to 130 ft. (40 m.) in length. Glass reinforced plastic in this context means a laminate made of several layers of 2 oz./sq. yd. (68 gr./sq. m.) glass fibre "mat" impregnated and bonded together with cold setting polyester resin. For convenience, this type of glass reinforced plastic is referred to as Polyester/Mat or P/M.

The raw materials of Polyester/Mat [P/M] laminate

The chemistry of cold setting polyester resin is outside the scope of this paper. It is now produced by a number of manufacturers. The resin is an almost colourless liquid which can be stored for considerable periods in a cool place. The resin is activated by the addition of small quantities of two other chemicals, generally known as the "accelerator" and the "catalyst", which cause it to set hard in a predetermined time. After the resin has set it will continue to harden over a period of about four weeks. For the purpose of building boats it is usual to arrange for the resin to set in 30 minutes.

Glass mat is made of short lengths of glass threads disposed at random and loosely held together like a very coarse felt. Glass thread is composed of glass fibres each of which is about one-tenth of the thickness of a human hair. These fibres are astonishingly strong and flexible. Comparative tensile strengths are:

Glass fibre:	180,000–300,000 lb./sq. in.
	(12,650– 21,000 kg./sq. cm.)
Cotton:	59,000–124,000 lb./sq. in.
	(4,150– 8,700 kg./sq. cm.)
Nylon:	65,000–117,000 lb./sq. in.
	(4,560– 8,200 kg./sq. cm.)
Silk:	68,000 lb./sq. in.
	(4,770 kg./sq. cm.).

Method of making laminate

The process by which glass mat is laid into a mould and impregnated with polyester resin so as to form a Polyester/Mat (P/M) laminate is generally referred to as a "wet lay-up". The surface of the mould is first treated with a separating agent such as wax to ensure that the laminate cannot stick to the mould. A "skincoat" is then applied by painting or spraying the surface of the mould with a film of polyester resin which will eventually become the outside surface of the laminate. This film of resin is generally coloured.

The next stage is to apply a layer of glass scrim and resin. Glass scrim is a very loosely woven cloth similar to the cloth used for covering bacon.

When the scrim coat has hardened, successive layers of 2 oz. glass mat, impregnated with resin, are applied until the required thickness has been achieved.

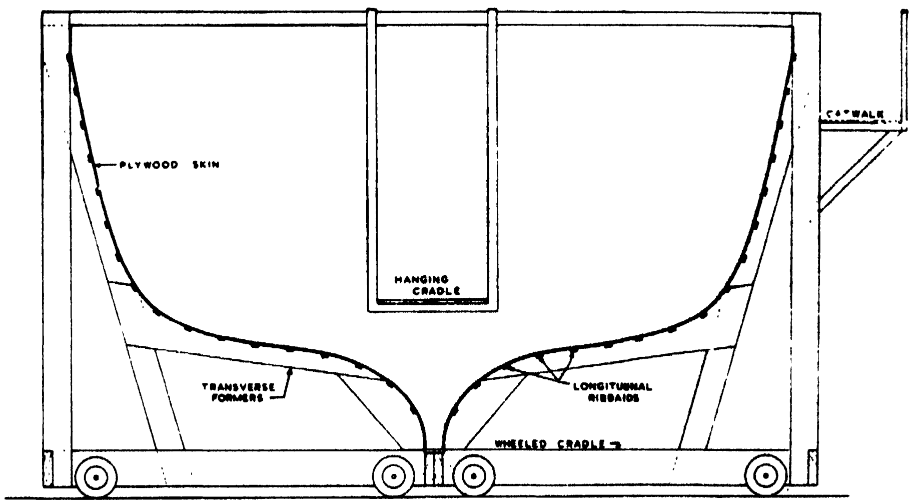


Fig. 170. Section through a wood mould for plastic construction

Each layer of glass mat will weigh approximately 4 lb./sq. yd. (3 lb. of resin and 1 lb. of mat), or 2.17 kg./sq. m. and will be approximately $\frac{1}{16}$ in. (1.6 mm.) thick. Hulls less than 30 ft. (9.15 m.) long require only three layers of mat which means that they will be about $\frac{3}{16}$ in. (4.75 mm.) thick; 30 to 40 ft. (9 to 12 m.) long hulls are 4 to 5 layers thick, 40 to 56 ft. (12 to 17 m.) long hulls are 6 to 7 layers thick, and hulls 57 to 80 ft. (17.4 to 24.5 m.) long are 7 to 10 layers thick—according to the purpose for which they are to be used.

Moulds

Hulls are laid up inside a female mould. The mould itself can be made of P/M by first making an exact model of the hull and then laying up the P/M mould over the model. This is convenient for complicated shapes such as deck-houses or where a great number of hulls are likely to be taken from the same mould.

It is, however, cheaper and quicker to build moulds of timber. The frames of the mould are cut from timber or steel to the outside shape of the hull at, say, 2 or 3 ft. (0.6 to 0.9 m.) stations down the length of the hull. The frames are mounted in a cradle built of steel or timber. Fore and aft 2×2 in. (50×50 mm.) wooden "ribbands" are secured to the inner face of the frames at about 5 in. (127 mm.) intervals.

The working surface of the mould is made of plywood secured to the ribbands. The inner surface of the plywood is then carefully sanded and painted. The outside finish of the hull will depend on the care taken to finish the inside surface of the mould. If proper care is taken when finishing the mould the surface of the P/M hulls will be equal to first-class paintwork.

A mould must be made in at least two parts so as to enable the hull to be removed. It is convenient if the transom can be removable and the main mould must be split down the centre line. The various sections of the mould are mounted on rollers so that they may easily be separated, see fig. 170 and 171.

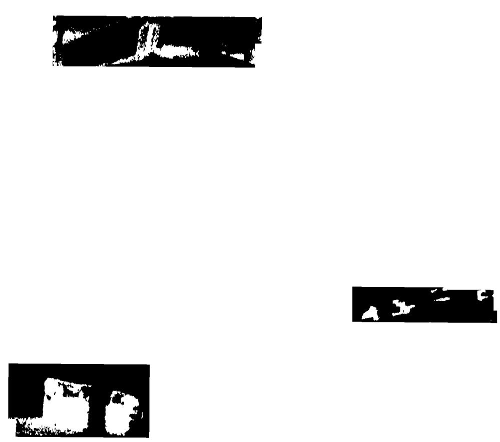


Fig. 171. A polyester/glass mat hull made in a wood and plaster master mould. The 2 halves of the mould have been separated but the hull has not yet been removed from the mould. Note the surface of the hull which is highly polished as it comes out of the mould. Note also the moulded spray chine

Temperature control

A large hull may take several weeks to build: a 56 ft. (17 m.) hull takes about 15 working days. It is therefore important that they should be built in a temperature-controlled building so that the temperature may be held constant day and night, otherwise there will be a difference in shrinkage in the various layers which will lead to strains and possible delamination.

Temperature control is unnecessary for very small boats, such as dinghies and small sailing boats, because the thickness of the hull is generally far greater than is necessary for strength, but with large hulls temperature control is of vital importance in order to avoid the risk of strains within the laminate caused by variable shrinkage.

Other kinds of laminate

It is possible to make laminates with glass cloth which have much higher tensile strength than laminates made with mat, but glass cloth is not suitable for boats because the resulting laminate is expensive, the high tensile strength is unnecessary, and glass cloth will easily delaminate if the surface is damaged.

Laminates can be made with other kinds of resin, in particular various kinds of "heat setting" resins, but they are not suitable for very large mouldings, like boat hulls which may weigh several tons, because it is not practical to heat such large moulds.

Many experiments have been carried out in the U.S.A. and U.K. with the object of making hulls of "sandwich" construction. A fibre glass "honeycomb", or some kind of "foamed" plastic, is sandwiched between an inner and an outer layer of glass cloth. The object is to produce a laminate which is light and rigid.

This sandwich technique has proved valuable in other fields such as radomes for aircraft, and it is sometimes convenient for small boats with flat bottoms, such as pontoons, but it is not yet satisfactory for large hulls because the tensile strength is inadequate; it is considerably more expensive than a P/M laminate; it is a great deal more difficult to repair, and, finally, it is difficult to inspect a sandwich laminate so as to ensure that it is effectively bonded.

Inspection

It is essential that large plastic hulls should be carefully inspected during construction. The largest P/M hulls in the world are built in the U.K. under Lloyd's survey, and the surveyor must have an easy means of ensuring that the quality of a laminate is up to specification.

It takes about 15 to 20 min. to lay 10 sq. ft. (1 sq. m.) of P/M. The resin can be made to set in about 30 min.; therefore, there is a clear 10 min. before the resin hardens after the operator has finished. It only takes an inspector 2 or 3 min. to examine the area, which leaves plenty of time to remove any air bubbles which he may detect.

Air bubbles can easily be seen if the resin is not coloured. For this reason it is customary to add colouring matter only to the outside skin of a large hull and to lay on subsequent layers of 2 oz. (56 g.) mat with colourless resin.

A P/M laminate can be inspected piece by piece and layer by layer but it is never easy to be sure what is happening inside laminates made with heat setting resins or laminates of "sandwich" construction. It must be emphasized that in addition to inspecting each square piece of P/M as it is laid, it is necessary to have the full-time services of a laboratory to test every batch of mat, and every consignment of resin. It is also necessary on a large hull to test samples of the laminate as it hardens in order to make sure that it is fully "cured".

If the resins are not of the correct specification, or if they are not correctly mixed, or if the temperature conditions vary, it is possible that a resin may apparently harden satisfactorily but will never fully cure. In these conditions the resin will gradually "leach" out of the laminate and within a comparatively short time the whole structure will become dangerous.

Strength

The tensile strength of polyester resin by itself is about 8,000 to 9,000 lb./sq. in. (560 to 635 kg./sq. cm.). After it has been reinforced by 2 oz./sq. yd. (56 gr./sq. m.) glass mat, the minimum tensile strength of the resulting laminate is 15,000 lb./sq. in. (1,050 kg./sq. cm.). The mat is composed of glass threads disposed in all directions, therefore the laminate will have this tensile strength in all directions.

Most boats less than 130 ft. (40 m.) in length are built of wood because it is cheaper than steel or aluminium. Therefore, P/M shall be compared with wood.

The tensile strength of wood is 4,000 to 10,000 lb./sq. in. (280 to 700 kg./sq. cm.) along the grain, and negligible across the grain. Needless to say, the tensile strength of wood used in building a hull is seriously diminished by the fastenings and by the fact that the grain often "runs out", whereas in a P/M hull there are no fastenings and the tensile strength is uniform.

The specific gravity of P/M is approximately 1.6. The specific gravity of a wooden hull, including the fastenings, will be somewhere between 0.8 and 0.9. This means that P/M is twice as heavy as wood but, in practice, it is so much stronger that even if the plastic is only half as thick as the timber, which means that it will have the same weight, it will still be stronger than wood.

To emphasize this point:

If a P/M hull is to be the same weight as a wooden hull, the volume of material in the P/M hull can be only half that of the timber hull. This is accomplished by making the skin of the P/M hull only half the thickness of the skin of the timber hull. Even so the P/M hull will be stronger in all respects. Not only will the tensile strength of the P/M hull (both longitudinally and laterally) be greater than the timber hull but the impact strength of the P/M hull will also be greater than a timber hull of twice the thickness.

The hulls of vessels shorter than 100 ft. (30.5 m.) are not highly stressed. On a 75 ft. (22.9 m.) trawler weighing 110 tons, the maximum stress on the extreme fibres at deck level or at the bottom of the skeg—according to whether the vessel is in a hogging or a sagging condition—will not exceed 1,000 lb./sq. in. (70 kg./sq. cm.) if the thickness of the P/M deck and hull is approximately ½ in. (12.5 mm.) thick.

The tensile strength of the P/M laminate is 15,000 lb./sq. in. (1,050 kg./sq. cm.), so this gives an ample margin of safety.

The only problem is to ensure that the hull is thick enough to withstand rough treatment in harbour where the vessel is likely to suffer from surging against the dock-side or against neighbouring vessels. This is more a problem of providing adequate frames and bulkheads.

Rigidity

The P/M laminate is very strong but it is also flexible. The secret of making a P/M hull so that it will be stronger than a timber hull of the same weight but equally rigid lies in stiffening the skin of the hull with hollow P/M "top-hat" transverse frames similar to the frames in a timber hull.

This technique was developed and patented by the author's firm, see fig. 172. It consists of making a thin aluminium former of top-hat section over which a layer of P/M can be laid while in a wet condition. After the first layer has solidified a layer of uni-directional glass fibres, known as "rovings" are laid along the top of the frame so as to increase the tensile strength of the top. The frame is then covered with a further layer of P/M. By this system it is easy to make transverse frames for strengthening the main structure or horizontal frames for strengthening the bow or other special regions.

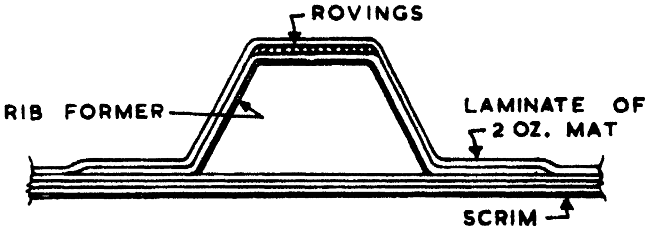


Fig. 172. Section through a top hat frame plastic construction

Hollow skegs

The skeg of a P/M hull is made in much the same way as the skeg of a steel hull. The skin of the hull is carried down to form a hollow skeg which is then reinforced by fitting P/M "diaphragms", or floors, in the way of the frames. These diaphragms are prefabricated—the top face is turned over to form a right angle flange. The diaphragms are bonded into the skeg and then the transverse frames are carried across the top flanges of the diaphragms with the result that the diaphragms become part of the frames and the whole structure is therefore immensely strong and rigid as shown in fig. 173.

Weight

P/M hulls for power-driven boats, up to 30 ft. (9.15 m.) in length, weigh approximately the same as equivalent wooden hulls. Larger power-driven hulls are lighter than equivalent wooden hulls, while still being of the same strength and equally rigid.

It may be of interest to note that a P/M hull for a sailing vessel is a great deal lighter than the equivalent timber hull, because in a wooden hull there has to be a considerable weight of timber whose only function is to serve as a foundation to which planks may be fastened. For example, a P/M 40 to 50 ft. (12 to 15 m.) sailing hull will only be half the weight of the equivalent timber hull.

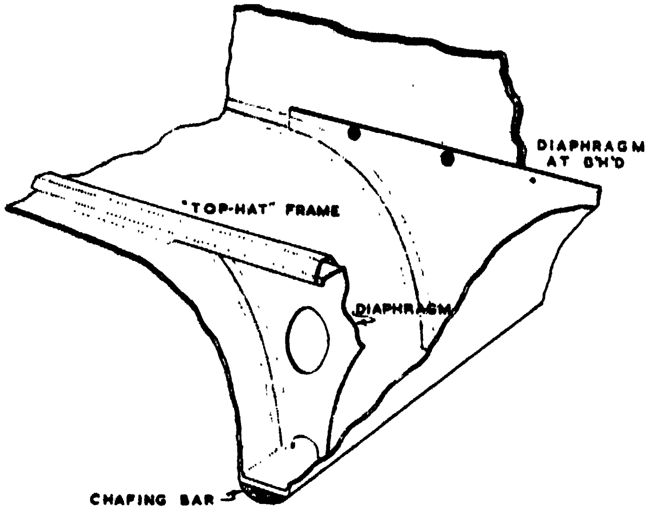


Fig. 173. Hollow polyester/glass mat skeg, or keel, with the top of the floor diaphragm flanged to carry the top hat frames

The horizontal and vertical faces of these tanks are prefabricated and then bonded into the hull before the frames are fitted. Large apertures are left in the top faces of the tanks so as to enable the tanks to be bonded internally as well as externally. These apertures are covered with conventional steel or aluminium cover plates with a neoprene gasket. The transverse frames of the hull are carried down to the top faces of the tanks and continued inside the tanks and up the vertical faces. The finished tank structure adds greatly to the strength and rigidity of the hull.

For smaller craft, or when built-in fuel tanks are not required, it has been found that the most convenient form of engine foundation consists of a pair of $\frac{3}{4}$ in. (19 mm.) marine plywood planks on edge running fore and aft. The bottom edge is bonded to the skin of the hull. Appropriate transverse members and anti-tripping brackets can be made either of marine plywood or P/M.

An angle-iron engine girder is through-bolted to the top edge of the fore and aft plank to carry the engines.

Tanks and engine foundations

In large power vessels it is now usual to fit P/M fuel tanks and sometimes P/M water tanks. Diesel fuel tanks can be built into the engine compartment in such a manner as to serve as foundations for the engine girder. This is accomplished in a twin screw vessel by building a centre tank and two wing tanks. The space between the side of the centre tank, and the side of each wing tank, being such as will conveniently accommodate the engines.

Steel or aluminium engine girders are then through-bolted to the sides of the tanks at an appropriate angle for the engines, and the engines are later bolted to these engine girders. A 56 ft. (17.1 m.) hull was designed to take two 250 h.p. light-weight diesel engines, weighing approximately 2 tons each, and to be mounted in this manner.

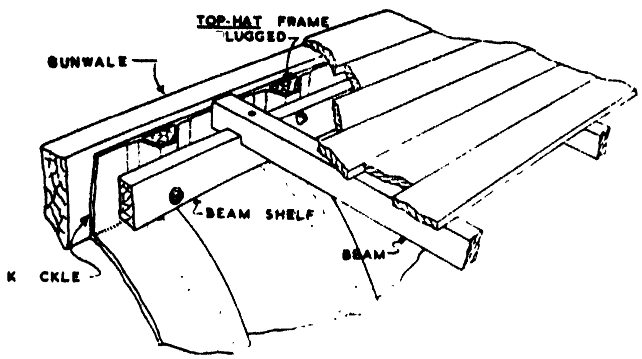


Fig. 175. Polyester/glass mat hull with traditional wood deck. Note the covering board lodged on the gunwale

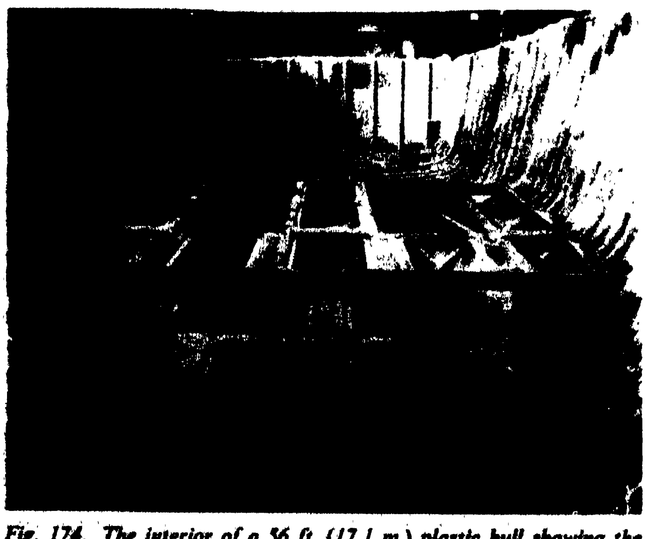


Fig. 174. The interior of a 56 ft. (17.1 m.) plastic hull showing the integral fuel tanks and foundations for the engine bearers

This arrangement is cheap. It has been approved by Lloyd's and has proved exceedingly satisfactory.

Tests have shown that a plywood plank mounted in this manner can take a thrust in excess of 6 tons/ft. (20 ton/m.) run of plank.

The great advantage of both these arrangements, i.e. the engine secured to fuel tanks or to plywood foundations, is that no bolts pass through the hull below the waterline and the engine load is transferred to the hull over a very wide area which helps to reduce vibration as shown in fig. 174.

Decks

All P/M hulls made by the author's firm incorporate a 6 in. (150 mm.) vertical knuckle at the sheerline so as to provide a vertical face for the attachment of gunwales, fenders, decks, etc.

It is easy to fit a wooden deck to a P/M hull. An outwale and an inwale or beam shelf are attached to the hull by through-fastening in the conventional manner as shown in fig. 175. Deck beams are fitted to the inwale or beam shelf in a conventional manner and planked. When wooden decks are required the top-hat frames are plugged with wood in the way of the knuckle so that the fastenings may be taken through the frames.

For small boats it is easy to make a deck as a separate moulding with a vertical flange all around at the sheerline designed to mate up with the vertical knuckle of the hull as shown in fig. 176. Frames are carried across the deck so as to match up with the transverse frames of the hull. After the deck has been dropped into place a timber outwale is fitted and secured to the hull by bolts which pass through the outwale, through the vertical deck flange, and through the knuckle of the hull.

The joint between the knuckle and the underside of the deck is covered with a layer of P/M so as to make it waterproof. The deck frames and transverse frames of the hull are then joined by hollow knees. Thus the finished frames are continuous and are homogeneous

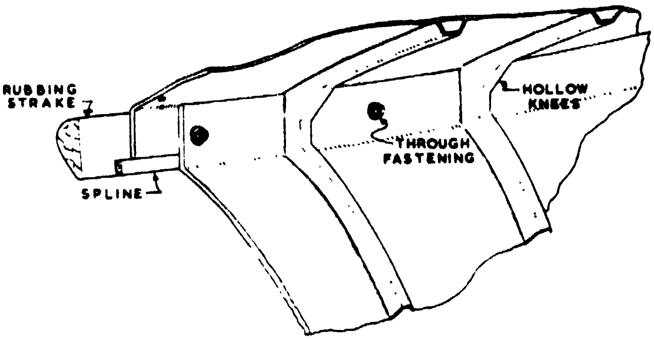


Fig. 176. Construction used in fitting a polyester/glass mat deck to a polyester/glass mat hull

with both the deck and the hull, which give great strength to the whole structure.

There is an alternative system which is more suitable for large boats. A 6 in. (150 mm.) wide horizontal flange facing inboard at the sheerline is moulded with the hull. This flange is recessed so as to take the thickness of the deck. The deck is made separately and can then be dropped into the recess of the horizontal flange to which it is both bolted and bonded. Again, the deck frames are bonded to the transverse frames with hollow knees.

In order to provide a non-slip surface it is customary to face a deck mould with a synthetic rubber floor covering indented with a diamond pattern. The pattern is reproduced on the P/M deck with excellent results.

Marine plywood bulkheads are cheap and convenient. While the hull is still in its mould the plywood bulkheads are cut to shape and bonded into the hull with two layers of P/M applied on each side of the bulkheads at the junction with the hull in such a manner that the bonding extends for 2 in. (50 mm.) up both faces of the bulkhead and 2 in. (50 mm.) along the skin of the hull. If the bulkheads are installed while the hull is in the mould they can be fitted with great accuracy (see fig. 177). Moreover,

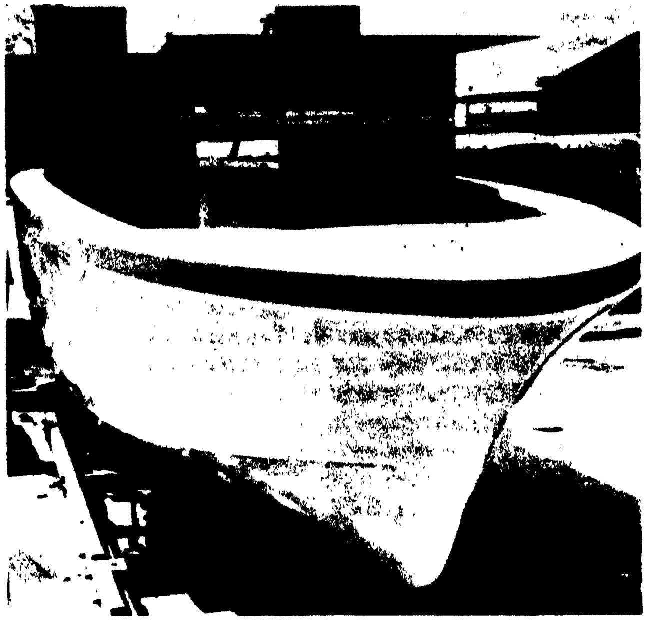


Fig. 177. A 31 ft. (9.45 m.) plastic hull ready for delivery to the outfitting yard. It has a built-in spray chine, a P/M deck and the wooden bulkheads are installed

the bulkheads serve to strengthen the hull and hold it rigid if the hull has to be transferred to some other shop, or delivered to some other yard for fitting out as shown in fig. 178.

Tests show that the joint between a bulkhead and a hull which has been bonded by this method is at least twice as strong as the conventional method of securing bulkheads to wooden hulls.

Bulkheads can be made of polyester mat but this is considerably more expensive than plywood. If steel or aluminium bulkheads are required a 4 in. (100 mm.) P/M transverse plate frame is moulded into the hull and the metal bulkheads are through-bolted to the frame.

Deep plate frames of this type are heavier and more expensive to mould than hollow top-hat frames, but they can be far stronger and far more rigid. They were used in making the superstructure of a submarine which has lately completed all its sea trials and has proved equally strong but much cheaper, lighter, and more durable than an aluminium or steel superstructure.

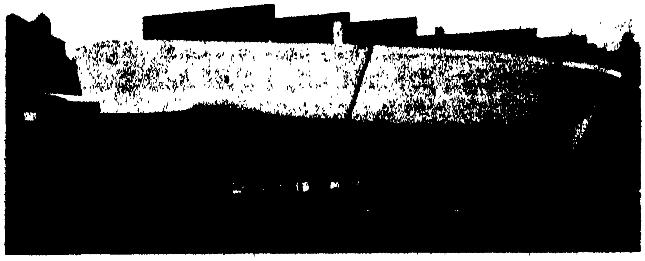


Fig. 178. A 56 ft. (17.1 m.) plastic hull awaiting delivery to an outfitting yard. Note the spray chine, the deep skeg and the bulkheads installed ready for the outfitting yard to complete

Colour

P/M hulls and decks can be coloured to suit the owner's requirements. The colouring matter is ball-milled into the resin with conventional paint-making machinery. It is of great importance that the colouring matter should be evenly distributed through the resin so as to avoid the risk of shade variations.

The coloured resin is generally only used for the skin of the hull and deck because it is wiser to use colourless resin for the subsequent layers of mat, since it is a great deal more easy to see and eliminate air bubbles in a laminate if colourless resin has been used.

There is a tendency for customers to ask for pastel shades of blue and green, and though hulls can easily be made in these colours it may lead to difficulties if the hull ever has to be repaired because it is almost impossible to match these colours perfectly at a later date. For this reason it is wiser for hulls to be made either black or white.

There is no need to protect a P/M hull with paint, but it is possible to change the colour of a hull by sanding down the surface of the hull in the ordinary way and painting it with a good quality paint.

A P/M hull requires no maintenance. It is a homogeneous structure, therefore it cannot leak; it cannot corrode and it is not attacked by marine borers.

Barnacles and algae will attach themselves to a P/M hull below the waterline in the same manner as a timber or metal hull, but they are far more easy to clean off. For example, there is no risk of damaging the hull by using a powerful detergent.

A 54 ft. (16.5 m.) hull, which has been working commercially at Aden for the past two years has never been painted with anti-fouling paint. It has been slipped every three months and cleaned off with a wooden scraper. The owners report that it can be cleaned in this way much more quickly than any other hull they have ever used. In spite of this, it is recommended that the underwater surface of hulls should be painted with an ordinary anti-fouling paint.

Repair

One of the greatest advantages of P/M hulls is that they can so easily be repaired. If a P/M hull is damaged in a collision it can be repaired in about one-tenth of the time which would be taken to repair a wooden hull. If a frame is damaged, there is no need to replace the frame as in a wooden hull, because the damaged portion of the P/M frame can be cut away and replaced.

The procedure for repairing a P/M hull is simple:

The damaged area is cut away with a hack-saw in such a manner as to produce a slight bevel—the wider part of the bevel on the outside of the hull. Cellophane, backed with any convenient form of hardboard—or even a hardboard with a waxed surface—is then secured to the outside of the hull with adhesive tape and the repair is carried out from the inside.

Repair kits are supplied which consist of ½ lb. (0.225 kg.) tins of resin, together with the appropriate quantities of activating chemicals in capsules. The first tin is opened, the chemicals added and stirred with a paint brush. The mixture will set within half an hour. The resin is applied with a paint brush from the inside of the hull to the cellophane surface covering the aperture. As soon as the area has been effectively covered with a film of resin, the tin with the remaining resin and the paint brush can be thrown away because they will solidify in half an hour.

The second tin of resin is then opened and activated with chemicals. A piece of glass mat is cut to the right shape to fill the cavity and the resin is painted into the mat with the paint brush until it is effectively impregnated and bonded to the skin-coat. Again the tin with its remaining resin and the paint brush are discarded. This process is repeated until sufficient thickness has been built up.

It will take half an hour to apply each layer, therefore, a hole in a 56 ft. (17.1 m.) hull, which is six layers thick, can be filled in about three hours. Even allowing for the time required to prepare the damaged area, and to sand off the outside after it has been filled, the whole job can generally be completed in an ordinary working day.

Cost of hulls

Cost is the only limit to the size of P/M hulls. Up to 130 ft. (40 m.) in length the initial cost of P/M hulls is less than a wooden, aluminium or steel hull. The initial cost of a steel hull exceeding 130 ft. (40 m.) is likely to be less than a P/M hull because the raw materials of P/M are a great deal more expensive than steel.

Where the shape of the hull does not involve much curvature, and in consequence little labour has to be spent in bending, steel has a clear advantage. However, with hulls of less than 130 ft. (40 m.) in length there is a great deal of curvature and much labour must be used to bend steel to shape. Moreover, the steel used for small vessels has to be so thin that it can easily rust through—if the steel is thick enough to withstand rust, the hull will be heavy and expensive.

P/M hulls cost the same or less than wooden hulls in spite of the fact that moulds are expensive, and in spite of the fact that the hulls for large power driven vessels must be properly stressed and must therefore be made in temperature controlled buildings, because it requires far less labour to build a P/M hull.

The cost of a P/M hull less than 31 ft. (9.45 m.) in length will be less than the cost of a wooden hull provided that at least three hulls are required from the same mould. Between 30 and 50 ft. (9.15 and 15.2 m.) a P/M hull can compete with a wooden hull provided two hulls are required from the same mould.

Above 50 ft. (15 m.) in length a P/M hull can compete with a wooden hull even if only one hull is required from a mould.

For example, a 27 ft. (8.2 m.) hull is supplied for £750 ($2,100); a 31 ft. (9.45 m.) hull for £1,000 ($2,800); a 56 ft. (17.1 m.) hull for £4,000 ($11,200); and a 75 ft. (22.8 m.) hull for £8,000 ($22,400).

Conclusion

P/M hulls are dry, more durable, and far more easy to maintain than hulls made in any other material A single P/M hull for any vessel up to 130 ft. (40 m.) in length costs about the same as a wooden hull, but if several hulls are required from the same mould they will cost less than wooden hulls—this is clearly of great importance for fishing fleets.

P/M does not absorb any significant amount of moisture and therefore there is no risk of the material being contaminated by fish: moreover, it is a very good insulator; consequently there is no risk of condensation in P/M hulls.

There remains one further advantage which has not yet been exploited to any great extent. P/M can be moulded into shapes which could not be economically made in wood. For example, the author's firm mould a "spray chine" into all their hulls. A spray chine not only serves to break the bow wave and prevent it being blown over the deck in windy weather, but also adds greatly to the rigidity of the bow section without adding to the weight. It would be expensive to make a similar spray chine in wood or steel.

Attention is drawn to the vertical knuckle which reduces the cost of fitting out and also adds to the strength. The author's firm have been able to introduce a generous and graceful flair into the bows of their hulls which again would not be possible in timber. It is believed that this is only scratching the surface of the possibilities and that there will soon be refinements of hull design which will, for example, permit greater speed for a given horsepower which will be easy to make in P/M but which would not be practical in other materials.

PLASTIC CONSTRUCTION — DISCUSSION

Plastic construction

MR. J-O. TRAUNG (FAO, Rapporteur): The only relevant paper on this subject was Gurtner's describing a novel method of using a combination of plastic and plywood for a surf boat which is now under construction in India. For larger surfaces plywood is used, and for the corners, which are expensive to make in wooden construction, reinforced plastic is used.

MR. E. FEA (Italy): It was said at the first Fishing Boat Congress that, if it is true that many people consider factory ships to be the fishing craft of the future, it does not mean that smaller craft are going to lose their leading position throughout the world. The same speaker added that even when guided missiles and jets dominate outer space, mules and carts will still be used.

Hardy in his valuable paper showed that of the thousands of craft throughout the world, all have elements in common, that is, there is a universal basis from which to start designing an efficient fishing boat. It can be asked if the many differences that exist in fishing craft are due to specific needs, or are the result of tradition, which is often more of a handicap—a noble handicap of course—than an aid to progress. Everyone knows that the first steel ships were severely criticised by sailing experts; they said that the hull would become gravely and dangerously bent due to unequal heating by the sun on the side exposed to its heat for many hours, and the other in the shadow. We know now that the sun, fortunately, had some other preoccupation.

Let us assume, therefore, that it is possible to reduce, on the basis of technical and experimental data, the large family of fishing boats. This immediately raises the possibility of prefabricating standard boats from the smallest to those of medium size. With existing lifting devices the prefabricated components can be of considerable weight; but this must be carefully studied so as not to introduce many difficult problems of transportation. We need not look far for examples of prefabrication; the Germans and the Americans have built big ships, prefabricated hundreds of miles away from the sea. Up to a certain point we should forget that we are speaking of boats; the designer and the engineers or naval architects know perfectly well that they are designing a boat and they will act according to the needs; but the workman who is riveting a steel plate is not so deeply interested in the ultimate end product, and does not necessarily require the boat to be built at the sea coast.

Prefabrication means lower costs, due both to standardization and to lower labour costs. Assembly can be with bolts or by welding; for the smallest craft there is no assembly, because they can be delivered complete.

With the above assumptions, the use of plastics for boatbuilding can be opportunely studied. It is not necessary now to detail the advantages of plastics; it is sufficient to summarise their characteristics, which are: continuous and monobloc structure, low weight, non-rusting, smooth surface, perfectly watertight, elastic and at the same time strong, no maintenance costs, easily repairable.

By plastics is meant polyester resins reinforced with fabric or fibre-glass, cold-lay. The construction of boats with thermo-plastic under pressure cannot be considered because the cost of the large moulds and tools needed is prohibitive. But this method can be used for small components which are needed in large numbers, such as fish containers, net buoys and various fittings.

Polyester resins can be perfectly married to the best insulating materials to obtain insulating panels for fish holds, refrigerator doors, etc.

Generally speaking, plastics can be used for the following: lifeboats with air tanks, boats up to roughly 100 ft. (30 m.), partial or complete superstructures on bigger boats, insulating and protective sheets for holds, movable and transportable fish hold compartments, containers for fish storage. Another use is for wooden hulls in the form of protective internal and external skins. When applied for this purpose, suitable vents are provided in the plastic to allow the wood to transpire.

Now would seem to be the time to formulate classification rules for plastic boats, with the co-operation of resin manufacturers, naval architects and boatbuilders. The rules should start from the "equivalent resistance" point of view, and bear in mind all the positive qualities of polyester fibre-glass materials, such as the absence of corrosion, warping, decay, etc.

Plastic is a lucky and enviable thing, because as it gets older it becomes stronger, without any particular care whereas for a man getting old is quite a disagreeable matter.

Mr. Fea concluded his remarks by proposing that, seeing there is now the opportunity, with so many international specialists assembled, and knowing that there is a need to bring together, away from vested interests, all the sound and unbiased opinions and data on the use of plastics for the construction of fishing voats, their gear and fittings, it is proposed that FAO, which is the authoritative and appropriate body, forms a permanent technical committee to study the aspects of plastics and their associated materials as they apply to fishing craft. It was further proposed that this committee, through FAO, collects information on plastics and disseminates it in the form of a periodical, or similar publication.

MR. E. MCGRUER (U.K.): He referred to de Laszlo's paper and mentioned that if the P/M was half the t of the equal weight of wood, then de Laszlo's conclusion was erroneous. The inertia of a section of 2t is 8 times that of t. If P/M is only 2.5 times stronger (larch 6,000, P/M 15,000) then the true relation should be: Wood 8, P/M 2.5. If there is bending then the intensity of stress in 2t is twice that of t and the relation under discussion becomes: Wood 8, P/M 5. For hulls, quality standard P/M should be compared with quality standard woods like teak, oak, Canadian rock elm, and Honduras mahogany.

Mr. T. Mitsui (Japan): Polyester resin is an interesting new material, especially because of its great strength. It seems to be important that the polyester fibre glass linings are continuous. For this reason the material should be good for panels, but there might be risks if it is used for parts where the fibreglass reinforcement is discontinued. The material may also not be successful for components subjected to great vibration or repeated stress, such as bottom fittings or engine beds. In order to maintain the strength, rigidity must be seriously considered.

In Japan many ships are built partly of plastic resin. He would appreciate it if additional information about the methods to maintain rigidity in polyester resins would become available.

Mr. J. G. de Wit (Netherlands): De Laszlo had given the thickness of the P/M hulls in relation to the length of the vessels. He wanted to know whether de Laszlo would inform him if the thicknesses had the approval of the classification societies or government organizations like the Ministry of Transport.

The same question arose in regard to the composition of the hull. De Laszlo pointed out that he preferred using an outer skin layer and a number of inner layers of glass mat. He understood that de Laszlo had something against rovings in the hull. However he considered that in some parts of the hull it would be inevitable to use rovings where there were local stresses.

He thought that the longitudinal strength of smaller P/M fishing vessels was of less importance that the resistance to local stresses.

In comparing prices of steel and P/M hulls the question of life time of these vessels arose. He expected that the answer to this question would be that the steel hull has a longer life.

Dr. E. Crosio (Italy): Everyone who is acquainted with the qualities of the new polyester-glass material is in favour of its being used more and more extensively in the construction of boats, even though their dimensions are limited for the present to lengths of from 100 to 130 ft. (30 to 40 m.). De Laszlo is to be congratulated on the brilliant results obtained by his company.

De Laszlo mentioned the care that has to be taken in constructing the hull, on account of the effects resulting from temperature variations. In fact, one might ask why, in view of all the advantages of this new material, which should interest a good many shipbuilders, polyester-glass has so far been used only for the construction of hulls for military or pleasure boats. The use of polyester-glass depends on the possibility of effectively controlling the chemical phenomenon or hardening and the means available for doing so. The use of temperature-controlled catalysers is a tricky matter; the quantity to be incorporated depends on the surrounding temperature and cannot be determined by the craftsmen without the risk of serious difficulties. The presence of a chemist is necessary, whereas most small shipyards have none.

These problems can be simplified by a new method of using polyester-glass which has already been used in Germany. A machine mixes the glass fibres, cut from rovings at the time of use, with the polyester resin in a compressed-air spray. The mixture is then directed in the form of a jet against the surface to be lined. The layer thus obtained is then pressed by hand with appropriate rollers. The polyester resin is kept in two containers, one with the required percentage of hardening, and the other with the catalyser. Thus there is no risk of getting premature hardening, because the various components only react as they issue from the spray gun.

The machine is capable of putting out about 310 lb./hr. (140 kg./hr.) and the hardening of the layer takes about 30 min. The percentage of glass in the polyester-glass mixture is about 30 per cent, a very high figure for hand work, but it gives a very satisfactory mechanical resistance. It should also be noted that the cost price of the layers when this method is used is much lower than in the case of other methods, either because rovings, which are cheaper than glass mat, are used, or because of the saving on man power.

Another possibility of using polyester-glass is in the lining of wooden hulls. In 1957 an Italian shipyard built a 40 ft. (12 m.) motor yacht, the hull of which was lined with a layer of polyester-glass. This Ligurian shipyard, which mass-produces such yachts, generally builds wooden frame hulls. The hulls are lined with planking consisting of a first layer of mahogany set diagonally and lined with cotton fabric impregnated with varnish and nailed by means of thick copper nails to the outer planking formed by parallel mahogany panels about 1¼ in. (30 mm.) thick. In the example mentioned. the outer planking and the cotton fabric were replaced by a single, continuous layer of polyester-glass, ⅝ in. (15 mm.) thick at the keel, and ⅜ in. (10 mm.) at the sides. These thicknesses were obtained by super-imposing several layers of glass mat. The results during two years' use have been excellent, and have confirmed the superior properties of polyester-glass. The use of the spray method for lining wooden hulls will open the way for small shipyards to turn the advantages of this new material to account, and will enable the shipyards already working in this field to reduce their cost price as a result of improved methods.

Strength and cost

Mr. W. A. MacCallum (Canada): What was the strength of glass fibre reinforced plastic at the high temperature which might result in case of fire aboard ship? Would marine insurance rates be affected by the use of plastic? Would the reinforced plastic fishing vessel which could be built economically be as good as the economically built wooden boat as far as resistance to impact is concerned? He suggested that in a cost analysis of wooden and plastic fishing boats costs of suitable fish rooms should be considered in each case. The plastic vessel would require an inner ceiling as well as the wooden vessel. Omission of a ceiling would expose the side and bottom of the vessel itself to abuse from implements, containers etc. Again on costs, Proskie's figures for Canadian wooden craft which include the cost of a deckhouse, complete crew's quarters, piping, galley, etc., are as follows:

37 ft. (11.3 m.) LOA longliner	£645 ($1,800)
45 ft. (13.7 m.) LOA „	£4,200 ($11,700)
58 ft. (17.7 m.) LOA „	£5,600 ($15,700)
65.5 ft. (20 m.) LOA trawler	£10,600 ($29,780)

The figures given for plastic boats are difficult to compare with the Canadian figures since the former cover the cost of the shell only. Canadian cost figures for a complete 37 ft. (11.3 m.) wooden longliner compare favourably with those for the 31 ft. (9.5 m.) plastic shell devoid of deckhouses etc. It would be helpful if de Laszlo could provide cost figures for completed vessels less engine and screw, electronic equipment, winch and gallows and miscellaneous deck equipment.

He suggested that Unit Pens as described in his own paper, might be a field in which the method of construction in plastic might be investigated.

MR. L. CATASTA (Italy): Plastic hulls is an innovation of great importance, although in order to pay off the cost of the mould, it is necessary to use it to build many boats of identical shape and dimensions. Once one has selected a specific type of hull that has proved good in comparative model tests, it is possible to produce standardized hulls very quickly and at ever diminishing construction and operating costs.

The insignificant water absorption of plastics is well known, and therefore the weight of the boat will not be increased, as happens with wooden hulls. Resin, reinforced with glass, makes a material of the best mechanical properties as compared with its specific weight. Its use makes it possible to build larger capacity, more durable, boats that offer better hygienic conditions, as well as effect a saving in power, because the hull was experimentally tested before the boat building was started. The problem is how to convince shipowners to use standardized boats which, in addition to being seaworthy, are also cheap and good.

Refrigerated holds are usually covered with insulation material (either cork, glass wool or sometimes sawdust, etc.), the inside being finished with wooden planking. Since they must be kept cool by ice or mechanical refrigeration, they are not ventilated. This means that there is a high degree of humidity permanently in the wooden planking and insulation material.

Water absorption by plastic materials can be considered insignificant, and the suggestion has been made that expanding resins be used to cover the planks with reinforced polyesters. Expanding resins adhere strongly to the hull as soon as they are applied, so that there is no danger of air pockets being formed to vibrations or slipping of the planks. In addition, expanding resins absorb no water, since structurally they consist of closed cells that form when polymerization occurs. Hence, a reinforced polyester covered planking also guarantees that the stanchions and joints can be covered with a cement made of the same resin, thus obtaining a smooth surface that permits the draining off of the water formed from melting ice.

However, the insulation material must be applied on the spot, and an Italian firm which is conducting experiments on the use of plastics has built special machinery for the application of resins on non-geometric surfaces, such as boat interiors. Even damage caused by violent blows (which is rare) can be quickly repaired by the boat's crew at minimum expense. In addition, the expanding resin can be used to prevent infiltration of water which occurs in any other type of boat, no matter how well it is caulked.

The low specific weight (between 0.02 and 0.04) makes it possible to use such a resin not only in the refrigerated hold, but also in many parts of fishing or cargo boats to ensure floatability in case of emergency. Plastic materials, because of their lightness, cheapness, durability and cleanliness, offer obvious advantages especially to the large and important fisheries industry.

MR. H. E. STEEL (U.K.): His previous Department had accepted P/M in the construction of lifeboats. No speaker so far has mentioned robustness as a necessary quality in fishing boat scantlings and construction. It is so regarded for lifeboats. Another question regarding P/M boats was how long would they last? It was found that in the U.S.A., P/M boats had been operated for ten years and much experience was gained. A prototype lifeboat was hoisted in derricks and allowed to smash against a ship's side. It was then dropped into the water from a height of 23 ft. (7 m.). Little damage occurred. Tests on the strength of lifeboats was carried out in order to ascertain longitudinal and lateral deflections. Tests on lifeboats made after 12 months gave good results. More than 600 P/M lifeboats are now being used in British merchant ships. Reliable experience has accrued on constructional methods. Scantlings can readily be reinforced for hard sea work. He concluded that there were good grounds for confidence in this material, at least for smaller classes of fishing boats.

MR. J. VENUS (U.K.): One of the boats made by de Laszlo's firm has been sent to Aden. The hull was found to be perfect as it stood much knocking about and the owner was satisfied. This boat is 56 ft. (17 m.) long and fitted with aluminium girders. The boat is used as a harbour launch.

MR. A. HUNTER (U.K.): He suggested the details of construction seem to have been rigidly modelled on orthodox construction and ignore many of the possibilities with P/M materials. The illustrations suggest an analogy with the early pratice when welding was introduced where riveted constructional design was rigidly followed. Sandwich P/M constructions had already been used in some applications. He was amazed at the statement about the cost of P/M hulls and how depending upon size, they could be comparable with wood construction even taking mould expenses into account. Prices for reinforced fibreglass lifeboats supplied to trawlers did not bear this out.

Author's reply

MR. P. D. DE LASZLO (U.K.): As far as could be seen from the discussions, little opposition to this material was found. In regard to the tensile strength of the material the problem is to compare plastic and wood. A thousand tests have been made but the comparison is very difficult because the tensile strength of wood can vary as much as 100 per cent. It would be better to campare with steel. A plastic hull must be twice as thick as a steel hull. Comparison here is again difficult as an allowance is made in the thickness of steel plating for corrosion.

The boats built so far were approved by Lloyds. Insulation value of fibre glass is good. There is little condensation as compared with steel. If glass mat is employed, fibres are arranged in all directions and no difficulty should arise regarding discontinuity of fibres when attached to the hull.

The engine foundations can be made in a number of ways. A cheap way is to use marine plywood planks which can stand a pressure of 6 tons per foot run, which is all that is necessary when considering the apparent loads and thrusts. Fatigue tests have revealed that glass reinforced plastic is six times better than aluminium and vibrations occurring are also smaller than when aluminium is used. Regarding bolting, this is no problem at all. Rovings are advantageous.

It is possible to increase the tensile strength up to 30,000 lb./sq. in. (2,100 kg./sq. cm.) by introducing glass fibre locally. This high tensile strength is normally not necessary as the maximum stresses occurring are only in the region of 15,000 lb./sq. in. (1,050 kg./sq. cm.). Frames of top hat section are also used, the tensile strength of which is increased by rovings. As regards the life of a hull built of P/M, this may be estimated to be 20 years. A steel hull may last for 50 to 100 years but, after 30 years, it may have corroded so much that the boat cannot be used. The conclusion is that, as far as small hulls are concerned, plastic hull is good. The plastic hulls must be made in temperature controlled rooms. A good plastic material can only be made by qualified chemists.

The German machine described is an ingenious device. He would, however, be reluctant to use this machine. As regards covering a wooden hull with plastic material, the necessary thickness of the plastic is 0.08 in. (2 mm.) and not 0.4 in. (10 mm.) as sometimes suggested. Wooden plankings with a plastic covering have, however, a greater tendency to rot. The cost of construction of the hull is competitive with wood. His firm is now making 40 hulls for the U.S.A. as this has been found to be cheaper than wooden hulls obtainable in the U.S.A.

THE CARE OF THE CATCH

by

G. A. REAY and J. M. SHEWAN

The main features of fish spoilage, largely caused by marine bacteria, and main factors in controlling it on trawlers, especially distant-water ones, are described and discussed.

Temperature is the most important single factor affecting spoilage and therefore in its control. With minimum delay the catch must be thoroughly chilled (typically iced) and kept so until landed. Delay should not exceed the lag phase of the spoiling bacteria, which, for example, is only about 2 to 3 hours at 59°F (15°C), a possible air temperature even in northern fisheries. Gutting and washing on deck inevitably delays stowage of the catch; but washing tanks now common on British distant-water vessels and the recently tested South African washing flume considerably reduce delay and warming up and permit a more even flow of fish into the hold and a steadier rate of stowage in ice. For most rapid overall cooling of the catch, ice should be well mixed with the fish, making contact with each one. An average satisfactory ratio of ice to fish might be 1:3. In British distant-water vessels the ratio is now nearly 1:1.

Deckhead refrigerating grids, sometimes installed, have not the advantage once assumed and can best be used only on the way to the fishing grounds to cool the fishroom and its fittings and to keep the ice crisp.

Care and cleanliness are the other important factors influencing quality. Fish, easily damaged by rough handling and even moderate pressure, become softer and flabbier and more spoiled when piled too deep on deck, when tramped on in deck operations, when stowed below between shelves more than 18 to 30 in. (45 to 75 cm.) apart, etc.

The bacterial load of the unused ice increases during the voyage from 10^2 to 10^3 per ml. to 10^6 to 10^7 per ml. as it lies in the ice pounds, the increase comprising mainly fish-spoiling types. Washed fish can thus rapidly regain their original bacterial loads. The effectiveness of antibiotic ices may partly be due to supression of bacterial multiplication in the ice itself.

Fishroom walls, fittings and shelves should be kept as clean as possible. Wood cannot be kept bacterially clean. Metal surfaces are much more easily cleaned and do not carry sub-surface infections. There is no clear evidence, however, that the bulk of the fish in well-cleaned metal holds is kept in improved condition.

LES SOINS A APPORTER AUX POISSONS PÊCHÉS

Les auteurs décrivent et examinent de façon critique les principales caractéristiques de l'altération du poisson, causée en grande partie par les bactéries marines, et les principaux facteurs servant à lutter contre l'altération à bord des chalutiers, en particulier ceux pêchent dans les eaux éloignées.

La température est le facteur simple le plus important dans l'altération et par conséquent dans la lutte contre cette altération. Dans un minimum de temps, la pêche doit être refroidie avec soin (généralement par mise on glace) et maintenue ainsi jusqu'au débarquement. Ce minimum de temps ne doit pas dépasser la phase de latence des bactéries de la putréfaction qui est, par exemple, d'environ 2 à 3 hres seulement à 59°F (15°C), température possible de l'air, même dans les pêches septentrionales. L'arrimage de la pêche est inévitablement retardé par l'éviscération et le lavage sur le pont, mais les bacs de lavage, qui sont maintenant communs à bord de navires britanniques pêchant dans les eaux éloignées, et l'auge de lavage sud-africaine essayée récemment, réduisent considérablement cette durée ainsi que le réchauffement et permettent un écoulement plus régulier des poissons dans la cale et une vitesse plus constante de l'arrimage dans la glace. Pour un refroidissement général plus rapide des captures, la glaces doit être bien mélangée aux poissons, étant en contact avec chacun d'eux. Une proportion moyenne de la glace par rapport au poisson, qui soit satisfaisante, pourrait être 1:3. Dans les navires britanniques pêchant dans les eaux éloignées, le rapport est actuellement plus voisin de 1:1.

Les serpentins réfrigérants, parfois installés sous le pont, ne présentent pas les avantages que l'on avait supposés et il est préférable de les utiliser seulement pendant la route vers les lieux de pêche pour refroidir la cale à poissons et ses annexes et conserver la glace craquante.

Le soin et la propreté sont les autres facteurs importants ayant une influence sur la qualité. Les poissons sont facilement endommagés per une manutention brutale et même des pressions modéres, et quand ils gisent en couches trop épaisses sur le pont, quand ils sont piétinés pendant le travail sur le pont, quand ils sont arrimés en cale entre des planches séparées de plus de 18 à 30 pouces (45 à 75 cm.), etc., ils deviennent plus mous, plus flasques et plus altérés qu'ils ne devraient.

La charge bactérienne augmente dans la glace pendant le transport de 10^2 à 10^3 par ml. à 10^6 à 10^7 par ml. quand les poissons sont mis dans des étagères avec de la glace, l'augmentation portant surtout sur les espèces putréfiant le poisson. Les poissons lavés peuvent ainsi rapidement regagner leurs charges bactériennes originales. L'efficacité des glaces aux antibiotiques peut être due partiellement à la suppression de la multiplication bactérienne dans la glace elle-même.

Les parois, les étagères et les planches de la cale à poisson doivent être maintenues aussi propres que possible. Le bois ne peut pas être maintenu bactériologiquement propre. Les surfaces métalliques, qui ne portent pas d'infection au-dessous de la surface, sont beaucoup plus faciles à nettoyer. Il n'est pas certain, cependant, que l'ensemble des poissons se maintienne en meilleur état dans des cales métalliques bien nettoyées.

EL CUIDADO DE LA CAPTURA

Se describen y examinan las características principales de la alteración del pescado, causadas en gran parte por las bacterias marinas, y los factores más importantes de la lucha contra la alteración a bordo en los arrastreros, particularmente los de gran altura.

La temperatura es el factor que más influye en la deterioración y, por lo tanto, en la lucha contra ésta. La captura debe ser enfriada (generalmente en hielo) sin pérdida de tiempo y mantenida fría hasta el momento de la descarga. Este mínimo de tiempo no debe exceder la fase latente de las bacterias deteriorativas, la que es, por ejemplo, de solamente 2 a 3 horas a 59°F (15°C), temperatura del aire que se encuentra aun en las pesquerías septentrionales. La estiba de la captura la retarda inevitablemente la evisceración y lavado en cubierta, pero con los tanques de lavado, ya muy comunes en los arrastreros británicos de gran altura y con los canalizos ensayados recientemente en Sudáfrica, se reduce considerablemente el retraso y el calentamiento y permiten una llegada más regular de pescado a la bodega y una velocidad

más constanto de almacenamiento en hielo. Para un enfriamiento general más rápido de la captura, el hielo debe estar muy mezclado con el pescado y en contacto con cada uno. Una relación media satisfactoria de hielo y pescado podría ser de 1:3. En los barcos británicos de gran altura la relación se aproxima más a 1:1.

Los serpentines refrigerantes que algunas veces se instalaban en las cubiertas no tienen las ventajas que se supusieron una vez y es preferible emplearlos solamente en el viaje de ida a los caladeros para enfriar la bodega de pescado y sus anexos y para conservar el hielo crujiente.

El cuidado y la limpieza son los otros factores de importancia que influyen en la calidad. El pescado se magulla con facilidad si no se trata con cuidado y aun si se somete a presión moderada, debido a lo cual se pone muy blando y se estropea más de lo necesario cuando se apilan muchos en las cubierta, cuando son pisoteados durante las labores normales y cuando se almacenan en estantes con separaciones de más de 18 a 30 pulg. (45 a 75 cm.), etc.

Durante el viaje, la carga bacteriana en el hielo aumento de 10^3 a 10^5 por ml. a 10^6 a 10^7 por ml. cuando el pescado está en los compartimientos, correspondiendo casi todo el aumento a las especies que deterioran el pescado. Debido a ello, el pescado lavado puede recuperar rápidamente sus cargas bacterianas originales. La eficacia de los hielos con antibióticos puede deberse parcialmente a la supresión de la multiplicación bacteriana en el hielo.

Las paredes, el material, y las planchas de la bodega de pescado deben mantenerse escrupulosamente limpios. La madera no se puede mantener libre de bacterias. Las superficies metálicas se limpian mucho más fácilmente y no son portadoras de infecciones debajo de la superficie. Sin embargo, no hay pruebas concretas de que la masa del pescado se conserve major en bodegas metálicas muy limpias.

THE function of a fishing vessel is to catch fish and to preserve and land the catch in as fresh a condition as possible. That function must clearly influence vessel design not only in relation to catching operations but also to those of handling and storing the catch. The purpose is to indicate the main principles of good practice, so far as they seem to have been established in taking care of the fish.

Whilst foods in general are perishable and delicate cargo, fish is exceptionally so; and the designers of fishing vessels are concerned with the supremely important first—and often long—link in the chain that joins catching to final consumption of the commodity. As far as the quality of the product is concerned, what is done on the fishing vessel cannot later be undone or offset.

The paper deals mainly with chilling preservation in trawlers at sea—typically by stowage in crushed ice—of demersal or "white" fish.

WHY AND HOW FISH GO BAD

The freshly-caught fish goes bad, i.e., suffers undesirable and finally unacceptable changes, particularly in odour, flavour and appearance, mainly through bacterial decomposition. In addition, enzymes naturally present in the flesh, organs, etc., of the fish play a still inadequately assessed part in deterioration either directly or by providing the bacteria with readily assimilable nutrients. Enzymes are, of course, involved in the first spectacular change occurring after death, *rigor mortis*, and this must have largely passed off before bacterial action can develop in the flesh.

In the very earliest stage of storage in ice it seems probable that bacteria take little part in the gradual loss of the characteristic delicate odour and flavour of very fresh fish. The chief causes appear to be leaching out of soluble flavorous substances by the ice water and enzymic activity. In the case of fatty fish, such as those of the herring, pilchard, mackerel and salmon groups, the flesh of which may contain about 2 to 25 per cent of oil, depending upon species and seasonal and biological factors, oxidation of the oil can contribute significantly to spoilage. Fish oils being of the unsaturated, "drying" type, readily combine with atmospheric oxygen, with the assistance of catalysts in the flesh, to give rise finally to rancid odours and flavours. In comparison, very lean fish, such as cod, haddock and whiting, which contain considerably less than 1 per cent. of fatty material in the flesh, do not noticeably exhibit this type of deterioration. In the very earliest stage of storage, before bacterial multiplication has set in, oxidation possibly contributes to the loss of very fresh aroma in both lean and fatty fish.

In the normal, healthy, newly-caught fish, the flesh and organs are completely free from bacteria (Reay and Shewan, 1949). The external surface, however, harbours large numbers and so does the gut unless, as happens at certain times, the fish is not feeding. The bacteria on the outside of the dead fish multiply in the slime covering the skin and gills, which is a good nutrient substance, producing stale and finally foul odours as well as rendering the initially clear slime opaque and finally discoloured. As a result, the flesh becomes tainted through absorption of the bacterial products and is also itself invaded by the beleaguering bacteria, which proceed to multiply in it.

More often than not there is food in the gut of the newly-caught fish in process of being broken down by the powerful enzymes of the digestive juices. The gut wall, which is resistant to attack in the live fish, readily succumbs after death to the digestive action of the enzymes, which can then proceed to penetrate into neighbouring organs and regions of the flesh, digesting, softening or "jellying" them. Moreover, the bacteria that are normally associated with the food in the gut can now readily penetrate into the same sites and multiply there, although there is no clear evidence that the particular types found in the gut produce the noisome products characteristic of spoilage. When much food is present, the speed with which the gut wall can break down and the belly walls be jellied and even perforated by the digestive enzymes is astonishingly great, even when the fish are chilled in ice. From this it will be apparent why, if possible, fish should be gutted and washed at sea soon after catching. For the most part, this is the custom in the trawl, seine and line fisheries for demersal or "white" fish; but it is never done in the fisheries for pelagic species, such as herring and pilchard, which are small fish usually caught in great numbers.

Progress of spoilage

The bacteria responsible for spoiling fish on the fishing vessel, and apparently during subsequent distribution, are marine types. They are of the psychrophilic—so-called cold-loving—variety, which exhibits most rapid increase in population in the region of 68° to 75° F (20° to 24° C). In comparison, most pathogenic bacteria —producing disease in hot-blooded animals—have much higher optimum temperatures, mostly about 99°F (37° C). All varieties of bacteria build up populations more slowly the lower the temperature is below the optimum; but whilst the growth of almost all pathogens is completely inhibited at melting ice temperature, the marine bacteria continue, although slowly, to multiply under such chill conditions. Some remain sluggishly active, even in frozen fish, down to a temperature of about 19.5° F (—7° C). There is considerable evidence to show that in lowering the temperature into the region around 32°F (0°C) the inhibitive effect of cooling accelerates markedly with each successive degree. All this means that spoilage can still proceed in ice-chilled fish, even before the fish is landed, at a rate and to an extent of the highest significance for commercial fish handling. Maintenance of the lowest possible temperature short of freezing is indeed far the most important requirement for retaining the quality of the catch. Apart from temperature and time, the other important factors affecting preservation are care and cleanliness in handling, which will be discussed later.

Table 45 (Cutting, Eddie, Reay and Shewan, 1950) shows the average course of spoilage during three weeks of carefully gutted and washed newly caught cod and haddocks kept in plenty of ice. Four fairly recognizable phases of spoilage, as observed sensorily, are shown side by side with indications of the corresponding increases in bacterial numbers in the flesh and in three volatile bases produced mainly by bacteria. The relevance of these data to distant-water white fisheries will be obvious. The average round voyage for such British trawlers is about 20 days, involving some 5 days for return to port from the grounds. Landings on the average comprise fish stored in ice for periods ranging from 5 to 15 days, i.e., fish in phases II and III. This illustrates the order of the limitations of ice as a preservative under the best possible normal conditions, i.e., without adding chemical preservatives or antibiotics. Vessels often have to return to port incompletely filled because of the spoilage of the early caught fish.

Table 45 applies specifically to gadoid, i.e., cod-like, species which account for the bulk of the demersal catches in the North Pacific, North Atlantic and Arctic areas. There are, of course, variations in the rate of spoilage under standard conditions dependent on intrinsic factors such as size, species, biological condition, fishing ground and season, the effects of which are far from being thoroughly evaluated. It seems clear, however, that other things being equal, large fish spoil somewhat more slowly than small fish; and flat fish generally keep better than gadoids.

It is possible that the bacteria on tropical or sub-tropical fish may be somewhat more susceptible to control by chilling than those found on fish whose habitat is in much colder waters and that in consequence fish kept well iced immediately after catching may take somewhat longer to become inedible. Some evidence is accumulating to this effect.

Control of spoilage

Spoilage being mainly due to bacterial activity, control mainly consists in combatting this. To do so means, in effect, reducing the bacterial population on the fish before stowing it in the hold and preventing subsequent increase whether through multiplication, for which temperature is the most important factor, or through additions arising from contamination.

TABLE 45

Diagram showing side by side the organoleptic, chemical and bacteriological changes in haddocks, carefully gutted and washed and stowed in plenty of ice

Storage time in ice in days:	0–5	6–11	12–15	16–20
ORGANOLEPTIC CHANGES	Phase I No marked spoilage	Phase II First definite signs of spoilage; softer flesh, staler appearance, strengthening of odour	Phase III Definite stale appearance and odour and soft flesh	Phase IV Rapid deterioration from staleness to putridity

Storage time in ice in days:	Change
CHEMICAL CHANGES: 0–11	Dimethylamine increases steadily
7–16	Trimethylamine increases rapidly
14–20	Ammonia increases rapidly
CHANGES IN BACTERIAL NUMBERS: 6–16	Bacterial numbers rapidly increase

TEMPERATURE CONTROL

Quick treatment on deck

The task of first importance in treating the catch is to chill it thoroughly as soon as possible and to keep it chilled until landing. It is, of course, impossible to express the effect of temperature on the rate of spoilage in a simple and, at the same time, accurate manner; but from bacteriological, chemical and taste panel data and "averaging out" over the period that elapses before the fish reaches the point of inedibility (taken at Torry Research Station as 15 days in ice), fish such as cod and haddock spoil about two and a half times as fast at 40°F (4.5°C) and about five and a half times as fast at 50°F (10°C) as at 32°F (0°C).

The white fish catch by trawlers is gutted and washed before being put below for sorting and stowage in ice; and there are no special arrangements on deck for cooling the fish. There is thus some delay before cooling can be effected but it should be reduced to the unavoidable minimum. Bacteria exhibit a "lag phase" before they multiply and, in theory, cooling should be commenced before this phase is passed. The duration of the "lag phase" for marine bacteria at 32°F (0°C) is about three or four days and at 68°F (20°C) possibly not more than two or three hours.

Just after World War II, when Arctic catches were much heavier than now and when a haul might be brought aboard before all the previous ones had been put below, delays on deck were observed to be at times as much as 12 to 24 hr. (Rep. Food Invest. Bd., Department of Scientific and Industrial Research (DSIR), 1948, 1949). The air temperature in northern latitudes can rise to 50°F (10°C) or even higher in summer, and it was found that the bacterial load of fish exposed on deck at 45°F (7.2°C) for 18 hr. increased 10 to 100 times. The quality of the fish at landing 15 days later corresponded to fish iced very soon after catching—after 17 days. (Cutting, Eddie, Reay and Shewan, 1950). Canadian workers (Castell, MacCallum and Power, 1950) have reported air temperatures on vessels on Eastern Canadian grounds of 37° to 70°F (3° to 21°C) from May to July. and that exposure on deck for more than two hours during the warmer weather is decidedly detrimental to the fish. The Fishing Industry Research Institute, Cape Town (Cooper and Rousseau, 1955) cites temperatures of stockfish as high as 81°F (27.2°C) after 99 min. on deck, the temperature of the fish at catching being about 59°F (15°C). Arrangements introduced since the war for mechanically washing the gutted fish and directing them by chute into the fishroom have very considerably contributed to diminishing delays on deck (see also page 241).

Sufficient supply of ice

Gutted fish are typically stowed in the hold with ice on shelves, or in boxes in some of the smaller vessels. Ice must be sufficient in amount to cool the fish as quickly as possible to just above the temperature at which freezing can begin, say 30°F (−1.2°C), for most "white" fish, and, in addition, to keep the fish cooled until landing.

It is of the utmost importance to mix the ice well with the fish for rapid cooling so that ice is in contact with each fish. It is surprising how little this is appreciated by many in the fish industry. Fish is, to use the canners' terminology, a solid non-convecting pack through which heat transfer is much slower than is often supposed. A rough practical rule would be that fish more than, say, 2 to 3 in. (50 to 75 mm.) thick should always be stowed in layers not more than one fish deep, between upper and lower layers of ice.

Although theoretically one part of ice is required to cool seven parts of fish from about 55° to 32°F (13° to 0°C), such cooling is impossible in practice. The admixture of ice with fish cannot be made sufficiently intimate; moreover, some ice is consumed in cooling shelves, fittings, etc., although this is relatively small in amount. MacCallum (1955) points out that while it is impossible to give rules for the amount of ice necessary for chilling the fish and the fittings completely, good results are obtained by mixing ice intimately with the fish in a ratio by weight of 1 to 3.8. The Torry Research Station has recommended a ratio of 1 to 3 (Cutting, Eddie, Reay and Shewan, 1953).

Heat leaks

Provision has also to be made for absorption of heat entering the fishroom from outside so that this does not denude any part of the catch and heat it up. Holds vary greatly as regards heat inleak, depending upon the absence or presence of insulation and mechanical refrigeration, whilst external climatic conditions vary widely. It is not sufficiently realized that heat inleak from the sea through the sides of the ship is almost as important as that through the deckhead. Obviously ice must be deployed in the right amounts and positions to ensure that at the end of a voyage there will still be ice in contact with linings and bulkheads and at the top of the stowage.

The correct deployment and requirement of ice can only be found out from experience with each particular vessel. Obviously the most difficult conditions are encountered in uninsulated ships; and satisfactory deployment of ice is probably easiest of all where the fishroom is simply insulated, or where insulation is combined with jacket cooling. Here temperature conditions in the hold should be at their most uniform and permit something like a standard stowage and icing procedure to be practised in any ship, some allowance being made for climatic variations.

The use of deckhead refrigerating grids, which have been installed in insulated holds in some instances, has been found in practice to have less advantage than expected. Deckhead grids, in which the refrigerant is usually well below the temperature of melting ice, cool the air immediately under the deckhead. As the cooled air falls all the air in the fishroom will gradually be cooled and it will cool any part of the room to which it can circulate. The chief uses of deckhead grids are thus apparently to cool the empty fishroom, to keep the ice in crisp, easily-handled condition and to cool all shelves and fittings *before* the fish is stowed (Cutting, Eddie, Reay and Shewan, 1953).

Grids can also keep the air cooled above "shelved" fish, i.e. in British practice, fish merely laid on a bed of ice with no more than a sprinkling of ice on top. At the top of the pounds containing "bulked" fish, i.e. fish completely stowed in ice, the pipes can merely absorb heat coming from the deckhead and can have no effect on the temperature of any fish more than a few inches down in the stowage, whether the linings, etc. are metal or not. There is some danger of superficial drying of the "shelved" fish and also of freezing some of the fish, whether "shelved" or "bulked". This latter can readily happen since unavoidable local variations in air temperature during stowing are bound to occur in the air above the pounds and accurate thermostatic control from one single point, which is attempted, is not really possible. Frosting and defrosting of the coils also contribute practical problems. On balance, it seems clear that deckhead grids offer no proved advantage in preserving the cargo as compared with the use of plenty of ice. The jacketted hold represents a much more sensible approach to this whole problem even than extended grids over the sides and bulkheads. However, unless the jacket is hermetically sealed off from the fishroom, desiccation of "shelved" fish may still occur.

Mechanical refrigeration

Quite apart from the dangers of slow and partial freezing of some of the fish in a mechanically refrigerated fishroom, some experimental results (Rep. Food Invest. Bd., DSIR, 1948; Ofterdinger, 1950) pose the question whether the quality of fish is not better if the air temperature in the hold is kept somewhat above 32°F (0°C) or if, more generally, the heat flow into the ice—apart from that coming from the fish itself—is such as to permit a steady melting throughout the voyage. Some data obtained at Torry Research Station (Rep. Food Invest. Bd., DSIR, 1954, 1955) with individual boxes of iced fish at different ambient air temperature, ranging from 32° to 53°F (0° to 12°C), showed that in the case of the highest ambient temperature the fish reached inedibility some 1 to 2 days later than the fish kept at 32°F (0°C). Chemical and bacteriological evidence supported this. It is doubtful if this effect, which presumably is due to removal of bacteria and leaching out of their products, would be completely reproduced in a fully stowed pound of fish. However, it seems clear that, to preserve good external appearance ("bloom") the surface of the fish should remain moist. This is another reason for mixing ice well with the fish and for specifying that mechanical refrigeration should be operated so that the lower limit of air temperature anywhere in the hold is, say 33°F (0.6°C), rather than, say, 31.5°F(—0.6°C), the freezing point of the fish.

Heat caused by bacteria

Another feature relevant to temperature control that might repay further investigation is the production of heat in stowage by the growing bacterial population on the fish and by possible tissue oxidation. Calorimetric experiments (Rep. Food Invest. Bd., DSIR, 1954) with chopped haddock muscle in ice have indicated a considerable production of heat, calculated as being equivalent to the melting of 25 tons of ice on a North Atlantic trawler trip, but the figure might be of quite different order for whole fish under conditions of commercial stowage.

Total amount of ice needed

MacCallum's (1955) calculated requirements of total ice to total catch (100 tons in the medium-sized Canadian trawlers considered) range from 1:1.5 for an uninsulated hold with wooden linings and boards poorly preserved to 1:3 for an insulated, wholly refrigerated metal surfaced hold. Ratios for actual usage in 1953 to 54 are quoted by MacCallum for a group of insulated wooden-lined vessels (1:3) and for another group of insulated, refrigerated wooden-lined vessels (1:2.25). The calculated requirement in the first case is 1:2, so that the amount used in practice is actually less. The calculated figure given for an insulated, metal lined (*not wooden-lined*) vessel is 1:3, this amount being satisfactory in practice. Requirements will, of course, vary with the size of the ship, the size of the catch, the duration of the voyage and the climatic conditions.

In British practice, vessels of 165 to 185 ft. (50 to 56 m.) making distant-water trips of 20 days on an average, take to sea about 90 to 110 tons of ice for catches which range from 75 to 200 tons—the average in 1956 was about 110 tons. Of the ice loaded, perhaps 70 to 80 tons is used for an average catch. These quantities are ample to meet the exigencies of adequate temperature control, and generally this seems to be satisfactorily achieved. A large number of observations in recent years show that the temperature of distant-water fish, mainly cod, at landing ranges from 31° to 42°F (—0.6° to 5.6°C), half the values laying between.

Mechanical refrigeration by itself is certainly not a satisfactory method of chilling fish and the only possible alternative to the use of ice seems to be stowage in chilled sea water. This has been developed so far for certain fisheries and species, mainly in Canada (Harrison and Roach, 1955).

CARE AND CLEANLINESS IN HANDLING

Pressure in stowage

Fish is very easily damaged by rough handling and even moderate pressure. Care should therefore be taken to avoid this. Pressure, such as may occur in bringing very large bags of fish on deck, in lying several feet deep in the deck ponds for some hours in being tramped upon during deck operations, gutting, etc., and at the unstowing in port, and in being stored in the hold with ice to depths of more than 2 or 3 ft. (0.6 to 0.9 m.) for days on end, results in the fish being softer and flabbier than they need otherwise be. Sudden, sharp pressure, as in being tramped upon, has been shown (Castell, MacCallum and Power, 1950) to result in abrasion of the skin and subdermal tissue cells, which become more readily penetrated by the surface bacteria with resulting enhanced spoilage readily distinguished after a week in ice. Bruising of freshly caught live fish may cause bloody discolouration of the flesh involving loss of yield if subsequent trimming has to be resorted to. The continuous pressure bearing on the fish when stowed in the hold results in the loss of juice and hence of weight to a notable extent (Cutting, 1951). For example, on trips of 18 to 24 days an average of 7 per cent. of the weight (and about 3 per cent. of the protein) of a catch of cod and haddock was lost. The staler the fish and the deeper the bulk of fish and ice, the greater was the loss. After 18 days at the bottom of a mass 4 to 5 ft. (1.2 to 1.5 m.) deep, the weight loss was 14 per cent. as against 3 per cent. at the top. At the other extreme fish stowed in single layers in shallow boxes, 8 in. (203 mm.) deep, gained 1 per cent. on the average, whilst the average loss was 3 per cent. for fish stowed between shelves 1 ft. (0.3 m.) apart.

In bulk stowage of fish and ice, the shelves should be placed at vertical intervals of not more than 18 to 30 in. (457 to 762 mm.). The space between shelves should be filled completely with fish and ice, but care should be taken that the fish is not subject to the weight of the shelf above. In other words, the shelves should be leaning on the rest-angles or battens.

Deterioration through pressure in stowage is seen at its worst in the case of oily, "feedy" herrings. This is being increasingly recognized on British vessels and boxes are coming into much more general use. Ice also is beginning to be used, but there is still some reluctance to do so even on larger vessels. This may be a survival from the days when salt curing was the chief outlet for the catch, it being held that iced herrings made a poor cure.

Cutting or piercing the flesh of fish, such as by knives in gutting and by hooks at unloading, opens the way for bacterial entry and local spoilage and often discolouration.

Some thought is being given to new methods of storage, e.g. large containers, which would be filled at sea with fish and ice, and lifted from the hold at the port. Besides saving labour in discharging, this would avoid the damage to the fish that occurs as the result of using hooks, ice shovels and throwing baskets into the hold. It would still be necessary to sort the fish on shore before exposure for sale. These new methods of stowage might require larger hatch openings, and even a single continuous hatch in the biggest trawlers. The adoption of the submarine manhole within the hatch proper for access at sea would seem to make this feasible.

From first principles and in relation to preserving the quality of the catch, cleanliness in handling is mainly concerned, on the one hand, with reducing the population of bacteria on the fish as it comes on board and, on the other, with preventing the addition of bacteria from the surfaces with which the fish comes into contact on the ship. The presumptive need for cleanliness in relation to quality is well recognized by the British industry. Further care in hygiene in various ways might not in its totality produce the enhanced quality of catch that might be expected. The scientific evidence is somewhat confused as yet—laboratory results not always being reproducible in commercial practice. But any relaxation of hygiene in handling and stowage would be most likely to result in lowered quality.

Mud from sea floor

Besides the bacteria naturally on the fish in the sea, others get on to it during trawling on the sea floor, especially if muddy. Indeed, considerable quantities of mud can be brought on deck along with the fish. It is presumed from its general type that the mud flora includes fish spoilers. There is also evidence (Lücke and Schwartz, 1937) that, as a result of pressure in the hoisted trawl bag, intestinal contents along with their bacteria are extruded and spread amongst the catch, although apparently this flora is not predominantly of a fish-spoiling character.

Despite the reservation made above regarding the effectiveness of still more cleanly handling than is practised, it is commonsense to recommend that decks and deck pond boards should be thoroughly hosed down with seawater between hauls.

Gutting

The fish should be carefully gutted as soon as possible after hauling, all viscera being removed without cutting into the flesh. Ideally, the guts should not be allowed to fall on ungutted or gutted fish. However, guts are often dropped on the ungutted fish, which become progressively dirtier, the guts being finally washed overboard. Layout of the deck ponds can be made to assist cleanliness here.

Washing fish

The next process is washing the gutted fish, if only to remove gross dirt, blood and slime. This, ideally, should in some way be done with running water. When washing was done properly, e.g. by hosing fish individually, it was shown (Georgala, 1957) that the surface bacterial load on cod ($10^{3.6}$ to 10^{6} per sq. cm.) was reduced by some 80 to 97 per cent. The fish thus carefully washed reached inedibility some two days later than unwashed fish, when kept in bacteriologically clean ice. Washing of this sort is practically impossible on trawlers catching fish at normal rates and it would not take much less than the percentage reduction in bacterial load just indicated to wipe out the enhanced preservation. Until recent years fish on British trawlers were washed by playing the hose upon heaps of fish stirred by foot or sometimes by hosing the fish in baskets given a rotary shaking.

Where there was room, fish have also been cleaned by passing them into a partially dammed deck pond fed by a hose.

In recent years a special washing tank has come increasingly into use. As they are gutted the fish are thrown into this tank, which is raised well above the deck and is fed with seawater through a jet on each side. The jets produce a swirl and the fish emerging from the partially dammed end of the tank, looking well washed and free from obvious blood and slime, are led by chute to the stowage pounds below. This washer has certainly introduced a new element of order into the deck procedure, the fish passing continuously from the deck to the fish hold. On an average the fish is stowed in ice much sooner than previously, in fact very soon after gutting. This is a notable improvement and the fishermen are enthusiastic about it. South African workers (Cooper and Rousseau, 1955) have adopted a flume washing apparatus, fig. 201, in which the fish are brought from gutting to delivery by chute into the fishroom with more than 50 per cent. reduction in the average maximum time of exposure of the fish on deck and considerable lowering of the fish temperature.

There are no data, so far as is known, concerning the greater bacteriological efficiency of these washers as compared with normal washing practice. There is, moreover, lack of agreement amongst investigators about the advantage in preservation to be gained by washing followed by normal stowage on trawlers. Ludorff and Kreuzer (1956) found after washing with greater care than might be possible in practice that the fish kept better after 16 days' stowage than those treated by the crew in the normal way. Castell, MacCallum and Power (1950), on the other hand, could find no advantage in washing with extra care but their fish was stowed for no longer than 6 to 7 days. In a number of experiments on a British distant-water trawler (Rep. Food Invest. Bd., DSIR, 1954 and 1955) no difference was found between unwashed and very carefully washed fish stowed in boxes with the ship's ice after 10 to 15 days' storage, most of which occurred on shore after landing. This result appears to conflict with that quoted above, viz. that some two days' advantage could be gained. However, the explanation may well lie in the fact that the ice was bacteriologically clean as compared with the ship's ice, which, in the experiment, was taken near the end of the fishing period.

Contamination of ice

The bacteriological condition of the ice as a separate factor has been found by both Canadian (Castell, MacCallum and Power, 1950) and British workers (Rep. Food Invest. Bd., DSIR, 1955) to be of considerable importance. Fresh crushed artificial ice as delivered to the fishing vessel contains relatively few bacteria, 10^2 to 10^3 per g. and these are mostly not considered to be fish spoiling types. While stowed in the ice pounds in the hold for the voyage the ice becomes more and more contaminated with bacteria, presumably from the ice pound walls and division boards, which have often previously served as fish pound boards or shelves, and from contact with shovels used for icing the fish, and with the fishermen's boots. All these infections carry nutriment with them which will support further growth.

On a typical distant-water Arctic trip from the Humber, the counts for samples of the trawler's ice on reaching the fishing grounds some four days out of port were about 10^5 per g., whilst at the end of the fishing and on return to port the figures were about 10^6 per g. The Canadians (Castell, MacCallum and Power, 1950) report, counts of the order of 10^7 per g. Several samples of unused ice from trawlers returning to Aberdeen have also had counts of this order. The flora of the unused ice after a voyage was found predominantly to resemble the flora of fish. When very well washed codlings were stowed in clean boxes with factory ice they became inedible some five days later than similar codlings stored with unused ice from a fishing vessel. However, too little work has yet been done to assess satisfactorily the significance of the part played by ice in increasing the spoilage of the catch under commercial conditions.

Contact with hold walls

Fish can be contaminated not only from contact with the trawler's ice but also from direct contact with dirty shelves, walls and linings. Most of these, however, are still wooden and shortly after being painted, varnished with shellac or coated with various surface sealers, become porous and water-sodden and harbour beneath the surface multitudes of bacteria. It is generally agreed that so far it is impossible in any simple, practicable manner to sterilize such wooden fittings. It is not surprising, therefore, that it has not proved possible in practice to demonstrate convincingly that fish stowed in wooden holds, cleaned by practicable methods, such as washing with detergents and disinfectants, are very much better in keeping quality than where cleaning has been less careful. Indeed, it is perhaps improbable that contamination from the wooden fittings can affect the quality of fish other than those in close contact with them. This, however, could perhaps amount to only a few per cent. of the catch in British distant-water trawlers, which use a high ratio of ice to fish (e.g. 1:1.5) and usually put extra ice between the fish and the walls of the fish hold.

Some Canadian workers in recent years (MacCallum, 1955; and McLean and Castell, 1956) illustrate how fish can be spoiled through contact with wooden walls and division boards and shelves. It was found that fish pressing closely on the wood during a voyage can frequently develop a particularly foul, sulphide-like odour, reminiscent of bilge water, which permeates part or at times the whole of the flesh, resulting in what is known to the trade as a "bilgy" fish. The cause was shown to be spoilage by facultative anaerobic bacteria resident in the wet, worn wood. This type of spoilage has also been recognized on British trawlers (Burgess and Spencer, 1958). To avoid it, the Canadians recommend that the fish be kept away from the wood by means of ample local icing or by heavy wire netting screens.

MacCallum (1955) recommends the use of a considerable amount of ice to make certain that the fish does not come into contact with the walls of the pen or pounds. As much ice by weight as 22 per cent. of the total catch is suggested in the case of holds with poorly preserved wooden linings and boards and about 8 per cent. when the holds are metal-lined.

Metal-lined holds and metal shelves can be much more effectively cleaned and sterilized than wood and, of course, do not carry sub-surface infections; but there is apparently no published evidence to show that, apart from the less frequent occurence of "bilgy" fish, the bulk of the catch is kept in improved conditions. On the commonsense ground, however, of maintaining a proper regard for care throughout the whole treatment of a foodstuff, good cleaning of fish holds and their fittings to prevent the accumulation of gross dirt must be strongly recommended.

As it is easier to clean portable boards than fixtures, vertical pounds divisions should, wherever possible, be built up from boards and stanchions, the fixed wings remaining only at the sides of the ship, where they are necessary to avoid the use of boards of special sizes and shapes. In the same way it is better to have separate, portable rest-angles to carry the horizontal shelves, rather than rest-angles fixed to stanchions or battens fixed to special boards. These features also make it easier to work in the fishroom both when stowing the fish and discharging it (Eddie and Waterman, 1958).

Although too little work has yet been done on the subject and sampling methods require closer investigation, direct contact with contaminated ice especially later in the voyage, would seem at present to be a source of spoilage. It is difficult to see how this could be entirely eliminated, even in a metal-fitted hold kept thoroughly clean, except by incorporating a bactericidal or bacteriostatic substance in the ice.

Work in many parts of the world has shown that at least two antibiotics, chlor-tetracycline and oxy-tetracycline, when incorporated in the ice can afford about a week's extra preservation beyond the normal point of inedibility (Shewan, 1958). Part at least of the effect of this treatment is no doubt to be accounted for by counteracting the spoiling load that builds up on the ice.

Anaerobic spoilage takes place only when the fish is directly in contact with smooth surfaces, especially infected wood, and can be avoided in the manner described. So long as this is done, it is the opinion of many practical men in the British industry that exclusion of as much air as possible from the stowage gives the best results, and considerable trouble is taken to avoid air spaces when bulk stowing fish, but whether in fact the result obtained is due to the exclusion of oxygen (in the air) or to some other factor, such as the prevention of warming-up by inflowing warm air, has not been examined scientifically. In any case trade practice is inconsistent as "shelfing" is advocated by the same people.

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THE FISH ROOM—ENGINEERING AND ARCHITECTURE

by

W. A. MacCALLUM

The naval architect can serve the fishing industry better if he understands fish preservation. Much "know-how" is at hand and the time to apply the results of engineering progress and technological advancement is when the vessel is in the planning stage. This paper concerns desirable shapes and dimensions of holds, compartments and containers for various fisheries and types of vessels; and improvements of old and development of new features for fish storage.

Particular importance is attached to the arrangement of fish rooms for the iced storage of "wet" fish, salted fish, and fish room construction for handling either iced "wet" fish or fish refrigerated in sea water. Both fixed and movable elements are considered for transverse partitions in fish rooms. Integral transverse partitions and ceiling linings of two designs in aluminium alloy are cited. Practical steps to cut costs and reduce difficulties in placing boards in divisions, transverse partitions and shelves in trawlers are outlined and details of construction are shown. Inadequate planning of fish room layouts in small wooden trawlers and longliners is described.

The features of some paints, woods, plastics, glass fibre reinforced plastics, galvanized steel and aluminium alloys are noted. Methods of preventing the catch from touching the woodwork are discussed. Tables show the types, characteristics, and gauges of aluminium alloys used.

The design and use of pen boards of wood and aluminium alloys components are discussed. Aspects of ventilation in wooden ships are discussed; and so is the undecked small fish carrier. A similar analysis is made of small decked boats, longliners, trawlers and cutters.

LES CALES A POISSON—TECHNIQUE ET ARCHITECTURE

L'architecte naval peut rendre de meilleurs services à l'industrie des pêches s'il connaît la préservation du poisson. Les connaissances acquises sont importantes, et c'est au moment de l'établissement des plans du navire qu'il convient de mettre en application les résultats des progrès mécaniques et de l'avancement des techniques. Les informations examinées concernent: les formes et dimensions désirables des cales, compartiments et récipients pour les diverses pêches et les divers types de navires; les améliorations des caractéristiques anciennes et la mise au point de nouvelles caractéristiques pour l'entreposage du poisson.

On attache une importance particulière à la disposition des cales à poisson pour l'entreposage en glace du poisson frais, du poisson salé et à la construction des cales à poisson devant recevoir soit le poisson frais en glace, soit le poisson réfrigéré dans l'eau de mer. Les éléments fixes et amovibles sont considérés pour les séparations transversales dans les cales à poisson. Les séparations transversales intégrales et deux types de doublage du plafond en alliage d'aluminium sont cités. L'auteur indique des moyens pratiques pour diminuer les dépenses et réduire les difficultés quand on place les planches dans les divisions, les séparations transversales et les étagères à bord des chalutiers, et il donne des détails de construction. Il décrit aussi des projets de disposition de cale à poisson ne convenant pas à bord de petits chalutiers et palangriers de bois.

Les caractéristiques de quelques peintures, bois, matières plastiques, matières plastiques renforcées de fibre de verre, acier galvanisé et alliages d'aluminium sont indiquées. L'auteur examine les méthodes pour empêcher le poisson de toucher le bois. Des tableaux indiquent les types caractéristiques et épaisseurs des alliages d'aluminium utilisés.

Le dessin et l'emploi de planches d'étagères de bois et d'alliages d'aluminium sont commentés. L'auteur examine les divers aspects de la ventilation à bord des navires de bois et aussi des petits transports de poisson non pontés. Il donne une analyse semblable des petits navires pontés, des palangriers, des chalutiers et des cotres.

LA BODEGA DE PESCADO—INGENIERIA Y ARQUITECTURA

El arquitecto naval puede prestar servicios más completos a la industria pesquera si posee conocimientos de conservación de pescado. Existe mucha información sobre el particular y el momento de aplicar los resultados de los adelantos de la ingeniería y de la técnica es cuando el barco está todavía en proyecto. La información que se discute está relacionada con: formas y dimensiones de las bodegas más convenientes, compartimientos y recipientes para diferentes clases de pesca y tipos de barco, mejora de las características viejas del almacenamiento de pescado y formulación de otras nuevas.

Se da especial importancia a la distribución de las bodegas de pescado para almacenar en hielo el pescado fresco y el pescado salado; la construcción de la bodega para manipular pescado fresco almacenado en hielo o enfriado con agua de mar. Se estudian los elementos fijos y móviles para las separaciones transversales de las bodegas de pescado. Se mencionan particiones transversales integrales y forros para techos de dos proyectos basados en el empleo de aleación de aluminio. Se mencionan medidas prácticas para reducir los costos y las dificultades de poner las panas en las divisiones y se dan datos y detalles de la construcción de particiones transversales y de estanterías en los arrastreros. Se describen los defectos de la madera para la pesca al arrastre y al palangre.

Se mencionan características de algunas pinturas, maderas, materiales plásticos, materiales plásticos reforzados con fibra de vidrio, acero galvanizado y aleaciones de aluminio. Se discuten los procedimientos que existen para evitar que el pescado esté en contacto con la madera. Se dan tablas de los tipos, características, y espesores de las aleaciones de aluminio.

Se examinan la construcción y empleo de panas de madera y de aleaciones de aluminio para los compartimientos de pescado. Se exponen aspectos de la ventilación en barcos de madera. Se discute el barco transportador de pescado sin cubierta y se hace un análisis análogo de algunas embarcaciones pequeñas, barcos para la pesca al arrastre, al palangre y cúteres, todos ellos con cubierta.

An important improvement would be realized if at the time a vessel is in the planning stage, fish room location, shape, construction and fitting out were given the same careful consideration as hull form, safety at sea and main engines. Thus boats should be designed with fish handling and fish preservation characteristics very much in mind. In many details the naval architect should be able to improve present facilities for handling and storing the catch.

The naval architect must co-operate with the fisheries engineer, the owner, and the builder in connection with the installation of sea-water chilling tanks, visceral and liver tanks, and changes from conventional practice in the relative positions of fuel tanks and stowed fish. He must also be a guide as to the effects these developments will have on stability, safety, and other operating characteristics of the fishing boat.

The first seven sections deal in the main with larger boats, and the last two sections with small fishing craft, with the exception that ventilation, in the last section, applies to wooden vessels of all sizes.

LARGE FISHING BOATS

The ideal storage room is the rectangular prism because it is easiest and cheapest to fit out and easiest to use. Hence it is of great advantage to have the fish room as uniform and as fully-shaped as possible from aft to forward. Barker suggests that a true rectangular parallelepiped be considered in diesel trawlers without double bottoms. He proposes that fuel be carried in wing tanks on each side of the fish room. For a given cubic capacity between engine room and forward bulkheads the fish room would be longer and narrower and of approximately the same volume as when transverse tanks are used. The design would:

- Provide less "lost" space where boxed fish are stowed
- Give complete interchangeability of all fish room boards used for bulk stowage
- Reduce costs and increase efficiency of space utilization if jacketed Unit Pen type construction (MacCallum, 1954a, 1955a) for bulk stowage were desired
- Give the same advantages with regard to installation of seawater chilling tanks
- Lead to shorter pens for bulk stowing, thus reducing the work of the icer and probably increasing efficiency of icing
- Result in more constant trim

The proposals are worthy of careful consideration by naval architects.

Obstructions in fish holds sometimes reduce the effectiveness of space available and increase costs when metal tanks, Unit Pens and metal linings are fitted. The architect should strive to provide an uncluttered fish storage space.

Typical fish and ice weights and states of stowage to help in design calculations are shown in table 46.

INSULATION

Typical considerations relating to the use of insulation

Whether or not to insulate depends on how many of the factors in table 47 apply. These and possibly other factors may have different significance depending upon which part of the fish room is considered, *viz.*, end bulkheads, deckhead or ship's ceiling. Special weight should be given to factors that are important in the area or conditions under consideration. The remarks opposite items 10 and 11 indicate the majority point of view, at least in some countries. The cost of insulation alone can seldom be balanced against the cost of refrigeration as is done in land storage. The insulation protective covering cost and possibly the cost of ventilating the vessel's structure behind the insulation must also be considered.

Table 47 indicates doubt concerning installing insulation on the fish room ceiling. But insulation is needed if too little ice is used, which otherwise results in poor quality fish.

Time in storage is of great importance in determining quality, and is dependent upon:

- Distance to the fishing grounds and vessel speed
- Rate of catching and stowing
- Carrying capacity of the fishing craft

Because of the relationship, varying though it may be, between vessel size and time of fish in storage, it is sometimes possible to by-pass certain factors and to associate the use of insulation with a particular type of boat of a certain size. Thus, Norwegian Fresh Fish Regulations, 1952 state that the end bulkheads in the fish room of wooden seiners 50 to 60 ft. (15 to 18 m.) long should be insulated, and in Japan insulation is applied on the ceilings, end bulkheads and deckheads of all steel and wooden boats over 50 GT. It is estimated by H. C. Hanson that in Southern California 100 per cent. of the tuna boats, both steel and wood, 90 ft. (27 m.) and more in length are insulated, and 25 per cent. of those between 60 and 90 ft. (18 and 27 m.) in length are similarly fitted out.

Quite apart from its contribution to fish-saving, insulation, when used effectively, contributes to better fish room operation. The saving in man-hours with insulation is worthwhile when icing the fish. It also saves fatigue and this results in more careful icing.

Judicious use of insulation can result in a gain in space for fish storage. Examples are illustrated in fig. 180, 181 and 182 and discussed later.

Insulation requirements in steel

As pointed out by Smith (1951) the calculation of heat flow through a wall of insulating material with intruding steel members is difficult and complicated. A stiffener adjacent to the lining will contribute to a substantial area which will be nearly as warm as the outside of the insulation. Isotherms do not run parallel to the outside

TABLE 46

Typical fish weight and states of stowage

	State	Weight lb./cu. ft.	Weight kg./cu. m.	References
a	**Ungutted cod** (in pre-rigor and rigor state, shallow bulked without ice)	47 to 52	753 to 833	MacCallum, 1958
b(i)	**Gutted cod** (laid in single rows on ice on individual shelves, per unit of *net* volume of fish hold, British trawlers)	15.5	248	Eddie and Waterman, 1958(a)
b(ii)	**Gutted cod** (in pre-rigor and rigor state, shallow bulked without ice)	45	721	MacCallum, 1958
c(i)	**Gutted cod and haddock landed** (shallow bulking in ice in ratio of ice to fish by weight 1:1 to 2 per unit of *net* volume of fish hold (Skagen, Denmark)	31 to 37	497 to 593	Bramsnaes, 1958(a)
c(ii)	**Gutted cod and haddock landed** (shallow bulking in ice in ratio of ice to fish by weight 1:2, per unit of *net* volume of fish hold, British trawlers)	35 (4.0 cu. ft./10 stone kit)	561	Eddie and Waterman, 1958(a)
c(iii)	**Gutted cod and haddock landed** (shallow bulking in ice in ratio of ice to fish by weight 1:2.5, per unit of *net* volume of fish hold on 7-day voyage, Esbjerg, Denmark)	41	657	Bramsnaes, 1958(a)
c(iv)	**Gutted cod and haddock** (held in ice for a period of 8 days, then removed from ice and shallow bulked without ice)	55	881	MacCallum, 1958
d	**Boxed fish** (per unit of *gross* volume of fish hold, British seiner)	31	497	Eddie and Waterman, 1958(a)
e(i)	**Crushed ice at 32°F (0°C)**, unpacked as at loading into the fishing boat[1]	35	561	MacCallum, 1958
e(ii)	**Crushed ice at 32°F (0°C)**, tending to solidify after prolonged storage, in the fishing boat, awaiting use	41	657	MacCallum and Dawson, 1959
f	**Flake ice at 32°F (0°C)**, unpacked, as at loading into the fishing boat[2]	26.5	425	MacCallum, 1958

Remark 1

Results of sieve analysis of crushed ice at 32°F (0°C) as at loading into the fishing boat

Sieve No.	Per cent. by weight of ice retained on sieve
1½ in. (38 mm.) mesh	5.9
1 in. (25 mm.) mesh	64.8
¾ in. (19 mm.) mesh	80.1
⅜ in. (9.5 mm.) mesh	97.5

Remark 2

Results of sieve analysis of flake ice at 32°F (0°C) as at loading into the fishing boat

Sieve No.	Per cent. by weight of ice retained on sieve
1½ in. (38 mm.) mesh	0.0
1 in. (25 mm.) mesh	41.8
¾ in. (19 mm.) mesh	75.2
⅜ in. (9.5 mm.) mesh	93.2

Remark 3

Net volume is less than gross volume by pen divisions, shelves, stanchions, etc. In bulk stowage, the weight of fish per unit gross volume of fish holds may be considered to be 10 per cent. less than the weight per unit net volume

TABLE 47

Typical considerations relating to the use of insulation on the ceiling of a small wooden trawler

Factors	Case considered	Insulation Recommended	Insulation Not recommended
1. Material used in construction of vessel	Wood	—	X
2. Air and water temperature	62°F (16.7°C) (ΔT=30°F or 16.7°C). See "Influence on fish hold carrying capacity" in text and fig. 181.	—	X
3. Available space in fish room in relation to catch.	A maximum of 2 in. (51 mm.) loss of space (including space for ice) against existing ceiling of uninsulated boat is original goal.	—	X (see fig. 181)
4. Effect of use of insulation in causing deterioration of the structure	Reasonable, though not guaranteed, provisions made to prevent dry rot.	—	X
5. Duration of fishing trip.	Seven days.	X	—
6. Species and type of fish landed.	Atlantic groundfish (cod, haddock, etc.) landed for fresh and frozen fish trade.	X	—
7. Fish handling in the area.	Relatively low-priced fish requiring high rate of stowing.	X	—
8. Cost and availability of ice.	Ice readily available at low price.	—	X
9. Quantities of ice required and cost of placing it.	High.	X	—
10. Cost and availability of suitable insulating materials.	Relatively easy to obtain, but price relatively high compared to price of fish.	—	X
11. Cost and availability of suitable protecting material for insulation.	Relatively easy to obtain, but price relatively high compared to price of fish.	—	X

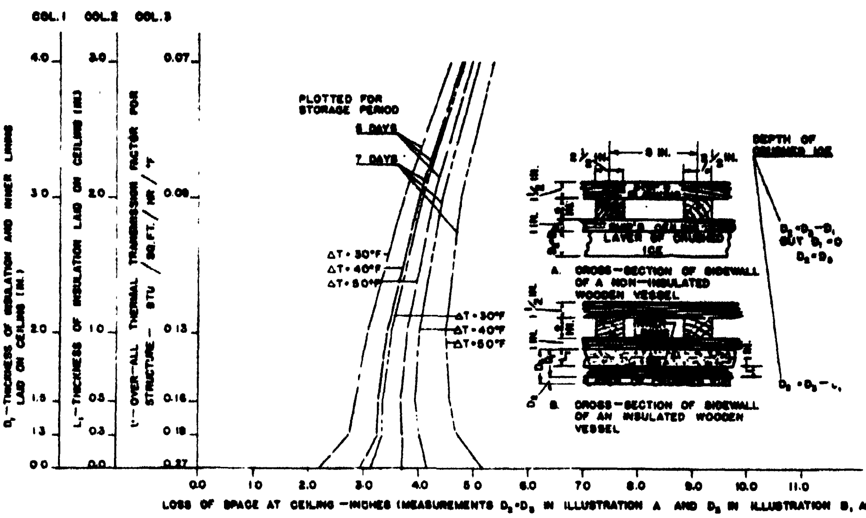


Fig. 180. Space lost diagram for the ship's side of a wooden longliner

and inside wall surfaces and the conductance of any section of unit length is larger than the sum of the conductances of each section comprising the unit. The equivalent insulation depth is in some cases less than half that of the overall insulation depth of the structure, due to the stiffeners alone and without considering the adverse effect of grounds, chocks, or fastenings.

Where the ship's wall, bulkhead or deckhead is built to offer the same resistance to heat flow as the conventional cold storage wall, having a chosen depth of insulation, the actual thickness of insulation required on the fishing boat may be determined as follows:

An average value of the desired* thermal transmission factor, U is put in the standard formula†

$$U=\frac{1}{\frac{1}{f_i}+\frac{1}{f_o}+\frac{L_1}{k_1}+\frac{L_2}{k_2}+\ldots\frac{L_n}{k_n}}$$

and then the values applicable to fishing boats for f_o and f_i for the surface conditions and of k_1, k_2 . . . k_n for materials and insulations are substituted. As required, the conductivity coefficient k used for the insulation may be adjusted to take care of water absorption, effect of convection currents in the wall, imperfect workmanship, etc. The equation is solved for the appropriate symbol L which refers to the net thickness of insulation when the walls are considered to be without frames, stiffeners, etc. This thickness will be denoted as L_e, the *effective* thickness of insulation.

The amount of adjustment to be made to k is purely arbitrary. For rockwool and corkboard an increase over manufacturers' ratings of 25 to 50 per cent. appears to be warranted for low temperature storages (Lorentzen and Brendeng, 1955; Merlin, 1955). A similar increase would appear to be justified for applications in some wet fish holds where wetting of insulation by absorption is prevalent. An increase in k could also take care of the effect of grounds between metal stiffeners and fish hold linings.

The overall insulation depth, always greater than L_e where ship's members intrude into the material and hence also greater than the depth of frames, may be determined through the use of available data, in the case of steel ships, obtained from the electric analogue method of accounting for the effect of frame and beam profiles (Smith, 1951).

In specifying insulation for steel ships, flanges of beams and stiffeners should be separated from the lining by unbroken layers of insulation, as shown by fig. 182, illustration B.

The Gregson System, found in such trawlers as the *Bay Ella*, formerly *Cayton Bay* (Birmabright Ltd., 1951), is one practical solution to the problem of insulating a wall into which steel stiffeners intrude.

Insulation requirements in wooden vessels

The standard formula (Appendix 1) is used for determining heat flow through the wall of an insulated wooden vessel and it is assumed that the conductance of any unit is the sum of the conductances of each section comprising the unit. The area of wooden frames and stiffeners represents a fairly large percentage of the wall structure. Thus, for ease of installation, etc., insulation is often omitted from between-frame spaces and is placed in uninterrupted layers over the ship's ceiling.

*The effect at various values of U on hold carrying capacity and the quantities of ice which should be stowed is considered in the following 2nd and 3rd sub-sections.

†See Appendix 1 for explanation of formula.

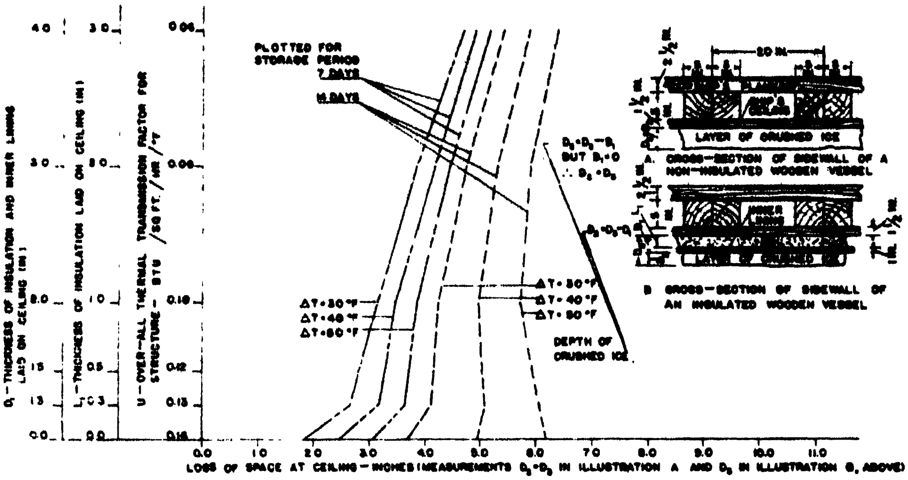


Fig. 181. Space lost diagram for the ship's side of a wooden trawler

Influence of insulation on fish hold carrying capacity

In deciding upon the thickness of insulation L_{ior} (fig. 182) and L_i (fig. 180, 181), it is helpful to recognize the point at which fish hold carrying capacity is being sacrificed. Typical instances for the sides of wooden longliners and wooden and steel trawlers are considered in fig. 180, 181, and 182. A study of bulkheads and deckheads can be made in a similar manner provided that in deckheads the effect of transfer of heat from the inner lining to the ice by convection be considered. The following assumptions have been made in connection with calculations used in making the diagrams.

Thermal conductivity of the insulation—0.33 BTU in./hr./sq. ft./°F (0.0001136 cal. cm./sec./sq. cm./°C).

The inner lining covering the insulation is 1 in. (25 mm.) pine for both steel and wooden vessels. The insulating effect of a covering or coating is very small and has not been considered.

Zero resistance ($1/f_i=0$) to heat flow exists in all cases between the inner linings and the ice with which these are in contact.

The ship's ceiling next to the frames of the wooden longliner is 1 in. (25 mm.), both non-insulated and insulated; 1½ in. (37 mm.) in the wooden trawler; and 1½ in. (37 mm.) with a ½ in. (12 mm.) air space for the uninsulated steel trawler.

Insulation is continuous between and over frames of the insulated steel vessel.

The U-value for the non-insulated wall in the steel vessel (fig. 182, illustration A) is computed as if the wall were without frames and battens.

A ¾ in. (19 mm.) thickness of crushed ice at 32°F (0°C) having a density of 36 lb./cu. ft. (577 kg./cu.m.) and a latent heat of fusion of 144 BTU/lb. (80 cal./g.) will melt in a period of 7 days, ΔT being 30°F (16.7°C) and the U-value of the wall being 0.07 BTU/hr./sq.ft./°F (0.34 kcal./hr./sq.m./°C). A U-value of this magnitude is a common goal in land-based storage rooms maintained at about 32°F (0°C).

In fig. 182 the reference line for computing loss of space at the ceiling has been taken 2 in. (51 mm.) inwards from the flange of the steel frames in both the insulated

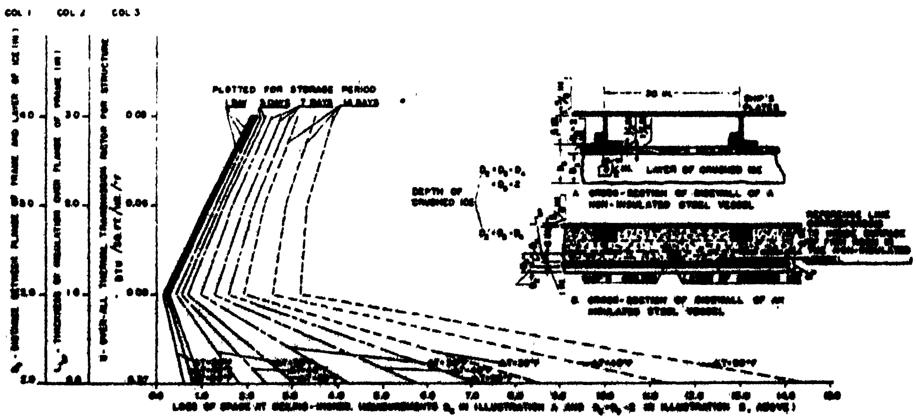


Fig. 182. Space lost diagram for the ship's side of a steel trawler

and non-insulated holds, which corresponds to the ceiling surface of the non-insulated hold.

Heat transmittance calculations have been made using the standard formula:

$Q = UA\,\Delta T$ where U = thermal transmission factor as defined in Appendix 1

A = area of the surface through which the heat flows

ΔT = temperature difference between the extreme surfaces of the structure

The thickness of ice, D_3, in the wooden boats may be obtained from fig. 180 and 181 by subtracting D_1 in column 1 from D_2 in the abscissa. Note that in the non-insulated wooden vessel ($L_i = 0$) the space lost at the ceiling, D_2, is equal to the depth of crushed ice used, D_3.

For the non-insulated steel vessel, the thickness of ice, D_3, may be obtained from fig. 182 by reading the number in the abscissa at which the curve in question meets $L_{ior} = O$. In this case, the space lost at the ceiling is equal to the depth of crushed ice, D_3.

The calculation requires an additional step for the insulated steel vessel. First add 2 in. (51 mm.) to $D_6 = (D_5 - 2)$ in. read from the abscissa in fig. 182 opposite the point on the curve which denotes the thickness of insulation considered. Second, from the algebraic sum (D_5) thus obtained subtract the number D_4 in column 1, namely the ordinate of the curves. Thus, from fig. 182, when heat flow is uniformly continuous for 14 days, ΔT being 30°F (16.7°C) and the steel vessel having 6 in. (152 mm.) frames at 30 in. (762 mm.) spacing with 3½ in. (89 mm.) flanges, the required thickness of ice is (2.4 + 2.0 in.) − 3.0 in. = 1.4 in. (112 − 76 mm. = 36 mm.). Here, the insulation is placed between and over the frames to a depth of 2 in. (51 mm.).

By such a calculation it will be seen in fig. 180 that gain in stowage space may occur in the wooden longliner when storage is 5 days or more, with ΔT being 50°F (27.8°C) and 7 days or more with ΔT being 40°F (22.2°C), namely combined space occupied by insulation and associated covering together with crushed ice becomes less than the space occupied by ice when insulation is not used. This gain in space, of course, will continue only to a certain maximum thickness of insulation beyond which space is lost. For all practical purposes the minimum transmission factor without loss of too much stowage space [assumed extra loss about 1 in. (25 mm.) of space as the result of using insulation] is 0.09 BTU/hr./sq. ft./°F (0.44 kcal./hr./sq. m./°C) corresponding to 2 in. (51 mm.) of insulation, when the storage periods are 5 days (ΔT=40°F, 22.2°C) and 7 days (ΔT=30°F, 16.7°C) respectively.

The curves for the wooden trawler in fig. 181 indicate that gain in stowage space occurs with the use of insulation when storage is for approximately 14 days, ΔT being 40°F (22.2°C). For the practical case where not too much stowage space is lost against the surface, the minimum transmission factor would be 0.10 BTU/hr./sq. ft./°F (0.48 kcal./hr./sq. m./°C), corresponding to the use of 1 in. of insulation, when the storage period is 7 days (ΔT=40 to 50°F, 22.2 to 27.8°C) and 0.08 BTU/hr./sq. ft./°F (0.39 kcal./hr./sq. m./°C) corresponding to 2 in. of insulation, when the storage period is 14 days (ΔT=30°F, 16.7°C).

Gain in stowage space may occur in the steel trawler [when combined space occupied by ice, insulation, etc. becomes less than that occupied by a ceiling over an uninsulated structure together with the required ice] when storage is for one day, ΔT being 30°F (16.7°C) depending on the thickness of insulation used between and over the frames as shown in fig. 182. For all longer periods, ΔT being 30°F (16.7°C) or higher, a saving of space may result. For example, space savings of 11.0, 10.9, and 10.3 in. (279, 277 and 262 mm.) result for a period of storage of 14 days, ΔT being 50°F (27.8°C) for the cases where insulation is placed between as well as over the frames to depths of 1, 2, and 3 in. (25, 51, and 76 mm.) respectively.

It thus appears to be quite practical to insulate both between steel frames and over the latter to a depth of approximately 3 in. (76 mm.) without sacrificing fish hold space when storage periods are 3 days or longer and ΔT being 30°F (16.7°C) or higher. The diagrams indicate that, generally, insulation can be used more advantageously on the steel than on the wooden vessel.

Influence of insulation on quantities of ice to be carried

The quantities of ice to be stowed against the ceiling to combat heat flow for a period of 7 days, ΔT being 40°F (22.2°C) are determined with the aid of fig. 180, 181, and 182, according to table 50 (see p. 226).

Water-vapour proof membranes. The best available vapour barriers and insulations should be selected and their application is most important. Normally, resistance to diffusion of moisture by the material covering the warm side of the insulation should be maximum, that of the material on the cold side should be minimum and that of the insulation some intermediate value.

The wet fish hold, finished on the inside with a watertight covering, needs little maintenance and is better for stowing fish than its poorly finished counterpart. Unfortunately such a highly resistant surface to the flow of water vapour is undesirably located on the cold side of the wall. Unless great care is taken to provide an efficient vapour barrier on the warm side or to prevent water vapour from passing through the insulation, such as in the Minikay system (Bain, 1955a), condensation in the insulation can be expected. The problem is not as significant in the steel boat where the plating acts as a good vapour barrier, or in the wooden boat where a vapour barrier of lowest permeability is applied to members and materials *in situ* in the walls and in heat-resisting partitions and decks.

No universally accepted standard of water vapour resistance exists. The Owens-Corning Fiberglas Corp., 1953, recommended that vapour barriers have a resistance of 0.2 grains/sq. ft. of surface/in. Hg. pressure differential/hr. (=0.2 perms) for storages above 30°F (16.7°C), and this appears to be satisfactory.

One of the most suitable materials for ships is bitumen (Bell, 1957) applied as either a gel-type cutback (used with a petroleum solvent) or a gel-type bitumen latex emulsion, in thicknesses of up to ⅛ in. (3.1 mm.) to give a dried film of approximately $\frac{1}{16}$ in. (1.6 mm.). In using the former, the space should be well ventilated and sufficient time allowed for the solvent to evaporate before covering with insulation.

Vapour barriers in sheet form, e.g. aluminium alloy foil or polyethylene, require considerable care in placing and are not particularly suitable for boats.

Specifications and inspections should ensure that the vapour barrier entirely covers all warm surfaces in one continuous layer. A good vapour barrier should also be used when the insulating material has a high moisture resistance.

Insulating materials

There is a wealth of general information on insulating materials. For boat use, the following combined qualities should be sought:

- Suitably low conductivity coefficient
- High resistance to the diffusion of water vapour
- High resistance to water absorption
- Suitable density
- Suitable compressive strength
- Suitable resistance to rot
- Dimensional stability under varying temperatures and humidity
- Suitable resistance to flame
- Availability and low price

The following types of insulation will be considered:

- ▶ Cellular, namely corkboard, foam plastics (polystyrene), expanded ebonite, cellular glass
- ▶ Glass fibre slabs
- ▶ Those whose efficiency depends upon layers of air, e.g. aluminium foils in an alueolar structure and layered, crimped sheets of cellulose acetate

For steel vessels where insulation is not load-bearing, resistance to water absorption is stressed, except perhaps when the insulation is used under the deck. For the wooden vessel, the insulation should also be resistant to rot. When it has to bear substantial loads, in both steel and wooden craft, high density and high compressive strength are needed.

to water absorption and rot

- With the exception of cork, the cellular materials listed qualify. Slabs of corkboard would be much more satisfactory if properly coated on all sides with bitumen than untreated
- Glass fibres in uncoated slab form do not qualify. Coatings improve them
- Layered aluminium alloy foils and cellulose acetate qualify

Various applications

The listed cellular insulations qualify in various degrees for load-bearing applications as do some of the heavier glass fibre materials, but none of the alloy foils or cellulose acetate sheets qualify.

Polystyrene is not recommended (Seiffert, 1956) where temperatures are above about 150°F (66°C). Expanded ebonite could burn if acetylene welding or cutting were carried out on adjacent steel plates. One solution is to use a non-inflammable insulation, e.g. cellular glass or glass fibres next to the steel plates, and other cellular materials, such as expanded ebonite or polystyrene for the inboard layers. Where interior linings or tank sides constituting the walls are also welded, the use of cellular glass could be indicated throughout, although compromise solutions would still be possible.

Air circulation within the insulation

Air can circulate across the cavities of an insulating material *in situ* where these are porous or are of crimped sheets, such as aluminium foils and cellulose acetate. There are sealing difficulties at the joints of layered, crimped sheets.

FEATURES CONDUCIVE TO EFFICIENT AND SAFE WORKING

Hatches

If each fish room has at least one large hatch, bulk-stowed fish can be quickly unloaded by the batch, continuous conveyor or bucket method and unloading of boxed fish can be facilitated. MacGregor hatches (Bain, 1955b) may be fitted. Large hatch covers need not be opened at sea. A successful method (Eddie and Waterman, 1958a) is used in newer British trawlers in which the larger hatch covers are fitted with screw-down manholes for access and for a chute from the fish washer erected above the hatches. Where deck-level wash boxes with screw-down fish valves are preferred and deck space is not available for separate wash boxes, the wash box could be built integral with the centre section of a MacGregor cover or a large cover of the conventional type.

Lighting

There should be a generous supply of flat marine type lights placed off-centre as nearly in line with transverse rows of stanchions as possible and protected by the stanchions. Three-way switches should be provided as well as a warning light visible from the bridge.

Most fish hold ladders are skimpy and some are extremely dangerous. The rung-and-stringer type is better than the one having steps on both sides of a pillar. Pillar-ladders located along the centre line of the fish hold slow down fish handling, and they are also dangerous.

A vertical rung-and-stringer ladder should preferably be of metal. Rungs should have a maximum spacing of 12 in. (305 mm.) and stringers at least 15 in. (381 mm.) apart.

Non-skid surfaces

Central gurry troughs should have skid-proof perforated metal covers. All fish room floorboards should be skid-proof.

Drainage and washing out facilities

Where pens extend down to the tank top or to the bottom of the fish room a tier of horizontal shelves should be provided at least 2 or 3 in. (51 to 76 mm.) above. Corrugated metal shelf boards assist drainage to the sides of the pens.

It is essential that fish pen drainage is unhampered and that free flow to the sump is maintained. Drainage can be assisted by stops at the bottoms of stanchions to prevent division boards from dropping. Another way to stop this is shown in fig. 186 illustration A.

Gurry troughs through the centre of fish rooms should be of generous size, isolated from the bilges, and should not carry piping or other facilities restricting flow or creating a cleaning problem.

The sump should be of ample capacity, watertight and completely isolated from the bilges and it should have a perforated cover. It should be possible to empty the sump by means of one or more power-driven pumps, independently of the bilges. Standby pumping arrangements for deck manipulation should be provided. Suction intakes should have strainers. An excessive liquid warning device is useful.

Hot water for cleaning fish rooms can be supplied by hoses through the hatches or by fixed pipes. Fixed pipes avoid confusion and overcrowding at the hatches and on deck, but provision must be made to prevent them from freezing when not in use.

PARTITIONS, SHELVING, ETC.

Transverse partitions

These are considered separately from ceilings. Pigeon holing the catch gives some of the benefits of boxed fish without the inconvenience of handling empty boxes. Its effectiveness depends on the use of portable and interchangeable movable boards in most of the pigeon-hole structure. Transverse partitions may be fixed as shown in fig. 183, movable as shown in fig. 184, 185, 186 or a combination of the two.

Fixed wooden components get wet even when painted, and this has led to the use of many portable boards in the hope that repeated cleaning, drying, and painting will

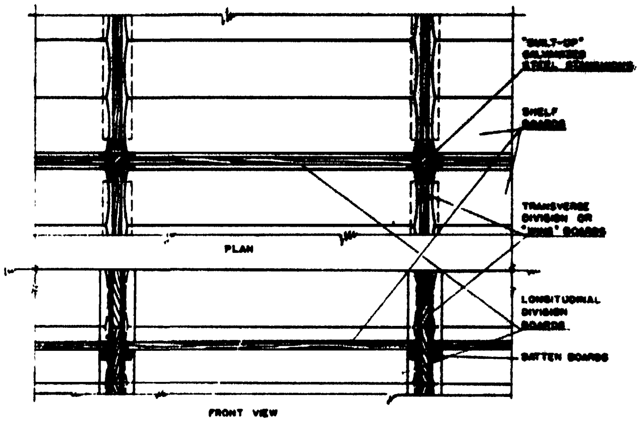


Fig. 184. Fish pens with movable wooden boards for transverse partitions, pen divisions and shelving. Note the discontinuity of battens at stanchions, and dependance on batten boards to assume vertical and side loads

keep them in a better state. Some aluminium alloy portable boards compare favourably in cost with painted wooden boards.

Other factors involved in the choice of movable or fixed partitions are:

Shelf supports, being standard angles on fixed wings in fig. 183, are apt to cost less than some of the special extrusions in fig. 185, 186, illustration A, used with movable partitions. However, standard angles can be used for portable boards in wings in fig. 186, illustration B.

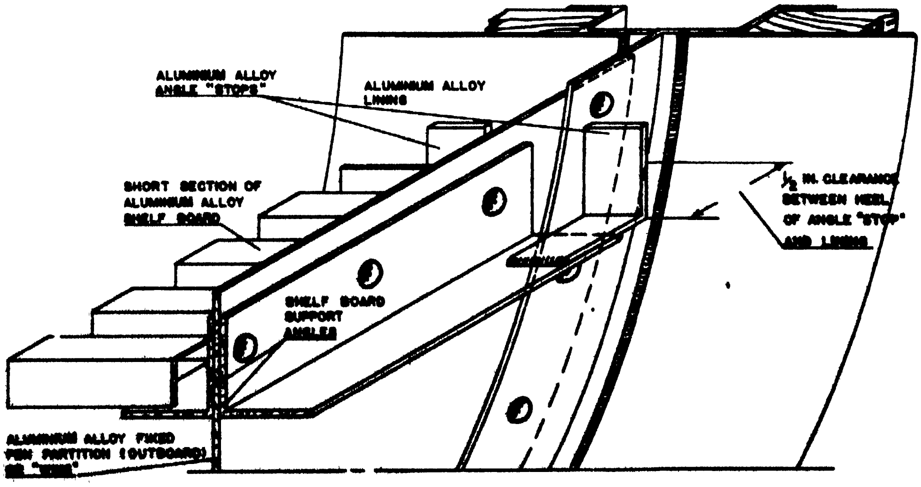


Fig. 183. Fish pens with a fixed transverse pen partition, fixed shelf board support angles and stops to prevent damage to the fish hold lining by shelf boards

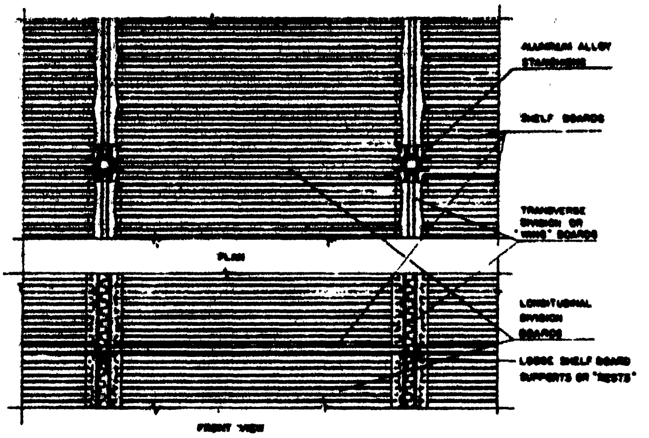


Fig. 185. Fish pens with movable corrugated aluminium alloy boards for transverse partitions, pen divisions and shelving. Note the discontinuity of battens at stanchions and dependance on those transverse boards with which the shelf boards are in contact to assume vertical and side loads

Loads can be taken on transverse portable boards to which the shelf board battens are fixed or on which they rest as shown in fig. 184, 185, but this is not recommended, because excessive side loads may be experienced. A satisfactory solution is shown in fig. 186.

In general, the most important improvements in connection with movable elements in transverse partitions of large trawlers would be:

- Loading directly onto the stanchions through suitable battens
- Arranging stanchions so that all movable boards are interchangeable

Integral transverse and ceiling coverings—the Unit Pen

The Unit Pen (fig. 187) provides pen partitions and pen bottom and back in integral unit form (MacCallum, 1954a, 1955a). Each aluminium alloy pen illustrated is made of three prefabricated sections.

The advantages of the Unit Pen are:

- Effective welding methods can be used
- The units can "work" freely without the welded joints breaking
- Heavy sheet or light plate can be used
- Unit Pens can be removed readily and replaced for hull inspection or repair
- Washing the pen between trips becomes a smaller problem than when wholly "built-up" pens are used

The main disadvantages are high first costs and wasted space behind them when Unit Pens are placed in fish rooms of non-uniform shape or in those in which the shape changes rather abruptly from full to narrow lines.

Pen widths

Pens should not be less than about 3 ft. 8 in. (1.1 m.) wide for best working conditions.

Shelving

The number of portable shelves should be decided on the basis of the fishery needs and on current practice. In areas where they have not been used before in fish holds up to about 6 ft. (1.8 m.) in depth, a bottom shelf to provide drainage and one additional shelf just below the mid-point of the pen height would be practicable—more would not be profitable.

Specific shelf positions as indicated in fig. 183, 186, and 187 are to be preferred to indefinite positions indicated by the arrangements shown in fig. 184 and 185 because in the former cases the shelves are more apt to be used.

Shelf supports

Undesirable side thrusts can be caused when shelves are jammed by pieces of ice and careless placing of the boards. This will occur more often when the location of the shelves is not specific as shown in fig. 184 and 185. Damage caused by side thrusts could be prevented by using heavier boards in transverse partitions as shown in fig. 184 and 185, but better still such loads can be taken by shelf supports and stanchions as shown in fig. 186, in which case lighter transverse boards may be employed.

COATINGS AND LININGS

Fish room paints can be classified as follows:

- Those with a hard-drying phenolic resin modified with specially formulated oil alkyd
- Shellac paints
- Plastic base paints requiring the addition of a catalyst

Plastic paints and varnishes containing epoxy resins require renewing yearly in whole or in part. None of them completely prevent the wood from getting wet in service, and they cost about twice as much as other types. The covering capacity of both plastic and non-plastic paints is about 500 sq. ft. per Imp. gal. (10.2 sq. m. per litre). Epoxy compounds in contrast to epoxy paints have much lower covering capacity.

The application of plastic paints is somewhat more complicated than that of conventional coatings, and the manufacturer's recommendations should be carefully followed.

Canadian experience is that fish hold paints should preferably be white with grey and aluminium finishes as

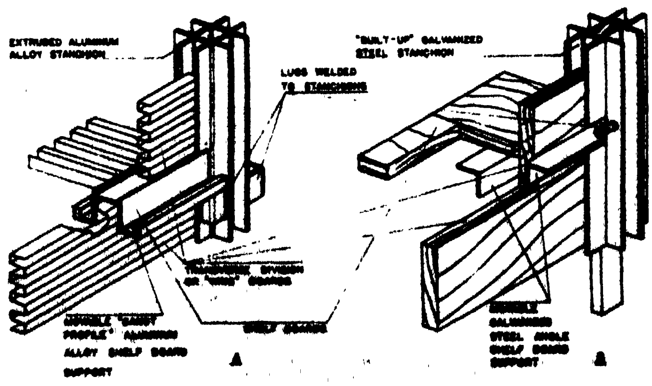


Fig. 186. Arrangements whereby the stanchions are used to support shelf board battens and shelf boards
(Courtesy La Revue de l'Aluminium)

the next choice. With these, the degree of covering may be judged effectively, an impression of cleanliness is realized and the effects of wear may be judged readily.

MATERIALS FOR FISH ROOMS

Materials in wet fish holds should be:

(a) Suitable for storing foodstuffs (MacCallum, 1954b; 1955a; 1955b; 1956)
(b) Sufficiently strong
(c) Waterproof
(d) Suitably resistant to corrosion and wear
(e) Of light weight where portability is required
(f) Of light colour or painted a light colour, preferably white
(g) Inexpensive

All items except (e) apply in whole or in part to fixed partitions, portable boards and most linings, and (e) may apply in the latter case when screens are used to cover ceilings.

Characteristics of aluminium alloys are referred to in a published Bulletin (MacCallum, 1955a).

The magnesium and magnesium silicide group of wrought alloys, heat-treatable and non-heat-treatable, are recommended. These metals have good physical properties (Aluminium, 1957a), excellent resistance to corrosion in marine environments, and good weldability with the correct equipment (Aluminium, 1957b). In general other groups should be avoided, particularly the copper group.

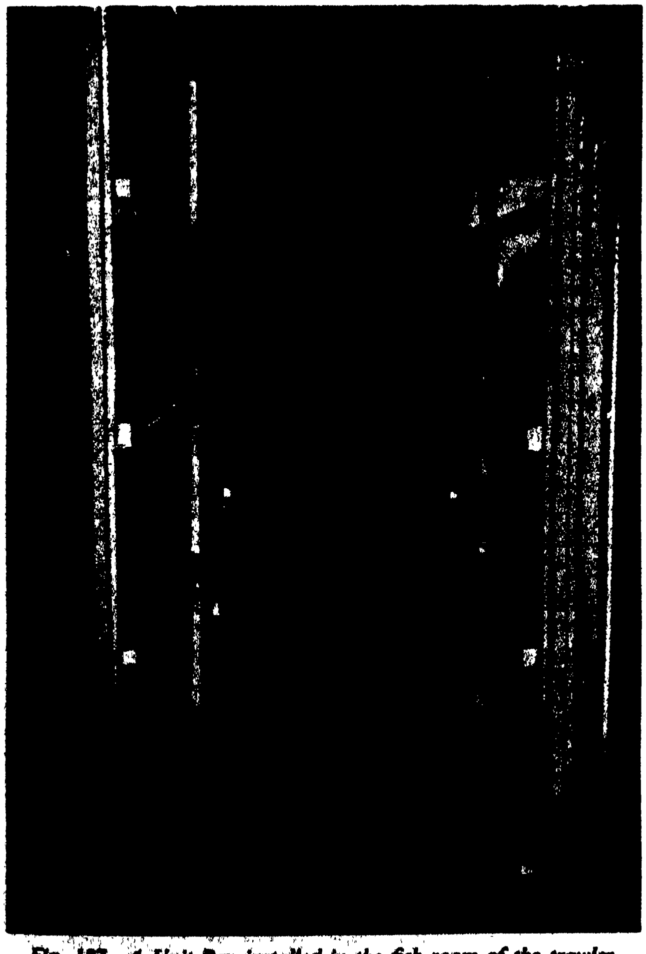


Fig. 187. A Unit Pen installed in the fish room of the trawler Cape Argos

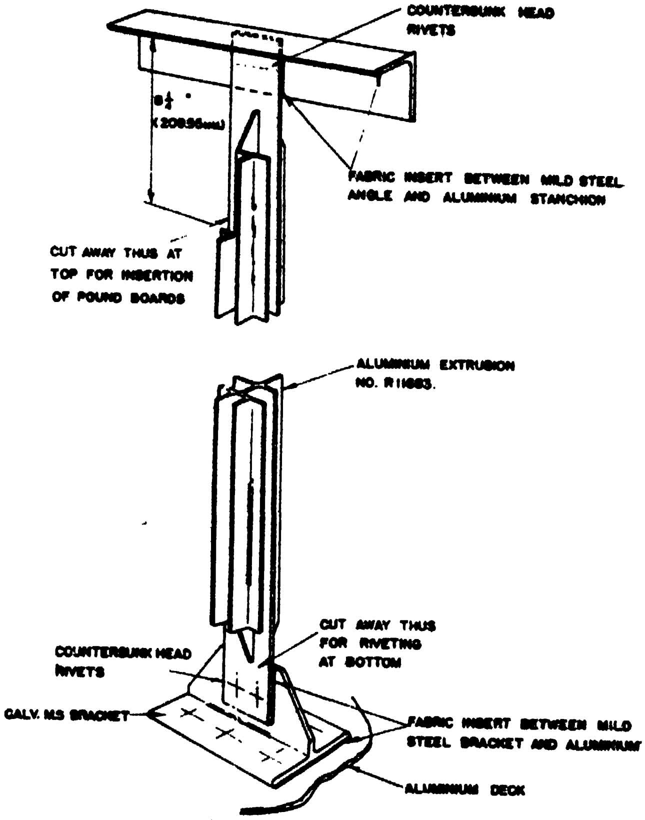


Fig. 188. Method of fixing aluminium alloy stanchions in fish rooms

Designs and specifications should be prepared with care, taking advantage of assistance available from aluminium producers.

Even with the alloys most resistant to corrosion, serious corrosion may result from poor fish room design. This can be avoided if:

- Aluminium alloy linings never rest on steel stiffeners
- The sheets are of adequate thickness to resist puncturing
- Other metals are isolated from them by at least 1 in. (25 mm.) air space. Where passage must be provided through aluminium alloy structures, a thick electric non-conductor should be used to separate the other metal from the aluminium alloy
- Aluminium alloy stanchions and stiffeners are suitably isolated from steel members as shown in fig. 188 and 189
- All fastenings used in connection with aluminium alloys are: (a) aluminium alloy; (b) zinc or cadmium coated if of steel (copper, brass or bronze should never be used); (c) non-metallic
- Portland cement concrete in fig. 189 and plaster are not poured or laid against aluminium alloys

Linings and coverings

To be considered here are:

Wood plus coatings and shielding of wooden boards, metal boards and metal screens. In wooden vessels, such structural members as deckbeams are included in the term "lining" where these form part of the inner storage space (as in uninsulated boats). All exposed woodwork in a wet fish hold tends to gain in moisture content after a short period of service despite the use of paints and coatings. Only woods with the highest resistance to fungal attack should be used in fish rooms, deck beams and frames included.

In the spring of 1958 a thick epoxy compound was applied to the rather imperfectly dried linings of two New Brunswick small trawlers with a good measure of success.

If it is known from experience in a particular fishery that added protection to that offered by paint is going to be needed, several possibilities exist: (a) at the time of building, the bare wood may be covered with glass fibre reinforced plastic; (b) portable wooden or metal boards may be provided to protect well-painted linings and bulkheads; (c) metal screens may be used as panels for the same purpose.

Polyester resins without reinforcement cannot be used successfully on fixed partitions and ceilings of trawlers which have been in service. A combination of resin and glass fibre reinforcement is not impractical but some cracking, tearing and loosening will tend to occur after a period of two to three years (MacCallum, 1958). Success in laying the material and in service was achieved in two Newfoundland longliners built in 1957 and 1958 according to Monroe. No shovels or forks are used in these fish holds.

The most economical use of these materials is on new woodwork on which one layer only of glass cloth is used with the resin. Structural strength is provided by the backing material which in the case of the ceiling may be the ship's sheathing. Where insulation is placed over the ceiling, ¼ in. (6.35 mm.) thick marine plywood may be placed over the insulation as backing material for the "glass".

Correct techniques must be used to obtain satisfactory results with glass fibre reinforced plastics. It is also essential that forced ventilation be provided during application to remove toxic gases and to reduce fire hazards.

Portable boards to protect linings may be desirable on certain areas of the linings. These movable boards, of painted wood or aluminium alloy, can be removed for washing and drying, and repainted, if required.

Metal screens can be used in the same way as given for portable boards above. There is the added benefit that screens in fig. 190 retain ice between them and the walls to which they are attached. (MacCallum, 1954c, 1955a, 1956).

Specifications

Aluminium alloy: These are given in table 48 and 49 for North Atlantic vessels.

Partitions: These are discussed under "Transverse partitions" and "Integral transverse and Ceiling coverings —the Unit Pen", above.

Watertightness in linings: The use of aluminium alloy linings to provide watertightness is feasible, but costs are high. Chilling in refrigerated sea water has stimulated the need for tanks involving quantities and gauges of materials and weldments similar to those used in the construction of the Unit Pen. (MacCallum, 1954a, 1955a.)

The simplest and cheapest watertight lining is welded metal. The main objection is said to be that the wall beneath can be reached only by removing the lining, but efficiently gasketed access doors to the hull can be provided in the lining, and modern welding techniques are such that patching and rewelding of cut areas can be done rapidly. The alternative is to use movable units such as the Unit Pen (fig. 187). Mechanical joints as typified by British Patent Specification No. 799, 238 (1958) appear to be of exceptional quality. They should be differentiated from applications in which simple mechanical lapping of plates or butting of plates on wooden grounds is practised. Failures of applications of the latter type have occurred.

Insulants used as seals in mechanical joints should be chosen with caution. The preparation of faying surfaces should be discussed with aluminium alloy suppliers.

Pen boards

The required characteristics of boards are the same as those outlined for materials for fish holds together with correct thickness and width; correct overall length; correct contour of ends.

In the case of wooden boards some of these factors should be more fully considered along with additional aspects, such as:

Checking: To prevent checks from developing, the timber should be properly seasoned and stored, and painted immediately the boards are cut.

Thickness and width: In general, a softwood board of about 1 in. (25 mm.) nominal thickness can be used in widths of up to 6 in. (152 mm.) without fear of excessive loss through splitting; but thicker boards are often used.

Shape of cross-section: Paint on softwood boards wears first at the square corners and then spreads to other areas (MacCallum, 1958). Whether or not a different cross-section will prolong the life of the paint has not been established.

Length of boards and end cutting: Boards should be about ½ in. (12.7 mm.) less in length than the distance between the grooves in the stanchions. Their ends should be cut to an arc or otherwise dubbed off.

With aluminium alloy boards the choice and design depends on the size, shape and distance apart of the stanchions, and the load or combination of loads the board will carry. Its design would be greatly simplified and costs lowered by supporting shelf battens directly on stanchions. Boards 4 ft. (1.22 m.) long and ⅞ to 1 in. (23 to 25 mm.) thick, used as shown in fig. 186, are satisfactory.

TABLE 48

Typical material specifications for aluminium alloy fish rooms for storage of bulk stowed, iced fish

Characteristic of material	*Floors and shelves of pens* — *Sheet*	*Floors and shelves of pens* — *Extrusions*	*Ceiling*	*Fixed partitions*	*Movable partitions*	*Bulkhead covering*	*Deckhead covering*	*Stanchions*	*Angle bars and other extrusions*
Alloy									
(a) Canadian practice[1]	HA.4.57[3]	HA.5.65	HA.4.57	HA.4.57	HA.5.65	HA.4.57	HA.4.57	HA.5.65[4]	HA.5.65
(b) British equivalent[2]	1470-NS 4	1476-HE 20	1470-NS 4	1470-NS 4	1476-HE 20	1470-NS 4	1470-NS 4	1476-HE 20	1476-HE 20
(c) British practice	1470-NS 4	1476-HE10[5] or 1476-HE 30	1470-NS 4	1470-NS 4	1476-HE 10 or 1476-HE 30	1470-NS 4	1470-NS 4	1476-HE 10 or 1476-HE 30	1476-HE 10 or 1476-HE 30
(d) Canadian equivalent . . .	HA.4.57	—	HA.4.57	HA.4.57	—	HA.4.57	HA.4.57		
Filler alloy . .	. Consult: Aluminum Welding and Allied Processes, Table 2-1-5, Aluminum Co. of Canada, Ltd., Montreal								
Gauge of material[6]									
(a) Not backed by wood or other strengthening material, other than at line of supports	1/8 to 3/16 in. (3.2 to 4.8 mm.) depending on centre to centre distance of supports for flat sheet on floors	Approximately 0.082 to 0.100 in. (2.08 to 2.54 mm.) for 7/8 to 1 in. (22.2 to 25.4 mm.) thick corrugated boards used to span up to about 4 ft. (1220 mm.) Approximately 0.082 in. (2.08 mm.) for 1/2 in. thick corrugated boards used to span up to about 3 ft. 6 in. (1,067 mm.)	1/8 to 3/16 in. (3.2 to 4.8 mm.) for lower portion (flat sheet)	3/16 in. (4.8 mm.) (flat sheet). Possibly 1/8 in. (3.2 mm.) when sheet stippled or otherwise beaded	Approximately 0.082 to 0.100 in. (2.08 to 2.54 mm.) for 7/8 to 1 in. (22.2 to 25.4 mm.) thick corrugated boards used to span up to about 4 ft. (1220 mm.)	1/8 in. (3.2 mm.) (flat sheet)	1/16 in. (1.6 mm.) or lighter (flat sheet)	—	—
(b) Backed	1/8 in. (3.2 mm.) (flat sheet on floors)	—	1/8 in. (3.2 mm.) for lower portion (flat sheet) 1/16 in. (1.6 mm.) for upper portion (flat sheet)	—	—	1/8 in. (3.2 mm.) for lower portion (flat sheet) 1/16 in. (1.6 mm.) for upper portion (flat sheet)	1/16 in. (1.6 mm.) or lighter (flat sheet)	—	—
Hardness	Non-heat treatable alloys of as high a work hardness as can be fabricated and erected successfully should be utilized in sheets and plates								

[1]Alloy numbers according to Canadian Standards Association (CSA).

[2]Alloy numbers according to British Standards Institute (BS).

[3]British Standards Institute alloy 1477-NP5/6 [e.g. Noral B 54S (Northern Aluminium Co. Ltd., Banbury, U.K.) and Alcan B 54S (Aluminum Co. of Canada, Ltd., Montreal, Canada)] may be an alternate choice when a major part of the fabrication work is by welding. There is very little loss in tensile strength of this alloy as the result of welding as compared to BS 1470-NS 4.

[4]BS 1476-NE6 [Alcan A 56S (Aluminum Co. of Canada, Ltd., Montreal, Canada)] may be an alternate choice when stanchions are fabricated from individual extrusions and welding is a major factor. Cognizance should be taken of the relative mechanical properties of alloys 1476-NE6 and 1476-HE 20.

[5]The nearest Canadian equivalent is HA 5.65.

[6]Gauges of metal have been selected to resist force of ice picks, puncturing action on lining of aluminium boards crashing end on, etc. Gauges could be reduced where less rigorous treatment is to be expected. In general it is easier to fabricate and erect heavy gauge sheets in Unit Pen than it is in custom-built pen applications.

TABLE 49

Some equivalent aluminium alloys used in fish rooms. The designation of heat-treatable alloys are in italic type. The remaining alloys designated are non-heat-treatable

(Courtesy: Aluminum Co. of Canada, Ltd., Montreal)

Aluminium Limited Designation	*Australia*	*Austria*	*Canada*	*France*	*Germany*	*Great Britain*	*Italy*	*Spain*	*Switzerland*	*U.S.A.*	*Composition*
51S	AA51S			Silalium Almasilium		Noral 51S Alminal W10 BA 25 Birmetal 069 Birmabright 019 Duralumin X Duralium R Kynal M41 Hiduminium 44 TI 441 Sigmagal 200 H 10	Alinoxit Re FS SAI L. 107	—	Aludur 533Cr Korrofestal Cr AR 51S Al-Si-Mg	6051	Al-Mg-Si 0.6 1
B51S		Dekoral S24	Alcan B51S	Carbiosi 4 Imperium Inoxalium Vival A-SG	AlMgSi Aluwe 4 Erbsloeh L 41 Erges 4 F and G 4 Fuchs 3355 Howal Legal Lennalsil MWU 4 Neumal S Pantal (19) Pantal (43) Polital Ulmal Vermasil Vernial Voltal 23 Zieral	Noral B51S Kynal M39/2 TI 441 TI 444 BA 25 Duralumin H Hiduminium 44 Alminal W30 AWCO 25 Birmetal 071 H30	Anticorodal 11 F177 Inalteral RE 2 P-Al Si 1 MgMn	—	Aludur 533 Anticorodal Korrofestal KSB Al-Si-Mg		Al-Mg-Si 0.6 1
54S	AA54S		Alcan 54S	Alumag 35 VB 3 Virgalium 3 A-G 2 A-G 3	AlMg 3	Noral 54S BA 27 Birmabright 3 Kynal M 35/2 MG 3 TI 223 Alminal W 5 Alumagnese 35 Hiduminium 33 TI 223 AWCO 27 N 5	F.M. 3 Itallumag 35 P 35 Peraluman 35 P-Al Mg 3.5 Almarit 30	—	Al-3Mg		Al-Mg 3.5
B54S			Alcan B54S CSA GM 40	Heddenal 54 AlMg 5		Noral B54S BA M27 Birmabright 3 Birmabright 5 Kynal M35/3 Kynal M36 MG 3 MG 5 TI 224 Hiduminium 35 N5/6		—	AR-B54S	5083 5086	Al-Mg-Mn 4.5 0.3
A56S			Alcan A56S CSA GM50N	Alumag 50 Duralinox H5 Scleral 6 A-G5		Noral A56S BA 28 Birmabright 5 Kynal M36 MG 5 TI 225 Alminal W 6 Alumagnese 50 Hiduminium 05 AWCO 28 N6	P-Al Mg 5	—	Aludur 500 Al-5 Mg		Al-Mg-Mn 5 0.3
57S	AA57S	Alramag 3	Alcan 57S CSA GR 20	Alumag 25 Carbinox 3 A-G2	Hydronalium Hy3 Peraluman 30S AlMg 3	MG 2 Noral 57S N4	F.M. 2 F.M. 24 MNG 3 Peraluman 25 SAI L. 113 Itallumag 25 P. AlMg 2.5 Almarit 25	—	Peraluman 30 Al-3Mg	5052 5152 5652 SAE 201 ASTM GR 20 A	Al-Mg-Cr 2.5 0.25
65S	AA65S		Alcan 65S CSA GS 11N			Noral 65S TI 445 Birmetal 016 Duralumin F Alminal W20 H20 Kynal M 40		—	AR 65S	6061 6066 SAE 281 ASTM GS 11A	Al-Mg-Si-Cu 0.95 0.6 0.3

The following points should be observed:

- **Edges should be square**
- **The flutings of a corrugated board should be such that sharp ridges are not presented to the stowed fish. Some firms make reversible boards with left and right hand edges which avoids any difficulty in this respect**
- **Boards with many corrugations become slippery in the central work area. It might be simpler, safer, and cheaper to use wooden boards in this area**
- A balance should be struck between the need to maintain a wide pitch of corrugations to reduce board weight and cost and the need to avoid a section which will fail through column effect.

For length of boards and end cutting the same remarks apply as made for wood.

Stanchions

Wood should be used only for smaller vessels. Galvanized steel or aluminium alloys are suitable materials for medium and large vessels. In general, extruded aluminium alloy stanchions are better than those of built-up galvanized steel, and they are the same or a slightly lower price (Jefferson, 1958a).

As to size, shape, strength and weight excellent advice concerning design of aluminium alloy stanchions can be obtained from some aluminium alloy sales development organizations. Fishery engineers probably have as good an appreciation as anyone of the necessary profile for a stanchion. The naval architect, of course, should have the last word in matters of strength.

The principles involved in the proper attachment of aluminium stanchions to concrete floors are illustrated by fig. 189.

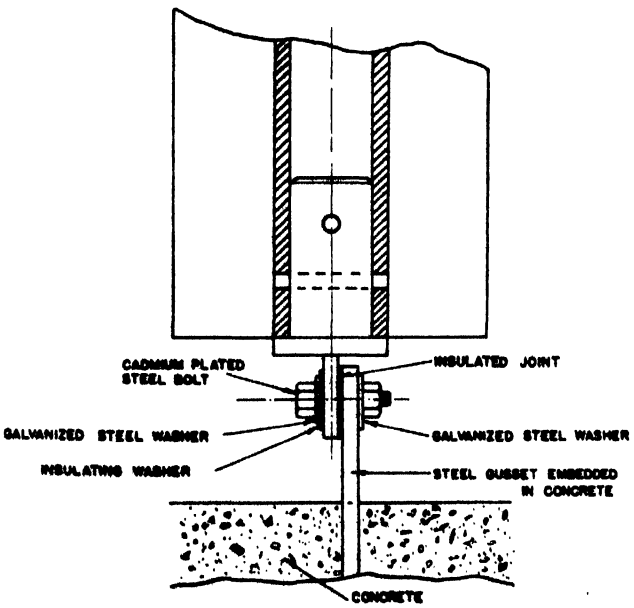


Fig. 189. Method of fixing aluminium alloy stanchions in fish rooms (Courtesy La Revue de l'Aluminium)

Fig. 190. Light weight aluminium alloy screens fabricated as panels are used over all fixed pen surfaces in the trawler Beausejour II

The cheapest method to attach studs or cleats to steel stanchions to support shelf battens is by welding. If for various reasons welding is not practicable, riveting (Jefferson, 1958b) may be substituted.

Every effort should be made to provide a deck structure which, combined with the regular fish room stanchions, obviates the need for pillars on the centre line of the vessel near hatch coamings or under winches, etc.

The use of glass fibre reinforced plastic for wet fish room linings, and aluminium alloys for stanchions, pen divisions and shelving might eventually become common practice.

SMALL FISHING CRAFT

Small fishing craft vary greatly in design and use, and the naval architect should consider each request for fish room and fish storage layouts and specifications according to the needs of the client. Nevertheless, it is possible by studying one basic craft to extract concepts concerning arrangement and use of materials which can be applied to other designs.

LONGLINERS

The basic design of the large Cape Island boat of 36 to 42 ft. (11 to 13 m.) LOA, shown in fig. 191, has an open cockpit with a watertight floor made from 1⅛ to 1¼ in. (29 to 32 mm.) wood. The floor is supported on cross-timbers laid on their flats athwartship above the keel and bolted to the underside of the knees. It is drained either by means of scuppers, with plugs, or by flow forward to a point aft of the engine, housed in a box as shown in fig. 191, thence to the bilges. Three hatches, flush with the floor, are fitted in each cockpit to give access to the space below. All fishing and stowage operations are conducted from the cockpit, the fish being taken from the power-hauled longlines and stowed ungutted in a centrally located bin of maximum capacity of about 6,000 lb. (2,720 kg.), placed fore and aft of the engine box.

Thwarts, on smaller boats, tie the vessel together just below the wash board. The floor is only a few inches

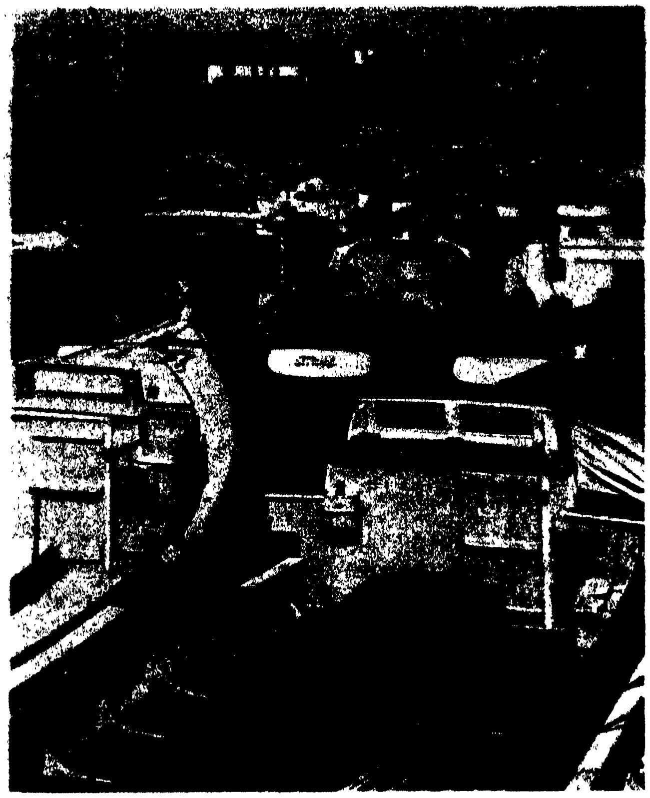


Fig. 191. Cape Island boats tied up at Clare's Harbour, Nova Scotia, Canada

above the top of the keel. Stowage and work space may be subdivided by transverse bulkheads of uncaulked softwood boards extending from the floor to just below the wash board. The thwarts may receive loose boards which are laid fore and aft to protect the catch from the sun.

The planking is 1 to 1½ in. (25 to 38 mm.) pine, caulked, puttied and painted outboard and treated with copper naphthenate on the inside. Steam-bent hackmatack frames of about ¾ to 1 in. (19 to 25 mm.) thickness and varying in width from 3½ to 5 in. (89 to 127 mm.) are used, clear distances between frames being approximately equal to frame width. There is no inner ceiling.

Almost all areas and surfacing materials are subject to great wear. Insulated boxes are seldom provided for ice, and the fishing trip lasts for hours, not days. A canopy could be fitted over the fish bin, particularly if it were placed athwartship. An epoxy resin paint or similar coating might well be used on floor boards and bulkhead boards for smaller boats, and both inside and outside the bin for larger boats. The latter could be fitted with a grating for drainage.

Insulated tanks or bins can be installed in the larger Cape Island boat at low cost because there is no upper deck. Bins should be well secured but easily removed, whether filled or empty. In the former case it might be necessary to have a number of smaller units. The size would depend upon lifting capacity at the dock and suitable bin construction to prevent hogging and wracking. 2 in. (51 mm.) or less insulation could be used in colder climates and 3 in. (76 mm.) or more in warmer. The material should be light and fire resistant where the bin or tank is fitted with a welded inner lining. Suitable materials for the linings are marine plywoods thoroughly coated with epoxy resins, glass fibre reinforced plastics and metal sheet or plate, such as weldable sea-water-resistant aluminium alloys, galvanized iron with soldered joints and steel covered with epoxy resins. Bin exteriors should be solidly made and have lifting lugs. Materials and coatings should be equal to lining material in resistance to dampness, water, and fish gurry, and should be able to endure the wear and punishment expected. Drainage should be provided in watertight bins, which should be suitably trapped to minimize the melting of ice.

Condensing units and heat exchangers can be installed below the cockpit sole, forward of the engine, where mechanical refrigeration is required for chilling and storing the catch in sea water. The condensing units, circulating pumps, etc. can be driven by the main engine.

LARGER LONGLINERS, SMALL TRAWLERS AND CUTTERS

Lack of co-ordination between those concerned and of interest in the space which is to carry the pay-load often result in an unnecessarily small and irregularly shaped fish room. The owner often has to accept two or more odd-sized pens. Much more satisfaction could be achieved if the naval architect and builder were to recognize that this topic is as important to the prospective owner in the planning stage as discussion of main engines, winches, etc.

Stanchions, hatches and "wings"

Wooden craft of 45 to 65 ft. (14 to 20 m.) LOA are almost always fitted with wooden fish rooms housed below a full deck. One small hatch can give access to the fish room, or the hatch can be considerably enlarged, particularly in some longliners where the opening provides headroom in a shallow-depth craft.

In selecting the size of hatch, a balance should be struck between space requirements for moving fish to and from the fish hold, deck space needed for fishing and gutting operations, and deck stowage space for small boats, while at the same time regulations concerning scantlings for hatches and hatch coamings must be observed. A hatch width of 3 ft. (91 cm.) should be considered minimum.

Generally two rows of stanchions, one on each side of the fish room, are provided in a fore-and-aft direction. Where the upper ends of stanchions make contact with hatch-end beams, the centre-to-centre distance of the latter will be an even multiple of transverse and longitudinal stanchion spacing to provide complete interchangeability of pen and shelf boards. In longliners, where the multiple is two, stanchions at the halfway position of the hatch may be secured to the underside of the hatch-dividing beam (strong-beam). In this case hatch width can be greater, equal to, or less than stanchion spacing.

When the stanchions make contact with the carlins, fore-and-afters, there cannot be complete interchangeability of pen and shelf boards unless the transverse distance between the centres of these carlins is equal to the longitudinal spacing of stanchions. Thus the spacing of stanchions is established with an arrangement of this type once the width of the fish hatch is selected, and vice versa.

A simple design for a stanchion, which has proved to be satisfactory, is used by an experienced builder (Wagstaff) in Nova Scotia, fig. 192. Although probably more costly than the ploughed section, it is cleaner, since its surfaces are easier to paint and repair effectively and cheaply by simple batten replacement. Where ploughed stanchions are used, the standing portions should be spiked according to Hines. The width of the grooves in the stanchions should be approximately ¼ in. (6.35 mm.) greater than the thickness of the penboard.

For larger boats an additional row of stanchions outboard of the first should be considered. Thus the normal fixed "wing" of the pen is broken down into a movable section between inboard and outboard stanchions and a fixed section between the outboard row of stanchions and the fish room ceiling. The movable section is filled in with individual penboards interchangeable with those used in the fore-and-aft directions, and those used athwartships between inner rows of stanchions and those used for shelves. The advantages are that more of the fish room fittings can be removed for washing, drying, repainting or renewing; for equal deflections the material used in wing construction can be lighter than that required where a deep fixed wing is used, and there is greater flexibility in stowing and unloading the catch. When there is one movable and one fixed section in each wing, the width of the fixed section can be reduced to between 3 and 4 ft. (0.9 to 1.2 m.) in any craft in this range of sizes. When costs allow the series of narrow boards to be substituted, it is possible to use ¾ in. (19 mm.) marine plywood or metal panels cut to the curve of the ship's ceiling. The plywood should be finished with epoxy resins or equally satisfactory coatings or with glass fibre reinforced plastic.

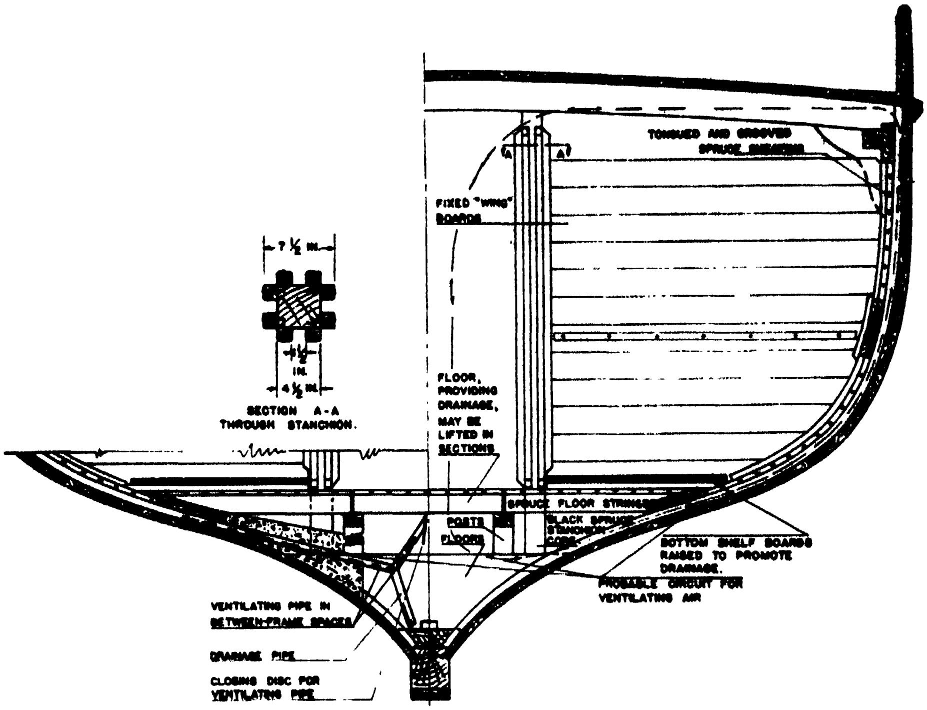


Fig. 192. Right hand: section through the fish hold of a longliner showing conventional provisions for ventilation of between-frame spaces, as practised by Wagstaff and Hatfield Ltd., Port Greville, Nova Scotia, Canada. Left hand: alternative method suggested by the author of venting space between frames

Movable stanchions—the boxing of fish

In Denmark most fish is landed in boxes: exterior box dimensions, including handle bars at each end, are 36 × 19$\frac{11}{16}$ × 7$\frac{3}{8}$ in. (914 × 500 × 187 mm.). The stanchions in the cutters are often removable to facilitate box stowage of herring. Empty boxes are often stacked on board in a wooden gallows on one side aft next to the steering house as shown in fig. 193.

Galvanized iron is generally used for stanchions in

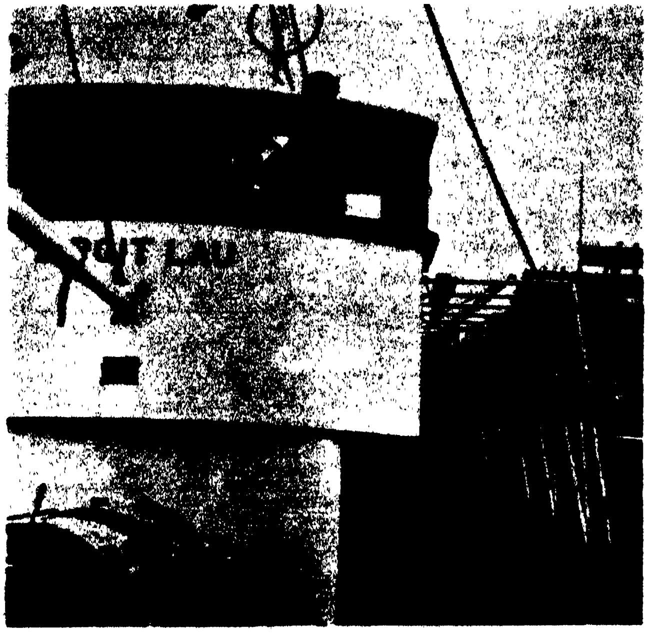


Fig. 193. Racks for stacking empty wooden boxes on a new Danish steel trawler of about 100 tons and 80 ft. (24.5 m.) length
Courtesy Fiskeriministeriets Forsøgslaboratorium, Copenhagen, Denmark)

modern Danish cutters and in comparable Norwegian boats. Metal lends itself particularly to use in stanchions which have to be fixed securely yet must be capable of quick removal and be good for repeated service.

Handling facilities for barrels

Aboard some Norwegian vessels herring are salted in barrels on deck and the barrels are stored in the hold. According to Haraldsvik, the main requirements on deck are to have two or three bins in which to keep the fish before salting, and a good winch and hooks for handling the barrels.

The holds should be readily accessible, and bins or pillars should not be fitted. The question has been raised by Traung whether tracks might be used efficiently and safely for the movement of barrels in the fish room.

Shelving

Shelving in pens in which the fish are bulk-stowed has the advantage that crushing is reduced and the whole catch can be more effectively segregated with respect to species and time of catch, thus facilitating discharge and subsequent disposal. For groundfish operations, shelving composed of individual movable boards can be used effectively every 2½ to 3 ft. (76 to 91 cm.) of stowage depth. The Norwegian practice of placing the intermediate shelf slightly above the one third point of the pen height, measured from the bottom drainage shelf, appears to be sound.

Pen drainage

To facilitate drainage from each pen used for bulk-stowed fish, stops can be placed at the bottom of each stanchion to support bottom pen boards clear of the floor. Likewise, battens can be used at the bottom of all wings for a bottom tier of shelves which should be at least 2 to 3 in. (51 to 76 mm.) clear of the floor of the fish room.

Ceilings, between-frames, between-deck-beams and stiffener ventilation

The need for ventilating the space between the wooden vessel planking and the ceiling is often given different significance from area to area. And sometimes a striking difference of opinion and practice exists among naval architects in a single area. The former differences are understandable in that species and characteristics of

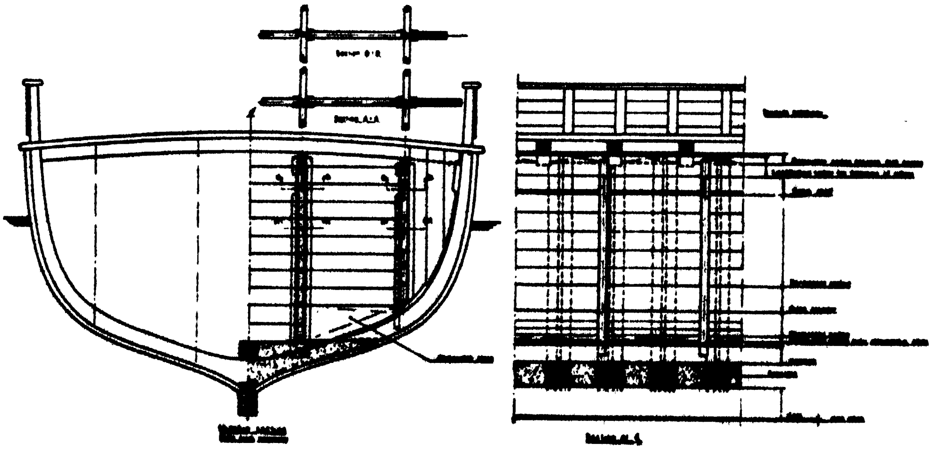


Fig. 194. Midship-section and side view of the fish room in a typical Danish fishing boat of about 32 GT and 46 ft. (14.1 m.) length
(Courtesy Fiskeriministeriets Forsøgslaboratorium, Copenhagen, Denmark)

wood used, type of construction and temperature of water and air may be responsible for various degrees of resistance to fungal attack.

Every boat owner, builder and naval architect should consider the need for ventilation. Ventilation installation may be costly and the quantity of ice melted might be expensive from the standpoint of fish lost. Further investigations are needed.

Aboard Esbjerg cutters, air circulation between frames is considered to be the cause of ice melting rapidly. Accordingly, provision is made to cut off air circulation while the fish are in stowage. To provide air circulation for drying when desirable and to allow washing behind the ceiling, a removable board is placed between each pair of frames where the ceiling meets the concrete, about half way up and again near the top of the ceiling in Skagen cutters and in the top and bottom positions in Esbjerg cutters as shown in fig. 194.

Similar procedures in any other area would depend upon:

(a) Ice losses due to continuous natural circulation of air behind the ceiling, e.g. the method used in Canadian longliners as shown in the cross-section shown to the right of fig. 192, where circulation is confined to the fish room only, and the method applied in some Nova Scotian small trawlers where means are provided for an exchange of air through a pipe and manifold system, between each between-frame space, throughout the whole of the boat, including the fish room, and engine room and forecastle spaces.

(b) An assessment in the area concerned of the relative effect on fungal development of alternate wetting and drying of the enclosed woodwork as in the Danish cases, in comparison with environmental conditions associated with other designs.

(c) Scale of scantlings used: Hines has indicated that scantling thickness has been reduced to a minimum and the cutting of sections from strakes in the inner ceiling cannot be tolerated in constructing Nova Scotian small trawlers. This difficulty could be avoided by increasing the thickness of the ceiling adjacent to the severed strakes, but in general the idea loses much appeal for craft such as those used in the Canadian Atlantic provinces where fish rooms may change shape drastically, thus requiring that several strakes be cut on a bias.

Were continuous air circulation, as in Canadian longliners as shown in the cross-section on right of fig. 192, not desirable, the author suggests, at the left of the same figure, a modification of the Danish system for non-insulated and insulated longliners. Closing discs are provided on the goosenecks which are connected to pipes leading up the sidewall between each adjacent pair of frames. It is intended that the discs close the pipes in front of the pens carrying iced fish or bulk ice.

Where air circulation between the fish room and the frames' space of the non-insulated and insulated trawler is considered to be necessary, on a continuous or on an intermittent basis, a system similar to that shown for the longliner at the left of fig. 192 might be a solution. The spaces to be ventilated might be vented to the central work area by pipes embedded in the concrete of the fish room bottom in a vessel of the trawler type.

Where loss of ice due to ventilation is serious, a remedy can be found if artificially refrigerated air is available. An application of this type is found in the trawlers *Cape Fourchu* and *Cape Scatari* (MacCallum, 1955a) fig. 195. A 1½ in. (38 mm.) diameter pipe was

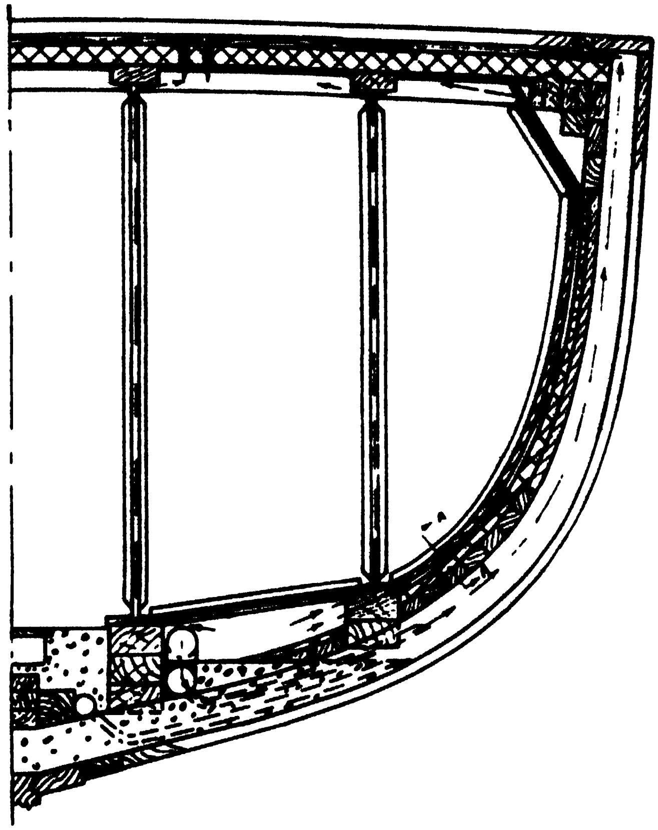


Fig. 195. Section through the fish hold of the trawler Cape Fourchu. *Two air circuits are in parallel, the ventilating air circuit outboard and the refrigerating air circuit inboard. The lower pipe in the drawing is for draining the between-frame spaces*

started up each frame space from two 5 in. (127 mm.) diameter headers extending fore and aft at the bottom of the hold. There was a connection between 'tween-frame and 'tween-deck-beam spaces. The air supply for the ventilating circuit was bled from a refrigerated air supply which had a primary duty to maintain a temperature of about 31°F (−0.5°C) within the jacket provided on the fish room side of the insulation. Thus the primary refrigerated air circuit and the ventilating air circuit were in parallel. About 5 per cent. of the recirculated, refrigerated air was made to pass through the ventilating pipes and into the 'tween-frames and 'tween-deck-beams spaces.

APPENDIX 1

The thermal transmittance U, overall coefficient of heat transmission or transmission factor, across a wall expressed in BTU/hr./°F/sq. ft. or in kcal./hr./°C/sq. m. of wall surface is the reciprocal of the total air-to-air or medium-to-medium resistance R to the flow of heat offered by the wall;

thus $U = \frac{1}{R}$ (1)

and $R = R_{S_i} + R_{S_o} + R_1 + R_2 + \ldots R_n$ (2)

where $R_{S_i} = \frac{1}{f_i}$ = resistance at the inside surface of the wall to the flow of heat where f_i = inside film or surface radiation, conductance, and convection in BTU/hr./sq. ft. of surface/°F temperature difference or kcal./hr./sq. m. of surface/°C temperature difference between the surface and the surrounding medium,

$R_{S_o} = \frac{1}{f_o}$ = resistance at the outside surface of the wall to the flow of heat where f_o = outside film or surface radiation, conductance and convection in BTU/hr./sq. ft. of surface/°F temperature difference or kcal./hr./sq. m. of surface/°C temperature difference between the surface and the surrounding medium,

$R_1, R_2, \ldots R_n$ = resistances of the various materials, of which the structure is composed, to the flow of heat.

$R_1 = \frac{L_1}{k_1}$, $R_2 = \frac{L_2}{k_2}$, $R_n = \frac{L_n}{k_n}$

where L_1, L_2, L_n = thickness in in. or cm. of each layer of homogeneous material in the wall and k_1, k_2, k_n = thermal conductivity for 1 in. or 1 cm. thickness of the corresponding homogeneous material in BTU/hr./sq. ft. of surface/°F temperature difference or kcal./hr./sq. m. of surface/°C temperature difference existing across a unit thickness of the homogeneous material,

whence $R = \frac{1}{f_i} + \frac{1}{f_o} + \frac{L_1}{k_1} + \frac{L_2}{k_2} + \ldots \frac{L_n}{k_n}$

showing that the resistance to the flow of heat increases with the thickness of the insulating materials.

Therefore $U = \dfrac{1}{\frac{1}{f_i} + \frac{1}{f_o} + \frac{L_1}{k_1} + \frac{L_2}{k_2} + \ldots \frac{L_n}{k_n}}$ (3)

Where an air space exists in a composite wall and the conductance of the air is a, the resistance offered by the air to the flow of heat is 1/a, hence this term will appear in the denominator of equation (3) along with L_n/k_n.

Reference should be made to suitable handbooks for values of the constants in equation (3).

TABLE 50

Necessary weight of crushed ice to carry boat heat flow for a period of 7 days

Type of boat	*Transmission factor* BTU/hr./sq. ft./0°F	*Depth of crushed ice* in.	mm.	*Weight of crushed ice* Short tons (2,000 lb.) per 1,000 sq. ft. surface	Metric ton per 100 sq. m. surface
Wooden longliner . .	0.27 (no insulation)	4.2	107	6.2	6.1
	0.13 [1 in. (25 mm.) insulation + inner lining]	2.0	51	3.0	2.9
	Saving	2.2	56	3.2	3.2
Wooden trawler . .	0.16 (no insulation)	2.5	63	3.7	3.6
	0.10 [1 in. (25 mm.) insulation + inner lining]	1.5	38	2.2	2.1
	Saving	1.0	25	1.5	1.5
Steel trawler . .	0.37 (no insulation)	5.7	145	8.5	8.3
	0.08 (full insulation between frames. 1 in. insulation over frames + inner lining)	1.3	33	1.9	1.9
	Saving	4.4	112	6.6	6.4

ICING VERSUS FREEZING

by

JOSEPH W. SLAVIN

A comparison is made of technological aspects of freezing and icing at sea. The freezing trawlers *Delaware* and *Northern Wave* are discussed in detail, and the procedures used aboard these vessels are evaluated in comparison with the procedures used on similar conventional trawlers, using ice. Emphasis is placed on (1) handling aboard the vessel, (2) storage on the vessel, (3) unloading and handling ashore, (4) quality aspects of frozen fish, and (5) the factors affecting the costs of freezing at sea.

On the *Delaware*, brine-freezing round fish prior to *rigor mortis* resulted in (1) slower handling aboard the vessel; (2) reduction of the vessel's capacity by 58 to 42 per cent., with capacity still higher, however, than the maximum capacity presently being utilized by Boston trawlers; (3) an increase in the time required to unload the vessel; and (4) increased handling at the shore-plant—as compared with icing on the vessel. Brine-frozen fish stored at 0°F (−18°C) for 8 months were of high quality; the texture was firm, and the fish was easy to fillet.

On the *Northern Wave*, plate-freezing eviscerated fish after *rigor mortis* set in resulted in (1) increased handling aboard the vessel; (2) reduction of the capacity of the vessel by about 30 per cent.; (3) an increase in the time required to unload the vessel; and (4) excessive handling at the shore plant because of the large space and long period of time required for air-thawing the fish—as compared with icing on the vessel. Plate-frozen fish must be stored at −20°F (−29°C) for maximum quality. Fish so stored were of high quality after 8 months; however, the texture was soft, and the fish were difficult to fillet.

The factors affecting increased costs of freezing at sea as compared with icing at sea are (1) extra personnel required to operate freezing equipment; (2) additional cost of vessel due to freezing equipment and additional space required for storing frozen fish; (3) repairs and maintenance of freezing equipment; (4) insurance and depreciation of freezing equipment; (5) fuel for operation of freezer; (6) additional equipment and labour required for unloading the frozen fish; (7) frozen storage and associated handling costs ashore; and (8) equipment and facilities for thawing the frozen fish. Despite the increased cost of freezing at sea, sight must not be lost of its many favourable aspects; namely, (1) the maximum utilization of the capacity of the freezer ship every trip; (2) the landing of fish of uniformly high quality; and (3) the storage of frozen fish ashore during glut periods for processing and marketing during slack periods. It is recommended that new vessels be built for freezing groundfish at sea rather than to convert existing trawlers, which are old and do not lend themselves to this application.

LA MISE EN GLACE OPPOSÉE A LA CONGÉLATION

L'auteur compare les aspects technologiques de la congélation et de la mise en glace à bord. Les chalutiers congélateurs *Delaware* et *Northern Wave* sont examinés en détail, et les procédures employées à bord de ces navires sont évaluées par comparaison à celles employées à bord des chalutiers similaires courants utilisant la glace. L'auteur insiste sur (1) la manipulation à bord ,(2) l'entreposage à bord, (3) le déchargement et la manipulation à terre, (4) les aspects de la qualité du poisson congelé, et (5) les facteurs affectant les coûts de la congélation à bord.

A bord du *Delaware*, la congélation en saumure des poissons entiers avant la *rigor mortis* a eu pour résultat (1) une manipulation plus lente à bord du navire; (2) la réduction de la capacité du navire de 58 à 42 pour cent, avec cependant une capacité encore plus grande que la capacité maximum utilisée actuellement par les chalutiers de Boston; (3) une augmentation de la durée nécessaire pour décharger le navire; et (4) une augmentation de la manipulation à l'usine à terre—par rapport à celle avec mise en glace à bord. Des poissons congelés en saumure, entreposés à 0°F (−18°C) pendant 8 mois étaient d'une qualité élevée, la texture était ferme et il était facile de fileter les poissons.

A bord du *Northern Wave*, la congélation dans un congélateur à plaques de poissons éviscérés après l'établissement de la *rigor mortis* a eu pour résultat (1) une augmentation de la manipulation à bord, (2) la réduction d'environ 30 pour cent de la capacité du navire, (3) une augmentation de la durée nécessaire pour décharger le navire, et (4) une manipulation excessive dans l'usine à terre à cause du grand espace et de la longue durée nécessaires pour décongeler les poissons dans l'air—par rapport à celle avec mise en glace à bord. Les poissons congelés dans un congélateur à plaques doivent être maintenus à −20°F (−29°C) pour obtenir la meilleure qualité. Les poissons ainsi entreposés étaient de haute qualité après 8 mois; cependant la texture était molle et il était difficile de les fileter.

Les facteurs affectant l'augmentation des coûts de la congélation en mer par rapport à la mise en glace à bord sont: (1) le personnel supplémentaire nécessaire pour faire fonctionner l'équipement de congélation, (2) le coût additionnel du navire dû à l'équipement de congélation et l'espace supplémentaire nécessaire pour entreposer les poissons congelés, (3) les réparations et l'entretien de l'équipement de congélation, (4) l'assurance et la dépréciation de l'équipement de congélation, (5) le carburant nécessaire pour faire fonctionner le congélateur, (6) l'équipement et le travail supplémentaire pour débarquer les poissons congelés, (7) l'entreposage frigorifique et les coûts de manipulation à terre, qui y sont associés, et (8) l'équipment et les installations pour décongeler les poissons congelés. En dépit des coûts plus élevés de la congélation à bord, il ne faut pas perdre de vue ses nombreux aspects favorables, à savoir; (1) l'utilisation maximum de la capacité du navire congélateur à chaque sortie, (2) le débarquement de poissons d'une qualité uniformément élevée, et (3) l'entreposage à terre de poissons congelés pendant les périodes d'abondance pour le traitement et la mise en vente pendant les périodes creuses. L'auteur recommande que, plutôt que de transformer les chalutiers existants, qui sont vieux et ne se prêtent pas à cette application, on construise de nouveaux bateaux pour congeler des poissons de chalut à bord.

LA CONSERVACION EN HIELO FRENTE A LA CONGELACION

El autor compara los aspectos tecnológicos de la congelación y de la conservación en hielo a bordo. Se examinan con pormenores os arrastreros congeladores *Delaware* y *Northern Wave* y los procedimientos empleados a bordo de ellos se evalúan en comparación con aquellos empleados a bordo de arrastreros análogos que emplean hielo. El autor insiste en (1) manipulación a bordo, (2) almacenamiento a bordo, (3) descarga y manipulación en tierra, (4) aspectos de la calidad del pescado congelado y (5) factores que influyen en el costo de la congelación a bordo.

A bordo del *Delaware* la congelación en salmuera del pescado entero antes de la *rigor mortis* dió por resultado (1) una manipulación más lenta a bordo del barco, (2) la reducción de la capacidad del barco de 58 a 42 %, pero aun así una capacidad mayor que la máxima utilizada

actualmente por los arrastreros de Boston, (3) un aumento del tiempo necesario para descargar el barco y (4) un aumento de la manipulación en la fábrica de tierra en comparación con el empleo de hielo en el barco. El pescado congelado en salmuera, almacenado a 0°F (−18°C) durante 8 meses era de muy buena calidad, de textura firme y fácil de filetear.

A bordo del *Northern Wave*, la congelación en congeladores de placas de pescado eviscerado después del comienzo de la *rigor mortis* resultó (1) en un aumento de la manipulación a bordo, (2) en la reducción en 30%, approx., de la capacidad del barco, (3) un aumento del tiempo necesario para descargar el barco, y (4) excesiva manipulación en las fábrica de tierra debido al much o espacio y largo tiempo necesarios para descongelar el pescado al aire, en comparación con el pescado conservado en hielo. El pescado congelado en congeladores de placas debe mantenerse a −20°F (−29°C) para obtener la mejor calidad. El pescado almacenado de esta manera era de gran calidad después de 8 meses, pero la textura era blanda y el pescado difícil de filetear.

Los factores que influyen en el aumento del costo de la congelación a bordo en comparación con el empleo del hielo son: (1) el personal suplementario que hace falta para manipular el equipo de congelación, (2) el costo adicional del barco debido al equipo de congelacion y al especio suplementario necesario para almacenar el pescado congelado, (3) las reparaciones y mantenimiento del equipo de congelación, (4) el seguro y la depreciación del equipo de congelación, (5) el combustible necesario para el congelador, (6) la mano de obra y equipo adicional necesarios para descargar el pescado congelado, (7) el almacenamiento en frigoríficos y los costos de manipulación en tierra relacionados con él, (8) el equipo y las instalaciones para descongelar el pescado congelado. A pesar del mayor costo de la congelación a bordo no se deben perder de vista muchos aspectos favorables entre los que están: (1) aprovechamiento máximo de la capacidad del buque congelador en cada viaje, (2) la descarga de pescado de calidad uniformemente alta, y (3) el almacenamiento en tierra de pescado congelado durante períodos de abundancia para tratarlo y venderlo durante épocas de escasez. El autor recomienda que se construyan barcos nuevos para congelar a bordo la pesca de arrastre, en vez de transformar los arrastreros existentes que, además de ser viejos, no se prestan para esta aplicación.

IN recent years much consideration has been given to the freezing of fish at sea. These considerations have been influenced by the limited period that fish can be satisfactorily stored in ice aboard the vessel, coupled with the need to fish farther away from home in order to return with a full pay load. Factory ships have been developed and are successfully being used by the U.K., West Germany, and Russia, for processing and freezing at sea. The high cost of these vessels and the problems in obtaining crews that are willing to stay at sea for several months at a time, however, have prevented their use in some countries, particularly the U.S.A.

The freezing of fish aboard the trawler, without processing, has been suggested as a solution to the high cost and labour problem associated with the operation of factory ships. It was thought that such a freezer trawler would enable the fishermen to return to port with a full pay load of fish, which could be either processed immediately or put into storage for future processing, depending on market conditions. Two trawlers recently have been developed for freezing the catch at sea, without processing aboard. These are the *Delaware* (fig. 196) in the U.S.A. and the *Northern Wave* in the U.K. Many reports have been issued concerning their development and operation. The object is not to review these reports but, instead, from data concerning the development of these vessels, mainly the *Delaware*, with which the writer is directly associated, to compare the technological aspects of freezing and icing on the vessel. Emphasis is placed on handling, storage and equipment requirements, keeping quality of the fish, and unloading and dock-side processing requirements. Some information on the factors affecting the costs of freezing and icing is also given.

The trawlers *Delaware* and *Northern Wave*

The *Delaware* is similar in size to the large trawlers operating out of Boston. It measures about 148 ft. (45 m.) in overall length, 25 ft. (7.62 m.) in beam and has a depth of 15 ft. (4.57 m.), a gross tonnage of 303, and a cruising range of 8,000 nautical miles.

The freezing method is:

Whole haddock are frozen in a 0°F (−18°C) sodium chloride brine (22 per cent. salt by weight) immediately after they are landed on the vessel. The normal procedure is to load the round fish into one or more of 11 metal baskets, each having a capacity of 450 lb. (204 kg.), located in the freezing tank. The baskets are moved by mechanical means through the cold brine. The fish are frozen in ¾ to 4 hr., depending on their size, are unloaded from the tank, and are conveyed by a chute to the 0°F (−18°C) fish hold, where they are stacked by hand. An ammonia absorption system, having a designed capacity of 25 tons of refrigeration (75,000 kcal./hr.), is used in connection with two heat exchangers to provide the necessary cooling of the brine and of the frozen fish hold. The freezing capacity is 1,000 lb. (454 kg.) of fish per hour, in terms of small haddock.

The *Delaware* has made several large-scale commercial trips. More than 50 short tons (45 ton) of brine-frozen fish were landed each time. These fish were distributed to fish processors and dealers, who thawed and filleted them. The fillets then were packaged, frozen, and marketed in the usual commercial manner.

The *Northern Wave* measures about 188 ft. (57 m.) overall and has a beam of 28 ft. (8.5 m.) and a draught of 15 ft. (4.6 m.). The fish were eviscerated on board and then stored, with ice, in a "buffer" storage pen. After *rigor mortis* set in and before the third day of storage, the fish were removed from the buffer pen and loaded into one or more of the 16 vertical plate-freezing units. Each freezing unit was capable of producing three 63-lb. (29 kg.) slabs of frozen fish. The freezer had an average capacity of 500 lb. (227 kg.) of fish slabs per hour. A period of 4½ to 5 hr. was required for freezing. The frozen slabs of fish were then stacked by hand in the −20°F (−29°C) hold of the vessel. This vessel has made eight commercial-scale trips and has landed over 250 short tons (227 ton) of frozen fish. Much of the frozen fish landed has been distributed to fish processors and dealers who air-thawed it and marketed it in the chilled or smoked state.

Fig. 196. The freezer trawler Delaware *with no processing equipment*

Differences in opinion exist between British and U.S. researchers as the merits of freezing in brine prior to *rigor mortis* and plate-freezing after *rigor mortis* sets in; good results are reported for both procedures.

Handling aboard the vessel

It is well known that fish must be iced immediately to minimize the loss of quality. Evisceration, washing, and icing of the fish can be accomplished quite rapidly under commercial conditions. On a Boston trawler, for example, a crew of six men can eviscerate, wash, and ice about 5,000 lb. (2,270 kg.) of fish within an hour after they are landed on deck. If the rate of catch exceeds the rate of handling, fishing must be stopped or the trawling period must be increased to allow more time to stow the fish. Similar handling rates are reported for British trawlers, using ice.

In freezing at sea, the fish must be handled as rapidly as in icing, otherwise a loss of quality also will result. On the *Delaware*, six men can normally sort and wash 1,000 lb. (454 kg.) of round haddock, load these fish into the freezer, and remove an equal amount of fish from the freezer in about 15 min. In an hour, these fishermen could theoretically handle 4,000 lb. (1,810 kg.) of fish both into and out of the freezer, which is slightly less than the rate of handling for iced fish. The freezing capacity is however not sufficient to permit the loading of 4,000 lb. (1,810 kg.) of fish at one time.

On the *Northern Wave*, the fish were first iced for a period of 12 hours to 3 days and then were removed from ice storage, put into aluminium boxes, and transferred from the boxes to the vertical plate-freezer. The labour and time required for handling were therefore more than were those required on the *Delaware* or on conventional trawlers using ice.

The capacity of the refrigeration system, the time required to freeze the fish, and the size of the catch must be given serious consideration in designing a freezer ship. The *Delaware* has a freezing capacity of 1,000 lb. (454 kg.) of fish per hour, and not more than 3,000 lb. (1,360 kg.) of fish can be put into the freezing tank at once without increasing the brine temperature excessively. Accordingly, if a catch of 6,000 lb. (2,720 kg.) is landed, 3 or 4 hr. may lapse before the last fish are put into the freezer. The capacity of the freezing system, therefore, must be based on the maximum catch that can be expected within a 24 hr. period; also, sufficient quantities of brine must be used to compensate for the large initial loads of fish. For Boston trawlers, a capacity of 2,000 to 2,500 lb. (907 to 1,130 kg.) of fish per hour would be satisfactory with sufficient quantity of brine to permit the loading of 6,000 to 7,500 lb. (2,720 to 3,400 kg.) of fish at once. Also, some space should be provided for icing the fish in the event of extra large catches. The freezing capacity for the *Northern Wave* of only 500 lb. (227 kg.) of fish per hour, which is less than that of the *Delaware*, was thought to be adequate because of the method used to store the fish in ice for a maximum of 3 days prior to freezing; thus, the storage of fish in ice served as a buffer, tending to smooth out the effects of large and small catches on the freezing load. It is possible, however, that this capacity would not be adequate if relatively large catches were landed during the first several days of fishing.

Storage on the vessel

Consideration must be given to the effect of freezing or icing on the storage capacity of the vessel, since the capacity governs the maximum pay load of fish that can be landed. The capacity of the vessel on which the fish are stored in ice is in direct relationship with the available hold space, the quantity of ice used, and the size of fish. In freezing at sea, the capacity of the vessel is reduced over that of a vessel of similar size using ice, because of reduction of hold space resulting from the installation of cooling coils, insulation, and refrigeration equipment. The additional space required for storing frozen fish as compared with that needed to store iced fish further reduces the quantity of fish that can be landed by the vessel.

In storing iced, gutted haddock on Boston trawlers, the ratio of fish to storage space was found to be about 45 lb./cu. ft. (721 kg./cu. m.) of hold space. On British vessels of the *Northern Wave* class, the ratio of fish to storage space is said to be lower than that on Boston vessels, being about 32 lb./cu. ft. (513 kg./cu. m.) of hold space. This is probably due to the additional ice used on British trawlers because of the long period of time that these vessels are at sea.

The *Delaware*, prior to being converted to a freezing trawler, had approximately 8,000 cu. ft. (226 cu. m.) of hold space for the storage of iced fish. In the conversion, however, the hold space was reduced to about 600 cu. ft. (17 cu. m.) for storing iced fish, presumably the last 2 days' catch, and 3,800 cu. ft. (108 cu. m.) for storing frozen fish. Thus, a reduction of 3,600 cu. ft. (102 cu. m.) or 45 per cent. in space available for fish storage resulted. The reduction in space was attributed to the following: freezing tank and brine piping—800 cu. ft. (23 cu. m.); refrigeration machinery—1,300 cu. ft. (37 cu. m.); and insulation, bulkheads, refrigerated pipe coils, and other miscellaneous lost space—1,500 cu. ft. (42 cu. m.).

Also, only 33 lb. of round brine-frozen fish could be stored per cu. ft. (529 kg./cu. m.) of hold space on the *Delaware* as compared with 45 lb./cu. ft. (721 kg./cu. m.) for storing iced fish. This further reduced the pay load of fish that could be landed. In all, owing to the reduction in hold space and the increased space required for storing frozen fish, a total reduction in carrying capacity from 360,000 lb. (163,300 kg.) of iced fish as originally designed, to 125,000 lb. (56,700 kg.) of frozen fish and about 25,000 lb. (11,340 kg.) of iced fish resulted because of conversion to freezing at sea. Thus, the total earning capacity of the *Delaware* was reduced by approximately 58 per cent. This loss in capacity could be decreased somewhat by installing the refrigeration machinery in the engine room rather than in the fish hold and by more efficient arrangement of bulkheads. These measures would result in an increase in the vessel's storage capacity, in terms of round frozen fish, from 125,000 lb. (56,700 kg.) to 185,000 lb. (83,910 kg.) thus, if these changes were made, the earning capacity of the *Delaware* would be reduced by about 42 per cent., instead of 58 per cent., as compared with its original capacity in terms of iced-gutted fish.

The *Northern Wave*, which is larger than the *Delaware*, had a fish hold of 18,000 cu. ft. (509 cu. m.) with a capacity of about 500,000 lb. (227,000 kg.) of iced fish, prior to conversion to a freezer ship. This capacity is proportionately less per cubic foot of hold space than is that of a Boston trawler of similar size. It is reported that the *Northern Wave*, as outfitted for freezing at sea, had 10,000 cu. ft. (283 cu. m.) of space for the storage of a maximum of 280,000 lb. (127,000 kg.) of iced fish and cold storage space for about 70,000 lb. (31,750 kg.) of frozen fish. The earning capacity therefore was reduced only about 30 per cent. because of conversion to freezing at sea. This vessel, however, was equipped to freeze only about 20 per cent. of its total possible catch, whereas the *Delaware* was able to freeze about 83 per cent. of its total possible catch. If the *Delaware* were equipped for freezing only 20 per cent. of its catch, as was the *Northern Wave*, the reduction in its original capacity would be only 25 per cent. This comparison shows that as the ratio of frozen fish storage space to iced fish storage space increases, the total capacity of the vessel decreases. Careful consideration, therefore, must be given to the maximum quantity of iced fish that is to be landed in determining the feasibility of freezing at sea.

The information presented above shows that freezing at sea results in a reduction in the maximum capacity of the vessel. In evaluating icing or freezing, however, one also must consider to what extent the maximum capacity of the vessel was utilized when handling iced fish, and how this capacity compares with that of the vessel as converted to a freezer ship. It has been observed that many vessels of the *Delaware's* size are now operating at 30 to 40 per cent. of their maximum capacity. It also may be noted that the *Delaware* can utilize its hold space fully, every trip, and thereby operate at 42 per cent. of its maximum iced fish capacity, as now outfitted. This figure can be increased to 58 per cent. with more efficient use of space. Thus, theoretically, the *Delaware* has a higher level of productivity per trip than have many existing trawlers, using ice. For proper evaluation, however, the increased productivity of the freezer ship, as compared with that of iced trawlers, must be weighed against the increased costs associated with freezing at sea.

Unloading and handling ashore

To determine the feasibility of freezing at sea, one must compare the time, labour and equipment required for unloading the frozen fish from the vessel and for handling these fish at the shore plant with those required for the similar handling of fish iced at sea in the conventional manner. Costs and requirements for handling the frozen fish then must be evaluated by both vessel operators and processors in terms of the overall advantages of this technique.

Unloading

In the unloading of iced fish from a large Boston trawler, the fish are loaded from the pens to a basket, which has a capacity of 150 to 175 lb. (68 to 79 kg.) of iced fish. The baskets of fish are then hoisted to the dock, and the fish are dumped into a weigh box mounted on a simple platform scale. Two scales customarily are used to weigh out the fish being unloaded through each of the two hatches on the vessel. The fish, after being weighed, are loaded from the weight boxes to carts or boxes and are hauled to the plant for filleting. About 16 men are used to unload iced fish, 6 in the hold, 4 on deck, and 6 on the dock. These 16 men can unload a large trawler at a rate of about 30,000 lb. (13,610 kg.) of fish per hour, which is a comparatively fast rate in spite of the primitive methods used. On trawlers of the *Northern Wave* class, the fish are handled somewhat similarly, except that a small hook often is used to transfer them from the hold to the unloading baskets. These fish are weighed into aluminium kits of 140 lb. (64 kg.) capacity, which are transferred to the auction hall.

The procedure used to unload frozen fish from the *Delaware* consists of transferring the fish by hand into the unloading baskets, hoisting the baskets to the dock, and dumping the fish into boxes of 500 lb. (227 kg.) capacity, in terms of frozen fish. The fish in the boxes are glazed by spraying with fresh water and then are transferred by mechanical lift trucks to the cold storage plant. Each lot of fish is weighed on a large platform scale, prior to being placed in the frozen storage room. The weight of frozen fish loaded by an experienced crew averages about 85 lb. (39 kg.) per basket, which is considerably less than the figure of 150 to 175 lb. (68 to 79 kg.) for iced fish. This decrease in the capacity of the basket and the additional time required in transferring the fish to the baskets reduce the rate of unloading considerably. Recent tests show that, with two hatches being unloaded, a gang of 14 men can unload the *Delaware* at a rate of about 15,000 lb. (6,800 kg.) of frozen fish per hour. This is a reduction of about 15,000 lb. (6,800 kg.) per hour or 50 per cent. as compared with the rate of 30,000 lb. (13,610 kg.) per hour for unloading iced fish. Thus, on the *Delaware*, the time required to unload frozen fish is twice that required for unloading iced fish on similar vessels.

On the *Northern Wave*, the size of the hatch openings was increased to facilitate unloading of the frozen fish. The slabs of frozen fish, averaging 63 lb. (29 kg.) were hoisted from the hold on wooden skids. At the beginning of unloading only 4 blocks could be used per skid because of the limited hold space available for handling the fish. After an hour, however, when the hold was partially emptied, 12 blocks could be unloaded on a single skid. It is reported that 10 men could unload about 70,000 lb. (31,750 kg.) of frozen fish blocks from this vessel in 5 to 6 hr. or at an average rate of about 12,500 lb. (5,670 kg.) per hour. Thus, on the *Northern Wave*, the reduction in unloading rate was similar to that which occurred on the *Delaware*.

It is believed that the quantity of frozen fish unloaded per hour from the *Delaware* and the *Northern Wave* could be increased considerably by more efficient arrangement of the fish hold to facilitate more rapid handling of the fish and through the use of elevator type conveyors, which can transfer the fish directly into a cold store located on the dock. It is doubtful, however, if the application of these methods would increase the rate of unloading frozen fish to a rate that would compare favourably with the one for iced fish.

Handling ashore

Much of the groundfish landed in New England is marketed in the form of frozen fish fillets, whereas, in the U.K., groundfish are marketed predominately in the fresh (chilled) and in the smoked state. The purpose of both the *Delaware* and *Northern Wave* projects was to provide a source of high quality raw material that could be stored ashore during glut seasons and then be removed from the cold store as needed, thawed, and processed in the manner common to the trade. It was thought that this would keep the processors supplied with raw material during the slack season.

In handling the fish ashore, the processor has to take into consideration, in addition to his normal processing requirements, the facilities and cost for storing the frozen fish and for equipment for thawing these fish prior to processing.

The fish frozen aboard the *Delaware* can be satisfactorily stored in the cold store in large boxes in lots of 500 lb. (227 kg.). The frozen-storage charges are higher than those for packaged fish because of the increased space required per pound of fish and the extra handling required to glaze the fish. If the fish are processed in small quantities, the boxes can be removed from storage the day prior to processing, and the fish can be thawed overnight by keeping the box flooded with a continuous stream of freshwater or clean seawater at temperatures from 45° to 60°F (7° to 16°C). Only 3 hours is required to thaw haddock of normal size thus, if necessary, the fish may be removed from the cold store early in the morning and processed in the afternoon. Thawing the fish in boxes, however, would not be practical for a large plant having a capacity of 2,000 lb. (907 kg.) of fillets per hour for an 8 hr. shift because of the large amount of storage space and the large supply of water required. Assuming a 33 per cent. fillet yield in such a plant, for example, approximately 48,500 lb. (22,000 kg.) of raw material or 97 boxes of fish would have to be thawed at one time. For handling large quantities of fish, thawing tanks made of wood or non-corrosive metal, therefore, should be installed in or adjacent to the plant. Three thawing tanks, each having a volume of 825 cu. ft. (23 cu. m.) and a capacity of 16,500 lb. (7,480 kg.) of frozen fish, would be suitable. The size of the storage tanks is based on a ratio for fish of 20 lb./cu. ft. (320 kg./cu. m.) of available space. Assuming a 20°F (11°C) drop in the temperature of the cooling water, about 1,250 U.S. gal. (1,040 Imp. gal., 4,730 l.) per hour of 60°F (16°C) water would be required for each tank if the fish were to be thawed in 12 hr., and 5,000 U.S. gal. (4,150 Imp. gal., 18,900 l.) per hr. would be required if they were to be thawed in only 3 hr.

The blocks of fish frozen aboard the *Northern Wave* can be satisfactorily stored in the cold store on pallets or wooden skids. Since these fish are in block form, they can be packed more tightly than can the *Delaware*'s individual brine-frozen fish and therefore will occupy less space in the cold store. It has been recommended, however, that these fish be stored at −20°F (−29°C) rather than at 0°F (−18°C) as suggested for the fish frozen on the *Delaware*. It is doubtful if there are sufficient cold storage facilities available in the U.S.A. or in other countries that will meet such temperature requirements.

Investigators working on the *Northern Wave* project recommended that the fish blocks be thawed in circulating 65°F (18°C) air prior to processing. The procedure followed was to remove the frozen fish from the cold store about 40 hr. before needed, lay the fish out on shelves in a specially designed room, and, with fans, maintain uniform circulation of the air over the product. Electric heaters were used to maintain the air at the required temperature. Under the above mentioned conditions, 20 to 24 hr. was required for thawing the fish; after which time, they were weighed out into 140 lb. (64 kg.) capacity boxes and iced, prior to filleting or smoking.

It appears that more space is required for thawing frozen fish with air than with water. In view of the requirement for more space and the long period of time required for thawing in air, air thawing might not be entirely practical for large scale commercial applications, where 50,000 lb. (22,700 kg.) of fish may have to be thawed at one time.

Quality aspects

It is generally known that fish stored in ice aboard the vessel will remain at an acceptable level of quality for only a relatively short time, even though they may have been handled under ideal sanitary conditions. The acceptable storage period for eviscerated haddock may vary from 8 to 16 days, depending on the handling, icing, and techniques of sanitation.

For freezing at sea to be a success, the quality of the thawed frozen fish must compare favourably with that of iced fish that has been properly handled. Nothing is to be gained by employing freezing-fish-at-sea techniques that will result in a product of lower quality; such a practice would have no possibility of financial success. Investigators on the *Delaware* and *Northern Wave* projects have taken this into consideration and have conducted extensive laboratory and industry tests to determine the quality of fish frozen at sea.

In the *Delaware* project, 30 short tons (27 ton) of brine-frozen haddock were examined, processed, and marketed by 19 fish processors and dealers at regular intervals of frozen storage. The fish were put into the 0°F (−18°C) cold store immediately after being unloaded from the vessel. Samples of fish were withdrawn from the cold store at bi-monthly intervals of storage by the participants, who water-thawed and filleted them; the fillets were then packaged, frozen and marketed in the manner customarily employed in the frozen fillet trade. The participants also noted the quality of the fish as compared with regular iced fish, on a form prepared for this purpose, and sent their comments to the U.S. Fish and Wildlife Service. The comments showed that water-thawed brine frozen haddock could be filleted easily, that the fillets were of good texture, flavour and odour, and that they compared favourably in quality with iced fish. It was noticed, however, that these fillets were of slightly darker colour than similar fillets from iced fish and that they had lost the characteristic bright sheen of iced fish fillets. This darker appearance was not considered to be detrimental to the product, since much of the colour bleached out during subsequent frozen storage.

The maximum acceptable storage period at 0°F (−18°C) for the brine-frozen fish was judged to be 8 months. Subsequent laboratory tests conducted on fillets prepared from brine-frozen haddock at intervals of 0°F (−18°C) frozen storage verified these results. Other tests showed that the average salt content of fillets prepared from water-thawed brine frozen fish was less than 0.5 per cent. for both round and eviscerated haddock. These tests demonstrate that haddock can also be brine frozen at sea in the eviscerated form as well as in the round, uneviscerated state.

In the *Northern Wave* project, over 250 short tons (227 ton) of fish frozen at sea in block form were made available to fish dealers and processors who thawed and marketed the fish in the chilled and smoked state. Similar samples were also evaluated by project investigators at intervals of −20°F (−29°C) frozen storage.

It was found that fish frozen on the *Northern Wave* kept their quality for 8 months of storage at −20°F (−29°C) and that these fish could be satisfactorily smoked. Industry commented, however, that the thawed fish were softer or looser in texture than were good quality iced fish. Some difficulty was also experienced in cutting the fillets from the thawed fish. The fillets lacked the characteristic sheen of iced fish fillets, as did the fillets prepared from brine frozen fish in the *Delaware* project. Some of this sheen was restored by dipping the fillets in a 50-per cent. saturated brine solution.

The aforementioned experiments indicate that the quality of fish frozen at sea compares favourably with that of iced fish. It is believed that the brine freezing process used on the *Delaware* firmed up the texture of the fish, making them easier to fillet than plate frozen fish. Much of the fish on the *Northern Wave* was smoked; therefore, texture was not as important a criterion of quality as in the *Delaware* project, where the fillets were marketed in the frozen state.

Factors affecting costs

The question of whether or not freezing fish at sea is economically sound depends to a great extent on the nature of the fishery involved and on many other factors common to vessel and processing plant operations and marketing techniques. Many times, even though a process may be economically sound, unexpected equipment failures and labour or marketing problems may result in financial loss. The *Delaware* and *Northern Wave* both were commercial vessels converted to freezer ships. They were, at best, experimental vessels. A study of the economics of their operations would mean little, since much was learned that could be put to advantageous use in the design of a new freezer ship. The purpose here then is not to make an economic analysis of these freezing operations, but instead to present information on how freezing at sea can be accomplished best and on the factors that should be considered in preparing a cost analysis of this technique.

Studies on the *Delaware* and *Northern Wave* projects indicate that conversion of an existing trawler for freezing at sea is costly and, in many cases, is not practical because of the age of existing trawlers and the limitations placed on the freezing process because of the design of the vessel. It would be far better to have a new vessel built that is designed specifically for freezing fish at sea.

In determining the costs of freezing at sea, the following should be considered, in addition to the costs associated with the handling of iced fish:

Factors affecting vessel costs

- Extra personnel required to operate freezing equipment
- Additional cost of vessel due to freezing equipment and additional space required for storing frozen fish
- Repairs and maintenance of freezing equipment
- Insurance for freezing equipment
- Depreciation of freezing equipment
- Fuel for operation of freezer
- Additional equipment and labour required for unloading the frozen fish

Factors affecting processor's costs

- Frozen storage and associated handling costs
- Equipment and facilities required for thawing the fish

For freezing at sea to be a profitable venture in a separate vessel-plant operation, the additional costs associated with vessel operation must be offset by the return resulting from the landing of a full pay load. It is probable that the processor would pay less for fish frozen at sea than for iced fish because of the additional expense in storing and thawing the frozen fish. This must also be taken into consideration by the vessel operator, since it would affect the price received for the catch. It therefore appears that the economics of freezing at sea become more attractive as the harvesting ability of the vessel increases. An integrated vessel-plant operation would seem to offer the best possibility of financial success. In such an operation, where prior to freezing at sea the plant only operated part-time owing to lack of fish, the financial gain due to full-time operation of the plant using frozen fish could be used to offset some of the high costs associated with vessel operations.

Overall evaluation

Freezing at sea, therefore, resulted in slower handling aboard the vessel, reduction of the vessel's capacity, an increase in the time required to unload the vessel, increased handling at the shore plant and increased costs, as compared with icing on the vessel. However, these factors must be weighed against the more favourable aspects of freezing fish at sea; namely, the maximum utilization of the capacity of the freezer ship every trip, the landing of fish of uniformly high quality and the "stock-piling" of frozen fish during glut periods for processing and marketing during slack periods.

TUNA FREEZING

by

CHOMATSU DOKE and SEIGORO CHIGUSA

Japanese tuna boats have highly developed refrigerating systems, because (i) they must operate in tropical waters, (ii) a fishing trip often lasts for two months or more.

Modern tuna freezing systems are described in detail, and the study is intended as a reference for the tropical operation of other fishing vessels.

LA CONGÉLATION DU THON

Les thoniers japonais sont munis de systèmes de réfrigération très développés parce que (i) ils doivent opérer dans les eaux tropicales, (ii) une sortie de pêche dure souvent deux mois ou plus.

Les systèmes japonais modernes pour la congélation du thon sont décrits en détail et l'étude est conçue pour servir de référence pour la pêche tropicale d'autres navires de pêche.

CONGELACION DE ATUN

Los barcos atuneros japoneses tienen sistemas de refrigeración muy perfeccionados porque (i) tienen que pescar en aguas tropicales, (ii) con frecuencia los viajes duran 2 meses y más.

Se describen con pormenores los sistemas modernos empleados por los japoneses para congelar atún. Tiene por objeto la comunicación servir de referencia para otros barcos que pescan en aguas tropicales.

AS TUNA boats operate mainly in tropical waters, their fishrooms are insulated and almost all are equipped with refrigeration. The larger and more recently built tuna boats also carry freezing equipment. The cost of this equipment often amounts to 20 per cent. of total construction.

METHODS OF PRESERVING THE CATCH

Fresh raw tuna is much in demand in Japan. The larger boats on long trips, however, freeze the entire catch, while the medium-sized boats bring back some of the catch frozen and the rest in the fresh and chilled state.

Storage by cold sea water

With this method, catches are preserved in cold sea water, which is cooled by crushed ice or evaporator grid, to about 32°F (0°C). The water is led directly into the fishroom, and the gutted, round tuna are kept submerged by a weight on the top; sometimes crushed ice or newly cooled water is added during storage. This method is often used for short trips. Stowage is about 45 lb./cu. ft. (0.72 ton/ cu. m.) of the fishroom.

Storage by crushed ice

Gutted round tuna are stored in the hold, together with crushed ice, and fishrooms are usually equipped with refrigeration to prevent the ice from melting. As air convection does not take place, evaporator coils are arranged on the bottom as well as sides, walls and ceiling, and special attention is given to draining the bilge water from the melting ice, which otherwise impairs the quality of the catches. The period of preservation should not exceed 45 days. Stowage is about 30 to 36 lb./ cu. ft. (0.48 to 0.58 ton/cu. m.).

Many boats pre-cool the fish in chilled sea water prior to storage in crushed ice, e.g. the gutted catches are put into a sea water tank and cooled to about 32°F (0°C) for 2 to 3 hr. before storage in the ice hold. This is called the pre-cooling system (fig. 197).

Freezing

There are three systems for freezing the fish, namely: (i) air blast; (ii) contact; (iii) brine—e.g. Ottesen type.

Air blast freezing. This is the most common method. Round or semi-circular gutted catches are put into a battery of refrigerating coil installed in the special freezing room, and are frozen by cold air blast of −13° to −22°F (−25° to −30°C), which is forced through the pipes by 2 to 3 h.p. electric blowers placed at the ends of the battery. The time necessary for freezing is 15 to 20 hr., and the rate of freezing is usually 5 to 10 ton per day. The pre-cooling system is sometimes used, in order to shorten the freezing time.

Contact freezing. Contact freezing by means of plate freezers is mainly used for fillets. This is a highly efficient method, as it can be carried out two or three times repeatedly in a day. It is, however, seldom used because of the small demand for fillets in Japan. Even if this equipment is installed, it is generally used only for about 30 per cent. of the catches, the main part being frozen as round fish.

Brine freezing (Ottesen's system, fig. 198). The brine, made by adding salt to water, is cooled to a temperature of 0° to −6°F (−18° to −21°C) by pumping circulation, the catches are submerged in this brine and frozen for 10 to 12 hr. This method is sometimes used in larger boats requiring good freezing but this is not so suitable for the tuna because it results in crooked shape and the penetration of salt. Frozen round tuna are stacked in the fishroom at about 0°F (−18°C). Stowage is about 36 lb./cu. ft. (0.58 ton/cu. m.). Flat fillets are put into cartons and stacked in the fishroom, stowage being about 45 lb./cu. ft. (0.72 ton/cu. m.).

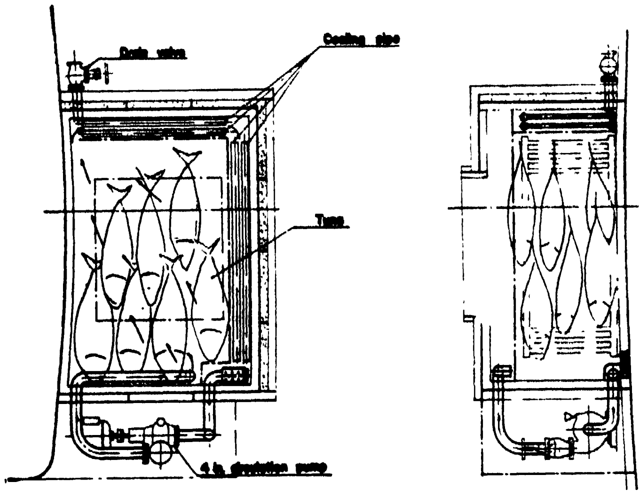


Fig. 197. Tuna pre-cooling installation in the forward part of the deckhouse working on the principle of chilled sea water

Examples

Most large ships are completely refrigerated and do not use ice. A typical example is the following:

Hoku Maru (1,200 GT), built April 1957

Freezing capacity (combined freezing system): 66,000 lb. (30,000 kg.) per day
Bait hold: 152 cu. ft. (4.3 cu. m.), 32°F (±0°C)
Pre-cooling tank: 671 cu. ft. (19 cu. m.), 32°F (±0°C)
Freezing room: 8,190 cu. ft. (232 cu. m.), −22°F (−30°C)
Frozen fish storage hold: 63,700 cu. ft. (1,804 cu. m.), 1.4°F (−17°C)

Ammonia compressors:
- 88.5 Japanese RT (1,160,000 BTU/hr., 294,000 kcal./hr.) 150 h.p. . . . 1
- 58.8 Japanese RT (775,000 BTU/hr., 194,000 kcal./hr.) 100 h.p. . . 2

Table 51

Volumes and temperatures in fish holds of the 200 GT *Sumiyoshi Maru No. 26* and *32*, built 1958

Pre-cooling tank	118 cu. ft. (3.35 cu. m.)	32°F (±0°C)
Preparation room	470 cu. ft. (13.3 cu. m.)	1.4°F (−17°C)
Freezing room	2,383 cu. ft. (67.5 cu. m.)	−22°F (−30°C)
Frozen fish storage hold	7,097 cu. ft. (201.0 cu. m.)	1.4°F(−17°C)and −13.0°F(−25°C)

Condensers, horizontal shell and tube types:
- 3 ft. (910 mm.) diam. × 11 ft. 10 in. (3,600 mm.) effective length × ⅝ in. (16 mm.) plate thickness . . 2
- Inner tubes, 2 in. (50.8 mm.) diam. . 120
- Effective area . . . . . 1,069 sq. ft. (99 sq. m.)
- Propeller fans, 3 h.p. . . . 14

An example for a boat of 250 to 300 GT is given in table 51. The principal machinery is:

Ammonia compressors:
- 36 Japanese RT (475,000 BTU/hr., 120,000 kcal./hr.) 75 h.p. . . 1
- 15 Japanese RT (198,000 BTU/hr., 50,000 kcal./hr.) 30 h.p. . . 1

Condensers, horizontal shell and tube type:
- 2½ ft. (760 mm.) diam. × 9 ft. 10 in. (3,000 mm.) length . . . 1
- Inner tubes, 2 in. (50.8 mm.) diam. . 80
- 2 ft. 2 in. (660 mm.) diam. × 5 ft. 11 in. (1,800 mm.) length 1
- Inner tubes, 2 in. (50.8 mm.) diam. . 48
- Propeller fans, 2 h.p. . . . 3
- „ „ 3 h.p. . . . 2

REFRIGERATING CAPACITY AND PIPING

Refrigerating capacity

The values in tables 52 to 54 are standard capacities for the direct expansion system: 20 per cent. must be added to the capacities in the case of indirect cooling.

Pre-cooling tank: For the pre-cooling tank, the refrigeration capacity can be selected from table 52.

Freezing room: The freezing capacity in relation to the refrigerating capacity for various types of freezing is given in table 53.

Storage hold: The refrigerating capacity of the fish storage hold is given in table 54.

TABLE 52

Refrigerating capacity for various pre-cooling capacities

Pre-cooling capacity per 24 hr.	*Refrigerating capacity, Japanese RT* (13,175 BTU/hr. or 3,320 kcal./hr.)
3 ton (6,600 lb.)	4.5
5 ton (11,000 lb.)	7.3
10 ton (22,000 lb.)	14.5

Piping

The standards for cooling coils in the direct expansion system are given in tables 55 to 57. In the indirect cooling system, the figures are increased by 20 per cent.

TABLE 53

Refrigerating capacity for various freezing capacities

Freezing capacity, per 24 hr.	*Refrigerating capacity, Japanese RT* (13,175 BTU/hr. or 3,320 kcal./hr.)		
	Brine freezing	*Semi air blast freezing*	*Contact freezing (plate freezer)*
3 ton (6,600 lb.)	8	11	9
5 ton (11,000 lb.)	13	18	15
10 ton (22,000 lb.)	25	35	30

Pre-cooling tank: Pipe lengths in the pre-cooling tank or sea water cooling hold are given in table 55.

Freezing room: Table 56 shows the length of pipes for given refrigerating capacities.

Storage hold: Table 57 gives the pipe fitting ratios corresponding to fish hold spaces, other than those listed in tables 55 and 56.

INSULATION

Combination boats

Boats of this type are engaged in skipjack pole and line fishing from April to September in the coastal and off-

TABLE 54

Necessary refrigerating capacity for fish holds of various sizes

Volume of storage hold	*Refrigerating capacity, Japanese RT* (13,175 BTU/hr. or 3,320 kcal./hr.)	
	Frozen fish storage hold	*Other fish hold*
530 cu. ft. (15 cu. m.) .	1.86	0.62
880 cu. ft. (25 cu. m.)	2.85	0.95
1,770 cu. ft. (50 cu. m.) .	4.65	1.55
2,650 cu. ft. (75 cu. m.) .	5.73	1.91
3,530 cu. ft. (100 cu. m.) .	6.57	2.19
4,420 cu. ft. (125 cu. m.) .	7.41	2.47
5,300 cu. ft. (150 cu. m.) .	8.01	2.67
6,180 cu. ft. (175 cu. m.) .	8.37	2.79
7,060 cu. ft. (200 cu. m.) .	8.76	2.92

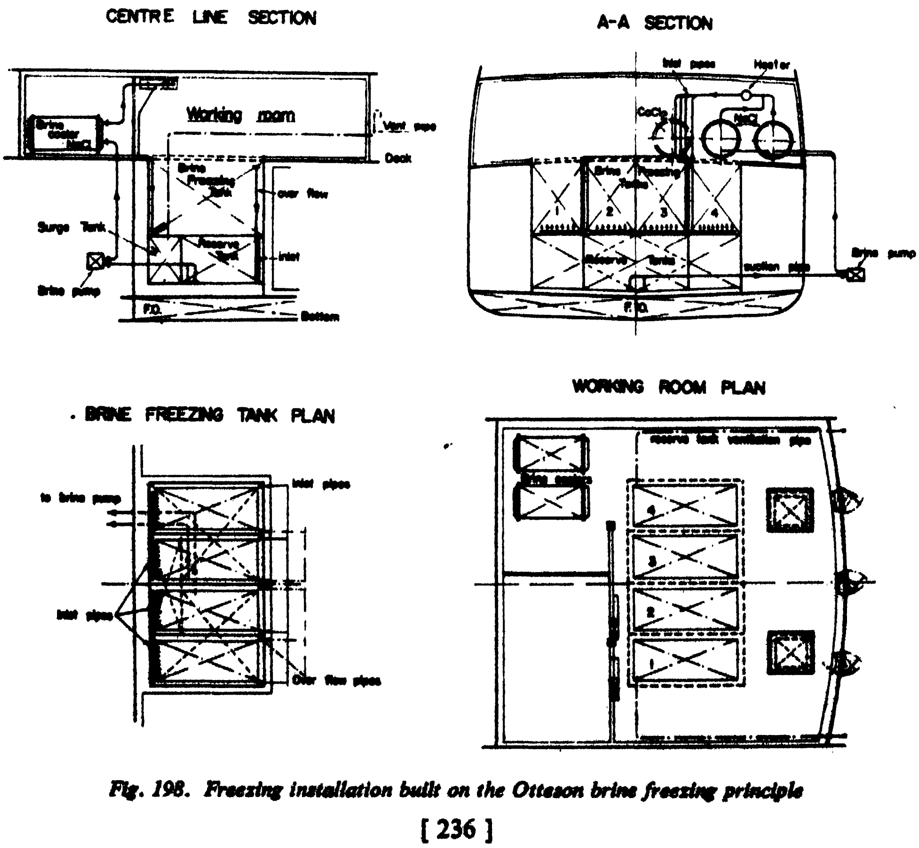


Fig. 198. Freezing installation built on the Ottesen brine freezing principle

TABLE 55

Necessary piping length for various cooling capacities

Pre-cooling capacity per 24 hr.	*Length of piping*
3 ton (6,600 lb.)	138 ft. (42 m.)
5 ton (11,000 lb.)	211 ft. (64 m.)
10 ton (22,000 lb.)	329 ft. (100 m.)
15 ton (33,000 lb.)	395 ft. (120 m.)

Remarks: The table above applies to the evaporation process for flooded type with cooled sea water circulation at 16 in. (0.4 m.) per second, with cooling coils of 1⅜ in. (34 mm.) outside diameter.

shore waters, and in tuna longline fishing during the skipjack off-season.

As skipjack fishing requires live bait, the tank must be constructed so as to keep the bait alive in sea water, this being circulated through valves in the bottom of the boat. On the homeward voyage, the bait tanks, as well as the ice holds on the sides, are used to store the catch. The tanks must, therefore, also be insulated.

The insulation is usually of two or three layers, each 2 in. (51 mm.) thick, sandwiched with soft wood sheathing planks. The inside sheathing is made watertight by caulking. Fig. 200 shows a typical example of this type of fishroom insulation.

Longliners

Longliners used exclusively for tuna do not require live bait tanks, so the fish hold is not divided into such small compartments as in the combination boats. A compartment is usually of 2,000 to 3,000 cu. ft. (57 to 85 cu. m.) for stowing raw tuna, and sometimes over 7,000 cu. ft. (200 cu. m.) when stowing only frozen tuna.

The insulation is usually of three layers, each 2 in. (51 mm.) thick, sandwiched with soft wood sheathing planks similar to those used in the combination boat. But the watertightness of the inside sheathing is not a major consideration.

TABLE 56

Necessary piping lengths for various freezing systems

Freezing capacity per 24 hr.	*Length of pipes* — *Brine freezing*	*Semi air-blast freezing*	*Contact freezing*
3 ton (6,600 lb.)	245 ft. (75 m.)	1,970 ft. (600 m.)	260 ft. (80 m.)
5 ton (11,000 lb.)	410 ft. (125 m.)	3,280 ft. (1,000 m.)	440 ft. (135 m.)
10 ton (22,000 lb.)	820 ft. (250 m.)	6,560 ft. (2,000 m.)	870 ft. (265 m.)

Remarks: The length of piping given in the preceding table applies for the brine type, to brine circulation at a speed of 16 in. (0.4 m.) per sec. through 1$\frac{11}{16}$ in. (43 mm.) diam. pipes; for in the semi air-blast type, to air circulation at a speed of 6 ft. 8 in. (2 m.) per sec.; and for contact freezing to the ammonia evaporation method.

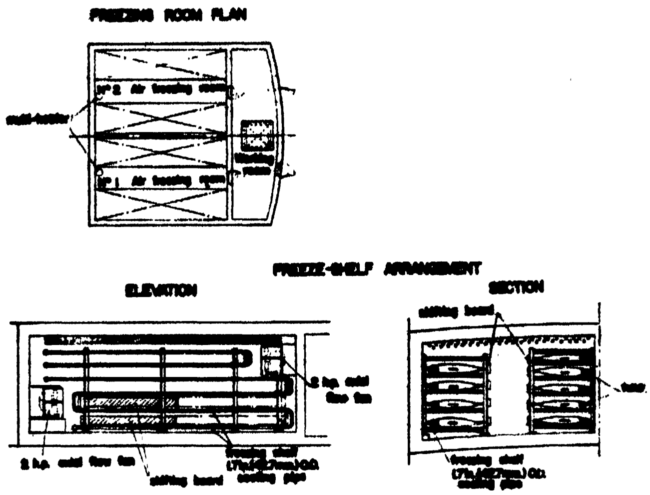


Fig. 199. Semi air-blast freezing installation for tuna long-liners

The insulation of the blast freezers is usually of four layers, each 2 in. (51 mm.) thick, because of the low temperatures.

Recent trends in insulation materials

At one time, insulation materials consisted almost exclusively of asphalted cork boards, but their use has declined since 1953 when new insulation materials were introduced.

TABLE 57

Necessary pipe fitting ratios for fish holds

Volume of fish storage hold	*Pipe fitting ratio* — *Frozen fish storage hold*	*Other fish hold*
530 cu. ft. (15 cu. m.)	1.21 ft./cu. ft. (13.00 m./cu. m.)	0.6 ft./cu. ft. (6.50 m./cu. m.)
880 cu. ft. (25 cu. m.)	1.12 ft./cu. ft. (12.00 m./cu. m.)	0.56 ft./cu. ft. (6.00 m./cu.m.)
1,770 cu. ft. (50 cu. m.)	0.91 ft./cu. ft. (9.80 m/cu. m.)	0.46 ft./cu. ft. (4.90 m./cu. m.)
2,650 cu. ft. (75 cu. m.)	0.74 ft./cu. ft. (8.00 m./cu. m.)	0.37 ft./cu. ft. (4.00 m./cu. m.)
3,530 cu. ft. (100 cu. m.)	0.65 ft./cu. ft. (7.00 m./cu. m.)	0.33 ft./cu. ft. (3.50 m./cu. m.)
4,420 cu. ft. (125 cu. m.)	0.58 ft./cu. ft. (6.20 m./cu. m.)	0.29 ft./cu. ft. (3.10 m./cu. m.)
5,300 cu. ft. (150 cu. m.)	0.52 ft./cu. ft. (5.60 m./cu. m.)	0.26 ft./cu. ft. (2.80 m./cu. m.)
6,180 cu. ft. (175 cu. m.)	0.47 ft./cu. ft. (5.00 m./cu. m.)	0.23 ft./cu. ft. (2.50 m./cu. m.)
7,060 cu. ft. (200 cu. m.)	0.43 ft./cu. ft. (4.60 m./cu. m.)	0.23 ft./cu. ft.) (2.50 m./cu. m.)

Remarks: Pipe fitting ratios in the above table apply to the ammonia-using hair-pin type without air circulation and with cooling coils of 1$\frac{11}{16}$ in. (43 mm.) outside diameter.

The first of the new materials was layer corrugated membranes, made of acetate or vinyl resin. This has been used extensively in tuna boats because of its light weight, waterproof quality, easy handling and moderate price. But this material could not replace cork boards completely because of its comparatively low heat capacity, and it is now giving place to the latest new materials including foam boards of vinyl or polystyrol resin. However, there are now many boats which use a combination of these materials.

Plywood panels are used in some boats for inside sheathing, but the sheathing planks formerly used still predominate, and a phenol resin coating or polyester resin lining is applied to the surface to ensure that they are watertight. Metal or plastic plating is not yet used in Japan.

As tuna boats are required to store fuel oil in their fishrooms on the outward voyage by means of drums or plastic bags, every endeavour is being made to ensure oiltightness of the inside sheathing, and it is expected that the development of synthetic resin will play a big role in this problem in the future.

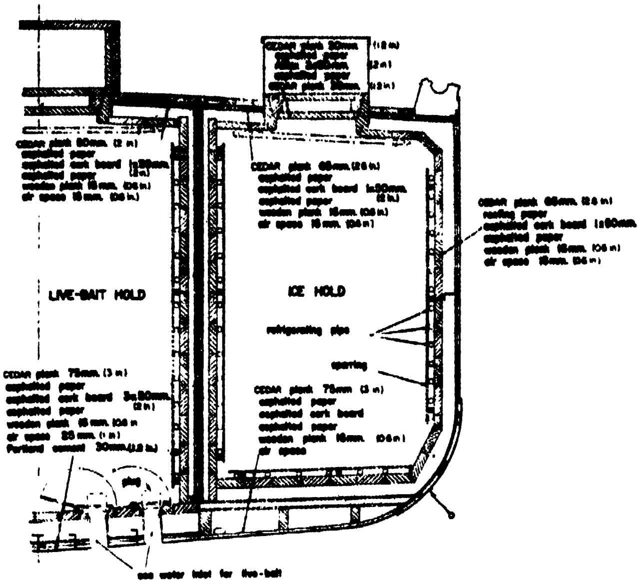


Fig. 200. Fish hold insulation of 260 GT combination boat

FISH HOLDS — DISCUSSION

Dr. E. Heen and Dr. R. Kreuzer (FAO, Rapporteurs): The papers emphasize fundamental points for the design of fishing vessels, e.g. the capacity of fish holds, which relate to fishing intensity and the time limit for preservation of catches. The papers deal particularly with distant water trawlers in Northern waters, but they have importance also on fishing boats in general.

Table 45 is based on long experience and carefully conducted experiments. These figures are valid for ideal conditions, and it is stated that even three hours on deck may show definite changes in the fish, thus indicating the need for rapid handling which necessitates care in design of equipment.

The hold's insulation is dealt with in a comprehensive way by MacCallum, who reviews appropriate materials and dimensions. Insulation can be compensated by the saving of ice. The prevention of humidity penetrating the insulation, for example, the use of water-proof lining on the warm side of the insulation, is unfortunately neglected to a great extent in fishing vessels. The need for a proper way of ventilation, drainage, etc., is also dealt with in some detail and the paper might be regarded as a handbook on the properties of sheathing and protective materials. MacCallum correctly refrains from advocating the use of one particular material. He only describes its properties, and leaves the choice to the naval architects, who have to consider the local conditions under which the vessel will have to operate.

Mechanical refrigeration as a supplement to icing is dealt with in many of the papers. The limitation lies in the properties of air as a heat carrier and its undesired desiccation of the fish.

Shelf-life of the fish may be extended by additional methods than chilling. In Eddie's paper reference is made to antibiotics as a possible means of prolonging storage and consequently longer stay on the fishing grounds, with influence in the economy. Some investigators indicate that antibiotics may reduce the percentage of spoiled fish, but it will not improve quality. There will be a greater quantity of slightly inferior fish in the fresh fish markets, and probably a less percentage of fish condemned.

In Slavin's paper, one approach to the problem of freezing the catches is described. He makes some comparison with the *Northern Wave* project in the U.K. and it is apparent that there is room for compromise between the regular factory freezing trawlers and round-fish freezing; it seems also clear that no generalization should be aimed at. Each project must be evaluated in the light of the working conditions, and marketing conditions in particular. The solution is, however, not merely a technical one. The particular desires and preferences of consumers may be a deciding factor in selection of equipment and methods.

On Japanese fishing boats, chilled seawater for cooling or storing fish is used, as reported by Doke and Sato. Japanese tuna boats, both multi-purpose boats and specialized longliners, are operated for extensive periods in regions with a tropical climate, and fish is pre-cooled prior to storing.

Pre-cooling: About 105 to 315 cu. ft. (3 to 9 cu. m.) with coils or plate coolers are used. Unfortunately no figures are given about cooling times, although it is obvious that pre-cooling in chilled seawater is an excellent method of preserving the quality on board fishing vessels, particularly under tropical conditions.

It is stressed that, despite refrigeration techniques, there are limits in the handling and preservation of fish on board caused by such factors as the working power of the crew, the fishing techniques used, the irregularity of the catches, and the economic factors as mentioned by Eddie. It is important that in the planning and development of fishing boats a close collaboration should exist between naval architects, fisheries technologists, biologists and experienced people from the trade.

ICING AND RELATED PROBLEMS

Dr. G. M. Dreosti (South Africa): He gave a summary of various investigations made by the Fishing Industry Research Institute (FIRI) into problems connected with the handling of fish on trawlers.

Temperatures in trawler fish holds. Measurements made with a 10-point thermocouple with electronic galvanometer instrument on board a trawler equipped with an insulated fish room, indicated that, while there was little appreciable difference in minimum temperatures reached in different parts of the fish room, there was an appreciable difference in the rate of cooling of fish between the areas of the pounds near the hull and those amidships.

Fish near the hull required an average of about 15 hr. to drop to within 1°F (½°C) of the average minimum temperature of 33.8°F (+1°C), while those amidships required an average of 3 hr.

Rates of cooling in ice. A series of experiments in which hake, surrounded by crushed ice, were covered by layers of either 1 or 5 in. (25 or 125 mm.) of ice, revealed that at an ambient temperature of 75°F (+24°C), the former fish took approximately 65 min. to cool from 60 to 35°F (+15° to +1.7°C), whereas the latter took about 83 min. to cool through the same temperature range.

At an ambient temperature of 40° to 45°F (4° to 7°C) a similar effect was observed, though cooling of the fish was slower. For 1 in. (25 mm.) ice the cooling time (60° to 35°F) was 100 min., but it was 130 min. under a 5 in. (125 mm.) layer.

Thus cooling under 1 in. of ice again took approximately 80 per cent. of the time under 5 in. of ice.

These results confirm earlier FIRI observations that cooling in ice is considerably faster at room temperature than at relatively low ambient temperatures.

Size and shape of ice: The size and shape of particles of ice used for chilling fish was found to have a profound effect on

TABLE 58

a five-day trawler trip in Cape waters

	Ice lb.	Ice kg.
(1) Cooling the fish cargo: 60 tons from 70° to 32°F (21° to 0°C)	31,700	14,400
(2) Pre-cooling of fish hold: 29 × 21 × 12 ft. 6 in. (8.8 × 6.4 × 3.8 m.) from 55° to 40°F (12.8° to 4.4°C)	2,000	910
(3) Preventing heat transfer through outer surfaces from warming cargo, 4 in. (102 mm.) cork insulation . . .	16,000	7,250
(4) Cooling of air leaking into hold . . .	1,000	450
(5) Removal of heat produced by men working in hold	600	270
Total	51,300	23,280

Say: 26 short tons (23.2 tons) of ice

the rate of chilling. This appears to be due primarily to the bridging which occurs with certain types of ice but not with others. When blocks of ice were crushed to a particle size of about 1 to 1.5 in. (25 to 38 mm.) and two layers of fish were packed in this ice, one above the other, the difference in time taken to cool from 45° to 35°F (7° to 1.7°C) for top and bottom layers was negligible—81 min. for the bottom layer as against 89 min. for the top. No bridging was observed in either layer.

When flake ice was used the difference in rates of cooling between bottom and top layers was significant, being 115 min. for the top layer as against 77 min. for the bottom. The bridging in the top layer was about half an inch. No bridging was observed in the bottom layer.

When the same fish were rolled in salt and put in crushed ice with some salt sprinkled on the fish, the bottom layer cooled faster than when unsalted fish were used (cooling time 40 min., no bridging observed) but was slower in the top layer where bridging now occurred (time 105 min.). With flake ice both layers cooled faster than when unsalted fish were used and bridging still occurred in the top layer (cooling time 57 min. in the bottom layer and 93 min. in the top).

It seems, therefore, that while the rate of cooling is accelerated by the use of salt on the fish, this acceleration can be more than offset by the retardation caused by bridging, which in turn is caused by the melting of ice in contact with the salted fish.

Use of ice on trawlers. Routine records, covering 105 trawler voyages and approximately 5,000 temperature readings during the period August 1954 to March 1955, were studied in an attempt to relate the quantity of ice used to the quantity of fish caught and its temperature at discharge.

It was first ascertained from data supplied by the Division of Fisheries that there is comparatively little change in air and seawater temperatures for winter and summer periods.

The amount of ice melted in a typical trawler during a 5-day trip in Cape waters was calculated according to table 58. The calculations illustrated the importance of insulating the fish hold; if insulation of only 2 in. (51 mm.) thickness had been used, the estimated overall ice consumption would have been increased from 26 to 31 short tons.

It was again found, as noted previously, that lower landing temperatures were obtained when the ambient temperature was high.

It was also found that the most economic usage was 1 ton of ice per 1 ton of fish, and that increasing the quantity of ice is relatively costly for the temperature advantage gained. Thus, for a 60-ton load of fish, 60 tons of ice would be used; of this only 26 tons are melted, so that 57 per cent. of the ice remains unmelted.

Re-use of ice. The above figures indicate the desirability of salvaging used ice for re-use ashore. Up to 10,000 tons of used ice are discarded each year by trawler companies. The dirt in the ice consists of scales, flesh and blood which sink in water, and pieces of fat and liver which rise to the surface, and bacteria from the fish.

The best method found of washing ice was to agitate in its own weight of fresh water, allow to stand for two minutes, lift it out and spray lightly with water to remove floating dirt. The yield of washed ice is 65 to 70 per cent. Bacteriological tests (total counts and coliform tests) showed that the washed ice was as clean as most of the fresh ice (at the time of use) from the bacteriological point of view.

Tests also showed that fish stored as well in washed used ice as they did in clean unused ice, whereas in dirty ice the fish deteriorated far more rapidly.

Bulk stacking of iced fish. When fish are bulk stacked, as in fish holds or trucks, to a height of 4 to 5 ft. (1.2 to 1.5 m.), with ice between layers, and below and on top of the fish, there is a certain loss in weight, thought to be due to the pressure on the fish; so tests were carried out to find the effect of this pressure on the fish.

Hake were stored in ice and trays containing heavy weights were placed on top of the stack of fish and ice. The loss in weight after 3 and 7 days was determined. Table 59 (abbreviated) gives the results.

The bulk density of hake closely packed worked out at 48 lb./cu. ft. (770 kg./cu. m.). Using this figure, together with those in the above table, the following equation was derived graphically between the daily loss of weight of a stack of fish and its depth.

$$x = 0.15 - h/100$$

where

x = average daily change in weight of hake in a stack as a percentage of the original weight of the stack

and

h = height of stack of iced fish in inches.

This equation is based on the assumption that the average loss of weight is found by using the pressure on the fish halfway down the stack as the average pressure on the fish. Thus the average daily loss of weight per cent. in a stack of iced fish 72 in. (1.83 m.) high = 0.57 per cent. It will be seen that in

TABLE 59

Loss of weight due to stacking

Pressure on top of fish		*Equivalent depth of stack of fish to produce this average pressure*		*Change in weight of fish per day as % of original lot of fish*	
lb./sq. ft.	*kg./sq. cm.*	*in.*	*m.*	*After 3 days in ice*	*After 7 days in ice*
0	—	—	—	+0.53	+0.26
11	0.77	2.7	0.069	+0.11	+0.07
172	12.1	43	1.1	−0.54	−0.81
194	13.6	48.5	1.24	−1.07	−0.89
297	20.9	74.2	1.89	−1.05	−1.01
332	23.4	83	2.11	−1.53	−1.28

single or double layers of fish (height less than 15 in. or 380 mm.) there is actually a gain in weight according to the above formula. This is in line with the experimental findings.

Cutting (*Fishing News*, 1951, No. 1975, p. 10) also found that the losses in weight of fish at sea were influenced by the depth of stacking and his figures are of the same order as the above.

It should be noted that the above equation holds for periods of up to seven days but has not been tested for longer periods of storage.

Delay in icing. It having been noted that a delay of only three hours before icing on board was sufficient to cause a noticeable effect on the keeping quality of hake, the matter was further investigated.

On a commercial trawling voyage a time study was made of 22 hauls, ranging from 400 to 8,200 lb. (180 to 3,700 kg.) of fish.

The time required for hauling up the net varied from about 20 to about 45 min. The average time spent by fish on deck (measured from moment of releasing codend until half the fish was stowed) was 57 min. The maximum time on deck, i.e. time till last fish was stowed, was 165 min. (This time was taken for a catch of 6,200 lb., or 3,000 kg.).

Maximum time on deck, excluding last haul each day was 98 min. (In the last haul only half the number of workers was used). Minimum time on deck, i.e. time till first basket was stowed, was less than 22 min. (3,200 lb., or 1,540 kg., catch).

It was observed that, while the unavoidable delay in icing increased with increasing weight of catch, the rate of cleaning the fish also increased in linear relation to the total weight cleaned. For instance, when the number of baskets (100 lb., or 45 kg., each) to be cleaned rose from 8 to 51, the number of fish cleaned per minute increased from 14 to 31. The time for cleaning varied between 3.7 and 0.9 times (averaging 1.8 times) the time required for stowing.

There was no relationship between the ratio of cleaning to stowing time and the time required for cleaning.

A trawler fish flume. As one of the most important precautions for the preservation of trawled fish is to keep its temperature as low as possible, the less time it lies on the deck, especially during the summer, the better. FIRI investigations have shown that the temperature of hake lying on deck in the summer sun can rise to 79 to 81°F (26°C) after 99 min.

The summer months coincide at the Cape with the largest trawled catches and, as has been shown above, with the existing system of working on fish decks, long exposure of the fish is unavoidable. Trawling has sometimes to be suspended while the catch is sorted, cleaned and stacked in ice below deck.

FIRI devised and tested at sea a fish flume which eliminates the batch system of cleaning and stowing and gives instead a regular flow of fish from the cleaning tables on deck directly to the fish hold. The flume runs along the port-side bulwark and is fed at the forward end by the deck hose. A small hatch amidships admits fish through a chute to the fish hold; the water drains away through a grating near this hatch. Fish pass down the aluminium chute directly into sorting baskets in the hold and are placed in ice within a minute or two of cleaning. Fig. 201 shows the fish flume.

The flume fitted smoothly into the trawler's organization, and has many advantages over the existing "basket" system of working. Among these advantages are:

- An important reduction—about 50 per cent.—in the time of exposure on deck
- Cooler fish enter the hold
- Protection of fish against trampling, bruising and contamination on deck

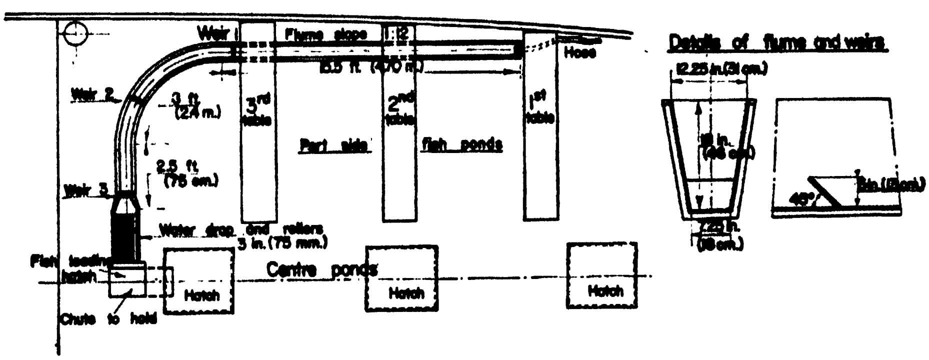


Fig. 201. Sketch of prototype flume for trawlers

- Controllable washing by adjustment of slope of flume and by fitting weirs or by variation in water flow
- Work on deck is reduced and contributes to better handling by the lessening of fatigue
- Hatches of the fish hold are closed except for the small fish hatch, 18 in. (457 mm.) square
- The icing of fish is more carefully done, because fish are not "dumped" into the hold in a last-minute rush
- The overall rate of working of the trawler is so greatly increased that even with large bags trawling can be resumed at once. A catch of 200 baskets was stowed away in 125 min. with the flume, whereas with the batch system the same crew would have taken at least 5 hr. and trawling would have been suspended

Almost the only disadvantage of the flume is the tendency to remove all surface blood from cut-ends and belly cavities, thus imparting a livid, grey and white appearance. This over-washing of the fish can be met, without impairing the characteristic extreme cleanliness of the catch, by adjustments to the flume and regulation of the water flow, as mentioned previously.

The flume has to be disconnected when the trawler is approaching port, but this is speedily done, and the aluminium sections can be stowed away on the engine room casing. The flume will stand up to heavy seas and wear and tear.

Carbon dioxide. Hake, previously chilled, were stored in airtight containers immersed in ice. Concentrations of CO_2, varying from 30 to 90 per cent., were maintained and the fish were compared with fish similarly chilled and stored in air. The controls kept for 10 days, whereas the CO_2 treatment extended the useful life to 14 days. In all cases, however, the flesh was softer than in the controls stored in air, and the colour browner, being least with 30 per cent. and very dark with 90 per cent. CO_2.

These findings are in line with those of other workers, and the advantage of longer storage life is outweighed by the undesirable colour and texture changes produced and by the considerable extra expense.

"Bilgy" fish

MR. W. A. MACCALLUM (Canada): Reay and Shewan have referred to Halifax work on bilgy fish. It has been noted both in the laboratory and aboard the boat that iced fish stowed against slime soaked wooden boards may spoil very rapidly in the areas in contact with the wood. Spoilage of this type has been observed within 1½ days of capture in freshly-caught eviscerated cod. This was observed in cases where the whole fish was reduced in temperature to 32°F (0°C). It also occurred within the same period in cod which were not permitted to cool below 43°F (6.1°C).

To his knowledge bilgy fish are a cause for concern in a few countries and may occur among the catch within a short time of stowing. While the effect may wear off in part when the unfilleted or filleted fish is exposed to air for a reasonable length of time, such an approach to the problem should not be tolerated by a firm seriously engaged in the business of selling fresh and frozen fillets, since even *one* bad fish can affect the sale of a great many pound of fillets. Thus industry and government inspection services should recognize the importance of the human factor in the use of ice and in the need for properly fitted out fish rooms which cannot harbour bacteria in and on materials with which the fish may come in contact.

Differing interpretations

MR. G. C. EDDIE (U.K.): Fish is one of the most perishable foodstuffs. The naval architect and marine engineers must therefore pay particular attention to the design of deck equipment and fish holds so as to prevent the rapid development of spoilage.

Reay's and Shewan's paper gives an account of the ways in which fish is spoilt and lays down broad principles of good practice in the design of holds and in the handling of fish, especially white-fish in the North Atlantic and Arctic trawl fisheries.

The paper represents over thirty years of research and study by scientists and engineers. Up to about 1920 the engineers and shipbuilders were much further ahead in the development of equipment for preserving all kinds of foodstuffs than were the biologists in their knowledge of how the equipment should be designed and used. This state of affairs led to the setting up of a number of national food research organizations of which the British Food Investigation was the prototype. These establishments were staffed at first mainly by bacteriologists and biochemists, and by the 1930's the knowledge they had acquired was sufficient to indicate where industrial practices could be improved, and where they must be changed. Since World War II engineers and naval architects have designed improved chilling and freezing equipment and processes on the basis of the scientists' discoveries and the time has now come when the scientific knowledge is again not complete enough to allow full understanding of the factors affecting the operation of the equipment. That is why the paper lays down broad principles only. It is also one of the reasons underlying the apparent conflict between the results of research in different countries. The biological systems involved are so complex that slight changes in practice, in size of fish or in the amount of fish can affect the exact manner of spoilage. For example, "bilgy" fish referred to by MacCallum seem to occur much more frequently in Canadian vessels than in British. The type of bacteria which will grow fastest is controlled by the environment and especially by the absence or presence of oxygen and carbon dioxide. Research on chilling in the U.K. is now devoted largely to the study of the effects of different types of stowage. Another cause of different results in different countries are possible differences in the physiology of different races of the same species of fish and differences in the bacterial flora.

The engineer and naval architect must beware in interpreting the reported results. For instance, total bacterial counts on cod kept in chilled seawater for 11 days were lower than for similar fish in crushed ice. It was subsequently discovered, however, that there were more of the types which cause spoilage on the chilled seawater fish than on the iced fish.

Results are also difficult to interpret because of different standards of judgement. There is no simple way of measuring the quality or freshness of a fish. Some aspects are more important in one country than in another. In the U.K., the standard used is "equivalent to x days in ice under ideal conditions" as judged by organoleptic and chemical tests and bacterial counts. A new method of preservation may be judged a success in one country and a failure in another.

This also depends on how well the orthodox method is applied in practice. Thus the reported success of chilled seawater in some parts of Canada and the less encouraging results in parts of the U.K. might possibly be explained not only by biological factors but also by the fact that the average temperature of normally iced fish is higher in the area where the success was reported. Nevertheless the broad principles of good preservation are clear. The fish must be well gutted and washed, cooled as soon as possible and kept cool. It must not be handled roughly or more frequently than necessary. The only successful chilling media are ice and chilled seawater. If ice is used, the design of the hold and its equipment must be such that the ice is allowed to melt. Sufficient care must be taken to prevent fish from touching each other or the surfaces of the hold. The hold, equipment and ice must be kept very clean in the ordinary sense but it seems that further improvements in keeping of fish cannot be gained short of achieving the sterility of the surgeon's operating table. The most important single factors are temperature and time.

The naval architect should, in designing decks and holds, bear in mind the principles laid down in Reay's and Shewan's paper. It does not attempt to suggest detailed designs but it is hoped it will form a useful source of background information when considering papers such as the one by MacCallum.

MR. J. PROSKIE (Canada): Reay and Shewan have produced the very interesting and useful table 45. Because fishing craft already cost so much would they recommend freezing at sea or using refrigerated seawater in preference to icing for vessels under 70 ft. (21.4 m.) LOA and which do not stay at sea for very long periods? Table 60 indicates the days at sea in fishing operations on the Atlantic coast for boats under 70 ft. (21.4 m.) LOA.

His own observations and conclusions so far indicate that the introduction of the more costly methods of preserving fish

TABLE 60

Days at sea of Canadian Atlantic coast vessels under 70 ft. [21 m.]

Area	*Nova Scotia*	*Newfoundland*	*Bay of Fundy*	*New Brunswick*	*Nova Scotia*
Type of boat	Longliner	Trawler	Trawler	Trawler	Trawler
			Percentage of total days at sea		
Trips made which were					
1 day at sea	41.1	19.1	27.8	1.3	7.8
2 days at sea	16.0	6.4	20.3	10.9	9.8
3 „ „ „	10.0	6.4	25.6	29.2	2.0
4 „ „ „	7.4	22.0	19.5	38.9	6.3
5 „ „ „	5.0	22.7	6.8	16.7	8.8
6 days and over at sea	20.5	23.4	—	3.0	65.3
Average days at sea per trip	3.6	4.1	1.7	3.7	6.3
Average landings per trip (tons)	6.4	12.1	8.1	12.9	14.7

at sea would reduce the profitability of operations under the existing cost-price relationships.

Better handling needed

COMMANDER M. B. F. RANKEN (U.K.): We should not lose sight of the paramount need to improve shore facilities for handling the fish and for processing, distributing and selling it.

Handling. Current practice at most fish docks for unloading fish is so primitive and unhygienic that there would appear to be little point in improving the treatment of fresh fish on board fishing vessels until it can be properly handled afterwards. Perhaps boxing on board offers a solution in conjunction with paternoster or other type hoists and conveyors, or, for wet fish only, the fish pumps used in some ports in the U.S.A. might be applied elsewhere at least for small fish.

If fish is to be handled efficiently and hygenically on shore it seems essential to suppress the fish auction markets as known today and to handle the fish right from catching to the fishmonger's shop through properly integrated organizations fully responsible for every step. This is already being done to some extent by a few big companies in the U.K., Greece and other countries and is presumably a salient point in the handling of fish in the U.S.S.R. The day should not be so very far off when fish, or at least frozen fish, can be handled right from the time it is sorted on board the vessel until the housewife begins to prepare it for cooking, without any contact with human hands (or feet).

Cold stores. Most cold stores currently being built for frozen fish in the U.K. are designed for a holding temperature of −20°F (−29°C). Many have already been completed but many more are needed not only at the ports but also at distribution centres all over the country. Similar trends exist in other countries though in some cases the temperatures being used at present are too high.

Transport. In the U.K. there is relatively little refrigerated land transport at present but large numbers of road and rail vehicles and/or containers will be needed capable of transporting frozen fish at −20°F (−29°C). Similar requirements exist in other countries. Some, like the U.S.A., are already well provided, although temperatures in depots, ships and shops are generally far too high.

Ice. Much has been said about the importance of ice on board fishing vessels particularly of conventional types, though it is also important for the buffer storage and chilling of fish before processing in many factory ships. However, we have inevitably taken for granted the supply of ice at the ports or on board ship.

Factory ships must make their own ice and various designs of so-called flake-ice machines are available for this purpose. In some cases it has been found necessary to make this ice from salt water, but this is not recommended as salt water ice freezes at too low a temperature which may damage the fish, the temperature rises as it melts, and a strong brine is formed which may penetrate the fish and give it an unpleasant flavour and poor appearance. Where it is impracticable to provide fresh water either from tanks or from a distilling plant, the objections to salt water ice may often be obviated by the use of chilled seawater circulated through fish precooling tanks. Such chilling plants are usually more economical of power and less costly than ice-making plants.

However, apart from a few using chilled seawater, all vessels landing wet fish require large quantities of ice in proportions as high as half a ton of ice per ton of fish to be cooled. As it takes as much as 5 to 6 BHP on the freezing compressor to produce one ton of ice per day, quite apart from the size of the apparatus, it is obviously impracticable in most cases to make this ice on board ship and it must therefore be obtained from shore. This point needs emphasis as many enquiries have been received in recent years for plants to be installed in very small fishing vessels where the power required for the ice-maker would often be greater than that of the main engine.

Ice is a cheap commodity in the large U.K. ports like Grimsby, Hull and Fleetwood where the cost is as low as 17s. ($2.4) a ton, but in many smaller ports supplies have to be carried considerable distances from the large ice factories and some British near-water fishermen have to pay more than £4 4s. ($11.8) per ton. Conditions are no doubt similar in many other countries, but they are far worse in some tropical ones where there is not only a shortage of ice but also of clean fresh water from which to make it.

Until recently plants suitable for use in these small ports have not been obtainable but today "rapid-ice" and "flake-ice" plants are available in small sizes, the latter even below one ton per day, and flake-ice at any rate appears to be competitive in price with the crushed ice produced at the larger ports, though rapid-ice is at present somewhat more expensive.

COMMODORE D. D. SILVA (Portugal): Portuguese trawlers (without cooling coils in the fish holds) use about one ton of

TABLE 61

Material	*Mahogany* Sq. ft. per Imp. gal.	Sq. m. per litre	*Spruce* Sq. ft. per Imp. gal.	Sq. m. per litre	*Douglas fir* Sq. ft. per Imp. gal.	Sq. m. per litre
Two-pack	555	11.3	682	13.9	530	10.8
2nd coat	755	15.4	775	15.8	740	15.1
Shellac	710	14.5	980	20.0	755	15.4
2nd coat	978	20.0	885	18.1	935	19.1
White paint	575	11.8	665	13.6	665	13.6
2nd coat	640	13.1	690	14.1	643	13.1

ice per ton of fish. One ton of ice actually in the hold will conserve more than one ton of fish since a loss of 10 to 15 per cent. in volume occurs by melting on the trip out to the fishing grounds.

It is well to note that the fish hold must be arranged with divisions as small as possible and temperatures obtained should not be lower than 30 to 28°F (−1 to −2°C).

Cooling coils under the deck had not proved to be of advantage, but he emphasized the great advantage of coils fitted on bulkheads and partitions, sides and bottom. With the latter considerable quantities of ice can be saved (about $\frac{1}{3}$ to $\frac{1}{2}$) and practice seems to indicate that the fish caught during the first days of a long fishing trip arrives in better condition than if kept only in ice.

However, he agreed with Reay and Shewan that fish kept only in ice, in a hold without cooling coils, is usually of better quality than the one kept in a hold with them, provided it is kept no longer than 10 to 12 days.

Portuguese distant-water trawlers are very often at sea considerably longer than that and the fish has to be stowed for as long as 15 days; then the slightly negative temperature maintained by the coils noticeably slows down the progress of protein decomposition provoked by bacteria in the fish.

The disadvantages resulting from absence of ice and consequently of humidity on the surface of the fish placed near the cooling sources, the partial freezing of a portion of fish placed practically against the coils are in his opinion compensated for by the better condition of the bulk of the fish.

Portugal had for many years been dedicating the greatest attention to the problems of handling and conserving the fish on board. In fact, the Fisheries Organization had distributed among the crews literature on the subject, advising on the best methods of handling and keeping the catch.

MR. J. W. SLAVIN (U.S.A.): He agreed with Reay and Shewan in the need for cleanliness on the vessel, even though scientific evidence as to its exact value was quite confusing. Within the past year they had investigated the use of chlorinated seawater on trawlers in U.S.A. Their observations showed that seawater containing about 60 p.p.m. of free chlorine was effective in washing the eviscerated fish, prior to icing, and in washing the vessel's hold in port. Also, the chlorinating equipment operated satisfactorily on the vessel and required little attention. As a result of these tests chlorinating equipment has been installed on ten Boston trawlers.

TABLE 62

Drying times of paints in normal temperatures

Wood	*Two-pack* 1st coat	2nd coat	*Shellac* 1st coat	2nd coat	*White paint* 1st coat	2nd coat
	Hours		*Minutes*		*Hours*	
Mahogany	3	3	30	30	1½	1½
Spruce	3	3	30	30	1½	1½
Douglas fir	3	3	30	30	1½	1½

Reay's and Shewan's suggestion about the need for larger hatch openings to permit better discharging of the fish is a good one. This should be given serious consideration in the design of new trawlers.

The ice-fish ratio of 1 to 1 for British trawlers seems high. This means that boats landing 200 tons of fish would have to carry at least 225 tons of ice to make up for the melting. They have found a ratio of 1 part ice to 3 parts fish to be quite satisfactory.

There may be some practical problems in storing and handling fish if the hold shelving is only 18 in. (0.46 m.) high. In the U.S.A. they have found a shelving height of 3 to 3.5 ft. (0.9 to 1.1 m.) to be satisfactory for commercial practice.

In tests conducted on the *Delaware* they observed that properly iced haddock and cod had a maximum acceptable iced storage period of only 12 days. Similar results have also been reported by Canadian workers. It seems, however, the storage period for British landed fish is from two to three days longer. Is this because in the U.S.A. and Canada a slightly milder product is required than in England, where the vessels have to stay out from 18 to 20 days?

TABLE 63

Drying times of paints in cold temperatures

Wood	*Two pack* 1st coat	2nd coat	*Shellac* 1st coat	2nd coat	*White paint* 1st coat	2nd coat
	Hours		*Hours*		*Hours*	
Mahogany	7	16	½	5	5	16
Spruce	7	16	½	5	5	16
Douglas fir	7	16	½	5	5	16

DESIGN OF FISH HOLDS

MR. ELLIS PRUCHNIE (U.K.): MacCallum's paper, section Coatings and Linings, p. 216, mentioned three types of paints:

- Hard-drying phenolic resin modified with specially formulated oil alkyd
- Shellac paints
- Plastic base paints requiring the addition of a catalyst

As MacCallum very clearly points out, plastic based paints, requiring the addition of a catalyst, need care in application if they are to provide the maximum protection of which they are capable. That they are far superior to other types of protective coatings, and therefore well worth the extra care in application, will be shown in the following results obtained from tests.

Three coatings were used: white fish room paint (hard drying phenolic resin modified type), shellac (an unpigmented, deep orange coloured shellac varnish) and a two-pack clear varnish (being a synthetic resin based varnish, chemically dried by adding an equal volume of suitably formulated

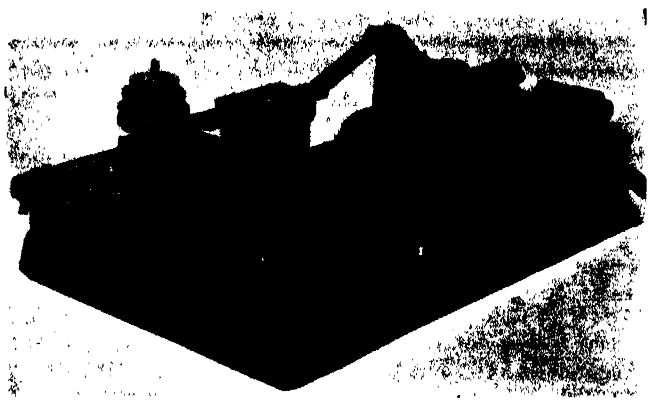


Fig. 202. Abrasion test machine for testing paints

catalyst). All the tests were carried out on mahogany, spruce and Douglas fir to illustrate different rates of absorption.

Spreading capacities. Two coats of paint were applied to the three different woods and the spreading capacity determined by subtracting the weight of brush, paints and container after application from the previous weight. Table 61 shows the results.

Drying times. The materials under test were applied to an area 12 × 12 in. (0.3 × 0.3 m.) on the different woods. Using a 1 in. (25 mm.) brush, panels were coated with 2 to 3 oz. per sq. yd. (35 to 50 g. per sq. m.) with the white paint, 1 to 1½ oz. per sq. yd. (35 to 50 g. per sq. m.) with the shellac and 1½ to 2 oz. per sq. yd. (50 to 70 g. per sq. m.) with the two-pack material. Normal room temperature was maintained throughout the drying period, which was 60° to 70°F (15° to 21°C), and the relative humidity was 60 to 70 per cent. Table 62 gives the results.

A set of results showing longer drying times at lower temperatures have also been recorded. In a specially constructed cabinet showing an internal temperature varying from 48° to 54°F (8.9° to 12.8°C), with a relative humidity of 70 to 80 per cent., the results are given in table 63.

Abrasion tests were carried out on twice-coated panels. The panels measured 6 × 4 × ¼ in. (150 × 100 × 6.35 mm.) to fit the "REL" abrasion test apparatus, fig. 202, which records the number of complete oscillations of the abrasion brush before signs of film wear appear. The brush had nylon bristles and had an applied load of 0.66 lb. (300 g.). During tests the surfaces were continually wetted with an 0.5 per cent.

Fig. 203. Results of abrasion tests. The white fish room varnish has been completely broken through as has the shellac, whilst no visible defect can be seen on the two-pack coating

solution of a commercially obtainable wetting agent, non ionic, polyethylene oxide type. The results shown in fig. 203 were as follows:

Two-pack: 225,000 strokes with no sign of wear
Shellac: 8,000 strokes worn through
White paint: 12,000 strokes worn through

Water absorption tests. Wooden panels, 6 × 4 × ¼ in., were given two coats of the materials under test. The ends were completely sealed off by dipping them in a tray of molten wax, leaving the absorption test areas equal on each panel. The uncoated control panels were similarly sealed on the ends. All the panels were totally immersed in water, and each was weighed before and after testing so that absorption figures, expressed as a percentage, could be calculated. The table 64 and fig. 204 illustrate the greater protective power of the two-pack varnish over the other two materials.

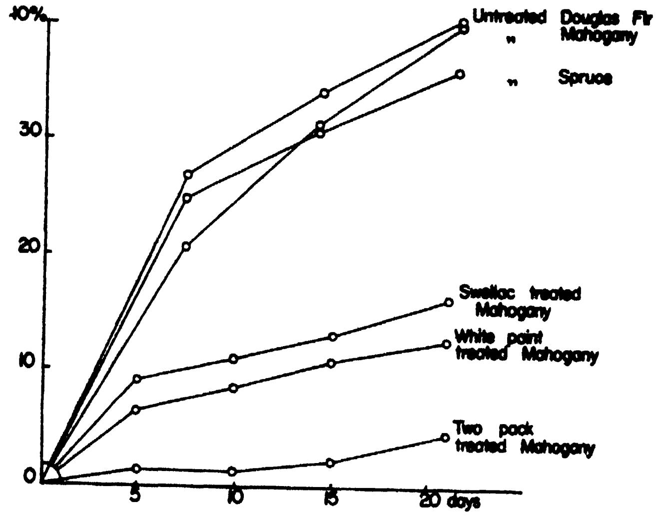


Fig. 204. Result of water absorption tests

Resistance to chemical solutions. Wooden panel surfaces had two coats of the material under test, but to ensure adequate sealing the ends had four coats. Seven days after coating, the panels were half immersed in the test solutions which were:

(a) 0.5 per cent. ammonia
(b) 2.0 per cent. caustic soda

The effects of the chemicals on the paints can be seen from fig. 205 and 206, and were as follows:

Shellac: 0.5 per cent. ammonia—complete removal within 24 hours
2.0 per cent. caustic soda—complete removal within 24 hours

TABLE 64

ı of wood protected with different paints

	5 days	7 days	10 days	14 days	15 days	21 days
Douglas fir (uncoated) .	—	26	—	33	—	40
Mahogany (uncoated) .	—	20	—	30	—	40
Spruce (uncoated) .	—	25	—	30	—	35
Shellac on mahogany .	8	—	10	—	12	15
White paint on mahogany	5	—	7	—	9	11
Two-pack on mahogany.	1	—	1	—	2	4

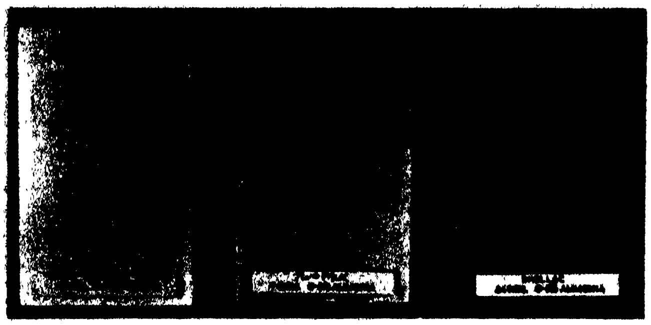


Fig. 205. Resistance to 0.5 per cent. ammonia. Both the white fish room paint and shellac have broken down whilst no breakdown is visible on the two-pack panel

White paint:	0.5 per cent. ammonia—complete removal within 24 hours
	2.0 per cent. caustic soda—complete removal within 24 hours
Two-pack:	0.5 per cent. ammonia—unaffected after immersion for 7 days
	2.0 per cent. caustic soda—unaffected after immersion for 7 days

Practical tests at sea. The laboratory results obtained were borne out under actual working conditions at sea. Apart from these, however, other observations were made which, although they emphasized the distinct advantages which the two-pack varnish had over the other two, also showed that extra care had to be taken to ensure success. In the case of new and unpainted woodwork, little difficulty was experienced providing that a reasonable drying time was allowed between coats and that the wood was also reasonably dry. Trouble can be experienced on previously painted wood unless extreme care is taken. It is essential that all the loose flaking material of the previous coating be removed and that adequate care is taken to dry out the wood. This latter is not always easy to accomplish as most owners cannot afford the time necessary to dry a fish room properly. Trouble can also occur on surfaces which have previously been treated with a paint that contained a large percentage of oil. Two-pack varnishes usually contain "searching" solvents and although the surface of the previous coating may seem quite sound, the solvents in the two-pack varnish will seep through and soften the film thereby reducing the adhesive properties of the new paint which leads to an early breakdown and "peeling". Temperature had a greater effect on the drying time of the two-pack varnish than on the other tested paints and it was found that the film would not cure below 45°F (7°C).

Conclusion. Two-pack varnishes, consisting of a varnish base and catalyst, are much more durable than conventional fish room protective paints due mainly to their hardness of finish, which is the nearest approach an air-drying material can get to a stoved finish. The varnish tested showed not only resistance to chemical and bacterial attack but also exhibited properties of pliability and a lack of brittleness. The smooth hard surface of this varnish does not afford an easy key for fish slime or other foreign matter and so is easily kept clean. Detergents normally used for cleaning have no effect on it. It is, of course, true that they are more expensive than conventional finishes and that extra care is needed during application, but practical results have shown that they protect the woodwork longer than other previously used paints and that they reduce the risk of bacterial contamination. Over one hundred vessels in the U.K. and elsewhere have now been treated in this manner and bear conclusive evidence of the test results which have been described.

Value of ice stressed

MR. F. STRAKOSCH (Italy): Ice has been and is still the most widely used medium for the preservation of fish. It represents cold in its most handy, concentrated and economical form. Mechanical refrigeration, as applied to fish holds, is a welcome complement to the basic preserver, known for very many years. It is reported that the old Romans used snow or natural ice to bring fish to the capital from far-away places.

The reason for its wide use is that ice when it freezes accumulates a considerable amount of heat — 145 BTU per lb. (80 kcal. per kg.)—which, when it melts, is released to the surrounding medium. This chilling potential can be directed at the user's discretion on to large or small surfaces to reduce the temperature of organic matter to a degree at which decomposition is almost inhibited.

The product of the operation is water, to the extent of some 660 lb. (300 kg.) per ton of fish treated, and may thus amount to a good many tons of water to be disposed of.

As known, the catch, after sorting, is stowed with ice, either in compartments of the fish holds divided by wooden or metal partitions and covers, or in boxes.

With both methods water is released from the stowed mass and drips underneath, finding its way to the bilges or a sump. Thus the liquid runs over a large portion of the insulation and some of it penetrates the insulating material, impairing its heat repelling capacity. The bottom of the hold is particularly affected in this way.

In colder regions insulation is frequently omitted from fish hold floors, but the floor is covered with wood planking which easily absorbs moisture. This practice of having uninsulated floors would be objectionable in warmer climates, since it is obvious that heat exchange is most active on such surfaces, the heat from the bilge being on the lower side and cold on the upper surface. By insulating a fish hold floor this heat exchange is considerably reduced.

But only by keeping the insulated surfaces dry can their heat repelling property be conveniently maintained. To attain this goal, it is necessary carefully to water-proof the inner side of all boundary surfaces of the fish hold, and to do this tongue-and groove planking is usually fitted over the layers of cork or other material and painted. Sometimes a layer of tarred cartoon is inserted between cork and planking; in other instances a light alloy sheathing is used.

Fig. 206. Resistance to 2 per cent. caustic soda. Both the white fish room paint and shellac have broken down, whilst no breakdown is visible on the two-pack panel

None of these systems, however, is completely successful, as small leaks can hardly be avoided; the best results have been obtained with a sheathing of zinc plates screwed or nailed to the tongue-and-groove boards and carefully soldered at all joints and on the screw or nail heads, so as to be thoroughly waterproof.

The floor sheathing should continue through the framing of all manhole covers so as to avoid penetration of water through the connections of such frames to the floor planking and insulation.

The efficient waterproofing of the inner side of insulations will lead to an all-over improvement of insulating efficiency, which in turn leads to better preservation, economy of ice, etc.

Galvanized iron sheets are not recommended because rust may make subsequent soldering for upkeep too difficult. Synthetic resin coating is reported to have been applied to fish hold surfaces with good results but appears to be still in the experimental stage. Developments in this field should be closely watched, especially in respect of subsequent upkeep to preserve the waterproof qualities.

These matters, important in any climate, are particularly serious with high ambient temperatures, with the increase of temperature differentials and, thus, of the quantity of water that has to be dealt with.

The attention of builders is therefore especially called to the proper design, installation and maintenance of the insulation in fish holds to ensure that it is heat as well as water repellent.

As stated, the greatest heat exchange occurs on the floors of fish holds; so for this reason an increase in the thickness of insulation on such surfaces by 1 in. (25 mm.) or more is recommended.

Another difficulty in the operation of fish holds—whatever the type of refrigeration used (ice only or ice plus refrigeration) —is the external temperature fluctuation. Air warmer than that in the fish hold and the catch packed there enters in large volumes every time the hatch door is opened. As a result, a large portion of the fish room vapour condenses on the surface of the stowed fish and the general temperature inside also rises. Both factors favour the growth of microbes and thus deterioration, even of the more delicate internal parts.

Refrigeration coils may worsen the situation because many fishermen run the plant with hatches or doors open with the mistaken idea that the fish will be better preserved and dripping from the overhead coils is avoided.

Temperature fluctuations can be reduced to a considerable extent by taking special care in the design of spaces intended for fish stowage and also the handling of the catch. The catch, after each haul, is put in the fish hold through its openings and thus warm air has full access for periods varying between 10 and 30 min. or more. This happens many times a day during fishing so it will be easily understood that the cumulative adverse effect on temperature and moisture conditions is great. To overcome these troubles, it is suggested that an insulated and—if the boat has refrigerating equipment—cooled packaging room be arranged where all the operations previous to storage are done so that the fish hold itself is opened only for shorter periods and perhaps at longer intervals. When fish is packed into cases with ice, the whole operation can be done in the packaging room and the cases left there until the next haul. This would have the further advantage that a product of uniform temperature would be stored in the fish hold where no—or very little—melting of ice would be required to reduce it to the right temperature. This method has given excellent results in practice. Obviously it is advisable to close the door of the packaging room and keep it shut as soon as the catch is placed therein, to the extent, of course, that the men working in the room have fresh air.

But matters are not as simple as that when large catches are stowed in bulk. Nevertheless, the ingenuity of designers and the skill of skippers and fishermen will no doubt overcome the difficulties.

On the refrigerating equipment itself, a few basic recommendations may be of use. Small or medium sized fishing boats can hardly afford to have a refrigerating mechanic among their crew; therefore the plant and its layout should be as simple as possible and easily accessible, so that the normal engine room personnel can handle it. To achieve this, these are the main points to bear in mind: automatic working as far as possible; standard parts for easy replacements; frequent inspection by specialists, preferably before each voyage; good and even distribution of cooling coils on the insulated surfaces to approach the conditions obtained in "jacketed holds"; setting the thermostat to maintain a temperature of, say, 30°F (−1°C) in fish holds, and 10 to 14°F (6 to 8°C) more in the packaging rooms, the thermostat controls to be outside the fish room.

When it is not practicable to pack and pre-cool the fish outside the final store room, measures should be taken to prevent melting water dripping on to the lower layers, and to direct the water away from the fish. Packing the first catches in closed, insulated, light alloy containers has given good results in trials.

Finally, it must be remembered that the water produced from the ice surrounding fresh fish gets loaded with organic matter and becomes a fairly concentrated bacterial broth likely to carry contamination anywhere it penetrates.

MR. J. W. SLAVIN (U.S.A.): MacCallum's suggestion to arrange the stanchions so as to permit interchangeability of the pen boards is a good one. This is sorely needed in many fishing trawlers.

All coatings used in a fish hold should of course be non-toxic, otherwise contamination of the fish may result. It is essential that the fish hold be thoroughly dried out before applying existing commercially available coating compounds. A coating that can be applied to a moist or only partially dried surface is badly needed to prevent excessive loss of time due to drying out of the hold. He would like to learn if MacCallum has found any coating materials that can be applied satisfactorily without drying out the fish hold.

In regard to the use of metal screens in the fish hold, it would seem that such screens would be very difficult to clean. Specifically, he would like to learn if MacCallum has observed any difficulty in cleaning these screens. MacCallum's paper will be of considerable value to naval architects in designing and fabricating fish holds.

COMPARISON OF FREEZING INSTALLATIONS

MR. G. C. EDDIE (U.K.): At the first Congress he had said, as does Slavin now, that the problems of freezing at sea are different for each fishery and different solutions will apply. Comparison of the *Delaware* and *Northern Wave* will be useful only if that is borne in mind.

This is particularly true when discussing the handling, processing and quality of the products and it is quite obvious that Slavin did not see for himself the products from the *Northern Wave*: the standard of quality aimed at in this experiment was very high for reasons which are given below and the assessment of the *Northern Wave* fish is therefore not directly comparable with that of the *Delaware* fish.

Before discussing the different standards further, it is necessary to take exception to the statement in Slavin's summary, that the texture of the *Northern Wave* fish was soft and the fish difficult to fillet. This is most misleading. Some of the fish was soft for biological reasons; it is true that, in general, slightly more care is required in filleting than with good-quality iced fish but sea-frozen fish is by no means difficult to fillet. Much sea-frozen fish is of a very firm texture.

Reports on the quality of fish as landed from the trawler in the U.K. and in the U.S.A. cannot be compared without examining the standards of comparison and taking into account the ultimate use of the product. In general, the quality of iced fish after a given number of days on the fishing vessel seems to be higher in the U.K. than on the western seaboard of the Atlantic, partly because of the more liberal use of ice, a mean fish temperature of below 32°F (−0°C) being usual on large British trawlers. The standard against which sea-frozen fish will be compared by the practical man is therefore in this sense higher, and the *Northern Wave* report must be read accordingly. More important, perhaps, is the fact that *Northern Wave* fish were produced to compete with iced fish for all purposes—that is, the fish were presented to the ultimate consumer as whole fish, steaks and fillets in the wet condition, as smoked fish or smoked fillets, as well as in the form of frozen fillets, fish fingers and so on. The appearance of the thawed whole fish is therefore of importance. Moreover, the most stringent and severe test of freezing and cold storage practice is to split or fillet the thawed fish and smoke it. High-grade products according to these very exacting criteria simply cannot be made by brine immersion freezing and cold storage at 0°F (−18°C). Slavin is not correct in implying that only plate-frozen fish must be stored at −20°F (−29°C) for maximum quality. This applies to all frozen fish, and the point is generally accepted in the U.K. where for many reasons, which need not be given here, most frozen fish stores operate at −20°F (−29°C), regardless of the type of freezing operation or product.

Where the product is frozen fillet in consumer packs some relaxation of these temperature requirements would, in British opinion, be possible for short periods of storage, say, no more than four months at −5°F (−21°C). Frozen fillet of reasonable quality can be produced from fish up to ten days in ice or more, but if the appearance of the thawed fish is important or it is to be smoked then the fish must be frozen within three days of catching and stored at −20°F (−29°C).

There is, therefore, a considerable difference between the type of product and the standards of judgment in the *Delaware* and *Northern Wave* experiments.

No difficulties are experienced with plate-freezing fish prior to the onset of *rigor mortis* except in a small percentage of cases and trouble can be avoided completely provided that the fish are stored for a period of several weeks.

Because storage at −20°F (−29°C) allows fish to be kept in ice for as much as three days before freezing, a considerable reduction in the size and capital cost of the freezing plant is possible as compared with what would otherwise be necessary. In the latest design, based upon the *Northern Wave*, the freezer throughput is 200 kits (12.7 ton) per day equivalent (1 kit equals 140 lb. or 63.5 kg.) but with a low temperature hold limited to 1,200 kits (75 tons) equivalent—this allows the freezer to deal with an average rate of catch of 400 kits (25.4 ton) per day, and a peak on any one day of 800 kits (51 ton). This is very heavy cod fishing indeed. The re-handling of the fish from the wet fish hold to freezer is done by the freezer hand who is not otherwise fully employed. The freezing operation is carried on entirely below decks. With this system, therefore, the freezer throughput can be as low as one-quarter of the maximum catch that can be expected in a 24-hr. period.

The ratio of fish in iced stowage to storage space in a British trawler may be 32 lb./cu. ft. (510 kg./cu. m.) or as low as 14 lb./cu. ft. (224 kg./cu. m.) depending upon the method of stowage. The latter figure refers to "shelfed" fish (see Reay's and Shewan's paper).

Regarding space occupied by freezing plant, the *Northern Wave* was for a number of reasons fitted with a plant larger than that which was necessary or desirable. The result was that on average no extension of voyage was possible. There seems little merit in subjecting more fish than necessary to the expensive freezing operation, the proportion of frozen fish should therefore be decided either by the limitations of crushed ice or by considerations of seasonal fluctuation in supply and demand. The higher proportion of frozen fish on the *Delaware* was no doubt due to the compactness of the plant, arising from the smaller size of the fish which in turn allows full advantage to be taken of the high rates of heat transfer possible in brine immersion freezing. The latest design of plant based on the *Northern Wave*, however, has a much improved throughput per unit of space occupied—about 40 per cent. higher—so that the throughputs mentioned above can be achieved in a freezer disposed athwartships, this saving yet more space as compared with the *Northern Wave*.

Some figures regarding hold size and utilization on British distant-water trawlers were given in his own paper.

The costs of unloading the frozen fish from the *Northern Wave* were rather less than for wet fish despite the makeshift apparatus used.

Water-thawing is not acceptable for large cod where appearance and texture is important, although thawing may be started in this way if under the control of an expert.

Development of compact dialectric thawing plant is proceeding, but it must be pointed out that the costs of air thawing have been taken into account in assessing the economics of freezing trawlers of the type described in the paper referred to above (see also Hunter and Eddie, 1959).

Quality aspects have been discussed above. Slavin is mistaken about the texture in cold-smoked fish; it is most important.

Regarding economics, it is to be noted that the *Delaware* experiment related to a fishery which would be viewed in the U.K. as a middle-water fishery rather than distant-water. Vessels generally under 140 ft. (42.7 m.) making 10 to 14 day trips can land fish in an acceptable condition without freezing, having regard to the more liberal use of ice, and some of the catch is fit for freezing on shore even by the highest standards. The advantages of freezing are much clearer in the case of the European distant-water fishery. As pointed out in his own paper, the limitations of crushed ice have resulted in the construction of ships with engines developing more than twice as much power as required in the trawling condition, and operating at speeds where the power is varying as the seventh index of the speed. Better preservation reduces the need for speed, and smaller engines and bunkers release more space for freezing plant (see also Hunter and Eddie, 1959).

Regarding Slavin's overall evaluation, it is not agreed that freezing at sea need result in slower handling on board, although it may require one or two extra men. The economic advantage of the ability to operate at lower speeds and powers, than at present necessary in some fisheries, has to be added to those listed by Slavin. The advantage to owner and crew of maximum utilization of capacity on every trip is, of course, that the trawler will spend more days in a year on the fishing grounds and fewer in running to and from the grounds. This in turn implies capital savings in terms of the number of vessels required to produce a given quantity of edible fish.

MR. T. MITSUI (Japan): He requested clarification on the following points regarding Slavin's paper:

- Which method was adopted to freeze the catches: was the brine stirred by propellers, pumps, etc., or were the baskets with the catch moved in the brine?
- How was the appearance of the fish when frozen by that method? In Japan appearance was determining the market value of the fish
- What was the exact meaning of "buffer" storage pen, and what are the details of the plate-freezing unit (including the weight of one charge)?

Preference for iced fish

SIR FRED PARKES (U.K.): One of his 190 ft. (58 m.) super trawlers was equipped with a refrigeration plant and a fish meal plant. With every catch that ship brought home a funny situation arose: the fresh fish, kept in ice, sold at a much higher price than the frozen fish. After two years he gave up the experiment as he felt that the greater expense in freezing over icing, and the consequent lower price of the frozen fish, created a very critical economic problem.

MR. H. HEINSOHN (Germany): The German freezer trawler, the *Heinrich Meins*, has a plate-freezer of 8 tons per day capacity. The owners confirm Sir Fred Parkes' remarks. They claimed only one small gain: the sea time, or the fishing time of the vessel was longer.

The quality of the deep-frozen fillets is excellent, a fact that is proved by the preference of the crew for frozen fish over fresh fish.

MR. E. ARCOULIS (Greece): He felt that conclusions based on the *Northern Wave* and the *Delaware* experiments were not very reliable as these boats were not worked on a business basis. As co-owner of a few fishing vessels with freezing equipment on board, he felt to be in a position to make the following observations:

- Question of cost: a freezer trawler costs much more than an ordinary trawler but is not more expensive than a diesel-electric trawler
- Freezing plants decrease the capacity of the vessel for storing fish
- Handling of frozen fish increases the cost of unloading the catch
- The question of handling on shore and storage presents other problems. It all depends on what is to be done with the fish. Circulating hot air to defrost the fish has been suggested, but it appears to be waste of money
- Quality: the fish is reported to lose its sheen and not to be good for filleting

The conception of the *Delaware* as a trawler with freezing equipment was obsolete. In the *Northern Wave* there was no necessity for using plate-freezers. He has been practising air-blast freezing for over three years and found it quite successful.

MR. S. O'MEALLAIN (Ireland): He noted that there had been much talk about freezing fish at sea in the round, unloading it in port, thawing the fish, filleting it, and re-freezing the fillets. He felt that the main difficulty lies in the thawing period. Freezing and storing on the ship can be done under optimum conditions. The suggestion put forward of thawing the fish by flushing it with water overnight is most unsuitable. He was of the opinion that thawed-out fish should never be re-frozen, as the result was not comparable to iced fish under a certain age. The quality reduction was small, but the effect was that the fish had a lesser appeal to the public.

New freezing methods

DR. ING. GINO GIANESI (Italy): Several Mediterranean fishing enterprises have recently begun to fish in the tropical waters of the Atlantic Ocean. The catch is frozen immediately after it has been washed and sorted, and the frozen fish is sold in various Mediterranean harbours. Satisfactory marketing arrangements have been established for the frozen fish and the good quality and low price are greatly appreciated by the consumers.

These projects have been a great success, partially due to the unfavourable state of the traditional fishing activities and to the depletion of the fishing grounds in the Mediterranean Sea, but also due in a great measure to the new freezing methods. Freezing is nearly a perfect way to preserve and store such a highly perishable product as fish. These projects also show that freezing is the safest way to offer a cheap and high-quality product to large sectors of the population, ensuring at the same time good profits to the fishermen.

Freezing plants on fishing vessels were not previously very common and there were no precedents of an industrial character to encourage the installation of such plants. Several circumstances have probably interfered with the introduction of freezing methods, such as the conservatism of fishermen, the prejudice against frozen fish by merchants and consumers, and perhaps also some mistrust of the technical installation, together with the general opinion that freezer trawlers had to be large vessels. By experience, freezing equipment requires a perfect knowledge of its operation, particularly so on small trawlers where the crew have not only a limited technical knowledge but also very inadequate repair and maintenance facilities. The equipment has to be simple, strong and safe, properly designed for working in tropical areas, and capable of being operated in a limited space. However, the freezing equipments so far installed have fulfilled these conditions, have proved to be easy to operate, and are now in common use.

Perhaps the first freezing plant to be installed on a medium-sized fishing vessel was during 1951 at Genoa on the Greek *Evridiki*. The owners planned to fish along the Atlantic shores of Africa, freeze the fish as soon as it was caught, and market the frozen product in Piraeus. Lacking experience in this field, a number of initial difficulties had to be overcome, especially as regards the installation and the operation of the plant. But the project proved to be a success because of the trouble-free operation of the equipment and the fact that the product was welcomed by all kinds of consumers.

This ship, still sailing the seas, has a length of 124 ft. (38 m.) and a displacement of 400 ton, it is powered by a 450 h.p. engine, has a speed of 11 knots and is provided with an ammonia plant having a refrigerating capacity of 715,132 BTU/hr. (180,000 kcal./hr.), working with two compression stages and operating two freezers at a temperature of −40° to −49°F (−40° to −45°C), able to produce about 6 tons of frozen fish a day, and to refrigerate the 9,900 cu. ft. (280 cu. m.) fish holds at a temperature of −4° to −13°F (−20° to −25°C). The holds have a capacity of only 264,000 to 286,000 lb.

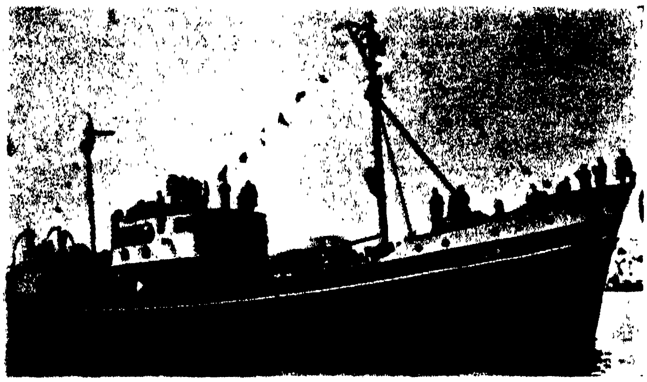


Fig. 207. First Greek freezer trawler Evridiki *operating in the South Atlantic and having vertical blast freezers*

(120 to 130 ton) of frozen fish and this has limited her profitability. The ship is shown in fig. 207 and 208. The *Evridiki* has worked excellently since 1952 without any particular interruption, making about five or six fishing trips every year, which, for such a ship, is really a remarkable achievement.

This early experiment showed that a number of the objections, which are still heard today, can be ignored. Some of these were a mistrust of ammonia as the refrigerating agent, the use of finned coils in the evaporators, high speed compressors and automatic control devices. The experience has given clear proof that a two-stage ammonia plant with proper characteristics can be installed on medium-sized fishing vessels and be operated with confidence by ordinary fishermen.

The Atlantis High Sea Fishing Company of the Piraeus, owners of the *Evridiki*, are certainly of this opinion, because they equipped two more trawlers with the same system but on a larger scale. The refrigeration plant, itself, is less cramped because the ships are about 229 ft. (70 m.) long and 29.5 ft. (9 m.) wide. The plants have a refrigerating capacity of 1,587,000 BTU/hr. (400,000 kcal./hr.), designed to freeze about 33,000 lb. (15 ton) of fish a day and to keep a temperature of −13°F (−25°C) in the fish holds of about 28,250 cu. ft. (about 800 cu. m.). The vessels are powered by 1,200 h.p. diesel engines, and they are also provided with 500 kW generating sets and their longitudinal section is shown in fig. 209.

In 1955 Messrs. Evangelistria of the Piraeus decided to have their 500 GT transport vessel *Grassholm* converted into a trawler by the same firm which converted the *Evridiki*. The trawler was renamed *Evangelistria I*. The operating results were such that her owners decided almost immediately to do the same with two more second-hand ships.

While the conversion of the *Grassholm* was a very unusual and difficult technical task as the ship was once a minesweeper, later converted to a merchant vessel, the installation of freezing plant in the other ships presented fewer difficulties. Nevertheless, *Evangelistria I* has been operating profitably for three years with a production of about 2,200,000 lb. (1,000 ton) of fish a year. She has a length of 157 ft. (48 m.) and is powered by a 650 h.p. diesel engine, giving her a speed of

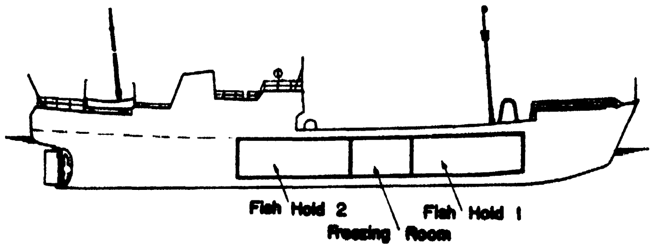


Fig. 209. Longitudinal section of Evridiki II *and* III

11 knots. She is provided with a 1,190,000 BTU/hr. (300,000 kcal./hr.) refrigerating plant, complete with four freezers capable of producing 26,500 lb. (12 ton) of frozen fish a day. Her two holds have a volume of about 14,100 cu. ft. (400 cu.m.) cooled to a temperature of −13°F (−25°C) and can carry about 510,000 lb. (230 ton) of frozen fish. The freezing

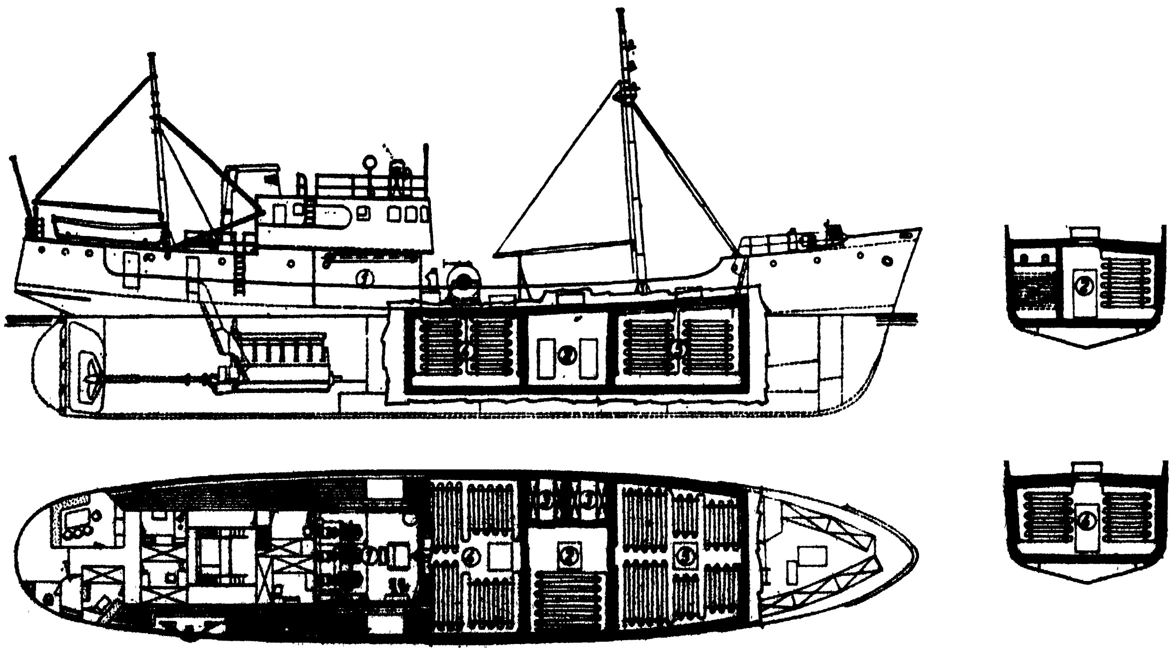


Fig. 208. General arrangement of Evridiki I *refrigerating installation*

process is similar to the one on board the *Evridiki*, but it is somewhat simpler and provided with a number of special devices for quick defrosting.

The two converted second-hand ships were renamed *Evangelistria II* and *Evangelistria III* (fig. 210), and apart from some slight differences in the volume of the fish holds and in their superstructures, they are fundamentally similar to one another.

Their technical characteristics are: length 117 ft. (54 m.); beam 27.9 ft. (8.50 m.); draught 12.5 ft. (3.80 m.); speed 13 knots; main engine 1,100 h.p.; 3 diesel generator sets with a total output of 350 kW. Refrigerating capacity 1,389,000 BTU/hr. (350,000 kcal./hr.). 4 short vertical tunnel freezers (fig. 212).

Quick-freezing capacity: 31,000 to 33,000 lb. (14 to 15 ton) of fish a day. Volume of fish holds refrigerated to −13°F (−25°C): 21,200 cu. ft. (600 cu. m.). Capacity of fish holds: about 661,000 lb. (300 ton) of frozen fish. Insulation of fish holds: 7.9 to 11.8 in. (20 to 30 cm.) porous cork slabs, with wood planking. Trawl winch power: 145 h.p., complete with Ward Leonard electric motor. Crew accommodation: 32 men.

They were first of all completely stripped down to the bare hulls. Then complete reconstruction of the inside began: insulated holds, main engines, crew accommodation, installing all the new equipment and machines and so on. Where necessary, the hull structures were replaced, modified or supplemented. The conversion took about four months, of which one month was for dismantling and three for the rebuilding work. The decision to convert instead of building a completely new trawler might be questioned. Although it is true that each such case must be carefully examined, after studying the particular vessels under discussion, it was decided that both time and money would be saved by converting these particular ships. Actually, cost of conversion was a third less than it would have been to build a new ship similarly equipped.

There was a great deal of discussion whether diesel-electric or diesel engines should be installed. Notwithstanding the advantages of diesel-electric power, it was decided to use the common diesel engine as the owners thought that this system was much more reliable with the crews they could recruit. This choice of power is debatable. In fact, these ships have three motor generating sets with a total output of about 400 kW, a part of which is used for the Ward-Leonard system, while the other part has to work at a constant voltage. Consequently, both the circuits and the control-board are rather complex and require, anyway, qualified technicians. There are usually three electricians in these ships, one of them being specially required for attending the refrigerating equipment.

Fig. 211. Evangelistria III *on trial*

The power required for the winch and the refrigerating installation is a factor that influences the choice and the subdivision of the electric generators' outputs. It is necessary for the winch to have its own generator. A second constant voltage set supplies the requirements of the refrigerating installation, while a third is a stand-by. This arrangement has proved practical and efficient.

The refrigeration and freezing equipment require considerable power which has to be generated in a very limited space; therefore it must all be of minimal overall sizes, for example, by using high speed compressors. The equipment occupies

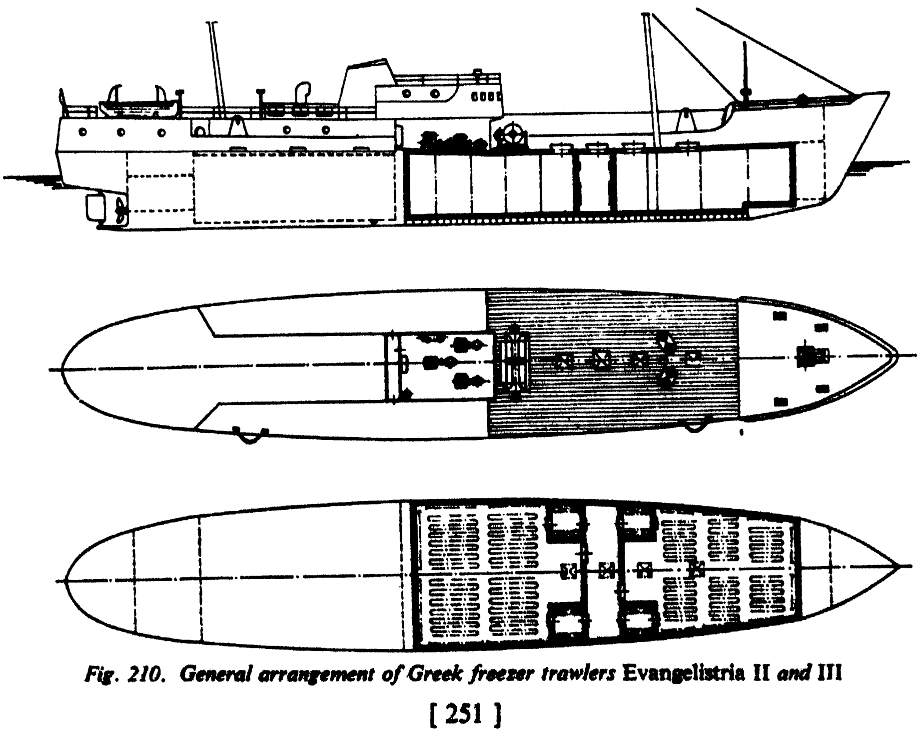


Fig. 210. General arrangement of Greek freezer trawlers Evangelistria II *and* III

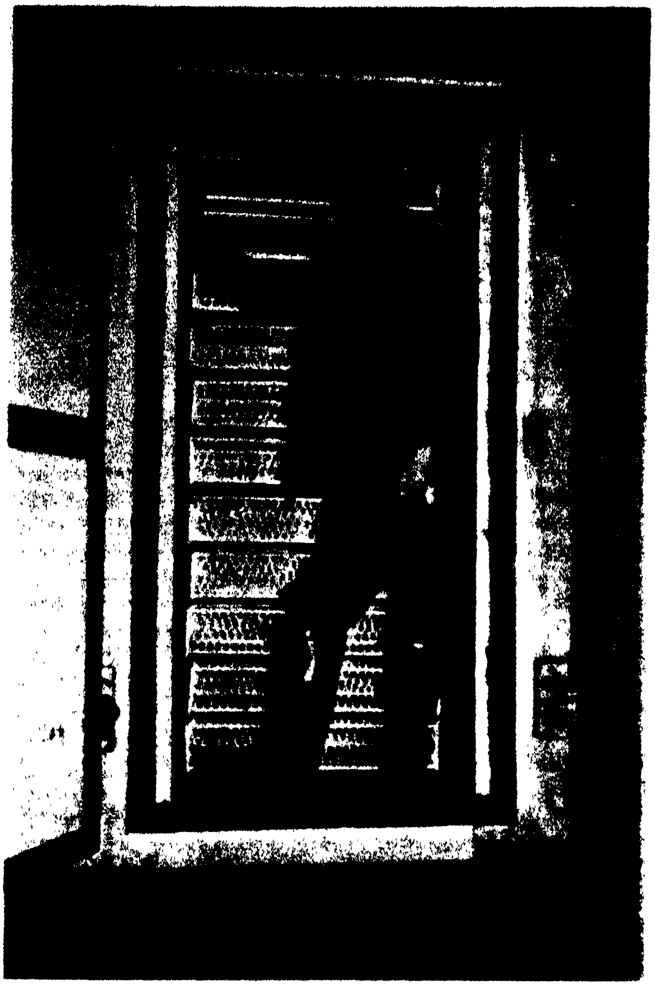


Fig. 212. Short vertical blast freezers, being used with great success on fresh whole fish. They are kept in wire mesh boxes both when being frozen and in storage

about 215 sq. ft. (20 sq. m.) for an installed power of 160 h.p., with a total weight of 66,000 to 77,000 lb. (30 to 35 ton). The absorbed power for freezing alone at full load is about 50 kW or 68 h.p. It is advisable, as a rule, that the refrigerating capacity does not exceed 50 per cent. of what is considered to be the daily average fishing capacity. Ammonia as the refrigerant has proved satisfactory in every way, and it is safer than freon. The main advantages of ammonia are:

- Distribution and control devices are very simple and sturdy
- Maintenance is easy even with unskilled labour
- Recharging does not need special care or precautions
- A high volumetric output is obtained with a low absorbed power

The refrigeration plants in these ships have automatic control and are composed of a two-stage ammonia circuit for the freezing and of a single-stage one for the holds. Each of the three compressors is directly driven by a variable-speed electric motor.

As far as possible all the connections should be welded and no cocks, valves, etc. should be in the holds. All controls, automatic or manual, should be within easy reach. The use of switches or devices relying on mercury was avoided, because the ship's motion could interfere. All controls have been so designed and arranged as to reduce manual operation as much as possible and improve safety. Thus in the three years operation of the Evangelistria trawlers and the seven years operation of the *Evridiki* there have been no breakdowns or failures.

Four blast freezers are used, having a short vertical freezing tunnel and with specially designed self-locking doors to avoid condensation. The freezers are of the standard liquid ammonia flooded type, properly recirculated by pumps. Special care has been given both to the feeding system and to the recirculating pump, one ammonia surge-drum being used for the four freezers. This arrangement allows an easy working, even when loading and unloading the freezers, as well as when defrosting.

After washing and gutting, the fish is placed in small wire-mesh boxes for loading in the freezer. When frozen, the boxes go directly into the refrigerated holds. This layout has proved much more practical than the *Evridiki's*, where the frozen fish has to be carried back into the processing room before entering the holds. The layout may vary as, for instance, when the fish has to be glazed. In general however, it is advisable not to have the freezer doors opening towards warm rooms, as this is very uncomfortable for the crew.

The freezers are loaded and unloaded by hand. In theory there are no difficulties in making them automatic, but on this type of vessel the conditions are not satisfactory for safe and proper working of such devices.

Each freezer is fitted internally with a pair of axial-flow fans directly driven by an electric motor of the enclosed type. Each freezer has a pair of cooling coils, complete with finned

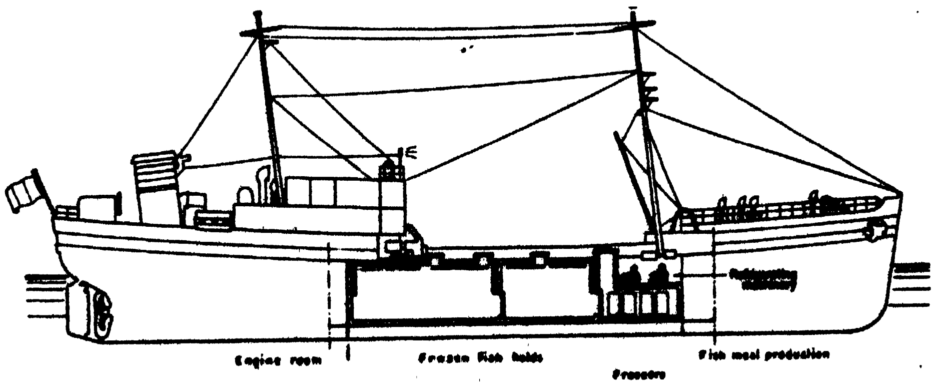


Fig. 213. Profile of Italian freezer trawler Genepesca IV

pipe evaporators, and well recessed to avoid damage. This gives a large radiating surface in a small space. The necessary defrosting is done manually with hot gas, once or twice a day in about 10 min., and when the freezer is empty. It cleans the surfaces perfectly and removes about 4.5 to 6.5 Imp. gal. (20 to 30 l.) of water each time. This water is discharged through a pipe into the bilge, which is kept closed during freezing operations.

Fish holds are refrigerated by means of 1⅝ in. (42 mm.) plain piping, working on direct expansion and controlled by thermal expansion valves. It would not be difficult to attain lower temperatures but it would lead to a considerable loss of space on account of the thicker insulation. The frozen fish, however, is not kept in the refrigerated holds for a long time, so a temperature of −13°F (−25°C) has proved to be satisfactory. The temperatures are controlled by means of tape recorders, besides the usual distance- and mercury-bulb thermometers.

The holds are insulated with first quality porous cork slabs, 8 in. (20 cm.) for the floors, and up to 10 to 12 in. (25 or 30 cm.) for the ceiling. The insulating cork slabs are fitted on the ship's frames with offset joints. The inside covering is of wood, sometimes covered with galvanized steel or anodized aluminium sheets. This type of insulation is sound and strong, although it is somewhat bulky and expensive. For example, a fish hold of 14,000 to 28,200 cu. ft. (400 to 800 cu.m.) is reduced by about 18 per cent. in volume by the insulation. The useful volume of a fish hold is an important factor and an accurate study was made for all ships in order to get the best utilization of space, even at the cost of some sacrifice in the accommodation for the crew. The trips between the Mediterranean and the Atlantic represent a time, so that inadequate holds, although satisfactory in other respects, might not be in a favourable competitive position.

Based on the experience gained, several other ships are now being converted, and entirely new vessels are projected. The new Evangelistria ships will have considerably different and much more complex characteristics and they will be classified as factory ships rather than freezer trawlers. Their refrigerating capacity will be 2,000,000 BTU/hr. (500,000 kcal./hr.), capable of processing about 44,100 lb. (20 ton) of frozen fish a day. Their fish holds will have a volume of about 46,000 cu. ft. (1,300 cu. m.) kept at a temperature of −13°F (−25°C).

The results of this long experience of freezing at sea may be summarized as follows:

- Freezing at sea can be considered practical and perfectly safe

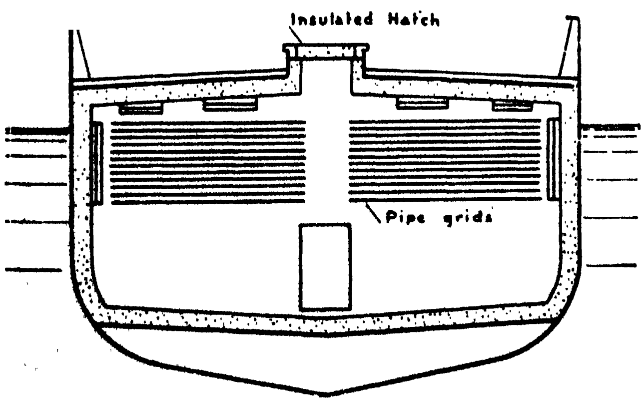


Fig. 214. Midship section of Genepesca IV *showing holds*

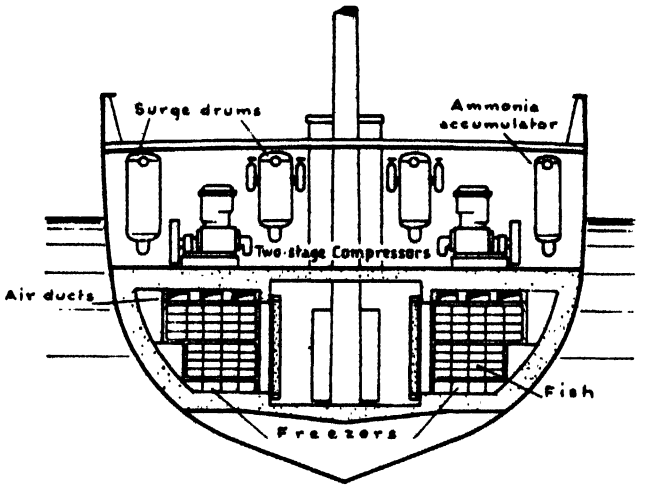


Fig. 215. Section showing refrigerating machinery and freezers of Genepesca IV

- Fish must be frozen as soon as possible
- Blast freezers, if properly designed, are simple, strong and easy to handle. They give the greatest flexibility because whole fish—both large and small—can be frozen in trays or in various types of packing, as well as fillets.
- Difficulties with frost are totally removed by accurate design of freezers and simple defrosting devices
- Installations must have adequate air velocities and temperatures to ensure a perfect freezing. A refrigerant, such as ammonia or freon, can be used; the former has proved to be reliable, simple and safe
- The problems posed by the construction of a freezer trawler, or by a conversion, are not simple. The refrigerating engineer and the shipbuilders should be consulted at an early stage

Freezing at sea is definitely out of the experimental stage, and is a working tool at the disposal of fishing enterprises. It will certainly be considerably used in the near future, especially in areas where the traditional short distance fishing activities are on the decline.

More Italian experience

DR. ORAZIO OSTI and CAPTAIN WALTER COSTA (Italy): *Genepesca IV* was formerly used for salt cod production. In 1957 she was converted to freeze and store frozen fish and to make fish meal. The main particulars of the ship, built at Le Havre in 1937, before conversion were: length 218.2 ft. (66.50 m.); beam 34 ft. (10.36 m.); depth 19.7 ft. (6.00 m.); 1,220 GT; 679 NT; two holds: total volume 40,153 cu. ft. (1,137 cu. m.); 6-cyl. main engine, 1,200 h.p.; two 180 h.p. auxiliary engines.

The new refrigerating equipment of *Genepesca IV*, fig. 213 to 215, is sufficient for the following while fishing in tropical waters:

- Freezing 20 tons daily by four freezers
- Preserving 400 tons frozen fish at a temperature of −4° to −8°F (−20° to −22°C) in the two holds

The main features are shown in fig. 216 and can be summarized as follows:

- Direct ammonia expansion for freezers and holds
- Multi-stage expansion with deep intermediate subcooling between the stages

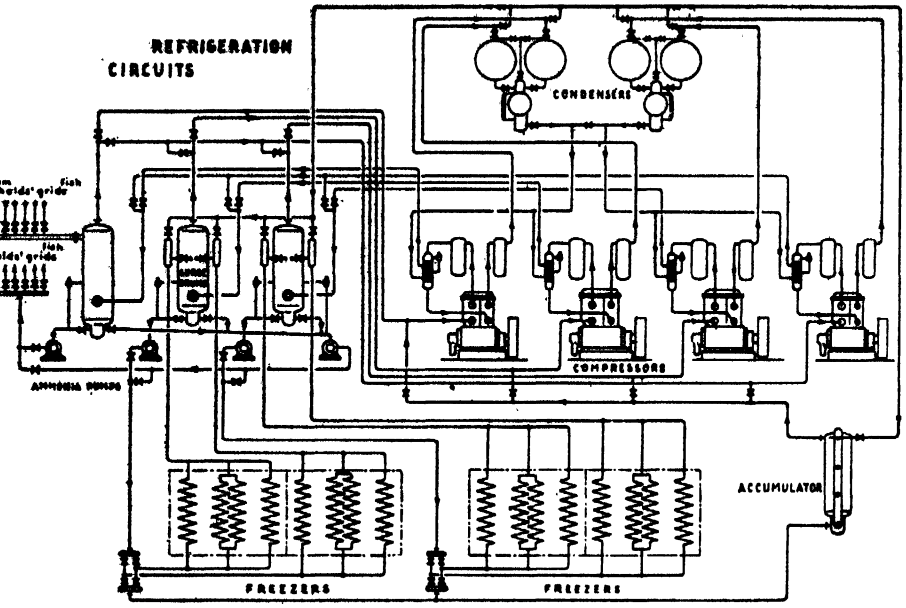


Fig. 216. The refrigeration circuits of Genepesca IV

- Forced circulation with electric ammonia pumps, for the evaporators in the holds and the freezers
- Four independent units with two-stage low-speed compressors; one being a spare
- Subdivision in three circuits, each at a different operating temperature
- Interconnection between compressors and between circuits
- Automatic regulation of refrigerant, high degree of safety in operation and easy control

The refrigeration machine room is in the 'tween-deck. Each of the four units is driven by a DC motor and connected to a shell and tube condenser. Two units are for freezing; the third is normally used for cooling the holds; the fourth as a standby.

Electric energy is provided by two diesel-electric units of 100 kW each, placed in the engine room. One of these generators is a standby.

The refrigerating capacity of each compressor for the freezer is about 40 RT (150,000 kcal./hr.) between 14° and 77°F (−10 and +25°C); the electric motor is 55 h.p. The refrigerating capacity of each compressor for the holds and for the spare is about 22 RT (85,000 kcal./hr.); the electric motor is 35 h.p. The compressors run at about 370 r.p.m.; this low speed is very important for the heavy operating conditions in equatorial waters and it contributes to regular working and long life.

The plant is divided into three suction circuits at different temperatures. The first and the second are for each of the freezers and are heading to the 40 RT compressors. The third circuit is for the holds and is connected with one of the 22 RT compressors.

The four large shell and tube condensers have roll-expanded pipes. The covers are easily removable for periodical cleaning. The diameter of the pipes is larger than normal to facilitate cleaning and avoid excessive water speeds. All parts in contact with seawater are treated with a special anti-corrosive paint.

The four freezers are placed under the machine room, directly communicating with the holds. Each freezer is divided into two compartments and each compartment has three shelves of galvanized coils. Air is forced uniformly over the fish and the evaporating coils in a horizontal direction. The fish is frozen in its wooden boxes.

By having two compartments in each freezer temperature reduction is minimized. This division has also proved very useful to maintain identical conditions and even freezing; it avoids having to reverse the direction of the air blast periodically. Freezers are planned for −31°F (−35°C). It is not advisable to lower the temperatures too quickly so as to shorten the freezing time, because the quality of the fish depends on the right ratio between the speed and the temperature of the circulating air.

Defrosting is done by emptying the refrigerant into a large ammonia accumulator. Evaporators are defrosted by injecting hot compressed ammonia distributed by a branch pipe on the plant's discharge side. The fish holds are cooled by suitable smooth pipe evaporating grids applied on sides and ceiling. Holds' and freezers' doors are of "overlap" type.

The ammonia is forced through the plant with four electric driven centrifugal pumps, of which one is a standby. The

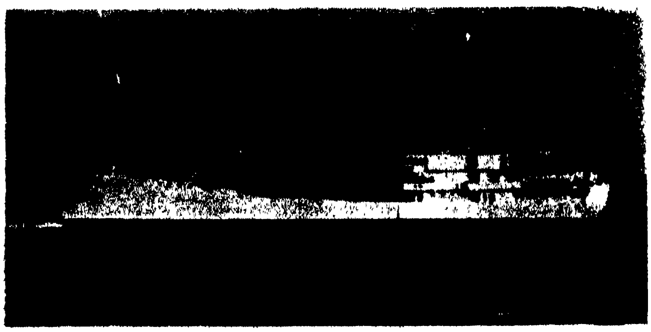


Fig. 217. Italian freezer trawler Genepesca IV

pumps are fed from vertical ammonia surge drums placed over them. Electric driven pumps are easy to regulate, being stable under load variations of the freezers and holds.

Among the several advantages of forced circulation is that the ammonia pipe can be installed according to the vessel's construction, there is no need to observe pipe slopes and level differences.

The insulation of the separator and the low temperature ammonia piping is one of the synthetic resins. The insulation of the holds and freezers was made with several cork layers coated with bituminous emulsions on the surfaces. The average thickness of the cork linings is about 12 in. (300 mm.) in the holds and about 14 in. (350 mm.) for the freezers. The sides and ceilings of the holds are litosilo lined, while the internal surfaces of the freezers are covered with galvanized iron sheet applied on the wood boarding to which the cork is fastened. The volume of the frozen fish holds is about 26,850 cu. ft. (760 cu. m.).

Two rooms at the bow are used for fish meal production, the first for machinery and the second for 65 tons storage.

The refrigerating plant has been carefully tested during many voyages to and from the fishing grounds near the Mauritania coast, which average 80 to 90 days and the experience was:

Direct expansion ammonia system has proved to be both economical and technically sound in a large capacity plant on ships. Refrigerating units should be mounted on deck or tween-decks, ammonia circuits must be welded, shut-off devices must be outside the holds, and proper ventilation is advisable for the compressor room. These recommendations, of course, apply also to other refrigerants, so the use of ammonia therefore does not demand special conditions. The plant should be divided into circuits operating at different temperatures for each freezer and hold, and several independent refrigerating compressors should be installed. Two-stage compressors are suitable at the very low temperatures needed for freezing and they are as trouble-free as the normal single-stage machines. Forced circulation of ammonia, with electric pumps, is practical, efficient and reliable.

Must study the market

MR. MOGENS JUL (Denmark): In the discussion of the preservation of white fish at sea many calculations are made regarding the economics of freezing the whole catch at sea immediately upon capture versus storage of at least a large part of the catch in ice for landing it in this condition. It is generally agreed that the latter method is the more economic.

It appeared to him, however, that insufficient attention is paid to the fact that the landing of white fish which has been up to 10 or even more days on ice may very well be an obsolete process, and that consumers may soon demand a fresher product. Large population groups have for years been accustomed to the use of white fish which has been up to two weeks on ice. On the other hand, people accustomed to really fresh fish, i.e. 2 to 3 days on ice at the utmost, or fish frozen within a few hours after capture, will not eat such 8 to 10 days old iced fish. The development in the U.S.A. has been that the whole distribution of fish is turning from fresh to frozen fish because it is in this way possible to supply the whole of the U.S.A. with fish of very good quality. This was not the case when iced fish was used.

It is likely that the distribution of fish which has been iced for 10 days will be possible for several years to come but eventually will have to be discontinued. Since large parts of the white fish catches are fished far away from the place where the fish is landed there seems no alternative to freezing that part of the fish at sea. Therefore, fishing craft with capacity for freezing the complete catch will have to be developed for fishing grounds where shore bases cannot be established.

Naval architects and fishing boat builders should study the market investigations which food technologists have carried out. They are trying to predict what the consumers prefer. This is not an easy task but it is essential. Studies indicate that where frozen fish and iced fish of average quality compete, the frozen fish, prepared of really fresh fish, is preferred and gets a better price. It is true that freezing at sea is costly but it may become a necessity and the consumers may eventually be willing to pay the increased cost.

Factors in fish room construction

COMMANDER M. B. F. RANKEN (U.K.): With regard to the use of refrigerated grids in wet fish rooms, it should be remembered that these were originally introduced in the days of poor insulation in steam vessels mainly to limit the amount of heat entering from the boiler room. The advent of the diesel engine had changed this and it was true that refrigeration was now somewhat of a luxury in Arctic waters except for preserving the ice on the outward voyage, but it was almost certainly essential for operation in warmer climates. De Silva mentioned the need to have bulkhead and ship's side grids, presumably in warm waters and this was certainly desirable in conjunction with good insulation. Strakosch raised the question of frosted pipes and this problem had certainly been troublesome in some British distant water trawlers but means were available for defrosting the grids in turn to limit the frost build-up and leave the grids almost clean on entering harbour. Refrigerated spaces in which to prepare the fish before storing it were definitely desirable in warm climates and were an important feature of modern designs of factory trawlers designed for operation in warm waters.

It was important to emphasize that the wet fish room cooling plant was only designed to deal with the heat influx from outside. It must not cool or freeze any of the fish in the hold below 32°F (0°C) and it must allow the ice to melt.

Various remarks had been made about ice and the very large quantities which were required. Ice is by no means easy to obtain in many areas, particularly in warm climates, and it may be very expensive. It seemed probable, therefore, that chilled sea water offered a better solution for warm water fishing provided sufficient power could be provided to drive the refrigerating plant.

Dreosti mentioned the particle shape of ice but this did not sound like a practical problem as it was clear that the cooling effect of a given weight of ice was always the same and the important thing was proper distribution through the fish. Washing of used ice between voyages did not seem practical by Dreosti's method and it would be better for the amount of ice remaining at the end of a voyage to be kept to a minimum.

MacCallum mentioned belt driving of refrigerating compressors from the main engine of small fishing vessels. An attractive alternative would be to use a hydraulic motor with the pump driven by the main engine. This method was currently used on a number of refrigerated vehicles and allowed the compressor to be sited in the most convenient place relative to the refrigerated space.

MacCallum's paper was obviously most valuable and would be used by many as their Bible. It was desirable, however, to raise one or two points. In table 40, MacCallum gave a figure of 0.08 BTU/hr./sq. ft./°F (0.391 kcal./hr./sq. m./°C) for the overall heat leakage factor into a steel trawler, but this was lower than that recorded in many fully refrigerated ships and equalled the value obtained in trials in the *Fairtry II*. In British practice where the tank top was uninsulated and the bulkheads, deckhead and ship's sides had between 2 and 4 in. (51 to 102 mm.) of insulation, a figure of 0.15 BTU/hr./sq. ft./°F (0.734 kcal./hr./sq. m./°C) was commonly used for calculating the heat leakage and this seemed more realistic. However, insulating the tank top as suggested by Strakosch would improve this figure and this was very desirable. The analysis of the optimum insulation thickness in relation to ice carried and fish hold capacity was most interesting, particularly in relation to warm water fisheries.

The water-tightness of the insulation was of paramount importance both on the outside and on the inside and this was rightly empahasized by MacCallum. However, the Minikay system was not a satisfactory method of sealing the inside of the insulation in ships as it was almost impossible to ensure a vapour-tight internal lining between the hold and the Minikay air space due to the working of the ship. As a result it was common to find that the produce in the store had lost weight. The system was often ideal on shore but was not worth considering on board ship although it had been fitted extensively by some West European and Scandinavian shipping lines as well as in at least two frozen fish holds in trawlers.

Mention should be made of the polyurethane light-weight rigid foams, which appeared to have a great future, particularly for low temperature fish holds and for doors and hatch plugs. They showed promise of having a completely sealed structure and were cheaper to erect than other cellular materials in common use.

MacCallum stated that aluminium foil was satisfactory so far as water absorption was concerned. This might be true of the material itself but it was not true of an insulated structure, as moisture could penetrate easily between the layers and freeze.

For frozen fish holds, the principle must be to keep the heat leakage to a minimum and so limit the refrigeration load. This in turn limited the amount of desiccation of the frozen fish, a most important point when fatty fish were involved. In general the equivalent of 12 in. (30 cm.) of cork (8 in. or 20 cm. over beams and frames) was required in Northern waters and rather more might be needed in warm climates.

The jacketed hold was the ideal but was not a practical proposition where space was at a premium and water-tightness of the inner lining could not be ensured.

He hoped that Slavin would forgive him for saying that he had undertaken an unhappy and indeed an impossible task in trying to compare the relative merits of the *Delaware* and the *Northern Wave*. On the one hand was a ship and a fishery with which he was intimately connected, while on the other was a ship he had never seen and a completely different fishery of which he obviously had no personal knowledge. Eddie dealt in detail with Slavin's paper. Only one or two points would be dealt with and a description given of the freezing equipment proposed for any new commercial vessel of this type which might be built for British owners.

Useful prototype

A vertical plate-freezer (fig. 218) was developed for the *Northern Wave* from a prototype built by the Torry Research Station, Aberdeen, and was in every sense a robust, practical and reliable unit, which never gave any trouble throughout the experiment, in spite of its situation at the forward end of a violently pitching vessel. The cycle time for loading, freezing and unloading the freezers was 4¼ hr., and on this basis the freezing capacity of the whole plant was 646 lb./hr. (294 kg./hr.) to −20°F (−29°C), not 500 lb./hr. (227 kg./hr.) as stated in Slavin's paper. In the *Northern Wave*, blocks 36 × 18 × 4½ in. (915 × 457 × 114 mm.) thick and weighing 64 lb. (29 kg.) were produced. For the future a block size of 42 × 21 × 4 in. (1,070 × 535 × 102 mm.) thick, weighing 84 lb. (39.2 kg.) was suggested. The installation proposed for a standard British diesel or diesel-electric distant-water trawler, 185 × 32½ ft. (57 × 9.9 m.) would have 13 three-station units and with the reduction in block thickness to 4 in. (102 mm.) as well as improved refrigerant distribution and control, a freezing time as low as 3¼ hr. had been achieved, though in practice, 3¾ hr. would be allowed for a complete cycle. On this basis such a plant would have a freezing capacity of 875 lb./hr. (397 kg./hr.) to −20°F (−29°C); if the trawler's beam were increased to 34 ft. (10.4 m.), a further three stations could be accommodated, which would raise the freezing capacity to 945 lb./hr. (430 kg./hr.). Handling of the fish between the buffer storage pounds and the freezers is much reduced with this athwartships layout.

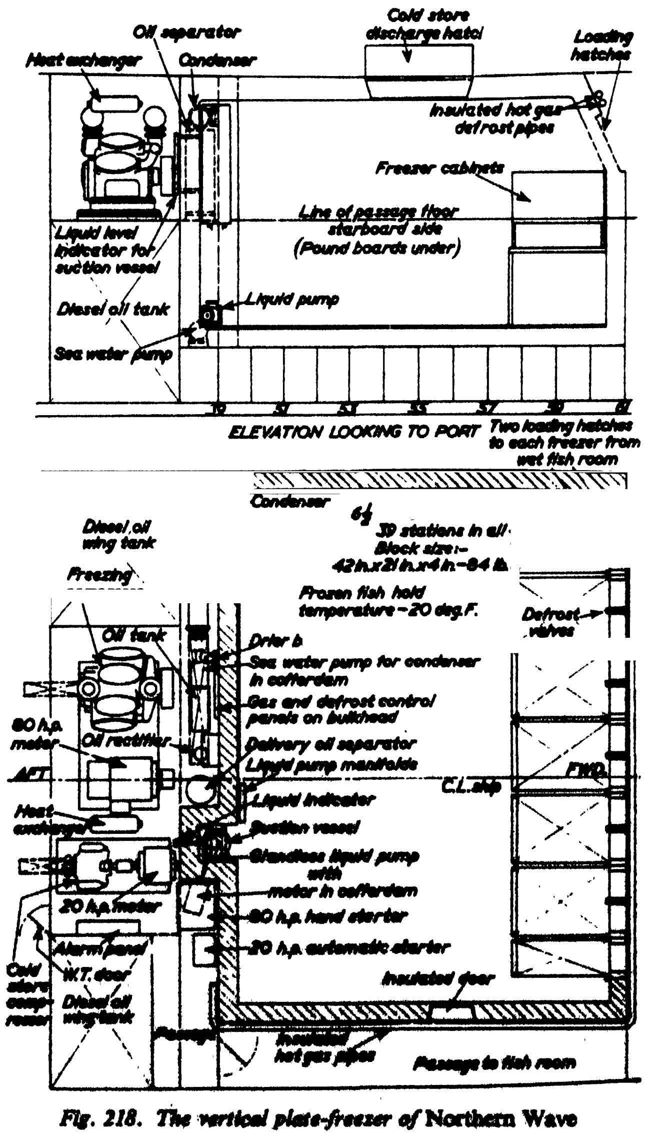


Fig. 218. The vertical plate-freezer of Northern Wave

The *Delaware*'s freezing plant could not be compared directly with that of the *Northern Wave* as it was freezing individual fish from about 1 to 4 in. (25 to 102 mm.) thick. Its capacity on thick fish only was presumably much less than that of the *Northern Wave* plant, a figure below 400 lb./hr. (182 kg./hr.) being likely. Also the temperature of 0°F (−18°C) was much above that found necessary in British practice, where −20°F (−29°C) was gradually becoming standard; this temperature was essential for the long storage of such fish as herring. He would not comment on the relative merits of brine-immersion and plate-freezers, but the former had not found favour in the U.K. for many years past, although it was first used there before 1890 (British Patent No. 6117, dated 9 April, 1889).

installation could only be really satisfactory in a ship specifically designed for the purpose. Conversions were always expensive and almost never ideal.

It had often been said that most of the damage done to fish occured during unloading and subsequent handling on shore, and Slavin gave a graphic description of the unhygienic and primitive methods used today. It was to be hoped that far more thought would be given to this aspect both for fresh and for frozen fish. He looked forward to the day when human hands would not come into contact with the fish at any time after it entered the fish hold up to the time it was prepared for cooling. This was already technically possible for frozen fish though it was not yet current practice. However, wet fish presented a bigger problem, and many changes

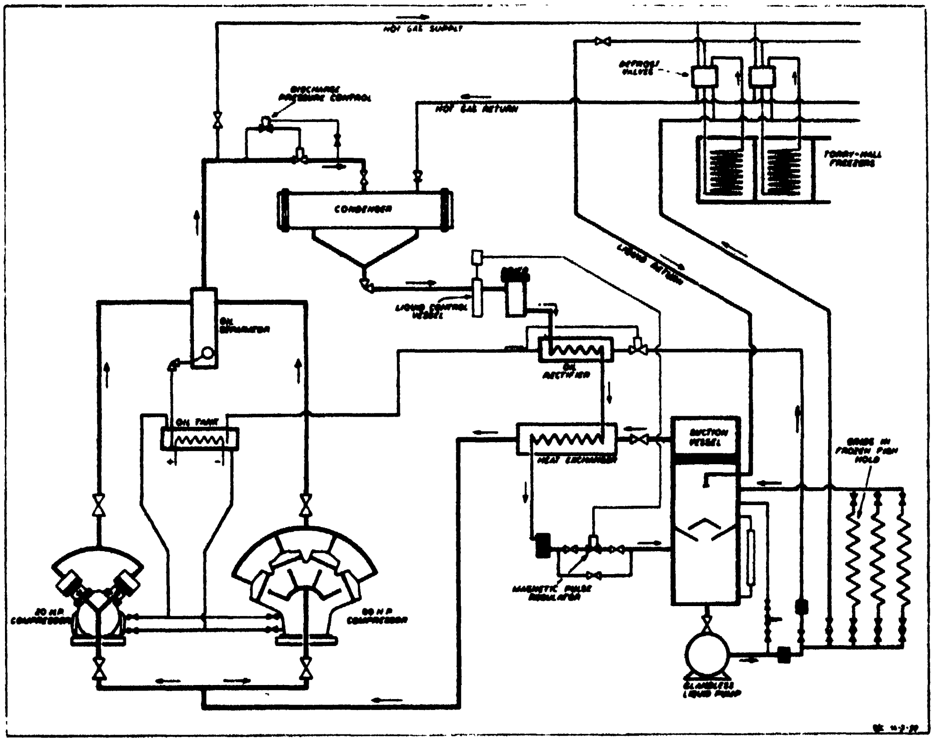


Fig. 219. Proposed refrigerating circuit using single-stage Refrigerant 12 or 22

To achieve the low temperature of −20°F (−29°C) was a considerable technical problem, as simplicity, reliability and ease of operation were essential in such small ships. Theoretically a two-stage refrigeration plant would be the right solution, but it was found that for this application a single-stage Refrigerant 12 (Arcton 6/Freon 12) or Refrigerant 22 (Arcton 4/Freon 22) plant, evaporating at −40°F (−40°C) was preferable and need not occupy excessive space. The proposed basic circuit was shown in fig. 219. In a diesel-electric trawler with a constant-current system, the possibility had been considered of including the freezing compressor as well as the trawl winch motor in the constant-current loop. A fully automatic plant with a single compressor also appeared practical, reliance being placed on capacity reduction and speed control to balance the refrigeration load under all conditions.

Some further information on the above scheme was given in the paper by Eddie. He agreed with Slavin that such an

in the organization and distributing fish would have to be made.

Arcoulis saw no point in using plate-freezers but in the conditions of the Arctic fisheries with very high catching rates, everything possible had to be done to reduce the freezing time while preserving the quality. The vertical plate-freezer could freeze 4 in. (102 mm.) thick blocks in as little as 3¼ hours compared with at least five hours in a freezing tunnel.

It was now common to thaw, fillet, and refreeze such large fish as cod and haddock and little was lost in the process provided that the initial freezing was done within the time limit and to the right low temperature.

Gianesi's very valuable contribution touched on some of the great problems involved in freezing fish in warm waters. Firstly there was the rapid onset of *rigor mortis* which necessitated either very rapid chilling or immediate freezing. In the latter case great difficulties were encountered with rapid frost formation on the tunnel air coolers and this was aggravated by the high atmospheric humidity. This showed the desirability of pre-cooling the fish before freezing, of limiting infiltration to the tunnels, and of air conditioning the working spaces to as low a temperature and humidity as possible, as was proposed for a number of projected designs of factory trawlers.

While appreciating the reasons for the choice of ammonia as the refrigerant he could not agree with Gianesi that this dangerous refrigerant was desirable in a small ship. A Refrigerant 12 or 22 plant either single-stage or two-stage was infinitely preferable and could be just as reliable and fool-proof with careful design. He doubted whether ammonia would be tolerated by any British owner. In ship's rotary boosters followed by high speed V-designs of reciprocating compressor were desirable to save space.

Sir Fred Parkes and Heinsohn had said that frozen fish could not command such high prices as could fresh fish. This had been true in Western Europe and the U.K. principally because of unsatisfactory freezing methods and bad handling of the fish resulting in poor quality. Coupled with this was the fact that no Western European country had a satisfactory organization for marketing frozen fish. When these fundamental points had been dealt with there was no reason to doubt that frozen fish would be able to hold its own against fresh fish, and in many cases surpass it, as had already occurred in U.S.S.R., U.S.A. and Greece. Jul had highlighted the crux of the matter when he said that the customer may eventually be willing to pay the increased cost.

State of ice important

Dr. G. M. Dreosti (South Africa): In commenting upon the use of ice, Ranken has apparently missed both points entirely. The particle shape of the ice naturally cannot affect the amount of cooling that can be obtained from a given weight of ice. That depends on the weight of ice alone. The rate at which fish can be cooled by that weight of ice, however, depends very largely on the particle shape and size of the ice. It is therefore the cooling rate, and not the total cooling effect, that is affected by particle size and shape.

In connection with the washing of used ice he could only say that in South Africa used ice is washed regularly and reused, not in the trawlers but in the railage of fish up country. Ice costs about £1 4s. per short ton, whilst water costs only 5d. per short ton. It is definitely an economical and indeed a very simple procedure. In South Africa it is very practical.

REPLIES OF AUTHORS

Dr. G. A. Reay and Dr. J. M. Shewan (U.K.): They did not wish at this stage to contribute anything further to the discussions other than to make some general remarks. They thought that Dreosti had made several important points in his contribution, particularly with regard to the different rates of cooling of fish in different positions in the hold; under layers of ice of different thicknesses; and when "flake" and crushed block ice are used. His enumeration of the striking advantages claimed for the use of the fish flume on board ship was also read with much interest.

MacCallum commented that fish in some circumstances, and in particular in contact with wood, although chilled with ice can spoil more rapidly than shown in table 45, they would like to have an assurance from MacCallum that he has in fact measured the temperatures of the fish under the circumstances he specified. In their experience it cannot be assumed that fish in direct contact with wood, even although otherwise surrounded with ice, are at 32°F (0°C)—the fish is usually a few degrees higher—and the more rapid spoilage claimed by MacCallum may in fact be due in some measure to a temperature difference.

Answering Proskie: they had not had as yet sufficient experience with chilled seawater to be able to give a balanced opinion as to the merits of this method of chilling as against icing. It is considered, however, that where the age of the first caught fish at landing never exceeds six to eight days, chilling would give as good an article as sea-frozen fish at landing. Moreover, it is doubtful whether it would be feasible or practical economics to instal freezing plant on board such small vessels.

They had no comments to make on Ranken's contributions.

They had noted Slavin's remarks about the effectiveness of washing fish in 60 p.p.m. free chlorine prior to stowage in the hold, and thought it very important that the scientific data on which this claim is based should be made available for all to see. Slavin's further point about the ratio of 1 : 1 for fish and ice being too high might well apply to the vessels whose round trips are not of such long duration as those of the British distant water fleet and to which the values specifically apply.

The several points made by Strakosch as applying particuiarly to conditions of high ambient temperatures are also very illuminating and would repay careful consideration by all interested parties. They serve to show, if nothing else, how difficult it is to generalize on matters affecting stowage of fish in a ship's hold, when the conditions under which the fishing is conducted can differ so widely.

Mr. W. A. MacCallum (Canada): The naval architect will serve the fishing industry well if he applies available knowledge of fish preservation in the design and layout of fish handling and fish holding facilities aboard ship. He can bridge the gap between technology and practical application best by specifying necessary materials, procedures and arrangements when the vessel is in the planning stage. Mr. MacCallum's paper had been prepared to assist him in this important task.

The method described for determining insulation requirements of a fishing craft would appear to be practical, having in mind the need to preserve the catch and to minimize the labour of the hold worker and loss of hold space. Mr. MacCallum wished to stress the need to make a wise choice of water-vapour proof membranes and insulations and to install them correctly. He did not feel that vibrations in the fish hold can be considered extreme and that they would contribute to the breakdown of polystyrene. The latter is reported to have been used with good satisfaction and without ill effects in insulated trucks where vibration intensity is probably higher than that experienced aboard the vessel.

Ranken's comments are appreciated. His report to the effect that a U-value of 0.15 BTU/hr./sq. ft./°F (0.734 kcal./hr./sq. m./°C) is commonly used in U.K. for calculating heat leakage is significant. One might well question but not necessarily condemn a practice which provides about half the effective insulation considered to be necessary for 32°F (0°C) storages on land.

It may easily be shown that if a wall in a steel vessel were insulated between the flange of the frame and the inner lining of the fish room to a depth of 1 in. (25 mm.) and the spaces between frames were insulated to give an over-all U-value of 0.15 BTU/hr./sq. ft./°F, the depth of crushed ice actually required under the otherwise unaltered conditions set out in table 50 would be 2.3 in. (58 mm.). A saving of 3.4 in. (86 mm.) of crushed ice or 5.1 short tons (2,000 lb.) per 1,000 sq. ft. (5.0 ton per 100 sq. m.) of surface area of insulated wall would be possible over the case where the wall was not insulated.

A U-value of 0.15 BTU/hr./sq. ft./°F corresponds to an effective depth of corkboard of about 1½ in. (37 mm.) only, where the insulation is incorporated into a fish hold wall (steel vessel). It is apparent that if minimal depths of insulation such as 2 to 4 in. (51 to 102 mm.) are used the greater portion of the insulation should be placed between the flange of the frames or stiffeners and the inner lining of the fish hold, otherwise a U-value of 0.15 BTU/hr./sq. ft./°F will not be realized. It would be better still to insulate as heavily as economically feasible between as well as over frames. This should be more feasible now than ever before as a result of the development of suitable light-weight insulation.

Theoretically, the jacketed fresh fish hold need not be a space waster. It could save space. Practice could match theory if the naval architect were to provide a fish room uniformly full from fore to aft. The Gregson system and the polyurethane foams which can be incorporated into jacketed fish rooms appear to be quite adequate as far as providing water-tightness. In Mr. MacCallum's opinion multiple unit pens could be incorporated also into a jacketed design which would have many pleasing and practical features. There seems little reason to doubt the success of the jacketed room from the engineering standpoint. Experience to date is not that alternatives to conventional construction are not satisfactory but that owners are loath—and naturally so—to increase capital expenditure when ice can be used successfully in place of a mechanically refrigerated jacket. In this connection it may be noted that builders have been under little or no pressure to develop cost saving techniques in jacketed hold construction. At any rate, radically changed techniques of hold construction in metal are apt to be fairly costly where vessels of a particular design are ordered in limited numbers.

As suggested in his paper it may become common practice to specify metal for stanchions, divisions and portable boards and strong, durable, corrosion-resistant, non-metallic, water-tight materials for ceilings and walls of the fish room. Latex-sand-cement compositions and glass fibre reinforced plastics are two possibilities for the latter application. Latex-sand-cement should be placed over a rigid sub surface. Reinforced plastics may be used in the same way or in a self-supporting structure. Too few applications of either material have yet been made however to give a good cost comparison with metals, e.g. aluminium alloys, for the construction of water-tight jackets.

Mr. MacCallum concurred with Reay's and Shewan's comments in their paper as to the role of deck grid refrigeration. It is his personal opinion that, in many instances, a very good case can be made for the use of a jacketed wet fish room.

Slavin, Eddie (1958 b) and he was in agreement as regards the arrangement and design of stanchions to permit interchangeability of pen boards. However, he did not feel that one should assert categorically that a fish room is best if it can be "built" and "torn-down" by the fishermen before, during and after each trip. "Wings" or portions of wings (transverse partitions) in aluminium alloys should be of movable boards when it is more convenient to ice and discharge the catch with such an arrangement that when partitions are wholly fixed and when this advantage is balanced against (1) the increased cost of handling and cleaning the boards, (2) shorter service life of the movable board as compared to the fixed sheet, (3) the more pleasing appearance of the fixed sheet throughout its service life. On the larger trawler there can be a distinct advantage in having the inboard section of the wing of each pen "built" of movable aluminium alloy boards while on medium and smaller trawlers there may be a distinct advantage in having fixed or permanent wings of aluminium alloy sheet; on trawlers of all sizes movable boards for "back halves" of wings (these being the sections between the outermost longitudinal row of stanchions and the ceiling) must be of various lengths and in the metal fish room are generally avoided, being replaced by fixed sheets. Everything else being equal, as many movable boards as can be handled conveniently and economically should be used in the wooden "wet" fish room since those responsible for maintenance may wash, dry and refinish these elements and operate a system which makes reconditioned boards available for installation at all times.

Mr. MacCallum was pleased to have the results of Prunchie's laboratory tests of catalyzed finishes. It would be expected that their superiority over the others tested would be apparent, but in reduced measure, in fish hold applications. His experience with catalyzed finishes in the fish room was that they keep the wood covered for longer periods between refits than do conventional paints if they are applied under conditions favourable to their setting. However, they are not considered permanent nor do they prevent the underlying wood from gaining moisture. To make laboratory tests more useful to the buyer of the product, modifications of presently used accelerated tests would have to be made and results should be expressed in such terms as guaranteed fish room surface covering characteristics for a given period for various grades and species of wood, with moisture content of the wood, and temperature and humidity conditions at time of applying and curing the paint being specified.

Slavin has again pointed out the perennial difficulty—the inability to keep wet wood covered with paint. The paint chemist has not solved this problem. Possible alternatives were:

Use wood: (a) in movable sections or boards which may be removed and dried thoroughly, albeit at high cost; (b) in fixed partitions, sides of fish hold, etc. only when it can be covered with screens, metal boards and painted wooden boards (all of which would be movable). In this case the lack of paint on the hidden surface has no effect on fish preservation.

Use materials other than wood which do not require painting, e.g. aluminium alloys, fibre glass, reinforced plastic.

Regarding Slavin's question on cleaning screens, Mr. MacCallum had not received reports of difficulties. It is quite probable that the frequency of removal of screens for cleaning need not be too great and most certainly will not be as great as that for movable boards. This should be the subject of a later report.

Strakosch has referred to the use of zinc sheathing (¾ to 1 mm. thickness) in fish holds. One would expect the material, if suitably joined, to be satisfactory for some applications, particularly where fish are handled in small boxes. The gauge mentioned would be far too light for "wet fish" rooms where fish and ice and ice alone are stored in bulk.

In the case of materials such as aluminium alloys, glass fibre reinforced plastics and plastic paints which are all new in the sense that shipbuilders are not too familiar with their use, the naval architect should know practically as much about the material and its use as the manufacturer, so that through design and installation techniques full advantage can be taken of the material. In this way failures which in truth might be the fault of the architect or the shipyard and not of the material itself, may be avoided.

Fish handling and storage space and timber ventilation in small boats—despite the worldwide importance of the latter —have been neglected heretofore by the naval architect and the technologist. Mr. MacCallum had analyzed certain types of small boats, both decked and undecked, in these respects. It is hoped that this may serve as a basis of discussion for the naval architect and the prospective owner of a new vessel.

He concurred in the opinions expressed throughout the the proceedings concerning the desirability of reducing the amount of strenuous work and of providing less onerous conditions aboard the vessel. Progress towards this goal could be made by giving the fishermen:

- Uniform and fully shaped fish-rooms from fore to aft, uniform boxes or uniform fish pens with uniform and interchangeable boards
- A practical method for handling larger catches in boxes
- A clean or protected (as with screens) fish room and fish containers made of materials which can be kept clean
- Insulation and refrigeration facilities to enable fish room air and surface temperatures to be kept at the desired level
- Suitable ice and means of handling it more easily

MR. J. W. SLAVIN (U.S.A.): There is no question that the fishing problems for each part of the world differ considerably. Freezing fish at sea, as Arcoulis pointed out, may solve many of Greece's fishing problems and provide that country with a plentiful supply of high quality raw material Yet, in other parts of the world, icing may be just as satisfactory. Therefore, only for evaluating, for each particular fishery, the factors of handling aboard the vessel, storage on the vessel, unloading and handling ashore, quality of the product and the associated costs can one determine whether freezing or icing is the most satisfactory.

Several of the contributors mentioned that the *Delaware* and *Northern Wave* are experimental vessels and thus as such should not be used as a basis for determining the success of freezing at sea. This is not completely true for only by comparing techniques used on these experimental freezer vessels with those used on conventional icing trawlers can remedies for existing problems be offered by naval architects, engineers, technologists and vessel owners and operators.

Eddie in his contribution made the interesting observation that the fish frozen on the *Northern Wave* were soft because of biological factors due to catch areas, not because of the freezing process. This is a good point and shows that in freezing fish at sea much thought must be given to the differences in fish quality due to biological factors. Mr. Slavin mentioned that during a recent trip to England, he had a chance to view plate-frozen fish that were caught in a different area than those in the *Northern Wave* project; these fish were of very good texture.

Eddie's statement that high grade products cannot be made by brine immersion freezing and cold storage at 0°F (−18°C) is without foundation. Fish brine-frozen immediately after catching and then stored at 0°F are of excellent quality. Also, storage at −20°F (−29°C) may only be necessary if the fish are iced for several days prior to freezing, as they were on the *Northern Wave.* In the U.S.A., temperatures of −20°F (−29°C) are not practical for storing fish if they are to be marketed along with other frozen foods.

It was good to learn from Eddie that fish can be satisfactorily plate-frozen prior to *rigor mortis* and that it is not always necessary to wait until they pass through this stage of *rigor mortis* until the start of freezing. In U.S.A. it was found that freezing immediately when caught is essential in order to obtain a high quality product.

It is true that the *Delaware* fish were produced to compete with fish that are normally marketed in the form of frozen fillets, whereas *Northern Wave* fish were produced to compete with wet or smoked fish. However, it was observed that fillets from thawed brine-frozen fish compared quite favourably to freshly landed fish. Also, Eddie implied that after a given number of days, the quality of fish on U.K. vessels seems to be higher than on vessels operating along the Western Seaboard of the Atlantic and that this influences the standard for comparison of sea-frozen fish. In evaluating this standard of comparison, Mr. Slavin pointed out that the length of time the fish are stored on the vessel is of prime importance and that, because of the long distance that British fishing vessels have to travel to and from the fishing grounds, fish landed in the U.K. are generally of much lower quality than those landed along the Western Seaboard of the Atlantic; he therefore could not agree with Eddie that the overall standard of comparison for evaluating fish frozen at sea for the *Northern Wave* project was higher than for the *Delaware* project. The studies now underway in the U.K. on dielectric thawing of frozen fish are very interesting. This work should be closely appraised for possible application in other freezing processes.

In regard to Ranken's discussion, it is difficult to determine what is meant by the capacity of thick fish. It is the overall rate of freezing (the number of pounds of fish that can be handled each hour) that is important, not the thickness of the fish or layers of fish. This is only important because it contributes to the rate of freezing. The rate of freezing should be equal to the mean catch rate in order to provide rapid handling of the fish and to minimize loss of quality. In this regard, the increase in freezing capacity recommended for future British freezer trawlers of over 875 lb./hr. (397 kg./hr.) is a step in the right direction. Mr. Slavin now recommends that freezer trawlers for the New England fishery have a freezing capacity of at least 3,000 lb. (1,360 kg.) of fish per hour.

In regard to Mitsui's questions, on the *Delaware*, the baskets of fish were moved through the cold brine and the appearance of these fish was quite satisfactory. The fillets prepared from the brine-frozen fish had lost the bright sheen of regular iced fish; this, however, was not considered to be objectionable. Also, buffer storage refers to the hold where the fish on the *Northern Wave* were iced and stored for one to three days after being caught and prior to freezing. Details of the plate-freezing unit can probably be obtained from the Torry Research Station, Aberdeen, Scotland, U.K.

In response to O'Meallain's question on water-thawing, this method has proven to be quite satisfactory for both haddock and cod; the thawed product being of very firm texture. These results may be influenced by the fact that the brine-frozen fish became quite firm due to the freezing process and, therefore, did not soften as much during water-thawing as did fish that were frozen by other more conventional means.

It was most interesting to learn from Arcoulis and Gianesi of the freezing of fish at sea on Greek fishing trawlers. More information would be desirable on the species of fish now being frozen on these vessels and on the methods for handling these fish on the vessel, and for thawing and storing them ashore.

PROPULSION ENGINES FOR FISHING BOATS

by

IVAR B. STOKKE

The designs of two-stroke and four-stroke diesel engines are compared, giving the advantages and disadvantages and indicating that the two-stroke full-diesel engine may give 60 to 70 per cent. more power than a normally aspirated four-stroke engine of the same cylinder volume and r.p.m. Scavenging is simpler in a four-stroke diesel, especially by supercharging. Supercharging of the four-stroke diesel is discussed, and it is stated that 60 to 100 per cent. more power can be obtained thereby. The high pressure supercharged four-stroke engine is a good competitor to the fully scavenged two-stroke engine. If, however, the two-stroke is supercharged, it will give a mean effective pressure of 85.5 to 99.5 lb./sq. in. (6 to 7 kg./sq. cm.), which is equivalent to 171 to 199 lb./sq. in. (12 to 14 kg./sq. cm.) for a high supercharged four-stroke diesel engine.

Recent developments in this field are dealt with, and a comparison of the space requirements for the various propulsion arrangements for trawlers is discussed. The reverse reduction gear with two reduction ratios ahead is discussed, as well as the controllable-pitch propeller with direct drive to the propeller. It is mentioned that a controllable-pitch propeller is better suited for this propelling system than a fixed-blade propeller when considering the various propulsion requirements for trawling and sailing.

If the conventional electric drive of the trawl winch is replaced by hydraulic drive, the space requirements will decrease. The hydraulic winch drive is more simple, robust and elastic and is therefore better suited for hard working conditions, especially those met in colder regions where trawling is often taking place.

A short outlook into the future development with diesel-electric propulsion, free piston gasifiers and gas turbines for big trawlers is given. It is warned against using too fast-running engines (1,500 to 2,200 r.p.m.) for fishing craft propulsion, because these light-built engines cannot stand the hard night and day working conditions without being worn down quickly.

MOTEURS DE PROPULSION POUR LES NAVIRES DE PÊCHE

L'auteur compare les conceptions des moteurs diesel à 2 temps et à 4 temps en donnant leurs avantages et inconvénients. Il indique que le moteur diesel à 2 temps peut fournir une puissance plus élevée de 60 à 70% qu'on moteur à 4 temps à alimentation normale et ayant la même cylindrée et le même nombre de t.p.m. Le balayage est plus simple dans un diesel à 4 temps, spécialement par suralimentation. La suralimentation du diesel à 4 temps est examinée, et l'auteur déclare que l'on peut ainsi obtenir une puissance plus élevée de 60 à 100%. Le moteur à 4 temps suralimenté sous pression élevée est un bon concurrent pour le moteur à 2 temps à balayage total. Cependant, si le 2-temps est suralimenté il donne une pression efficace moyenne de 85,5 à 99,5 lb/pouce carré (6 à 7 kg./cm²) qui est équivalente aux 171 à 199 lb/pouce carré (12 à 14 kg./cm²) pour un moteur diesel 4 temps à suralimentation poussée.

Il est traité des récents développements dans ce domaine et l'auteur examine la comparaison des exigences d'espace pour les divers dispositifs de propulsion pour les chalutiers. Le réducteur à renversement de marche avec deux rapports de réduction en avant est comparé à l'hélice à pas variable avec entraînement direct de l'hélice. Il est mentionné qu'une hélice à pas variable convient mieux pour ce système de propulsion qu'une hélice à ailes fixes quand on considère les diverses exigences de propulsion pour le chalutage et la route libre.

Si l'entraînement électrique courant du treuil de chalut est remplacé par l'entraînement hydraulique, cela diminue les exigences d'espace. L'entraînement hydraulique du treuil est plus simple, plus robuste et plus élastique, et il convient donc mieux pour les conditions de travail dures, spécialement celles recontrées dans les régions froides où on chalute souvent.

L'auteur donne un court aperçu du développement futur de la propulsion diesel électrique, par turbines à gaz et générateurs à pistons libres pour les gros chalutiers. Il met en garde contre l'emploi de moteurs trop rapides (1,500 à 2,200 t.p.m.) pour la propulsion des bateaux de pêche, parce que ces moteurs de construction légère ne peuvent pas supporter les dures conditions de travail nuit et jour sans être rapidement usés.

MAQUINARIA PROPULSORA PARA BARCOS DE PESCA

Se comparan los proyectos de motores Diesel de 2 y 4 tiempos; se citan sus ventajas e inconvenientes y se menciona que un motor Diesel de 2 tiempos puede rendir de 60 a 70% más potencia que un motor de 4 tiempos aspirado normalmente, de iguales cilindrada y r.p.m. La evacuación es más sencilla en el motor de 4 tiempos, particularmente por sobrealimentación. Se examina la sobrealimentación del Diesel de 4 tiempos y que se afirma que con ella se puede obtener de 60 a 100% más fuerza motriz. El motor de 4 tiempos, sobrealimentado, de gran presión, es un buen rival del motor de 2 tiempos. Pero si se sobrealimenta el motor de 2 tiempos, dará una potencia efectiva media de 85,5 a 99,5 lb./pulg² (6 a 7 kg./cm²), que equivale a entre 171 y 199 lb./pulg² (12 y 14 kg./cm²) para un motor Diesel de 4 tiempos muy sobriealimentado.

Trata el autor de los últimos adelantos en este sector y comenta una comparación de varias clases de propulsión para arrastreros. Se examina el engranaje reductor con marcha atrás con 2 relaciones de reducción en marcha avante y se compara con la hélice de paso variable accionada directamente. Al considerer las diversas necesidades de fuerza motriz en pesca y en ruta, se menciona que la hélice de paso variable es más adecuada para la transmisión directa que la de palas fijas.

Si en lugar de la transmisión eléctrica normal de la maquinilla de pesca se emplea la hidráulica, se reducen las necesidades de espacio. La transmisión hidráulica de la maquinilla de arrastre es más sencilla, robusta y elástica y, por tanto, más conveniente para las condiciones de trabajo duras, especialmente las que se encuentran en las regiones frías en las que se pesca mucho al arrastre.

Se menciona brevemente el futuro de la propulsión Diesel eléctrica, gasificadores de pistón libre y turbinas de gas para arrastreros grandes. Se hace una advertencia contra el empleo de motores muy revolucionados (1.500 a 2.000 r.p.m.) para la propulsion de pesqueros, porque estos motores ligeros se gastan rápidamente cuando se someten a las duras condiciones de trabajo diarias.

URING recent years there have been rapid in propulsion engines for fishing vessels, not only in design but also in the use of better materials, fuel and lubricating oils.

There is still competition between the four-stroke and the two-stroke systems. The two-stroke is simpler in design, especially with Curtis or loop scavenging. But the design becomes more complicated when the scavenging and exhaust ducts are placed both in the cylinder liner and in the cylinder block. This design also requires many seals, especially between the cooling space and the exhaust and scavenging ducts, and that complicates the maintenance. Some of these difficulties are not great in very big two-stroke diesels, where the ducts can be finished after the cylinder liner has been placed in the cylinder block. It is important to design cylinder liners with the least possible concentration of material around the scavenging and exhaust ducts (Stokke, 1957).

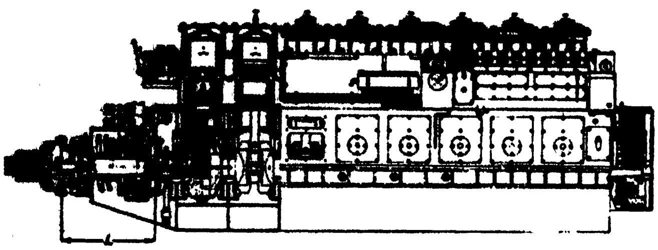


Fig. 220. Wichmann engine, with built-in hydraulic reverse gear

COMPARISON OF TWO- AND FOUR-STROKE DIESELS

The two-stroke system with uniflow scavenging has scavenging ducts in the lower part of the liners, while the exhaust gas escapes through valves (or a valve) in the cylinder cover. This results in a more constant temperature in the cylinder liner and improved lubrication of the cylinder wall. The wear on the cylinder liners is also decreased because the exhaust escapes the shortest way. The piston top is also better cooled by cold air. Uniflow scavenging requires a longitudinal camshaft to operate the exhaust valves, but the injection pumps, etc., can also be driven from this camshaft so that one pump can be placed near each cylinder. The fuel pipes to the nozzles will be short, facilitating efficient working conditions for the injection equipment. The tightening arrangements between the cylinder liner and the cylinder block are simpler. There is a similar simplification and better shape of the scavenging and exhaust ducts when the cylinder liner itself has a cooling water space (Wichmann). The same is true for the ducts of the two-stroke diesel with separate cylinders, but with a smaller cooling space in each cylinder (Alpha). This, however, makes the distance between the cylinders somewhat greater. Such a design is normally only used for cylinders with a bore diameter up to about 10½ to 11½ in. (270 to 290 mm.) because in larger engines a cylinder liner with cooling space could be too expensive to maintain if not chromium plated.

A two-stroke engine with the same r.p.m. and cylinder volume as a normally aspirated four-stroke engine may produce about 60 to 70 per cent. more h.p. Indeed, it can be built somewhat smaller, and is simpler in construction and easier to maintain. The length of the two-stroke is increased if a scavenging pump is used on the free end (Alpha) but not if a rotating scavenging pump is placed on the side (Wichmann). The scavenging pumps can also be placed in front of each cylinder (Sulzer).

The lubricating oil consumption of two-stroke engines was once considered to be too high, but a modern two-stroke compares favourably with that of a four-stroke. Improved oil film conditions, etc., for the cylinders have overcome many of the problems, especially the coking of the exhaust ducts.

The spacing of the cylinders, i.e. the distance between the axes of two adjacent cylinders on the four-stroke is from about 1.4 to 1.6 D (D=diam. of the cylinder bore) as compared with 1.7 to 1.9 D for the two-stroke engine. The low values will be attained for the two-stroke engine with uniflow scavenging and the high with Curtis scavenging, the cooling water space being in the cylinder liner itself.

The four-stroke cylinder liner has no scavenging and exhaust ducts and can be of uniform thickness and thus evenly cooled, which is important, particularly for uncooled pistons. There will be a better lubricating film and the liner wall will be less fouled by exhaust, with longer time between overhauls of the piston as the result.

The four-stroke engine has, therefore, some advantages compared with the two-stroke, especially if the two-stroke has a symmetrical scavenging and exhaust steering diagram.

SUPERCHARGING OF DIESELS

It is easier to build a four-stroke diesel with supercharging than a two-stroke trunk-piston engine with a symmetrical steering diagram. This, and the rapid development of supercharging equipment has an effect on the competition between the supercharged four-stroke and two-stroke full diesel engines. Supercharging will

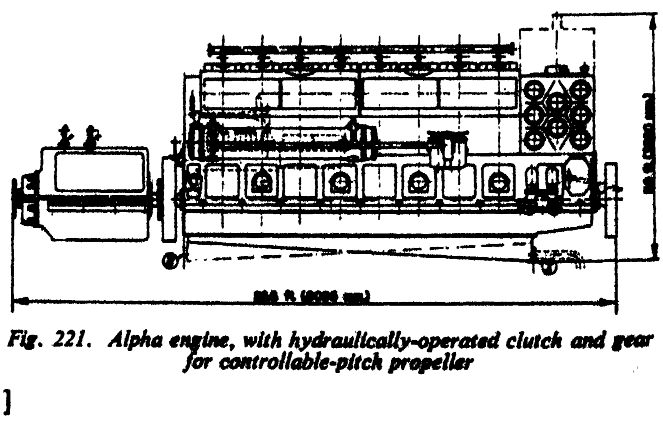


Fig. 221. Alpha engine, with hydraulically-operated clutch and gear for controllable-pitch propeller

increase the output of a normally aspirated four-stroke diesel by 60 to 100 per cent. When the charging air pressure is higher than about 8.5 lb./sq. in. (0.6 kg./sq. cm.) it is easy to cool the air with sea water and the temperature of the supercharged four-stroke can be decreased (Stokke, 1958a). The thermal loading of a supercharged engine may even be lower than that of a not supercharged one, and the fuel consumption will decrease by about 6 per cent. The maximum combustion pressure will, however, increase a little, but not in proportion to the increased power because the scavenging efficiency is very good. The increased oxygen concentration in combustion reduces the ignition lag, and thus the maximum combustion pressure. The engine will burn heavier and cheaper fuel, if the cylinder dimensions are large enough, and a higher cooling water temperature can be maintained by fresh-water cooling. The air and exhaust valves with the necessary valve gear might make the four-stroke engine more expensive to build, but in maintenance costs it compares favourably with the two-stroke.

It is possible to make a supercharged two-stroke engine, but a turbine blower driven by the exhaust gas will not deliver sufficient air at lower engine loads, so an auxiliary scavenging pump is often necessary.

The supercharged four-stroke diesel engine has become a keen competitor of the fully scavenged two-stroke with Curtis or loop scavenging, especially for trawlers of about 165 to 215 ft. (50 to 65 m.) overall length.

If a normally aspirated four-stroke diesel of 70 BHP per cylinder is supercharged, and the power can be increased by 75 per cent., it will produce about 123 BHP per cylinder. Eight cylinders will therefore give about 980 BHP, suitable for a trawler.

A normally aspirated four-stroke with 70 BHP per cylinder has a continuous mean effective pressure (p_e) of 81 lb./sq. in. (5.7 kg./sq. cm.). With supercharging, the p_e will be 142 lb./sq. in. (10 kg./sq. cm.).

A comparable normally aspirated fully scavenged two-stroke engine has a continuous p_e of about 64 lb./sq. in. (4.5 kg./sq. cm.). To attain the same output as the supercharged four-stroke, the two-stroke engine has to be overcharged to a p_e of 71.12 lb./sq. in. (5 kg./sq. cm.) by, for instance, the use of oscillating flaps in the exhaust ducts (Wichmann). The flaps are however omitted by the

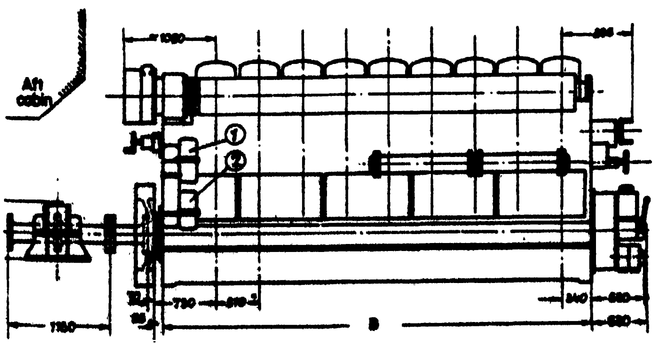


Fig. 222. MAN supercharged four-stroke diesel engine

newer types by tuning the exhaust system thoroughly, especially by turbocharged engines. But as the two-stroke engine is still using a mechanically-driven piston scavenging pump (or pumps) or a mechanically driven Roots or centrifugal blower, the specific fuel consumption will be about 5 per cent. higher than for the supercharged four-stroke engine. This difference can, however, be overcome by an exhaust-driven, constant-pressure supercharger (Wichmann) which will increase the output by at least 25 per cent. That would give a p_e of 89 lb./sq. in. (6.25 kg./sq.cm.) which is equivalent to a mean pressure of 178 lb./sq. in. (12.5 kg./sq. cm.) of a highly super-

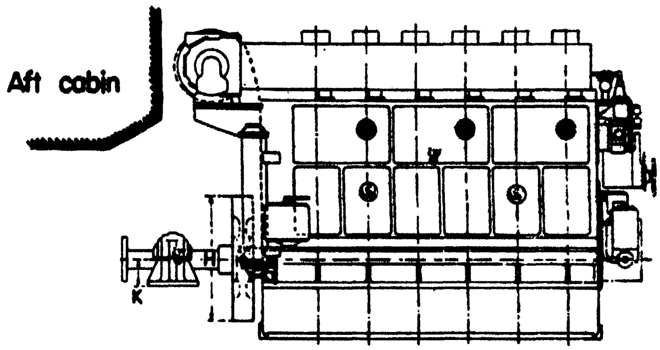


Fig. 223. Werkspoor supercharged four-stroke diesel engine

charged four-stroke engine. Both engines will have to cool the charging air and their fuel consumption will be equal.

COMPARISON OF TYPICAL ENGINES

Table 65 gives cylinder dimensions, the normal output in BHP (metric) and the corresponding r.p.m. by continuous day and night rating for some four-stroke and two-stroke diesel engines used in fishing boats. The table also gives the stroke/bore ratio (S/D), the weight per unit h.p. and the number of cylinders.

(a) **Cylinder spacing.** The table shows that a two-stroke diesel engine with Curtis scavenging and the cooling water space in the cylinder liner (Wichmann) has a cylinder distance of about 1.9 D (D=the cylinder bore). A similar fully scavenged diesel engine with separate cylinders (Alpha) has about the same cylinder distance. On the other hand, a two-stroke diesel with uniflow scavenging has a distance of 1.7 D and a four-stroke has 1.4 to 1.6 D (1.7 for the Vølund four-stroke engine).

(b) **Stroke/bore ratio.** The length of a diesel also depends on the stroke/bore ratio. The four-stroke engine is often designed with a lower stroke/bore ratio of 1.2 to 1.45 to provide enough space for the valves. The two-stroke engine stroke/bore ratio is from 1.5 to 1.72. The four-stroke Mirrlees diesel has a S/D=1.2 and two air and two exhaust valves, while the Werkspoor four-stroke engine has a S/D=1.82. This is rather high and can result in too small an air valve space in a highly supercharged engine. A lower stroke/bore ratio results

TABLE 65

Engine make and type	*Two- or four-stroke*	*Number of cylinders*	*Normal rating—BHP*	*r.p.m.*	*Cyl. Bore* in.	*Cyl. Bore* mm.	*Stroke* in.	*Stroke* mm.	*Total cyl. volume* cu. in.	*Total cyl. volume* l.	*Ratio Stroke/Bore*	*Ratio Distance between cyl. centre lines/Bore*	*Mean piston speed* ft./sec.	*Mean piston speed* m./sec.
B & W Alpha 496 VO	2	6	720	310	11.41	290	19.29	490	11,820	194.0	1.69	1.85	16.60	5.06
„ 498 VO	„	8	960	„	„	„	„	„	15,740	258.0	„	„	„	„
Wichmann 6 ACA	2	6	600	350	11.02	280	16.54	420	9,490	155.4	1.50	1.93	16.07	4.90
„ 8 ACA	„	8	800 [1]	„	„	„	„	„	12,630	207.2	„	„	„	„
Bergen Diesel RP 8	4	8	400	450	9.84	250	14.17	360	8,600	141.2	1.44	1.63	17.72	5.40
„ RTP 8	„	„	495	390	„	„	„	„	„	„	„	„	15.42	4.70
Deutz R/V 8M545	4	8	660/521	380/300	12.60	320	17.72	450	17,690	290.0	1.41	1.38	18.70/14.76	5.70/4.50
„ R/BV8M545	„	„	1,060/837	„	„	„	„	„	„	„	„	„	„	„
MAN G 8V30/45	4	8	910/765	360/300	11.81	300	17.72	450	15,530	254.4	1.50	1.70	17.72/14.76	5.40/4.50
„ G 9V30/45	„	9	1,025/860	„	„	„	„	„	17,480	286.2	„	„	„	„
Mirrlees KSSDM 6	4	6	993	300	15.00	381	17.99	457	19,120	313.5	1.20	1.61	14.99	4.57
„ KSSDM7	„	7	1,160	„	„	„	„	„	22,270	365.0	„	„	„	„
Sulzer 8BW29	4	8	600	500	11.41	290	14.17	360	11,620	190.4	1.24	1.66	19.69	6.00
„ 8BAW29	„	„	950/1,200	„	„	„	„	„	„	„	„	„	„	„
Vølund DM 830	4	8	600	375	11.81	300	16.14	410	14,150	232.0	1.37	1.70	16.83	5.13
„ DMT 830	„	„	880	„	„	„	„	„	„	„	„	„	„	„
Werkspoor TMAS336	4	6	600	300	12.99	330	23.62	600	18,820	308.5	1.82	1.61	19.69	6.00
„ TMABS336	„	„	870	„	„	„	„	„	„	„	„	„	„	„

[1] Maximum output in about one hour: 1,000 BHP at 375 r.p.m. with a mean effective pressure of 82.5 lb./sq. in. (5.8 kg./sq. cm.)
[2] Length from front of engine to aft of flywheel

in a lower mean piston speed (for instance 15 ft./sec. or 4.57 m./sec. for Mirrlees as compared with 19.7 ft./sec. or 6.0 m./sec. for the Werkspoor) which is an advantage. A moderate piston speed will decrease cylinder wear.

The normally aspirated Werkspoor engine has a mean effective pressure of 83.4 lb./sq. in. (5.86 kg./sq. cm.) while the p_e is only 121 lb./sq. in. (8.5 kg./sq. cm.) for the supercharged engine, which might depend on the high S/D ratio.

(c) **Influence of manoeuvring gear (Alpha and Wichmann).** Table 66 gives the main characteristics of eight supercharged two- and four-stroke diesel engines. The weights of the Alpha and the Wichmann diesels include the hydraulic equipment. The Alpha has the hydraulic operated clutch and gear for the controllable-pitch propeller, etc., in a box which results in a comparatively long engine, as shown in fig. 221. All the hydraulic equipment of the Wichmann engine is built in,

TABLE 65 (*continued*)

Mean effective pressure (p_e)		Unit weight		Total length of engine		Arrangement of thrust bearing: Inside engine = I Outside engine = O	Comments
lb./sq. in.	*kg./sq. cm.*	*lb./BHP*	*kg./BHP*	*in.*	*mm.*		
76.52	5.38	82.01	37.2	269.29	6,840	I	Piston scavenging pump. Curtis scavenging. Separate cylinders. Controllable-pitch propellers.
,,	,,	77.60	35.2	318.70	8,095	,,	
71.12	5.00	62.39	28.3	201.18	5,110	,,	Roots blower. Curtis scavenging. Controllable-pitch propeller
,,	,,	57.98	26.3	243.70	6,190	,,	
79.65	5.60	80.03	36.3	209.92	5,332	,,	Controllable pitch propeller
113.79	8.00	66.80	30.3	204.71	5,206	,,	43 per cent. increase in BHP by supercharging
76.81	5.40	—	—	200.79	5,100	,,	Direct reversible
123.32	8.67	49.82/63.27	22.6/28.7	,,	,,	,,	60 per cent. increase in BHP by supercharging
128.01	9.00	—	—	265.35 224.02 [3]	6,740 5,690 [3]	O	50 per cent. increase in BHP by supercharging. MAN turboblower. Direct reversible
,,	,,	51.37/61.29	23.3/27.8	285.43 244.09 [3]	7,250 6,200 [3]	,,	
135.12	9.50	89.29	40.5	300.00 227.96 [3]	7,620 5,792 [3]	,,	70 per cent. increase in BHP by supercharging. B.B. turboblower with air cooler. Direct reversible.
,,	,,	83.55	37.9	326.97 261.02 [3]	8,305 6,630 [3]	,,	
80.65	5.67	91.05	41.3	—	—	In the gear	Reversible reduction gear [4]
127.73/161.43	8.98/11.35	64.82/53.35	29.4/24.2	ca.295.67 ca.234.25 [3]	ca.7,510 ca.5,950 [3]	,,	58.2/100 [3] per cent. increase in BHP by supercharging
88.19	6.20	107.37	48.7	258.27	6,560	I	Controllable pitch propeller
129.43	9.10	78.00	35.3	,,	,,	,,	46.5 per cent. increase in BHP by supercharging
83.35	5.86	104.72	47.5	225.39 176.77 [3]	5,725 4,490 [3]	O	Direct reversible
120.90	8.50	76.5	34.1	225.39 176.77 [3]	5,725 4,490 [3]	,,	45 per cent. increase in BHP by supercharging

[3] The engines with 100 per cent. increase of BHP by supercharging are of the type BCAW 29. These engines have B.B. turboblowers with air cooling

[4] With two reduction ratios ahead, the propeller r.p.m. is either 204 or 246

which reduces its overall length, as shown in fig. 220. Engines which are directly reversible and, consequently, have a fixed-blade propeller, are usually somewhat shorter than those with controllable-pitch propellers.

(d) **Deutz.** The p_e of the Deutz four-stroke engine, type R/V8M 545 in table 65, is 76.8 lb./sq. in. (5.4 kg./sq. cm.). The supercharged Deutz (table 66) with a p_e of 123 lb./sq. in. (8.67 kg./sq. cm.) has a 60 per cent. increased output.

(e) **MAN.** The G9V 30/45 MAN four-stroke in table 66 has 9 cylinders with a cylinder volume about the same as the Deutz.. The p_e with supercharging is 128 lb./sq. in. (9 kg./sq. cm.) compared with the normal 85.4 lb./sq. in. (6 kg./sq. cm.); so supercharging increases this engine's output by 50 per cent. If the p_e of the normally aspirated engine is reduced to 81 lb./sq. in. (5.7 kg./sq. cm.) the increase by supercharging will be about 60 per cent., which can perhaps be reached without air

TABLE 66

Main characteristics of sea

Engine make and type	*Two- or four-stroke*	*Number of cylinders*	*Normal rating—BHP*	*r.p.m.*	*Cyl. Bore* in.	*Cyl. Bore* mm.	*Stroke* in.	*Stroke* mm.	*Total cyl. volume* cu. in.	*Total cyl. volume* l.	*Ratio Stroke/Bore*	*Ratio Distance between cyl. centre lines/Bore*	*Mean piston speed* ft./sec.	*Mean piston speed* m./sec.
B & W Alpha 497 VO	2	7	840/813	310/300	11.41	290	19.29	490	13,820	226.5	1.69	1.85	16.60/16.07	5.06/4.90
Wichmann 8 ACA	2	8	800/686 [1]	350/300	11.02	280	16.54	420	12,630	207.2	1.50	1.93	16.07/13.78	4.90/4.20
Deutz R/BV8M545	4	8	1,060/837	380/300	12.60	320	17.72	450	17,690	290.0	1.41	1.38	18.70/14.76	5.70/4.50
MAN G9V 30/45	4	9	1,025/860	360/300	11.81	300	17.72	450	17,480	286.2	1.50	1.70	17.72/14.76	5.40/4.50
Mirrlees KSSDM6	4	6	993	300	15.00	381	17.99	457	19,120	313.5	1.20	1.61	14.99	4.57
Sulzer 8BAW29	4	8	950/1,200	500	11.41	290	14.17	360	11,620	190.4	1.24	1.66	19.69	6.00
Vølund DMT830	4	8	880/705	375/300	11.81	300	16.14	410	14,150	232.0	1.37	1.70	16.83/13.45	5.13/4.10
Werkspoor TMABS336	4	6	870	300	12.99	330	23.62	600	18,820	308.5	1.82	1.61	19.69	6.00

[1] Maximum output in about one hour: 1,000 BHP at 375 r.p.m., with a mean effective pressure of 82.5 lb./sq. in. (5.8 kg./sq. cm.). Continuous rating by supercharging 1,000 to 1,200 BHP
[2] Length from front of engine to aft of flywheel

cooling. The length of the engine, but without the intermediate shaft with thrust bearing in fig. 222 is longer than that of the Deutz engine. With the intermediate shaft and the thrust bearing the length will be 25.2 ft. (7.69 m.) but the thrust bearing can be placed at the end of the engine room out of the way.

(f) **Mirrlees.** The Mirrlees in table 66 is highly supercharged and has air cooling. The length to the coupling flange is greater than that of the MAN engine of lower output, but this is of little importance (see fig. 229).

(g) **Vølund.** The four-stroke Vølund engine in table 66 has eight cylinders with the same diameter as the MAN, but has a smaller cylinder volume. It gives 705 BHP at continuous rating and 300 r.p.m. This engine has a lower normal output than the Deutz and the MAN and its total length is 21.5 ft. (6.56 m.) to the flange of the propeller shaft. The hydraulic equipment is placed in the engine frame. The p_e of the supercharged Vølund is 129.5 lb./sq. in. (9.1 kg./sq. cm.) or a 46.5 per cent. increase in BHP. If the mean effective pressure of the normally aspirated Vølund is decreased to 81 lb./sq. in. (5.7 kg./sq. cm.), supercharging will increase the output 60 per cent. It would perhaps have been advantageous to use air cooling for this engine, although that would increase its price.

(h) **Werkspoor.** The Werkspoor four-stroke engine with supercharging, type TMABS 336, in table 66, has almost the same normal output as the MAN but less than the Deutz. The p_e is 121 lb./sq. in. (8.5 kg./sq. cm.) which is somewhat low in relation to the p_e of the normally aspirated engine. The Werkspoor engine has a high stroke/bore ratio and a comparatively small cylinder distance. The total length to the coupling flange is only 14.73 ft. (4.49 m.) which is shorter than other four-strokes of the same output and r.p.m. The thrust bearing is placed on the intermediate shaft as shown in fig. 223 and the length to the flange is 18.78 ft. (5.725 m.). This is also less than other four-strokes and shows the advantage of a bigger stroke/bore ratio. It has the disadvantages of higher piston speed and smaller space for the air valve.

(i) **Bergen Diesel.** This eight-cyl. four-stroke diesel,

TABLE 66 (*continued*)

Mean effective pressure (p_e)		Unit weight		Total length of engine		Arrangement of thrust bearing: Inside engine =I Outside engine =O	BHP/Unit cylinder volume		Comments
lb./sq. in.	kg./sq. cm.	lb./BHP	kg./BHP	in.	mm.		(BHP/cu. in.) $\times 10^{-3}$	BHP/l.	
76.52	5.38	79.37/82.01	36.0/37.2	290.16	7,370	I	6.08/5.88	3.71/3.59	Piston scavenging pump. Curtis scavenging. Separate cylinders. CP propeller
71.12	5.00	57.98/67.68	26.3/30.7	243.70	6,190	,,	6.33/5.42	3.86/3.31	Roots blower. Curtis scavenging. CP propeller
123.32	8.67	49.82/63.27	22.6/28.7	200.79	5,100	,,	6.00/4.74	3.66/2.89	60 per cent. increase in BHP by supercharging. B.B. turboblower Direct reversible
128.01	9.00	51.37/61.29	23.3/27.8	285.43 224.09 [3]	7,250 6,200 [3]	O	5.86/4.92	3.58/3.00	50 per cent. increase in BHP by supercharging. MAN turboblower Direct reversible
135.12	9.50	89.29	40.5	300.00 227.96 [3]	7,620 5,792 [3]	,,	5.19	3.17	70 per cent. increase in BHP by supercharging. BB turboblower with aircooler. Direct reversible
127.73/161.43	8.98/11.35	64.82/53.35	29.4/24.2	ca.295.67 ca.234.25 [3]	ca.7,510 ca.5,950 [3]	In the gearbox	8.18/10.32	4.99/6.30	58.2/100 [3] per cent. increase in BHP by supercharging. BB turboblower Reversible-reduction gear[4]
129.43	9.10	78.00/97.00	35.3/44.0	258.27	6,560	I	6.21/4.98	3.79/3.04	46.5 per cent. increase in BHP by supercharging. CP propeller
120.90	8.50	76.5	34.6	225.39 176.77 [3]	5,725 4,490 [3]	O	4.62	2.82	45 per cent. increase in BHP by supercharging. B.B turboblower. Direct reversible

[3] The engines with 100 per cent. increase of BHP by supercharging are of the type BCAW29. These engines have B.B. turboblowers with air cooling

[4] With two reduction ratios ahead, the propeller r.p.m. is either 204 or 246

type RTP 8 in table 65, gives about 43 per cent. power increase by supercharging. With 62 BHP per cylinder at 390 r.p.m. it is a comparatively small engine. Due to the fact that this small engine uses valve cavities which facilitate inspection of the valves, and has a stroke/bore ratio of 1.44, space, especially for the air valve, is limited which might make high supercharging difficult. The engines have hydraulically-operated controllable-pitch propellers and clutches. The unit weight is only 66.8 lb./BHP (30.3 kg./BHP), because the cylinder block and the high bedplate are made of welded steel plates and forged steel, and also because of the very short hydraulic equipment.

INFLUENCE OF R.P.M. ON LENGTH

The two Sulzer four-stroke diesel engines in table 65 and fig. 224 work at 500 r.p.m. and have a reduction gear to the propeller and hydraulic reverse gear. This engine, with supercharging and eight cylinders, is longer than a slow running, direct-drive diesel with the same h.p. To make such an engine arrangement shorter than the direct-drive, the r.p.m. must be higher than 500. This is evident from fig. 225 where a direct-drive Mirrlees supercharged four-stroke eight-cylinder engine (type KSSDM 8) of 1,490 BHP at 345 r.p.m. is compared with two four-stroke Mirrlees (dotted lines) each of 745 BHP at 750 r.p.m. Both work on the same reduction gear with an oil-operated reverse gear, reducing the speed of the propeller to about 345 r.p.m., sometimes to 250 r.p.m. With a belt drive on one of the diesels, or a trawl winch generator, the length of this unit will be practically the same as the direct-drive alternative. If, however, the generator is separately driven, the difference in length will be about 5 ft. (1.5 m.).

A greater reduction ratio of 3.5: 1 to 3: 1, resulting in a propeller r.p.m. of 200 to 250, will increase the propeller efficiency over the direct-drive diesels, but the reduction gear efficiency must also be taken into account.

SEMI-DIESELS

The modern semi-diesel has a far better performance than the older hot bulb engines. The semi-diesel is cheap to

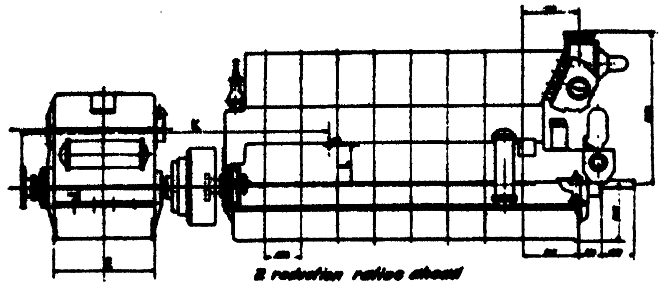


Fig. 224. Sulzer supercharged two-stroke diesel running at 500 r.p.m.

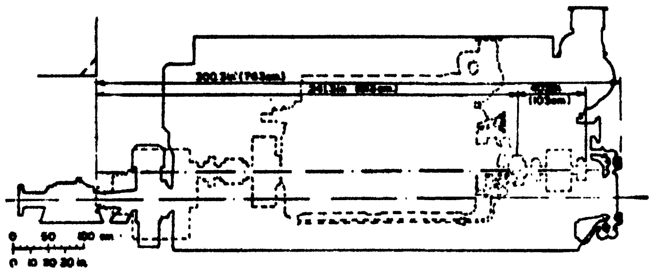


Fig. 225. Comparison between a direct drive Mirrlees supercharged four-stroke engine with 1,490 BHP and 345 r.p.m. and two Mirrlees four-stroke diesels, with 745 BHP and 750 r.p.m.

build and low in maintenance costs, and total working expences are lower than other engines of similar h.p.

Table 67 gives ratings and dimensions of a few modern Norwegian semi-diesels. Fig. 226 shows a Union semi-diesel, type P, with hydraulic operation of the controllable-pitch propeller and a hydraulic clutch. The total length of this three-cyl. engine at 240 BHP is only 9.35 ft. (2.85 m.). The normal p_e is 47 lb./sq. in. (3.3 kg./sq. cm.), equivalent to 93 lb./sq. in. (6.6 kg./sq. cm.) for a four-stroke. Fuel consumption is 0.41 lb./BHP/hr. (187g./BHP/hr.). The weight is only 74 lb./BHP (33.7 kg./BHP). This is partly due to a combustion pressure of only 427 lb./sq. in. (30 kg./sq. cm.) and partly to the short length of the engine with hydraulic equipment (fig. 226).

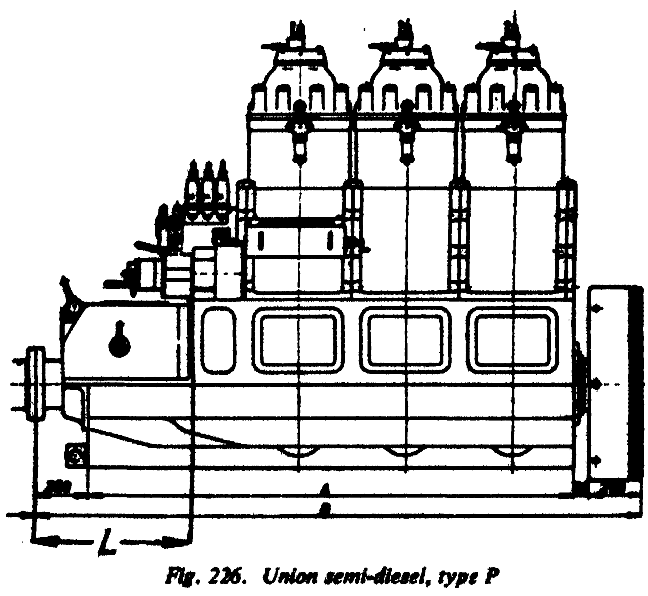


Fig. 226. Union semi-diesel, type P

OPERATION OF ENGINES

It is very important that engines in all fishing vessels are operated at moderate outputs and have suitable excess of air during combustion. If they are pressed unduly hard their reliability will, in the long run, be decreased. There is a tendency to produce fast-running diesel engines up to 1,500 r.p.m. and even to use very light automobile diesels of up to 1,800 to 2,200 r.p.m. in the bigger fishing boats. But a diesel, specifically built for automobile service, cannot stand the hard and continuous operation in fishing.

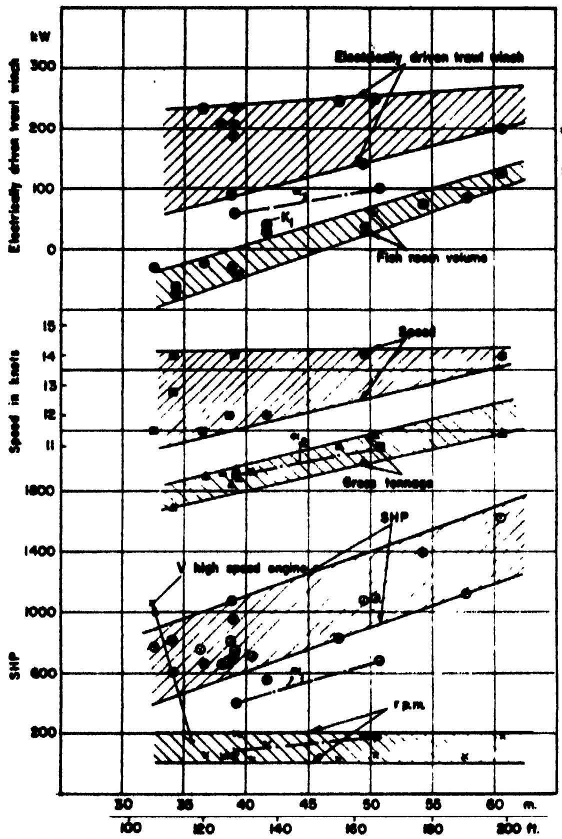
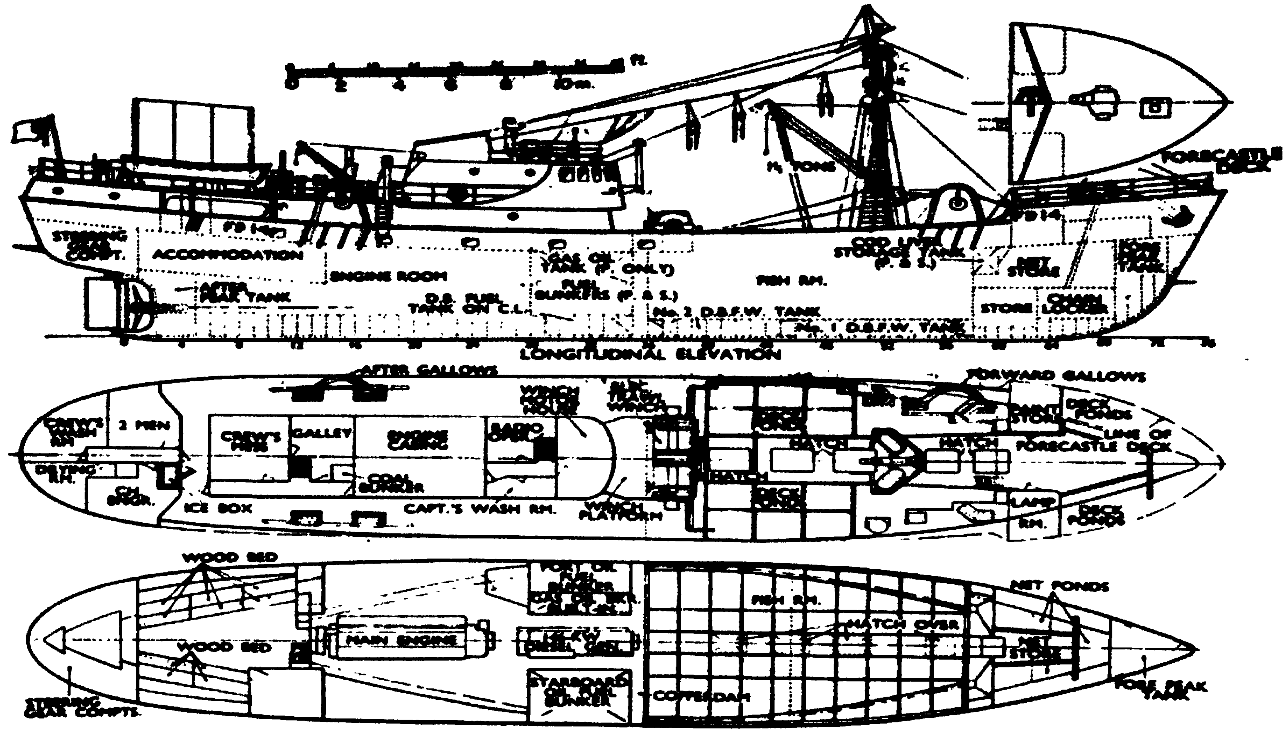


Fig. 227. Design particulars of fishing boats: engine SHP. r.p.m., speed, fish volume, GT and trawl winch

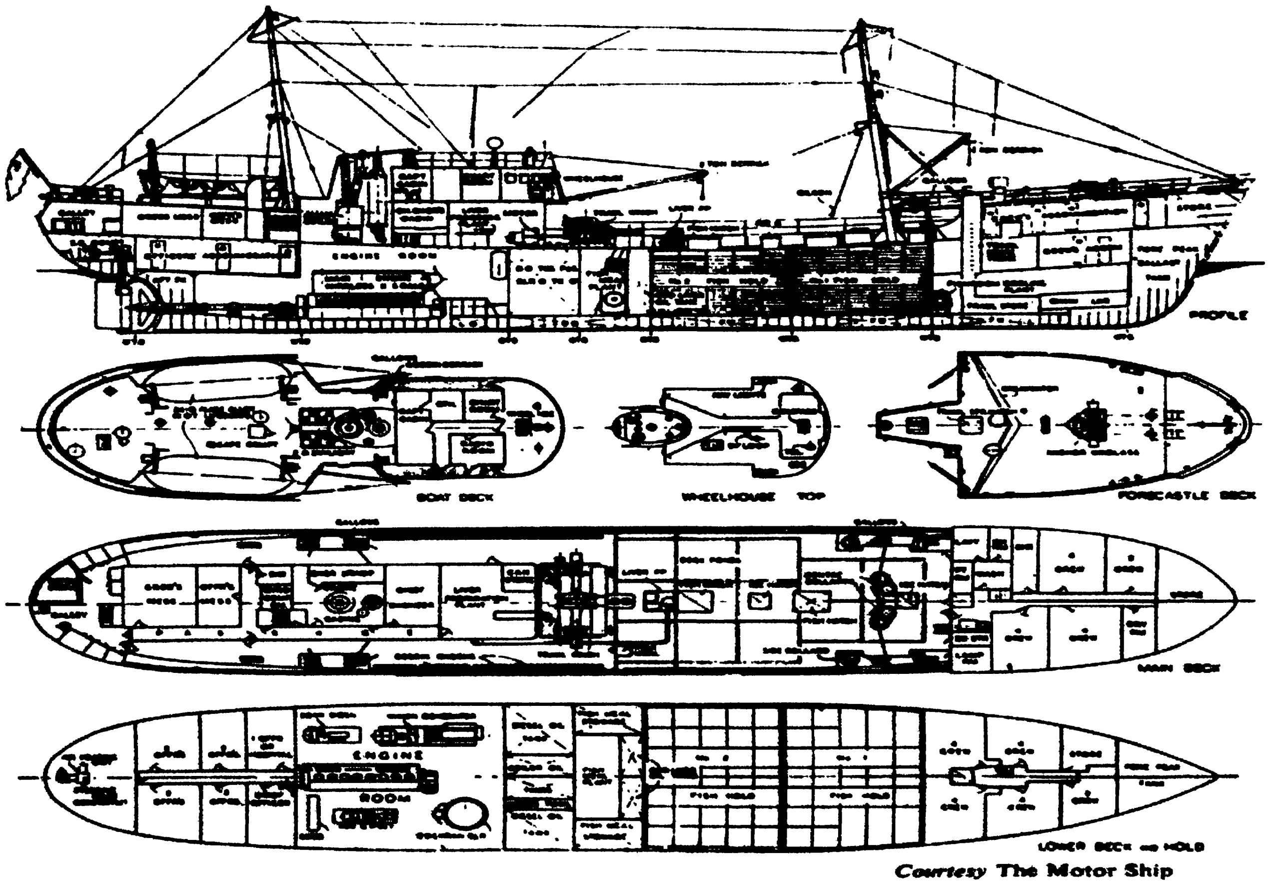
CONTROLLABLE-PITCH PROPELLERS

A controllable-pitch propeller, or a reduction gear with two speed ratios forward for the propeller in table 68, which has been used in France, will improve propulsion. The controllable-pitch propeller, used in Norway, Denmark and Sweden since before 1920, is a relatively simple device, which permits great manoeuvrability and better use of the engine both when trawling and when



Courtesy The Motor Ship

Fig. 228. MT Boston Neptune



Courtesy The Motor Ship

Fig. 229. MT Pioneer

TABLE 67

Engine make and type	Two- or four-stroke	Number of cylinders	Normal rating—BHP	r.p.m.	Cyl. Bore in.	Cyl. Bore mm.	Stroke in.	Stroke mm.	Total cyl. volume cu. in.	Total cyl. volume l.	Ratio Stroke/Bore	Ratio Distance between cyl. centre lines/Bore	Mean piston speed ft./sec.	Mean piston speed m./sec.
Bergen semi-diesel engine. Union P	2	2	160	355	12.99	330	14.17	360	3,758	61.6	1.09	1.52	13.97	4.26
,, ,,	2	3	240	,,	,,	,,	,,	,,	5,636	92.4	,,	,,	,,	,,
,, ,,	2	4	320	,,	,,	,,	,,	,,	7,515	123.2	,,	,,	,,	,,
Brunvoll semi-diesel engine. Type M	2	2	140	340	12.40	315	14.96	380	3,611	59.2	1.21	1.78	14.11	4.30
,, ,,	2	3	220	,,	,,	,,	,,	,,	5,417	88.8	,,	,,	,,	,,
,, ,,	2	4	280	,,	,,	,,	,,	,,	7,222	118.4	,,	,,	,,	,,

sailing. A gear with two reduction ratios and a hydraulic reverse gear would be more complicated to build and operate and would have a lower total efficiency. Therefore the modern controllable-pitch propeller will make its way into this field.

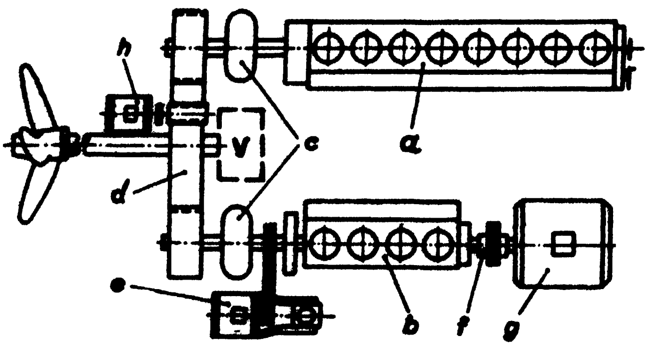


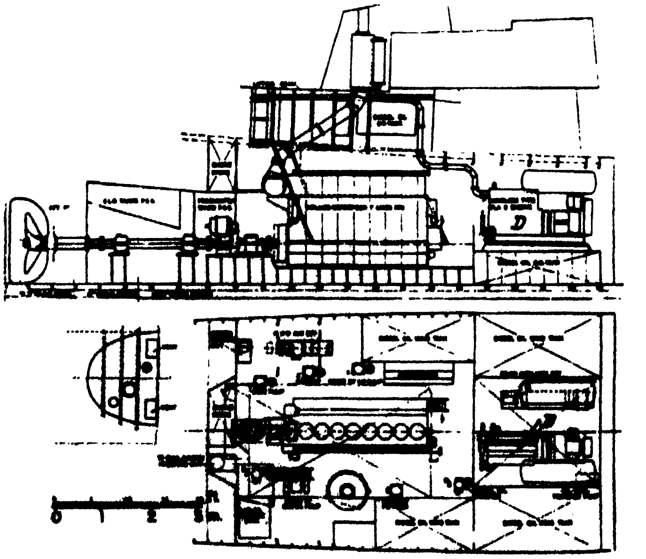
Fig. 230.
MAN supercharged four-stroke "father and son" arrangement

INSTALLATION EXAMPLES AND TRAWL WINCH DRIVE

Table 68 gives particulars for fishing boats. Fig. 227 shows the values graphically. The r.p.m. varies from 200 to 400 depending on the size of the boat and the engine. High-speed engines do not to any great extent lead to greater fish room capacity.

Most of the engines are direct coupled to the propeller and are supercharged and direct reversible. The trawler *Boston Neptune* with a Mirrlees engine is shown in fig. 228. The diesel generator for the trawl winch occupies much space in the engine room, while the electric motor for driving the trawl winch takes up space under the wheelhouse. A similar arrangement is used for the *Pioneer* (fig. 229).

Two MAN super-charged four-stroke "father and son" engines are used in the German-built trawler *Bahrenfeld* (see fig. 230 for the engine arrangement). Both engines are direct-reversible. It would probably have been better to use an engine with a higher r.p.m., say, 500 r.p.m. with a reduction ratio of about 2.5: 1 and a controllable-pitch propeller instead of Vulcan couplings. Although



D: Dieselelectric aggreg. for driving the trawl winch.

Fig. 231. Propulsion equipment for Prince Charles

TABLE 67 (*continued*)

Mean effective pressure (p_e) lb./sq. in.	Mean effective pressure (p_e) kg./sq. cm.	Unit weight lb./BHP	Unit weight kg./BHP	Total length of engine in.	Total length of engine mm.	Arrangement of thrust bearing: Inside engine = I, Outside engine = O	Comments
46.79	3.29	83.55	37.9	92.52	2,350	I	Curtis scavenging. Hydraulic operated CP propeller and clutch placed in engine frame (fig. 226).
,,	,,	74.30	33.7	112.21	2,850	,,	
,,	,,	69.23	31.4	131.89	3,350	,,	
44.52	3.13	108.69	49.3	92.60	2,352	I	,, ,, ,, ,,
46.65	3.28	87.30	39.6	114.64	2,912	,,	,, ,, ,, ,,
44.52	3.13	—	—	136.69	3,472	,,	,, ,, ,, ,,

more expensive, this arrangement would have increased manoeuvrability and shortened the length. 500 r.p.m. is today fully acceptable for night and day work, and is only one-third of the 1,500 r.p.m. recommended by some optimistic diesel engine manufacturers.

The trawler *Prince Charles* has a Holmes-Werkspoor four-stroke supercharged engine with direct drive to a fixed-blade propeller. There is a separate diesel-driven generator for the trawl winch drive, and the engine room occupies more space although it is placed so far aft as possible as shown in fig. 231.

The drawings for *Kirkholmen*, with a Wichmann two-stroke engine and controllable -pitch propeller, are shown in fig. 232. The trawl winch is operated by a hydraulic oil pump driven from the forward end of the propelling engine. An oil motor is placed directly on the trawl winch and does not occupy special space. This winch drive is very robust and elastic and has been manufactured and used in Norway during the last 15 years. The efficiency of the hydraulic system is, however, a little lower than the efficiency of the electric drive, but the hydraulic drive takes much less space, as can be seen from fig. 233, and the space for the electric winch motor can be used for a spacious crew's mess.

Dimensions and output of engines for two trawlers which fish in the Baltic from Strahlsund, Germany, are also listed in table 68. These trawlers have a shorter voyage to and from the fishing grounds, so they can be equipped with smaller engines, and consequently they have a lower speed, with a somewhat greater fish room capacity.

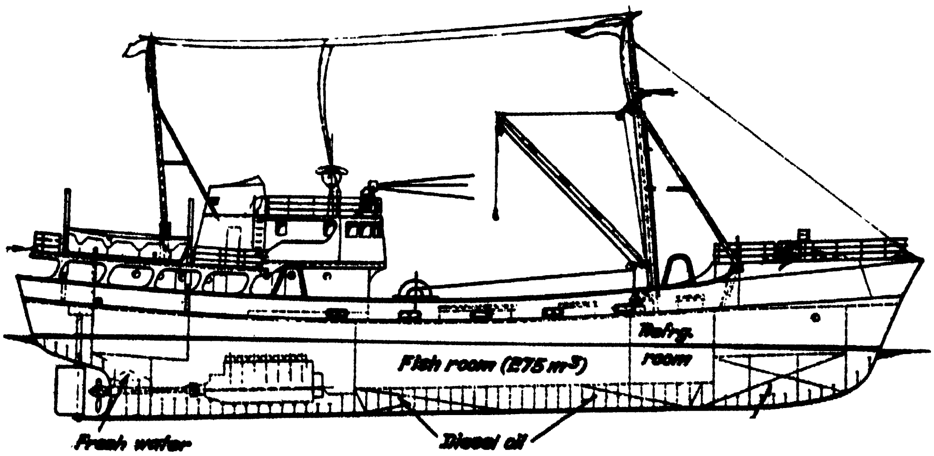


Fig. 232. Kirkholmen *with Wichmann two-stroke engine*

TABLE 68

of 1

Name of trawler	LOA		Trawl winch		Gross tonnage	Capacity of fish hold		Speed	Engine make	Engine power	Engine revolutions	Comments
	ft.	m.	BHP	kW	GT	cu. ft.	cu. m.	Knots		BHP	r.p.m.	
Gavina	127.75	38.90	284	209	315.92	—	—	—	Mirrlees	705	228	Direct reversible. Turbocharged
Idena	128.25	39.10	284	209	296.00	—	—	—	,,	705	228	,, ,, ,,
St Chad	165.00	50.30	344	253	575.00	—	—	—	,,	1,095	260	,, ,, ,,
Jacinta	132.50	40.40	—	—	334.14	—	—	—	,,	705	228	,, ,, ,,
Kriteggen[4]	128.70	39.15	—	—	—	8,680	246	—	Deutz	480	360	CP propeller. Turbocharged
Juvel[4]	123.30	37.50	—	—	—	10,100	285	—	A.M.L. (Norway)	375	—	,, Two-stroke
Fishing craft from Bolsønes shipyard[4]	110.00	33.53	—	—	170.00	—	—	10		350	—	,, ,,
Le Printemps	178.67	54.34	—	—	—	14,100	400	13.5	2 engines	1,380	—	Reduction gear and CP propeller
Notre Dame du Calme	127.58	38.90	—	—	—	5,650	160	14		1,075	380	
Le Vent	111.58	34.00	—	—	—	4,230	120	12.8	Deutz	810	—	CP propeller
Balbcya[1]	119.00	36.25	—	—	—	7,200	204	11.5	M.G.O.	760	1 250	,, and reduction gear
Pioneer	189.75	57.80	385	—	—	14,800	418	—	Mirrlees	1,115	260	Direct reversible. Turbocharged
Boston Vanguard	126.50	38.80	—	—	—	6,750	191	12	,,	675	250	,, , ,,
Projected French trawlers	255.92	78.00	—	330	1,450.0	42,400	1,200	15	2 French engines	2,430	380	Reversible-reduction gear
	199.00	60.70	10 ton	200	580.0	17,700	500	14	1 ,, engine	1,625	380	,, ,, ,,
	127.00	38.70	6.5 ton	90	249.0	5,650	160	12	1 ,, ,,	810	380	,, ,, ,
	162.41	49.50	8.0 ton	140	400.0	11,300	320	14	1 ,, ,,	1,075	380	,, ,, ,,
	111.55	34.00	5.0 ton	—	192.0	3,780	107	11 to 12	1 ,, ,,	405 to 608	375	,, ,, ,,
Wyre Defence	127.50	38.90	320	236	340.0	7,230	205	—	Mirrlees	747	235	Direct reversible. Turbocharged
Boston Firefly	124.70	38.00	284	209	318.0	—	—	—	,,	660	250	,, ,, ,,
St Just II	155.30	47.40	335	247	498.0	—	—	—	,,	820	230	,, ,,
Mount Everest	120.00	36.60	320	236	303.0	—	—	—	,,	660	250	,, ,, ,,
Boston Neptune	128.00	39.00	254	187	328.13	—	—	—	,,	950	250	,, ,, ,,
Boston Fury	165.35	50.40	344	253	577.0	—	—	—	,,	1.095	260	,, ,, ,,
Gerpir	195.00	63.90	275	202	804.0	21,200	600	13.8	MAN	1,470	275	Reduction gear with Vulcan clutch
Prince Charles	176.50[2]	53.80[2]	211	155	—	17,600	497	—	Holmes-Werkspoor	1,420	245	Direct reversible. Turbocharged
Kirkholmen	136.75	41.68	250 Hydraulic drive		300	11,700	331	12	Wichmann[3]	560	330	CP propeller (see fig. 232)
VEB Volkswerft Strahlsund	128.00	39.15	77.5	57	—	6,420	182	10	*K.-Liebknecht*	406	275	Direct reversible
	166.00	50.80	136	100	—	12,400	350	11	,,	700	360	,, ,,

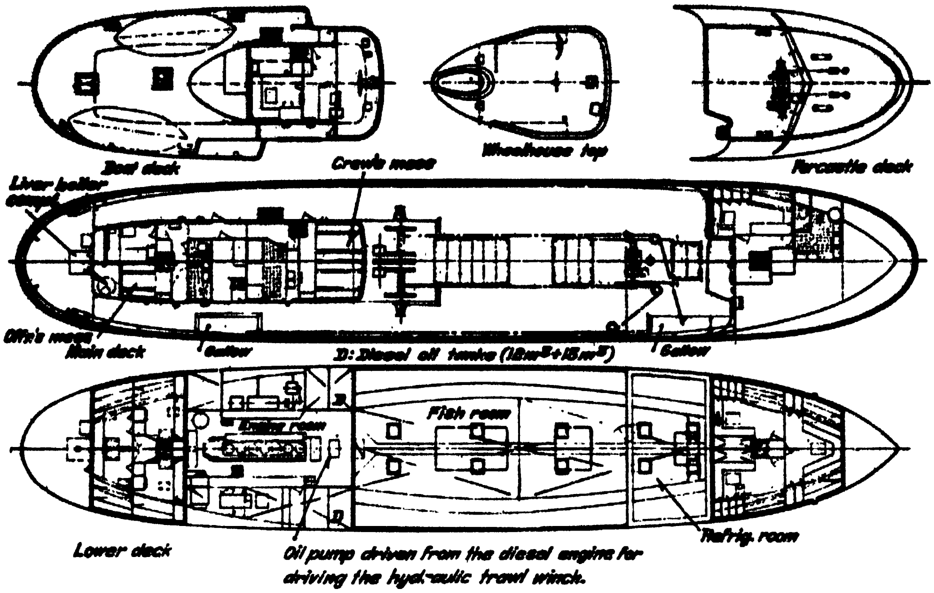
[1]Motor tuna clipper [2]Between perpendiculars. [3]Seven cylinders [4]Norwegian sea-going fishing craft

Diesel-electric propulsion is especially suitable for very large trawlers. There is, for example, the French deep-sea trawler *Louis Girard*, the details of which are as follows: length overall 246 ft. (75 m.), capacity of fish room 22,900 cu. ft. (650 cu. m.), volume of liver-oil tanks 3,520 cu. ft. (100 cu. m.), total output of the two electric Ward-Leonard propulsion motors 1,700 h.p., and speed 15 knots. The trawler has 3 diesel-electric generators with a normal output of 950 BHP each. The eight-cyl. diesels are supercharged four-stroke Sulzer trunk-piston engines, type 8 BAH, 500 r.p.m.

The stern trawler, *Sagitta*, has two free piston gasifiers for driving a turbine of 1,800 BHP, which drives a controllable-pitch propeller through a reduction gear. The trawl winch is hydraulically driven. The temperature in an engine room with free-piston gasifiers is much higher than in a ship with an ordinary diesel. The refrigeration room in the *Sagitta* must for that reason be very well insulated, as it is placed between the fish room and the engine room.

FUTURE DEVELOPMENT

Future development seems to be towards still bigger trawlers because they must go to more remote fishing grounds. At the same time, fish will be caught in still deeper waters, which will demand stronger and, perhaps, new driving and fishing arrangements.



Courtesy Ankerløkken Ltd, Flora, Norway

Fig. 233. Kirkholmen *with hydraulic trawl winch*

Thus trawlers will need a greater radius of action and must be factory ships as they will have to process the fish on board. If not, the trawlers will have to operate as catchers, supplying fish to a factory ship, on the same principle as in the whaling fleets. The trawlers must, in this case, be able to bunker from the mothership and, perhaps, be generally supplied from her.

Delivering fish and receiving supplies from the mothership may be very difficult in open seas in unfavourable weather conditions. This suggests that self-supporting factory trawlers will be a better solution than a mothership with catchers. If helicopters could be used to help transport fish and supplies, it would make the operation easier but would also be difficult in unfavourable weather conditions.

For fishing vessels of several thousand tons, the supercharged two-stroke cross-head engine might be used instead of supercharged four-strokes. The use of atomic power remains, as yet, a future hope for fishing boats, but it would make the radius of action unlimited.

The use of aircraft for quick transport of catches to market has been suggested. It would dispense with the need for the factory ship, but whether such a proposal would be economically feasible seems among other things, to depend on the price of fish in the future.

Acknowledgements

The author wishes to express his thanks to all the many firms which provided him with specifications and drawings of fishing craft and accessories.

STEAM VERSUS DIESEL

by

G. HOPWOOD and H. W. N. MEWSE

A comparison indicates the advantages of diesel over steam as regards fuel economy, power for fishing, acceleration, fish room capacity and constant draught and trim.

A maintenance schedule is given for the main engine.

Teething troubles experienced are discussed, such as removal of piston castellations to avoid uneven liner wear, use of detergent lubricating oil and increased lubricating oil temperatures to reduce carbon deposition, correct lubricating oil filter usage and regular checking of oil samples, and of small accessories.

Wear figures are given. The turbocharger system is referred to, including air supplies and some troubles with erosion of the gas outlet casing. The type of fuel oil is defined and a fuel consumption curve is given.

The importance of satisfactory alignment of engine and shafting is emphasized and the recommended installation procedure detailed. There are no barred speed ranges and a description is given of the torsional investigation.

The anticipated loss in propeller efficiency in changing from a steam engine running at 120 r.p.m. to a diesel at 230 r.p.m. has been reduced by the use of modern bronze propellers. Details of these are given, together with curves of efficiency, etc.

The importance of power balance between the winch motor and diesel is stressed. Troubles on earlier vessels with carbonization of pistons, etc. and armature difficulties are described. Reference is made to maintenance procedure, lubricating oil and alarm systems.

The two general service sets, each driving a generator, pump and compressor, are described, as well as some difficulties with the lubrication of the compressor big-end bearing and suggestions made about starting, and also about driving the pump and compressor electrically. Reference is made to steam boiler heating which has been superseded by small oil fired hot water circulation boilers.

LA VAPEUR COMPARÉE AU DIESEL

Une comparaison indique les avantages du diesel par rapport à la vapeur en ce qui concerne l'économie de carburant, une plus grande puissance pour la pêche, une plus grande accélération, une plus grande capacité de la cale à poisson, et l'assiette et le tirant d'eau plus constants.

Le temps passé pour l'entretien du moteur principal est détaillé.

L'auteur donne une description des ennuis rencontrés à l'origine et concernant des sujets tels que: la suppression des créneaux des pistons pour éviter une usure inégale des chemises, l'emploi d'huile de graissage détersive et l'augmentation des températures de l'huile de graissage pour éviter la formation de calamine, l'emploi correct du filtre à huile de graissage et la vérification régulière des échantillons d'huile et de petites pièces telles que les soupapes de pompe à eau, les injecteurs de carburant, etc.

Des chiffres d'usure sont donnés. Il est fait mention du système de suralimentation par turbo-compresseur, y compris les arrivées d'air, et des ennuis éprouvés avec l'érosion des pipes d'échappement. L'auteur décrit le type de fuel oil et donne la courbe de consommation de carburant.

L'importance d'un alignement satisfaisant est soulignée, et la procédure d'installation recommandée est détaillée. Il n'y a pas de gammes de vitesse interdites, et il est donné une description des recherches sur les efforts de torsion.

La perte prévue du rendement de l'hélice en passant d'une machine à vapeur tournant à 120 t.p.m. à un diesel à 230 t.p.m. a été réduite par l'emploi d'hélices de bronze d'un type moderne. Des détails de celles-ci sont donnés avec des courbes de rendement, etc.

L'auteur insiste sur l'importance de l'équilibre de puissance entre le moteur du treuil et le diesel. Il décrit les ennuis sur les navires anciens, avec le calaminage des pistons, etc., et les difficultés avec le bloc. Les procédés d'entretien, l'huile de lubrification et le système d'alarme sont aussi mentionnés.

Les deux groupes du service général, entraînant chacun un générateur, une pompe et un compresseur, sont décrits, ainsi que quelques difficultés avec la lubrification du palier d'extrémité du compresseur, et des suggestions sont données concernant le démarrage de même que l'entraînement électrique de la pompe et du compresseur. Il est aussi fait mention du chauffage par chaudière à vapeur, qui a été supplanté par une petite chaudière à mazout à circulation d'eau chaude.

LAS MAQUINAS DE VAPOR FRENTE A LOS MOTORES DIESEL

Se subrayan, mediante comparaciones, las ventajas del motor Diesel sobre la máquina de vapor en lo que concierne a la economía de combustible, mayor potencia para la pesca, mayor aceleración, más capacidad de bodega de pescado y asiento y calado más constantes.

Se detalla el tiempo dedicado al mantenimiento del motor principal.

Se describen las dificultades encontradas al principio en lo referente a: supresión de las entalladuras de los pistones para evitar desgastes desiguales de las camisas, empleo de un aceite lubricante detergente y aumento de las temperaturas del aceite de engrase para evitar la formación de depósitos de carbón, empleo correcto del filtro del aceite lubricante y comprobación periódica de las muestras de aceite y de piezas pequeñas como las válvulas de la bomba de agua, los inyectores de combustible, etc.

Se dan datos sobre el desgaste. Se alude al sistema de sobrealimentación por turbocompresor, comprendido el suministro de aire y algunas dificultades causadas por la erosión en los tubos de escape. Se describe el tipo de fuel oil y se da una curva de consumo de combustible.

Se recalca la importancia de una alineación satisfactoria y se dan pormenores de los procedimientos de instalación recomendados. No hay gamas de velocidad prohibida y se hace una descripción de las investigaciones sobre los efectos de la torsión.

Mediante el empleo de hélices de bronce modernas se ha reducido la pérdida prevista de rendimiento de la hélice al pasar de una máquina de vapor que gira a 120 r.p.m. a un Diesel a 230 r.p.m. Se dan detalles de éstos, junto con curvas de rendimiento, etc.

El autor insiste en la importancia del equilibrio de potencia entre la maquinilla de arrastre y el Diesel. Se describen las dificultades experimentadas por los primeros barcos con la carbonización de los pistones, etc. y con el bloque. Se alude a los procedimientos de mantenimiento, aceite lubricante y sistema de alarma.

Los dos grupos de servicio general, cada uno accionando un generador, bomba, y compresor se describen junto con algunas dificultades del engrase del cojinete del compresor y se hacen sugestiones sobre el arranque del mismo, así como del funcionamiento eléctrico de la bomba y del compresor. Se hace referencia al calentamiento por caldera de vapor que ha sido substituído por una pequeña caldera de petróleo de circulación de agua caliente.

SINCE 1953, the diesel trawler has, in the British West Coast hake fishing, superseded the Castle class of coal fired steam trawlers (fig. 234), which were built in large numbers from 1917 to 1920 and were the mainstay vessel for middle-water fishing.

COMPARISON OF WEST COAST STEAM AND DIESEL TRAWLERS

The principal characteristics of a modern motor trawler shown in figs. 235 and 236, 5 to 6 years of age, as compared with the Castle type are:

		Diesel	*Steam*
		LBP B D	LBP B D
Size	ft.	128.17×26.58×13	125.42×23.42×12.58
	m.	39.06×8.10×3.96	38.23×7.14×3.84
Fuel consumption (daily)		2.2 tons (2.23 ton)	8½ to 9½ tons coal (8.64 to 9.65 ton)
Speed		11 knots	9½ to 10 knots
Bunker capacity		65 tons (66.04 ton)	140 tons (142.25 ton)
Average 14-day fish catch		34 tons (34.54 ton)	25 tons (25.40 ton)
r.p.m. steaming		230	112
fishing		200	88 to 90
Power		695 BHP	540 IHP

Performances

Table 69 indicates the sea time, the coal consumption and number of voyages per year of five Castle class ships. Ships L and M are sister vessels operating on wet steam; N and O are sister ships operating with superheated steam. Ship P is a post-war ship, operating on wet steam during the first two years and with superheated steam during the third and fourth years. As a matter of interest, the fuel efficiency was better in the latter than it was in the wet steam period.

Table 70 shows the corresponding figures for five motor trawlers.

A comparison of the operating costs and catch of the two types is given in fig. 237. This information, with the tables and fig. 237, was obtained from owners with considerable experience of both coal burning and diesel trawlers.

Periods of four years have been taken in each case, the coal burners from 1951 to 1954 and the diesels from 1954 to 1957. The statistical averages were based on actual gross earnings and the operating costs were limited to fuel, oils and stores, together with repairs and maintenance. Repair and maintenance costs cover the hull and auxiliary equipment as well as the propulsion machinery.

TABLE 69

Sea times and fuel consumption of Castle ships

Year	*Voyages*	*Sea time* Days	*Sea time* Hours	*Coal used* Tons	*Coal used* Metric ton	*Average consumption per day* Tons	*Average consumption per day* Metric ton
Ship L							
First	17	241	1	2,137.10	2,171.3	8.7	8.83
Second	24	306	22	2,874.40	2,920.1	9.6	9.75
Third	24	307	18½	2,899.65	2,945.6	9.3	9.44
Fourth	24	274	11	2,603.90	2,644.8	9.45	9.60
Ship M							
First	17	234	3	1,950.30	1,981.3	8.5	8.63
Second	20	267	15	2,279.40	2,315.6	8.55	8.68
Third	20	253	0	2,271.45	2,307.4	8.9	9.04
Fourth	23	243	11	2,326.85	2,363.4	9.5	9.65
Fifth	23	290	17½	2,710.15	2,753.6	9.05	9.19
Ship N							
First	20	277	13	2,474.50	2,513.7	8.9	9.02
Second	21	262	6½	2,358.25	2,395.8	8.9	9.04
Third	23	304	0	2,659.15	2,701.6	8.6	8.73
Fourth	22	296	2	2,442.05	2,481.2	8.2	8.31
Fifth	22	277	14	2,481.95	2,520.8	8.85	8.99
Ship O							
First	20	269	15	2,359.70	2,396.9	8.6	8.73
Second	22	292	18½	2,583.85	2,624.5	8.75	8.89
Third	22	298	11	2,698.05	2,741.3	8.9	9.04
Fourth	24	285	1	2,559.00	2,600.0	8.9	9.02
Ship P							
First	18	266	11	2,929.20	2,976.0	11.0	11.17
Second	21	288	1	3,077.95	3,126.3	10.6	10.76
Third	21	290	0	2,561.95	2,603.1	8.8	8.94
Fourth	21	280	19	2,584.90	2,728.1	9.5	9.65
Averages	21.34	278	8	2,256.64	2,293.2	9.1	9.26

[Average yearly catch for all vessels = 507 tons (515.13 metric ton)]

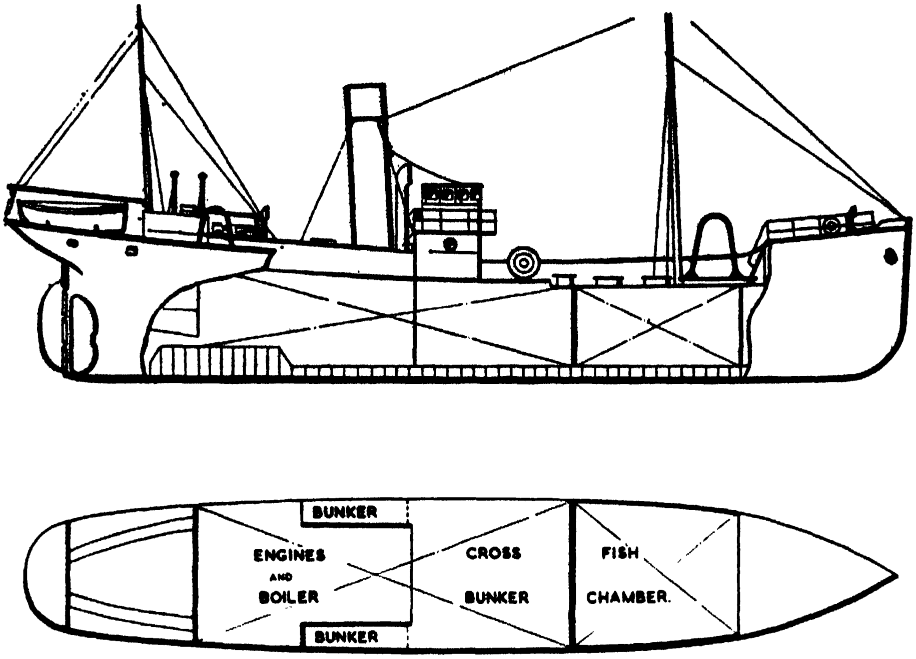


Fig. 234. Castle steam trawler LBP×B×D=125 ft. 5 in.×23 ft. 5 in.×12 ft. 7 in. (38.2×7.1×3.8 m.)

There are, of course, other vital factors which are independent of the ship or its propulsion machinery, such as the skipper's competence and ability, the proficiency of the crew, perils at sea, accidents and, in no small measure, the type of fishing and its relative earning potential. No account was taken of any inflationary trends during the periods under review, actual figures being quoted throughout.

Obviously, there are great differences in fuel consumption and speed. The diesel engine, possessing considerably more power for trawling, results in increased catches because more ground is swept in a given time. A similar oil fired steam trawler, built within the last ten years, would have a power about 600 h.p., with a daily fuel consumption of about 7 tons (7.11 ton). The endurance of the diesel trawler in bunker capacity is twice that of the coal burner.

The reduced space required for machinery and bunkers in a motor trawler allows for a larger fish room in a vessel of the same length and the fish room can be placed further aft. This improved subdivision, combined with the reduced weight of machinery and bunkers, results in better freeboard and stability. Fuel and water consumed by a motor trawler on a fishing voyage amounts on average to the weight of fish caught. This results in more constant draught and trim, and the decreased displacement allows a finer and more seakindly hull to be designed. The diesel trawler can fish when the older steam trawler has to heave-to. Cleaner fuel, more easily loaded, offers the possibility of better maintenance of hull and machinery. Due to the better acceleration of the diesel, the ship is kept well away from the fishing gear, particularly in heavy weather. The result is a more efficient fishing machine, despite the reduction in propeller efficiency because of the increased revolutions of a diesel engine.

MACHINERY ON A DIESEL TRAWLER

The following installation of one of five sister ships has been found to be very suitable. Fig. 236 shows the general arrangement of the engine room.

- **Main engine.** This is a 15 in. (381 mm.) bore × 18 in. (457.2 mm.) stroke, four-stroke, seven-cyl., direct reversing, exhaust gas turbocharged diesel, developing 695 SHP at 230 r.p.m. and is direct-coupled through a Michell thrust bearing, intermediate and tail shaft to a four-bladed propeller.
- **Winch engine.** This is a $9\frac{3}{4}$ in. (247.6 mm.) bore × $10\frac{1}{2}$ in. (266.7 mm.) stroke, four-stroke, five-cyl. diesel developing 252 BHP at 600 r.p.m. driving a 101 kW DC generator supplying power to a 126 h.p. winch motor.
- **Auxiliaries.** These comprise two composite general service auxiliary sets, each engine being at $4\frac{1}{8}$ in. (104.8 mm.) bore × 6 in. (152.4 mm.) stroke, four-stroke, four-cyl. diesel, developing 36 h.p. at 1,000 r.p.m.

MAINTENANCE AND OPERATION OF MAIN DIESEL ENGINE

The reliability, simplicity, inexpensive maintenance and economy of the diesel trawler has proved itself, and almost 100 of the type of main engine in question have been sold within the last six years.

Table 70 shows that the sea time of the five vessels has averaged 288 days and a maximum of 316 days over a period of five years. Generally, only 48 hr. are spent in dock between trips, except sometimes at weekends, and this would account for the varying times shown in the table. The vessel is at sea for about 300 days per year, doing 22 to 24 trips. During the normal 48 hr. turn round, engine maintenance is carried out, and further, there is a week in dock every four months for settling and resting the crew. Therefore, an average year is:

300 days at sea
44 days turn-round
21 days settling
—
365 days

Maintenance schedule

Readiness to proceed to sea has been assured by the maintenance procedure laid down by the diesel engine builders and implemented by the Superintendent Engineer and the shore-based engineering staff, and there are many records of long trouble-free running. There is no doubt that an efficient and well-ordered maintenance programme is a sound investment and that neglect results only in heavy expenses and loss of fishing time. This, of course, applies to machinery of any type. The maintenance schedule is based on:

Annual engine working time of 6,000 hr.
Exhaust valves serviced every 1,000 hr.
Fuel injectors serviced every 1,000 hr.
Pistons serviced every 4,000 hr.
Turbocharger air filter cleaned every 800 hr.
Turboblower fan cleaned every 3,000 hr.
Turbocharger bearings examined every 3,000 hr.
Starting air valves serviced every 3,000 hr.

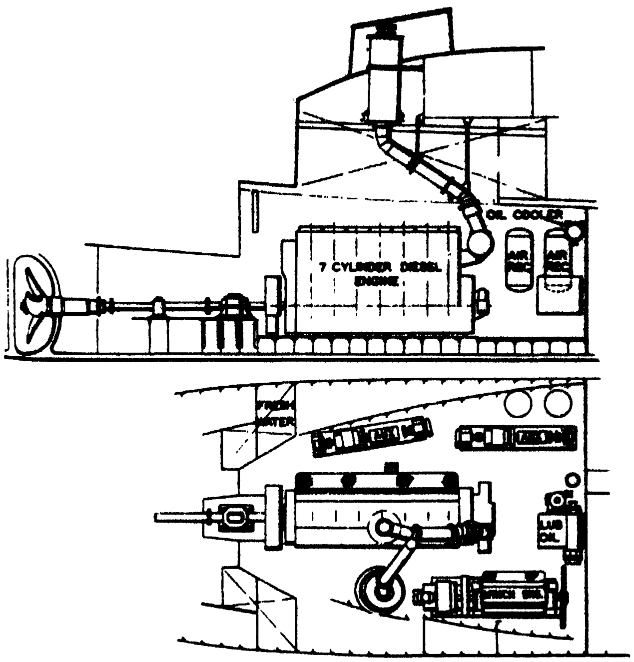


Fig. 236. Diesel trawler engine room

To meet the conditions of Lloyds' continuous survey, which has to be completed inside four years, two pistons, two big end and main bearings and two cylinder heads are overhauled annually.

The maintenance of the exhaust valves and injectors is so arranged that two lines are done between each trip, so that all are maintained within the period of 1,000 hr. Other items, such as the governor and gear, tappet levers, relief valves, are examined annually.

With the first engine, the maintenance routine was

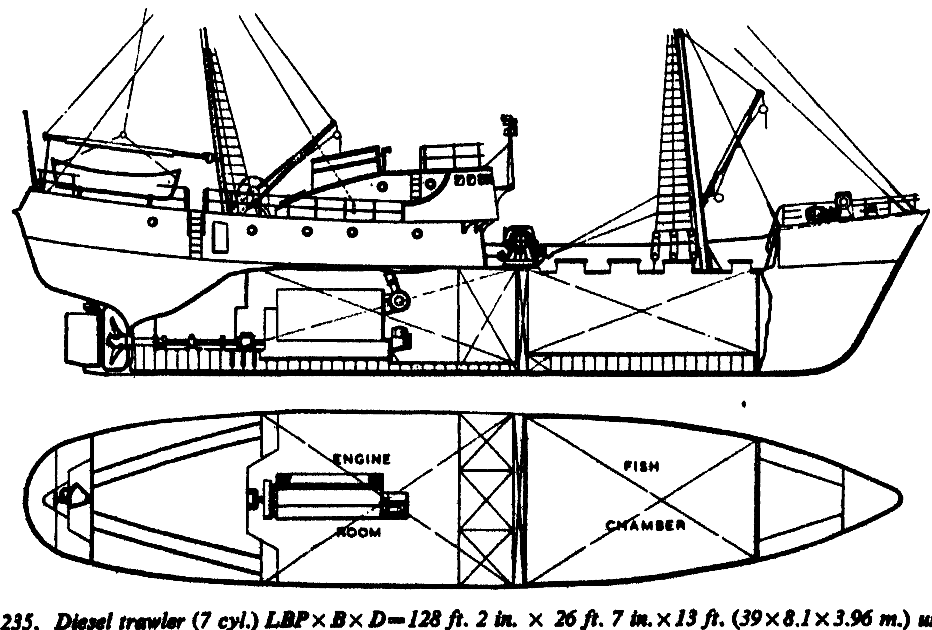


Fig. 235. Diesel trawler (7 cyl.) LBP × B × D = 128 ft. 2 in. × 26 ft. 7 in. × 13 ft. (39 × 8.1 × 3.96 m.) used in British West Coast lake fishing

TABLE 70

Sea times and fuel consumption of 128 ft. [39 m.] diesel trawler

Year	Voyages	Sea time		Fuel consumption per year		Average consumption per day		Main engine hours	
		Days	Hours	Tons	Metric ton	Tons	Metric ton	Working	Idling
Ship A									
First	22	290	20	689.71	700.05	2.37	2.40	6,280	700
Second	20	267	19½	561.67	569.99	2.10	2.13	5,684	1,443½
Third	23	301	23½	610.88	620.60	2.02	2.05	6,363	884½
Fourth	26	315	3	618.32	627.91	1.96	1.99	6,501	1,062
Fifth	26	269	21	547.45	555.77	2.03	2.06	5,645	832
Ship B									
First	21	277	12	619.62	628.93	2.24	2.27	5,979	681
Second	23	309	4	665.16	675.67	2.12	2.15	6,670	750
Third	22	284	½	593.48	602.51	2.09	2.12	6,157	659½
Fourth	22	259	21	529.40	537.48	2.04	2.07	5,540	697
Fifth	24	287	6	594.96	603.52	2.07	2.10	6,199	695
Ship C									
First	24	316	10½	717.27	728.50	2.27	2.30	6,772	822½
Second	21	283	2	594.68	603.51	2.11	2.14	5,938	856
Third	24	302	19½	616.80	625.88	2.04	2.07	6,313	954½
Fourth	23	282	1	539.58	547.64	1.91	1.94	5,672	1,097
Fifth	21	256	1½	519.36	527.32	2.03	2.06	5,411	734½
Ship D									
First	23	310	12	716.86	727.48	2.31	2.34	6,972	480
Second	20	271	14½	588.00	597.43	2.16	2.19	6.026	492½
Third	23	298	17	607.68	616.74	2.03	2.06	6,715	454
Fourth	23	273	4½	555.54	563.90	2.03	2.06	5,813	743½
Fifth	22	272	9½	600.44	609.63	2.20	2.23	6,020	517½
Ship E									
First	24	304	20½	708.16	719.35	2.32	2.35	6,657	659½
Second	24	304	20	678.70	688.88	2.22	2.25	6,730	586
Third	22	274	23	593.95	602.51	2.16	2.19	5,772	827
Fourth	24	299	10½	608.16	617.75	2.03	2.06	6,174	1,012½
Fifth	23	287	22½	603.48	612.67	2.10	2.13	6,268	642½
Averages	22.8	288	—	611.57	620.80	2.11	2.13	6,171	771

[Average yearly catch for all vessels = 695 tons (706.1 metric ton)]

carried out at shorter intervals. For example, the pistons were removed every 2,500 hr., but it was found that this time could be extended.

Castellations

Certain teething troubles will inevitably arise with any prime mover, particularly when associated with such arduous conditions experienced in trawling.

One was with the cast iron pistons which, due to the valve overlap necessary for supercharged engines using the Buchi exhaust gas turbo system, had deep pockets in the top resulting in four, what might be termed, "castellations". It was found that uneven vertical bands of liner wear were taking place corresponding to the piston castellations. The uneven wear was found to be due to the operation of the ship. The ship often lays to for hours, and the engine cools down. Then, suddenly, the trawl may be shot, requiring the engine to be on full power immediately. This results in distortion of the piston castellations and the subsequent liner wear. The engine makers carried out tests with the castellations machined off, which gave a lower compression ratio but, as it was found that the engine would still start easily under cold conditions, it was decided to modify the pistons. This was done after a short period in service, and no further liner wear of this nature has taken place.

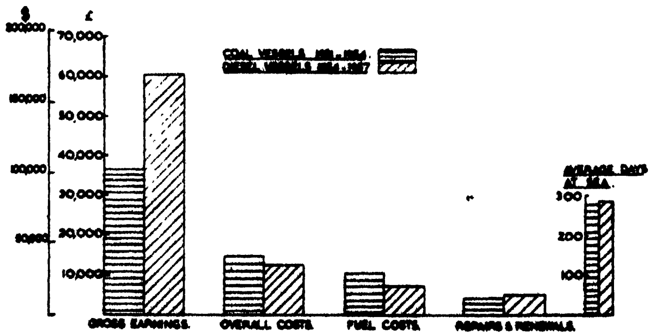


Fig. 237. Comparative earnings and costs of coal and diesel trawlers

Lubricating oil

The type of oil used for cooling the piston and for general lubrication is important, as the piston cooling oil is taken off the main system. It was found that the oil returns from the pistons were being choked by carbon because a straight mineral oil was being used and, when a change was made to a detergent oil, the trouble was minimised to a considerable extent but not entirely cured. A further investigation was made, which disclosed that the choking was, to some extent, due to low operating oil temperatures of 90 to 110°F (32 to 43°C). Now these temperatures have been increased to 130 to 140°F (54 to 60°C) and the trouble is practically non-existent. Furthermore, the circulation of the oil at 140°F (60°C) is three times as fast as at 100°F (38°C) so that the underside of the pistons receives three times as much oil for cooling purposes, which prevents the build up of carbon.

Cases of piston cooling cavity choking are now nearly always due to the pack type of oil filter not being operated properly. With detergent lubricating oils, not only are the oil cooling cavities kept clean but it is an exception to be troubled by stuck piston rings, so the period between overhaul has been extended.

Contrary to general opinion, the pack type of lubricating oil filter is being successfully operated on these vessels. It has been found that the time for a complete change of oil is indicated when three pints of carbon and heavy sludge are removed daily from the filters. Experience has shown that oil changes should be made every 4,000 hr., not every 2,000 hr. as was first done. Samples of oil are analysed regularly by the supplying companies and the oil is always renewed before the analysis shows it has deteriorated. A moderately priced oil, which is changed fairly often, is economical. Frequent changes also result in a clean sump and sump tank. Considerable trouble can be experienced by not paying special attention to the quality and condition of the oil. The cost of oil changes is an insurance against damage and expensive renewals. The average lubricating oil consumption per 24 hr., including that of the auxiliary diesels, has been 9.75 Imp. gal. (44.4 l.), and that includes the sump change of 240 Imp. gal. (1,092 l.) every 4,000 hr.

TABLE 71

7 Cyl. Main Propulsion Diesel Wear

Crankshaft and crankpin	No appreciable wear in 34,000 hr.					
Connecting rod big end bearing	Adjusted to makers' recommended clearance where necessary; average 0.002/0.004 in. (0.0508/0.1016 mm) shims removed, in 34,000 hr.					
Connecting rod small end bearing	Clearance 0.006 in. (0.1524 mm.), original 0.003/0.004 in. (0.0762/0.1016 mm.) in 34,000 hr.					
Cylinder liners, cast iron	*Cyl.*	*Hours*	*Total wear* *in.*	*Total wear* *mm.*	*Wear/1,000 hr.* *in.*	*Wear/1,000 hr.* *mm.*
	1	12,998	0.022	0.559	0.0017	0.0432
	2	12,998	0.027	0.686	0.0021	0.0533
	3	12,998	0.026	0.660	0.0020	0.0508
	4	10,314	0.026	0.660	0.0025	0.0635
	5	10,972	0.024	0.610	0.0022	0.0559
	6	10,972	0.020	0.508	0.0018	0.0457
	7	10,657	0.025	0.635	0.00235	0.0597
Cylinder liners, chrome bore	1	21,708	0.006	0.152	0.0003	0.0076
	2	20,583	0.006	0.152	0.0003	0.0076
	3	(Cast iron liner fitted)				
	4	21,537	0.006	0.152	0.0003	0.0076
	5	22,881	0.006	0.152	0.00026	0.0066
	6	22,329	0.005	0.127	0.00027	0.0069
	7	24,337	0.006	0.152	0.00025	0.0064
Piston pin bosses	Clearance 0.006 in. (0.1524 mm.) original 0.003/0.004 in. (0.0762/0.1016 mm) after 25,276 hr.					
Top piston ring groove	0.015 in. (0.381 mm.) after 25,276 hr.					
Second piston ring groove	0.008 in. (0.203 mm.) after 25,276 hr.					
Third piston ring groove	0.008 in. (0.203 mm.) after 25,276 hr.					
Top scraper ring groove	0.008 in. (0.203 mm.) after 25,276 hr.					
Bottom scraper ring groove	0.008 in. (0.203 mm.) after 25,276 hr.					
Piston pins	Maximum wear 0.001 in. (0.025 mm.) in 30,000 hr.					
Camshaft bearings	Negligible wear in 30,000 hr.					
Cams	No wear in 30,000 hr.					

Cylinder liners

The original cylinder liners were made of centrifugal cast iron and, once the vertical bands of wear had been overcome by modifying the pistons, the average wear figures were in the region of 0.0015 to 0.002 in. (0.0381 to 0.0508 mm.) per 1,000 hr. as shown in Wear Down Chart, table 71. The liners, when worn between 0.020 and 0.030 in. (0.508 to 0.762 mm.), can be chrome plated at half the cost of a new liner. From experience gained, it is recommended, after about three years, to so treat two liners annually, until all have been chrome plated. Furthermore, the wear on chrome liners has been under 0.0005 in. (0.0127 mm.) per 1,000 hr. or 25 to 30 per cent. of that on cast iron liners.

The original liner water joint rings were of natural white rubber and it was found that the detergent oil caused some of these rings to fail. The rings are now made of a synthetic material, and no trouble has since been experienced.

In one ship the cylinder head cracked during the first voyage. This was found to be due to cooling stresses. An alteration in foundry practice, including annealing of the casting, solved the problem.

Exhaust valves

The exhaust valves tended to stick but when the oiling procedure was altered and a reamer passed through the valve guides, which are given a good wire brushing during the overhaul, there has been no sticking. The valves are cleaned with a power wire brush.

Injectors

The maintenance period of the injectors has been considerably extended by fitting a light weight spring spindle of aluminium alloy in the nozzle holder body. This has less inertia, so that it keeps the needle valve firm on its seat, thus reducing the tendency of the needle to become lacquered.

Cooling water

The original ram type of water pumps were fitted with fibre valves which gave rise to some difficulties. They were replaced by metal valves which have a much longer life and improved performance.

The first vessels were fitted with engine driven ram type freshwater pumps. It was found that a muddy deposit of corroded material, about 1 in. (25.4 mm.) deep gathered in the cooling water space at the bottom of the cylinder liner and in the cylinder heads. The corrosion making the deposit took place in the header tank, and was caused by a snifting valve on a ram pump which resulted in the water becoming aerated. Every six months it was necessary to flush the cylinder heads down through the outlet doors on the back of the cylinder block. A soluble oil added to the cooling water was successful in reducing the corrosion. On one occasion, salt water was used for cooling the engine and it caused the oil to separate out, there being about 8 Imp. gal. (36.4 l.) of oil in the cooling system. To clean the system, it was necessary to run the engine with a water temperature of about 160°F (71.11°C) and soda was put into circulation to absorb the oil. In spite of this mishap, the liners can be withdrawn easily and the whole fresh water side of the system, including iron pipes and header tanks, is free from corrosion.

The independent electric driven saltwater cooling pump is started one or two hours after sailing to allow the engine to warm up quickly. From the experience gained with the ram pumps, it is now felt that separate electrically driven pumps are better also for the freshwater side, and later engines are equipped with two electric pumps with a variable speed control. This ensures a good temperature control without opening and closing the by-passes. In addition, the water can be circulated when the engine is idle. There is still trouble from corrosion on cast iron parts on the sea water side and it is proposed to try out various rubberized and resin protective coatings which have now come into general use. If this move is successful, protection will be achieved without the expense of costly bronze fittings.

Turbochargers

The naturally aspirated engine, whether two- or four-stoke, will soon be the exception rather than the rule. The Buchi turbochargers have been found to be efficient. On the first engines, the air for the turbochargers was taken from the engine room via a ventilator and, when the engine room was battened down, there was insufficient air for combustion, with a resulting increase in exhaust temperatures. When additional ventilation was installed to feed air to the turbocharger from the deck, the exhaust temperatures dropped by 30°F (17°C) and conditions in the engine room were improved. The turbocharger compressor blades tend to foul because the oil mist in the engine room is drawn in with the air. An increase in the exhaust temperatures, therefore, might indicate that the compressor and the air filter need to be cleaned.

The only major trouble experienced with the turbocharger has been erosion of the gas outlet casing, the temperature of which, owing to the conditions of trawling, is often below the dew point of the water in the gases. The vessel stops every three or four hours, whilst trawling, and it is then not possible to keep the water temperature over 140°F (60°C). At low temperatures, the moisture settles on the casing walls and the acid from the sulphur in the fuel gases eats away the metal. In one case, the corrosion made a hole through the casing to the water side, and the engine was flooded. However, the vessel was able to dock under her own power, at reduced revolutions, with the turbocharger functioning without water circulation. A casing, sprayed with cupro-nickel, is being tested to see how it resists this cold corrosion.

Fuel oil

The engines originally operated on gas fuel oil; later marine diesel oil was tried. Some waxing of the fuel filters was eliminated by heating the fuel slightly. All the vessels are now operating satisfactorily on distillate fuel at a saving of about 14 per cent. in cost. Fig 238 shows the fuel consumption curve—and a typical specification of the distillate fuel is:

Specific gravity at 60°F (15.56°C)	0.830 min. 0.890 max.
Flash point (closed) °F (°C)	150 (65.56) min.
Viscosity Redwood No. 1 at 100°F (37.78°C)	34 min. 45 max.
Pour point °F (°C)	25 (–3.89) max.
Sulphur % weight	1.2 max.
Carbon residue (Conradson) % weight	0.2 max.
Cetane number	28 min.
Water % volume	0.05 max.
Sediment % weight	0.01 max.

The cost of this fuel is approximately 14 per cent. less than that of gas oil.

INSTALLATION

The importance of satisfactory alignment of engine and shaft at installation cannot be too strongly emphasised.

With a properly chocked engine, the crankshaft alignment seldom changes in many years running. Malalignment of the crankshaft is often caused by incorrectly fitted chocks. Such faulty alignment causes crankweb spring and, if this condition is allowed to continue, the repeated alternating stresses in the crankshaft will set up crystallization and fatigue stresses which could lead to a fracture of the crankshaft.

Regular crankshaft alignment checks should be made annually, unless some malalignment has appeared. After this has been corrected, it is usual to check at three months, six months and yearly intervals.

In order to ensure satisfactory alignment and satisfactory checking of the engine, it is recommended that the following procedure be adopted:

- The seatings should be ground and scraped absolutely flat over the full area of each chock, using a steel straight edge.
- The chock facings should slope one degree outwards, to ensure that the chocks can be fitted easily and without disturbing the true alignment. After the engine has been lined up correctly on the jacking screws, the chock should be fitted to within 0.0005 in. (0.0127 mm.) by precision scraping with the aid of suitable thickness gauge feelers and marking compound. By using this method on an absolutely flat engine seating, the possibility of distorting the bedplate, and thus creating malalignment of the crankshaft when tightening the bolts, is eliminated.
- Furthermore, if care is taken to obtain smooth bores for the bolts and bolts of the correct diameter are fitted, i.e. a tapping fit, there is no doubt that the alignment will be satisfactory and will remain so for a long period.

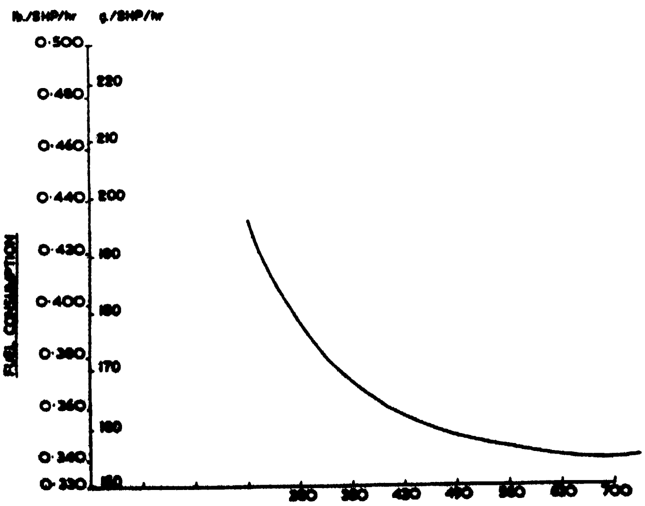


Fig. 238. Diesel engine fuel consumption curve

TORSIONALS

With the direct-reversing, direct-drive diesel engine, with a crankshaft designed not only for torque carrying capacity but to give a high natural frequency of vibration, the possibility of resonance and dangerous harmonics of the firing frequency within the operating speed range is eliminated.

In the engines under review, the natural frequency of the stern gear system has been arranged to fall at 1,043 vibrations per minute so that the fundamental 3½th order critical lies at 298 r.p.m., whilst the next major harmonic, which is the 7th order, lies at 149 r.p.m. and gives rise to a vibration stress with propeller damping of 745 lb./sq. in. (52.2 kg./sq. cm.). The natural frequency of the crankshaft is such that the running speed is situated beyond the 12th order harmonic and there are therefore no significant criticals in the running range. The installation is consequently completely free of criticals within the operating range and the vibration stress, therefore, in any portion of the shafting system will not exceed 745 lb./sq. in. (52.2 kg./sq. cm.) as stated above. This is due entirely to the provision of a large diameter crankshaft and stern gear, and, while the latter is considerably in excess of Lloyds' requirements, there is no barred speed range at all.

SHAFTING

The shafting is a normal installation and comprises thrust block, intermediate shaft, stern shaft and propeller.

The shafts for the first vessels were fitted with brass liners running in *lignum vitae* bushes. It was recognized that the wear of the *lignum vitae* would be rapid and at 0.060 in. (1.524 mm.) wear a gland was fitted at the outboard end of the brass tube and the tube was drilled for greasing. The results were excellent and, over four years,

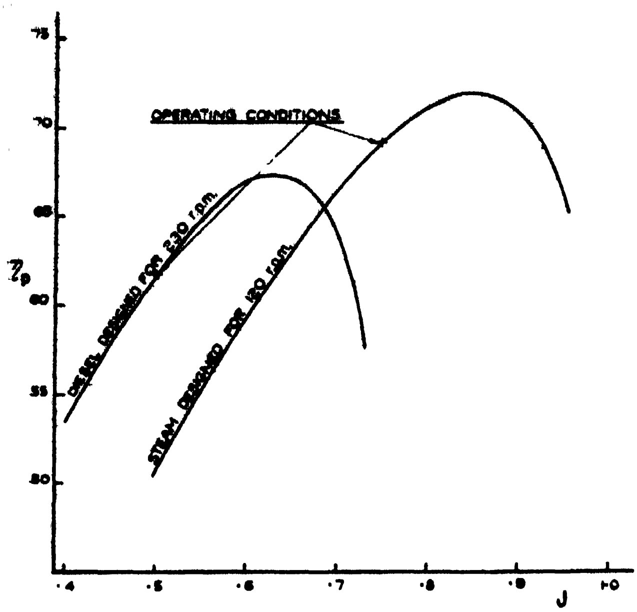


Fig. 239. Propeller efficiency for typical installations of steam and diesel trawlers

none of the tubes have had to be re-wooded. There was, however, some apparent swelling of the wood and it is therefore considered inadvisable to have less than 0.035 in. (0.889 mm.) clearance to allow for greasing.

The shafts on the later vessels run in white-metal-lined bushes and are lubricated from a header tank and fitted with outboard and inboard oil sealing glands. The first had glands with soft packing, but excess oil leaked from them despite the use of metal-wrapped packings. All now have an improved type of gland and packing.

As emulsified oil tends to solidify when cold, a two-pint (1.14 l.) capacity hand-operated oil-feed pump is now fitted whereby fresh oil can be injected direct to the tube. The return oil from the shafts is led into a drum and can be disposed of or re-used after cleaning.

PROPELLERS

Propeller efficiency

In changing from the conventional steam engine turning at about 120 r.p.m. to diesels with a propeller speed of 230 r.p.m., a loss of propeller efficiency naturally results. On the other hand, many of the earlier steam trawlers were still fitted with cast-iron propellers of elementary design. Modern, well-designed bronze propellers, with aerofoil blade sections, which are now standard equipment on the diesel trawlers, have reduced the efficiency loss to a minimum. Furthermore, the optimum propeller diameter is smaller for the higher shaft revolutions, thus providing improved immersion and reducing the possibility of fouling the fishing gear. Fig. 239 shows curves of propeller efficiency plotted to a base of advance coefficient J for typical installations of the diesel trawlers under consideration.

When translated into ship speed, the loss in propulsive efficiency is small, especially when consideration is given to recent developments in hull design, and any loss in speed is easily outweighed by the increase in horsepower delivered to the shaft by the diesel engine. This point is illustrated by fig. 240.

Loading

As diesel machinery is obviously less flexible than its steam counterpart, particular care had to be taken when designing the propellers to ensure that there will be no serious overloading in the trawling condition. Power measurements were carried out with a torsion meter on one of the earlier diesel vessels. The SHP thus determined gave satisfactory confirmation of estimated values, and the data formed a reliable basis for subsequent propeller design.

Thrust

As a result of experimenting with various combinations of pitch and diameter, the screw giving the most satisfactory compromise between ideal free running and

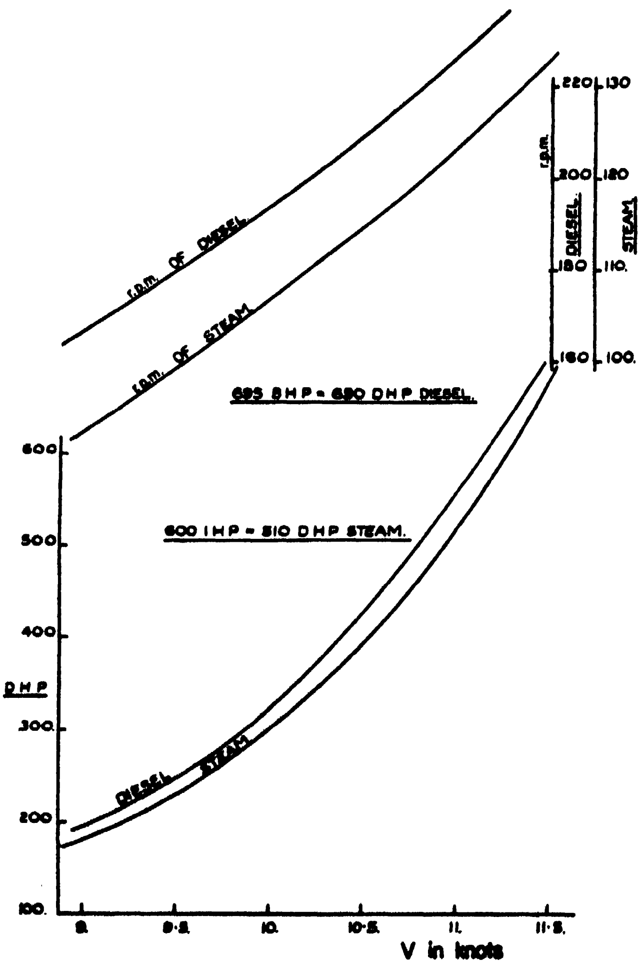


Fig. 240. DHP and r.p.m. versus curves of speed for typical steam and diesel trawlers

trawling was established. Fig. 241 shows estimated values of thrust for steam and diesel installations when free running and trawling. These serve to indicate the superiority of the diesel ships when comparing thrust at the appropriate operating revolutions. Attempts have been made on some more recent diesel vessels to measure the actual thrust by the use of a thrust meter. While the results gave reasonable agreement with the estimated figures in certain trawling conditions, some discrepancies were found in the free running results. Unfortunately, no similar thrust measurements are available from steamships for comparison purposes. It is hoped to obtain further data from diesel vessels in the future.

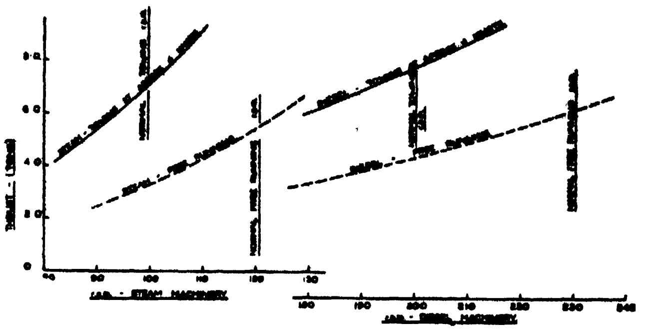


Fig. 241. Estimated values of thrust for steam and diesel machinery

Material

The early diesel trawlers were initially fitted with cast iron propellers but it was soon obvious that they would have a short life and were discarded after only nine months' service. Manganese bronze propellers are now standard and an appreciable saving in fuel results, in addition to a considerably longer life. None has yet had to be discarded and experience suggests that those originally fitted should last at least seven years, provided they are not seriously damaged. But it seems that a relatively high rate of wastage must be expected, due to the severe operating conditions. The propeller manufacturer, however, is fully aware of these conditions and has produced improved manganese bronzes at little extra cost. Such propellers will have a useful life of twelve years. This is satisfactory, considering the possibility of damage and also that the propeller may have to be modified by a change in the ship's service.

WINCH ENGINE

Balance of load of winch and main engine

Experience indicates that the power for the electric winch motor must be about 25 per cent. of the main engine power required when trawling. From the operational and maintenance point of view, it is essential to obtain power balance between the diesel engine and the electric winch motor. The first two vessels were fitted with 126 h.p. winch motors, whereas the last three vessels had 150 h.p. motors, all being driven by diesel generators of a similar type and power.

Difficulties in keeping the diesel engine running satisfactorily were experienced with the 126 h.p. winches. The diesel operated for long periods on light loads and, even when hauling, the power requirements were less than its normal output. The result was excessive carbon build-up on the pistons and cylinder heads, and heavy carbon deposits in the water-cooled exhaust manifold. In one case, the exhaust manifold became carboned and the manifold accumulated wet carbon containing unburnt fuel and lubricating oil which, due to the light load operation, had passed the pistons. The remedy was an uncooled manifold and by-passes to the fresh water heat exchanger and the lubricating oil cooler to obtain higher diesel temperatures as quickly as possible. It is important to avoid cold running, which is the cause of cylinder liner wear. A warming connection should be arranged from the main engine cooling system.

The three later vessels with 150 h.p. motors were more satisfactory both for trawl winch duty and in the better loading of the diesel when hauling.

One earlier vessel developed two armature defects due to hauling for prolonged periods near the stall condition in heavy weather. This condition could have been relieved by slowing down the main engine and thereby the ship, but was not desirable in this type of fishing. The gear ratio of the winches has now been lowered. Although this should give slower hauling, practice proves otherwise because a steady pull is better than slowing a motor to near stall on rising swells.

The selection of the winch diesel and generator power can now be safely based on the overload rating of the diesel being equal to the momentary overload of approximately 50 per cent. of the electric winch motor.

Following is a comparison between the trawl winch equipment on the first vessel and a later vessel, built in 1956:

	First vessel	*Later vessel*
r.p.m.	600	650
Diesel engine rating, continuous BHP	252	306
,, ,, ,, 12 hr. BHP .	280	340
,, ,, ,, 1 hr. BHP .	308	374
Electric winch motor, h.p. . . .	126	208
Motor momentary overload, max. h.p.	189	312
With allowance for losses and efficiency, the diesel must develop to meet the maximum momentary overload of the electric winch motor	230	377

The allowances are 10 per cent. for motor losses and 92 per cent. generator efficiency. For the first vessel, the diesel is lightly loaded even at the momentary overload of the winch motor, whereas the later diesel's one-hour rating is slightly exceeded but, as the overload is momentary, this is acceptable. The later diesel is, therefore, operated with better load.

The winch diesel runs some eight hours daily. There are approximately six hauls with 15 min. full load but for the remainder of the time the diesel is on light load, for general deck usage, or not in operation.

The maintenance schedules show that piston ring and liner wear figures are negligible, the greatest fault being the fuel dilution of the lubricating oil of the under-rated diesels. Fuel lines should be so placed that, in the event of porosity or leaking, fuel cannot get into the crank chamber.

The cylinder heads of the first vessel were serviced:

1st	year, after	1,485 hr.
2nd	„ „	2,663 „
3rd	„ „	3,860 „
4th	„ „	5,321 „
5th	„ „	6,500 „

The later winch sets with a more balanced power ratio have twice the maintenance period.

Lubrication

Two lubricating systems are used, i.e., a wet sump system with the oil in the bedplate, and a dry sump system with the oil in a separate sump tank fed by gravity from the bedplate or by a pump. It has been found desirable to omit the automatic lubricating oil emergency devices to avoid automatic cut-out of the diesel when operation of the winch is imperative. In the present system, audible alarms give the engineer warning.

Others

Winch electric overload cut-outs are now fitted with a timing device to avoid cutting out on a short rising swell. A push-button in the wheel house enables the skipper to stop the winch at once should a dangerous situation arise. Furthermore, remote control is fitted from the magnetic brake in the trawl winch electric motor room to the wheel house, so that the brake can be easily released in an emergency.

AUXILIARIES

Main specifications

The two general service sets, one being a standby, each comprise a 36 h.p. diesel engine, driving, through a flexible coupling, one 20 kW 110 volt DC generator and, through a friction clutch, one self-priming pump with a capacity of 30 tons (30.50 ton) per hour against a 70 ft. (21 m.) total head, and, through another friction clutch, one two-cyl. air compressor, capable of compressing 18½ cu. ft. (524 l.) of free air per minute to 350 lb./sq. in. (24.6 kg./sq. cm.). The diesels are hand started.

Loading

The general auxiliary electric loading is 12 to 15 kW, plus the power required to drive a pump or alternatively compressor. On average, an 80 per cent. load is carried, which has resulted in satisfactory diesel performance.

Maintenance

There have been no major renewals, except for the normal replacements of pistons and liners; the shell main bearings and the crankshaft are in good condition. There has been little or no wear.

Starting

Occasionally, in extremely cold weather, the auxiliary sets have been difficult to hand start and the diesels are now fitted with pneumatic starters. However, air starting on a dead ship requires a small auxiliary compressor of about 5 h.p., so a cartridge type of combustion starter may prove better and would save the small compressor.

Occasional trouble has been experienced in the main compressor due to the failure of the babbit lining in the big end bearings, caused by lack of lubrication. A change of trim or list results in a false oil level and reduction of the splash lubrication. It has been found advisable to fill the crankcase sump above the high oil level mark.

Future problem

One other factor was the loosening of the clutch housings on the shafts, and it is felt that, in future vessels, some improvement could be obtained by installing a larger generator to drive the compressor and general service pumps. This arrangement is most attractive as the general service pumps could be interchangeable with the main engine pumps. However, in the event of a switchboard failure, a direct driven pump is desirable to circulate the sea-water emergency cooling of the main engine.

The earlier vessels had an auxiliary steam boiler to supply heat for the radiators and for the fish liver oil plant. Many of the subsequent vessels have dispensed with the steam boiler, as initial outlay and maintenance costs outweigh the revenue from the oil. A small oil-fired hot water circulation boiler is now used for the radiators and the fish livers are landed raw.

TRAINING OF PERSONNEL

Many diesel engineers have graduated from the steam trawler. These men have, after a short training at the engine manufacturers' works, become most keen and proficient. The first diesel engineers have trained their colleagues, and experienced engineers, with the local port certificate, are now available for the increasing number of new diesel vessels.

PROPULSION SYSTEMS FOR MOTOR TRAWLERS

by

FRANZ SÜBERKRÜB

Difficulties in trawler design arise because of the two different requirements, high sailing speed and high trawling power. The paper describes how trawling power decreases in the case of a normal trawler, and how this loss can be avoided by the use of a multiple-speed gear, a controllable-pitch propeller or a propeller nozzle. These three devices are compared. A recent test showed that the multiple-speed gear system gave the best results.

LES SYSTÈMES DE PROPULSION POUR LES CHALUTIERS A MOTEUR

Deux exigences différentes: vitesse de route élevée et grande puissance pour le chalutage, soulèvent des difficultés dans le dessin de chalutiers. L'auteur décrit comment la puissance pour le chalutage diminue dans le cas d'un chalutier normal et comment cette perte peut être évitée en employant une boîte de vitesse, une hélice à ailes orientables ou une tuyère d'hélice. Ces trois dispositifs sont comparés. Un essai récent a montré que la boîte de vitesse donnait les meilleurs résultats.

SISTEMAS DE PROPULSION PARA MOTOARRASTREROS

Satisfacer dos necesidades distintas: mucha velocidad en ruta y mucha potencia en el arrastre, plantea importantes problemas al proyectista de arrastreros. En la ponencia se describe la disminución de potencia de arrastre en el arrastrero normal y cómo se puede evitar esta pérdida empleando transmisiones de varias velocidades, hélices de paso variable y hélices con toberas. Se comparan los tres sistemas. En una prueba efectuada recientemente se comprobó que el sistema de transmisiones de varias velocidades da los mejores resultados.

TRAWLERS frequently face a combination of unfavourable conditions, such as rough weather and heavy seas, and a considerable reserve of trawling power is required. To obtain a high sailing speed, the propeller must be designed to deliver maximum torque at the nominal (100 per cent.) r.p.m. of the engine. But the propeller also requires maximum torque when trawling, and as the engine cannot maintain this torque at a reduced speed of the ship, its r.p.m. and power drop. A vessel with a propeller of 11.8 ft. (3.6 m.) diam. was tested at a trawling speed of 3.5 knots under several different head wind forces. Table 72 gives the results.

When the same vessel was tested in the sailing condition at 14.5 knots its engine developed 1,025 SHP at 118 propeller r.p.m. and a measured propeller torque of 45,000 lb.ft. (6,200 kg.m.). This torque could be obtained without overloading the engine when trawling, the two higher torques in the table being recorded for very short periods only. The tests thus show that, while trawling, the maximum effective power of the engine is limited to 720 SHP.

The loss of about 300 h.p. when trawling can be avoided if a multiple-speed gear or a controllable-pitch propeller is used, or a diesel-electric drive.

MULTIPLE-SPEED GEAR

Regaining the lost power

Table 73 shows the results of a model test, based on the same propeller of 11.8 ft. (3.6 m.) diam., designed for a sailing speed of 14.5 knots, and trawling at 3.5 knots with a wake of 18 per cent. The engine output was 1,060 SHP and the loss of power before the propeller was assumed to be 6 per cent., so the available propeller power was 1,000 DHP in the sailing condition.

The slight variations between tables 72 and 73 occur because the figures in table 72 were obtained under unfavourable conditions at sea during trawling, while those in table 73 were derived from model tests. Even so, the tables reveal similarities. The main points of the four service conditions in table 73 are:

(1) The main engine output of 1,060 SHP at 350 r.p.m. gave a torque of 15,700 lb.ft. (2,170 kg.m.). The gear ratio of 1 : 2.84 resulted in a propeller speed of 123 r.p.m., with a corresponding torque of 15,700 lb.ft. $\times 2.84 \times 94\%$ $= 41,900$ lb.ft. (5,800 kg.m.), and a propeller thrust of 9.2 ton.

(2) While trawling, the engine delivered the same torque, 15,700 lb.ft. (2,170 kg.m.), as when sailing, but the engine speed dropped from 350 to 245 r.p.m. This resulted in reducing the engine output to 1,060 SHP $\times 245/350$ r.p.m. $= 740$ SHP. The propeller speed decreased by the same ratio from 123 to 86 r.p.m. and the propeller thrust was about 11.6 ton, which gave a pull of approximately 11 ton.

(3) With a multiple-speed gear of 1 : 3.54 ratio, the engine speed was increased from 245 to 305 r.p.m. while trawling, maintaining the output of 740 SHP, when the torque of the engine dropped to 15,700 lb.ft. $\times 245/350$ r.p.m. $= 12,600$ lb.ft. (1,740 kg.m.), while the propeller performance remained the same as for (2).

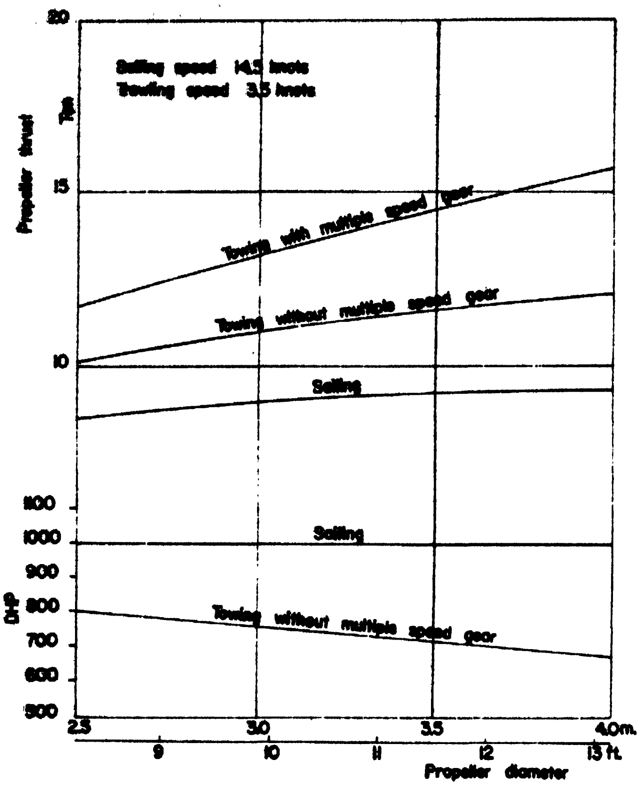


Fig. 242. Propeller thrust and DHP with and without multiple-speed gear

(4) To increase trawling power in a heavy sea, the engine speed was increased to produce a torque of 15,700 lb.ft. (2,170 kg.m.) and the same full engine output of 1,060 SHP at 350 r.p.m. as for the sailing condition. The propeller torque was increased from 42,400 to 54,100 lb.ft. (5,860 to 7,500 kg.m.), a 28 per cent. increase. Thus, by using a trawling-speed gear reduction, the propeller output was increased from 700 to 1,000 DHP, i.e., by 43 per cent.

Possibility of low power and low speed

In fair weather trawling conditions, Möckel found the SHP to be about 550 at 78 r.p.m. of the propeller or 276 r.p.m. (78 r.p.m. × 3.54) of the engine. According to the example in table 73 when using a speed gear reduction, the torque of the engine would be approximately 15,700 lb.ft. × 550/1,060 SHP × 350/276 r.p.m. = 10,300 lb.ft. (1,400 kg.m.) in this case. This provides for a propeller trawling power range from about 500 to 1,000 DHP which is obtained only by adjusting the engine speed, and shows the advantage of using a multiple-speed reduction gear. Another advantage of the multiple-speed gear is that the propeller speed can be reduced considerably while setting and/or hauling the trawl. If the engine speed can be reduced from 350 to 125 r.p.m., the corresponding propeller speed will be 44 r.p.m. with a gear ratio of 1 : 2.84 and 35 r.p.m. with a ratio of 1 : 3.54. Such a low speed makes it possible to keep the vessel in any desired position in relation to the trawl.

Effect of propeller diameter

Fig. 242 (top) shows the possible propeller thrusts for various propeller diameters when the power output is 1,000 DHP. These curves prove that greater thrusts are obtained by larger propellers and show how the thrust can be increased by a multiple-speed gear. Fig. 242 (bottom) shows that the DHP losses in trawling without a multiple-speed gear are smaller for smaller size propellers, e.g. 200 DHP for the propeller of 8.2 ft. (2.5 m.) diam., and more than 300 DHP for bigger propellers and naturally the gain in thrust by multiple-speed reduction gears is greater with large diameter propellers.

Reduction gear mechanism

The multiple-speed equipment consists of a reversible reduction gear of normal oil pressure as used for many decades aboard fishing boats. The only difference is that, instead of a single speed reduction for ahead, there are two, one for sailing and another for trawling. Full engine power can be used at any time with these. Changing from one speed to the other and to 'astern' is done in seconds with oil pressure laminated disc clutches. The gear can be used with non-reversible main propulsion diesels by de-clutching and allowing the engine to run. As there is no direct connection between propeller and engine, the propeller can be automatically stopped by a brake. The advantages of this design have been proved in practice (Ferdinande, 1958). According to him, five trawlers obtained optimum catches around Boulogne-sur-Mer by using multiple-speed reversible gears. The captains state that catches were less when they did not use the trawling-speed gear. The report also records: "In order to get the best fishing performance in a heavy sea, it seems to be extremely important to go considerably below the maximum torque, so that the towing power remains flexible in any circumstances".

TABLE 72

Tests of trawler without multiple-speed gear

Service condition	*Windforce Beaufort*	*Engine*	*Propeller*		
		Towing power SHP	*r.p.m.*	*Torque lb.ft.*	*Torque kg.m.*
Towing at 3.5 knots *without* multiple-speed gear	4	625	80	40,500	5,600
	6	720	83	44,100	6,200
	8	780	87	48,400	6,700
	10	960	92	54,200	7,500

CONTROLLABLE-PITCH PROPELLER

General description

Similar performances can be obtained with controllable-pitch propellers. The multiple-speed gear gives full power when trawling by adjusting the propeller speed, while the controllable-pitch propeller changes its pitch when trawling, maintaining a constant propeller speed. In both cases it is possible to operate the engine when trawling under full power at the nominal engine speed. However, to improve the efficiency of a controllable-pitch propeller under various load conditions, it is necessary to change not only the pitch but also the r.p.m. To obtain good thrust results, a controllable-pitch propeller must have a large diameter, as is shown in fig. 242 (top), and a comparatively low propeller r.p.m., and this requires a gear to reduce the engine r.p.m. A large controllable-pitch propeller, say 11.8 ft. (3.6 m.) diam., combined with a reduction gear is, however, very expensive and complicated, so that a careful study should be made as to whether or not a multiple-speed gear with a fixed propeller is more economical.

Comparison with multiple-speed gear

Inexpensive vessels have recently been built with controllable-pitch propellers to get 20 to 30 per cent. higher thrust at full engine power while trawling. A propeller of 8.5 ft. (2.6 m.) diam. has been used for an engine of approximately 1,000 h.p. without reduction gear. As shown in fig. 242 (top), the propeller thrust for 1,000 h.p. at 8.5 ft. (2.6 m.) diam. at full power is 12 ton and at 11.8 ft. (3.6 m.) diam., 14.6 ton. If a thrust of 12 ton is sufficient, then an 11.8 ft. (3.6 m.) diam. propeller and an engine of 700 h.p. with multiple-speed gear could be used, as shown in table 72. In this case, the higher cost of a large propeller with reduction gear would be offset by the less expensive engine of smaller power, and operation expenses would be considerably lower. The deciding

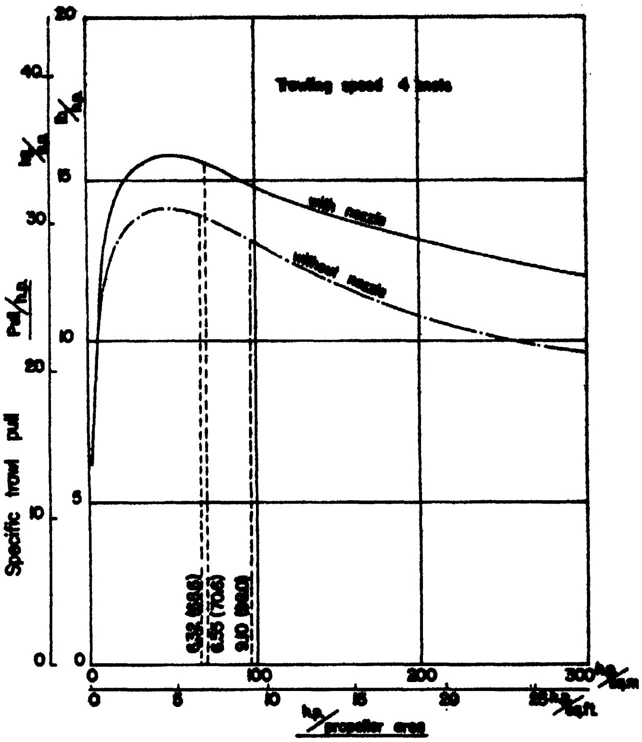


Fig. 243. Trawl pull improvement when using a propeller nozzle

factor is, however, the distance to the fishing grounds. If the distances are great, high sailing speeds are required and, in practice, it has been proved that large diameter propellers produce higher speeds for the same engine output, especially in heavy seas.

It has been said that trawler captains do not like the way the controllable-pitch propeller rotates after being put into the stop position when hauling the trawl. The

TABLE 73

Model tests of trawler with and without multiple-speed gear

Service condition	*Engine* r.p.m.	*Engine* Torque lb.ft.	*Engine* Torque kg.m.	*Engine* Power SHP	*Gear Ratio*	*Propeller* r.p.m.	*Propeller* Torque lb.ft.	*Propeller* Torque kg.m.	*Propeller* Power DHP	*Propeller* Thrust ton
Sailing	350	15,700	2,170	1,060	1:2.84	123	41,900	5,800	1,000	9.2
Towing at 3.5 knots *without* multiple-speed gear . .	245	15,700	2,170	740	1:2.84	86	42,400	5,860	700	11.6
Towing at 3.5 knots *with* multiple-speed gear	305	12,600	1,740	740	1:3.54	86	42,400	5,860	700	11.6
Towing at 3.5 knots *with* multiple-speed gear	350	15,700	2,170	1,060	1:3.54	96	54,100	7,500	1,000	14.6

$$\frac{\text{r.p.m.} \times \text{torque}}{\text{power}} = \text{constant}$$

TABLE 74

Pull improvements with nozzle and with multiple-speed gear

Service condition	*Power h.p.*	*SHP/sq. ft. (sq. m.)*	*Pull lb./SHP (kg./SHP)*	*Pull in ton*	*Pull improvement per cent.*
Towing at 4 knots *without* nozzle	700	6.32 (68.6)	30.93 (13.65)	9.56	0
Towing at 4 knots *with* nozzle	720	6.55 (70.6)	33.73 (15.3)	11.0	15
Towing at 4 knots *with* multiple-speed gear	1,000	9.1 (98.0)	28.66 (13.0)	13.0	36

danger that it might damage the trawl is obvious and this cannot happen with a stopped propeller. The controllable-pitch propeller normally only stops when the engine stops.

Cavitation is harmful to any propeller's efficiency and eventually damages the propeller and the rudder. Cavitation, of course, depends on various factors, but primarily on the load per propeller area, which in turn depends on the propeller diameter. There is normally no cavitation with propellers of 9.8 ft. (3 m.) diam. and larger with 1,000 h.p. but it occurs with those of smaller diameters, e.g., 8.5 ft. (2.6 m.).

DIESEL-ELECTRIC DRIVE

The diesel-electric drive supplies full power to the propeller under any load conditions and at all speeds. The main engine operates at constant r.p.m. and does not have to be reversed as the electric motor deals with all manoeuvres. The disadvantage is the high initial cost and the electrical losses—as much as 20 per cent.—between the diesel and the electric motor. However, the system can supply auxiliary power, which eliminates the need for auxiliary generators, and this partly offsets the loss, particularly if the auxiliary power requirements are very high.

PROPELLER NOZZLE

Improvements in trawling power with the propeller nozzle and its influence on the sailing speed were shown in tests made in the Hamburg Tank. The results are summarized in fig. 243, where the specific trawling power (pull/h.p.) obtained from a number of model tests on well-designed tugs is shown against the SHP/sq. ft. (sq. m.) of the propeller area at a speed of 4 knots with and without nozzle. Table 74, from fig. 243, allows comparison with the other tables. The improvements in pull under different conditions, with 1,000 h.p. and 11.8 ft. (3.6 m.) diam. propellers having blade areas of 109.8 sq. ft. (10.2 sq. m.) are shown.

The main points of comparison are:

- Without the nozzle, the power loss was 30 per cent., namely from 1,000 h.p. to 700 h.p., and resulted in a pull of 9.56 ton
- With nozzle, the power loss was 28 per cent. This means that 720 h.p. was available for the propeller, but the nozzle gave a pull of 11 ton, an improvement of 15 per cent. in thrust.
- Without the nozzle, but using the full 1,000 h.p. while trawling, with the help of a multiple-speed gear, the resulting pull was 13 ton, an improvement of 36 per cent. in thrust

Similar tests were made at Wageningen with propellers of various diameters. Where the diameters of propellers without nozzles were 3 per cent. larger than those with nozzles, the increase in trawling power of the latter was only 10 per cent. at 4 knots, and there was no increase when the speed was 6.25 knots. In table 74 the nozzle propeller and the normal propeller are of the same diameter. According to Helm, the sailing speed of a tug, with the same power, was 10.75 knots with nozzle and 11.03 knots without nozzle. Another sailing test was made at Wageningen and about 0.5 knot higher speed was obtained without a nozzle when the speed was about 13 knots.

These tests indicate that the speed losses caused by a propeller nozzle increase at higher sailing speeds. While good results are obtainable at low trawling speeds, speed losses have to be considered for the sailing condition, and as a high sailing speed is important for trawlers careful consideration should be given before the installation of a nozzle.

RECENT TRAWLERS FITTED WITH MULTIPLE REDUCTION GEARS

by

ALEXANDRE CHARDOME

The first trawler to be fitted with a multiple reduction gear was the *Belgian Skipper*, delivered in September 1953. Since then, 15 similarly fitted trawlers have been built or are under construction in Belgium, mostly powered by diesel engines of 1,200 to 1,500 h.p. In France, 25 similar trawlers of smaller power have been built.

The latest trawler built in Belgium, the 628 GT *Pierre*, has the following main dimensions: length overall 192 ft. 9 in. (58.80 m.); length between perpendiculars 170 ft. 10 in. (52.10 m.); moulded breadth 30 ft. 10 in. (9.40 m.) and depth 17 ft. 5 in. (5.32 m.). Its hold capacity is 14,830 cu. ft. (420 cu. m.)

With a load of 288 tons of fuel, fresh water, ice and fishing gear, the *Pierre* did 15 knots on trials, while developing less than 1,400 h.p. at the engine coupling flange. The main propulsion engine is a four-stroke supercharged diesel with a continuous output of 1,500 h.p. at 300 r.p.m. The reverse reduction gear has two ahead and one astern speeds. The ahead speeds are 154 r.p.m. for free running and 113 r.p.m. for trawling. With the astern gear clutch engaged, the propeller runs at 88 r.p.m. The fixed-blade propeller has a diameter of 10 ft. 11 in. (3.33 m.).

The propeller of a trawler must meet the very different working conditions of trawling and free running. Based on the propeller charts of the B4-70 Troost series, the author provides a comparison between a controllable-pitch propeller of 10 ft. 10 in. (3.30 m.) diam. and a fixed-blade propeller of 11 ft. 4 in. (3.46 m.) diam. and 11 ft. 4 in. (3.46 m.) pitch. This shows that unless the propeller diameter is strictly limited, there is no valid hydrodynamic reason for preferring one type of propeller to the other.

CHALUTIERS RÉCENTS MUNIS DE RÉDUCTEURS A PLUSIEURS VITESSES

Le premier chalutier muni d'un réducteur à plusieurs vitesses a été le *Belgian Skipper*, livré en septembre 1953.

Depuis lors, quinze chalutiers équipés de façon semblable ont été construits ou sont en construction on Belgique, le plus souvent propulsés par des diesels de 1.200 à 1.500 c.v. Vingt-cinq chalutiers semblables mais moins puissants ont été construits en France.

Le plus récent chalutier construit en Belgique, le *Pierre*, de 628 tx de jauge brute, qui a fait l'objet d'essais de modèle au bassin avant d'être dessiné et construit, a les dimensions principales suivantes: Longueur hors-tout, 192 pi. 9 pouces (58,80 m.); longueur entre perpendiculaires, 170 pi. 10 pouces (52,10 m.); largeur hors membrures, 30 pi. 10 pouces (9,40 m.), et creux 17 pi. 5 pouces (5,32 m.). Sa cale a une capacité de 14.830 pi. cubes (420 m³).

Avec un chargement de 288 tonnes de carburant, eau douce, glace et engins de pêche, le *Pierre* a filé 15 noeuds aux essais en développant moins de 1.400 c.v. à la bride d'accouplement du moteur. Le moteur principal de propulsion est un diesel à 4 temps suralimenté avec une puissance continue de 1.500 c.v. à 300 t.p.m. Le réducteur-inverseur posséde deux vitesses avant et une arriére. Les vitesses avant sont 154 t.p.m. en route libre et 113 t.p.m. en chalutage. Avec la marche arriére engagée, l'hélice tourne à 88 t.p.m. L'hélice à ailes fixes a un diamétre de 10 pi. 11 pouces (3,33 m.).

L'hélice d'un chalutier doit satisfaire a des conditions de travail très différentes: en chalutage d'une part, en faisant route d'autre part. En se basant sur les tables de la série Troost B4-70, l'auteur établit la comparaison entre une hélice à ailes orientables de 10 pi. 10 pouces (3,30 m.) de diam. et une hélice à ailes fixes de 11 pi. 4 pouces (3,46 m.) de diam. et un pas de 11 pi. 4 pouces. Cela montre qu'à moins que le diamétre de l'hélice soit strictement limité, il n'y a pas de raison hydro-dynamique valable pour préférer un type d'hélice à l'autre.

ARRASTREROS MODERNOS DOTADOS DE REDUCTORES DE VARIAS VELOCIDADES

El *Belgian Skipper*, entregado en septimbre de 1953, fué el primer arrastrero dotado de un reductor de varias velocidades.

Desde entonces se han construído o se construyen en Bélgica otros 15 equipados de manera analoga, casi todos ellos accionados por motores diesel de 1.200 a 1.500 c.v. En Francia se han construdo 25 arrastreros análogos, pero menos potentes.

El más reciente arrastrero construido en Bélgica, el *Pierre*, de 628 tons. brutas de registro, tiene las dimensiones principales siguientes: Eslora total, 192 pies y 9 pulg. (58,80 m.); eslora entre perpendiculares, 170 pies, 10 pulg. (52,10 m.); manga de trazado, 30 pies 10 pulg. (9,40 m.); y calado, 17 pies 5 pulg. (5,32 m.). La bodega tiene una capacidad de 14.830 pies³ (420 m³).

Con una carga de 288 tons. de combustible, agua dulce, hielo y artes de pesca, el *Pierre* alcanzó 15 nudos en las pruebas, desarrollando menos de 1.400 c.v. en el plato de acoplamiento del motor. El motor principal de propulsión es un Diesel de 4 tiempos, sobrealimentado, con un rendimiento continuo de 1.500 c.v. a 300 r.p.m. El engranaje reductor de inversión tiene dos velocidades avante y una atrás. Las velocidades avante son de 154 r.p.m. en ruta libre y de 113 r.p.m. cuando pesca al arrastre. Cuando se da la marcha atrás, la hélice gira a 88 r.p.m. La hélice de palas fijas tiene un diámetro de 10 pies 1 pulg. (3,33 m.).

La hélice de un arrastrero encuentra condiciones muy distintas de trabajo pescando al arrastre y navegando en ruta libre. Basándose en las tablas de la serie B4-70, el autor hace comparaciones entre la hélice de paso variable de 10 pies 10 pulg. (3,30 m.) de diám. y la de palas fijas de 11 pies 4 pulg. (3,46 m.) de diám. y un paso de 11 pies 4 pulg. Demuestra que a menos que el diámetro de la hélice se limite estrictamente, no hay ninguna razón hidrodinámica válida para preferir un tipo de hélice a otro.

THE first trawler to be fitted with a multiple reduction gear was the *Belgian Skipper*, delivered in September 1953 (Chardome, 1955). Since then, 12 trawlers fitted with similar gear have been built in Belgium and three more are now under construction. Within the same period about 25 trawlers of lower power have been built in French shipyards.

Table 75 gives particulars of the 15 Belgian trawlers. All have a low prismatic coefficient and are designed to operate at maximum speed. The choice of a propeller to suit both working conditions—free running and trawling—is, therefore, a problem of primary importance.

Auxiliary diesel for propulsion

The *Belgian Skipper* has proved to be a very successful ship from both the mechanical and fishing point of view. Two targets were aimed at during its design:

- Full use of the main engine developing a practically constant torque at all r.p.m., while driving a propeller requiring different torques at different speeds
- Use, while cruising, of the source of energy which drives the trawl winch on the fishing grounds.

Development during the past five years has led to the abandonment of the second requirement. In the first three trawlers of table 75, the "father and son" propulsion system was used with the auxiliary engine driving the propeller shaft through an electric motor, but in all later vessels there is no connection between the main and the winch diesel engines.

An independent auxiliary engine for the winch drive can be any reliable high r.p.m. diesel, with a high degree of supercharging and costing comparatively less per h.p. than if this engine were also to be used for propulsion. Such dual-purpose use, of course, introduces complications.

The use of twin diesels has been considered too expensive when single diesels are available to give the required propulsion output at sufficiently high r.p.m.

Breakdown of reduction gear

It must be mentioned that three trawlers, namely No. 1, No. 2 and 4 of table 75, suffered from breakdowns of gear teeth after a few months' service. These breakdowns, however, were not caused by the multiple-speed reduction gear; they were the result of inadequate surface-hardening during manufacture. To eliminate such breakdowns, the hardening process was modified, components of larger dimensions were used, and ultra-sonic control was introduced in the hardening shop. These measures have cured the weakness.

The many repeat orders for trawlers with multiple reduction gear provide concrete evidence of the satisfactory performance of this system.

Latest development

Fig. 244 shows the *Pierre* of Boulogne S/Mer, the latest and most modern trawler to be delivered. It has an overall length of 192 ft. 9 in. (58.80 m.), a length between perpendiculars of 170 ft. 10 in. (52.10 m.), a moulded breadth of 30 ft. 10 in. (9.40 m.) and a depth of 17 ft. 5 in. (5.32 m.).

Model self-propulsion and wave tests were carried out in 1954 in the Paris tank.

The ship's tonnage is 628 GT, and the capacity of the insulated fish holds is 14,830 cu. ft. (420 cu. m.). The fuel tanks hold 45,100 Imp. gal. (205 cu. m.) and the freshwater tanks 10,000 Imp. gal. (46 cu. m.).

The main propulsion engine in fig. 245 is a four-stroke, supercharged diesel with a continuous output of 1,500 h.p. at 300 r.p.m. The reverse reduction gear in fig. 246 is the Suberkrub patent and has a 154 r.p.m. ahead speed for free running and 115 r.p.m. for trawling. The astern speed is 88 r.p.m. The fixed-blade propeller has a diameter of 10 ft. 11 in. (3.33 m.).

The auxiliary diesel only drives a generator supplying power to the trawl winch electric motor through a Ward Leonard coupling. This eight-cyl. engine is supercharged and has an output of 230 h.p. at 1,350 r.p.m.

Use of a heavy flywheel, a Periflex type rubber coupling and a very accurate calculation of torsional vibrations enables the propulsion engine to run from 75 to 300 r.p.m. without entering a critical vibration field. A totally progressive thrust of the propeller is, therefore, ensured.

Carrying a load of 288 ton of fuel, fresh water, ice and

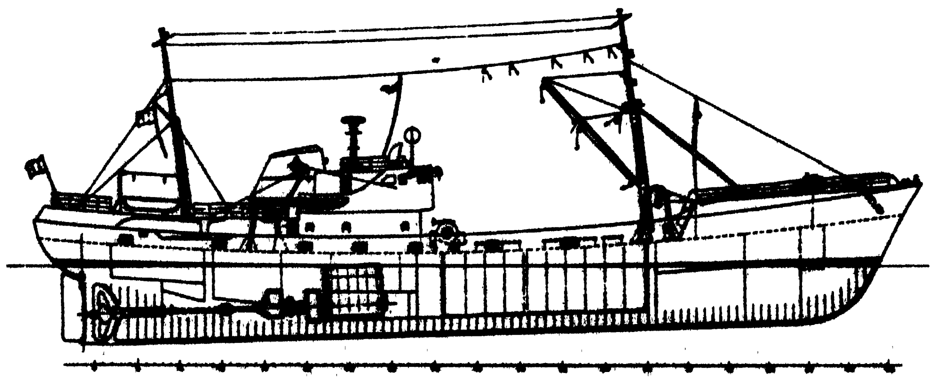


Fig. 244. Belgian traw

TABLE 75

Engine powers of various trawlers all with multiple speed gear, the first three with the "father and son" propulsion system

No.	*Year*	*Name*	*h.p.*	*Registration harbour*
1	1955	*Pierre Barris*	1,540	Boulogne S/Mer
2	1955	*Commandant Charcot*	1,540	Boulogne S/Mer
3	1956	*Duchesse de Brabant*	1,540	Ostend
4	1956	*Joseph Manesse*	1,250	Boulogne S/Mer
5	1956	*Dupleix*	1,250	Boulogne S/Mer
6	1956	*Champlain*	1,250	Boulogne S/Mer
7	1956	*Rene Goeman*	440	Ostend
8	1957	*Shamrock III*	1,500	Fécamp
9	1957	*La Fayette*	1,250	Boulogne S/Mer
10	1957	*Nicolas Appert*	1,250	Boulogne S/Mer
11	1958	*Courbet*	1,250	Boulogne S/Mer
12	1958	*Pierre*	1,500	Boulogne S/Mer
13	—	*Pierre Staner*	440	Ostend
14	—	—	1,500	Boulogne S/Mer
15	—	—	1,200	Ostend

fishing gear, the *Pierre* had a measured trial speed of 15 knots while developing somewhat less than 1,400 h.p. at the engine coupling flange. See fig. 247.

The astern clutch is easily engaged, even at the highest speed, as the astern reduction ratio is higher than the free running reduction ratio. A registering camera, used during the trials showed that the ship, running at 15 knots, was stopped in 410 ft. (125 m.) after the astern clutch was engaged.

Efficiencies

The author (Chardome, 1955) stated that diesel-electric drive means about 15 per cent. increased fuel consumption. This has been disputed by some but the author considers that consumption is, in fact, still higher.

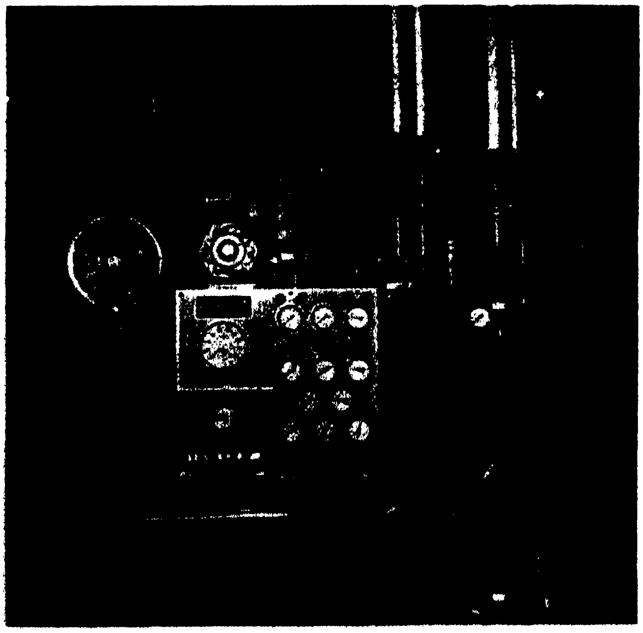


Fig. 245. Control board of the main propulsion engine

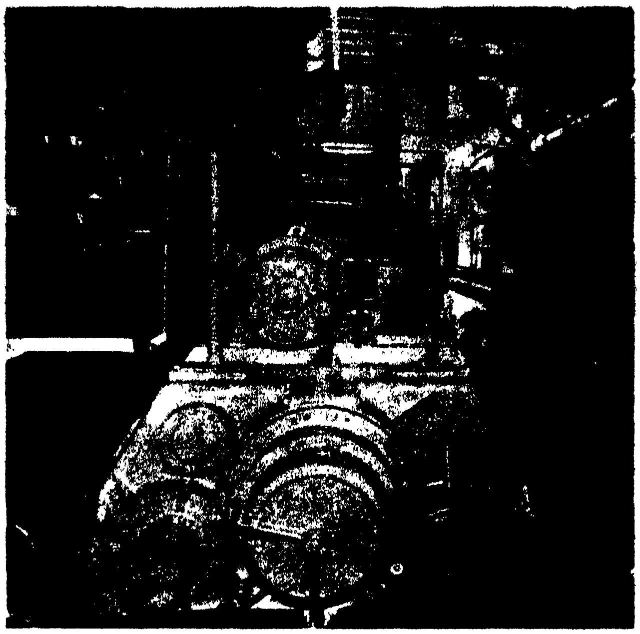


Fig. 246. Engine room and multiple reverse-reduction gear

The propeller calculation for the *Belgian Skipper* was 900 h.p. for the propeller, corresponding to 1,000 h.p. for the engine coupling flange. Some concluded that 10 per cent. loss of efficiency was the result of the multiple reduction gear, but that is not true. The 10 per cent. was due to a shaft-driven generator and a bad weather margin. The efficiency of a multiple-speed reverse reduction gear is higher than 97 per cent., as against less than 99 per cent. for the normal reduction gear incorporated in the diesel-electric drive. The difference is actually some 1.5 per cent.

Multiple reduction gear versus controllable-pitch propeller

The simplest way to explain the propulsion results of the *Pierre* is with a thrust speed diagram as shown in fig. 248. The thrusts, h.p., r.p.m. and efficiencies are based on open-water propeller tests carried out in the Paris tank. The speeds, in knots, were noted on the diagram, using the wake coefficient resulting from the self-propulsion tests. The thrusts along FG also come from the self-propulsion tests. The relative rotative efficiency which is opposite to and has the same order of magnitude as the loss in the shaft line, has not been taken into consideration and the slight increase in r.p.m. which should result from the wake scale effect is also disregarded. Each point of the diagram represents approximately the output of the engine, the revolutions of the propeller and the resulting thrust.

The surface, AEFGK, is the field where the trawler could have worked if it had been fitted with a free-running speed propeller only, taking for granted a normal lowest engine speed of about one-third of the nominal speed, i.e. about 50 r.p.m. of the propeller.

The surfaces, ABDE and JKGH (vertically hatched)

Fig. 247. Pierre at 15 knots on the measured mile

result from using a trawling speed gear and a heavy fly-wheel. The engine running steadily at 75 r.p.m. drives the propeller at 28 r.p.m. through the trawling speed gear, instead of 50 r.p.m.

If a controllable-pitch propeller had been fitted to give, at trawling speed, the same thrust as that of the *Pierre* (Point D of diagram) three additional working fields would have appeared (cross-hatched on the diagram): triangles BCD, DEF and OJH. These fields represent the following theoretical advantages for a trawler:

(a) Consider triangle BCD. A ship fitted with a controllable-pitch propeller cannot while trawling adjust the pitch for the passage of each wave along the ship. The propeller must work at a certain pre-set position which renders it equivalent to a fixed-blade propeller. If this position corresponds to point D, lines of torque and revolution very close to BD and DE will similarly limit its field of action.

(b) Consider that part of line DF close to F. If the ship is running free in bad weather, and if it is assumed that the weather conditions do not necessitate a reduction of the propulsion output, it is theoretically possible to adjust the pitch so as to obtain an additional speed of two-tenths of a knot. But such a pitch adjustment can only be made empirically, by trial and error, which will not guarantee the expected increase in speed.

(c) Consider triangle JOH. Diesel engines are built which run steadily at 20 per cent. of the nominal r.p.m. This brings line JH down to line J_1 H_1. If still lower propeller revolutions were necessary, the output of the auxiliary diesel could be transmitted to the reduction gear quite simply through an electric motor connected by clutch to the free end of a convenient intermediate shaft in the gear. But as fishing companies do not seem interested in such a device, its usefulness seems only to be relative.

It has been fully realized during recent years that the propeller of a trawler needs to be adapted to suit the contrasting working conditions of trawling and free running.

A point less clear is the difference between propeller adjustment through speed change in the reduction gear, and propeller adjustment through pitch change in the propeller itself. The standard series diagrams do not afford a composite view of the problem, but the author has tried to fill out the picture in fig. 249, 250 and 251, based on charts of the Troost B4-70 series. These give

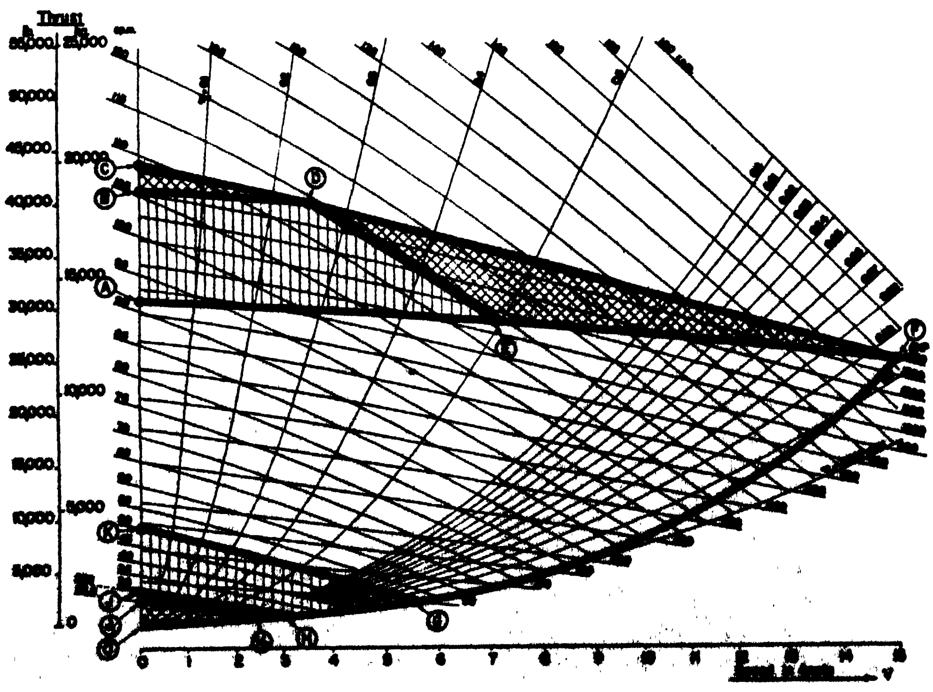


Fig. 248. Thrust-speed diagram of trawler Pierre based on open water model tests

the thrusts as a function of propeller r.p.m., with diameters ranging from 9 ft. 10 in. to 11 ft. 10 in. (3.0 to 3.6 m.) and pitch ratios ranging from 0.6 to 1.2. The x-axis gives the r.p.m., the y-axis the thrusts, and the intersection of both perpendiculars the pitch ratio and the diameter.

Fig. 249 has been prepared for a propeller absorbing 1,400 h.p., with the water entering the propeller at speeds of 4.92 ft./sec. (1.5 m./sec.), corresponding to trawling, and 21.3 ft./sec. (6.5 m./sec.), corresponding to free-running.

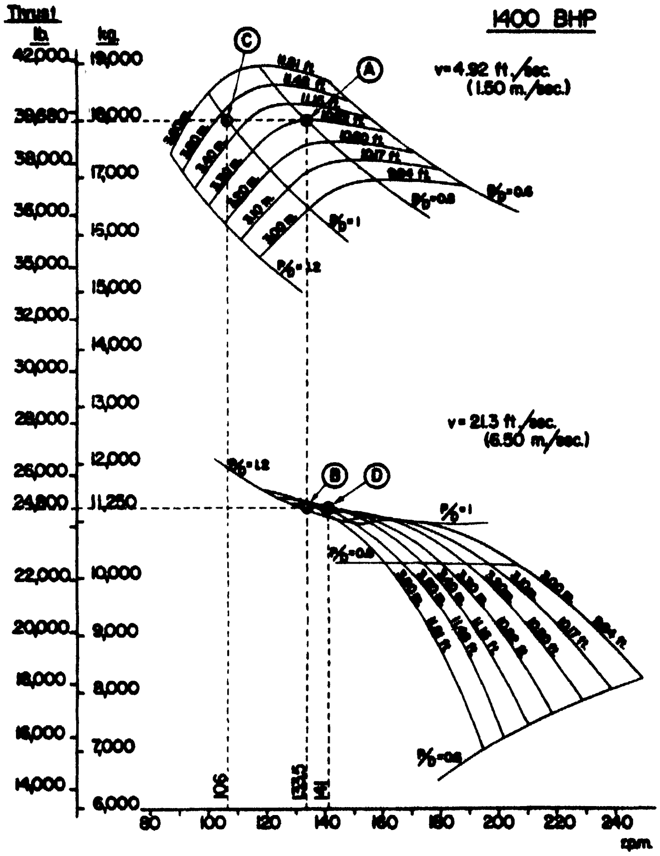


Fig. 249. Comparison between controllable-pitch and multiple reduction gear propellers at 1,400 h.p.

Fig. 250 is for 1,000 h.p. at the propeller, 4.92 ft./sec. (1.5 m./sec.) water speed when trawling, and 19.36 ft./sec. (5.9 m./sec.) water speed when free-running.

Fig. 251 is for 600 h.p. at the propeller, 4.92 ft./sec. (1.5 m./sec.) water speed when trawling, and 16.73 ft./sec. (5.1 m./sec.) water speed when free-running.

The following comments are made about these charts:

(1) The author has assumed that a controllable-pitch propeller, adjusted to a given pitch, has the same efficiency as a fixed-blade propeller directly devised for that pitch. This assumption might be too favourable to the controllable-pitch propeller, because both the size of the boss, and the disturbed pitch distribution, when a blade leaves its original position, cause loss of efficiency. This disturbance in pitch distribution becomes very pernicious

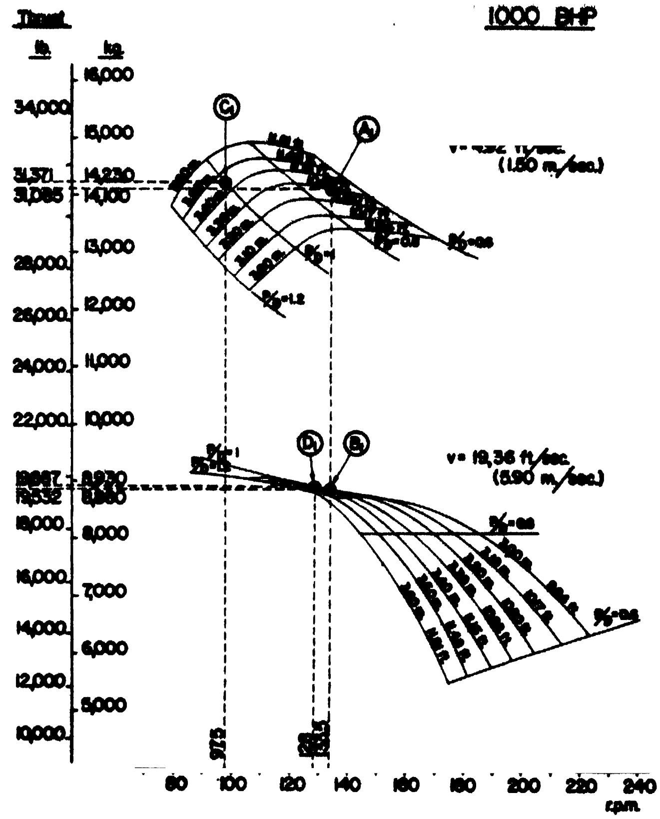


Fig. 250. Comparison between controllable-pitch and multiple reduction gear propellers at 1,000 h.p.

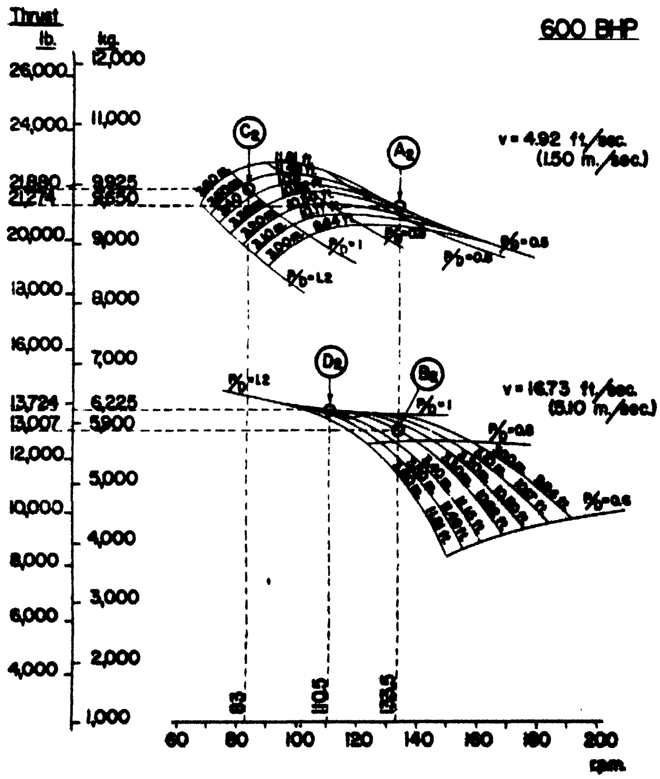


Fig. 251. Comparison between controllable-pitch and multiple reduction gear propellers at 600 h.p.

TABLE 76

Comparison between controllable-pitch and fixed-blade propellers

Fixed-blade propeller

	h.p.	Thrust lb.	Thrust kg.		r.p.m.
Trawling at	1,400	39,680	18,000		106
,,	1,000	31,371	14,230		97.5
,,	600	21,880	9,925		83
Sailing at	1,400	24,800	11,250		141
,,	1,000	19,687	8,930		128
,,	600	13,724	6,225		110.5

Controllable-pitch propeller

	h.p.	Thrust lb.	Thrust kg.		r.p.m.
Trawling at	1,400	39,680	18,000		133.5
,,	1,000	31,085	14,100	(−130 kg.)	133.5
,,	600	21,274	9,650	(−275 kg.)	133.5
Sailing at	1,400	24,800	11,250		133.5
,,	1,000	19,532	8,860	(−70 kg.)	133.5
,,	600	13,007	5,900	(−325 kg.)	133.5

when running astern. The pitch of a controllable-pitch propeller is reduced by from 20 to 25 per cent. between free-running and trawling. Within these limits, the loss of efficiency should be low and can be assumed to be not more than a small percentage for well-designed propellers.

(2) A controllable-pitch propeller of diameter D has been compared with a fixed-blade propeller of diam. 1.05 D, so as to get the same thrust at trawling speed.

(3) Points A and B represent the controllable-pitch propeller when trawling and when running free; points C and D represent the fixed-blade propeller in the corresponding conditions.

Table 76 provides a comparison between a controllable-pitch propeller of, say, 10 ft. 10 in. (3.3 m.) diam., absorbing 1,400 h.p. at the optimum revolutions for the trawling thrust, i.e. 133.5 r.p.m., with a fixed-blade propeller of 11 ft. 4 in. (3.45 m.) diam. and 11 ft. 4 in. (3.45 m.) pitch.

Any similar comparison would be equally simple.

Cavitation checks should, of course, be made before considering a solution as definitely valid.

Unless the propeller diameter is strictly limited, there seems to be no valid hydrodynamic reason why there must be a choice between a fixed-blade propeller with multiple reduction gear and a controllable-pitch propeller. A well-designed trawler using either type of propeller will have similar cruising and trawling qualities.

Apart from performance, there are other factors which influence owners in their choice of a propeller. These are the purchase price, maintenance costs, reliability, and simplified drive control. Owners' reports on the working of both systems are therefore invited.

DEVICE FOR RAISING AND LOWERING PROPELLERS

by

KEIGO INAMURA and MOTOJIRO NINOMIYA

Small, conventional Japanese fishing boats, when motorized, are fitted with a device for raising and lowering the propeller and tail end of the shaft. This facilitates their safe landing on beaches. The device is simple but its mechanism involves many problems yet to be solved.

UN DISPOSITIF POUR RELEVER ET ABAISSER LES HÉLICES

Quand ils sont motorisés, les petits bateaux de pêche courants sont munis d'un dispositif pour relever et abaisser l'hélice et l'arbre porte-hélice. Cela facilite leur échouement sur les plages. Le dispositif est simple mais son mécanisme crée de nombreux problèmes qui sont encore à résoudre.

DISPOSITIVO PARA LEVANTAR Y BAJAR LAS HELICES

Cuando se motorizan los pesqueros pequeños corrientes, cuentan con un dispositivo para levantar la hélice y el extremo exterior del árbol. Esto facilita sus varadas en las playas. El dispositivo es sencillo, pero su mecanismo presenta muchos problemas que todavía no se han resuelto.

THERE are about 403,000 fishing craft working the inland and coastal waters of Japan, and of these some 157,000 are powered, 130,000 being boats of less than 5 GT, mostly built in typical Japanese style. They are engaged in pole and line fishing, longlining, shellfish and aquatic plant collecting, seine fishing, etc. Many work along the stretches of the coast where there are no suitable harbours so they must anchor in shallow water or be hauled on a beach. Their propellers, therefore, must be protected from damage, and this has led to the development of a device for raising and lowering propellers.

As the propulsive efficiency of a propeller in a small craft is generally best at the greatest possible depth from the water surface, such boats usually have their propellers below the keel line, despite some damage risks.

The device is especially useful when:

(1) Approaching shallow waters. After bringing the engine to a stop and raising the propeller, the boat is steered by hand. If the depth of water is sufficient, the propeller can be raised slightly to enable the boat to run at slow speed.

(2) Landing and beaching. Small boats are usually launched or hauled ashore by man power or winch and the device can be used to raise both propeller and shaft.

(3) Mooring in rivers or where the water level may be affected by an ebb tide or the bottom of the boat may touch the ground. The device can be used to raise and secure the propeller and shaft.

Structure and materials

The general arrangement of a wooden pole and line fishing boat of about 23 ft. (7 m.) length overall is shown in fig. 252. The main engine is a 6-h.p. diesel. Fig. 253 shows the details of the raising and lowering device used for diesels of 5 to 20 h.p. It consists of a universal joint and a vertical sliding assembly supporting a hanging bearing.

(a) Universal joint. The propeller shaft is in two parts connected by a universal joint. The aft part of the shaft is movable up and down, its fulcrum being the centre of the universal joint spider. Fig. 254 shows a universal joint with key and set screw.

(b) Sliding assembly. The sliding assembly is shown in fig. 253 and 255. It consists of the tubular sliding component which is free to move axially in a vertically supported guide. The lower part of the sliding tube is connected to the hanging bearing housing.

By moving the sliding tube, up or down, the propeller is raised or lowered, and the propeller can be fixed in any selected position. The hanging bearing housing is secured to the sliding tube by a cross pin as shown in fig. 257. One of three methods to raise and lower the propeller can be used:

- By sliding tube with hinge as shown in fig. 255
- By a sliding tube without hinge as shown in fig. 253
- With a screw as shown in fig. 256

The third method is used for propeller shafts of engines of

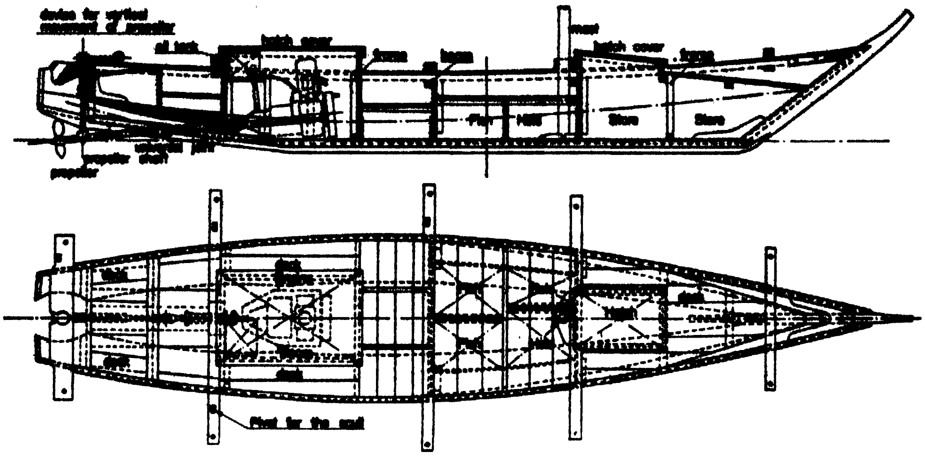


Fig. 252. General arrangement of Japanese wooden pole and line fishing boat of about 23 ft. (7 m.) length overall

30 to 60 h.p. Either of the first two methods is suitable for lighter engines.

(c) Hanging bearing. The hanging bearing supports, raises and lowers the propeller shaft and through it the propeller, the smooth up or down movement being provided by the sliding member.

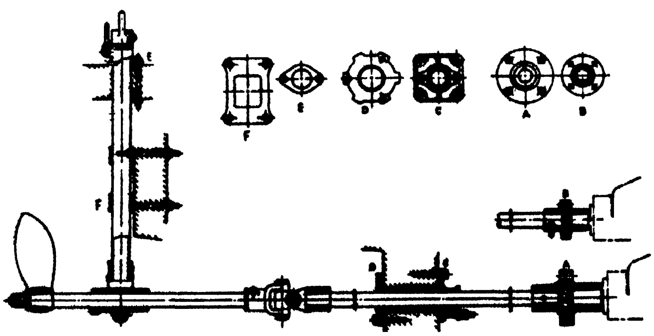


Fig. 253. Details of device for raising propeller

A breakdown of the device may seriously affect the operation of the boat, so it is imperative that it be constructed of strong, good quality and non-corroding materials. Table 77 lists the materials now being used for the device.

When installing the device, special attention should be paid to the location of main components:

(a) The hanging bearing. The hanging bearing should be co-axial with the propeller shaft when there is no angularity in the universal joint. The location of the main engine should be determined by convenience of operation. The angle of inclination of the propeller shaft should, preferably, be less than 8° to the ship's base line.

(b) The propeller. The distance between the propeller and the hanging bearing should be as short as possible. If it is too long, the propeller will vibrate excessively and frequent repairs will be necessary.

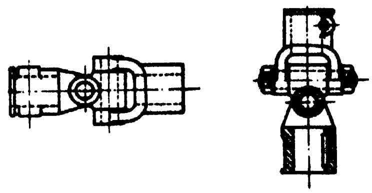


Fig. 254. Details of universal joint

(c) The universal joint. This should be as close as possible to the outer end of the stern tube to facilitate repair work. If it is not so placed, it will protrude downward and be liable to damage.

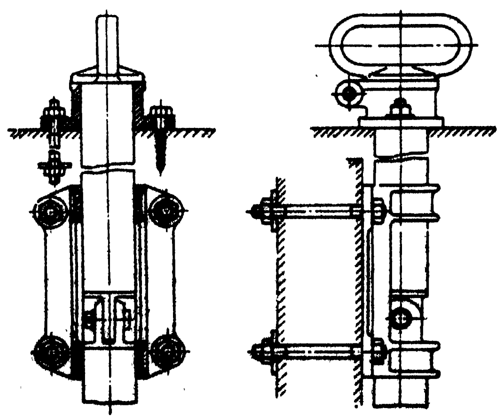


Fig. 255. Hand type of sliding assembly

(d) **The vertical guide.** Put this as low as possible, otherwise its free movement will be restricted, the propeller shaft will be inadequately supported and will vibrate excessively.

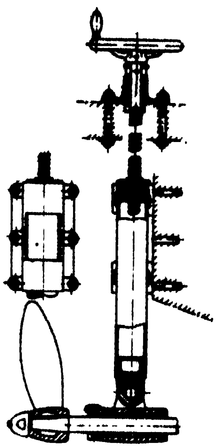


Fig. 256. Screw type of sliding assembly

The propeller shaft should be properly aligned, otherwise it may adversely affect the clutch and the bearings and lead to breakdowns. The propeller shaft is positioned as follows:

First, drill the hole in the aft bulkhead for the propeller shaft tube, then stretch a string along the line on which the axes of the crankshaft, the propeller shaft tube and the hanging bearing will lie. Using the stretched string as the datum line, the arrangement of the shaft tube, the correct inclination of the engine bed, the location and length of the sliding tube, and the length of the shaft can then be decided. The centre of the engine and other integral parts should then be firmly fixed.

TABLE 77

Materials used in propeller arrangement

Item	*Material*
Propeller shaft	High tensile brass bar
Propeller	Brass casting
Propeller—set nut	Brass bar
set key	,,
Stern—tube	Brass casting
bearing	*Lignum vitae* or white metal
Universal joint coupling	Aluminium bronze casting
Universal spider	,, ,, ,,
Universal bolt and nut	Arms bronze
Hanging bearing housing	Brass casting
Hanging bolt	Brass bar
,, bearing	*Lignum vitae* or white metal
Sliding tube	Seamless brass tube
,, joint	Brass bar
,, pin	,,
Guide	Brass casting
Handle	,, bar

Problems to be solved

Even though the device is very effective, there are many structural problems to be solved. Among them are:

- Wear or breakage of the universal joint pin. The pin of the universal joint transmits both the torque from the engine to the propeller, and the thrust from the propeller to the engine and hull. Any malalignment of the shaft or any wear on the bearing creates a slight gap around the pin, which often causes it to wear. Special attention, therefore, should be paid to this

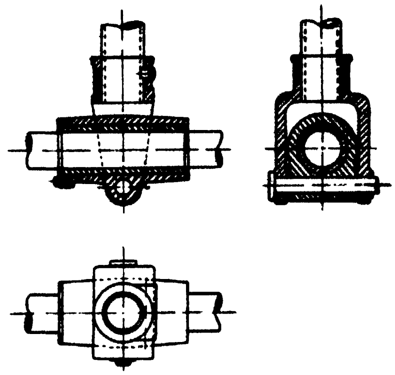


Fig. 257. Details of hanging bearing

- Decreased efficiency of the propeller. As the stern of boats on which the device is installed is squarish, turbulence is apt to occur over the propeller. This has the effect of reducing the efficiency of the propeller

- Wear of the hanging bearing. The low position of the hanging bearing makes it difficult to keep it free from sand and other solid matter stirred up by the propeller, and this causes wear. The bearing lining should, therefore, be made of *lignum vitae*, which is much tougher than white metal. White metal bearings must be renewed at least once a year.

Conclusion

The device is not only of use for boats which have to be beached but also for those which anchor or fish in shallow waters. It is being widely used on such boats, but the device needs to be improved.

VIBRATION IN TRAWLERS

by

H. LACKENBY

The paper reviews the vibration research carried out at the British Shipbuilding Research Association (BSRA) so far as trawlers are concerned.

Experience has shown that trawlers have not been troubled with vibration problems to the same extent as other classes of sea-going ships, but with the present trend for higher speeds and powers, the matter is now assuming increasing importance. For this reason BSRA has been giving more attention recently to the vibration characteristics of trawlers.

One of the main problems is to avoid resonant conditions, that is, to ensure that the natural frequencies of the hull do not coincide with those of pulsating forces emanating from the propelling machinery and usually related in some way to the r.p.m. The first requirement is therefore to determine in the design stages these natural hull frequencies, but experience shows that, from first principles, this is a very tedious matter and sometimes quite impracticable. Moreover, the detailed information required is not generally available.

Efforts have therefore been made to improve and simplify methods of estimating critical frequencies and at the same time to relate the amplitudes to the exciting forces. This is being effected by determining experimentally the natural frequencies for a range of ship sizes and then correlating these in terms of simple parameters involving only factors known in the design stages. At first, measurements were made during trials using the propelling machinery as the means of excitation. This work has now been supplemented by controlled tests using a vibration exciter specially designed for the purpose, which enables more comprehensive data to be obtained. Some typical results are presented and an indication given of the manner in which they are being correlated.

LES VIBRATIONS A BORD DES CHALUTIERS

La communication passe en revue les progrès des recherches de la British Shipbuilding Research Association (BSRA) en ce qui concerne les chalutiers.

L'expérience semble montrer qu'en ce qui concerne les problèmes de vibrations, les chalutiers n'ont pas d'ennuis de la même importance que les autres classes de navires de mer, mais avec la tendance actuelle, qui est d'avoir des vitesses et des puissances plus élevées, cette question prend maintenant une importance croissante. C'est pourquoi l'Association a, ces derniers temps, porté plus d'attention aux caractéristiques des vibrations des chalutiers.

Un des problèmes principaux est d'éviter les conditions de résonance, c'est-à-dire de s'assurer que les fréquences naturelles de la coque ne coïncident pas avec celles des forces pulsées provenant de la machinerie de propulsion et qui sont généralement en relation d'une façon quelconque avec la vitesse de révolution. La première nécessité est donc de déterminer, aux stades de l'établissement des plans, ces fréquences naturelles de la coque, mais l'expérience a montré que, d'après les premiers principes, c'est un problème très fastidieux et parfois impossible à résoudre. En outre, on ne dispose généralement pas des renseignements détaillés dont on a besoin.

On s'est donc efforcé d'améliorer et de simplifier les méthodes d'estimation des fréquences critiques et, en même temps, de mettre en relation les amplitudes et les forces d'excitation. Pour cela, on détermine expérimentalement les fréquences naturelles pour une gamme de dimensions de navires et ensuite on les met en corrélation en termes de paramètres simples comprenant seulement les facteurs connus aux stades de l'établissement des plans. On a d'abord fait des mesures pendant les essais en utilisant la machinerie de propulsion comme moyen d'excitation. Ce travail a maintenant été complété par des essais contrôlés à l'aide d'un excitateur de vibrations conçu spécialement dans ce but, qui permet d'obtenir des données plus complètes. La communication présente quelques résultats caractéristiques et donne une indication sur la façon selon laquelle ils sont mis en corrélation.

LAS VIBRACIONES A BORDO DE LOS ARRASTREROS

Reseña la ponencia los adelantos logrados en las investigaciones realizadas por la British Shipbuilding Research Association (BSRA) relativas a los arrastreros.

La experiencia demuestra que los arrastreros no han tenido problemas de vibraciones en el mismo grado que otras clases de barcos de navegación de altura, pero debido a la actual tendencia a darles más velocidad y potencia, éste es un asunto que adquiere cada vez mayor importancia. Debido a ello, la Association ha prestado últimamente más atención a las características de las vibraciones de los arrastreros.

Uno de los principales problemas consiste en evitar condiciones de resonancia, es decir, lograr que las frecuencias naturales del casco no coincidan con las de las fuerzas pulsantes que emanan de la maquinaria propulsora y que en general guardan una cierta relación con las r.p.m. Por lo tanto, la primera condición es determinar mientras se proyecta el barco cuáles son las frecuencias naturales del casco, pero la experiencia demuestra desde el primer momento que ésta es una tarea muy larga y algunas veces imposible. Además, por regla general no se dispone de la información detallada que hace falta. A causa de ello se ha tratado de mejorar y simplificar los métodos de calcular las frecuencias críticas y al mismo tiempo de relacionar sus amplitudes y las fuerzas que las causan. Esto se logra determinando experimentalmente las frecuencias naturales para barcos de tamaños distintos y relacionándolas entre sí mediante parámetros sencillos en los que sólo se emplean factores conocidos al proyectar los barcos. Al principio se hicieron cálculos durante las pruebas empleando la maquinaria propulsora como fuerza causante. Esta labor se ha complementado con ensayos regulados en los que se emplea un generador de vibraciones construido especialmente para ello, que permite obtener datos más completos. En la ponencia se dan algunos resultados típicos y se indica la manera en que se establecen las relaciones.

THIS paper reviews the research progress of the British Shipbuilding Research Association (BSRA) in so far as the vibration of trawlers are concerned. This has involved systematic measurements of vibration on ships and their correlation in terms of simple parameters with the object of simplifying the estimation of critical frequencies and vibration amplitudes in the design stage.

Excessive vibration in ships can be very troublesome, mostly from the point of view of the comfort of the people on board, but it may also give rise to difficulties in the operation of instruments and gear. The stresses induced in the structure by main hull vibration are generally not significant, but severe local vibration can actually lead to failure of components. As far as trawlers are concerned, experience seems to show that, in general, they have not been troubled with vibration problems to the same extent as other larger classes of sea-going ships, but with the present trend for higher speeds, powers and r.p.m., the matter is now assuming increasing importance. For this reason BSRA has been giving more attention recently to the vibration characteristics of trawlers.

Of course, the principal object underlying all vibration research is to try to avoid vibration altogether and, if this is not possible, then to reduce it to acceptable proportions. There are several factors involved in this:

- The natural frequencies of vibration of the hull girder and its response to excitation
- The frequencies and magnitude of the exciting forces, or couples, which are generally related in some way to the r.p.m. of the propelling machinery
- The criteria for acceptable limits of vibration

As is well known, when there is coincidence between an exciting frequency and a natural frequency of the hull, a "resonant" or "critical" condition arises and serious vibration may result. This is characterized by a rapid build-up of vibration amplitude much in excess of the deflection which would arise from the same force applied statically. The designer's problem is therefore to try and avoid such "resonant" or "critical" conditions especially in the neighbourhood of the service speed.

The modes of vibration

Unfortunately the hull girder can vibrate in a variety of modes or patterns and some of the more common are shown diagrammatically in fig. 258. Each mode is associated with its own "natural frequency" and this becomes progressively higher the more complex the pattern, that is, the greater the number of nodes. For lateral vibration including both vertical and horizontal, the simplest or "fundamental" mode is that corresponding to two nodal positions and has the lowest frequency. For torsional vibration the fundamental mode has only one nodal position as shown. Strictly speaking, there are an infinite number of modes of vibration but in ship work the fundamental and one or two of the higher modes immediately adjacent to it are generally of most importance. The mode of vibration having the lowest natural frequency is generally the two-node vertical.

The nature of excitation

The pulsating forces causing vibration generally arise from the main propelling machinery and the propeller or a combination of both and sometimes also from auxiliaries.

In reciprocating engines, there can be unbalanced forces and couples occurring at a frequency equal to the r.p.m. and there are also secondary forces, generally of smaller magnitude, occurring at even multiples of the r.p.m. Torque reaction can also give rise to transverse forces on the engine at a frequency equal to that of the combined working strokes in all cylinders. For a single

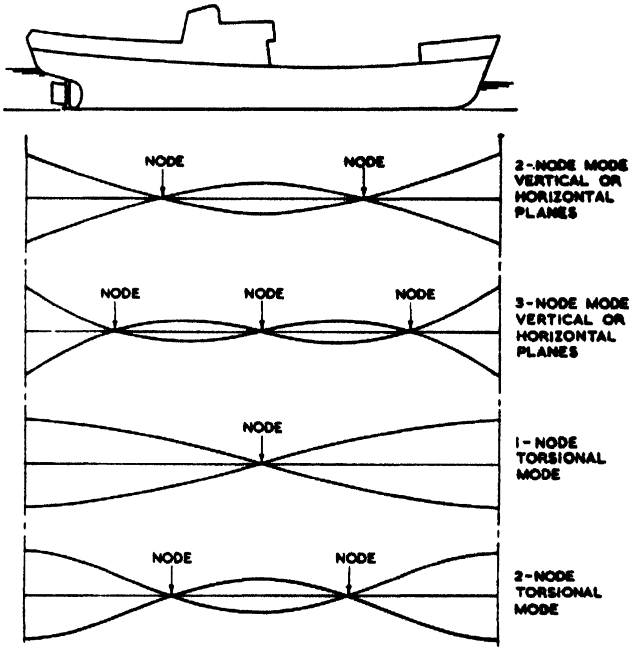


Fig. 258. Typical modes of hull vibration

acting two-stroke engine this amounts simply to the product of the r.p.m. and the number of cylinders.

The propeller can produce excitation in a number of ways. If it is not properly balanced either statically or dynamically, "first order" forces are produced, that is, those occurring at a frequency equal to the r.p.m. Such forces will also arise from hydrodynamic unbalance where the geometry of each blade is not identical. In most modern propellers, however, such first order forces are generally quite small and cause little trouble.

Of greater importance are forces excited by the propeller at "blade frequency", that is, the product of r.p.m. and number of blades. These can take two forms:

- Surface forces on the hull due to the pressure field surrounding each blade as it passes in the vicinity
- Reactions at the stern bearing due to wake variations over the screw disc

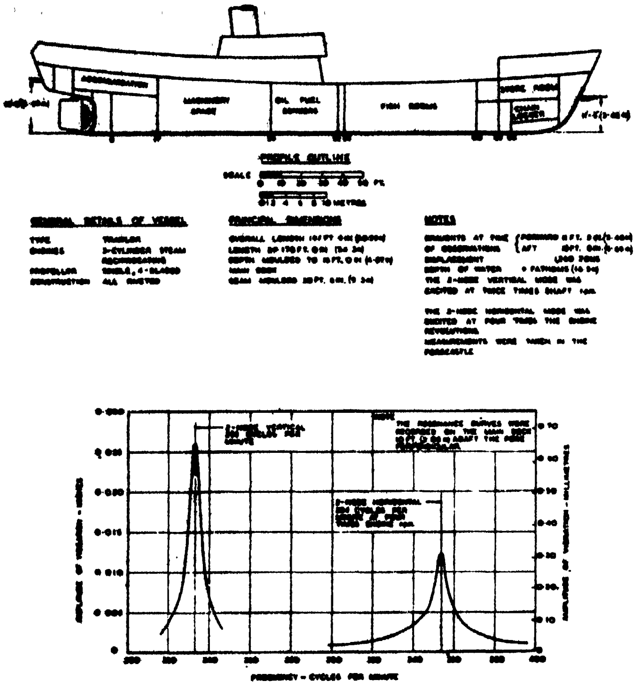


Fig. 259. Typical results from full-scale tests using engine and propeller excitation

These are primarily affected by hull-tip clearance and the after body lines respectively.

As far as trawlers are concerned, experience shows that the most significant forms of excitation are: engine primary and secondary unbalance and "blade-frequency" impulses, that is, frequencies corresponding to engine r.p.m., twice engine r.p.m. and the product of propeller r.p.m. and number of blades respectively.

It will be apparent from the above that there are quite a number of combinations of excitation and natural hull frequencies which could bring about resonant conditions. In the circumstances the designer and research worker are faced with two main problems.

The first is to be able to determine readily the relevant hull frequencies in the design stage when decisions are being made as to choice of machinery, propeller r.p.m. and number of blades. The second is to ascertain whether the forces coming from the different sources are likely to excite vibration of serious magnitude.

Determination of vibration frequencies

Efforts have therefore been made by BSRA to improve and simplify methods of estimating ship vibration frequencies and to relate the amplitudes to the exciting forces. In this connection it was very desirable to have comprehensive data for a range of ship sizes and, with the willing and active co-operation of trawler builders and owners in the U.K., measurements have now been made on a number of ships.

At first, measurements were made during acceptance trials using the propelling machinery as the means of excitation. The practice was to run slowly through a range of revolutions and then record the vibration amplitudes in the neighbourhood of the critical frequencies as they were encountered. Some typical records from such a trial are shown in fig. 259. This shows for the two-node vertical and two-node horizontal modes the amplitude-frequency relationship corresponding to measurements made on the forecastle. The former was excited at 116½ r.p.m. by secondary engine forces and the latter at 88½ r.p.m. by blade frequency forces. The service r.p.m. was in the region of 120.

For various reasons it is not always possible to obtain clearly defined frequencies in the above manner using "natural" excitation and to obtain really comprehensive data it is better to carry out controlled tests using a vibration exciter designed for the purpose. Such a machine has now been built to BSRA design especially for use on small ships such as trawlers. This exciter has been described by Livingstone Smith (1959), but it will be of interest to mention that it is capable of exciting pulsating forces in any chosen direction up to a frequency of 600 per min. and with a maximum rating of ±3 tons. These forces are generated by rotating masses and control is exercised by adjusting their eccentricity and speed of rotation. The unit is self-contained, electrically driven and power is supplied by its own diesel generator.

The earlier work has recently been supplemented by controlled exciter tests on a series of three trawlers of different sizes and the response of the hulls has been accurately determined over a wide range of frequencies.

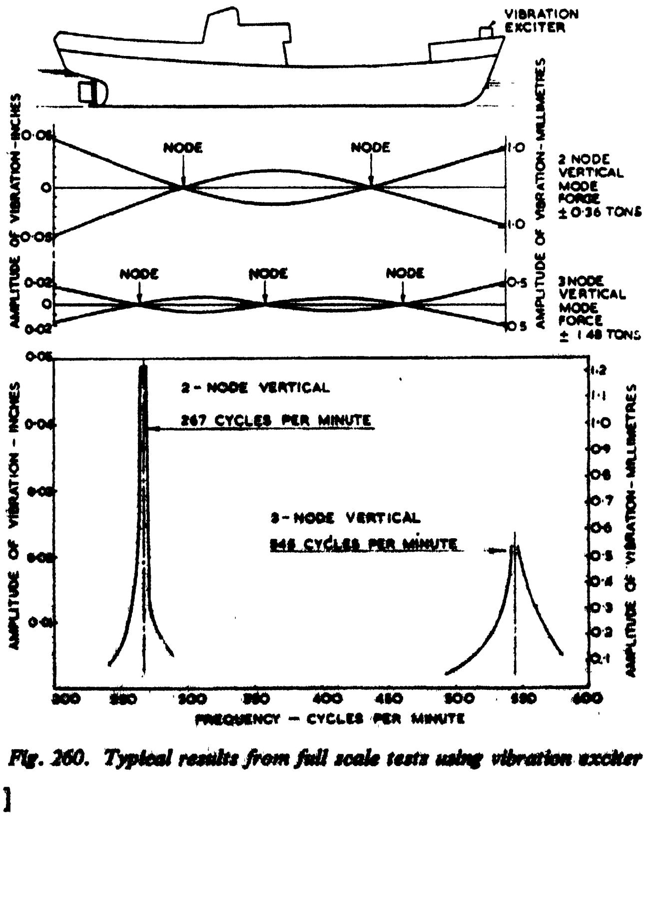


Fig. 260. Typical results from full scale tests using vibration exciter

Some typical results from such a test with the exciter sited on the forecastle are shown in fig. 260. It will be seen that the complete vibration profiles as well as the response curves at a particular position have been obtained. The vibration profile, of course, identifies the mode beyond any doubt and what is more, the exciting forces are now accurately known and can be related to the amplitudes produced. It will be noted that the "tuning" is very much sharper in the case of the fundamental than the higher mode. This attenuation of the response in the higher modes is characteristic and is explained by relatively greater damping.

In the early days vibration amplitudes were measured by simple seismic instruments, but latterly the work has been extended and facilitated by the use of electrical pick-ups in conjunction with multi-channel recorders.

Table 78 gives details of critical frequencies measured on trawlers by BSRA together with the ship dimensions and displacements. This refers to vibration stimulated artificially by the exciter as well as by "natural" means.

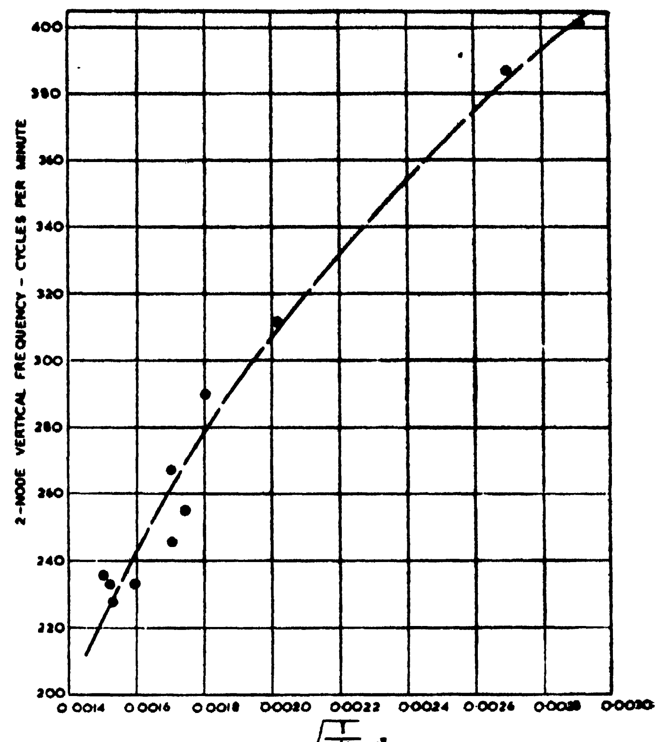


Fig. 261. Estimate of two-node vertical frequency

Estimation of vibration frequencies

Reasonable estimates of natural frequencies for the fundamental modes can, of course, be made from first principles knowing the detailed mass distribution along the length and the inertia of the sections. It is a tedious process, however, and the information required is not generally available in the design stage. Moreover, the estimation of the higher modes by such means is extremely difficult and normally impracticable. To overcome these difficulties, efforts are now being made to correlate the actual experimental data for a range of ships in terms of simple parameters involving factors known in the design stage. For example, fig. 261 shows such a correlation for the two-node vertical mode. Here the critical frequencies given in table 78 have been plotted against a simple parameter of the type used by Todd and Marwood (1947–8), viz.:

$$\sqrt{\frac{I}{\Delta'_i\,(LBP)^3}}$$

where I = inertia of section in way of the fish room, in^2.ft.^{2}.

LBP = length between perpendiculars in ft.

Δ'_i = displacement in tons augmented for entrained water effect*.

It will be seen that a fair measure of correlation has been achieved covering a range of ship sizes. It is to be underlined, however, that this applies particularly to ships of the general type shown in fig. 259 and 260, where the superstructure extends from about amidships to the after end. The scatter might well be explained by slight variations in the superstructure from ship to ship which have not been taken into account. It is intended to refine this approach if possible and to develop similar relationships for the higher modes. In this way it is hoped to provide trawler designers with information which will enable them to make rapid estimates in the early stages of the more important hull criticals with a reasonable degree of accuracy.

At the same time, attention is being given to the development of force-amplitude relationships so that the intensity of vibration can be readily estimated from a knowledge of the exciting forces. This is an important aspect when resonance or near resonance cannot be avoided. This applies particularly to high frequency excitation such as propeller blade impulses where the higher modes are likely to be involved. In this region the criticals are more closely spaced in the frequency spectrum. This, coupled with variations due to changes in loading, makes them difficult to avoid. Even if it is possible to keep clear, the improvement may not be significant due to the flattening of the response curves referred to earlier. In other words, the ship response at high frequency tends to be an irregular wide band without very sharp peaks. In these circumstances, the only thing to do is to remove or reduce the source of excitation. For propeller blade impulses, this would probably mean increasing the hull-tip clearance and obtaining a more uniform inflow to the propeller. A comprehensive programme of work on these aspects is now being undertaken by BSRA.

*Methods of estimating the entrained water effect are given by Johnson and Ayling (1957), for example that due to Todd and Marwood viz.:

$\Delta'_i = \Delta_i\,(1.2 + B/3T)$, where B and T are the beam and draught respectively.

TABLE 78

Trawler	LBP *ft.*	LBP *m.*	*Breadth* *ft.*	*Breadth* *m.*	*Depth* *ft.*	*Depth* *m.*	Δ_1 *tons*	Natural frequencies of vibration (cycles per min.) Vertical *2 node*	Vertical *3 node*	Horizontal *2 node*	Horizontal *3 node*
A	134.0	40.9	27.5	8.38	14.25	4.34	540	401	798	574	—
,,	,,	,,	,,	,,	,,	,,	680	387	—	564	—
B	161.9	49.4	30.0	9.15	15.25	4.65	735	312	617	485	—
,,	,,	,,	,,	,,	,,	,,	1,015	290	574	419	838
C	178.0	54.3	30.5	9.30	16.0	4.87	1,260	233	—	354	—
D	180.0	54.8	30.5	9.30	16.0	4.87	948	255	—	405	—
E	180.0	54.8	30.5	9.30	16.0	4.87	980	246	—	—	—
,,	,,	,,	,,	,,	,,	,,	1,345	228	—	—	—
F	185.0	56.4	32.0	9.75	16.25	4.95	1,390	236	—	358	—
G	185.0	56.4	32.5	9.91	17.5	5.33	1,001	267	545	409	—
,,	,,	,,	,,	,,	,,	,,	1,436	234	—	338	—

It is perhaps appropriate to conclude this paper with a general comment which was touched on at the beginning. Reference to table 78 will show that the range of the lowest hull critical frequency, i.e. the two-node vertical, is from about 230 to 400 cycles per minute which, until recently, was generally well above the r.p.m. of the propelling machinery. In other larger classes of seagoing ships the corresponding critical frequency is much lower and often of the same order as that of the r.p.m. This doubtless explains why hitherto, trawlers have not been subject to vibration troubles to the same extent as other classes of ship. With the trend for higher speeds, powers and r.p.m., however, the position will have to be carefully watched. In this connection it is understood that the operating r.p.m. of certain direct-coupled diesels fitted in modern trawlers is already within the range of critical frequencies referred to above. Careful consideration will also have to be given to propeller hull-tip clearances. Those which proved satisfactory in the past may no longer be adequate.

Acknowledgments
The author is indebted to the Council and Director of Research of the BSRA for permission to publish this paper and wishes to express his thanks to members of BSRA staff for help in its preparation.

INSTALLATION OF MACHINERY — DISCUSSION

ENGINE DESIGN IN GENERAL

SIR FRED PARKES (U.K.): At the Paris Congress in 1953 he stressed the necessity for reliable engines. They must stand up to the hard work and be reliable. He felt very happy to say that diesel engines are now as reliable as the old steam engines used to be.

MR. A. HUNTER (U.K.): On the paper by Hopwood and Mewse—he wondered after how many hours they renewed the roller bearings on the turbo-charger and if any further developments had been made towards extending the life of solid bearings. Hopwood and Mewse referred to the advantages of making-good cylinder liners after they had been worn. He asked whether it would not be better to have them chrome-plated to begin with, and if it would not be cheaper also.

Hopwood and Mewse referred to the tendency to have independent auxiliaries. He had often wondered if that was quite right for a trawler. It meant more work for the engineer, who might have to obey several commands at one time. He had with independent pumps to throttle down to the speeding conditions of the engine, whereas there might be some more safeguard if the auxiliaries were geared to the engine speed. There was also the remote possibility that the electrics might fail at a critical time during the vessel's voyage.

It seemed that the propeller efficiency given in the diagrams was rather high for the revolutions of the diesel vessel.

MR. W. A. GREENHILL (U.K.): It was generally agreed that steam was out and diesel coming in, with a two-stroke engine for the mid and deep water trawling, and the medium speed four-stroke engine for the inshore trawling.

In his company, where they had specialized on four-stroke engines, it was found most satisfactory to cast iron liners centrifugally, and to chrome harden the top compression ring. This was found most satisfactory from both the economic and wear points of view. On an engine brought into the market in 1959 with this arrangement, the liner wear was less that 1/1,000 in. for 1,500 hours' run.

One point in the paper by Hopwood and Mewse was the number of auxiliaries required. Apart from the main engine there was one unit driving the winch and two general service, diesel powered, auxiliary units. He thought it might be better to have just one main unit and one larger auxiliary set for the other drives.

As regards turbo-chargers, they would come into both two- and four-stroke engines.

As regards controllable-pitch propellers which have shown many advantages, it must be borne in mind that these were very expensive pieces of equipment and expensive in maintenance.

MR. M. AKASAKA (Japan): With only a few exceptions, the engines mentioned in Stokke's paper are low and medium speed: why are high-speed engines not used in European trawlers?

In the paper by Hopwood and Mewse a diesel engine of 252 h.p. is used for a 101 kW generator. Is not the engine power too high for the generator?

Again, with regard to this paper, superchargers were once used in Japan for 500 to 1,800 h.p. engines in fishing vessels, but after two years, or about 10,000 hr. of running, the cooling water side of the supercharger became corroded. Seawater was used for cooling to save engine room space because of difficulties in supplying freshwater. What is the practice in European countries?

MR. H. R. BARDARSON (Iceland): In a typical Icelandic trawler like the *Gerpir* the main engine is not reversible, but is connected through an hydraulic coupling to a gear, driving a fixed-pitch propeller. The trawl winch generator is connected through an hydraulic coupling at the forward end of the main engine. This engine arrangement is preferred up to now and is what their British colleagues have so nicely named the "Christmas tree", because almost everything is hung on to the main engine. There is no Icelandic trawler using the "father and son" system.

Regarding the Norwegian 300 GT trawler, *Kirkholmen*, he wondered if Stokke could possibly give the horsepower available on the hydraulic winch drive; also the wire holding capacity of the drums on the trawl winch and the pulling power with half-filled drums and the corresponding hauling speed. This would enable the hydraulic winch to be compared with the electrical winch.

In Iceland, for a 300 GT vessel like this, 700 to 800 BHP would be required, together with a 140 h.p. engine for the trawl winch drive.

There were many things that could be said about trawler engine arrangements but from the Icelandic point of view it could briefly be said that diesel engines are preferred; controllable-pitch propellers are of very great interest, as gear boxes could then be omitted.

MR. S. TAKAHASHI (Japan): The chrome-plated liner was well known in Japan and it would be appreciated if Hopwood or Mewse could give some information about the capacity of the generator used for the chrome-plating.

MR. HANS VESTRE HUSE (Norway): He had met a certain interest in Germany for converting old steam trawlers to diesel propulsion. A wider circle might want to take advantage of the experience gained in this respect in Norway where the main part of the steam trawlers are converted to diesel drive

As mentioned in Stokke's paper, the diesel trawlers always have controllable-pitch propellers and hydraulic pumps for the trawl winch driven off the front end of the main engine. The same arrangement is done for all the converted trawlers as well, but in these cases the old steam trawl winches have been converted to hydraulic drive with very low expense, as a special drive arrangement has been developed which permits negligible alterations on the mechanical parts of the old steam trawl winch.

As conversion of a steam trawler to diesel propulsion is quite an expensive job, this saving on the winch side is quite important, according to their customers' information.

MR. E. I. FLINDT (U.K.): He endorsed Hopwood's recommendation for the use of detergent lubricating oils, but the frequency of top overhauls and maintenance appears to be excessive. Hunter and Greenhill commented on the use of chromed liners or alternatively a chrome-plated top ring.

Hopwood mentioned—in his opinion only too briefly— the effect of cold running engines, and he felt that far too little attention is given by operators to the benefits of running a diesel engine at a high operative temperature. The diesel engine is, of course, a heat engine and today there are a number of well tried and reliable automatic temperature controls which are worth while fitting, and so relieving the engineer from manual control of the engine temperature, which would have to be done frequently in trawlers where there is a continual load fluctuation.

It is particularly noticeable that engineers used to steam machinery, going over to diesel engine operation, are reluctant to maintain the high temperatures necessary for optimum results.

His company, which for over 20 years have used chrome hardened liners, have how adopted centrifugally cast iron liners, and use a chromium-plated fire ring to each piston.

Service results measured accurately in the same engine over an extensive period show that the average maximum wear on the plated liner was 0.0002 in. per 1,000 hr., compared with an average of 0.00015 in. per 1,000 hr. for the plain cast iron liner. These figures were taken over a period of 40,000 hr. for the plated liner, followed by 22,000 hr. for the plain liner with the chromed ring. The maximum wear occurred at the turning point at the top piston ring on the thrust side of each liner. With both types of surface, the wear on the remainder of the liner was negligible, an average at the bottom in the line of thrust being 0.00005 in. per 1,000 hr.

It may be interesting to know that throughout this long period, the big end bearings were never replaced or remetalled, and the main bearings were not changed.

Hopwood also commented on the benefits of fitting a light-weight spindle in the nozzle body holder. It is surprising to learn that injector seating wear occurred in an engine operaing at 230 r.p.m. maximum, but he could endorse the benefits which have been derived from reducing the inertia forces from these spindles, particularly when engine speeds increase.

Referring to Chardome's paper, although discussing a comparatively slow speed main engine of 300 r.p.m., Chardome mentioned the use of a heavy fly-wheel and a rubber coupling. Quite apart from any torsional consideration, a heavy fly-wheel is beneficial by improving the cyclic variation figure at low engine revolutions and is important as the avoidance of torsionals is the elimination of tooth separation and reversal of stresses in a geared drive. The use of a simple rubber flexible coupling in itself is not the cure. There is the possibility of the frequency of the rubber coupling accentuating the difficulty, and his company have completely solved this problem by a combination of rubber flexible coupling combined with viscous damping.

MR. F. H. TODD (U.K.): With reference to the paper by Hopwood and Mewse, he expressed fear as regards the conversion to oil from the national point of view, since in war the U.K. depended on the fishing fleet for much of its food. He also pointed out that it was unfair to make comparison with the class of steam trawler chosen in this paper, which dates from 1917. The reason for this was that in 1934 tests were carried out on the Castle class trawler, with which the diesel is compared, and it was found that by improving hull form, propeller and machinery, the fuel consumption could be cut by as much as 60 per cent. Propellers must also be of the same quality when comparison is made between different hulls. This is, however, not the case here, as a modern design of manganese bronze propeller was used with the diesel and an old-type cast iron one with the steam powered vessel. To get a proper comparison, a modern steam trawler should be compared with a modern diesel trawler, and it would be of great interest if some builder would give this information.

MR. DWIGHT S. SIMPSON (U.S.A.): It is interesting to read such a paper as Hopwood's, especially in the U.S.A. where the first diesel trawler was built in 1918; the first and only diesel-electric in 1919 and the last steam trawler departed in 1937.

The discussion concerns type and manufacture of diesels; the kind and quality of service available at the vessel's home port, and the high speed versus low speed engines. More and more owners are going in for high speed engines—up to 1200 r.p.m. in 600 to 800 h.p. and to 1800 r.p.m. in 200 to 300 h.p. units. All diesels have had closed circuit freshwater jacket cooling since about 1936. These engines have proved their reliability; both first cost, installation costs and maintenance are low and the saving in engine room length and weight can be put into more cargo, greater cruising range, more speed—or a little of each.

The high speed, non-reversing engine is also receptive of easy wheel house control. Multiple-speed gears have been much discussed and are finally on order. About the same applies to the controllable-pitch propeller. In New England and the Canadian Maritime Provinces he thought only three have been installed so far. Eleven vessels now in the design stage will all have them.

In the smaller vessels winches are driven from the main engine. The larger ships have diesel-electric drive. A few recent installations have direct separate engine drives through fluid couplings. Most of those in the design stage will have hydraulic drive.

DIESEL-ELECTRIC PROPULSION

MR. R. LEROUX (France): He supplemented Stokke's statement concerning the *Louis Girard* deep sea trawler. The *Louis Girard* was delivered by his shipyard in 1957, thus he could give some particulars regarding the results. The diesel-electric propulsion consists of three generating sets, and power has been calculated so that during trawling, only two of them are in service. Each unit comprises a 950 h.p. diesel driving a 560 kW generator coupled with a 165 kW auxiliary generator which can be used as exciter and generator for the winch motor. Two electric propelling motors drive the propeller-shaft through a gearing.

The disadvantages of this system are:

- The loss of power in the electric motors, due to the Joule effect, can be estimated at 18 per cent. It is necessary, however, to take into account the fact that when using multiple-reduction gear, there is a loss of 5 to 10 per cent. in the gearing and clutches. Also, with a controllable-pitch propeller, highest propeller efficiency is ensured in one pitch position only, hence there is a loss of power in the others. However, there is still a loss of 8 to 14 per cent. in the diesel-electric solution as compared to other solutions.
- The cost, which is referred to later on.
- The temperature in the engine room has been criticized. After a two year observation, he could assert that with usual ventilation methods, there was no trouble.

The advantages of the diesel-electric propulsion are:

- Saving due to the fact that only two units are in service during trawling and that a special diesel for driving the winch is not necessary. Such an auxiliary diesel is very costly and it has a high fuel consumption, because it has to be restarted frequently and is often running idle.
- Saving due to the fact that each electric power unit runs at the most economic speed.
- Increased safety in dangerous waters (Spitzbergen, Greenland, White Sea), when the ship is far from any help she can then sail with a single unit and a single propelling engine.
- Elimination of the torsional vibrations of the diesel engine, and, very probably, improved efficiency of the propeller which works with a constant torque.
- Improved living comfort due to the absence of vibrations, which is very important for trips lasting from three to four months.
- Improved seakindliness of the ship, which is very important in waters with risk of icing. The work of the crew is simplified by this type of propulsion which constitutes a long step towards automation. The possibilities of using the ship are increased to the maximum with a minimum staff in the engine room, since the propelling motors are controlled from the wheelhouse.

The shipowner definitely noted that, when sailing, fuel consumption is higher compared with a vessel without electric propulsion. On the other hand, the longer trawling period is more economical, and it is estimated by the owner that total consumption during a fishing season does not exceed that of a normal ship. More specially, capacity of fuel oil bunkers is comparable.

Diesel-electric propulsion is more expensive when relatively low r.p.m. engines are used, for example 500 to 700 r.p.m. But, if it is accepted having engines running at 1,000 or 1,200 r.p.m., which is possible with the present progress of diesel designs, the cost of the electrical and mechanical equipment is considerably reduced, and the total cost becomes comparable with the cost of normal ships. When gas turbines become readily available, it will be necessary to use them with this type of propultion.

Presently, when great attention is being given to stern trawling, diesel-electric propulsion provides certain advantages since by moving the generating units forward, it is possible to obtain considerable space aft, for the processing work and refrigeration.

He felt he had to give these particulars, but wanted to point out that it does not eliminate other solutions. His shipyard has been constructing a series of trawlers, 157 ft. (48 m.) LBP, with a special type of adjustable-pitch propeller made in France, which gives complete satisfaction. The adjustable-pitch propeller is much simpler than the controllable-pitch propeller and costs much less. The pitch is adjusted for the trawling or sailing condition when the engine is stopped and it can therefore not be controlled continuously from the bridge as the controllable-pitch propeller.

They had also built some small 112 ft. (34 m.) trawlers, equipped with multiple reduction gear, similar to those advocated by Chardome, and these trawlers did not cause any trouble.

It is therefore necessary to examine for each type of fishing the best propulsion system, and if the shipowners give the designers and builders complete particulars regarding the future use of the projected boat, they will be in a position to propose the most economical solution, concerning the cost as well as running expenses.

MULTIPLE-SPEED GEAR

MR. A. HUNTER (U.K.): Regarding Chardome's paper, he observed that in Britain they had always tried to find the simplest solution to any problem in a trawler, and for that reason they had not gone in for so many involved devices. On efficiency—Chardome seemed to think that with multiple-gear drive there was a great advantage as far as fuel consumption was concerned, compared with the diesel-electric drive, He did not think from experience that the question could be disposed of as easily as that. They all knew that there were electrical losses but they were partly recovered in propeller efficiency and there were also other advantages. One point about diesel-electric was that it did not always need full power at sea; sometimes the sea conditions did not permit it. One could automatically save by shutting down one of the generators. Moreover, in a straight through diesel job, one had to start up another auxiliary when trawling and all the time one had to have some auxiliary running to give light and power. When all these factors were added up, he very much questioned if the favour were not towards diesel-electric.

The efficiency of the multiple gear was given as 97 per cent. That seemed to be very high. Years ago the efficiency of a reverse-reduction, oil-operated gear was given as 97½ per cent. It was now given as 92½ per cent. and that had been well borne out by experience.

The stopping time seemed to be very good indeed. From full revolutions the ship was reported as having been stopped from 15 knots ahead in 410 ft. (125 m.). It certainly meant that the stern clutch must have been slipped in very quickly and perhaps Chardome could show the types of gear in a further contribution.

MR. H. KLAASSEN (Netherlands): Süberkrüb's paper outlines fairly well the problem of the propeller coupled to a constant torque engine, having to operate under more or less varying conditions. He made the following comments:

- It was a pity that in the comparison made between the controllable-pitch propeller and the two-speed gear box the case of the controllable-pitch propeller being driven by a 700 h.p. engine (if necessary with the appropriate speed reduction) had not been presented.

- Süberkrüb stated in his paper that it has been said that captains do not like the way the controllable-pitch propeller rotates after being put into the stop position when hauling the nets. This was indeed a complaint that was sometimes heard. In his opinion all difficulties in this respect could be avoided by using the extremely f... ...ring possibilities offered by the controllable- ... the engine is running at its minimum r.p.m. With these possibilities of engine control, hauling the net will be even easier. This is again a matter of educating the crews in handling new equipment at their disposal.
- Regarding nozzles, he wanted to ask whether the speed of the propeller in the nozzle was the same as that without the nozzle. If so, the propeller diameter in the nozzle must have been too large, which should be the reason for the speed loss in the sailing condition. Model tests have shown that a reduction of up to 25 per cent. in diameter is possible, as compared with the propeller without nozzle, if they are running at the same r.p.m. and a Kaplan blade contour is used. If the larger propeller diameter can be adapted in the stern frame the propeller could run at lower r.p.m. with all the well known advantages.

Chardome made an interesting comparison between the performance of the two-speed gear box and the controllable-pitch propeller. Fig. 249 to 251 are especially worth considering, and he wanted to make a few remarks on this comparison.

- Chardome stated that the controllable-pitch propeller had been designed to give the same thrust while trawling under full power as the fixed-pitch propeller. The diameter of the controllable-pitch propeller, however, is smaller, presumably due to the fact that it is running faster. Would not the comparison have been more strict if the conditions for both propellers had been identical in the reference point; in this case the trawling condition?
- The comparison in table 76 shows the controllable-pitch propeller to be always running at 133.5 r.p.m. The controllable-pitch propeller should, however, never be associated with running at constant speed! In this respect he would like to make the comparison in two parts:

  (a) When *full power* is required, the engine is running at maximum rated r.p.m. in both cases. For the controllable-pitch propeller the speed both for trawling and free running is engine r.p.m., divided by reduction ratio, if there is one. For the two-speed gear box propeller, speed for the two conditions will be different. Figures for these conditions can be found in the paper.

  (b) When *less than full power* is required, the aforementioned does not apply any more. For the controllable-pitch propeller, it is certainly not necessary, and indeed not advantageous, to keep it running at maximum r.p.m., not only because propeller efficiency at very low pitch-diameter ratios will drop, but perhaps still more because engine efficiency will drop when running at high r.p.m. and low mean effective pressure (p_e). Therefore, not only pitch control is necessary, but also r.p.m. control. In doing this one should be guided by the fact that an engine renders the lowest fuel consumption if the p_e is kept on the high side. When reducing output, this will result in the controllable-pitch propeller running at *lower* revolutions and *higher* pitch than the fixed-pitch propeller. One-handle control of engine and pitch should therefore be the rule for controllable-pitch propellers in the h.p. range covered in the paper by Chardome.

Chardome has said that for a controllable-pitch propeller it is difficult to adjust the pitch in such a way that under all weather conditions full engine power is absorbed. This is true if the pitch position has to be found empirically. However this has been the reason why simple systems have been developed which allow for automatic pitch adjustment, so that full power is absorbed irrespective of the prevailing conditions. In this way, the theoretical advantages of the controllable-pitch propeller as mentioned by Chardome can be realized in practice.

Fig. 262 shows an engine diagram which is not always presented by engine manufacturers. The diagram covers the

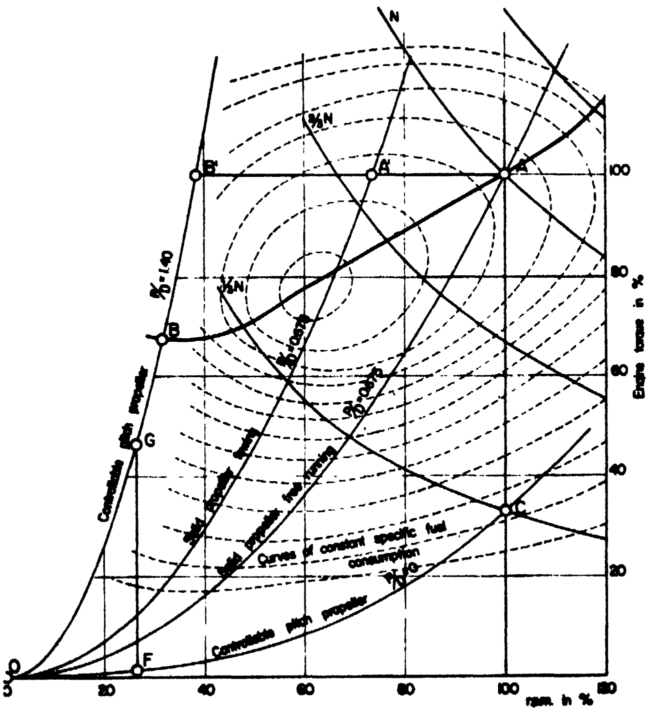


Fig. 262. An engine diagram showing constant specific fuel consumption demonstrates best how a controllable-pitch propeller should be operated to attain highest efficiency

whole field of possible engine operating conditions, while in practice the fixed-pitch propeller limits operating conditions to a single curve. Therefore in most cases only particulars connected to this single curve are supplied. When controllable-pitch propellers or electric propulsion are discussed, the full diagram is valuable.

The diagram shows curves of constant specific fuel consumption and curves of constant engine output (1/3 N, 2/3 N and N) as a function of engine p_e (or engine torque) and engine r.p.m.

If A represents the maximum output of the engine, a fixed-pitch propeller designed for the ship's speed under certain prevailing conditions will show a relation between torque and r.p.m. as shown by curve OA. If, however, the speed of the ship decreases due to an increase in hull resistance or due to towing, the torque required by the propeller at a certain number of revolutions will increase. Therefore, under these conditions not curve OA but curve OA′ will be followed.

OBB′ shows the relation between torque and revolutions for the controllable-pitch propeller with the blades in maximum pitch position, OC is the line representing the relation between torque and revolutions for the controllable-pitch propeller blades in zero pitch position.

Let us assume that the engine maximum allowable torque is the same for all engine speeds (border line B′A) and the maximum allowable engine speed is the same for all values of engine torque (border line AC). The minimum speed of the engine is shown by border line FG. It is evident that all operating conditions of the engine in the area B′ACFG can be realised when a controllable-pitch propeller (or DC electric transmission) is used, irrespective of weather conditions, hull fouling, towing etc. From the diagram it is clear that not all parts of this area are favourable as far as fuel consumption is concerned. There is only one relation between engine torque and speed which renders the lowest fuel consumption i.e. curve AB, being the locus of all points of minimum specific fuel consumption for a certain engine output (tangents of curves of constant engine output to curves of constant specific fuel consumption).

In order to obtain the highest efficiency, the product of engine efficiency and propeller efficiency must both be maximum. So engine efficiency is not the only factor.

Where curve AB means an increase in pitch and a decrease in revolutions at a certain engine output, as compared with the fixed-pitch propeller, it can at least be said that propeller efficiency will not be unfavourably influenced. Mr. Klaassen did not want to go into the exact determination of optimum efficiency, but only to show the principles. If AB represents the minimum fuel consumption curve when propeller efficiency has been taken into account the following conclusions can be drawn:

- Only the controllable-pitch propeller and the DC electric drive can realize the maximum efficiency curve AB when operating at smaller engine outputs, which indeed frequently happens in practice. With the latter, however, the electrical losses will be far greater than the gain in efficiency due to being able to realize the curve AB.
- The figures will only partly show the adverse effect on the efficiency of constant speed operation of a controllable-pitch propeller, because propeller efficiency will also be lower than the corresponding fixed-pitch case. As can be seen in the diagram, engine specific fuel consumption will considerably increase going from A to C.
- The ideal curve along which a controllable-pitch propeller should be operated is FGBA. In F the engine is running at minimum revolutions, the propeller pitch being in zero pitch position. It is often said that a controllable-pitch propeller absorbs very much power when running in zero pitch position. However, the figure clearly shows that this is only true when running at high r.p.m.

From F to G the engine is still kept running at minimum r.p.m., but pitch is increased to its maximum value. It should be noted that extremely fine manoeuvring possibilities are presented due to the fact that the full pitch range can be used for covering a very limited horsepower range.

From G to B, propeller pitch is kept at its maximum value, while r.p.m. is increased.

Between B and A, propeller pitch and engine revolutions are simultaneously adjusted in such a way that maximum combined efficiency of engine and propeller is ensured.

Various methods of one-handle simultaneous remote control of engine revolutions and propeller pitch have been developed. From the above it follows however that, strictly speaking, combined control of engine revolutions and fuel supply (determining p_e) should be carried out, the propeller pitch being adjusted by the mechanism.

The two-speed gear box only serves to come closer to the maximum engine output under various conditions under which a trawler has to operate, when this output is required. It does not contribute to an increase in efficiency from an engine point of view as compared with the fixed-pitch propeller driven through a fixed reduction ratio gear box. Mr. Klaassen agreed with Chardome, however, that it is very unlikely that the electrical losses of DC electric drive can be fully compensated by operating the engines near their best efficiency curve.

Hunter had remarked that the higher fuel consumption of diesel-electric drive as compared with a mechanically driven fixed-pitch propeller is not as evident as one would think at first sight. Shutting down one of the generators when full power is not needed is mentioned as one of the factors that will increase efficiency. In terms of the diagram, this means increasing the torque of the remaining engines (constant r.p.m.) thus coming nearer to curve AB.

That additional gains in efficiency are possible with electric drive if much auxiliary power is needed is well known. In spite of this, the high electrical losses in DC electric systems are very unlikely to be compensated. In cases where much auxiliary power must be available perhaps the best solution would be AC electric generators driving AC electric propeller motors. The advantage would be better efficiency than DC drive (but electrical losses are still there), and lower installation cost.

Manoeuvring and adapting the propellers to the various conditions should then be realised by a controllable-pitch propeller, because the AC synchronous propeller motors cannot perform this task.

MR. J. HØJSGAARD (Denmark): Regarding Chardome's paper (table 76), he agreed with Klaassen that if propellers were going to be compared, they must be given similar conditions under which to work. One could not compare a propeller running at 133 and one at 106 r.p.m. If one had not had to overload the engine with a fixed propeller at 106 r.p.m. one would have a very light running engine at 133. It would perhaps be necessary to have a look at what was required of a propeller.

One important question already raised: was it necessary to keep the speed of the boat when the trawl was being taken up from the bottom? The problem could be solved by underwater photography, but trawler owners and captains had said that it was necessary to keep the speed of the trawl the same when lifting it from the bottom.

MR. L. VARRIALE (Italy): Commenting upon the papers by Chardome and Süberkrüb, he had been able to study more than 20 years' records of the performance of several hundred trawlers with 200 to 300 h.p. engines used in the Mediterranean fisheries. The trawling speed for one and the same boat was very different, depending on the depth and nature of the fishing grounds and the type of fish population. In his opinion, the multiple-speed gear, permitting two speeds, one for sailing and one for trawling, is not the best because the use of a single speed for trawling is too rigid a limitation. A three-speed reversing gear would no doubt be a very complicated and certainly a costly one. They had tried the solution of using a controllable-pitch propeller, and the first four 300 h.p. trawlers that had been in service for several years, had proved satisfactory. The fishermen using them got a 20 to 25 per cent. higher catch in each haul.

MR. W. ORSZULOK (Poland): There was one question he wanted to ask in connection with Chardome's paper: What in the author's opinion are the criteria to design a propeller with multiple-reduction gear. In other words, what speed, revolutions and power are to be chosen for the fixed-blade propeller in this case? He emphasized that he agreed with what Klaassen had said about the diagrams—fig. 249 to 251.

CONTROLLABLE-PITCH PROPELLERS

MR. E. BEAUDOUX (France): Chardome has given some very precise information on the results obtained with multiple-reduction gear trawlers powered by 1,200 to 1,500 h.p. diesel engines. Chardome mentioned that France had built a large number of low powered trawlers with multiple-reduction gears and that in France they had confined themselves to the two-speed reduction gear, because multiple-reduction gear has too many drawbacks for small boats and two speeds are quite sufficient; one for sailing and one for trawling at an average speed of 3 to 4 knots.

As Mr. Beaudoux had built many of these trawlers, he was able to give some figures regarding the results obtained with different propulsion methods.

They had always considered it necessary to simplify the propulsion equipment of a fishing boat of relatively small dimensions; that is from 80 to 130 ft. (25 to 40 m.), and their experience was that fuel consumption was not a determining factor in the operation of a boat, and that, while trying to get the maximum performance, it was necessary to think on the one hand of the purchase price of the boat and on the other of the current operating expenses, which might greatly affect the returns. They had always considered that up to 800 h.p., it was possible to use a maximum r.p.m. of 350 to 380 without reduction gear, i.e. by direct propeller drive, especially if there was no need for any considerable traction. Above this r.p.m., reduction gear is always necessary. In the case of an adjustable-pitch propeller, the motor is reversible, and if it is not, a controllable-pitch propeller must be installed. With an adjustable-pitch propeller, the pitch for sailing oı trawling is installed with the engine stopped. The pitch of a controllable-pitch propeller can be installed continuously.

In cases where reduction gear is required in order to reduce the r.p.m. of the propeller (the lowest possible compatible with a maximum diameter of the propeller as permitted by the propeller aperture), a two-speed reduction gear should preferably be used.

Nevertheless, adjustable-pitch propellers and reduction gears have been installed—an additional complication which should be avoided if possible, unless the engine has very high r.p.m., say 1,000 to 1,500; this would probably necessitate very costly and cumbersome reversible multi-speed reduction gear.

Three types of trawlers were tested in the Paris tank, one a 90.2 ft. (27.5 m.) LOA trawler, having an engine of 350 to 400 h.p., had an average displacement (on trials) of 170 tons, block coefficient of 0.42 and prismatic coefficient of 0.579. The results were:

(a) 350 h.p. engine with normal reduction gear—215 r.p.m. at the cast-iron propeller. Bollard pull: 31.5 lb./h.p. (14.3 kg./h.p.).

(b) 350 h.p. engine with two-speed reduction gear, cast-iron propeller, 214/174 r.p.m. Bollard pull at low r.p.m.: 34.8 lb./h.p. (15.8 kg./h.p.); with bronze propeller, Mr. Beaudoux thought that the bollard pull would reach 35.2 lb./h.p. (16 kg./h.p.).

(c) Supercharged 375 h.p. engine, reduction-reverse gear, adjustable-pitch propeller, 225 r.p.m. Bollard pull with cast-iron propeller: 29.9 lb./h.p. (13.6 kg./h.p.); with bronze blades: 31.7 lb./h.p. (14.4 kg./h.p.).

(d) Supercharged 375 h.p. engine, two-speed reduction gear, 270/222 r.p.m. Bollard pull with cast-iron propeller: 34.2 lb./h.p. (15.5 kg./h.p.); with bronze propeller, one would no doubt have got 36.2 lb./h.p. (16 kg./h.p.).

In the case of the normal reduction gear, to obtain a bollard pull/h.p. very close to that of the adjustable-pitch propeller, it would have been necessary to make a considerable compromise in the propeller design, reducing the free running speed by 6 to 8 per cent. For this type of boat the economic speed is about 10.5 knots, this reduction, being operative only during the outward and homeward bound trips, has no marked effect on the commercial use of the boat.

The results obtained at the Paris tank have been fulfilled and can thus be summarized in regard to this type of trawler, which has the following general features:

- Cast-iron propeller: Free running speed 10.4 knots, traction 30.8 lb./h.p. (14 kg./h.p.), 215 r.p.m.
- Adjustable-pitch propeller: Free running speed 11 knots, traction 31.7 lb./h.p. (14.4 kg./h.p.), that is, 0.7 per cent. better.
- Two-speed propeller with 174/214 r.p.m.: Free running speed 11 knots, traction 34.8 lb./h.p. (15.8 kg./h.p.). That is 10.5 per cent. better than the propeller with normal reduction gear and 9.7 per cent. better than the adjustable-pitch propeller.
- Two-speed propeller with 222/270 r.p.m.: Free running speed 11 knots, traction 34.1 lb./h.p. (15.5 kg./h.p.) That is 8.4 per cent. better than the one-speed propeller at 214 r.p.m. and 7.6 per cent. better than the adjustable-pitch propeller.

It should be pointed out, however, that the figures for adjustable- or controllable-pitch propellers will be higher if a better design is made of the blades, but he thought that, with regard to the small-powered engines, there is a marked advantage for the two-speed reduction gear, and that it is always advisable ın connection with a high-speed engine, because the reversing and speed control operations can be carried out from the wheelhouse, as can be done in the case of controllable-pitch propellers.

Mr. Beaudoux had no accurate figures regarding thrust when trawling, but he thought that the relations between the alternatives are practically the same as at the bollard pull test. It should be pointed out moreover that the propulsion powers of this type of boat are very great, which makes it possible for these small French fishing boats to work at great depth and in rough seas. Of course, the hulls of these boats have been designed with a view to getting good sea behaviour and the stern shape in particular makes it possible to use a good propeller diameter while retaining the maximum

MR. H. M. SALOMON (Italy): On the matter of controllable-pitch propellers, his experience was limited to Italy where he had been connected with the installation and maintenance of over 150 diesel engines from 100 to 600 BHP.

These engines were all of the two-stroke type with revolutions ranging from 450 to 310 r.p.m. and were fitted in fishing craft from 50 GT upwards.

The price of such a diesel engine not exceeding 400 BHP furnished with a controllable-pitch propeller was not more than a plant furnished with a conventional reverse gear. Above this output, the price of an engine with a controllable-pitch propeller would be about 8 per cent. more than that of a direct reversible plant. No reduction gears are used.

He was glad to say that Italian owners were enthusiastic about the controllable-pitch propellers on their engines and since the war 90 per cent. of the engines they had fitted to trawlers were equipped with this type of propeller. All the enquiries they received today were exclusively for plants equipped with controllable-pitch propellers and this should be a sufficient proof of the economical advantages to be gained by this method of propulsion.

MR. V. SEGHERS (Belgium): Chardome's paper was undoubtedly most interesting for the builders of new trawlers. However, it would be worth while emphasizing the fact that controllable-pitch propellers have also been adopted on existing boats. As shipbuilder-refitter and owner, he was speaking from experience.

Before the 1953 FAO Congress, not a single Belgian trawler was equipped with controllable-pitch propellers. Some boats, however, had had their mechanical reversing gear installed over 20 to 25 years ago, and they were so worn out that replacement was indispensable. One of these boats belonged to his fleet, and was equipped with a diesel developing 200 h.p. at 300 r.p.m.

After studying and discussing the various reports, it was decided to replace the mechanical reversing device by a mechanically operated controllable-pitch propeller, and it was decided to place a simple clutch between the pitch adjustment mechanism and the diesel, so that the propeller could be stopped during hoisting of the trawl, thus eliminating the risk of wires or trawl boards getting into the rotating propeller. This propeller has been in use for nearly 4 years, and has never given the slightest trouble. The adjustment mechanism is operated by switch-bars and bevel gear from the wheel-house where the engaging lever is located.

After a year's trial, it was decided to equip a second 200 h.p. trawler of his fleet with this same kind of propeller. The result was just as satisfactory as in the first case, and it was decided to fit out another two boats, one with a direct-drive diesel engine that develops 300 h.p. at 310 r.p.m. and the other with a 500 h.p. diesel equipped with reverse-reduction gear. The latter boat was fitted with only a controllable-pitch propeller as the hydraulically operated reverse gear was retained, but on the 300 h.p. boat, the adjustment and reversing mechanism is operated by a small electric motor controlled from the wheel-house. This is the ideal solution for rapid manoeuvring in harbours and in front of tide-gates.

In the meantime his shipyard had fitted out two more Ostend trawlers with controllable-pitch propellers; one of these boats has a 150 h.p. at 300 r.p.m. diesel engine, and the other a 240 h.p. at 300 r.p.m. engine. Their owners are highly satisfied with their performance.

The sea-going speed of all the boats equipped with these propellers has been increased by about 10 per cent. and the trawl pull has also been increased substantially. The boats with 200 h.p. engines and controllable-pitch propellers trawl just as rapidly as the 250 h.p. engine boats with fixed propeller and the 500 h.p. trawler is quite as good as the 700 h.p. boats, expecially in bad weather.

If it were not for the slump in Belgian fisheries, he felt sure that many more shipowners would install controllable-pitch propellers.

PROPELLER SHAFTS

DR. G. RAPPINI (Italy): Propeller shafts in fishing boats are subject to heavier stress than those in other vessels, such as big tonnage ships, etc. Fishing boat shafts must combat the following difficulties:

- Uneven stresses due to the limited number of cylinders of small diesel engines.
- Working irregularities of small craft propellers due to the sea conditions.
- Specific stresses in connection with trawling.
- Frequent speed variations during normal sailing.
- Practical difficulties of carrying out continuous and effective maintenance.

Such difficulties do not occur, for example, on large ships where, due to the service uniformity and the size of shafts, materials have less wear and tear and consequently last longer. In fishing boats with smaller shaft diameters, stresses are more apparent.

Constructional problems must be taken into consideration, e.g. propeller shafts of small diameters are subject to relatively higher stress and corrosion fatigue.

As a result of the experience gained in research, forged steel with copper alloy linings, such as manganese bronzes, aluminium bronzes, etc., is used in the construction of the larger propeller shafts of diameters between 7.9 and 19.7 in. (200 and 500 mm.) for merchant vessels.

For small diameter propellers shafts, a protective lining cannot be made in a single piece due to the length/diameter ratio of the shafts. Liners are, therefore, made in short elements connected by welding or spaced so that parts of the steel shaft are uncovered or specially coated. Corrosion fatigue and stress corrosion may appear in the joints and in the unlined zones, even though properly coated. As the shaft diameter is small, the liner forms a considerable percentage of total shaft diameter and takes up relatively higher torsional stress.

Great deal of experimental work is being done in the field of thin, effective coverings such as bituminous and plastic linings and various paints, as well as galvanic coating and metal spraying—to overcome the problem of corrosion in small diameter shafts.

The main problems are:

(a) Slow or rapid deterioration due to wear or corrosion, i.e. systematic wear of moving parts. Such deterioration is present in large diameter propeller shafts and affects mainly journals and bearings.

(b) Stress failures (sudden failures due to accidents) and fatigue failures, i.e., casual and unexpected deteriorations.

In general, the last type of failure occurs in positions where there are sudden sectional changes (near the keyway as well as in changes between different diameters), and at points such as the propeller connecting cone or between two supporting bearings.

Fig. 263. Fishing boat propeller shaft made of 18/8 steel. Unaffectea

Experiments over the last few years with all possible systems, such as copper alloy liners, chrome galvanic coatings, ›verings and spray metallisation, may lead one to think that a propeller shaft of high quality material, such as a suitable copper alloy (manganese bronze or aluminium bronze) or stainless steel, represents the best solution.

Materials for propeller shafts

Copper alloy shafts, forged and heat-treated to produce high mechanical properties, are difficult to obtain, and results have not always been satisfactory. The trend in Italy, therefore, as in other European countries, is to use stainless steel. Experience in actual operation is, however, rather limited and reports from country to country are conflicting.

The American Bureau of Shipping has given some advice about the crevice corrosion problems arising when using 18/8 stainless steel, and has expressed its doubt about using plain chrome magnetic steels. U.S. engine builders suggest high quality metals (copper nickel alloys—such as Monel with high iron content) for small diameter propeller shafts, while British engine builders suggest Monel K (low content iron with aluminium addition).

Swedish engine makers tend towards the use of high quality 18/8 stainless steel, as they do not consider it necessary to use low carbon steel or titanium stabilized steel. They are also using 17 per cent. chrome magnetic steel with 1 or 2 per cent. nickel, and 16 per cent. chromium, 1 per cent. molybdenum, as well as 26 per cent. chromium, 4 per cent. nickel—molybdenum steel. Though the last material is very resistant to corrosion, it deforms when heat treated and machined, and it is rather difficult, therefore, to make straight shafts.

German engine builders seem to be using 18/8 high quality stainless steel (forged steel is preferred) or 16 per cent. chromium magnetic steel with molybdenum, keeping in mind that, as contact with copper alloy metals must be avoided stainless steel bushes are to be used.

Some French steel producers exclude the use of normal 18/8 steel and suggest the use of 18/8 titanium stabilized steel with molybdenum.

Italian engine builders have so far used normal 18/8 good quality steel, both in rolled and forged bars (either produced abroad or in Italy), as well as 18 per cent. chromium and 2 per cent. nickel magnetic steel without molybdenum. Mr. Rappini's company has been using 18/8 steel with molybdenum for about a year. Experiments with 18/8 steel, stress relieved after machining and treated in a nitric acid bath for passivation, are now being carried out.

Such a differing use of materials is a consequence of the results obtained in practice. Sometimes, in fact, materials such as manganese bronze, aluminium bronze, as well as semiferritic, martensitic and common type austenitic 18/8 steel have given good results over long periods of operation, while in other cases the same materials suffered serious damage due to corrosion and breakdowns, with consequent heavy economical losses.

Research at Mr. Rappini's company which ended in March 1959, covered the running of shafts for periods of up to five years. Trials with sixteen 18/8 stainless steel propeller shafts of the same quality and produced by the same steel works, gave the following results:

Eight shafts in good condition—fig. 263
Four shafts with corrosion areas after two or three years.
One shaft with big pits after two years.
Three shafts with wide pits and corrosion areas after two years.

Different results were obtained with three propeller shafts of high quality 18/8 steel, each manufactured in a different European country: one had hardly any corrosion pits, one showed considerable corrosion (fig. 264), and one was so heavily corroded (fig. 265) that it had to be replaced after only two years.

Such differences were mainly due to the varying working conditions of the shafts; in the third case, the copper sheathing of the bottom was the reason for the corrosion of the shaft, as was later clearly demonstrated by laboratory tests.

Five similar propeller shafts made of 18/8 steel with a high carbon content (about 0.12 per cent.), all from the same steel works, did not present defects after one year.

Research with 18/8 austenitic steels proved that a special type of steel with molybdenum content was in very good condition after more than one year.

Forty semiferritic and semimartensitic magnetic stainless steel shafts of very small diameter, 2.3 in. (58 mm.) were tested together with shafts of 4.5 in. (120 mm.) diam., all made of semiferritic steel of the same type with 18 per cent. chrome

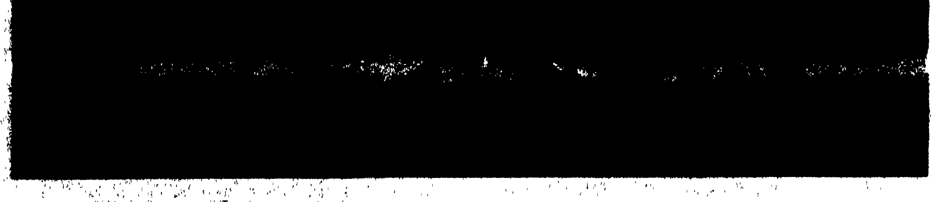


Fig. 264. Localized corrosion pits on a 18/8 steel propeller shaft after three ye

and 2 per cent. nickel, manufactured by the same steel works. Results were tolerable: only some galvanic corrosion by microcells appeared where there was contact with the copper alloy supports or leather seals.

Two propeller shafts in motor boats now in service in the Messina Strait— one of the same type of semiferritic steel as the preceding one and from the same works, and the other of semimartensitic steel with 14 per cent. chromium and 2 per cent. nickel in order to obtain better mechanical properties— give after three years better results than those of austenitic steels.

Various Monel metal propeller shafts with high iron content has given very good results after ten years service.

Stainless steel of the same type and from the same works may therefore give quite different—even opposite—results. The problem seems to be in the actual working conditions of the shafts.

The presence of copper around the propeller shafts exerts a considerable influence; conventional 18/8 stainless steel does not give good results when near a copper sheathed ship bottom, while its behaviour is quite different under other conditions.

It is impossible to state whether forged stainless steel is to be preferred to rolled bars as trials have shown that high quality 18/8 forged steel is, under certain conditions, also subject to corrosion (see fig. 265). On the other hand, the stainless steel shafts used in the above research mostly came from rolled bars.

The very good behaviour in motor boats of Monel metal after ten years service is to be noted, such boats working, more or less, under the same conditions as trawlers.

The good behaviour of 18/8 austenitic steel with 2 per cent. molybdenum was also proved by investigations, even if this material has not been thoroughly tested in a sufficient number of shafts and over an adequate period of time. These shafts have only recently been put into service.

Six different types of stainless steel (three magnetic and three non-magnetic) and Monel K, manufactured in Europe, were chosen for special laboratory tests. Their chemical compositions are given in table 79, while the mechanical properties are given in table 80.

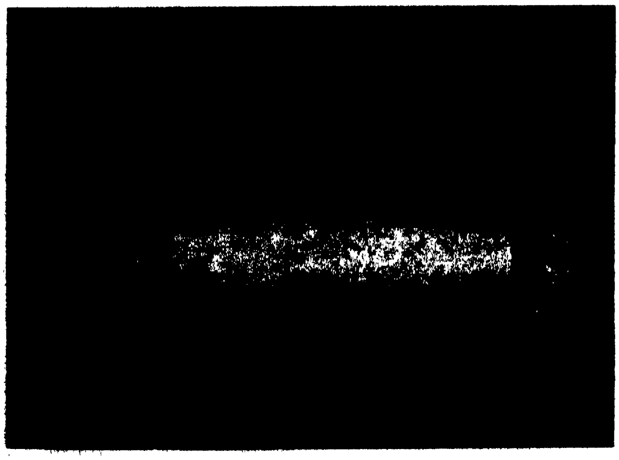


Fig. 265. Diffused corrosion pattern on a 18/8 steel propeller shaft, fitted on a copper bottom ship

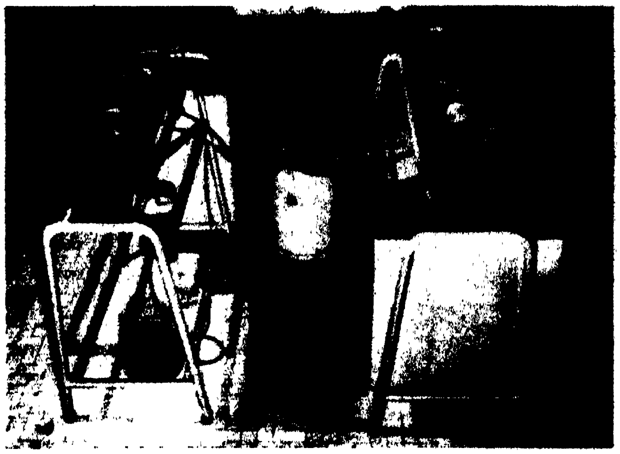


Fig. 266. Rotating beam fatigue tests. Test machines are equipped with a special fitting to carry out tests in sea water with copper ions at controlled temperature

Rotating beam fatigue tests

Rotating beam fatigue tests were carried out in a Baldwin Moore machine, fig. 266, running at 4,000 r.p.m. and with the sample kept in sea water at a constant temperature of 104°F (40°C), fig. 267. The circulation system of the water was constructed of plastic material to avoid foreign metal ions. Fig. 268 and 269 show the fatigue curves obtained for the various materials, in air and in sea water with copper ion addition. A comparison of the behaviour in actual operation and during laboratory tests shows that copper might exert a considerable influence.

Magnetic steels in sea water with copper ions show a considerably reduced endurance limit (figures of endurance limit refer to ten million revolutions). Endurance drops from 64,000 to 14,200 lb./sq. in. (45 to 10 kg./sq. mm.) and even down to 1,100 lb./sq. in. (5 kg./sq. mm.), see fig. 268.

However, such materials may have a higher resistance, provided that working conditions are not so heavy as the experimental ones reported. The results may give an idea of the natural trend of each material towards corrosion fatigue attack.

Conventional 18/8 steel has a considerable drop of endurance limit, ranging from 32,700 lb./sq. in. (23 kg./sq. mm.) in

TABLE 79

Chemical composition of materials for propeller shafts

Materials	Chemical composition % C	Cr	Ni	Mo	Cu	Si	Mn
X11 CN 18 .	0.15	18.70	2.65	—	—	0.41	0.29
X40 CD 15 .	0.40	15.60	0.80	1.08	—	0.54	0.45
X9 CND 26.4 .	0.09	26.40	4.60	1.44	—	0.70	0.65
X5 CN 18.8 .	0.065	17.90	8.40	—	—	0.41	0.77
X5 CN 18.9 .	0.05	17.60	9.20	—	—	0.45	1.72
X6 CND 17.11 .	0.05	17.10	10.55	2.40	—	0.69	1.27
MONEL K* .	0.16	—	64.39	—	29.95	0.18	0.45

*Al=2.8; Fe=1.23; Co=0.27; Ti=0.5%

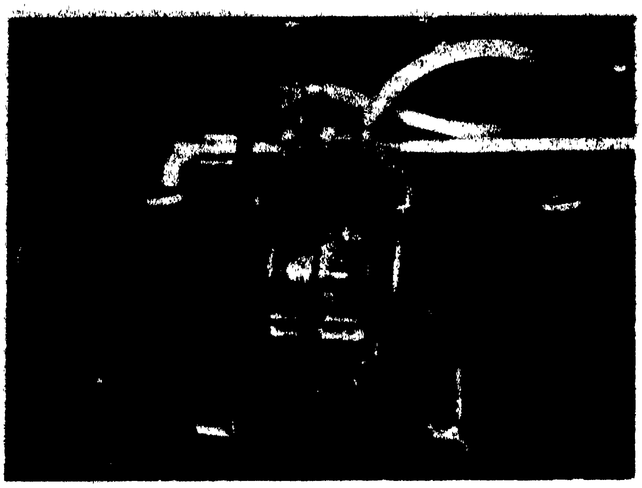


Fig. 267. Detail of seawater cup and nozzle for specimen immersion

dry condition, to 21,300 lb./sq. in. (15 kg./sq. mm.) in sea water with copper ions, thus showing a certain alteration.

This fact may explain the corrosion of the propeller shaft of the ship with copper sheathed bottom in fig. 265.

However, 18/8 steel with molybdenum proved to be unattacked in practice and maintained its endurance limit, both in dry condition and in sea water with copper ions.

Monel K is subject to a considerable drop of endurance limit in sea water with copper ions, but it tends to settle in an asymptotic pattern at 14,200 lb./sq. in. (10 kg./sq. mm.).

These tests show why results of various types of stainless steel may vary according to the service conditions: 18/8 steel with molybdenum and Monel prove, here, to be the most suitable materials to withstand the heavy test conditions. This fact may also be interesting when comparing the costs of the two materials.

In spite of the results obtained, the use of magnetic steels cannot be ignored as those materials often give good results, as shown by the research on shafts in service conditions.

Accelerated cavitation

Accelerated cavitation tests were carried out in a special supersonic device capable of reproducing arbitrary cavitation conditions (fig. 270); they were made in water with 34 per cent. sodium chloride, either with or without copper ion addition. Fig. 271, 272 and 273 show the weight losses after 18 hr. testing.

A material scale similar to that obtained in the U.S.A. for "crevice tests" (McGrew, 1957) has been obtained from these rather severe experiments, which do not, however, reproduce the working conditions of propeller shafts.

Austenitic 18/8 stainless steels apear to be the most resistant, and any differences between them seem to be essentially dependent on the metallographic structure, the best results being given (fig. 274) by the fine-grained austenitic-ferritic structure (this also explains the effect of molybdenum). The better behaviour of the X5CN18/8 steel sample when compared with the X5CN18/9 (both having the same chemical composition) is due to a difference in the metallographic structure.

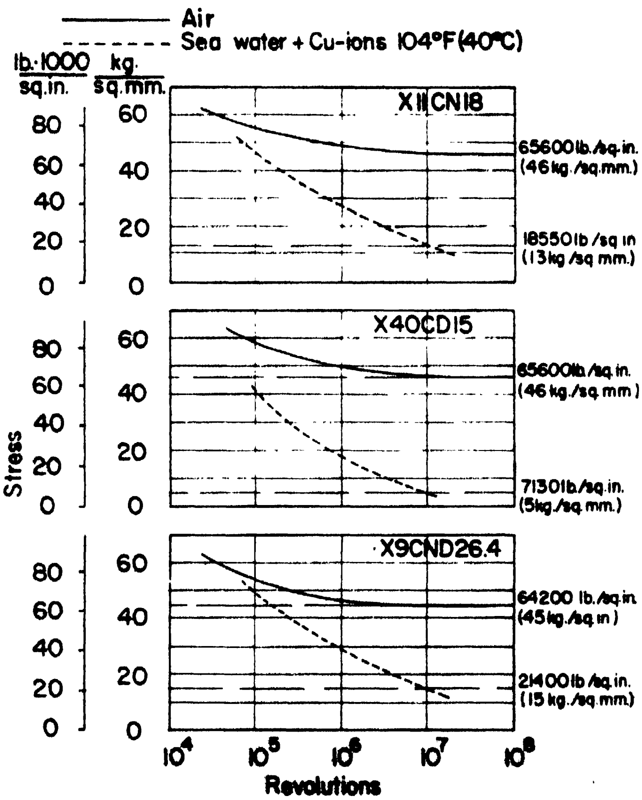


Fig. 268. Rotating beam fatigue tests: reversal of stress revolutions

TABLE 80

Mechanical properties of materials for propeller shafts

Material	Ultimate tensile strength tons/sq. in.	Ultimate tensile strength kg./sq. mm.	Yield point tons/sq. in.	Yield point kg./sq. mm.	Elongation %	Reduction of area %	Impact (Mesnager) lb.ft./sq.in.	Impact (Mesnager) kg.m./sq.cm.	Brinell hardness tons/sq. in.	Brinell hardness kg./sq. mm.
X11 CN18	55.2	86.9	43.8	69.0	17.1	52.8	311	6.67	162.0	255
X40 CD15	52.4	82.6	41.0	64.6	19.4	51.0	238	5.10	154.2	243
X9 CND26.4	48.4	76.2	41.2	64.9	21.0	53.7	36.4	0.78	186.0	293
X5 CN18.8	43.7	68.8	23.05	36.3	58.0	56.3	1,068	22.9	145.5	229
X5 CN18.9	34.95	55.0	16.20	25.5	64.0	75.0	1,068	22.9	94.7	149
X6 CND17.11	36.15	56.9	18.17	28.6	55.0	75.0	—	—	—	—
Monel K	68.5	107.9	49.7	78.3	21.4	40.5	602	12.9	186.0	293

Results of magnetic steel tests, with a greater loss in weight under cavitation conditions, correspond well with the results of fatigue tests in sea water with copper ions.

Galvanic corrosion tests with propeller bronze

To define the influence of copper alloys, laboratory static tests were carried out (fig. 275) to determine the difference of electrical potential between various shaft materials and manganese propeller bronze, and to estimate the metal solution in the water. Table 81 indicates the galvanic corrosion tendency of chrome magnetic inoxydable steel (X11CN18 and X40CD15) with or without molybdenum

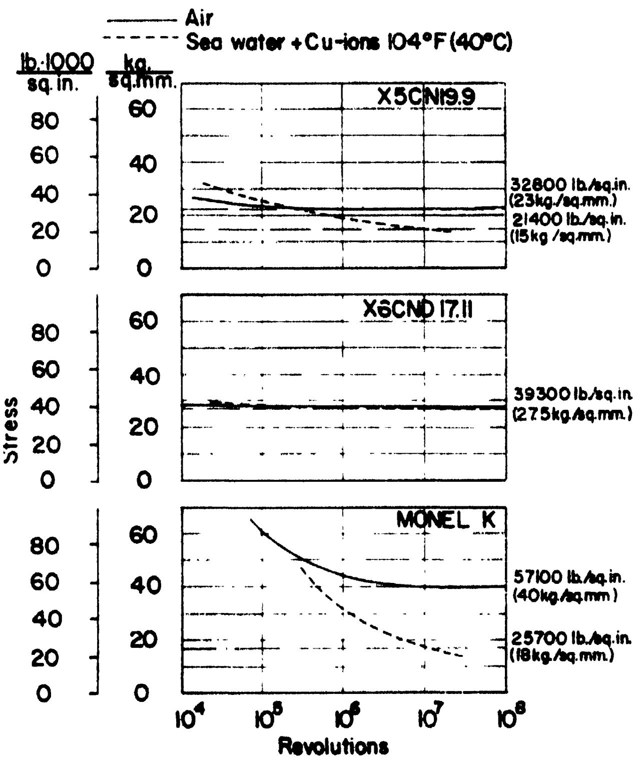


Fig. 269. Rotating beam fatigue tests: reversals of stress revolutions

being in contact with copper alloys (see also fig. 276). This confirms the need of using stainless steel instead of bronze bushes and accessories.

Comment on the laboratory tests

These have confirmed what practical experience has revealed. High quality metals like stainless steel (either magnetic or non-magnetic) and Monel, are suitable materials for the propeller shafts of trawlers. They must, however, be chosen and used carefully.

Copper ions may exert a considerable influence on the life of such shafts and on the formation of localized and diffused corrosion.

Chemical composition being the same, the physical conditions of material, i.e. metallographic structure, which should be ensured through suitable hot working and proper heat treatment, may exert a considerable influence.

The low carbon content titanium stabilization in the

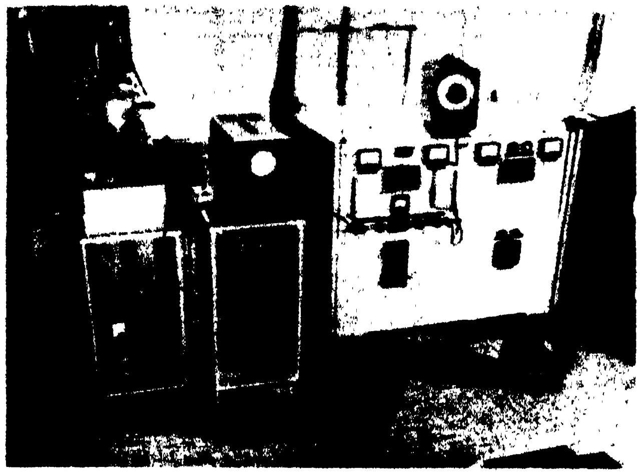


Fig. 270. Accelerated cavitation test—equipment

austenitic steels seems not to be as important as the addition of molybdenum.

Research shows that 18/8 austenitic steel with molybdenum addition affords the best guarantee of long duration and good results.

Many craft have been built by Mr. Rappini's firm during the last few years by using such materials, while others are under construction which might confirm the satisfactory result already obtained.

REPLIES OF AUTHORS

Mr. Ivar B. Stokke (Norway): In answering Leroux he considered a diesel-electric machinery to be more complicated than an arrangement with a direct drive diesel engine with controllable-pitch propeller, as mentioned in his paper for *Kirkholmen*. Also the maintenance cost will be less, especially when hydraulic drive is used for the trawl winch.

Diesel engines with controllable-pitch propellers can be manoeuvred from the bridge, as easily as the diesel-electric installation. He also thought that the operation and maintenance staff of a diesel-electric machinery would be greater and more costly. Advantages of diesel-electric propulsion are that more fast-running diesel engines, say at maximum 1,000 r.p.m. can be used, and that in a stern trawler the diesel part can be placed forward. At the same time there is no torsional

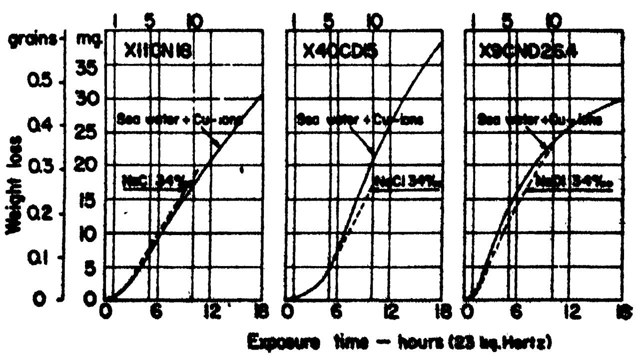


Fig. 271. Vibration accelerated cavitation tests: exposure time—hours

TABLE 81

Galvanic corrosion tests, each material being in contact with manganese bronze

Materials	*Corrosion products (mg.)* Fe	Cu	*Remarks*
X11 CN18 .	. 3.60	0.15	Stainless steel is corroded
X40 CD15 .	. 0.90	1.30	Both are corroded
X9 CND 26.4	. 0.15	0.48	Steel corrodes bronze and becomes passive
X5 CN18.8	. 0.27	0.54	Bronze is corroded more than steel
X5 CN18.9	. 0.15	0.43	As above (equal analysis)
X6 CND17.11	. 0.25	1.42	Bronze is corroded more than steel
MONEL K	. 0.07	0.15	Bronze corrodes most

vibration problem as Leroux has stated. He also thought that expecially in very large stern trawlers, as mentioned in his paper, a diesel-electric system would have some advantages.

He did, however, not agree with Leroux' statement that the overall efficiency of a controllable-pitch propeller would be less than with an electrically driven fixed-blade propeller. when the controllable-pitch propeller can be installed with an automatic control of the pitch and also given an optimum efficiency by varying the r.p.m. in relation to the power, this system would give a greater overall efficiency as explained by Klaassen.

He would like to refer to Salomon's report that Italian fisherman have had very good experience of the controllable-pitch propeller. A similar statement has been made by Seghers from Belgium. Seghers' statement is very interesting especially because the controllable-pitch propeller had not been used in Belgium before 1953, and since that time many Belgian fishing boats and trawlers have been equipped with controllable-pitch propellers, which have given very good results, as both the sailing speed and the trawling pull have been increased.

To Bardarson's question about the horsepower available on the hydraulic winch drive for *Kirkholmen* he answered that it has a horsepower of about 250. This will give a pull on the wire with empty winch drums of about 15 tons. The exact data for the pulling power by half-filled drums are not available at this moment. The propulsion engine of *Kirkholmen* has a brake horsepower of up to 700 when trawling, especially for the newest types of these diesel engines.

It is, however, very interesting to note that Bardarson prefers direct drive for a controllable-pitch propeller for all Icelandic trawlers, because gear boxes can be omitted. It is exactly the same experience as that which has been gained in Norway during more than the last 40 years.

A Norwegian engine manufacturer has also used a small electric motor operated from the wheelhouse for adjusting the controllable-pitch propeller, just as Seghers reported from Belgium.

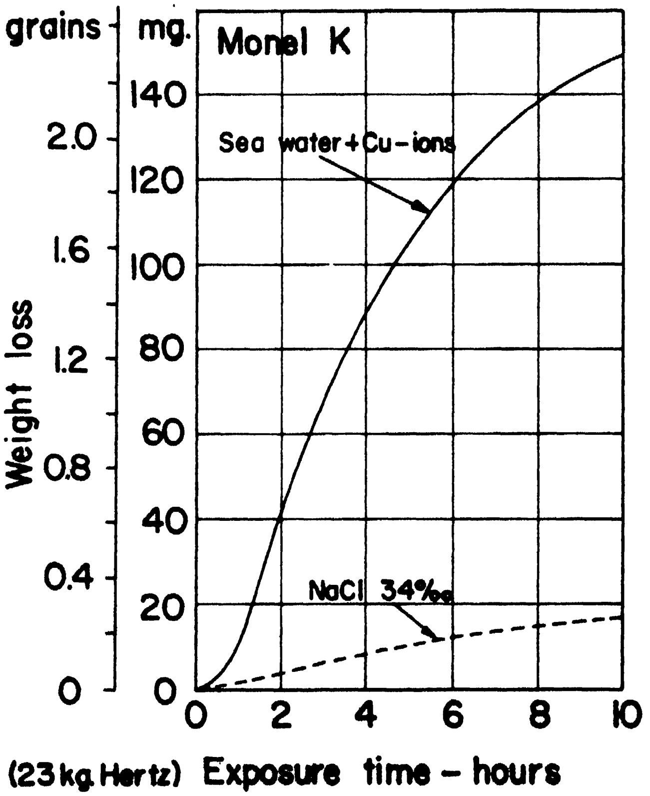


Fig. 273. Vibration accelerated cavitation tests—Monel K: exposure time—hours

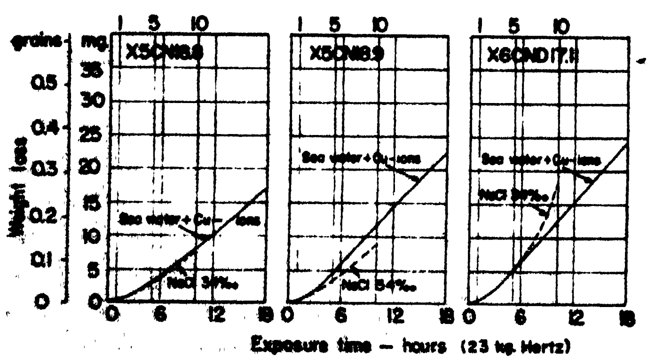


Fig. 272. Vibration accelerated cavitation tests: exposure time—hours

To Akasaka he replied that all Norwegian fishing craft are using low and medium speed propulsion engines. A reason for this is that the Norwegian fishermen etc., who have used high speed engines with reduction gear, especially the light-built engines with 1,500 to 2,000 r.p.m., have had very bad experience of the reliability of these engines in the long run. Therefore he had in several articles in the Norwegian technical press stated that the highest r.p.m. one may use by night and day rating is 1,000 to 1,200 r.p.m. for high speed engines up to say 400 BHP and 750 r.p.m. for bigger propulsion engines (as by diesel locomotives). Their experience, consequently, is that very high speed engines will have too great a maintenance cost and the time for overhaul will be too great for a fisherman who wants to use his engine for fishing and not for overhaul.

When Simpson stated that a high speed engine of 1,200 r.p.m.

with a reduction gear to the controllable-pitch propeller would be lighter and hence give a bigger fishroom, he wanted to reply that the saving in space with a 1,200 r.p.m. diesel engine, especially when fitted with a reverse-reduction gear, would not be as great as one might imagine, and the fuel consumption of the fastrunning engine would usually be greater than that of a medium speed diesel engine with direct drive to the propeller.

The arrangement will be more complicated and give greater maintenance cost than a diesel engine with direct drive, especially when several high speed engines are used for the propeller drive. This is especially the case when a medium speed propulsion engine is built as a high-pressure supercharged four-stroke engine, or as a two-stroke engine with supercharging and with a rotating scavenging pump together with a very short hydraulic equipment for operating the controllable-pitch propeller, built into the engine as shown in fig. 220.

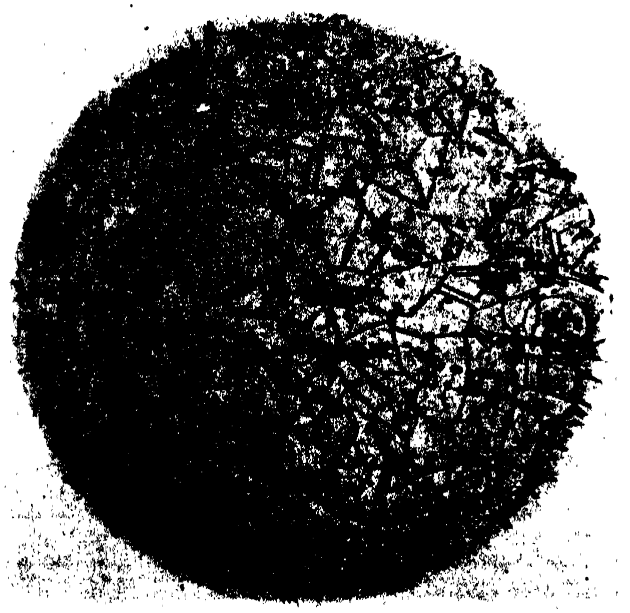


Fig. 274. Metallographic structure of non-magnetic steels. Top picture shows X5CN 18-8; middle, X5CN 18-9; and lower, X6CNB 17-11 magnified 100 times

The Norwegian systems of driving the hydraulic pumps are from the fore end of the main engine. The pumps normally have a higher r.p.m. than the engine. The drive is therefore made either by chain or by gear, and the oil pumps can be declutched when not in use. Neither chain nor gear reduction have given completely satisfactory results. One Norwegian trawl winch manufacturer has therefore constructed a unit which has one hydraulic pump driven direct through a clutch from the fore end of the propulsion engine. This has given no trouble, and he therefore recommended direct drive when a very big tractive force is desirable from the trawl winch.

Mr. G. Hopwood (U.K.): Regarding turbo-chargers: Regular examination of the roller bearings and changing the lubricating oil in the turbo-charger in accordance with the procedure laid down in the paper was all that was necessary to ensure trouble-free running. Some bearings had been run for two years and were found to be in excellent condition on examination. The turbo-charger makers had increased the recommended life of the bearings. In a new building the engine had

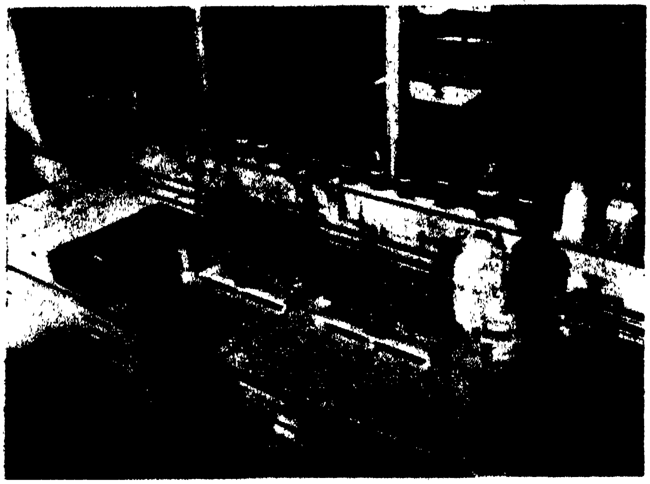


Fig. 275. Corrosion and d.d.p. tests equipment

been fitted with an air-cooled turbo-charger to combat cold corrosion. The turbo-charger was also fitted with bronze sleeve bearings which could easily be renewed at low cost should this be found necessary.

With regard to independent, electrically-driven pumps: Easier and better control of the engine cooling system was obtained without the engineer having to be continually opening and closing by-pass valves. Furthermore, the fresh water pumps could be left running on shut-down of the main engine to provide after cooling, and could also be used when the ship was laid to provide a warming circulation of the main engine from the auxiliary. It had been established over a period of years by the ships engineers, that the electrically-driven pumps were favoured by them. In the unlikely event of a complete electrical failure, a clutch driven pump off the auxiliary could be used for water circulation of the main engine. On the question of circulating water he agreed entirely with the use of freshwater rather than seawater.

Regarding liners: Some owners did not wish to pay the initial cost of chrome-plated liners but preferred to re-condition the engine after a few years in service in accordance with classification requirements for survey. It was not suggested that the life of the liner was so short that it was necessary to re-condition by chrome-plating the bores but, starting with a plain liner, some years of operation could be obtained, the liner bore chromed and engine efficiency could be maintained without major cost of replacement of liners after 8 to 10 years.

Regarding the use of chrome-plated top compression piston rings: This had been the practice on the smaller engines, in particular the winch engine size as fitted to the ships discussed in the paper, with results equivalent to those given by the questioner.

Propeller efficiency: The curves and information were as given by the propeller manufacturer. Thrust meter readings had been taken and whilst the results gave reasonable agreement with the estimated figures in certain trawling conditions, some discrepancies were found. Further data was expected to be obtained in the near future. Whilst on the subject of propellers, the authors would like to have further practical information from Klaassen in connection with a good skipper's usage of the controllable-pitch propeller, particularly as they should soon have in operation their first 900 h.p. vessel with a controllable-pitch propeller.

Propeller shafts: With regard to the question of materials they had indicated in the paper their findings on the shaftings in operation. However, they were pleased to learn of the stainless steel type of shafts.

Auxiliaries: To suit the type and load experienced with deep water working a separate winch engine up to the present time was accepted as the correct machinery. The table on p. 283 shows the ratings required particularly with regard to the h.p. of the diesel engine compared with the output of the winch motor and generator. Two small auxiliaries were fitted, one being a standby.

Lubricating oils: They agreed with Flindt that it was advantageous to keep the temperature high. Difficulties were experienced with the ships engineers in the first case to increase the temperature. However, this had now been overcome. They agreed with the use of thermostatic valves for both oil and water.

Fuel injectors: Spring spindles having reduced inertia, i.e. hollow spindles, were in use. The figure of maintenance time given did not mean that the nozzles had to be serviced generally; it was merely a check and re-testing.

Steam versus diesel: They would refer Todd to Steam Ship P, table 69, on p. 275 of their paper, which was a model tested post-war vessel.

In reply to Simpson's comments: It is interesting to note that diesel trawlers have been in constant use in the U.S.A. for many years in comparison with their use in the U.K. There is no doubt that this is more due to an economic reason than for any other. The use of diesels in U.K. has developed mainly after World War II particularly for the fishing grounds as discussed in their paper i.e. the British West Coast hake fishing industry and was bound up with the high cost of coal and the necessity for new building.

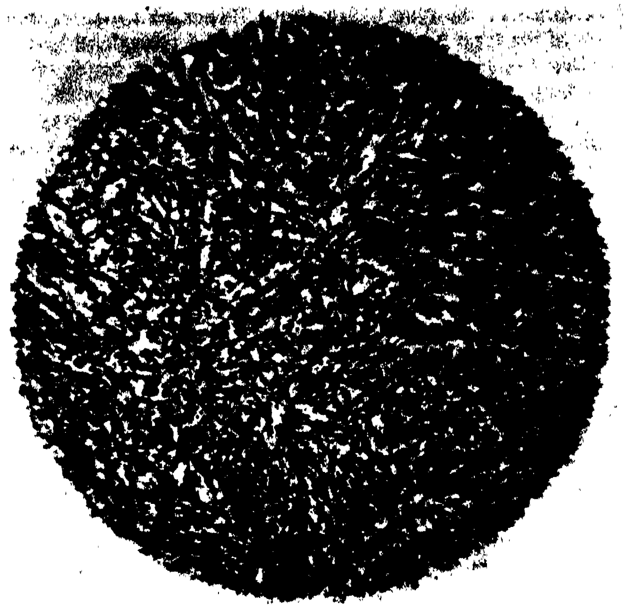
With regard to high speed engines with gearboxes versus direct-reversing, direct-drive engines: It is their opinion, particularly with British conditions of fishing, that there is a use for both types and, in fact, for the home water fishing, the higher speed engine with reverse-reduction gearbox and with a winch drive driven from the forward end of the main engine, is in common use. However, for the particular fishing duty on the West Coast, the low speed engine has proved its worth and is considered more suitable for this particular type of fishing which calls for a high torque from the engine, under trawling conditions. In fact, it is generally found that the engine is on a much higher load when trawling than when free running.

With regard to the reliability of this type of engine: The figures given in the paper prove that the engines are particularly suitable, as the days at sea and the overall costs are comparable with any other type of propelling machinery. It has been standard practice on these vessels to provide a separate diesel-electric winch drive set, as given in their paper with diesel engine powers around 375 h.p. and, for powers of this magnitude, and with the engine on full torque under trawling conditions, it is considered better as a separate unit.

It is interesting to note that owners are now considering the use of controllable-pitch propellers and, at the present time, there are two sister ships, just in service, one with a fixed-propeller and the other with a controllable-pitch propeller, from which they hope to obtain some interesting data, not only for running conditions but for the ability of a vessel for fishing.

It is also interesting to note in Simpson's remarks that their diesels have had closed circuit freshwater jacket cooling systems since about 1936. There is no doubt that this type of cooling is far superior to seawater cooling, particularly for satisfactory engine operating conditions and to eliminate corrosion, and this had been their standard on marine work since the post war years.

MR. A. CHARDOME (Belgium): Beaudoux stated that he had built identical trawler hulls, some of them fitted with two-speed reduction gears, others fitted with controllable-pitch propellers, which enabled comparative readings to be taken. The results seem to prove that the controllable-pitch propeller loses more efficiency than expected, because of the boss diameter and the disturbed pitch distribution.



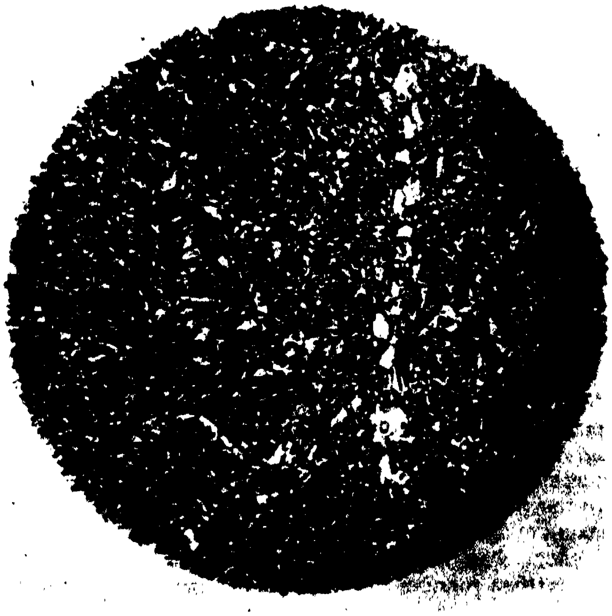


Fig. 276. Metallographic structure of magnetic steels. Top picture shows X11CN 18; middle, X40CD15; and lower, X9CND26-4 magnified 100 times

Hunter expressed doubts concerning a 97 per cent. efficiency for the multiple-speed reduction gear. Mr. Chardome had no reason to disagree with the figure given by the gear manufacturers, as the oil cooler calculated under this assumption proved to be rather too efficient. He would, however, ask Captain Möckel of the Hamburg Tank to make a direct reading in the summer of 1959 during a trial trip, and he was willing to communicate the results to those interested.

Hunter stated further that the electrical losses of a diesel-electric drive might be compensated partly by other advantages such as fitting a slow running propeller with better efficiency or stopping part of the generator sets when the load permitted. Mr. Chardome thought one should try to ensure that such compensations were effective. An example is given in Heinsohn's paper: if a controllable-pitch propeller running at 250 r.p.m. is replaced by a slow running propeller of great diameter, 16 per cent. of electrical losses can be compensated by 15 per cent. improved propeller efficiency; but if a slow turning propeller of large diameter is used in both cases, the 16 per cent. electrical losses remain uncompensated. Experience would indicate if stopping part of the generator sets would result in a lower average fuel consumption.

It might be interesting to note the following: Trawler No. 8 of table 75 is identical with the type A indicated in Gueroult's paper. Gueroult's type C is a diesel-electric ship. The

dimensions of the type C are about 10 per cent greater than those of the type A. Both trawlers spend a considerable time trawling the Newfoundland fishing grounds, in order to fill their large holds with salted fish, thus the horsepowers used cannot be very different. According to the owners, the average fuel consumption of type C is, for each day at sea, 73 per cent. higher than that of type A. This does not seem to indicate that the electrical losses of type C have been compensated in any way.

Klaassen and Højsgaard questioned why a controllable-pitch propeller of 10 ft. 10 in. (3.30 m.) diameter, turning at 133.5 r.p.m., was compared with a fixed-blade propeller of 11 ft. 4 in. (3.46 m.) diameter, with 83 and 141 r.p.m. This comparison seems arbitrary to them.

The r.p.m. of the propeller of 10 ft. 10 in. (3.30 m.) diameter was chosen so that the thrust would be a maximum when absorbing 1,400 h.p. at trawling speed. Fig. 249 shows that this number of revolutions is 133.5 and also indicates that the P/D ratio is near to 0.8.

Mr. Chardome had tried to determine whether it was possible to design a fixed-blade propeller capable of absorbing the same 1,400 h.p. and of delivering, whilst trawling and whilst free running, the same thrust as the controllable-pitch propeller described above.

The answer is given in the diagram fig. 249: the diameter must be increased by 4 to 5 per cent. and a P/D ratio near to 1 must be adopted to obtain an equivalent fixed-blade propeller, provided the power is delivered with variable torque, either by mechanical or by electrical transmission. He arrived in this way to the fixed-blade propeller of 11 ft. 4 in. (3.46 m.) diameter and P/D ratio equal to 1. The revolutions in the different working conditions result then necessarily from fig. 249, 250 and 251 and are staggered between 83 and 141, as stated above.

With hydrodynamically equivalent installations it becomes interesting for the shipbuilder to compare the prices, the maintenance costs, the fuel consumption, etc. What would have been the use of comparing the controllable-pitch propeller to a fixed-blade propeller having the same diameter or the same r.p.m. at trawling conditions? Both installations indeed would have been hydrodynamically completely different, having nothing in common but the diameter or the r.p.m. It would have brought no instructive information to the shipbuilder.

Klaassen remarked further that in the case of a controllable-pitch propeller, when the full power is not requested, it is advisable to reduce the r.p.m. and to increase the pitch above the pitch of the fixed-blade propeller rather than to maintain the maximum r.p.m.

An increase of thrust is indeed recorded as indicated in fig. 250 and 251, if the r.p.m. of the controllable-pitch propeller are reduced by partial load. But if they are reduced under a given optimum, the thrust will again decrease correspondingly,

Mr. Chardome recalculated the lower part of his table 76 assuming variable r.p.m. and obtained the results given in table 82.

The difference which were already negligible are now practically non-existent, but in no case has the efficiency of the fixed-blade propeller been exceeded. A complicated mechanism thus allows a controllable-pitch propeller to follow the curve of optimum efficiency, at a risk of numerous failures, while the fixed-blade propeller with gear, having a diameter increased by 4 to 5 per cent. and a P/D ratio equal to 1, follows the same curve without any complicated regulation and without any risk of error. According to Klaassen, simple systems have been developed which allow for automatic adjustment of a controllable-pitch propeller so that full power is absorbed while free running, irrespective of prevailing sea conditions.

The theoretical advantage pointed out under "Multiple-reduction gear versus controllable-pitch propeller", might in this way become a practical advantage. It would, however, be useful to measure the advantage claimed. Modern trawlers owing to their improved hull lines and to their high propulsion power, are little affected by bad weather. Hunter and Eddie (1959) mention a difference of one half knot between trial speed and service speed. Fig. 248 shows that even if the speed loss was one full knot, in this case the automatic adjusting device would allow the controllable-pitch propeller to absorb 50 h.p. more than the fixed-blade propeller.

Klaassen has presented a diagram showing for a given diesel engine the curves of specific fuel consumption as a function of engine torque and engine r.p.m. with a curve AB being the locus of all points of minimum specific fuel consumption for a certain engine output; and he assumed, for argument sake, that AB represented the minimum consumption curve when propeller efficiency has been taken into account.

He did not go into the exact determination of this optimum efficiency curve but went on to show the principles. He stated that the controllable-pitch propeller and the propeller with DC electric drive can work along the curve AB, and therefore have an advantage over the mechanically driven fixed-blade propeller.

Mr. Chardome emphasized that this argumentation depended entirely on the position of the curve AB on the diagram and that he had never met a similar position with modern diesel engines and high speed vessels.

In the trawlers his firm was building, where the curve AB (maximum product of engine efficiency and propeller efficiency) was situated along the so-called "fixed-blade propeller free running curve", a second speed resulted in the trawling curve and free running curve both being superposed upon the region of lowest fuel consumption.

The reasons for this important difference are:

- Diagrams showing curves of constant specific fuel consumption vary considerably with the type of diesel engine and with the increasing supercharge. The region of lowest fuel consumption in four-stroke supercharged engines is normally and intentionally situated along the so-called "fixed-blade propeller free running curve". Klaassen's diagram must concern an unusual case as the region of lowest fuel consumption is situated much higher.
- In modern trawlers (Chardome, 1955), if the efficiency of a fixed-blade propeller is maximum at 100 per cent. r.p.m. in free running condition with a pitch ratio in the region of unity, it will remain practically maximum along the free running curve when revolutions are decreasing. The pitch ratio of 0.675 at full speed as in Klaassen's diagram is unusual for high speed vessels.

In order to check this statement, Mr. Chardome had used the consumption diagram of the main propulsion engine of trawler *Pierre* to compute the specific fuel consumption for the six cases in table 76 referring to the fixed-blade propeller, and also for the six revised cases of table 82 referring to the controllable-pitch propeller.

TABLE 82

Controllable-pitch propeller at variable r.p.m.

	h.p.	Thrust lb.	Thrust kg.		r.p.m.
Trawling at	1,400	39,800	18,000		133.5
,,	1,000	31,200	14,150	(−80)	122
,,	600	21,600	9,800	(−125)	96
Sailing at	1,400	24,800	11,250		133.5
,,	1,000	19,700	8,930	(−0)	120
,,	600	13,750	6,225	(−0)	110

The results were exactly the same in both cases, respectively:

.352, .345, .343, .352, .345, .343 lb./h.p. (159, 156, 155, 159, 156, 155 g./h.p.).

Contrary to Klaassen's statement, he found that the controllable-pitch propeller with simultaneous control of engine revolutions and propeller pitch can, if the bad influence of boss diameter and disturbed pitch distribution is neglected, reach practically the same thrust and consumption results as the two-speed driven fixed-blade propeller, but cannot go beyond.

Orszulok had asked for criteria to design a propeller with multiple-reduction gear. As may be seen in fig. 249, the best pitch ratio is near to 1; diameter and disc area ratio are then selected in order to avoid cavitation in trawling condition. The number of revolutions in sailing condition is fixed in the same way as with a single-speed reduction, i.e. by keeping a certain reserve of torque at trial speed. Finally, the number of revolutions of the second speed correspond to full power at about 4 knots.

Varriale had expressed the opinion that two speeds, one for sailing and one for trawling, give too rigid a limitation and that a three-speed reversing gear would no doubt be very complicated and certainly costly. Mr. Chardome's experience was the contrary, because r.p.m. can always be adjusted to get the desired flexibility

Trawlers No. 1, 2, 3, 4, 5, 9 and 10 in table 75 have all three ahead speed reductions. Two-speed gears were used in No. 7, 11, 12, 13, 14 and 15, because the diesel with its heavy flywheel and after careful torsional consideration, proved to be much more flexible than supposed. Four more trawlers have been ordered since table 75 was prepared, with h.p. ranging from 1,200 to 1,600. All will have two-speed ahead reduction.

AN ANALYSIS OF U.S. FISHING BOATS—DIMENSIONS, WEIGHTS AND COSTS

by

HARRY BENFORD and MIKLOS KOSSA

Dimensions, weights and costs of the principal types of U.S.-built, steel-hulled fishing vessels have been analyzed and the results are presented graphically. Methods of estimating weights and costs are suggested and the influence of overheads, wage rates, profit and miscellaneous costs are discussed. The proposed cost estimates are assimilated into a final set of curves showing the trends in total cost for vessels of various sizes and powers. To meet an apparent need, the paper concludes with a proposed cost and weight recording system suitable for small-craft yards.

UNE ANALYSE DES DIMENSIONS, DES POIDS ET DES COÛTS

On a analysé les dimensions, les poids et les coûts des principaux types de navires de pêche à coque d'acier construits aux E.-U., et les résultats sont représentés graphiquement. Il est suggéré des méthodes d'estimation des poids et des coûts, et l'auteur examine l'influence des frais généraux, des salaires, des bénéfices et des dépenses diverses. Les estimations de coût proposées sont assimilées dans un groupe final de courbes montrant les tendances dans le coût total de navires de diverses dimensions et puissances. Pour satisfaire un besoin évident, l'auteur conclut par la proposition d'un système de relevé du coût et du poids adapté pour les chantiers construisant de petits navires.

ANALISIS DE LAS DIMENSIONES, LOS PESOS Y LOS COSTOS

Se han analizado las dimensiones, los pesos y los costos de los principales tipos de barcos de pesca con casco de acero construídos en los E.U.A. y los resultados se presentan gráficamente. Se proponen diversos métodos para estimar los pesos y los costos y se examina la influencia de los gastos generales, salarios, beneficios y gastos diversos. Las estimaciones de los costos propuestas se asimilan en un grupo final de curvas que indican las tendencias de los costos totales de barcos de diversos tamaños y potencias. Para satisfacer una necesidad aparente, el autor termina proponiendo un sistema de registros de costos y de pesos adecuado para astilleros donde se construyen barcos pequeños.

NAVAL architects are becoming increasingly aware of the importance of economic considerations in making technical decisions and are realizing that the best measure of engineering success is commercial success. The prospective fishing boat owner may be impressed with the naval architect's calculations of stability, strength and fuel rate; but what he is really interested in knowing is, first of all, how much the boat will cost and, second, how soon he can expect the profits to repay his investment. It is the primary intent of this paper to suggest means by which the naval architect can show the prospective owner how variations in possible size or power will influence building costs. Since any cost analysis involves dimension and weight studies, the paper deals, not only in cost estimating, but in weight and dimension approximations as well.

This study is confined to U.S. type fishing boats, principally trawlers, tuna clippers, seiners and combination craft. Unless otherwise stated, all figures are based on steel hull construction, although deckhouses may be either steel or wood. Vessel sizes range up to 200 ft. (60 m.) in length. Propulsion is by single screw diesel engines in powers up to 2,000 BHP.

With a little care and judgment, the results of the study can be applied to fishing vessels outside the types mentioned.

Difficulties encountered

In gathering the information for this study, the authors were impressed by two things: (1) almost without exception, administrators and technical people are very willing to co-operate in furnishing cost and weight figures, but, (2) the common failure to keep any sort of systematic record of costs and weights meant that, for the most part, there was nothing available to contribute. In other instances, the recording systems were so confused that they were of little use.

While it is not expected that much factual cost information will be found in the published literature, it is cause for dismay to comb every available technical paper on fishing boat design to find next to nothing published on weights. Simpson (1951) is a notable exception. Let this be a plea, then, to future writers: publish your weight breakdown, or if you have none, at least state the deadweight and displacement at some specified waterline!

Despite the dearth of figures, it was decided to embark on the study and to publish the findings to provoke further discussion.

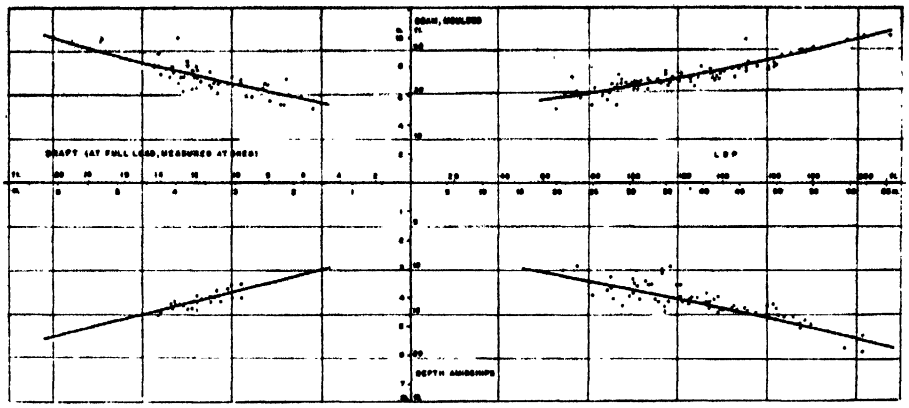


Fig. 277. Principal dimensions of U.S.-built trawlers

Finally, to meet an apparent need, a cost and weight recording system is proposed which should be suitable for most small-craft yards.

Proportions

Fig. 277, 278 and 279 show the principal dimensions of the major types of U.S.-built fishing craft, while fig. 280, 281 and 282 give the approximate relationship between length and displacement. These figures were developed as part of the weight study but should also prove useful in preliminary design. The mean lines drawn on the charts represent good average practice but are not intended as the final word. In many instances, special operating conditions will dictate departures from these mean values.

An attempt was made to put to use Posdunine's formula relating length, displacement and speed (Schokker *et al*, 1953) but it was not found to be particularly applicable, except for trawlers in the range of length between 111 to 170 ft. (34 to 52 m.). The formula then is as follows:

$$LBP = C\frac{V}{V+2}\Delta^{\frac{1}{3}}$$

where C = 18.4 based on existing data (if using metric ton, a value of C = 5.58 will give LBP in metres)
V = normal sea speed in knots
Δ = displacement in long tons, saltwater

WEIGHTS

Naval architects must know how to estimate weights of a proposed vessel. First, and most obvious, such knowledge is essential as a means of guaranteeing sufficient payload

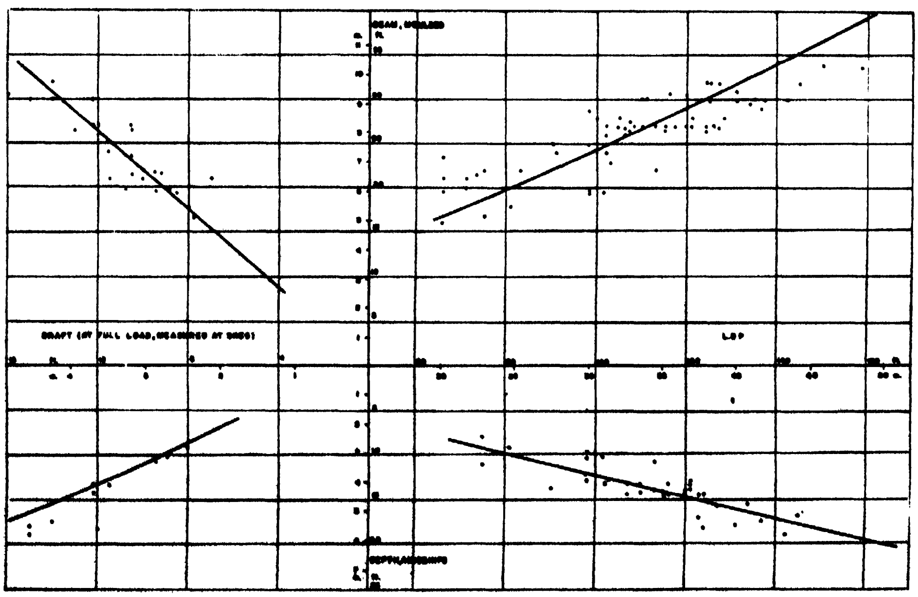


Fig. 278. Principal dimensions of U.S.-built tuna clippers

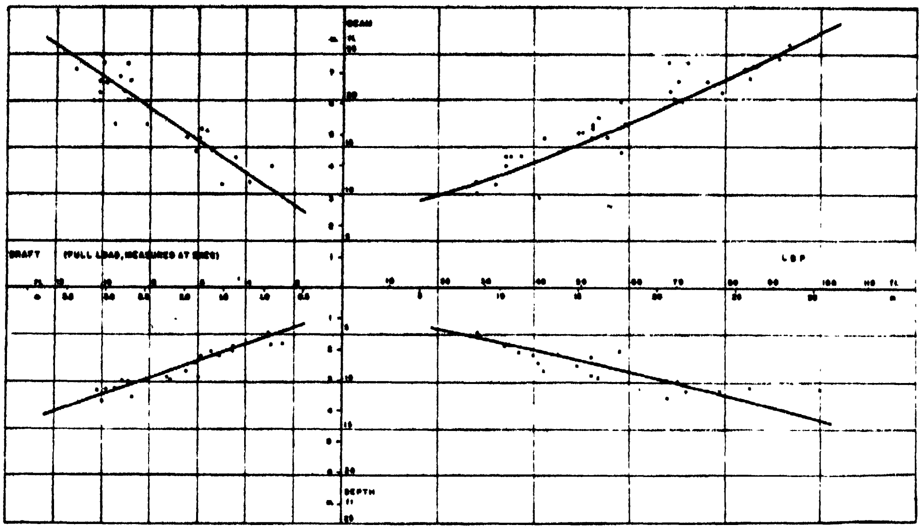


Fig. 279. Principal dimensions of U.S.-built seiners and miscellaneous fishing craft

capacity, stability, trim and similar technical considerations. Second, it furnishes a rational method for estimating most of the building cost components.

This section is devoted to the problem of estimating weights in the early stages of design and presupposes that the dimensions and power have been tentatively set.

The proposed cost and weight breakdown presented at the end of the paper does not in every instance agree with that used in this study. The authors were forced to depart from what they considered the best because of the manner in which their available weight data were presented.

Structural hull weight

This category includes the main hull structure, superstructure, deckhouse, bulkheads, bulwarks, decks, foundations, etc. In general, welded steel construction is assumed, although the deckhouses will usually be of wood, except in the larger trawlers.

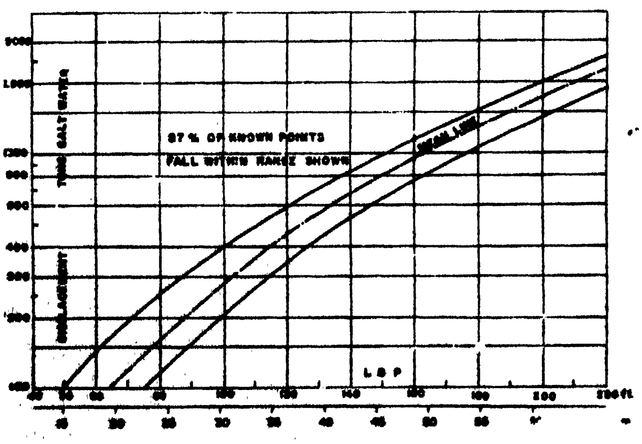


Fig. 280. Approximate relationship between displacement and length of U.S.-built trawlers

Fig. 283 may be used to estimate the net weight of steel in any normal type of fishing vessel with wood deckhouse. When the deckhouse is of steel, its weight in tons can be estimated (Simpson, 1951) as 0.004 times the product of the structure's length, width and height. In metric units, the constant would become 0.144. These figures appear to be on the safe side. The same reference stated that wood deckhouses will weigh the same as steel. If the dimensions of the deckhouse are unknown, the following approximations can be used for either wood or steel:

Seiners:

$$\text{deckhouse weight} = \frac{LBP \times B \times D}{100} \times 0.025$$

Tuna clippers:

$$\text{deckhouse weight} = \frac{LBP \times B \times D}{100} \times 0.015$$

Fig. 283 shows the influence of size, as measured by the cubic number: LBP × B × D/100 in cubic feet, on the weight characteristics. This parameter is commonly used in big ship analysis and seems quite in order for small craft as well. Above a cubic number of 300, the unit weights decrease as size increases. This is quite in keeping with similar plots on large ships and is sound. In the smaller sizes, however, the trend is reversed. This can be explained by the fact that the raised superstructures, which are standard on the larger craft, usually disappear as size decreases and, finally, in the smallest craft, the deck will be partially or completely eliminated.

Considerable deviation from normal weights can be expected. Extent of superstructure, block coefficient and arbitrary choice of plating thickness, will all influence the final figure. It is suprising, then, to find that fig. 283 seems to be generally correct within 10 per cent. in the range of sizes above a cubic number of 100.

Fixed ballast

There is considerable variation in the amount of fixed ballast carried, and in many instances there is none. No correlation seems to exist between ballast weight and vessel size. Ballast weight cannot be fixed in the preliminary design stage but is generally introduced only as found necessary for stability after the design is fairly well advanced. While ballast must not be overlooked in the weight analysis, it is of only minor importance in calculating costs.

Outfitting and hull engineering weight

This category includes such items as the rudder, propeller and shafting, bait boxes, hull piping, joiner work, wiring, refrigeration equipment, ventilation, heating, hatches and rigging.

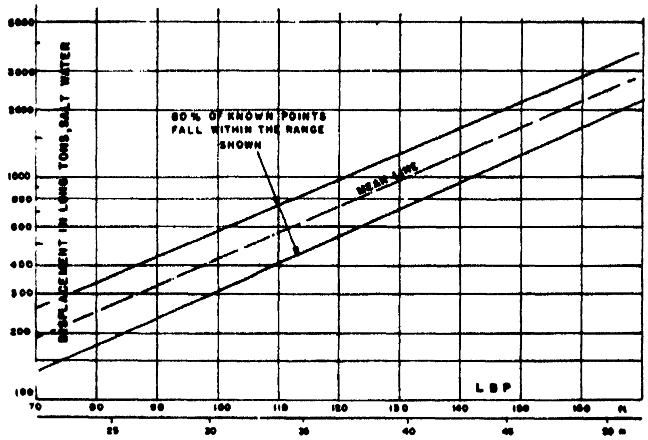


Fig. 281. Approximate relationship between displacement and length of U.S.-built tuna clippers

Fig. 284 can be used to estimate the weight of outfitting and hull engineering. The figure shows the influence of size on this weight category and it is found that the unit weight definitely increases with vessel size. While this is quite the opposite in larger ships, it can be explained by the fact that larger fishing craft tend strongly towards a greater use of electronic gear, deck machinery, steering gear and "hotel service" systems. In the very small sizes, weights within this category are almost non-existent.

Actual data details from existing ships show considerable variation and in some cases depart from the mean line by as much as 30 to 35 per cent. While fig. 284 is believed to indicate the general trend, it should be used with great caution.

Fishing gear weight

This category consists essentially of that portion of the vessel's fishing equipment, such as trawl winches, gurdies and seine reels, which are more or less permanently fixed. It specifically exempts fishing nets, fishing lines, poles and other loose gear which the fisherman can change at

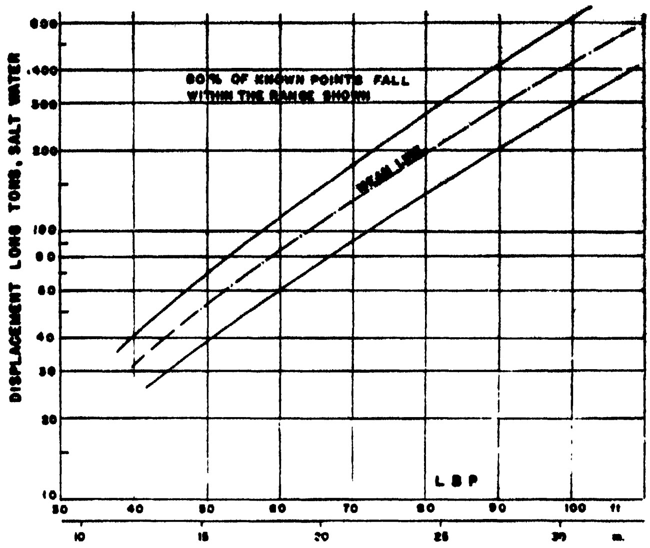


Fig. 282. Approximate relationship between displacement and length of U.S.-built seiners and miscellaneous fishing craft

will. Work boats used primarily for fishing are included here, whereas lifeboats would be grouped with outfitting. Bait tanks are grouped with hull engineering because of their elaborate piping.

It is difficult to generalize about this category. Its weight will depend on the fishing method to be used and normally the owner will dictate the equipment to the naval architect.

In seiners, this weight will vary from about 10 per cent. of the light ship weight in 30 ft. (10 m.) boats to about 2 per cent. in 85 ft. (26 m.) boats. For small trawlers, this ratio should be about 5 per cent. in the smaller and somewhat less in the larger sizes.

Perhaps this category should have been at the top of the list because the fishing method dictates the gear which is the crux of vessel design.

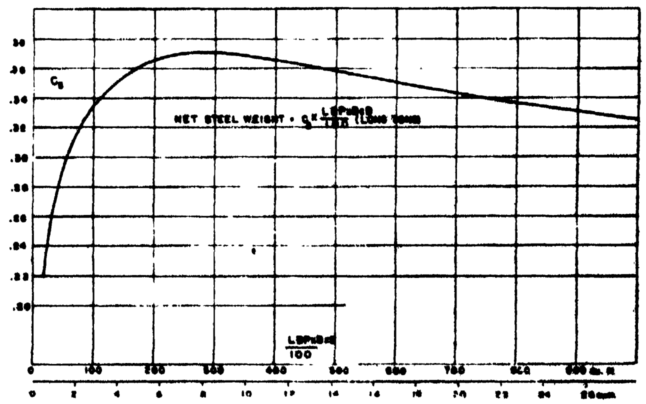


Fig. 283. Net steel weight coefficients for seiners and tuna clippers (for trawlers with steel deckhouses, add 0.03 to C_s value given from curve)

Fig. 284. Relationship between outfitting weight coefficient and cubic number

Main propulsion machinery weight

This category includes the main propulsion engine, together with its lubricating oil, fuel oil and cooling systems. Also included are the gears, starting air system and controls.

U.S. fishing vessels today are almost 100 per cent. diesel powered with single screw propulsion. As a general rule, the engines are installed as single rather than multiple units. Direct engine drive is frequently found on the bigger vessels, while geared engines are more common in the smaller craft where weight and space restrictions are acute.

Fig. 285 has been prepared as an aid in calculating the weight of the main propulsion machinery. It should be noted that the weights are plotted on a basis of BHP. This is not to be confused with SHP which will be somewhat smaller. Dervin (1950) and Argyriadis (1957) give excellent conversion factors for various arrangements.

Liquids within the machinery will add a small extra weight, perhaps 2.5 per cent. to the dry weights shown in fig. 285.

The weight of the propeller, shafting and shaft bearings really should be included in this category. However, in the data available to the authors, these weights were generally grouped with hull engineering, so this practice was of necessity followed here. The outfitting and hull engineering weights of fig. 284 take this into account.

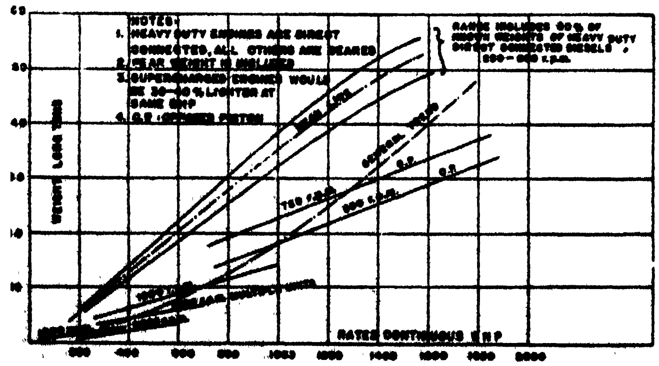


Fig. 285. Dry weight of U.S. diesel engines

Auxiliary machinery weight

This category includes all the engine room items other than those directly concerned with the main engine.

The weight of most of the auxiliary machinery, such as the generators, bilge pumps and refrigeration machinery, is more a function of vessel size than of power of the main engine, and is, therefore, analyzed on a basis of cubic numbers.

Fig. 286 indicates a rough method for estimating the weight of the auxiliary machinery. The unit weights tend to increase with size because of the increasing importance of auxiliary mechanisms in larger craft. Individual deviations from the mean line may be as much as 80 per cent. so that this plot should be used with care, in fact, a better method of approach is required.

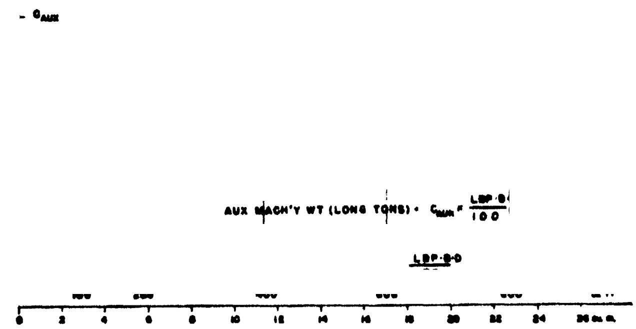


Fig. 286. Relationship between auxiliary weight coefficient and cubic number

Light ship

The sum of all of the above weight categories (that is: structural hull, fixed ballast, outfitting and hull engineering, fishing gear, main propulsion machinery and auxiliary machinery) equals the weight of the light ship. For a specific design, the prudent naval architect will also append a designer's margin of 5 to 20 per cent., depending on confidence in his estimates. For wood hulls, another 10 per cent. for soakage may be added.

Fig. 287 shows the general trends of light ship weight versus cubic number. It is obvious that many factors can throw an actual weight figure off these mean lines. Trawlers, in particular, seem to be stoutly built and tend towards weights between 15 per cent. and 25 per cent. above curve values.

The difference between the design displacement and the light ship weight is, of course, the deadweight. This comprises the variable weights which the fisherman can use in various combinations and over which the naval architect will have no control. While it is beyond the scope of this paper to provide means of estimating these variable weights, the suggested breakdown of cost and weight at the end of the paper will serve as a reminder as to what should be considered.

CONSTRUCTION COSTS

The very nature of boatbuilding costs is such that it is quite impossible to write a definitive treatise on the subject. Variations in design, different production methods between yards, changing hourly rates, disparity between local taxes and shifting dollar values, place any cost analysis on shaky ground although this does not rule out the usefulness of such studies. When engineering economy is used as a tool in design, it is generally satisfactory to have correct relative values of cost. Therefore, while the end results of a comprehensive study may not be exact today (and will surely be wrong tomorrow), they can still serve a very useful purpose.

The remainder of this section outlines a method for estimating the cost of construction of a single-contract, U.S.-built, steel fishing vessel. Dollar values are based on mid-1958 conditions. The term "material cost" includes not only outside purchases, but services of the vendors' engineers and similar expenditures.

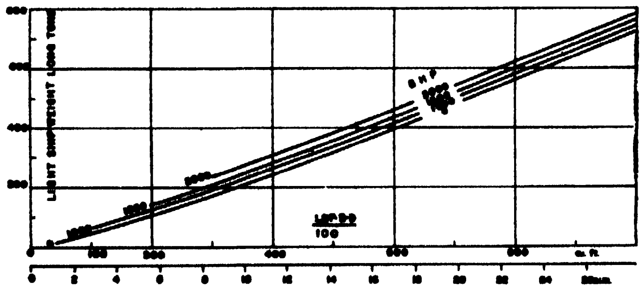


Fig. 287. Relationship between light ship weight and cubic number (exclusive of fishing gear)

Structural hull costs

These will vary with the steel weight, which can be estimated from fig. 283.

Net steel weight should be increased by about 15 per cent. to arrive at the invoiced weight. Current delivered costs are about $200 (£71) per long ton from the steel mill or about $250 (£89) per long ton from a warehouse.

The man-hours of labour involved in the steel hull construction can be estimated from fig. 288. These values include mould loft work and wooden forms.

Wooden deckhouses may be estimated on a basis of $250 (£89) per long ton of material and 100 man-hours per long ton for labour. Both figures are based on the finished weight.

Outfitting and hull engineering costs

The weight of material involved can be estimated from fig. 284. The costs will average about $265 (£95) per long ton, based on the net weight. The figure may be considerably higher, however, if a greater-than-average amount of electronic gear is installed.

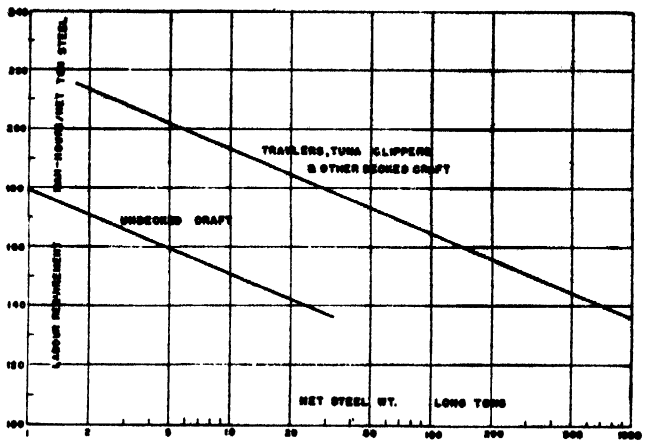


Fig. 288. Steel hull labour requirements

The man-hours required to fabricate and install the outfitting and hull engineering items can be estimated by the use of fig. 289.

Fishing gear costs

This particular category is one in which the authors could find no exact information. It seems reasonable to believe, however, that the unit costs for both material and labour should be very nearly the same as for outfitting and hull engineering. Recent trends towards power reels and other labour-saving devices will, of course, tend to increase costs within this category.

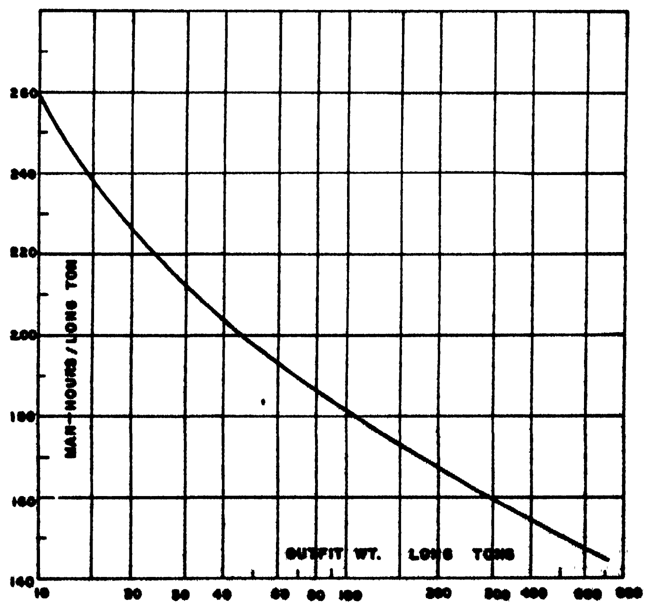


Fig. 289. Outfitting man hours per ton

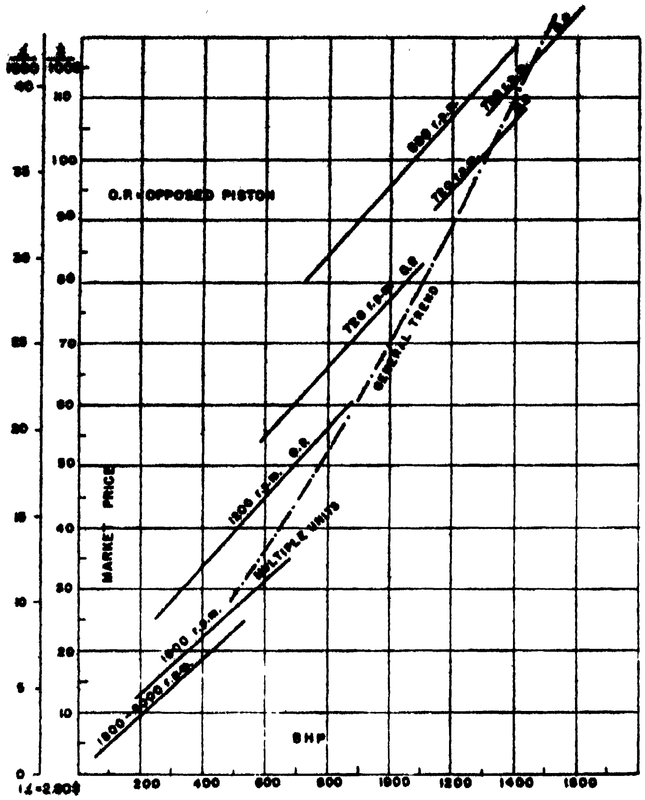


Fig. 290. U.S. marine diesel engine costs

Main propulsion machinery costs

The costs for the main engine can be obtained from the diesel manufacturers or, lacking that source, by reference to fig. 290.

The labour of installing the main engine should vary with the weight of the unit. This may be about 50 man-hours per long ton (see fig. 285).

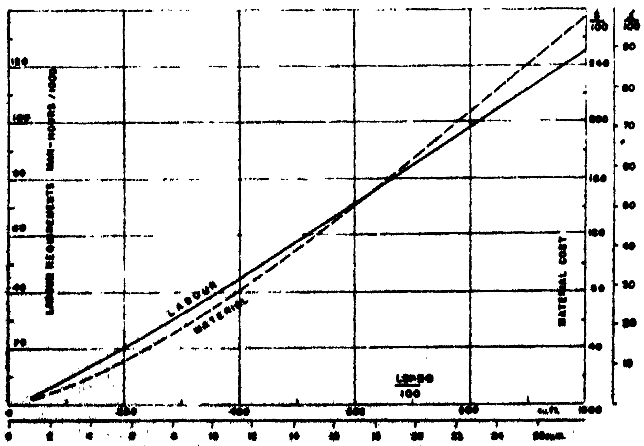


Fig. 291. Material and labour costs (exclusive of main engine and fishing gear)

Auxiliary machinery costs

These figures can be estimated on a weight basis, fig. 286. Material costs should average about \$1,200 (£429) per long ton. The labour involved in handling and installing the auxiliary machinery generally requires about 180 man-hours per long ton.

Hourly rates

The average hourly rates, including a normal amount of bonus and overtime pay, comes to about \$2.65 (19s.) on the East Coast and \$2.75 (19s. 9d.) on the West Coast.

Overheads

This cost division includes most of the operating expenses which cannot be charged to any particular contract.

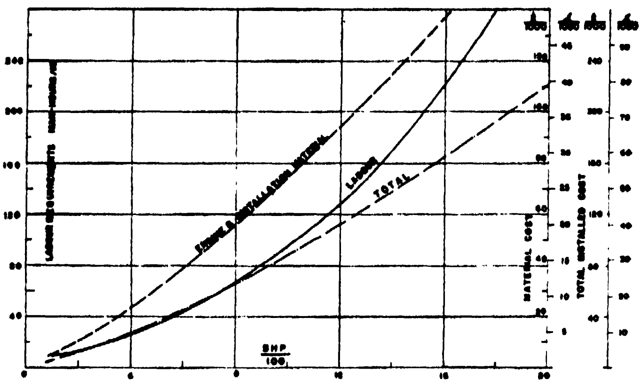


Fig. 292. Approximate main engine costs

Executives' salaries, watchmen's wages, property taxes and fuel costs represent a few typical examples. The total cost chargeable to any given boat will depend on the number of contracts handled during the year and numerous other factors.

Overheads are generally estimated as a percentage of the direct labour costs and various yards report this as being from 30 per cent. to as high as 125 per cent. For general purposes, a figure of 80 per cent. is appropriate.

Miscellaneous costs, profit and insurance

The sub-total of all material costs listed above should be increased by about 5 per cent. and labour costs (not part of the overheads) by some 10 per cent. to cover engineering, launching, material handling, cleaning, trials and other necessary miscellaneous costs.

For estimating purposes, a profit of 10 per cent. on all of the above costs is frequently assigned. Insurance on the vessel may add another ½ to 1½ per cent.

Duplication

Building several consecutive boats from the same set of drawings, templates and forms will, of course, effect considerable savings in cost. In addition to the non-recurring expenses just mentioned there are reductions due to increased labour efficiency and the vendors' savings.

The cost of each of two identical vessels may be only 90 per cent. of the cost of a single boat. If the number of repetitions reaches eight or ten, the unit cost should level out at about 80 per cent. of the single-contract cost.

Sample estimate

The Appendix contains a sample estimate which illustrates the use of the foregoing cost and weight estimates. The example is based on an actual bid and shows satisfactory agreement with the average of the bids submitted.

Cost summary

The preceding parts of this section suggest methods for estimating costs of the major components of fishing boats. The method of presentation allows the reader to modify those particular items for which he has more authentic estimating data. Where speed is more important than accuracy, however, the following material should prove convenient. The detailed figures of the previous paragraphs have been assimilated in order to provide curves of total cost for fishing craft of various sizes and powers.

Fig. 291 shows the general trends in material costs and labour requirements for vessels of different sizes. **The costs associated with buying and installing the main engine and fishing gear are specifically excluded.** The figures are high enough to include miscellaneous material and labour costs, for example engineering, launching, etc. but no overheads, profit or insurance.

Fig. 292 shows the general trends in the cost of furnishing and installing the main engine. These curves are rough and are intended only for quick estimates. The values are high enough to include miscellaneous material and labour costs. The total cost curve also includes overheads at 80 per cent. of labour, profit at 10 per cent. and insurance at 1 per cent. Hourly rates are assumed to be $2.75 (19s. 9d.).

Fig. 293 shows the trends in total cost for fishing vessels of various sizes and powers. The curve of zero power represents a hull without main engine and is based on the material and labour curves of fig. 291, with an hourly rate of $2.75 (19s. 9d.), overheads at 80 per cent., 10 per cent. profit and 1 per cent. insurance. The other contours are taken by combining fig. 291 and 292. It is probable that trawlers would tend to cost from 5 to 10 per cent. more than indicated by the curves.

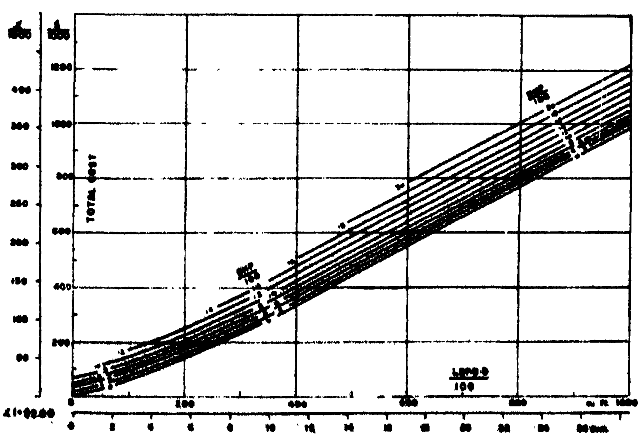


Fig. 293. Trends in total cost versus cubic number (exclusive of fishing gear)

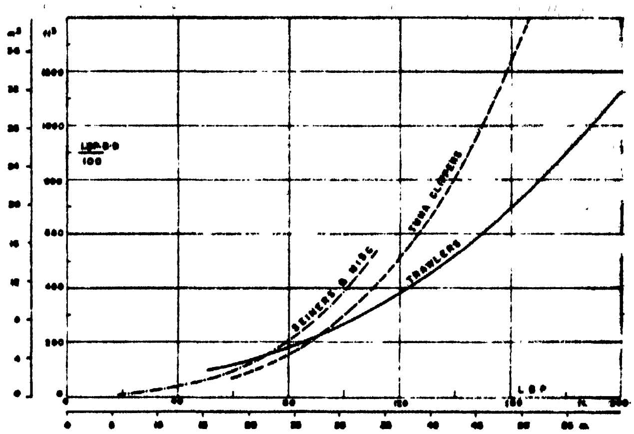


Fig. 294. Approximate relationship between length and cubic number

Fig. 294 shows the approximate relationship between vessel length and cubic number. This allows quick conversion to the size parameter used in the curves when thinking in terms of vessel length. Obviously, such an approximation causes a further lessening in the accuracy of the estimate.

For rule-of-thumb estimates, the following approximations have been derived from fig. 292 and 293:

- Total cost, exclusive of main engine and fishing gear, in thousands of dollars (thousands of pounds sterling):

$$=0.70 \times \frac{LBP \times B \times D}{100} \left(0.25 \times \frac{LBP \times B \times D}{100}\right), \text{when } \frac{LBP \times B \times D}{100} \text{ is less than } 250$$

$$=1.09 \times \frac{LBP \times B \times D}{100} - 100 \left(0.39 \times \frac{LBP \times B \times D}{100} - 36\right) \text{ when } \frac{LBP \times B \times D}{100} \text{ is greater than } 250$$

- **Cost of furnishing and installing main engine, in thousands of dollars (in thousands of pounds sterling).**

$$=6.7 \times \frac{BHP}{100} \left(2.4 \times \frac{BHP}{100}\right), \text{ when}$$

BHP is less than 600

$$=13 \times \frac{BHP}{100} - 38 \left(4.65 \times \frac{BHP}{100} - 13.6\right), \text{ when}$$

BHP is greater than 600

PROPOSED COST AND WEIGHT SYSTEM

By way of definition, the authors mean the categories into which the costs and weights involved in building a boat may be divided. Each category is given a code number for ease of identification and the same code numbers are used on every boat building contract. After a few boats have been built and recorded under such a system, the yard will possess a goldmine of economic and technical data of great usefulness in subsequent contracts. The following departments will benefit particularly:

- Accountants, who must keep a record of how the money is received and disbursed
- Cost estimators, who must be able to predict quickly and accurately how much any proposed vessel should cost even when the new design is different from any previously built.
- Naval architects, who must be able to assure the owner of adequate capacity, and proper stability and trim
- Production planners, who must have some basis for predicting labour requirements and for gauging progress during construction

The ideal system should be identical for both weight and cost records. When this is so, the estimator can readily establish a large number of exceedingly useful coefficients, such as man-hours per ton for steel shell construction. Thus, as each contract is completed, weights and costs are analysed and the resulting coefficients plotted or otherwise recorded. Then, when a competitive bid is requested, the estimator can use these tools for predicting the cost of each element of the proposed craft. The new design may at first seem radical, but when broken down into each of its components, it can be analysed with confidence. This is not to say that any estimating system will eliminate the need for judgment and common sense. It is simply that a bid prepared by these means is bound to be better than one arrived at by gazing at the ceiling or by going to the other extreme and estimating the cost of installing each individual plate and angle.

The system should be detailed enough to yield reasonably meaningful coefficients and ill-assorted items should not be lumped in one category. On the other hand, a certain amount of compromise is necessary here or things will become altogether too complicated. The yard supervisors, who are responsible for keeping track of the man-hours devoted to each type of work, are generally not too well qualified to memorize a long and elaborate list of charge numbers and their meanings. Over-complicated systems defeat their own purpose since they lead to loose reporting. It is suggested that the best place to effect these compromises is in the smaller, less expensive categories where rather crude estimates can do little harm.

When installing a system such as proposed here, it is important to remember that it cannot possibly work without the active co-operation of the yard supervisors. These individuals must be properly instructed and convinced of the importance of reporting time accurately and they must, of course, be furnished with copies of the numbering system.

The cost numbers should be made an integral part of each drawing number and all material should be plainly marked with its appropriate number.

In studying and comparing various existing systems, four different philosophies seem to have been applied. Some yards divide the work according to what the object is: bulkheads, foundations, rudders, etc. Others may divide it according to who does it: sheet iron, plumbing, painting, etc. A variation on this is a division according to what sort of tools are used. Most systems now in use show the combined influence of all these philosophies and most contain rather peculiar oddities having their roots in the history of the yard. Several years ago the U.S. Navy considered adopting a system based entirely on function. Thus the charge number for propulsion machinery, as an example, would embrace not only the engine and gears but associated foundations, wiring and piping. The proposed system had considerable merit but was too alien to established systems in yards throughout the country.

First proposal

The first proposed method for breaking down cost and weight has been prepared by the authors and can be recommended for all kinds of small craft construction. It is generally similar to the methods used in large shipyards, differing principally in that special categories are established for deckhouses as well as for special equipment—in this case, fishing gear. Deckhouses are set out because of wide difference in configuration between various types of boats. Another point of difference is that hull engineering is lumped with outfitting because of the difficulty of drawing a line between them in small-craft work. Finally, engine room auxiliaries are independent of the main engine since their functions are more akin to the hull than to the prime mover.

The breakdown is made according to what the object is, rather than who builds it, what tools are used, or what function it fulfils.

The list is by no means complete but enough details are given to express the authors' ideas. Each yard will have its own special requirements and these may vary, depending on the type of vessel. In any event, every conceivable item of work should be set down in one category or another. This will prevent vacillation in the case of ill-defined items and ensure that nothing is forgotten in a cost estimate.

Zero division (cost items other than ship materials):

01 Engineering and design
02 Specifications and contract plans
03 Insurance and miscellaneous fees
04 Staging, launching, cleaning, temporary lights, inspection and other miscellaneous labour and material
05 Mould loft work
06 Tests and trials
=
99 Handling materials involved in the above

100 division (hull structure)

100 Shell plating and bulwarks
101 Double bottom framing
102 Other framing
103 Tanktop
104 Decks, hatch coamings and pillars
105 Bulkheads
106 Foundations
107 Castings and forgings
108 Fastenings
—
—
199 Structural material handling (no weight)

Note: The cost of fitting and welding two items in different categories should be charged to the smaller of the two items. For example, the work of fastening a frame to the shell would be charged to the frame

200 division (deckhouse)

200 Deckhouse, wheelhouse, etc.
201 Open bridge, wind screens, etc.
202 Wood or metal awnings
—
—
299 Deckhouse material handling (no weight)

300 division (outfitting and hull engineering)

300 Joiner and carpentry work
301 Hatch covers and other closures
302 Boatswain's and other stores
303 Canvas awnings, hatch covers, etc.
304 Furniture
305 Navigating equipment
306 Masts and rigging (except sailing craft)
307 Electrical wiring, fixtures and appliances
308 Heating, ventilating and air conditioning
309 Refrigeration equipment (outside engine room)
310 Hull insulation
311 Lifeboats and davits
312 Other lifesaving gear, firefighting equipment
313 Bedding, mattresses, linen
314 Galley and messroom equipment
315 Sanitary fixtures
316 Piping outside engine room
317 Steering gear and rudder
318 Deck machinery and mooring equipment
319 Independent tanks
—
—
399 Outfitting material handling (no weight)

400 division (propulsion machinery)

400 Main engine
401 Reversing and reduction gears
402 Propeller, shafting and bearings
403 Cooling, fuel, lubricating and exhaust systems for main engine
404 Attached auxiliaries
405 Starting equipment
406 Governing and control systems
407 Liquids in propulsion machinery
—
—
499 Propulsion machinery material handling (no weight)

500 division (engine room auxiliaries)

500 Generators
501 Pumps and compressors
502 Heat exchangers
503 Refrigeration machinery
504 Auxiliary boilers
505 Switchboard and wiring in engine room
506 Service systems for auxiliary machinery
507 Liquids in auxiliary machinery
—
—
599 Engine room auxiliary material handling (no weight)

600 division (fixed ballast)

600 Fixed ballast

700 division (vessel function)

This category is reserved for equipment peculiar to the needs of various types of craft.

701 Fishing gear and bait tanks
702 Towing gear on tugs
703 Cargo gear on coasters
704 Masts, sails and rigging on sailing boats
705 Firefighting gear on fireboats
706 Scientific gear on research vessels

The sum of all of these weights and costs will indicate the light ship weight and cost of labour and material to the shipyard. If further analysis leading to displacement is desired, the following categories are suggested as extensions of the above (most of these involve no cost to the yard):

800 division (cargo deadweight)

800 Payload, other than passengers
801 Dunnage

900 division (miscellaneous deadweight)

900 Fuel
901 Fresh water (cooling, boiler feed, sanitary and potable)
902 Ballast water
903 Lubricating oil
904 Passengers, crew and effects
905 Stores and provisions
906 Bait and water in bait tanks
907 Nets and other owner's furnished outfit

Second proposal

Another, more systematic, approach to this problem of identifying the various categories allows considerably finer division of the vessel's components. This method involves the use of primary, secondary, and tertiary breakdowns. While boatbuilders may feel that such elaboration is undesirable, there are several advantages to the system. It is so logically arranged that it may be no more difficult to grasp than the first proposal. Further, it would be ideally suited to electronic data processing.

The authors are indebted to Mr. Géza Magyari-Kossa, former cost estimator of the Danube Shipyard in Vác, Hungary, for permission to publish this system which he developed several years ago.

Space limitations preclude the presentation of the system in all its details. It is a decimal system. There are ten primary divisions, each of which is divided into ten secondary divisions (or sometimes fewer). Each secondary division is in turn divided into ten or fewer tertiary divisions. Thus, a logical arrangement of up to 1,000 categories is generated.

Primary divisions

- 0 Design and engineering
- 1 Hull
- 2 Propelling machinery
- 3 Auxiliary machinery
- 4 Piping systems
- 5 Steering gear and deck machinery
- 6 Joiner and carpentry work
- 7 Electrical
- 8 Owner's outfit and spares
- 9 Trials and delivery

Typical secondary division (of primary division (4): piping systems)

- 40 Bilge and ballast piping
- 41 Engine room piping
- 42 Fire system piping
- 43 Sanitary and potable water piping
- 44 Special piping
- 45 Stacks and uptakes
- 46 Pumps
- 47 Compressors
- 48 Tanks
- 49 (Unassigned)

Typical tertiary division (of secondary division (41): engine room piping)

- 410 Steam piping
- 411 Boiler feed piping
- 412 Fuel oil piping
- 413 Cooling water piping
- 414 Lubricating oil piping
- 415 Diesel fuel piping
- 416 Compressed air piping
- 417 Exhaust piping
- 418 (Unassigned)
- 419 (Unassigned)

It is the authors' hope that this paper will stimulate fishermen and naval architects to devote more attention to the cost factors in fishing boat design. It is their further wish that boatyard managers will install weight and cost accounting systems where they have not already done so. Once this is done, it will be for the naval architects to compile such information in complete, yet concise, form and to publish it for the benefit of all. Perhaps FAO could provide a standard form for the recording and dissemination of such data.

As already explained, the authors had to develop the suggested weight and cost figures on insufficient data. The task is at best only half done. Fishermen and naval architects need a complete kit of economic tools in order to make rational design decisions. This study has attempted to show what sort of investment will be required in a fishing boat. What is needed next is a study which will furnish methods for estimating annual profits for craft of various types, sizes and speeds. Then design decisions can be based on the attainment of the maximum possible rate of return on investment, rather than on the crystal ball. It has been shown (Benford, 1957; 1958) what can be done along these lines for larger ships.

Acknowledgments

The authors wish to acknowledge the help of the following individuals and their organizations: Robert F. Allen, A. W. Anderson, R. O. Anderson, Francis G. Bartlett, Robert Bennett, George F. Cary II, Wilton Colberg, Ernest Collins, Stephen B. Dowell, Lauritz Erling, Andreas Faste, Milton Fillius, James F. Goodrich, H. C. Hanson, William Hickman, U. W. Hird, Robert E. Hunter, Wayne A. Johnson, S. W. Newell, George Nickum, James F. Petrich, Myles Rados, Donald V. Reardon, Peter G. Schmidt, Charles S. Sinclair, Gordon Snyder, Leslie Southgate, Philip F. Spaulding, Howard Springer, Yoshitane Tanaka, Wesley D. Wheeler and Bruce Whittemore.

APPENDIX

Sample estimate

To clarify the suggested methods of estimating weights and costs, the following typical problem has been worked out.

Problem: Estimate the deadweight and cost of a single-contract steel tuna clipper of 1,200 long tons displacement, powered by a 1,600 BHP, 1,720 r.p.m. opposed-piston diesel engine. Assume the vessel was built on the West Coast during 1958. Calculations are done on a slide rule with weights figured no closer than the nearest ton and costs to the nearest $100 (£35.7). Each step is numbered for clarity:

(1) From fig. 281, LBP = 138 ft.
(2) From fig. 278, Beam = 33.6 ft.; Depth = 16.8 ft.
(3) Cubic number, LBP × B × D/100 = 138 × 33.6 × 16.8/100 = 780
(4) Steel weight coefficient in fig. 283 = 0.337
(5) Steel weight = 0.337 × 780 = 263 tons
(6) Wood deckhouse weight = 0.015 × 780 = 12 tons
(7) Outfitting weight coefficient in fig. 284 = 0.267
(8) Outfitting weight = 0.267 × 780 = 208 tons
(9) Fishing gear weight = nil
(10) Main engine weight, wet in fig. 285 = 35 tons
(11) Auxiliary machinery weight coefficient in fig. 286 = 0.079
(12) Auxiliary machinery weight = 0.079 × 780 = 62 tons
(13) Weight summary:

	Tons
Steel hull	263
Wood deckhouse	12
Outfitting	208
Fishing gear	0
Main engine (wet)	35
Auxiliary machine	62
Sub-total	580
Designer's margin and leeway for ballast (7½%)	43
Light ship	623
Displacement	1,200
Deadweight	577

Structural hull invoiced weight = 1.15 × 263 = 302 tons
Structural hull material cost = \$200 × 302 = \$60,400 (£21,600)
Structural hull man-hours per ton of steel in fig. 288 = 153
Structural hull man-hours = 153 × 263 = 40,200
Wood deckhouse material cost = \$250 × 12 = \$3,000 (£1,070)
Wood deckhouse man-hours, 100 × 12 = 1,200

(20) Outfitting material cost, \$265 × 208 = \$55,200 (£19,750)
(21) Outfitting man-hours per ton of outfit in fig. 289 = 167
(22) Outfitting man-hours, 167 × 208 = 34,700
(23) Fishing gear material costs = nil
(24) Fishing gear man-hours = nil
(25) Main engine material cost in fig. 290 = \$124,000 (£44,300)
(26) Main engine installation man-hours, 50 × 35 = 1,750
(27) Auxiliary machinery material costs, \$1,200 × 62 = \$74,400 (£26,600)
(28) Auxiliary machinery installation man-hours, 180 × 62 = 11,200
(29) Total man-hours (sum of lines 17, 19, 22, 24, 26 and 28) × 1.10 = 98,000
(30) Total labour cost, \$2.75 × 98,000 = \$269,600 (£96,300)
(31) Total material cost (sum of lines 15, 18, 20, 23, 25 and 27) × 1.05 = \$333,000 (£119,000)
(32) Cost summary:

Material	\$333,000	£119,000
Labour	269,600	96,300
Overhead (80%)	215,700	77,000
Sub-total	818,300	292,300
Profit (10%)	81,800	29,200
Insurance (1%)	8,200	2,900
Bid price	\$908,300	£324,400

This compares with an average bid of about \$855,000 (£305,000) on a recently proposed vessel of comparable size and power. The actual proposal involved the use of a surplus main engine which probably accounts for the difference. It is also possible that profit margins were somewhat reduced owing to the prevalent slump in fishing boat construction.

The estimated cost, based on fig. 293 is \$920,000 (£329,000) and the rule-of-thumb formula happens to give exactly the same figure: \$750,000 (£268,000) for hull plus \$170,000 (£6,070) for engine.

H. C. Hanson's curves

Fig. 295 shows the result of a cost study prepared by Mr. H. C. Hanson of Seattle, Washington. Mr. Hanson has generously permitted these curves to be included in this paper. While the quantitative values shown in fig. 295 are not in agreement with those developed by the authors, they nevertheless represent the considered opinion of a fishing boat designer of many years experience and, as such, warrant serious consideration.

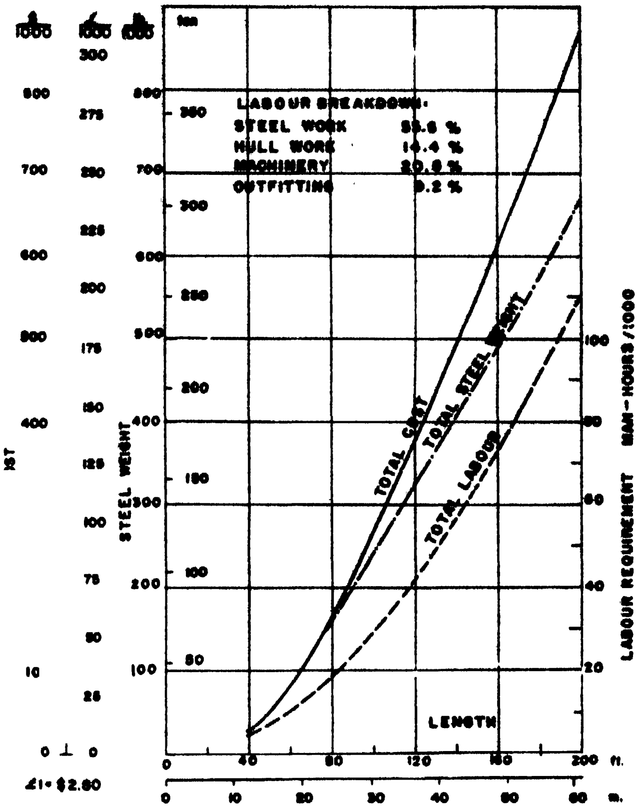


Fig. 295. H. C. Hanson's curves of cost, man hours and steel weight for Pacific coast combination type vessel

COSTS OF CONSTRUCTION — DISCUSSION

MR. H. C. HANSON (U.S.A.): He wanted to amplify his statements made at the 1st Fishing Boat Congress as to the desirability of using simple V-bottom designs in preference to the normal round-bottom (see pp. 107-109 and 250-260 and fig. 326 in *Fishing Boats of the World.*) The truth of these statements has been confirmed because the inflationary trend in the world has made it less profitable to construct new fishing vessels. Fig. 296 shows the 1958 U.S. steel buildings costs and that a small 30 ft. (9.14 m.) vessel cost $14,000 (£5,000) and a 75 ft. vessel $140,000 (£50,000) complete. At the 1953 Congress the author complained about high prices, the 30 ft. vessel then costing $10,000 (£3,600) and the 75 ft. vessel $100,000 (£36,000), thus there has been a 40 per cent. increase in five and a half years, which, if it goes on at that rate, might have a very serious effect on the fishing boat building industry.

One way to reduce hull costs is to simplify designs by using V-bottoms wherever possible, both in wood and steel. Savings of from 7.5 to 10 per cent. can be made with simplified designs. Such changes sacrifice nothing in the way of good construction or operational qualities but actually produce better results. During the past five years the majority of new constructions from 30 to 57 ft. (9.14 to 17.37 m.) have been, in both wooden and steel vessels, of V-bottom type.

Fig. 297 shows the profile of a 45×13×4.5 ft. (13.41×4.06×1.37 m.) steel combination trawler and purse seiner designed with both round- and V-bottom. Fig. 298 and 299 show the lines. Each version has the same appearance above the waterline. The bow entrances are identical, being 24° off centre. The chine of the V-bottom disappears under water; thus there is no pounding in a seaway as in the normal chine boat.

The rise of floor in the V-bottom should be noted, fig. 299A, being necessary for an easy motion of a chine boat in the seaway. Too little rise of floor would offset the advantage of the chine and give the vessels more violent motions. Many round-bottom boats require bilge keels to counteract rolling. The effect of the V-bottom design is actually the same as a bilge keel in round-bottom boats, and it also gives additional support to the vessel from the stability point of view. Another advantage is that it allows longer, flatter buttock lines which give higher speed, and a better directional stability.

A so-called double chine is indicated in fig. 299B. A simple flat plate, say 12 in. (0.31 m.) wide at the chine is all right but excessive width of plate, reduces cost, but it removes a considerable displacement in the very place where it will do a vessel the most good. In these small vessels, where every cubic inch of displacement is necessary, removing 1,560 lb. (708 kg.) cubic support at the bilge is bad practice. It helps to make a tender vessel, particularly if the vessel is heavily powered. This 45 ft. (13.41 m.) V-bottom type boat will make 10 to 10½ knots and then produce a wave system when under way about as indicated in fig. 300. It will be noted that the side of the hull is unsupported well below the still water line. When this occurs the fallacy of the double chine design is evident. The round-bottom type would make less speed, a maximum of 10 knots, because she has a tendency to squat more than the V-bottom type. This is due to shorter and more curved buttock lines fore and after. Fig. 301 gives a general comparison of the form curves for the 45 ft. (13.7 m.) round- and V-bottom hulls. There are no great differences between them.

The loft and pattern work for the V-bottom type can be done in about half the time. With a round-bottom vessel, every inch of plating and frames has to be either pressed or bent, sometimes by heating. The V-bottom boat plates can be wrapped on easily, with very little, if any, roll work. Actually, the stern can be built with four plates, which is simplification at its best. The bow has to be plated in smaller pieces, but this work is also reduced to a minimum. The frames on the V-bottom type are straight, thus simple to make. Great savings are possible in construction compared with the round-bottom type and therein lie the savings as depicted on fig. 296.

Naturally, plating can also be simplified on the round-bottom vessel if it is worked into place vertically, but still its costs are far in excess of the V-bottom type work. Another form of simple plating results from the use of what is known as "Conical Hull Development". This is a method of rolling the plates on the hull, all the plating being shaped in the arc of a circle, but it is expensive to lay out the hull to the exact shape to receive the plating and it is doubtful whether it is less costly than the regular V-bottom type, although it does produce a fine finished hull.

Almost all the advantages in the use of steel V-bottom hold true for the wooden V-bottom as well. Fig. 302 and 303 show a 57 ft. (17.37 m.) Alaska limit seiner, built of wood. The first boat of this type was built in 1913 and it is still in operation. Built of American yellow cedar, a life of 30 up to 50 years can be expected. This type is used at present for crabbing off the Washington Coast and, when opportunities arise, for purse seining in Alaska. Brine holds have been built in, and the structure itself is well suited to this heavy load because the harder bilge lends itself well to the support of liquid loads, and tighter tanks can be made, due to the straight side structure.

The cost of such a V-bottom wooden boat has proved to be 10 to 15 per cent. less than the corresponding round-bottom wooden vessel. A large part of this reduced cost is in the labour saved, due to its ease of construction.

MR. J. PROSKIE (Canada): For the past seven years the Canadian Department of Fisheries, in co-operation with the provincial Departments of Fisheries and Fishermen's Loan Boards, has carried out a study of the economics of the operations of modern fishing craft on the Atlantic seaboard.

This study also included the determination of capital cost of fishing boats and equipment to fishermen. Since 1951 information on capital costs of boats (equipped and ready for fishing) by type, size and area has been published by the Department of Fisheries of Canada (Proskie, 1952 to 58). Although data on capital costs is gathered in some detail, the published cost analysis is released in summary form as follows:

Original capital cost

1. Hull
2. Engine
3. Specialized equipment (electronics, etc.)
4. Winch and gallows or gurdy
5. Fishing gear
6. Total cost

As a guide in respect of trends in capital costs and other related data, information is also released as follows:

1. Area
2. Type of craft
3. Year built
4. Gross tonnage
5. Original capital cost per craft
6. Capital cost per gross ton

The level of profitability has also been calculated for the various types and sizes of craft and the maximum level of investment per fishing enterprise has been arrived at for optimum operations.

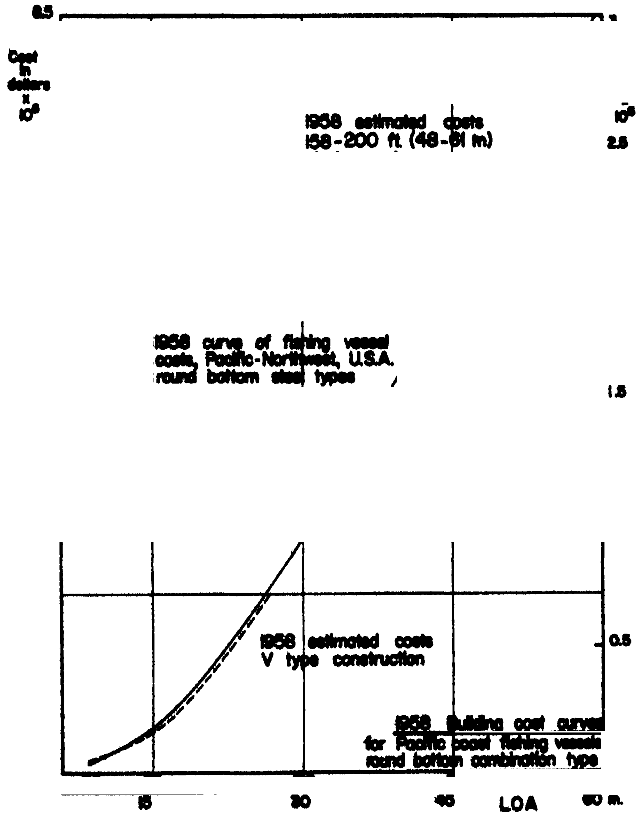


Fig. 296. 1958 U.S. steel building costs for various types of vessels

Benford and Kossa in their paper conclude that it is their hope that their contribution will stimulate "attention to the cost factors in fishing boat design". Proskie endorsed this hope and wished to point out that in Canada it is already in effect to some degree and many have used their publications as a guide. Tothill, in his paper, is only one example of a naval architect who is making some use of the results of an investigation that has been carried out in Canada.

MR. C. HAMLIN (U.S.A.): All too often costs are a neglected area of shipyard operation, particularly in the smaller, low-overhead units. This lack of attention frequently results in quotations which are too low, thus depressing the overall industry price structure and causing many shipyard failures.

For several years he used the curve shown in fig. 304 for preliminary estimation of building hours for yachts and it has stood the test of critical examination very well. The spots on the low side of the curve invariably represent a simple grade of construction, and the spots on the high side, first class yacht quality. The boats represented on this graph range from a 12 ft. (3.7 m.) rowboat to a 65 ft. (19.8 m.) trawler-type yacht.

The value of the graph lies in the constant slope of the curve. This is of considerably greater importance than the actual position of the line as shown, since it makes it possible to extrapolate fairly accurately on the basis of only one boat.

For example, he plotted the hours estimated by Benford and Kossa for the construction of a 1,200-ton tuna clipper. He used the light ship displacement (1,360,000 lb.), including ballast, thus making the comparison more valid by removal of

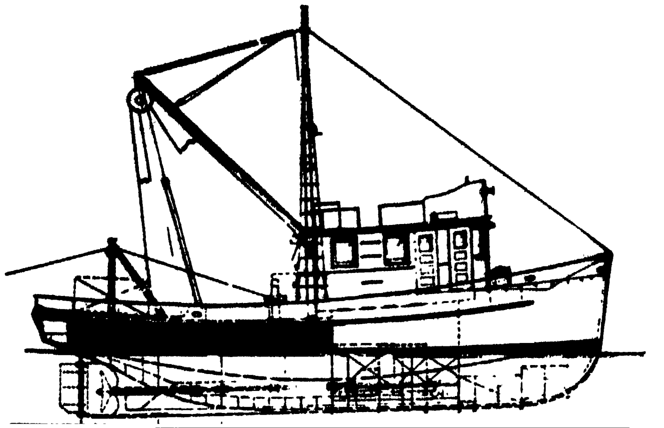


Fig. 297. Steel combination trawler designed with both V- and round-bottom

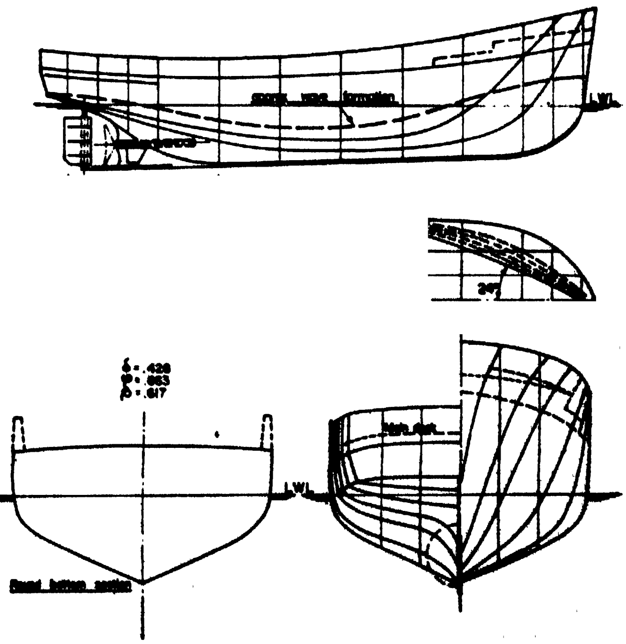


Fig. 298. Round-bo

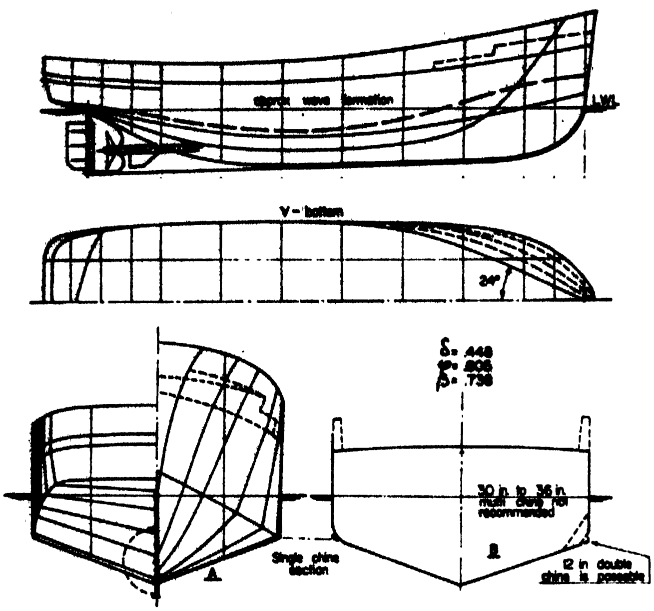


Fig. 299. V-bottom steel combination trawler

the cargo variable. If this spot represented the actual performance on a previous vessel, the building yard could estimate the labour involved in a vessel of similar type and quality but of any size, by using a curve parallel to the one given, as shown by the dashed line. For instance, a clipper displacing 500,000 lb. in light condition, and built of steel with wooden superstructure, could thus be expected to require approximately 44,500 hr. for her construction.

He felt that consistent use of a curve such as this would give more accurate estimating values for labour than would detailed breakdowns by operation. At least it should provide an extremely accurate check upon quotations. Since displacement seems to be the vital factor in man-hours, the builder should, before estimating a job, find out exactly what condition the specified displacement applies to, and, by comparison with similar vessels of the same size and type, whether the displacement is accurate.

Mr. W. Zwolsman (Netherlands): It was a great pleasure to read the clear explanation in the paper by Benford and Kossa. It will probably be useful to also record some European data. Fig. 305 shows a number of curves giving the prices for steel fishing craft in the Netherlands. The lines are not straight due to the fact that the small boats are arranged and equipped more simply and the larger boats have the same electronics and auxiliaries as ships of 70 and 80 tons.

From these figures it appears that the price of the steel hull constitutes about $\frac{1}{3}$ of the price of the complete boat. The prices do not include fishing gear. The net steel weight of a Dutch fishing boat is 13.5 to 14 per cent. of L×B×D in metres, in connection with which it is to be remarked that boats of 70 to 80 tons have shell plates of $\frac{5}{16}$ in. (8 mm.). The classification societies permit thinner shell plates, but there would only be a small difference in the total price of the boat, if $\frac{1}{4}$ in. (6.35 mm.) plate were used instead of $\frac{5}{16}$ in. (8 mm.), while the lifetime of the hull would be shortened by 35 per cent., for when the shell thickness has become $\frac{5}{32}$ in. (4 mm.), the shell plates have to be replaced.

From the curve it appears that an 80-ton boat has a length of 75 ft. 6 in. (23.00 m.) and that the total price of the steel hull of this boat, including the deck house, a complete steel deck over the whole boat, five water-tight steel bulkheads, engine foundation, streamlined steel rudder with quadrant and chain transmission with hand steering gear on the bridge and a whaleback, amounts to £8,000 (U.S. $23,000), inclusive of the built-in fuel tanks, drinking water tanks and steel masts. This price also includes the fixed portholes, and portholes in the deckhouse, as well as the bollards and the galvanized stanchions in the fish hold.

The price shows the great difference in hourly wages between the Netherlands and the U.S.A., while also the steel price is about $\frac{1}{3}$ lower than the U.S. $200 which is mentioned.

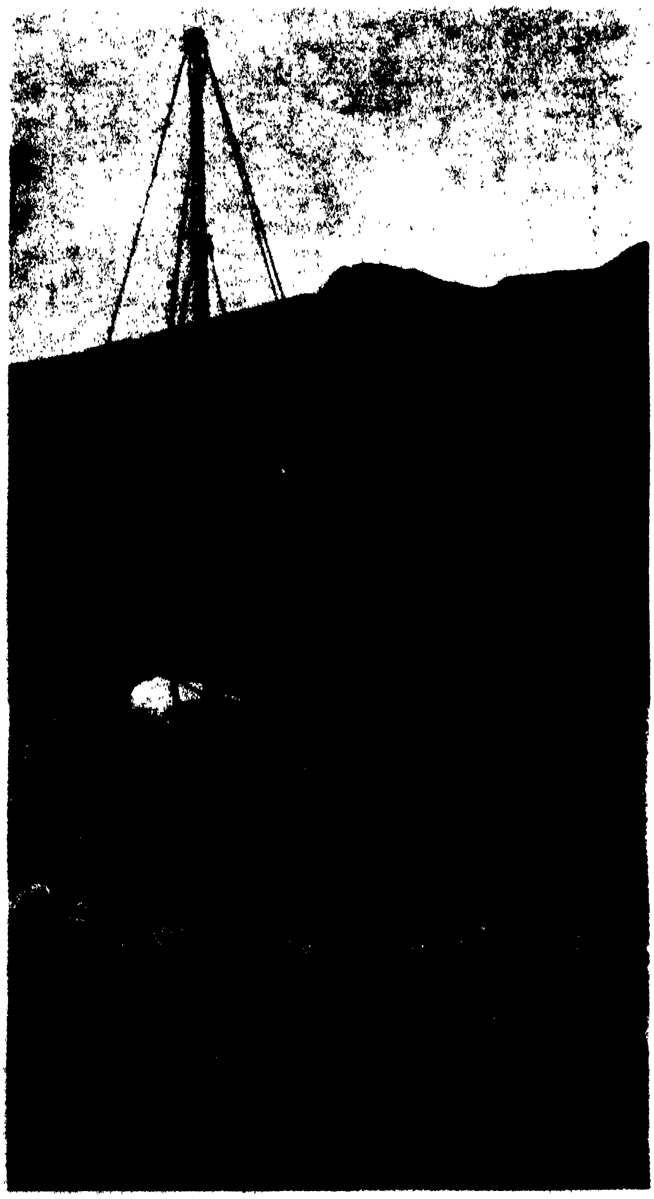


Fig. 300. Wave system produced by a V-bottom trawler

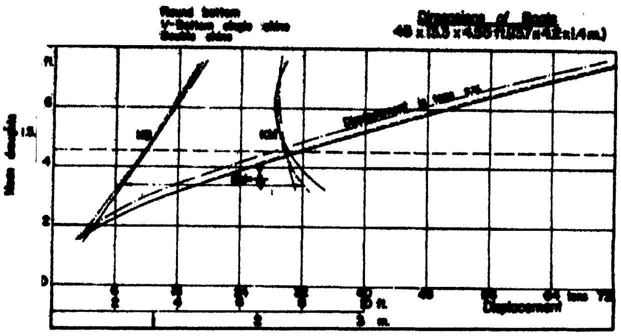


Fig. 301. Form curves for round- and V-bottom combination trawlers

In this connection it may also be remarked that the same price of £8,000 for a 75 ft. (22.9 m.) plastic hull is mentioned by de Laszlo and that this probably does not cover everything included in the description of the steel hull, while further in general the steel boat is likely to have a longer lifetime than the plastic boat. Time will still have to prove this, but it will be long before the builders of plastic hulls can show that their boats, under the heavy work in the fishery and in the fishing ports, can operate for 40 years without repairs to the hull.

An 80-ton steel hull requires 6,300 man-hours, which also includes the mouldloft work and wooden forms, so that in case of several boats of the same type the price will be somewhat lower, but the price difference can never fall so low as the 80 per cent. which is supposed. For a series of eight or ten, the number of man-hours can be reduced to 80 per cent. but not the total cost-price.

The price of £8,000 ($23,000) for an 80-ton hull is composed as follows:

Steel plates and angle irons . .	£3,200
Steel masts	270
Forgings and pipes and steering gear	650
Portholes and lights . . .	100
Welding rods	200
Painting	120
Wages and overheads, including profit	3,460
Total	£8,000

In the Netherlands no high-speed engines are used in the fishery for outputs higher than 100 h.p. The engines that have been used the last ten years in outputs ranging from 150 to 700 h.p., vary from 300 to 750 r.p.m. Also, because the further arrangement and equipment of the U.S. boats differ much from that of the Dutch ones, it is of no avail to mention comparative figures here.

In their paper, Corlett and Venus state that the cost of a double chine type is *considerably lower* than that of the normal round shape.

In Mr. Zwolsman's opinion the double chine form will only have little influence on the total cost-price of the boat.

For the steel fishing craft of 30 to 200 tons, tens of which are made in the Netherlands every year, the price of the steel hull is about 30 per cent. of the entire price of the boat and this often is reduced to 26 or 27 per cent. when, as frequently occurs nowadays, many electronic instruments and hydraulic winches are used.

Of this 26 to 30 per cent. of the total cost-price, only about one-sixth is spent on direct wages in the shipyard, from which it appears that only 5 per cent. of the total cost-price of the boat is spent on direct wages for the steel hull. For these wages, which constitute 6,300 man-hours for an 80-ton hull, 400 hours are spent on bending the frames and the curvature of the plates.

Shaping the frames and plates of the double chine boat will cost at least 150 hours, so that there will be a saving of

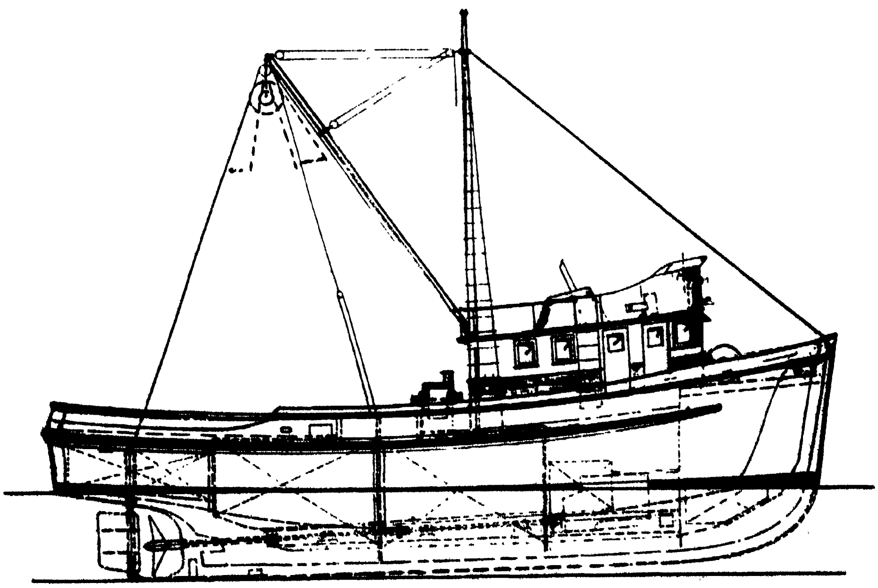


Fig. 302. Wooden built Alaska limit seiner

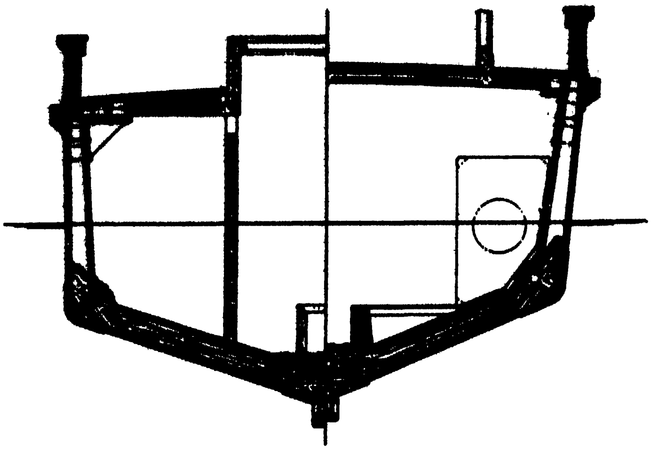


Fig. 303. Wooden built Alaska limit seiner

only 250 hours at the utmost or $\frac{1}{25}$ of the total number of hours spent on the work of the hull. So this turns out at $\frac{1}{25}$ of 5 per cent. which is a difference in cost-price of 0.2 per cent. of the complete boat.

However, the arrangement of a shipyard can be somewhat cheaper if *exclusively* boats with straight framing and single curvature plating are built, but this is of hardly perceptible influence on the total cost-price of the boat.

Mr. A. Hunter (U.K.): A good system of costing is necessary for budgetary control as well as records. The cost make-up suggested by Benford and Kossa depends very much on the use of the cubic number. Naval architects will appreciate the dangers inherent in using this parameter blindly unless ships of very similar characteristics and without large dimensional changes are being compared.

The proposed grouping of costs is rational and orderly, but between various establishments will depend largely upon the demarcation employed in a particular establishment. The main difficulty in an expanding post-war world is to make workpeople cost conscious right down the line from management to shop floor. The more detailed a system can be without employing an army of clerks the more readily will expensive differences be thrown up.

Mr. S. O Meallain (Ireland): Benford and Kossa's paper is of considerable interest and value as an analysis of the make-up of the cost of a fishing boat and indicating relationship between dimensions, weights and costs. The fact that the data used are those applicable to steel hulls does not take from the validity of the presentation. There is, however, an omission which detracts somewhat from the value of the paper—adequate reference to and emphasis on cost control. It is not sufficient to be able to make a satisfactory estimate or know, on completion, how much any particular vessel has cost. We should be able to keep track of and control costs during actual construction, and know also whether the yard as a whole is working at a profit or a loss. It is clearly essential to be able to determine at all times whether physical is keeping pace with expenditure, and to measure in of money any discrepancy which may exist between the two rates of progress.

In any yard engaged on the construction and repair of boats, it is necessary to have early and accurate information on progress, not only of new vessels under construction, but of the yard operations as a whole. As far as new is concerned, the procedure which will give the desired results is the establishment of the standard cost of labour and overheads, based on the estimate for the vessel for each of the sections into which the total of operations is divided, and comparison weekly or monthly of the value of the work done as measured by the standard cost with the actual expenditure on labour and overheads. Materials do not come into this operation. The quantities and value of any materials used in each section of the work can be established in advance with great precision: they are in fact in the bill of quantities; and these materials can be issued in accordance with the programme of work. Incipient wastage shows up at once, and can be readily controlled. Application to the overall yard operation is relatively simple.

Thus the comparison of standard cost, which will include only labour and overheads, with actual expenditure, shows up savings or excesses at regular time intervals, and enables suitable corrective measures to be applied as necessary. The original standard costs must be reviewed continually to ensure maximum efficiency.

In that connection it is well to draw attention to the fact that the most potent factor in inefficient working is loss of time:

Waiting for instructions
Waiting for materials
Waiting for assistance
Waiting for tools
Absence of operative

Failure in any period to show a saving as compared with standard cost should be followed up by investigation into loss of time under any of the above heads.

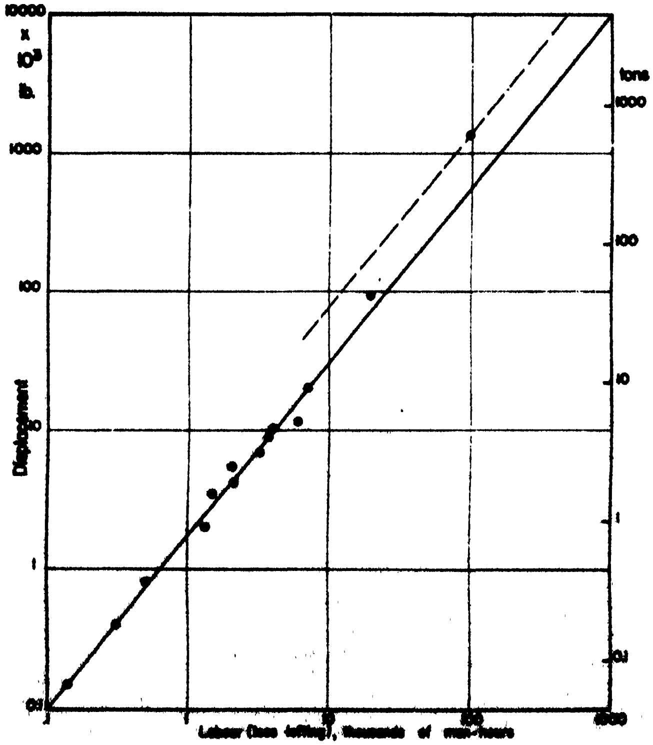


Fig. 304. Hamlin's diagram for preliminary estimation of building hours for yachts

Suitable costing and cost control will not of themselves ensure profitable or efficient working; but they are the means towards the application of such measures as can ensure it.

MR. F. E. POPPER (FAO): Commercial fishing is undertaken for economic gain, either individual or collective. The main object is to produce the most income at the least cost, or the greatest value of output with the least value of inputs. The allocation of the income between producer, trader and consumer, and within each group, is a separate problem, not predominantly economic.

Greater efficiency in the economic sense means lower cost per value unit produced. This can be brought about by saving on physical inputs, by making inputs cheaper, by increasing output for a given level of inputs, or by making the output more valuable. Such changes are often interdependent and unless there is lower cost per value unit produced, there is no economic gain.

Where the total output is severely limited, for instance by the biological nature of the fish stocks, increased output by one unit means reduced output by others. Capital and other costs incurred for this purpose do not produce corresponding output value over all and there is economic loss.

In the economic sense, production is not completed until the produce is consumed. The efficiency of the whole process of getting the fish from the sea to the consumer's table must be considered. Fishing is only one part of the process, and over-all efficiency depends on the others also.

PROF. H. VÖLKER (Austria): Benford's valuable paper shows how to arrive at the weight and cost of a fishing boat and how these values change if the main characteristics of the boat are altered. He is right in saying that thereby the task of the naval architect is at best only half done. It is not *any* cost of *any* boat which satisfies the requirements that is wanted, but the *most economic ship*.

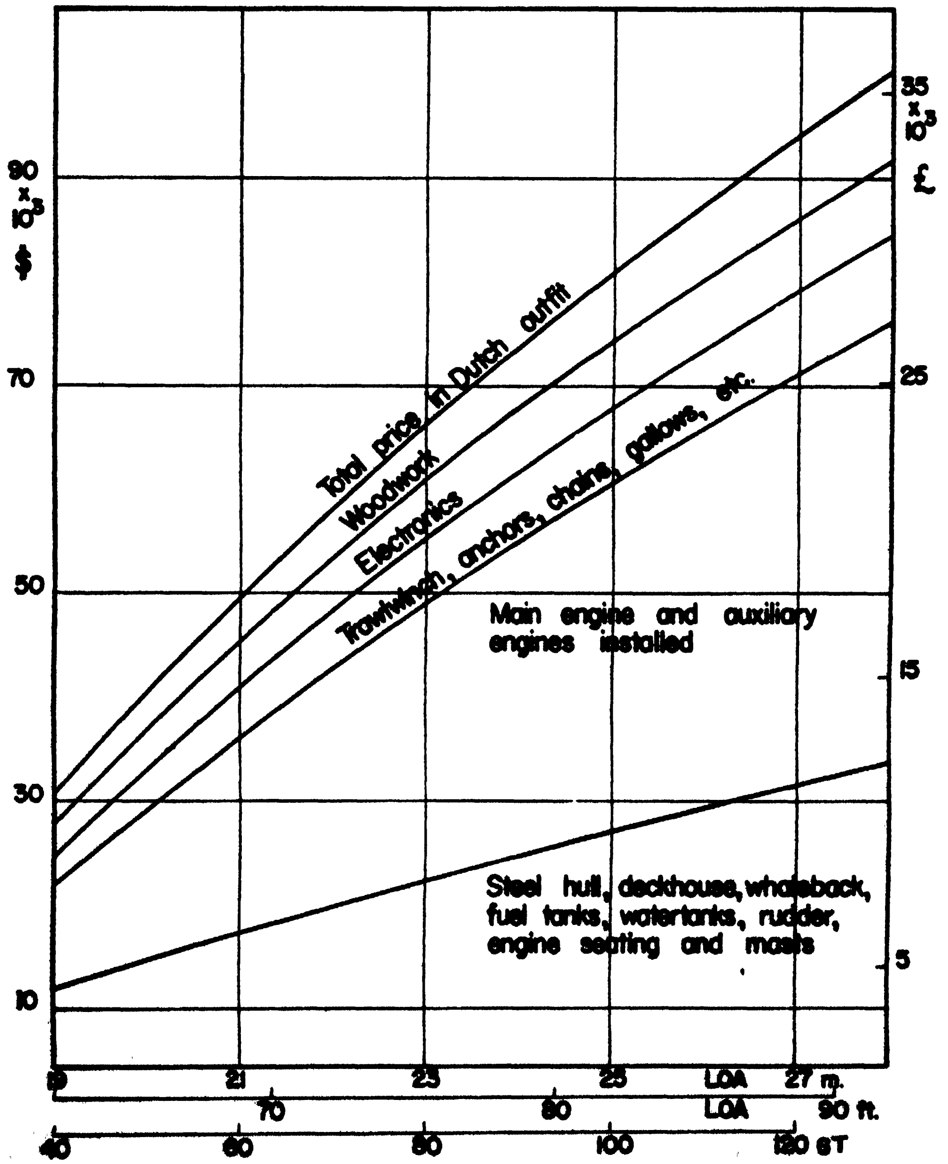


Fig. 305. Zwolsman's curves for costs of Dutch steel fishing

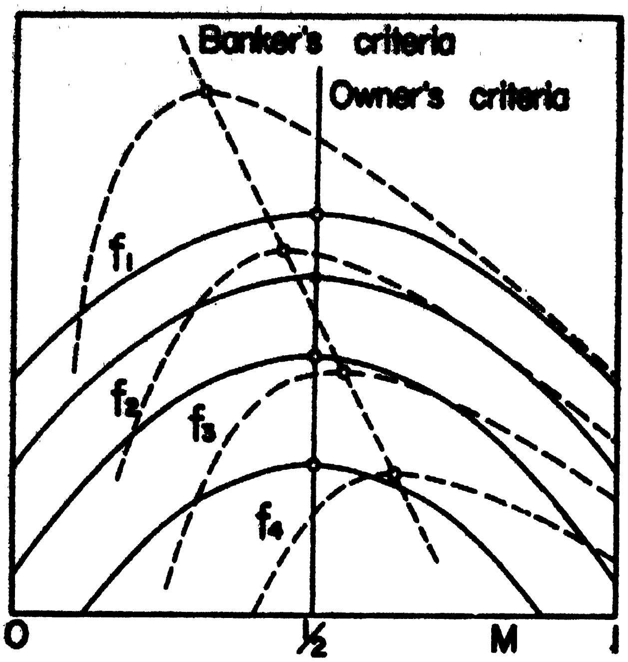


Fig. 306. Optimum design of vessels depending on what criteria of economy is taken into account

In his paper, and also in his earlier publications on tankers and on ore carriers, Benford says that the criterion for the most economic ship is the annual rate of return from investment. This means; receipts minus cost divided by capital or profit by capital. This may be termed the "banker's criterion", because it is practically the annual rate of interest accruing from the capital. It can be shown by simple mathematical calculations that the optimum value of the banker's criterion is largely influenced by income, i.e. in our case by the average price per unit of fish sold after landing. A boat constructed for a high fish price will, therefore, show other optimum characteristics, say of length or of speed, as compared with a boat built to sell fish at a low price.

Therefore, it seems better to follow Popper's definition who pointed out that the cost per unit produced is the only correct criterion. He calls the relation: annual receipts minus cost divided by receipts, or profit by receipt, the "economic efficiency". In analogy with the banker's criterion, the term "shipowner's criterion" could be used. It can be shown (fig. 306) that its optimum value is independent of income. The mathematical formulation of both criteria (Völker, 1959) reveals a fundamental difference between them. The application of the banker's criterion must lead to erroneous results if used for finding out the various characteristics of the most economic ship.

Prof. Harry Benford and Mr. Miklos Kossa (U.S.A.): The authors were pleased with the interest shown in their paper, and noted with considerable satisfaction the widespread geographical sources of the discussions.

H. C. Hanson has made a good case for simplified hull forms although Zwolsman, in his discussion, found less cause for optimism. Hanson's comments were particularly valuable in their practical counsel concerning single and double chine hull forms. One minor comment was suggested by his remarks on conical hull development: such a form is not confined to circular arcs; it is generated by a straight line between any fair line, such as a chine, and a focal point which may shift along the generating line. A surface designed in this way is developable; that is, it allows construction without recourse to furnacing. The transverse sections of such a form are frequently very nearly straight. When this is not true, the frames may be installed in straight sections by orienting them along the radial generating lines.

Proskie's discussion was particularly welcome in that it called attention to the valuable cost data available from the Department of Fisheries of Canada. The authors expressed their apologies for their regrettable oversight in this connection.

Hamlin's generosity in making available his man-hour curve for yachts was gratefully acknowledged. It was noted that his values showed reasonable agreement with those proposed in the paper, recognizing the basic differences between pleasure and commercial craft. Hamlin's views on the relative accuracy of curve versus detailed cost estimates were felt to be well worth noting. Such opinions, while not as yet widely accepted, were thought to be gaining ground.

Zwolsman's cost curves and practical discussion were received with pleasure since their inclusion added greatly to the value of the paper. His criticism of the author's estimate of the possible savings through duplication was noted. Benford (1957) showed that average costs per tanker levelled out at about 85 per cent. of the cost of a single tanker. Since design, lofting and other non-recurring costs are relatively more important in small craft, it was not felt that an average levelling-off figure of 80 per cent. was an unreasonable estimate for fishing craft. The exact figure would, of course, vary from yard to yard and, even in a given establishment, would be heavily influenced by relative complexity of design as well as other factors.

Hunter has cautioned against placing too much reliance on the cubic number as a tool in estimating weights and costs. The authors concurred that there were dangers in the use of this (or any other) parameter when comparing ships of unlike characteristics. Hunter was felt to be by no means alone in his dissatisfaction with the manner in which the authors grouped both hull and machinery items in certain instances. There was admittedly room for improvement in that respect but a universally agreed-upon solution was not held to be readily found.

Völker's comments were confined to a comparison of two differing views on the proper economic criterion applicable to ship design. The authors felt it best to withhold reply until the referred-to publication became available. The entire subject, while of interest, was of only minor significance in this particular paper.

O Meallain's remarks on the importance of cost control were well taken. The authors noted that accurate gauging of shipyard progress was exceedingly difficult and that the entire subject might be worth a paper at some future Congress.

In closing, the authors believed that the general tone of the discussions was one of endorsement of the main points of the paper. Most of the discussors generously contributed additional factual data which enhanced the value of the paper. All comments were most welcome.

MODEL TESTS OF SOME FISHING LAUNCHES

by

THOMAS C. GILLMER

During 1958 the Ship Model Towing Tank at the U.S. Naval Academy began model tests of small, light displacement fishing launches of similar dimensions to those used in the Maine Coast lobster and the Chesapeake Bay crab and oyster industries.

All models were approximately 4 ft. (1.22 m.) on the water-line. The tests were made up to a speed-length ratio $V/\sqrt{L}=1.45$ ($v/\sqrt{gL}=0.43$) The results were presented as: (1) horsepower versus speed in knots; (2) specific resistance versus speed-length ratio; (3) residual resistance coefficient versus speed-length ratio.

It is possible to conclude, provisionally, that the most advantageous hull forms are those with fine entrance angles combined with displacements distributed uniformly from amidships to the stern. To qualify the advantages of these features, the half entrance angle would appear to be optimum between 10° and 12°, with a prismatic coefficient of .65 to .70 resulting from a flat run from amidships to the transom. The powering would then be most advantageous in the speed-length ratio range of 1.1 to 1.4 ($v/\sqrt{gL}=0.33$ to 0.415), the speed range apparently most frequently used in practice.

ESSAIS DE MODÈLES DE QUELQUES BATEAUX DE PÊCHE NON-PONTÉS

En 1958, le Ship Model Towing Tank à l'Académie Navale des E.-U. a commencé des essais de modèle de petits bateaux de pêche non-pontés, de faible déplacement, de dimensions semblables à celles des bateaux utilisés par les industries du homard de la Côte du Maine et par celles des crabes et des huîtres de la baie de Chesapeake.

Tous les modéles mesuraient approximativement 4 pi. (1,22 m.) à la flottaison. On a fait les essais jusqu'à un rapport vitesse-longueur $V/\sqrt{L}=1,45$ ($v/\sqrt{gL}=0.43$) Les résultats ont été présentés comme suit: (1) puissance en c.v. en raison de la vitesse en noeuds; (2) résistance spécifique en raison du rapport vitesse-longueur; (3) coefficient de résistance résiduaire en raison du rapport vitesse-longueur.

Provisoirement, il est possible de conclure que les formes de coque les plus avantageuses sont celles comportant des façons de l'avant fines, combinées à des déplacements distribués uniformément du milieu du bateau à l'arrière. Pour obtenir les avantages de ces caractéristiques, le demi-angle d'acuité paraîtrait être optimum entre 10° et 12°, avec un coefficient prismatique de 0,65 à 0,70 ayant pour résultat des facons de l'arrière plates du milieu du bateau à l'arcasse. La mécanisation serait alors très avantageuse pour des rapports vitesse-longueur compris entre 1,1 et 1,4 ($v/\sqrt{gL}=0,33$ à 0,415) la gamme de vitesses étant apparemment celle utilisée dans la pratique.

ENSAYOS DE MODELOS DE ALGUNAS LANCHAS DE PESCA

Durante 1958, en el estanque de remolque de modelos de barcos de la Academia Naval de los E.U.A. se inició una serie de ensayos de modelos de lanchas de pesca pequeñas de poco desplazamiento, de dimensiones análogas a las empleadas por los pescadores de boganvante de la costa de Maine y por los de cangrejo de mar y ostras de la Bahía de Chesapeake.

Todos los modelos tenían unos 4 pies (1,22 m.) de eslora en la línea de flotación. Los ensayos se hicieron con una relación velocidad eslora $V/\sqrt{L}=1,45$ ($v/\sqrt{gL}=0,43$) Los resultados se presentaron como: (1) fuerza motriz con relación a la velocidad en nudos; (2) resistencia específica con relación a la velocidad-eslora; (3) coeficiente de resistencia residual con relación a la velocidad-eslora.

Provisionalmente se puede decir que las formas de casco más ventajosas son las que tienen ángulos de entrada finos junto con desplazamientos distribuídos uniformemente desde la medianía del barco hasta la popa. Para obtener las ventajas de estas características el semiángulo de entrada parece ser óptimo entre 10° y 12° con un coeficiente prismático de 0,65 a 0,70 resultante de un lanzamiento plano desda la medianía hasta el yugo. La mecanización resultaría entonces más ventajosa para las relaciones velocidad-eslora comprendidas entre 1,1 y 1,4 ($v/\sqrt{gL}=0,33$ a 0,415) la gama de velocidades al parecer más empleada en la práctica.

THE need to investigate small fishing launch design has been long felt in the U.S.A. but no attempt has ever been made to initiate any programme to improve the design.

The problem of model testing small commercial craft is primarily one of limited financial resources. Designers and builders, not to mention the owners, are in an unfavourable position to enlist the services of model testing tanks.

The model tanks in the U.S.A. are essentially of two kinds: (1) the large and elaborately equipped installations, either government owned or subsidised by large government contract work; (2) privately owned by large shipbuilding firms or educational institutions. With either, research and testing are costly. Testing schedules are planned months in advance. This type of model testing obscures any apparent benefits to the owner, builder or operator of small fishing boats. The lack of financial backing, indifference and prejudice beset any scientific investigation of fishing craft.

In the tests being discussed the motivation originated simultaneously with the editorial vision of a trade journal, the interest of several commercial craft designers and the availability of a small model testing tank. Because of lack of funds, the programme has been modest. The tests at present are limited to resistance.

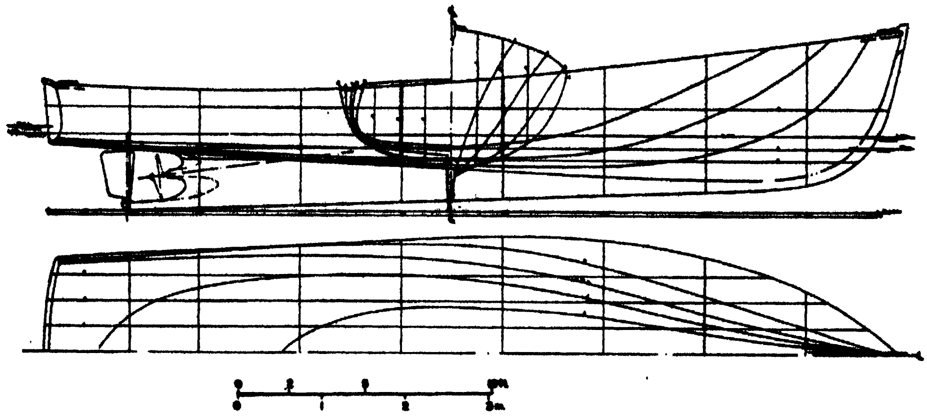


Fig. 311. Lines: Hull M-1, Main Coast lobster boat, LOA=34 ft. (10.36 m.), L=32 ft. 9 in. (9.98 m.), Beam= 9 ft. 1 in. (2.77 m), Draught=3 ft. (0.914 m.), Displacement=4.15 tons, Prismatic coefficient=0.662

However, the studies show clearly the dangers in over-powering small commercial craft—the over-powered boats result only in higher fish costs. The paper is a beginning, and is a limited attempt to provide information on typical existing boats, with some practical recommendations.

Facilities and apparatus

The Ship Model Towing Tank at the U.S. Naval Academy is small and of the gravity powered type. The size is 85 ft. (26 m.) long, 6 ft. (1.8 m.) wide and 4 ft. (1.2 m.) deep. It is limited to normal resistance tests, and to models between 3.5 and 6 ft. (1.07 to 1.83 m.) in length depending upon their fineness.

Towing is by an accurately calibrated weight drive system. The towing force is pre-established and the speed determined by instruments during the run. The primary advantages of the gravity tank are its small staff, the small models permit frequent test runs, all resulting in economical testing procedures. It can be argued that tests in a gravity powered tank are less precise than those in the carriage type. This, however, is only true where the model scale is 1/50 or less instead of 1/8 as it was in the tests discussed in this paper. The most important instrument in a gravity tank is the device used to measure speed. The towing force is simply determined by the weights. The speed-measuring instrument is an electronic counter, continuously showing any deviations, either acceleration or deceleration. It is motivated by a photo-cell impulse originating in one of the towing wheels. The "Eput" meter, as the electronic counter is called, gives direct readings at one-second intervals to the nearest one-thousandth of a knot.

Models tested

The selection of the models was initiated in 1958 through the good offices of Mr. John Gardner, Technical Editor of "Maine Coast Fisherman", and Mr. Howard I. Chapelle, Naval Architect and Curator of Transportation, U.S. National Museum. Mr. Phillip Bolger, Naval Architect of Gloucester, Mass., was helpful in supplying take-off lines of Maine fishing boats, and increasing

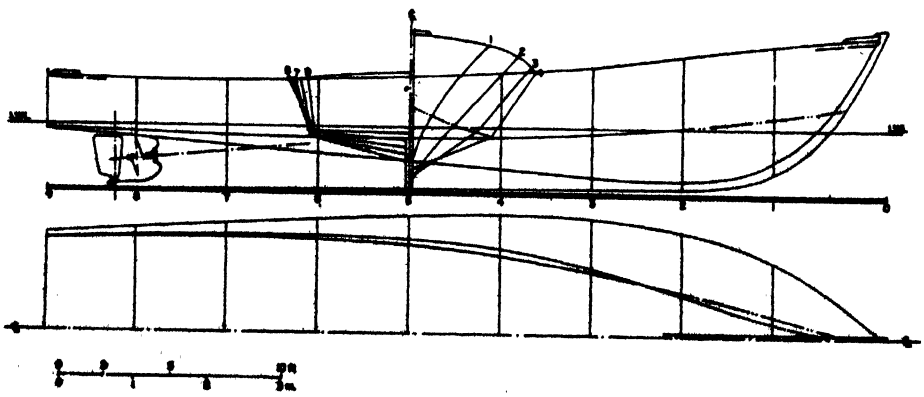


Fig. 312. Lines: Hull M-2, Maine Coast lobster boat, V-bottom type, LOA=37 ft. (11.28 m.), L=34 ft. 5 in. (10.49 m.), Beam=11 ft. (3.35 m.), Draught=3 ft. (0.914 m.), Displacement=5.3 tons, Prismatic coefficient=0.589

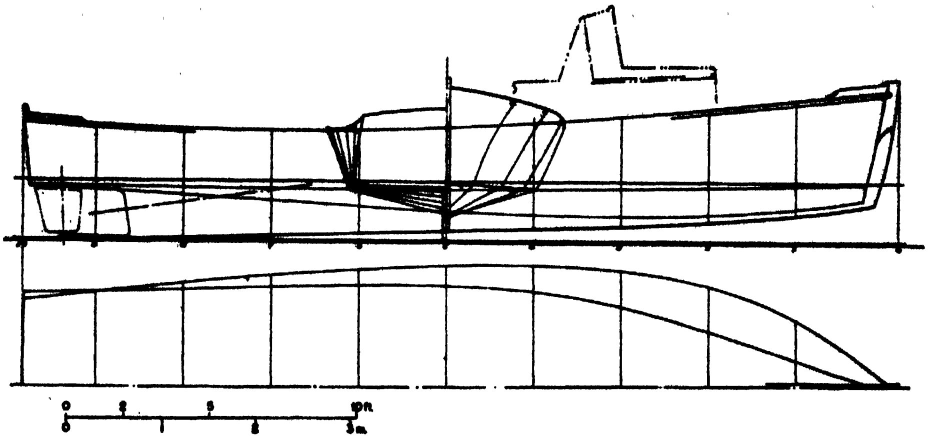


Fig. 313. Lines: Hull C-1, Chesapeake crabbing launch, LOA=30 ft. (9.14 m.), L=29 ft. 1 in. (8.86 m.), Beam=8 ft. 2 in., (2.49 m.), Draught=2 ft. (0.61 m.), Displacement=3.17 tons, Prismatic coefficient=0.754

interest and co-operation are being shown by such reputable commercial fishing craft builders as Hodgdon Brothers, Inc., of E. Boothbay, Maine.

It was decided that the models must be of boats typical of regional traditions and characteristic of their type. They were to have similar coefficients, comparative power and speed ranges and similar capacity, all regardless of locality of origin. Variations in hull form for comparative data would be in reference to the basic models.

Four models were chosen. The first, M-1, was a 34 ft. (10.36 m.) launch for lobstering, built in Portland, Maine, in 1946, "one of several to the same moulds", according to her builder. The naval architect who took off her lines reported that she was powered with a 6-cylinder automobile engine of about 105 SHP, and "made a clean natural drift, but not fast, say 12 knots".

The forward sections show a flare which does not settle into tumble home until well abaft of amidships, as shown in fig. 311. The bilges are gentle to almost slack, while the run is absolutely flat at an angle of 3.5° from amidship aft. There is a fine entrance with a half angle of 10.5°, and only a very slight hollow accounting for the slack sections carrying well aft. The dimensions are 34 ft. (10.36 m.) LOA, 32 ft. 9 in. (9.98 m.) length in waterline, 9 ft. 1 in. (2.77 m.) extreme beam, 8 ft. 5 in. (2.58 m.) beam (WL), 3 ft. (0.914 m.) draught at heel of skeg. The displacement to the waterline is 9,140 lb. (4.15 ton).

The second model, M-2, is considered as a fairly recent design modification among the Atlantic Coast fishing boats. This has a V-bottom, hard chine hull form. The lines, fig. 312, show a powerful hull with large freeboard, large flare and raking stem. It is, in terms of displacement, the largest of the boats tested. Her dimensions are: 37 ft. (11.28 m.) LOA, 34 ft. 5 in. (10.49 m.) waterline, 11 ft. (3.35 m.) beam, 3 ft. (0.914 m.) draught at heel of skeg. Her displacement is 11,800 lb. (5.35 ton) to the waterline.

The third model, C-1, is the Chesapeake boat which is to some degree less regional but of a V-bottom form known locally as a "deadrise" type. Probably the most typical boat of this design is a square stern "deadrise"

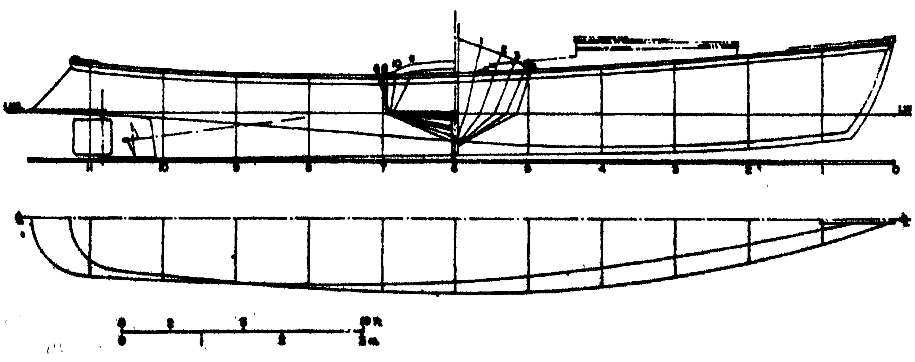


Fig. 314. Lines: Hull C-2, Chesapeake crabbing launch, Hooper Island boat. LOA=35 ft. 6 in. (10.85 m.), L=34 ft. 7 in. (10.55 m.), Beam=6 ft. 5in. (1.95 m.), Displacement=2.15 tons, Prismatic coefficient=0.575

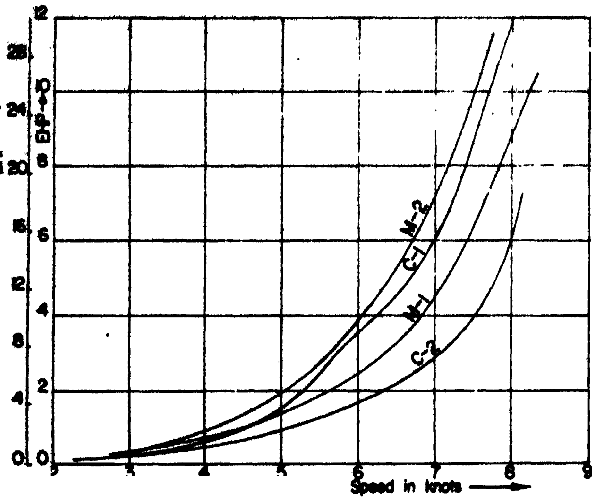


Fig. 315. EHP and BHP versus speed of hulls (assumed η_p = 40 per cent.) plotted in speed ranges for displacement hulls

crabbing launch of Cambridge, Maryland (lines by H. I. Chapelle, 1955). It has a typical cross-planked bottom with continuous chine of very little compound curvature which lies below the waterline its entire length, as shown in fig. 313. The underwater sections are straight; the run is flat from amidships aft at an angle of 3.25°. The entrance at the waterline is straight with no hollow and with a half angle of 18°. The dimensions of this boat are 30 ft. (9.14 m.) LOA, 29 ft. 1 in. (8.86 m.) length waterline, 8 ft. 2 in. (2.49 m.) extreme beam, 6 ft. 10 in. (2.08 m.) beam (WL), 2 ft. (0.61 m.) draught at heel of skeg. The displacement is 6,990 lb. (3.17 ton).

The fourth model, C-2, also of the Chesapeake design is a crabbing launch of similar dimensions but with rounded stern and more deadrise. It has a finer hull but greater length-to-beam ratio. Her stern and deadrise make her typical of the "Hooper Island" boats. While

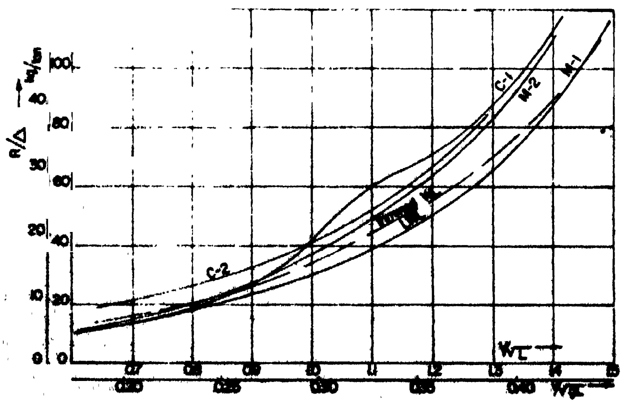


Fig. 316. Specific resistance versus speed-length ratios (showing for model M-1 an additional resistance curve for a normal trimmed waterline)

the forward-raking, "tub" stern of these boats makes them easily recognisable, their underwater form is also unique and contributes to a certain hydro-dynamic superiority that will be noted in the test results. The boat is: 35 ft. 6 in. (10.85 m.) LOA, 34 ft. 7 in. (10.55 m.) length waterline, 6 ft. 5 in. (1.95 m.) beam, and 2 ft. (0.61 m.) draught at heel of the skeg. The displacement is 4,740 lb. (2.15 ton). It will be noted from fig. 314 and the dimensions that she is smaller in terms of capacity than the C-1 and M-1 models, although slightly longer. The bottom shows a distinct hollow or inverted curvature in the run, tapering off at the waterline at the after end. Her chine lies on the designed waterline for the entire length. The half angle of entrance on the waterline is 11.5°. While there is still a substantial number of this type of boat in use in the Chesapeake Bay area, the type has been abandoned by the builders. This is perhaps unfortunate but is undoubtedly due to the availability of much higher

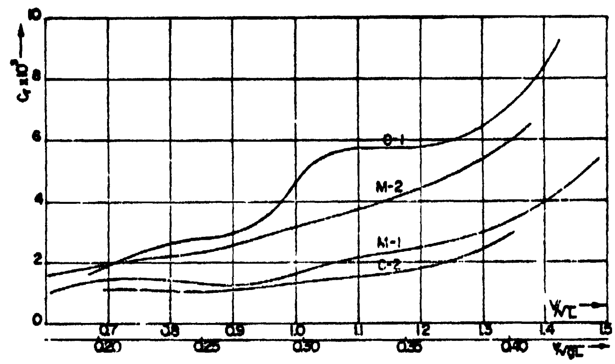


Fig. 317. Residual resistance coefficient versus speed-length ratio. This plot exhibits the primary cause for the difference in resistance characteristics

powered engines and the demands by fishermen for greater speed—greater speed regardless of fuel consumption.

All the boats operate in coastal or partially protected waters, within approximately 50 miles of the base harbour. The catch does not require a large capacity because it seldom consists of more than several hundred pounds of lobsters or crabs. Hence the hulls generally are of light displacement with attempts at semi-planing forms. Because of their all-season usage, they are, like most fishing craft, of rugged construction. The Maine boats are generally planked with native cedar over steam-bent oak frames. The Chesapeake boats are planked in cedar, cypress or pine, and have sawn frames of oak or yellow pine.

While speed in both lobster and crab and oyster boats is desirable, it is more important that the boats are economical, fairly dry, and sea-kindly. A very few, authoritatively estimated at about 0.7 per cent. Maine boats make 20 knots. The remainder, both in Maine and the Chesapeake, operate at 10 knots or less.

The engines used in both areas are generally automobile conversions and very seldom engines built purely for marine service. This practice, following the automobile trend, led to the installation of engines of progressively higher horse power. This in turn over the two last decades has led to boats of greater beam and broader, flatter sterns, essentially a semi-planing type. The economical operation of such boats is dubious. In analysing the results of the tests, the developments above should be kept in mind.

Nature of the model tests

The Maine lobster boat models will be referred to as Models M-1 and M-2, the Chesapeake square-sterned model as C-1, and the Chesapeake Hooper Island boat as C-2. They were all constructed of soft pine and finished to a gloss surface.

All models were built to approximately $^1/_8$ scale making them 4 ft. (1.22 m.) on the waterline.

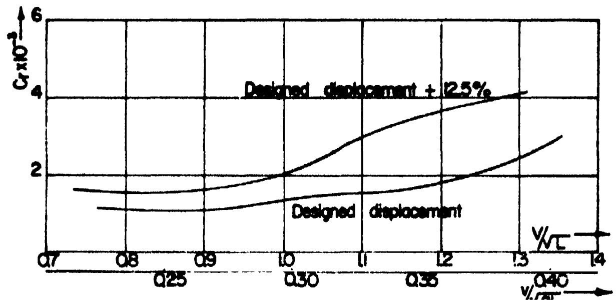


Fig. 318. Residuary resistance coefficient of model C-2 at designed displacement and at displacement increased by 12.5 per cent

The primary tests were for pure resistance in order to study the powering problem. The results are plotted both in terms of total effective horsepower versus speed in knots, and in terms of specific resistance and residual resistance coefficients, against speed-length ratio. The last presentation is thought to be significant, inasmuch as frictional resistance is basically independent of form, and the results of form variation can be more clearly studied by the residual resistance coefficients. The upper range of speed, being approximately at a speed-length ratio $V/\sqrt{L}$ of 1.5 ($v/\sqrt{gL}=0.45$), is well within the limits of customary operating speeds, and, indeed, beyond the capacity of many of the boats.

Test results

On the basis of the test data, generally conclusive results cannot be expected. However, the results can be of definite significance. They are also subject to a limited amount of extrapolation and in several instances will indicate the direction for improvement.

Three basic plots believed to be most understandable to the greatest number of readers, are presented: fig. 315, EHP and SHP versus speed in knots; fig. 316, specific

Fig. 319. Model M-1 during towing run. Model speed=2.845 knots, speed-length ratio=1.42 ($v/\sqrt{gL}=0.422$)

resistance versus speed-length ratio; and fig. 317, residual resistance coefficient versus speed-length ratio.

Fig. 315. *Horsepower versus speed.* This comparison is the least significant, and it is perhaps the most subject to misinterpretation, because of the direct horsepower values, both EHP and SHP. The propulsive coefficient relating SHP to EHP was deliberately chosen on the conservative side, being 40 per cent. Such poor efficiency is by no means too pessimistic, and in many cases of poorly selected propellers is considerably lower. The curves are for the full scale boats; the Maine boats, being somewhat heavier, are at low speeds, up to 5 knots, at a very slight disadvantage. Above 5 knots, however, model M-1 is considerably better than M-2, with model C-2 showing the lowest power requirements and consequently, boat for boat, the highest hydrodynamic efficiency. All curves show a characteristic steepness at higher speeds, indicating an excessive engine load at speeds above 8 knots.

Fig. 316. *Specific resistance versus speed-length ratio.* The specific resistance (R/Δ), resistance per ton of displacement, in relation to the speed-length ratio,

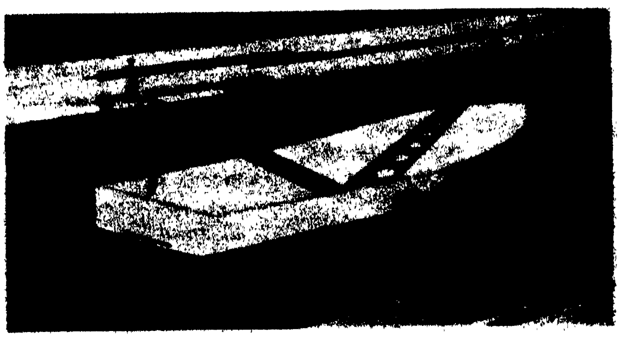


Fig. 320. Model M-2 during towing run. Model speed=2.232 knots, speed-length ratio=1.12 ($v/\sqrt{gL}=0.333$)

Fig. 321. Model C-1 during towing run. Model speed=2.646 knots, speed-length ratio=1.38 ($v/\sqrt{gL}$=0.410)

provides a more realistic criterion of hydrodynamic performance.

Model M-1 shows the lowest resistance or power requirement throughout the complete displacement speed range. Model C-2, which looked so well on a boat-to-boat basis, is relegated to a position more indicative of its ability among boats of equal weight. A resistance "hump" in the curve for the Chesapeake model, C-1, between speed-length ratios of 1.0 to 1.2 ($v/\sqrt{gL}$= 0.3 to 0.36) or about 6 knots, is discernible.

The specific resistance might seem excessive compared with larger vessels. A value of 20 lb./ton (9.07 kg./ton) at $V/\sqrt{L}=1.0$ ($v/\sqrt{gL}=0.30$) might be expected in a well-designed, displacement type of yacht or trawler. However, with the broad flat runs and wide immersed transoms in smaller planing or semi-planing craft the values can go to ten times this amount. Actually, the tested models might, in a broad sense, be described as semi-planing forms and as such the values are within acceptable limits. The Chesapeake model, C-1, having the maximum resistance of 110 lb./ton (49.9 kg./ton) at $v/\sqrt{L}=1.4$ ($v/\sqrt{gL}=0.415$) could be described as normal or moderately good, and that of the Maine hull, M-1, of 80 lb./ton (36.2 kg./ton) at the same speed, as very good.

Fig. 317. *Residual resistance coefficient versus speed-length ratio.* The frictional coefficients for all hulls (not shown) were naturally in very close agreement. Residual resistance, of which the wave resistance is the greater portion, is normally, in comparative tests of similar size boats, the significant factor. The photographs of the models at similar speeds, fig. 319 to 322, show clearly the different character of the waves generated by the models. The high values of C-1 and the "lumpy" character of its curve indicate a less efficient hydrodynamic form.

It is apparent that model C-1, at speed-length ratios of 1.0 to 1.2 ($v/\sqrt{gL}$=0.3 to 0.36) has a relatively poor operating range. There seem to be no comparable critical speeds for the other models. The values of C_r for model C-1 appear to be higher than normally expected for boats of this type and size. Model C-2 is the best throughout the range and its curve is uniform.

No firm and general conclusions on the basis of these four models only can be made. However, it is at once apparent that the round-bottom hull of the Maine boat, M-1, is hydrodynamically superior. This would seem to be true irrespective of the difference in dimensions, which was not great.

The C_r versus $V/\sqrt{L}$ for model C-1 indicates a fairly early build-up of waves at low speeds. The normal cause of such phenomena is the form of entrance at the bow. The half entrance angle at the waterline of C-1 is 18°. This angle for model M-1 is 10°. While this difference is considerable and significant it is not by itself the entire cause. Unless a fine entrance angle is combined with easy, gentle curvature, without "shoulder", the form cannot be hydrodynamically efficient. An entrance that is excessively sharp will cause weak bilges with resulting poor stability and capacity. Model M-1 borders on the minimum entrance angle without loss of other very important characteristics. The low forward chines in C-1, because of the Chesapeake bottom construction, would seem to be a matter for serious study in any effort to improve these boats. However, there should be some room for variation in the entrance form in Chesapeake boats.

Comparing the two Chesapeake models, C-1 and C-2, the superiority of the latter is apparent in all criteria. The entrance of C-2 is considerably finer than C-1 and the chine "knuckle" becomes negligible near the stem. The chine in this model also is on the designed waterline throughout its length. The good results of C-2 in fig. 317 is due also to the slight concavity or hollow "run" of the bottom, flattening out to tangency with the waterline at the stern. The comparatively light displacement and moderate beam also contribute to the low power requirements of this hull at the designed waterline. The additional plot, fig. 318, shows model C-2 in the waterline condition and at an increased displacement of 12.5 per cent. or 600 lb. (272 kg.), and it indicates a considerable increase in residual resistance. This is caused largely by increased eddy resistance due to submergence of the type of stern. The admirable hydrodynamic characteristics and promise of low power of this boat are limited to a very narrow range of waterlines or loads. Her bottom

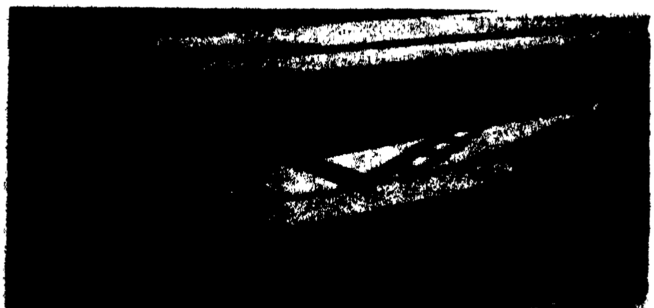


Fig. 322. Model C-2 during towing run. Model speed=2.655 knots, speed-length ratio=1.27 ($v/\sqrt{gL}$=0.378)

and chine design, however, should not be overlooked for additional study.

The V-bottom Maine boat M-2 has the highest power requirements in the boat-to-boat comparison in fig. 315. M-2 is the largest and heaviest, being 2.5 times heavier than the Chesapeake Hooper Island C-2 boat. The beam and wetted surface is also considerably greater than the other models. These features indicate, of course, greater capacity. The non-dimensional comparisons in fig. 316 and 317 further reveal the character of M-2. The absence of any lumpiness in the curves indicates little variation in operating conditions. The clear superiority of M-2 over C-1 in fig. 317 indicates an improved chine form and the advantage of a fine entrance combined with a faired out and lifted forward chine.

The speed of the models did not approach speed-length ratios associated with dynamic support or planing. The upper limits of the speed-length ratios were 1.45 ($v/\sqrt{gL}=0.43$). Some tests were made as high as $V/\sqrt{L}=1.65$ ($v/\sqrt{gL}=0.49$) where, in model M-1, a change in trim by the stern began to be apparent. Partial dynamic support could be expected to begin in this range.

The "steepness" of the resistance curves in fig. 315 and 316 indicates that all hulls would demand excessively high power to reach partial planing conditions. The operational maximum speed claimed for the Maine boat, M-1, was in the neighbourhood of 12 knots. This is at $V/\sqrt{L}=2.09$ ($v/\sqrt{gL}=0.62$) in the partial planing range. It is estimated that at this speed the power would be 2.6 times that required for 8 knots, as shown in fig. 315. This means an actual engine power output of approximately 60 h.p., whereas for 8 knots only 23 h.p. is required.

It has been recognised traditionally that small entrance angles are of considerable importance in obtaining favourable powering characteristics. However, in order to combine a small entrance angle with ample displacement it is either necessary to widen abruptly to a full hull with hollow waterlines or carry the fullness gradually towards the stern. The distribution of displacement towards the stern, combined with a small entrance angle, would appear to be best solved by hull M-1 when compared with C-2. These two hulls both have fine entrances but the prismatic coefficients (M-1, $\varphi=0.66$ and C-2, $\varphi=0.57$) show that the displacement of M-1 is distributed toward the stern to a substantially greater extent. The evidence of the advantage of this is apparent in the fig. 316 curves, and the values compared in table 85.

Hull M-1 when trimmed by the stern and with 10 per cent. higher displacement, as indicated on fig. 311, shows a slightly increased specific power requirement at moderate speeds as shown in fig. 316. At higher speeds the specific resistance is no greater than at her designed waterline.

TABLE 85

Comparative values of entrance angles, prismatic coefficients and specific resistances for the various models at $V/\sqrt{L}=1.3$

Model	$\frac{1}{2}\alpha_e$	φ	R/Δ
C-1	18°	0.75	88
C-2	11–1/2°	0.57	86
M-1	10–1/2°	0.66	65
M-2	14°	0.59	84

These general conclusions are felt to be justified, but as the tests continue, attention will undoubtedly be given to specific advantageous hull forms.

These types of boats work in a transitory hydrodynamic area. They are for the most part operating as displacement hulls, yet they often have adequate power to be forced into a semi-planing condition. The requirements in these two situations are incompatible. It would seem then that the most suitable hull type is that one whose specific resistance is lowest at the upper speeds of the displacement condition. It is for such a hull that the present investigation is primarily directed. At this stage, hull M-1 is clearly superior, while M-2 shows considerable promise with only slight modifications in prismatic coefficient and entrance angle.

MODEL TESTS OF SMALL SIMPLIFIED BOATS

by

YOSHINORI OTSU, NOBUTATSU YOKOYAMA and TSUTOMU KOBAYASHI

Traditional Japanese coastal fishing boats are simple and inexpensive to construct.
Results of model tests indicate a problem on selection of L/B and deadrise angle. Resistance and propulsive efficiency is comparable to those of ordinary round-bottom boats in spite of the angular shaped hull with hard chines.

ESSAIS DE MODÈLES DE PETIT BATEAUX SIMPLIFIES

Les bateaux de pêche côtiers traditionnels japonais sont de construction simple et peu coûteuse.
Les résultats d'essais de modèles indiquent l'existence d'un problème sur le choix de L/B et du relevé des varangues. La résistance et le rendement propulsifs sont comparables à ceux de bateaux ordinaires à fond rond, malgré la coque de forme anguleuse avec des bouchains vifs.

ENSAYOS DE MODELOS DE BARCOS PEQUENOS SIMPLIFICADOS

Las embarcaciones tradicionales japonesas dedicadas a la pesca costera son sencillas y baratas de construir.
Los resultados de los ensayos de modelos indican que existe un problema en la selección de L/B y del ángulo de la astilla muerta. La resistencia y el rendimiento del propulsor son comparables a los de las embarcaciones corrientes de fondo redondo, a pesar de la forma angular del casco y de las aristas agudas.

ALTHOUGH there is a tremendous number of small fishing craft along the coast of Japan, they have rarely been model tested.

Here a typical example, the Yamato type, of which the scantlings are described on page 146, is analysed from the resistance point of view. The results prove to be quite good. It is hoped that more attention will be paid to this simple craft, which could be used in many underdeveloped areas.

Model tests

The craft has a sharp entrance, straight frames, rather high deadrise and hard chine. Tests were undertaken with 6.5 ft. (2 m.) models, whose parent is the *Akatsuki*. The particulars of the parent model vary: $\varphi=0.57$ to 0.66, $\beta=0.68$ to 0.73, $\nabla/(L/10)^3=4.6$ to 5.8, $B/T=3.6$ to 4.2, due to the different displacements and trims tested, and $v/\sqrt{gL}$ is from 0.14 to 0.48. Four models were developed as outlined in fig. 323. Two models have a deadrise different from the parent, and the other two have the same deadrise but different beams. Thus a series of LBP/B=4, 5, 6 and of $\beta=0.7$, 0.8, 0.9 are obtained. The lines of the models are shown in fig. 324.

The influence of different LBP/B — and β for a specific displacement is presented in fig. 325 and 326, together with the influence of trimming. It is apparent that larger LBP/B gives smaller EHP in speeds higher than 7.5 knots when the displacement is fixed. The minimum EHP is obtained in the even keel condition. The 12° deadrise of the parent model gives the maximum EHP. These

TABLE 86

Hull form parameters of the series models

	Δ	LBP/B	φ	B/T	β
Fig. 325	6.2	3.92	0.615	5.29	0.619
	6.2	4.87	0.606	3.97	0.705
	6.2	5.81	0.631	3.07	0.736
Fig. 326	6.4	4.87	0.667	3.87	0.650
	6.4	4.87	0.609	3.90	0.712
	6.4	4.87	0.610	4.30	0.760

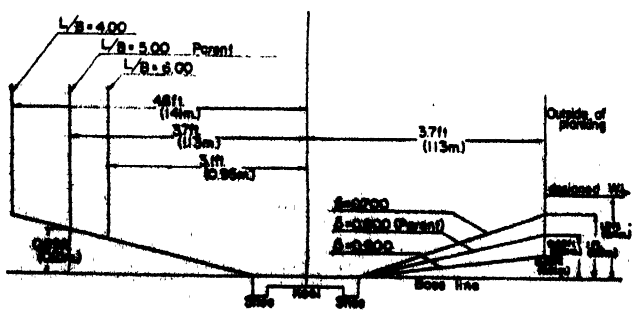


Fig. 323. Development of a model series based on the Japanese Yamato type boat Akatsuki. Sections at ordinate No. 4

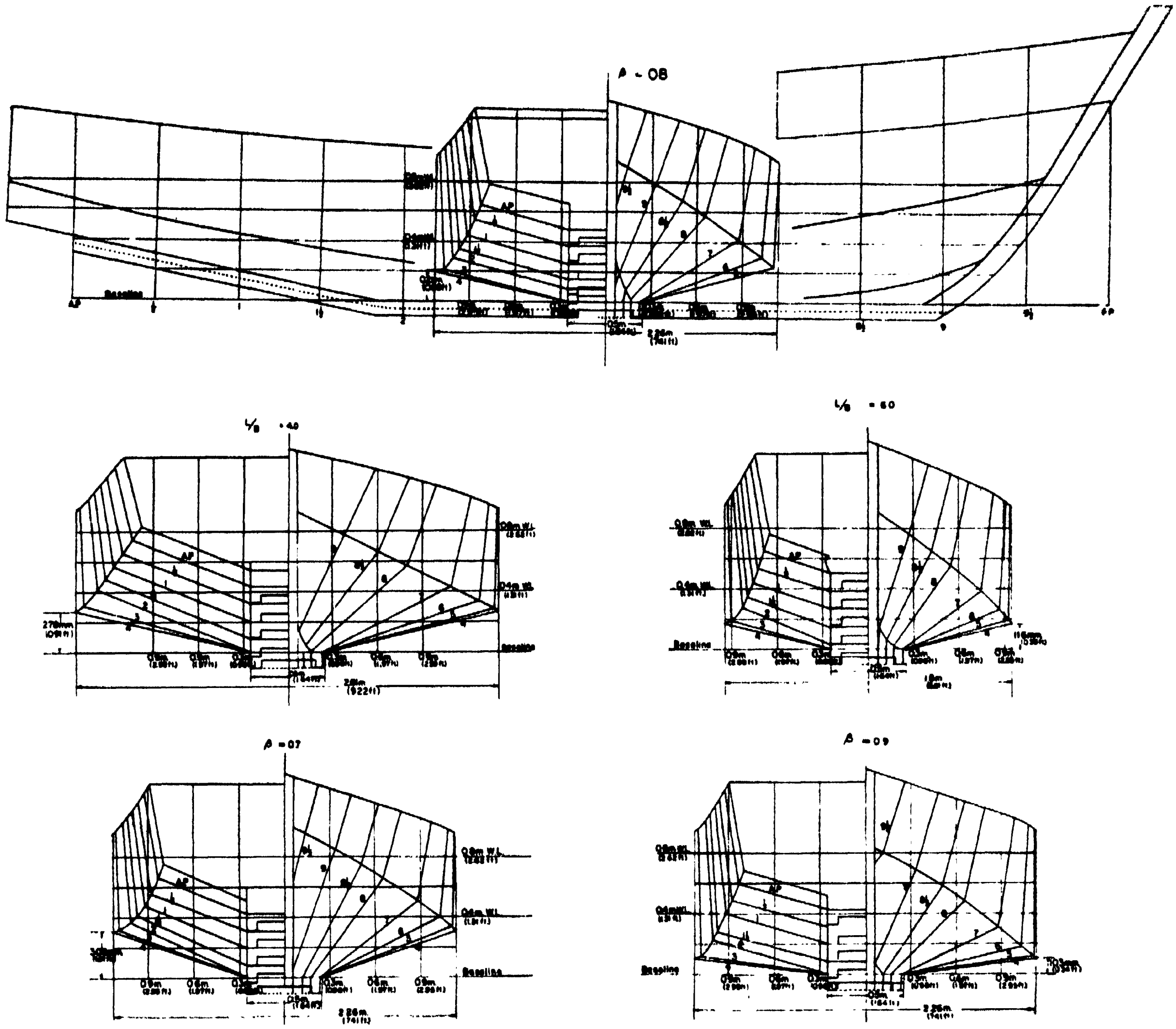


Fig. 324. Lines of the Akatsuki *model family*

results must also be analysed, considering the combined effect of the coefficients φ, B/T, LBP/B and β, shown in table 86.

The effect of B/T on the results in fig. 325 might be larger than those of φ and β especially above the Froude number of 0.4 or 8 knots. The residual resistance coefficient C_r versus B/T is shown in fig. 327, indicating an increase of C_r by increase of β.

Fig. 326 is somewhat difficult to understand. As the gain by B/T is contrary to the benefit of φ, the convexity of the EHP curves plotted on the base of the deadrise angle is probably the result of a disturbed flow around or leaving the chine than the combined effect of φ, B/T and β. The independent effects could be studied by making many variations of the model. Most of such variations, however, are not always practical, because the lines may become so distorted that planking might become difficult and the structural simplicity might be lost. So further model tests were not made.

Full-scale test

The 36 ft. (11 m.) experimental boat, *Akatsuki*, was tested seven different times at sea. It was fitted with a torsion-and-thrust meter. The particulars of the boat and one of the test conditions are given in table 87. Some of the results are shown in fig. 328.

The propulsion efficiency is less than that of large steel ships, and varies with minor changes of the sea which do not affect larger vessels. The efficiency is in the range of 30 to 50 per cent. A test in a rough sea, Beaufort scale 6, showed that about 20 per cent. more power was required than in a calm sea. The test also showed that this type adapted itself to the waves and was unexpectedly seaworthy.

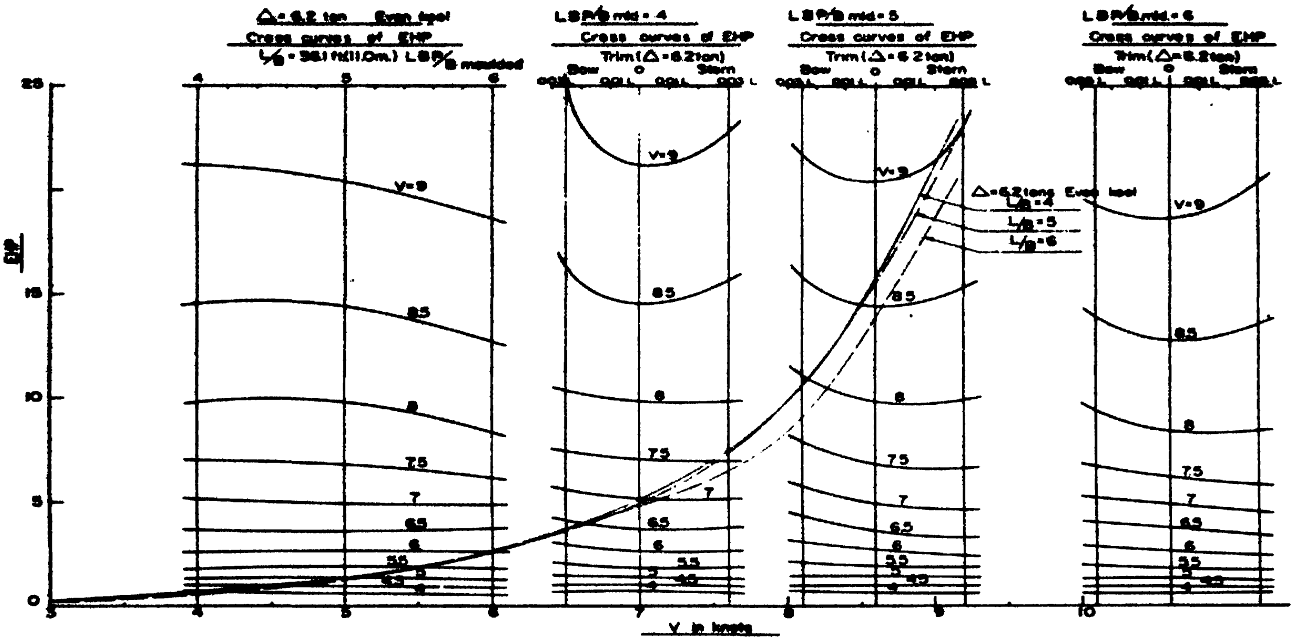


Fig. 325. The effect of LBP/B and trim on EHP for the Akatsuki *model series*

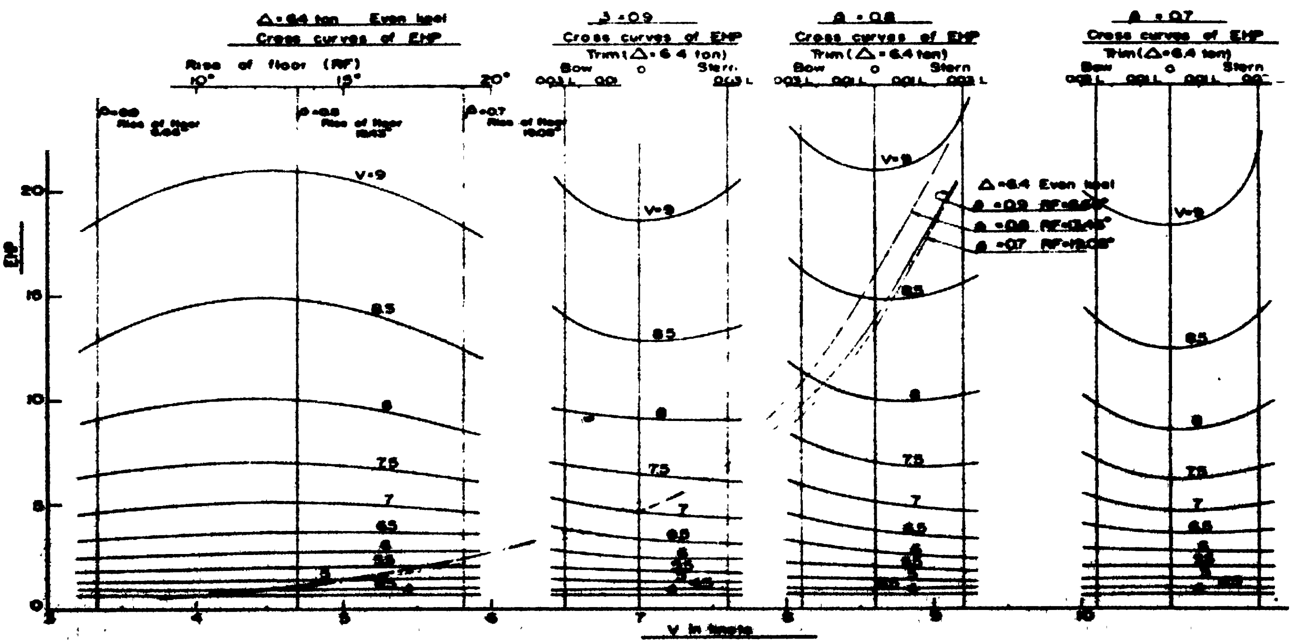


Fig. 326. The effect of rise of floor and trim on EHP for the Akatsuki *model series*

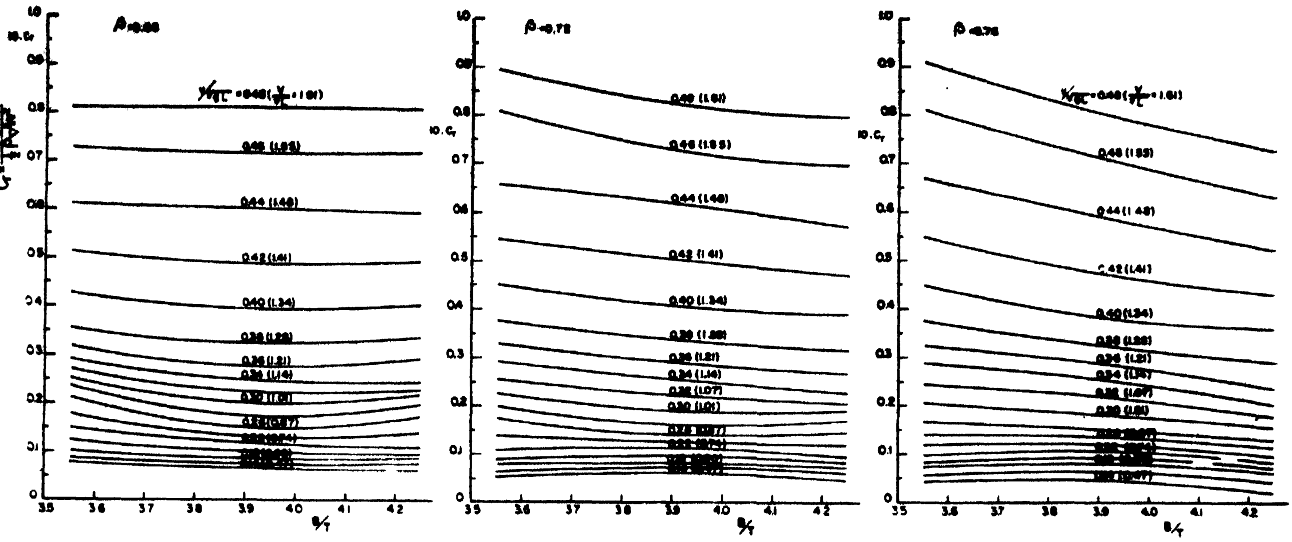


Fig. 327. Residual resistance coefficient of a model series

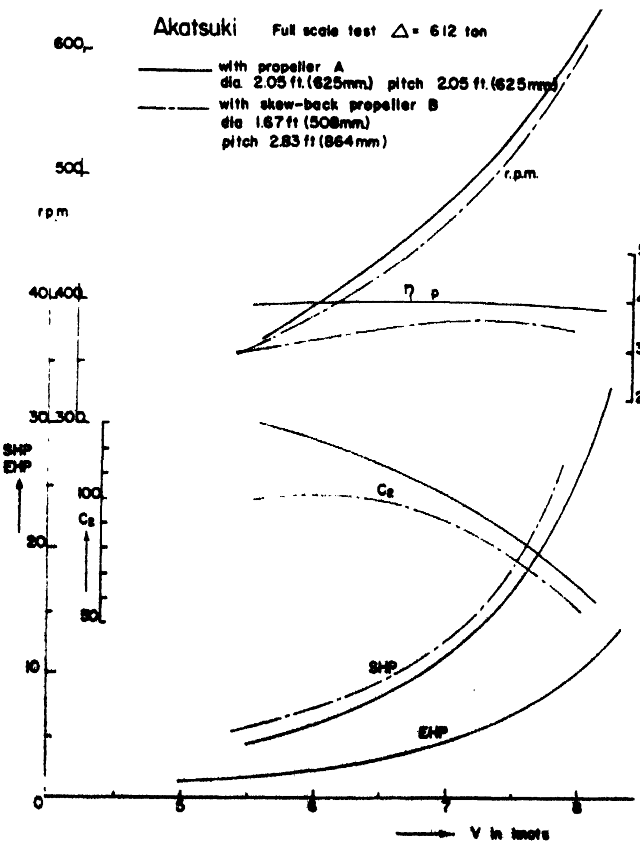


Fig. 328. Trial result of Akatsuki

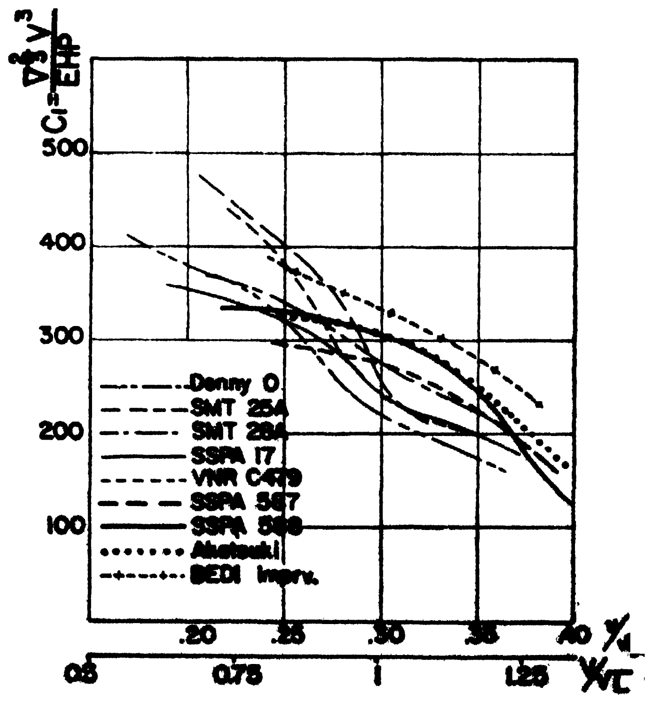


Fig. 329. Comparison of Akatsuki and different boats

TABLE 87

Main particulars of *Akatsuki* and test conditions

Ship		*Sea condition*	
L	36.1 ft. (11.0 m.)	Weather	Fair
B	7.2 ft. (2.2 m.)	Sea	Calm
D	2.9 ft. (0.9 m.)	Temperature	64.4°F (18°C)
Power	25 h.p.	Wind	N. 10 ft./sec. (3.1 m./sec.)
r.p.m. of engine	900	Water temp.	59.0°F (15°C)
r.p.m. of shaft	558	Tide	No current
Designed speed	9 knots	Specific gravity	1.020
Standard propeller A		*Ship condition*	
D	24.6 in. (625 mm.)	Bottom	Clean
P	24.6 in. (625 mm.)	Draught mean	1.76 ft. (0.537 m.)
A_d	164 sq. in. (1,057 sq. cm.)	Trim	1.34 ft. (0.407 m.) by stern
No. of blades	3	Displacement	6.12 tons
Rake	0	β	0.794
Material	Manganese bronze	φ	0.715

Comparison with similar sized boats

The construction of the boat somewhat resembles the Long Island Sharpie launch and the New Jersey Garvey in U.S.A., and the hull shape can be considered to be in between the Sharpie or Garvey and the Virginian Bateau or Hatteras boat described by Chapelle (1955). The type does not have a skeg and would have little directional stability if not actually being controlled by the extraordinarily long plough-shaped rudder, which is hung deep in the water.

In fig. 329 the Admiralty constant curves are shown in dotted lines together with those of Pakistani and European fishing boats, as was done by Traung (1955).

The towing resistance of the type is compared with the Hora and the Bedi boats of Pakistan; the test results of SSPA 587-A and 588-A (Traung, 1955) have been calculated to the same length and displacement as *Akatsuki* and are shown in fig. 330. It is interesting to note that the *Akatsuki* has almost the same EHP below 7 knots as the model of the original Bedi (Froude No. 0.35), disregarding the strict comparability between test conditions.

Mention should be made here of the low cost of the small Japanese craft which has a comparatively good performance in spite of its simplified construction. It is recommended that naval architects should give further consideration to this type of vessel which is used by very many poor fishermen.

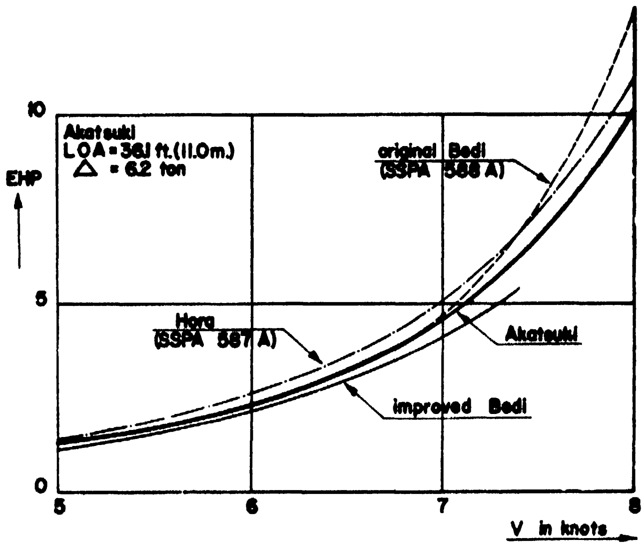


Fig. 330. Comparison of Akatsuki *and Pakistan boat*

AN ADVANCED HULL AND PROPELLER DESIGN

by

J. THOMAS TOTHILL

Model tests of recent fishing boat designs reveal considerable scope for improvement in hull form and propulsive efficiency. A model of a 75-ft. (22.86 m.), 100-ton, 10-knot "fishing boat of the near future" was designed from a hydrodynamic point of view, incorporating a bulbous bow, 2-bladed propeller, and a steerable nozzle which replaces the rudder. Tests of this model show exceptionally low resistance, exceptionally high propulsive efficiency, and a high efficiency when trawling. The power required at 10 knots is only 105 BHP compared with 250 BHP for the average recent Canadian fishing vessel of the same size and speed.

The results are expanded to all sizes for ready comparison with existing vessels.

UNE NOUVELLE CONCEPTION DE LA COQUE ET DE L'HÉLICE

Les essais au bassin de modèles récents de navires de pêche révèlent de grandes possibilités pour le perfectionnement des formes de coque et le rendement de la propulsion. Du point de vue hydrodynamique, on a établi un modèle de "navire de pêche du proche avenir" de 75 pi. (22,86 m.), 100 tonneaux, 10 noeuds, comportant un avant à bulbe, une hélice à 2 ailes et une tuyère orientable qui remplace le gouvernail. Les essais au bassin de ce modèle montrent une résistance exceptionnellement basse, un rendement exceptionnellement élevé de la propulsion et un rendement élevé pendant le chalutage. La puissance nécessaire à 10 noeuds est de 105 c.v. au frein seulement au lieu de 250 c.v. au frein pour le récent navire de pêche moyen canadien de mêmes dimension et vitesse.

Les résultats sont étendus à toutes les dimensions pour la comparaison facile avec les navires existants.

UN NUEVO PROYECTO DEL CASCO Y DE LA HELICE

Los ensayos en estanques de experimentación de modelos recientes de barcos de pesca revelan que existen grandes posibilidades para mejorar la forma del casco y el rendimiento de la propulsión. Desde un punto de vista hidrodinámico se hizo un modelo de un "pesquero del futuro próximo" de 75 pies (22,86 m.) de eslora, 100 ton, y 10 nudos, con proa de bulbo, hélice de 2 palas y una tobera orientable en lugar de timón. Los ensayos en canales de experimentación de este modelo muestran una resistencia excepcionalmente baja, un rendimiento excepcionalmente alto de la propulsión y una elevadísima eficacia durante el arrastre. La potencia necesaria a 10 nudos es solamente de 105 c.v. al freno en vez de 250 c.v. al freno para los recientes pesqueros medios canadienses de las mismas dimensiones y velocidad.

Los resultados se amplían a todas las dimensiones para hacer comparaciones fáciles con los barcos existentes.

IN the last few years a number of models of fishing vessels have been tested for various Canadian organizations in the tank of the Ship Laboratory of the National Research Council of Canada. At the same time, a research project has been pursued with the general objective of improving the design and economic performance of fishing boats.

Model tests of five recent fishing boats

Five models were selected for study. The displacement of the full-size vessels varied from 45 to 913 tons. Because models can be expanded to any size, they have all for purposes of comparison been expanded to 100 tons (101.6 ton) displacement in salt water. The 100-ton dimensions are compared in table 89, from which it will be noted that the waterline lengths range from about 60 to 80 ft. (18 to 24 m.).

The effective power curves are shown in fig. 331 in English h.p. units. The designed speed of each model is shown by an arrow. Rudders and dummy hubs were fitted, but not bilge keels.

Examination of results

Below 7½ knots, the curves separate according to the wetted surface. Above 10½ knots, the curves separate according to the length.

At the mean designed speed of 10 knots, the effective power ranges from 80 h.p. for the best model to 137 h.p. for the worst, a very considerable spread. The spread in engine power will be even larger since the better models should have a higher propulsive efficiency, and in practice the worst model will require about twice the engine power of the best model at 10 knots.

The reasons for these large differences lie in the proportions and shape of the hulls, and in the wetted surface. Much of the resistance is caused by the bow wave, and it is important to shape the boat to minimize the height of the bow wave. The half angle of entrance of the load waterline, the waterplane area coefficient of the entrance, and the prismatic coefficient of the entrance are important in this respect. Maximum use must also be made of the length, by reducing overhangs to the minimum. Wetted surface should be reduced to the minimum by

TABLE 89

100-ton dimensions of six different fishing boat designs

Model No.		*85A*	*91*	*140*	*146*	*147*	*149A*
L	ft.	71.72	76.73	62.65	61.76	79.51	75.00
	m.	21.86	23.39	19.10	18.82	24.23	22.86
B	ft.	15.37	21.99	20.67	18.97	15.31	17.33
	m.	4.68	6.70	6.30	5.78	4.67	5.28
T (ex. keel)	ft.	6.58	6.64	8.02	6.50	5.58	5.11
	m.	2.01	2.02	2.44	1.98	1.70	1.56
Δ_s	tons	100	100	100	100	100	100
Δ	ton	101.6	101.6	101.6	101.6	101.6	101.6
∇_s	cu. ft.	3,500	3,500	3,500	3,500	3,500	3,500
∇	cu. m.	99.1	99.1	99.1	99.1	99.1	99.1
S	sq. ft.	1,322	1,633	1,504	1,384	1,378	1,365
	sq. m.	122.8	151.7	139.7	128.6	128.0	126.8
$L/\nabla^{1/3}$		4.724	5.054	4.126	4.068	5.237	4.940
$S/\nabla^{2/3}$		5.734	7.083	6.524	6.005	5.976	5.921
$S/\sqrt{\nabla L}$		2.639	3.150	3.215	2.977	2.611	2.664
δ		0.480	0.312	0.337	0.460	0.515	0.503
φ		0.558	0.609	0.595	0.601	0.590	0.559
β		0.861	0.512	0.567	0.765	0.873	0.900
α		0.744	0.746	0.717	0.753	0.754	0.671
φ_e		0.543	0.587	0.563	0.603	0.598	0.585
α_e		0.706	0.652	0.651	0.675	0.707	0.562
$\frac{1}{2}\alpha_e$		22°	21°	20°	31°	24°	8°

eliminating external keels, curving the sections into the deadwood at the stern, and adopting a fairly full mid-section.

The shape of the bow primarily affects the resistance, and the shape of the stern primarily affects the propulsive efficiency.

Model 85A incorporates a Maierform bow, a low prismatic coefficient, and low wetted surface to give a good result just below the designed speed. At higher speeds, more length would be desirable.

Model 91 is fairly well designed in relation to speed, except that the wetted surface is excessive due to a large external wood keel. It is questionable whether such a high-powered boat would prove economic to operate, although this case is typical of the smaller modern boats.

Model 140 could fairly be described as "the FAO boat of 1953", having been designed with the 1953 Congress recommendations in mind. This is a short, wide, deep boat with some transom immersion and an external wood keel. It is too short for the designed speed and has too much wetted surface for good results.

Model 146 is a double-chine steel boat with straight-line sections, which cause increased wetted surface, particularly at the skeg. This boat is the shortest of the group and has the bluffest entrance angle and highest entrance prismatic, due in part to the forward location of the engine.

Model 147 is evidently unnecessarily long in relation to the low designed speed. The high waterplane entrance coefficient gives rise to a very high bow wave.

All the above models were designed by eminent naval architects and were good of their kind. A plot of the registered dimensions and engine powers of all Canadian boats built in the last five years suggests very strongly that the average boat is worse than any of the models shown in fig. 331. The average today, is a 9-knot hull powered by an 11-knot engine.

Design of an improved hull form

Several well-known features of hull form, which have evolved through research in model basins over the past 80 years, did not appear in any of the above models, and it was considered worthwhile to try to design a hull incorporating every known feature which would be conducive to low resistance and high propulsive efficiency. This hull might then serve as a parent form for further development.

Displacement and speed. The hull was designed for 10 knots on 100 tons (101.6 ton) medium displacement.

Length. First, to select the length L. From a structural point of view, the shorter the boat the better, since the weight of the longitudinal material in the hull, for a given total displacement, varies as $L^{2.5}$. From a powering point of view, on the other hand, the optimum length is about 110 ft. (33.5 m.) and the minimum effective power 38 h.p. Thus a longer, slimmer boat tends to have lower machinery and fuel weight, and higher hull weight. But

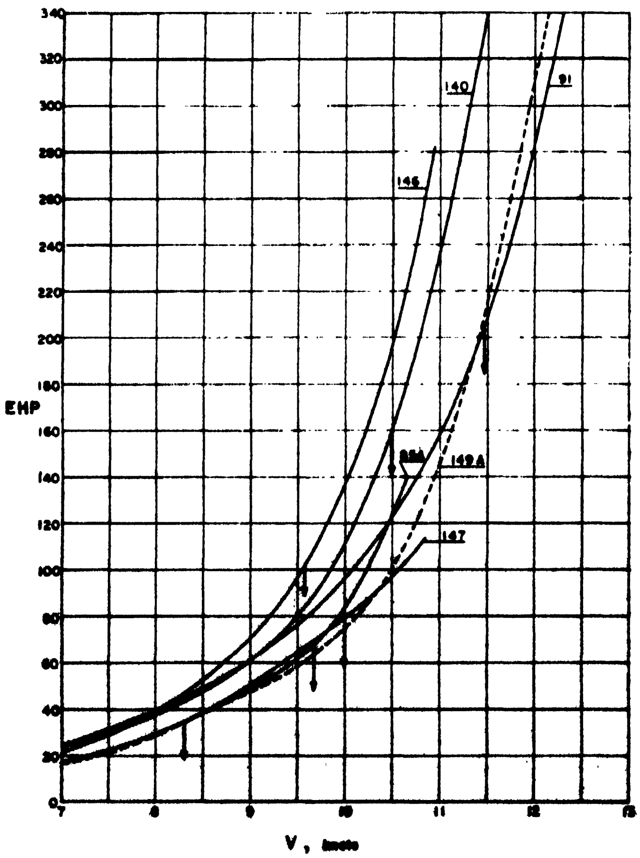


Fig. 331. Effective power for six 100-ton hulls designed for fishin'
The arrow indicates designed speed

since the hull weight is the major item, a strong preference remains in favour of short length.

The choice, then, narrowed down to finding the minimum length at which the resistance coefficient for 10 knots would remain substantially on the level part of the curve. Using Taylor's standard series (1943) as a guide, a waterline length, L, of 75 ft. (22.86 m.) was finally chosen.

The resulting Froude number $V/\sqrt{L}$ is 1.15 ($v/\sqrt{gL}$= 0.3437), which is about the upper limit for economical propulsion at all speeds and requires a prismatic coefficient, φ, of 0.56 on the Taylor form.

Beam/draught ratio. The beam/draught ratio, B/T, was then selected to put the metacentre, M, at a point 2.0 ft. (0.61 m.) above the load waterline, since the centre of gravity is expected to be at or near the load waterline. The resulting B/T for the Taylor form was 3.33.

Basic Taylor form. The Taylor form was now fixed, with dimensions 75 ft. × 17.33 ft. × 5.20 ft. = 100 tons (22.86 × 5.28 × 1.59 m. = 101.6 ton). At 10 knots, the effective power is 79.4 h.p. (English) which is on a par with the much longer model 147 in fig. 331.

Improved Taylor form. How to improve the Taylor form? The obvious choice at this speed is to move the longitudinal centre of buoyancy, LCB, aft. It was found that the LCB could be moved back to about 0.53 L from the bow before the slope of the diagonals in the afterbody exceeded 18 degrees. The latter figure is considered to be about the limit for satisfactory flow to the propeller.

This modified Taylor form was drawn up to provide a physical picture and serve as a guide for further work. It was immediately clear that extensive alterations would have to be made in the afterbody to accommodate a single screw. Also a rake of keel would need to be introduced to accommodate a larger propeller and to avoid the steering instability which might result from trim by the bow in the deep condition. It was envisaged that, with the engine aft and fish hold just forward of amidships, in their logical positions, the boat would sail at a substantially constant draught aft, regardless of loading, and still have a slight aft rake of keel when loaded to capacity.

Bulbous bow. At the Froude number for 10 knots, Taylor's (1943) bulbous bow experiments suggest a useful application for a bulbous bow, although his experiments were made on very much slimmer models. To guess the best bulb, a rough extrapolation was made as follows:

Vessel	*Taylor Series A*	*Taylor Series B*	*Present form*
$\Delta_s/(L/100)^3$	60	150	237
Best value of Taylor's f	0.14	0.14?	0.14
Best value of Taylor's t	1.1	0.5	0.1

The effect of moving the LCB aft and adopting a bulbous bow should be to reduce the resistance by 5 to 10 per cent., and the effect of introducing a rake of keel should be to increase the resistance slightly, so that the probable effective power at this stage was estimated at about 75 h.p.

Propulsive factors affecting hull form

Attention was then devoted to propulsive efficiency. The broad features leading to high propulsive efficiency are well known. They include the use of a large, slow-turning propeller with as few blades as possible, located as far aft and as high as possible. Van Manen (1957) has made systematic experiments with propellers in nozzles which revealed for the first time that, by suitable design of the propeller and nozzle, an overall gain in efficiency could be secured in both the free-running and the trawling condition over a conventional propeller. Further gains were expected if the propellers were re-designed for operation inside a nozzle, by broadening the blade tips and increasing the pitch towards the tips and roots.

Nozzle design. Application of van Manen's results to the present case involved a series of extrapolations beyond his tests in an effort to try to take advantage of the trend in each of the many variables involved. These include, on the nozzle, the chord/diameter ratio, the thickness/chord ratio, the camber/chord ratio, and the angle of attack, and, on the propeller, the diameter, number of blades, pitch ratio, blade area ratio, blade thickness ratio, and pitch distribution.

The nozzle was intended to show no loss in the free-running condition and a moderate gain in the trawling condition. By adopting a steerable nozzle, the rudder was eliminated and the nozzle could be placed farther aft where it would be larger and collect a greater proportion of the frictional wake. The nozzle characteristics finally chosen are as follows:

Outside diameter/draught	0.900
Inside diameter/draught	0.800
Chord/draught	0.240
Profile shape	NACA 4412
Angle of incidence	−10°

The steering axis of the nozzle was placed at the ¼-chord point and the propeller tips at 0.425 chord, giving minimum tip clearance at zero steering angle. The aft face of the nozzle was placed at the aft end of the load water line.

This arrangement represents practically the largest propeller and nozzle which are possible in relation to draught, and the propeller has a considerably larger diameter than is possible with the conventional combination of propeller and rudder.

When the top of the nozzle emerges from the water during severe pitching, it is expected that it will throw up a wave and remain full of water, thereby avoiding any severe pounding of the propeller.

Other advantages of the nozzle are that it helps to protect the propeller from entanglement with lines and nets, and provides some damping of pitching motion.

The main disadvantage of a nozzle is that if it should become bent, it may stop the propeller. Protection against accidental contact with harbour walls was, therefore, provided by broadening the stern sections to a knuckle just above the waterline.

Contra stern frame. Elimination of the rudder has the disadvantage that there is no recovery of the rotational energy in the water behind the propeller. Compensation was therefore provided by adopting a contra stern frame ahead of the propeller to give a pre-rotation of the flow in the opposite direction to that of the propeller rotation. Slopes on the suction side of the contra stern frame were held to 18 degrees to avoid breakdown of the flow.

Bow flare. The fine shape of the waterlines forward was maintained from the light load line to the deep load line so as to ensure a minimum of spray formation at the bow when navigating in icing conditions. Above the deep load line, however, a pronounced flare was considered necessary in rough water to limit the angle of pitch and to throw the wave crests out laterally. This should help to maintain a dry deck at sea; also, it gives protection to the bulbous bow when coming alongside a dock. The combination of flare and bulb may be expected to provide an appreciable damping of the pitching motion.

TABLE 90

Hull form particulars of Model 149A developed from a Taylor form, after various features had been incorporated

Condition		*Light*	*Medium*	*Deep*
L	ft.	75.00	75.00	75.00
	m.	22.86	22.86	22.86
B	ft.	17.33	17.33	17.33
	m.	5.28	5.28	5.28
T_a	ft.	6.50	6.50	6.50
	m.	1.98	1.98	1.98
T_f	ft.	1.94	3.72	5.49
	m.	0.59	1.13	1.67
Δ_s, salt water	tons	80.0	100.0	120.0
Δ, salt water	ton	81.3	101.6	121.9
∇_s	cu. ft.	2,800	3,500	4,200
∇	cu. m.	79.3	99.1	118.9
S	sq. ft.	1,222	1,365	1,506
	sq. m.	113.5	126.8	139.9
A_w	sq. ft.	858	869	890
	sq. m.	79.7	80.7	82.7
I_t	ft⁴	14,697	15,678	16,641
	m⁴	126.9	135.3	143.6
LCB/L from bow		0.536	0.516	0.504
LCF/L from bow		0.537	0.547	0.551
δ		0.458	0.503	0.533
φ		0.523	0.559	0.584
β		0.875	0.900	0.913
α		0.666	0.671	0.685
Transverse inertia coefficient		0.463	0.487	0.512

Particulars of the model

When all the above features had been incorporated, the only remaining resemblance to the original Taylor form was the shape of the midship section. The lines and body plan are given in fig. 332. The main dimensions and coefficients are given in table 90.

Model 149A was made in wax on a scale of 1/7.5 to give a waterline length of 10 ft. (3.05 m.). A trip wire of 0.040 in. (1 mm.) diameter was fitted at 5 per cent. of the length from the bow to stimulate turbulent flow.

Resistance and stream flow tests

The model was tested for resistance at displacements corresponding to 80, 100, and 120 per cent. of the designed displacement, the draught aft being maintained constant at 6.5 ft. (1.98 m.). A dummy propeller hub was the only appendage.

In the light condition, a pronounced hump appears in the resistance curve at 6 knots, and this is associated with an extremely sharp hollow in the wave profile at the after end of the bulb. Both features disappear at higher speeds and displacements.

In the region of 10 knots, the bow wave formation is extremely clean at all draughts, with hardly more than a feather of foam along the top to cause spray. The model has a pronounced sinkage at this speed, particularly at the bow, but the bow rises again at higher speeds. The sinkage at the stern is just sufficient to immerse the after knuckle at 10 knots, but there is little or no dead water dragged along behind the transom.

Stream flow tests were made at 10 knots in the 100-ton condition. The wave profile and streamlines are given on the body plan.

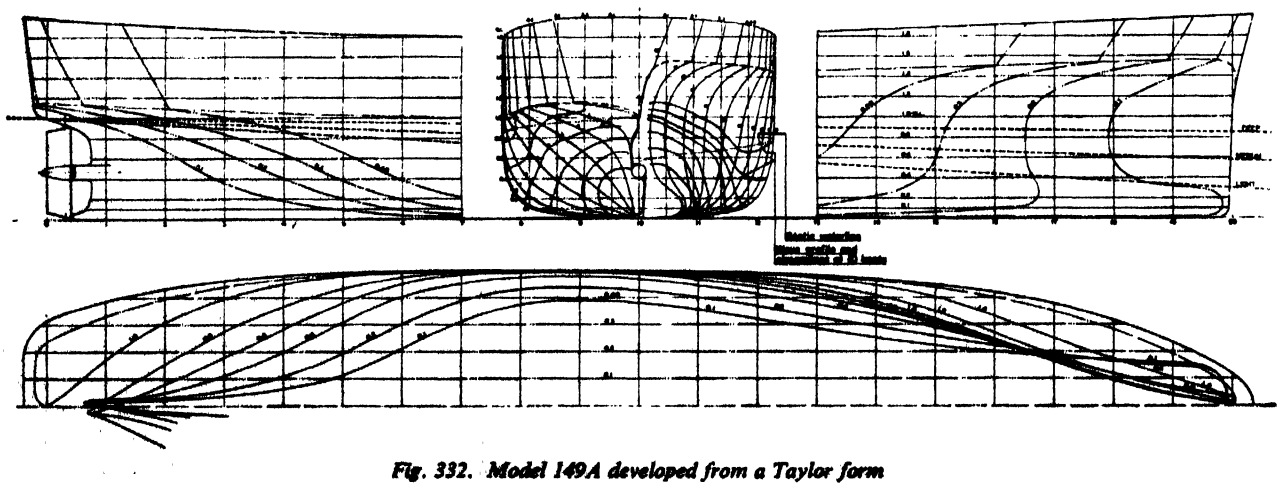


Fig. 332. Model 149A developed from a Taylor form

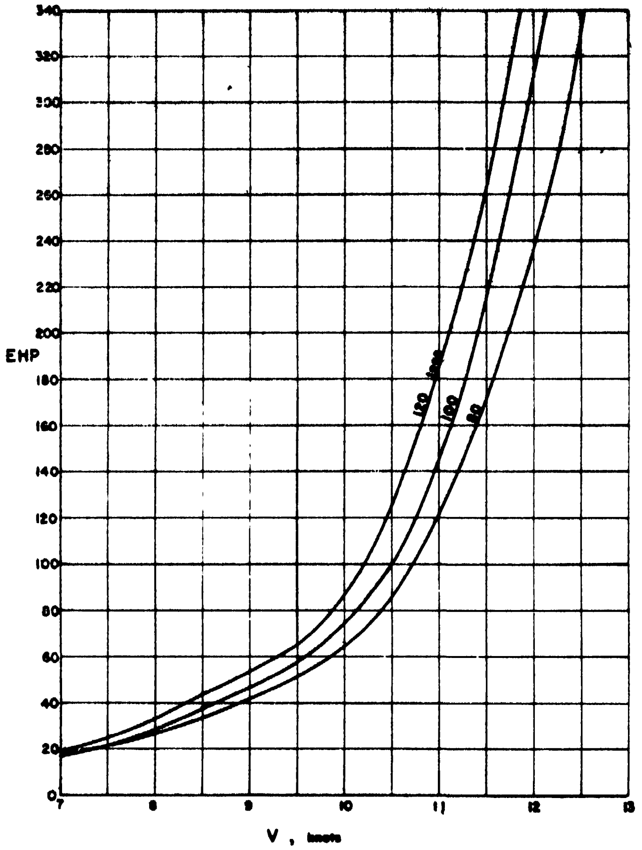


Fig. 333. Effective power at different displacements, model 149A

Table 91

Effective powers of Model 149A obtained by using the ITTC 1957 friction line. Salt water at 59°F (15°C). Roughness allowance 0.0004

Condition	Light	Medium	Deep
Δ_s	80.0	100.0	120.0
Δ	81.3	101.6	121.9
V		*EHP (English)*	
	Light	*Medium*	*Deep*
2.0	0.31	0.36	0.47
2.5	0.58	0.67	0.90
3.0	0.99	1.09	1.49
3.5	1.66	1.69	2.31
4.0	2.69	2.52	3.37
4.5	4.17	3.70	4.63
5.0	6.36	5.33	6.22
5.5	9.06	7.56	8.43
6.0	12.9	10.2	11.3
6.5	16.0	13.2	14.6
7.0	18.4	16.5	18.7
7.5	21.5	21.2	24.8
8.0	26.5	28.2	33.4
8.5	33.6	37.7	43.8
9.0	42.0	47.1	53.8
9.5	51.6	57.4	64.8
10.0	64.1	74.4	86.3
10.5	85.7	99.8	125.9
11.0	122.0	144.9	185.7
11.5	172.1	214.9	263.9
12.0	235.8	309.4	367.1
12.5	325.9	414.6	486.3

Effective powers

The resistance test results were expanded by the ITTC 1957 line with a ship roughness allowance of 0.0004. The ITTC formula gives about 1.3 per cent. lower power than the Schoenherr for this model at 10 knots. The effective power curves are shown in fig. 333 and the 100-ton curve in fig. 331 as a dotted line. Table 91 lists the effective powers.

Effective powers for other sizes of vessel

To facilitate comparisons with existing vessels of all sizes, the effective powers and speeds for model 149A are plotted on a log-log basis versus displacement from 10 tons to 1,000 tons in fig. 334 to 336. Each figure refers

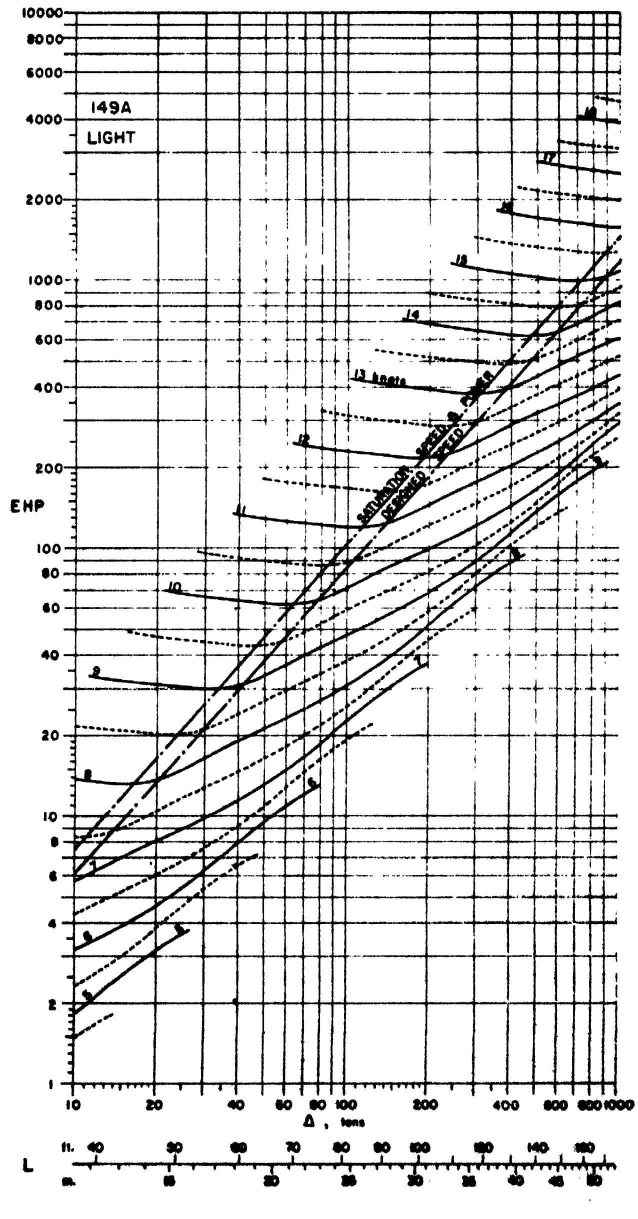


Fig. 334. Effective power at even speeds in light condition

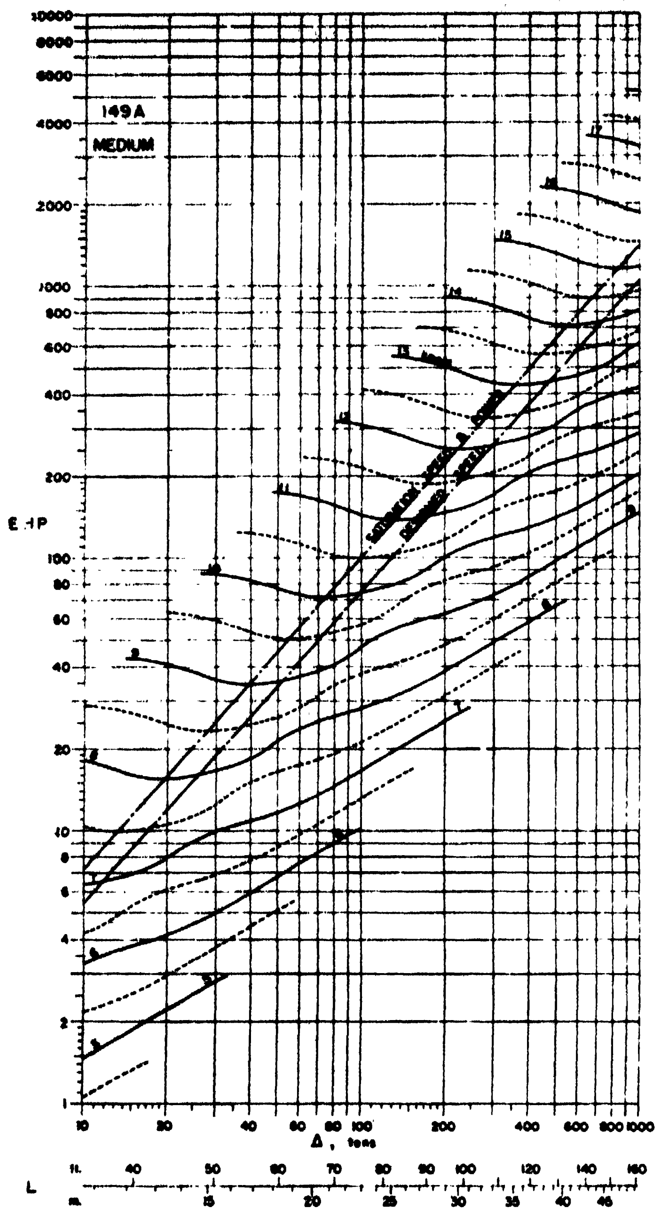


Fig. 335. Effective power at even speeds in medium condition

to a different load condition, and secondary scales along the bottom show the waterline lengths, in feet and metres, for salt water.

Choose the diagram which most nearly fits the displacement and length of your vessel and read off effective power at any speed. For a more careful comparison, read off the power from each diagram your displacement and speed, plot the power against length (from the bottom scale), and read off the power at your length.

It will generally be found that, in the region of the designed speed, model 149A is hard to beat. At the designed condition it is 6.3 per cent. better than Taylor's Standard Series, in spite of having 4.9 per cent. more wetted surface.

Fig. 334 to 336 may also be used in selecting, for example, the proper speed in relation to size or vice versa. At any speed there is a certain size for minimum power. In the medium condition, fig. 335, the 100-ton vessel appears better suited to the speed of 10½ knots than to the designed speed of 10 knots, but it should be remembered that in terms of engine power the best speed is likely to be somewhat less, since the propulsive efficiency will fall off as speed increases.

The plot used in fig. 334 to 336 is quite simple to draw, is fully corrected for scale effect, gives constant accuracy all over the diagram, and uses practical units of power, speed, and displacement. Only three calculations are

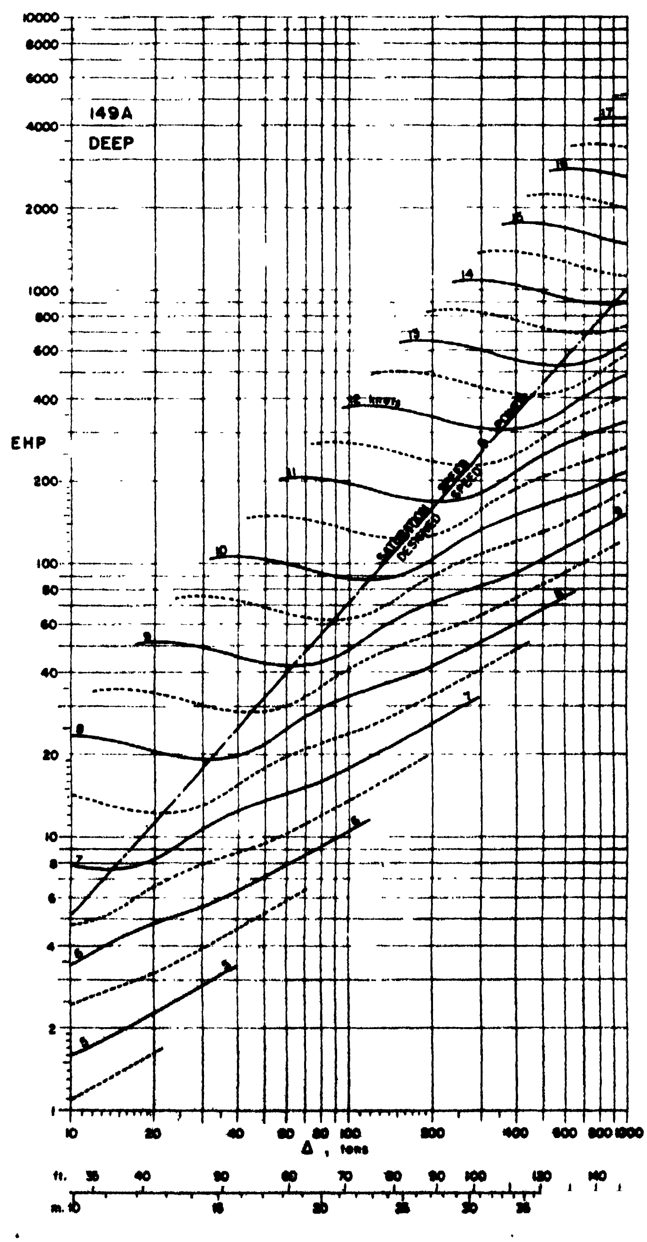
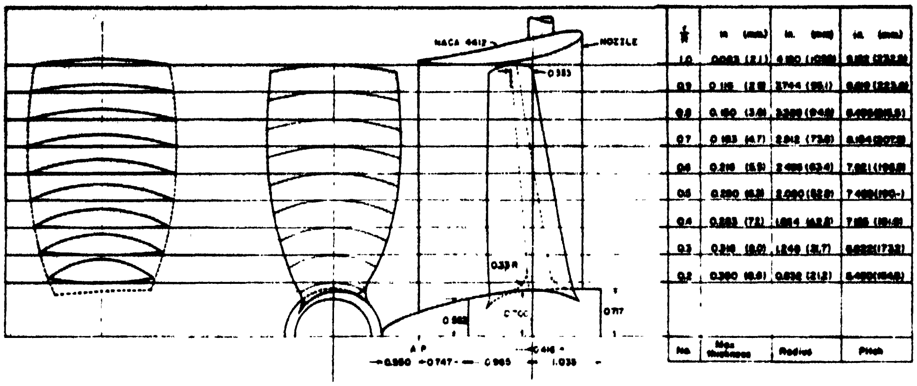


Fig. 336. Effective power at even speeds in deep condition



FORMPLAN			
SHIP		MODEL	
Diameter	D = 5.200 ft (1.59m)	8.32 in (212 mm)	Pitch ratio P/D = 0.980
Pitch at 0.7R	P = 5.096 ft (1.55m)	8.164 in (208mm)	Boss diam ratio d/D = 0.188
Pitch at tip	P_t = 5.720 ft (1.74m)	9.152 in (232mm)	Max. thickness ratio t_0/D = 0.050
Pitch at boss	P_b = 3.980 ft (1.22m)	6.383 in (162 mm)	Exp area ratio = 0.283
Expanded area	A_E = 5.565 ft² (0.52 m²)	14.30 in² (92.2 cm²)	Proj area ratio = 0.227
Projected area	A_p = 4.813 ft² (0.45 m²)	12.32 in² (79.4 cm²)	Number of blades = 2
Material	Trolon		

Fig. 337. Propeller and nozzle drawing

needed—the powers and speeds for 10, 100 and 1,000 tons displacement—to draw the whole diagram accurately. As the author has not seen this plot used before, he commends it to the attention of towing tank authorities and naval architects as a straightforward method of presenting model test data in a form suitable for practical design purposes.

The seventh power law

A little analysis reveals that the "optimum" speed always occurs at the point where the power is varying as the seventh power index of the speed. Once the power curve, preferably shaft power, has been determined from model tests, it is a simple matter to plot power versus $(\text{speed})^7$ and draw a tangent from the origin. The tangent point then gives the "optimum" speed. This is the speed for which both a larger and a smaller version of the same vessel will require more power, and might better be called the "saturation" speed and power.

Applying the seventh power law to the vessels of fig. 331, the following results are obtained.

Model	*Designed speed knots*	*Saturation speed knots*
85A	9.67	10.0
91	11.47	11.8
140	10.49	10.0
146	9.58	10.0
147	8.30	—
149A	10.00	10.5

These saturation speeds are based on effective power curves instead of shaft power, and are therefore somewhat too high for the reason already stated. Model 147 was not tested to a speed high enough to determine the optimum. Model 140 is evidently seriously overpowered.

Hull forms which are appreciably longer and slimmer than those commonly used in fishing boats have flatter power curves which never reach the seventh power relationship, and for these hulls the power will increase continuously with speed and with size.

The seventh power law may, therefore, only be regarded as a method of assessing the upper limit of practical speed for heavy displacement forms, and the designed speed should undoubtedly be somewhat less.

Velocities in the nozzle

The steerable nozzle was machined out of brass and fitted to the model, and a rake of pitot tubes was placed in the nozzle with their orifices approximately in the position of the leading edge of the propeller blades. Velocities in the nozzle were then measured at 60-degree intervals at three different radii at a speed corresponding to 10 knots. The tests indicated local wake fractions from zero to 90 per cent. at different points of the disc, the average wake being 24.6 per cent.

Without the propeller, the nozzle undoubtedly induces some wake at all points of the propeller disc, and the wake distribution without the nozzle will be measured when time permits. These tests will show whether the nozzle does in fact have a homogenizing action on the wake, as is sometimes claimed. Judging by the wake measurements in the nozzle, the effect cannot be large.

Design of the propeller

Having established the merits of the hull form and selected the nozzle, the propeller design was considered.

Y

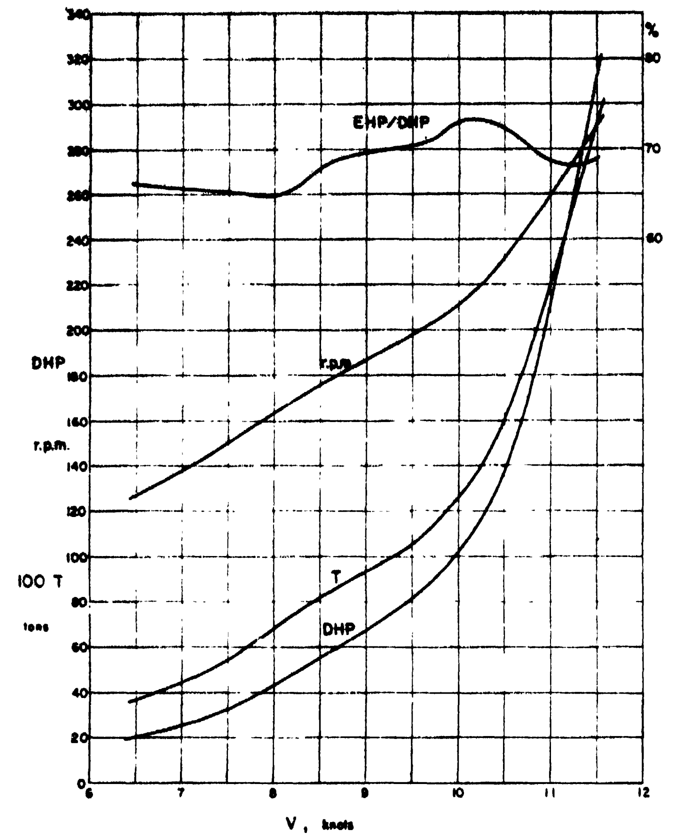


Fig. 338. Self propulsion analysis for 100-ton vessel, model 149A, in medium condition, with propeller 31 and nozzle

Diameter. The diameter was fixed by the nozzle, already selected as the biggest that could be accommodated in the stern contour without projecting aft of the load waterline ending. The propeller diameter was made the same as the internal diameter of the nozzle so that the propeller can be withdrawn aft without disturbing the nozzle. The necessary tip clearance is available when running because the propeller tips are forward of the point of minimum diameter of the nozzle. To maintain the clearance when the nozzle is turned for steering, the blade tips were made part of a spherical surface whose centre is the intersection of the nozzle axis and the shaft axis.

Number of blades. A two-bladed propeller was selected, for highest efficiency, high r.p.m. in relation to size, and simplicity of manufacture.

Blade thickness. The blade thickness ratio for adequate strength free-running is about 4 per cent. A value of 5 per cent. was adopted to cover the trawling condition. The tip thickness ratio is 1 per cent.

Blade outline. If the clearance between the blade tips and the nozzle were infinitely small, it would be logical to design the blade outline as a half ellipse touching the shaft axis, the tip being the widest part of the blade. As some escape of water will occur in the tip clearance, the blade tips were narrowed slightly and the greatest blade width was placed at 0.7 radius. The blade outline is thus an ellipse whose major axis is 1.4 radius, with the tip cut off.

Blade width. The blade width was chosen to give 0.25 mean width ratio, which, though excessive from the point of view of cavitation, is consistent with the blade thickness.

Blade sections. The blade sections were made ogival from the tips to 0.6 radius, and lenticular below 0.6 radius in such a way as to provide a nearly linear increase of camber from tip to root. Better types of blade section are available today, but, when cavitation is not a problem, their advantage is marginal unless they are made to extreme standards of accuracy and finish.

Pitch. The pitch distribution for a propeller in a nozzle is not easy to determine. By analogy with axial pump design theory, van Manen (1957) has expressed the view that the pitch should be increased at both the root and the tip. This conclusion is based on the assumption of a constant pressure increase over the whole propeller radius and must, the author believes, be rejected for ship propellers. What is needed in ships is a constant velocity increase so as to leave the water astern of the propeller, with a small but uniform velocity aft.

On the other hand, an increase in pitch at the tip will undoubtedly increase the circulation around the nozzle section and increase the thrust of the nozzle, besides collecting somewhat more of the frictional wake at the top of the disc.

Also the mean peripheral wake increases towards the root of the blade and a lower pitch would seem to be required at the root for wake adaptation.

The pitch distribution finally adopted was a linear increase in face pitch ratio from 0.7 at the axis to 1.1 at the tip, the pitch ratio at 0.7 radius being 0.98. Although at first sight this may seem to be a rather considerable manipulation of the pitch, it must be remembered that the camber of the sections confers a virtual increase in pitch, and the camber increases from tip to root. Thus, the hydrodynamic pitch is more nearly constant than the face pitch values, although there is still some increase from root to tip.

The resulting propeller design is different in so many respects from anything tested before that it must be regarded more as a first guess than as a final design.

Particulars of the propeller

The propeller drawing is given in fig. 337. The model propeller was cut out of solid trolon, a stiff plastic material which machines and files well and takes a good polish. Axial offsets were drilled at 5-degree intervals on the face and back of the blades to an accuracy well within one-thousandth of an inch, and the surface was filed down and polished until the drill marks disappeared. The sharp edges of the blades were then rounded back very slightly.

Self-propulsion tests

The model was self-propelled, with nozzle and propeller in place at designed displacement. Tow-rope forces of, 0.45 and 0.9 lb. (0.204 and 0.408 kg.) were used to cover the range of propeller loading from model to ship, the speed range being 6.5 to 11.5 knots for the 100-ton ship. On each run, propeller thrust, torque, and revolutions per minute were measured, and the model speed. The thrust of the nozzle was not measured. The results plotted in a very consistent manner and hardly any fairing was required.

Self-propulsion analysis

The results were analysed at the correct propeller loadings for 10, 100, and 1,000 ton vessels, using the ITTC friction line with a roughness allowance of 0.0004. Results for the 100 ton vessel are given in fig. 338 and table 92.

At the designed speed of 10 knots, the delivered power is 102 h.p. at 211 r.p.m., giving a propulsive coefficient of 0.73, which is considered satisfactory. If the nozzle were regarded as part of the hull, the propulsive coefficient would be higher, but the author prefers to regard it as part of the propeller because its action is largely induced by the propeller.

The propeller thrust is given in table 92. It is higher than the resistance, particularly at low propeller loadings, and it appears that the nozzle is contributing little or nothing to the thrust in the free-running condition. The nozzle thrust will be measured when a dynamometer is available for the purpose.

Open water tests are necessary for the complete analysis and these also will be made when the nozzle thrust can be measured.

In the meantime it appears that the propeller is not far from being correctly designed, since the peak propulsive coefficient occurs at the designed speed of 10 knots, and it could be said that the design should be highly effective for longlining with an engine of about 105 BHP, geared to give 211 r.p.m. at the propeller.

TABLE 92

Self-propulsion analysis of Model 149A—medium load. Propeller 31 and nozzle. Salt water at 59°F (15°C). Roughness allowance 0.0004

V	*DHP (English)*	*r.p.m.*	*Propeller thrust, long tons*	*PC*
6.5	20.0	126.7	0.366	0.662
7.0	25.2	137.5	0.443	0.656
7.5	32.4	149.9	0.541	0.653
8.0	43.5	163.7	0.685	0.649
8.5	55.4	175.8	0.819	0.680
9.0	67.7	187.1	0.934	0.696
9.5	81.5	197.8	1.055	0.704
10.0	101.9	211.2	1.259	0.730
10.5	138.0	232.0	1.611	0.724
11.0	211.3	259.8	2.217	0.686
11.5	311.9	290.0	2.904	0.689

Delivered powers for other sizes of vessel

Fig. 339 gives the delivered powers at even speed for any size of vessel between 10 and 1,000 tons.

Trawling tests

The model was tested for trawling at the designed dis-

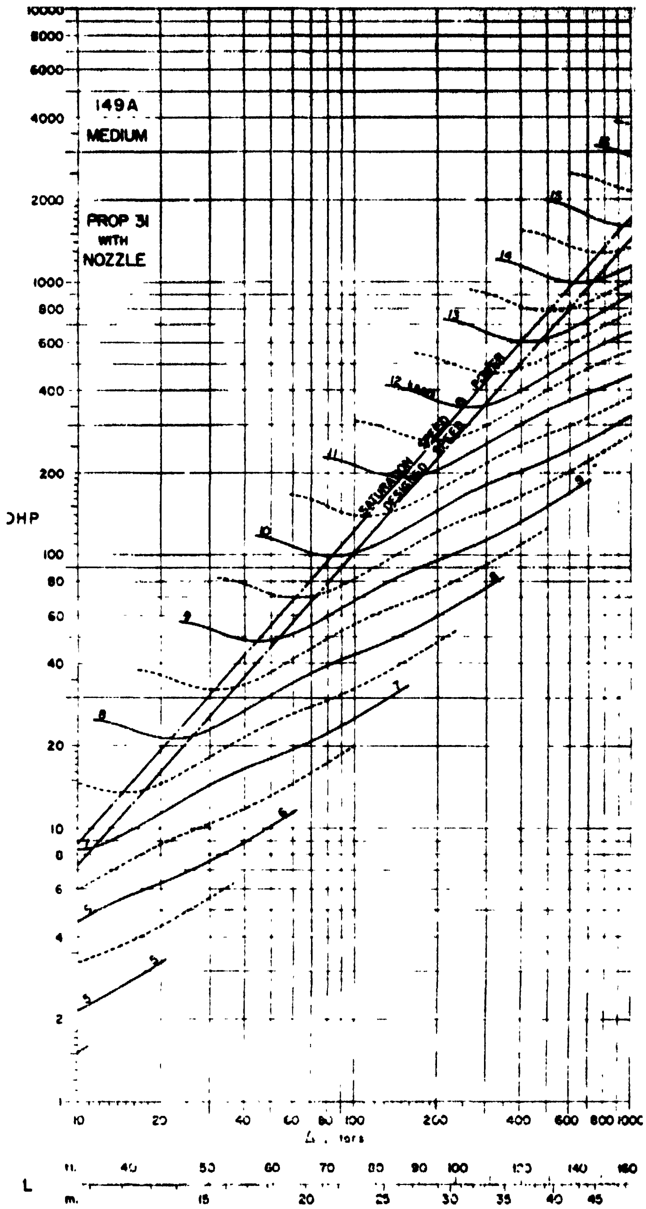


Fig. 339. Delivered power at even speeds in medium condition

placement, pulls of 6, 8, and 10 lb. (2.72, 3,63. and 4.54 kg.) being applied over a speed range of 2 to 6 knots for the 100 ton vessel.

One point on each curve, in the region of 2½ to 3½ knots, gave a speed which was some 10 per cent. below expectation, but as the point did not appear to be due to error in measurement, the curves were taken through all the points.

The sum of the pull and the model resistance was always greater than the propeller thrust, showing that the nozzle was contributing substantial thrust, although this was not measured. The ratio (P+R)/T ranged from 1.12 at 6 knots to 1.42 at 2 knots, increasing slightly with the pull.

The results were corrected to the 100-ton vessel on the basis of the ITTC friction formula with a roughness allowance of 0.0004. They are plotted in fig. 340 as pull in long tons versus delivered power in h.p. (English) for even values of speed and r.p.m.

Trawling efficiency. The trawling efficiency η_t is the ratio of the power absorbed by the trawl to the power delivered to the propeller.

In any consistent units for the pull P, the speed V, and the delivered power DHP (e.g. ft.lb./sec. or kg.m./sec. units)

$$\eta_t = \frac{PV}{DHP}$$

With P in long tons, V in knots, and DHP in h.p. (English), as in fig. 340,

$$\eta_t = \frac{6.88\ PV}{DHP}$$

With P in metric tons, v in m./sec. and DHP (metric),

$$\eta_t = \frac{Pv}{DHP75} \times 1000$$

It ranges from 32 to 56 per cent., increasing with the speed and varying only slightly with the pull. Compared with trawling tests on another model, the efficiency is 68 per cent higher at 2 knots and 53 per cent. higher at 4 knots. This is partly due to the larger propeller which is possible with the steerable nozzle, and partly due to the nozzle thrust.

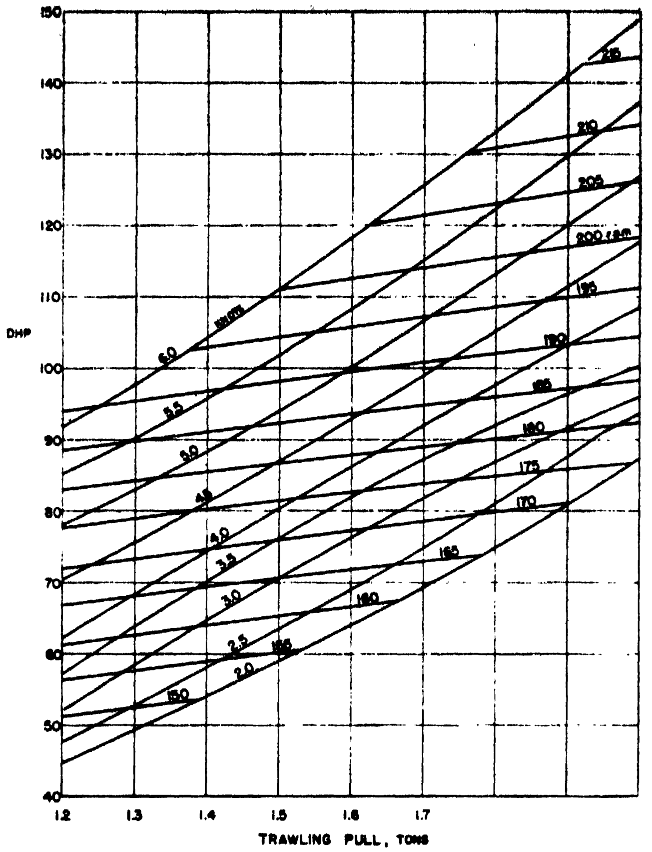


Fig. 340. Trawling pull in relation to delivered power at even speeds and r.p.m., model 149A, in medium condition, with propeller 31 and nozzle

Trawling economics. Though it is a valid yardstick for comparing boat against boat, the trawling efficiency is not a good criterion, since the object in trawling is not to get a lot of power into the net but a lot of fish.

Mathews (1958) has treated the subject analytically and proved beyond a doubt that the largest practical net at the lowest practical towing speed gives the highest rate of catching fish and therefore the highest gross earnings. The costs associated with power (which include fuel, oil, grease, capital charges on the engine, winch, and fishing gear and their maintenance, insurance and depreciation) must then be deducted to give the net earnings. The ideal power to install for trawling is presumably the power which will give the highest net earnings per hour of trawling.

Proskie (1952 to 1958) has recorded the economic performance of some 100 boats in the Atlantic provinces of Canada for the past seven years. From his data, average trends regarding costs and earnings can be inferred. While the author does not claim any great reliability for the figures, the following table gives estimated earnings, power costs, and net earnings per year for the present vessel with various engine powers, based in part on Proskie's data and in part on the trawling tests of the model. The constant costs associated with the hull are not included in the table below.

It will be noted that the net earnings are reaching a peak at 220 BHP, at which point the power costs are one-third of the gross earnings.

A practical compromise is, therefore, required between 105 BHP for free-running, and 220 BHP for trawling. From fig. 339 the saturation power of 140 BHP would seem to be the proper choice for the 100 ton trawler based on the present design.

Unfortunately, 140 BHP is beyond the scope of the trawling tests, but extrapolating the results indicates that the pull available for the net at 4 knots trawling speed would be close to 2.5 tons, and the r.p.m. about 207.

BHP	*100*		*140*		*180*		*220*	
Gross earnings	£9,780	($27,400)	£13,180	($36,900)	£15,830	($44,300)	£17,900	($50,100)
Power costs	£2,140	($6,000)	£3,320	($9,300)	£4,670	($13,100)	£6,250	($17,500)
Net earnings	£7,640	($21,400)	£9,860	($27,600)	£11,160	($31,200)	11,650	($32,600)

(£1 = $2.80)

Trawl

The proper trawl for 140 BHP on this vessel is one that requires a pull of 2.5 tons at 4 knots—if that is the correct trawling speed. Speeds of 3 to 5 knots seem to be favoured by different skippers, but lower speeds lead to a larger trawl, greater pull, and a higher swept volume of water per unit time.

Information on the pull required by trawls, at different speeds under actual fishing conditions, is badly needed to assist in the selection of the proper trawl in relation to power.

Diesel with two-speed gearbox. The diesel engine has a "constant torque" characteristic so that if the gear ratio is right for trawling it is wrong for free-running and vice-versa. A two-speed gearbox is well worth considering on trawlers. One gear ratio is chosen to give full power at the propeller when running free and the other to give full power when trawling. The engine then runs at designed power and revolutions in both conditions,

Diesel with single-speed gearbox. An acceptable solution for the present design is an engine geared to develop 140 BHP at 207 propeller r.p.m., with a governor limiting the maximum r.p.m. to 211. When trawling, full power is available, but, when running free, the governor cuts down the power to 105 BHP and the speed to an economical 10 knots.

Free-piston turbines. A competitor of the near future, the free-piston engine driving a gas turbine, has a "constant power" characteristic and can deliver full power at any propeller r.p.m. It is, therefore, particularly well worth considering for trawlers.

Conclusions

The design may fairly be claimed to have exceptionally low resistance, an exceptionally high propulsive coefficient and exceptionally high trawling efficiency, when compared with current designs.

Further improvements of the hull form and propeller design can undoubtedly be achieved, but in the author's opinion a greater scope for advance now exists in the design of trawls from a hydrodynamic point of view.

RESISTANCE OF TRAWLERS

by

H. LACKENBY

The paper reviews the research progress of the British Shipbuilding Research Association (BSRA) on the resistance of trawlers.

The object has been to provide design data to cover a practical range of proportions and fullnesses including systematic variation of mid-section area coefficient, beam-draught ratio, length-displacement ratio and other geometrical features. The basic models represented to scale a 150 ft. (45.7 m.) trawler of 847 tons displacement with a service speed of about 12 knots. Throughout the work the results have been compared on a basis of constant displacement.

The mid-section variations showed the beneficial effect on resistance of reducing the prismatic coefficient by fining the ends and filling out the midship section.

At speeds below 11 knots there was a significant increase in resistance as the beam-draught ratio was increased. An interesting and important feature, however, was that in the neighbourhood of the service speed of 12 knots the resistance appeared to be insensitive to changes in this ratio.

The length-displacement ratio group showed very clearly the advantage to be gained by lengthening the form while maintaining the other geometrical features.

Tests in which the block coefficient was systematically varied showed that, at constant displacement, the resistance progressively increased with block coefficient.

LA RÉSISTANCE DES CHALUTIERS

La communication passe en revue les progrès des recherches de la British Shipbuilding Research Association (BSRA) sur la résistance des chalutiers.

Le but était de fournir des données de dessin pour couvrir une gamme pratique de proportions et de formes pleines, comprenant une variation systématique du coefficient de remplissage du maître-couple, du rapport largeur-tirant d'eau, du rapport longueur-déplacement et autres caractéristiques géométriques. Les modèles de base représentaient à l'échelle un chalutier de 150 pi. (45,7 m.) ayant un déplacement de 847 tonnes avec une vitesse d'utilisation de 12 noeuds. Dans tout le travail, les résultats ont été comparés sur la base du déplacement constant.

Les variations du maître-couple ont montré l'effet avantageux sur la résistance de la réduction du coefficient prismatique en affinant les extrémités et en donnant une forme plus pleine au maître-couple.

A des vitesses inférieures à 11 noeuds, il y avait une nette augmentation de la résistance quand le rapport largeur-tirant d'eau augmentait. Cependant, il est important et intéressant de noter qu'au voisinage de la vitesse d'utilisation de 12 noeuds, la résistance ne paraissait pas être affectée par les variations de ce rapport.

Le groupe du rapport longueur-déplacement montrait très clairement l'avantage obtenu en allongeant la forme tout en conservant les autres caractéristiques géométriques.

Les essais dans lesquels on faisait varier systématiquement le coefficient de remplissage ont montré qu'à un déplacement constant. la résistance augmentait progressivement avec le coefficient de remplissage.

LA RESISTENCIA DE LOS ARRASTREROS

Reseña la ponencia los adelantos logrados en las investigaciones realizadas por la British Shipbuilding Research Association (BSRA) relativas a la resistencia de los arrastreros.

En este caso se trataba de facilitar datos que comprendiesen una gama práctica de proporciones y formas, inclusive la variación sistemática del coeficiente del área de la cuaderna maestra, la relación manga-puntal, la relación eslora-desplazamiento y otras características geométricas. Los modelos básicos representaban un arrastrero de 150 pies (45,7 m.) de eslora, 847 tons. de desplazamiento y una velocidad de servicio de unos 12 nudos. Durante toda la labor los resultados se compararon sobre una base de desplazamiento constante.

Las variaciones de las cuadernas maestras demostraron el buen efecto que tenía en la resistencia la reducción del coeficiente prismático, el afinamiento de los extremos y el redondeamiento de la sección mediana.

A velocidades de menos de 11 nudos hubo un sensible aumento en la resistencia al aumentar la relación manga-puntal. Sin embargo, un detalle de interés e importancia fué que en las proximidades de la velocidad de servicio de 12 nudos, la resistencia parecía ser insensible a los cambios en esta relación.

El grupo de relaciones eslora-desplazamiento puso de relieve con mayor claridad las ventajas que se obtienen alargando la forma mientras se conservan constantes las otras características geométricas.

Los ensayos en los que se alteró sistemáticamente el coeficiente de bloque demostraron que a desplazamiento constante, la resistencia aumenta progresivamente con el coeficiente de bloque.

THIS paper reviews the research progress of the British Shipbuilding Research Association (BSRA) in so far as trawler resistance is concerned. The object has been to provide design data to cover a practical range of proportions and fullness including systematic variation of mid-section area coefficient, beam-draught ratio, length-displacement ratio and other geometrical features.

Methodical series resistance tests with trawler models

The object has been to obtain from systematic model tests practical design data on the resistance of trawler forms. The general plan has been to select representative parent forms and then to derive others from them to cover a practical range of the following:

- Midship section area coefficient, β
- Beam-draught ratio, B/T
- Length-displacement ratio, $L/\nabla^{1/3}$

Throughout this work the displacement was generally maintained constant. The midship section area variations were carried out first, after which the parent form was changed. The tests with the original parent form have been referred to as Series A and those with the later form as Series B.

Series A—systematic variations of midship section area

In this series the primary variable was the fullness of the midship section as defined by the midship area coefficient:

$$\beta = A_m/BT$$

The series comprised 3 models having β values of 0.887, 0.854 and 0.823, the body sections of which are shown in fig. 341. The model having $\beta=0.887$ was the parent form and corresponded to a 150 ft. (45.7 m.) trawler of $\delta=0.582$ with a speed of about 11 to 12 knots. This was considered representative of current practice at the time, that is, the immediate post-war years. The two other forms of finer midship section were developed from the

TABLE 93

Principal particulars of parent trawler form

Series		*A*	*B*
Length from after side of stern post to fore side of stem bar at main deck	ft.	150.0	153.0
	m.	45.72	46.63
Length from after side of stern post to fore side of stem bar at load waterline—L	ft.	147.0	150.0
	m.	44.80	45.72
Mean draught—T	ft.	13.17	13.17
	m.	4.01	4.01
Trim by stern	ft.	6.00	6.00
	m.	1.83	1.83
Breadth—B	ft.	26.33	26.33
	m.	8.03	8.03
Displacement (tons salt water)—Δ_s		847	847
Breadth-draught ratio—B/T		2.00	2.00
Length-breadth ratio—L/B		5.58	5.70
Length-displacement ratio—$L/\nabla^{1/3}$		4.75	4.85
Wetted surface coefficient—$S/\nabla^{2/3}$		5.83	5.78
Block coefficient—$\delta=\nabla/LBT$		0.582	0.571
Midship area coefficient—β		0.887	0.885
Prismatic coefficient—φ		0.656	0.645
LCB as per centage of L from amidships		2.01	2.88

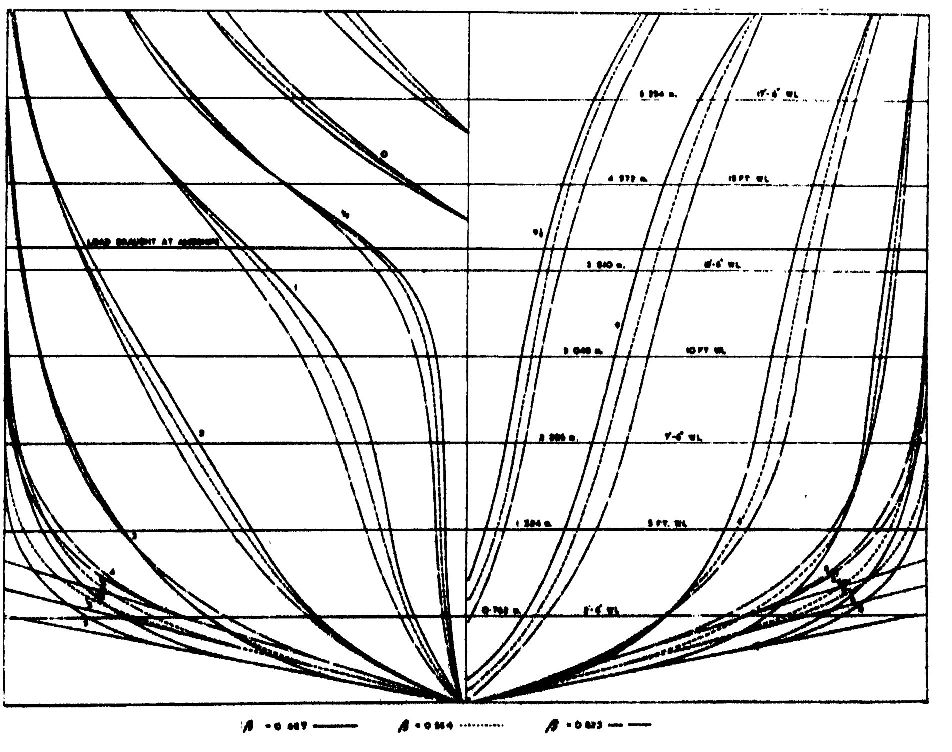


Fig. 341. BSRA Trawler Series A, body plans

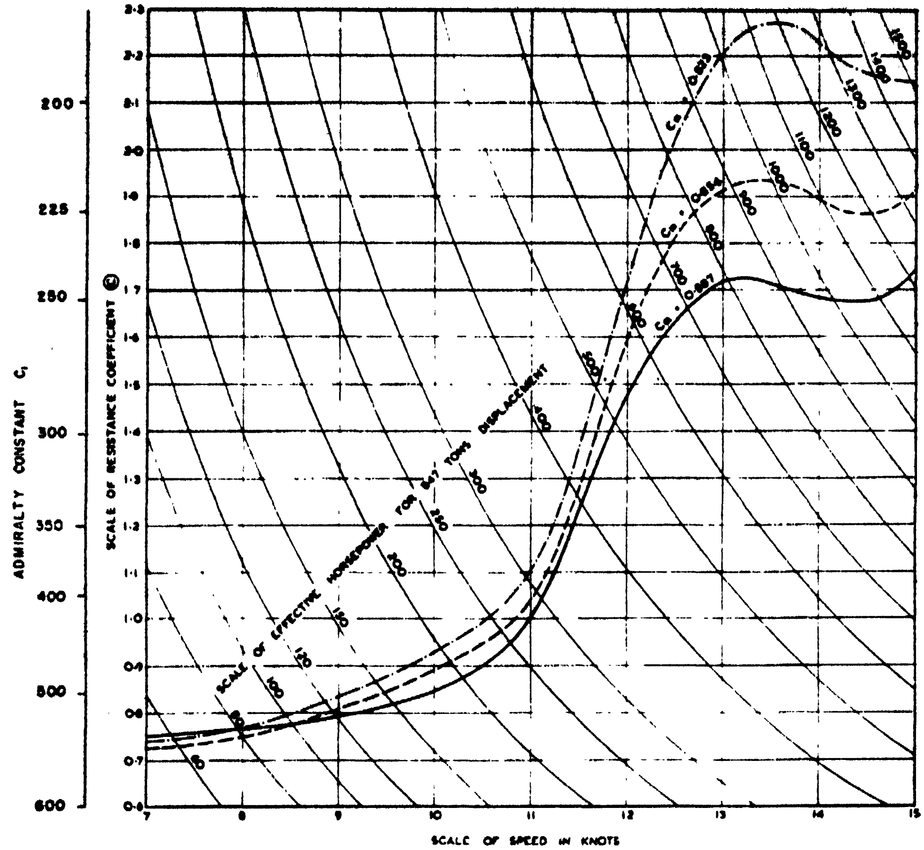


Fig. 342. BSRA Trawler Series A: effect of varying midship section area on effective horsepower, © and C_1

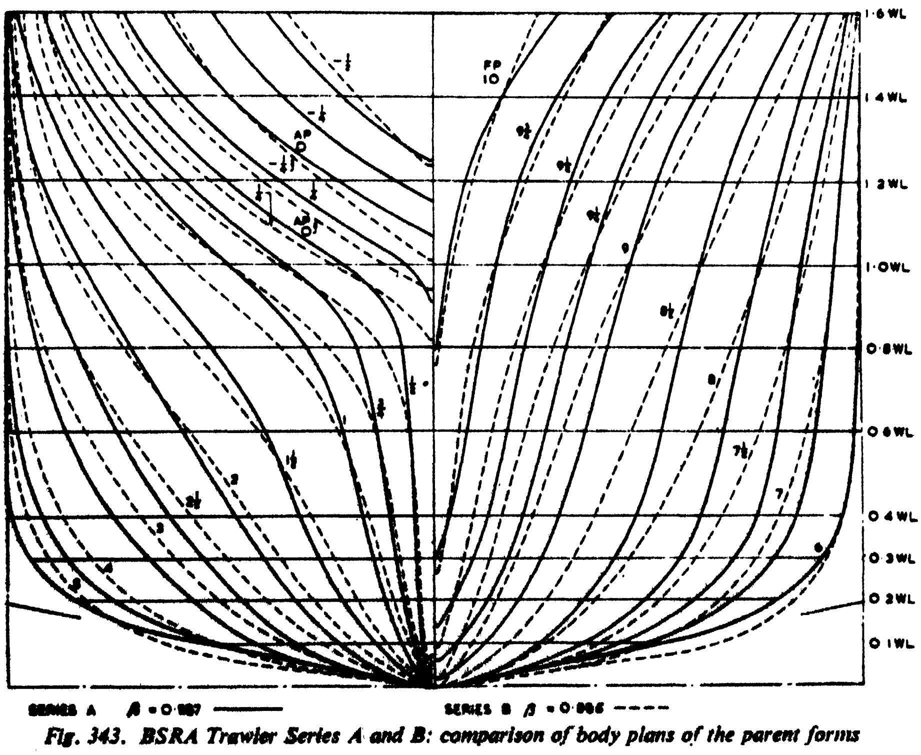


Fig. 343. BSRA Trawler Series A and B: comparison of body plans of the parent forms

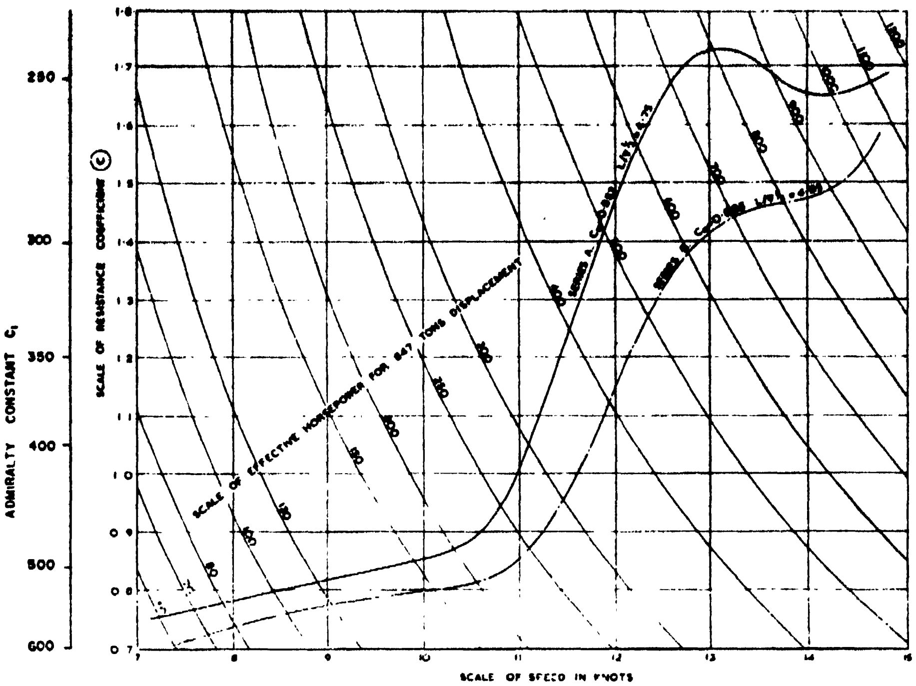


Fig. 344. BSRA Trawler Series A and B: comparison of effective horsepower, C_1 and © curves for parent models

parent by progressively increasing the rise of floor to give β values of 0.854 and 0.823 respectively. At the same time, and on the same overall dimensions, the entrance and run were filled out in a systematic manner so as to maintain the original displacement of 847 tons. The principal particulars of the parent form are shown in table 93.

Resistance tests were carried out at a number of draughts and trims in the experiment tank of Denny's, Dumbarton. These included three displacements: loaded, 85 per cent. loaded and 70 per cent. loaded, and four trims: level, 2 per cent., 4 per cent. and 6 per cent. Ł by the stern. The results for the loaded 4 per cent. stern trim at departure condition are shown in fig. 342 in terms of R. E. Froude's non-dimensional resistance coefficient ©* on a base of ship speed in knots. The © values correspond to the 150 ft. (45.7 m.) ship, the translation from the model scale having been effected by R. E. Froude's skin friction coefficients. The corresponding EHP's can also be read directly from the figure. All the models were of wax, 12 ft. 6 in. (3.81 m.) long and the results shown refer to tests carried out with trip wires as turbulence stimulators.

Referring to fig. 342, it will be seen that, except at very low speeds, fining the midship section, and filling out the ends generally resulted in increased resistance, and above 12 knots this becomes very marked indeed. Comparing the two extreme forms (i.e. β=0.887 and 0.823) the difference in resistance amounts to 12 per cent. in way of the service speed at about 11½ knots and between 13 and 15 knots the difference is as high as 30 per cent. In this connection it is pertinent to point out that in fining the midship section from 0.887 to 0.823 the prismatic coefficient has been increased from 0.656 to 0.707. The comparative behaviour at other trims and displacements was generally similar, but at higher speeds the benefit of trimming a ship with full ends was evident in all conditions.

The beneficial effect on trawler resistance of reducing the prismatic coefficient by fining the ends and filling out the midship section is now well enough known and it is understood that the latest design trends have been in that direction.

Further work was planned on this series including systematic changes in proportions, but for various reasons this was subject to considerable delay, not the least of which was the upheaval caused by the introduction of turbulence stimulation on models. Many of the tests referred to had been run without such stimulation and these had to be repeated with trip wires fitted to the models. In the interval there had been considerable development in the design of trawlers and it was considered that the parent form, designed originally in 1946, was no longer representative and that an improved set of lines should be prepared for the subsequent investigation.

* $© = \frac{1{,}000\,R}{4\pi\rho\, v^2\, \nabla^{2/3}}$ in any consistent system of units.

$= \frac{427.1\,EHP}{V^3\,\Delta_s^{2/3}}$ with V in knots and Δ_s in tons salt water.

where ρ = mass density of the water.

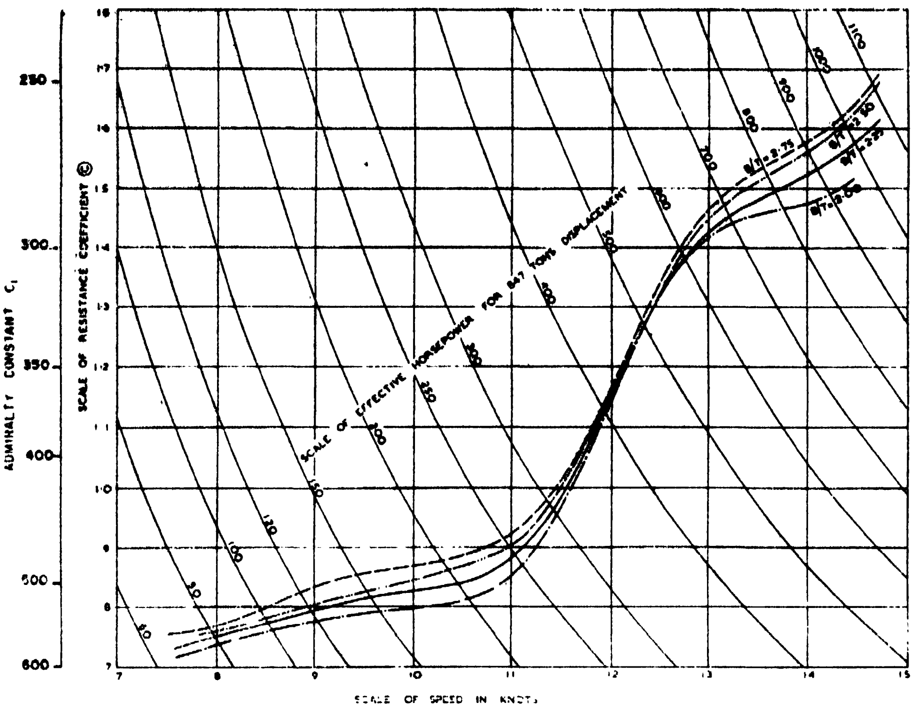


Fig. 345. BSRA Trawler Series B: effect of varying beam-draught ratio on effective horsepower, © and C_1

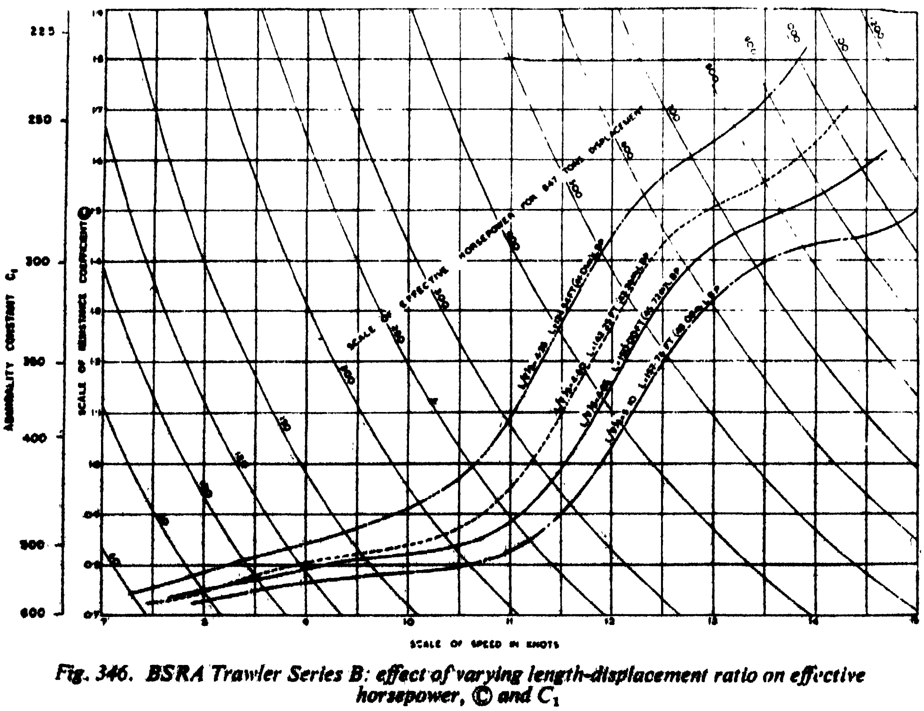


Fig. 346. BSRA Trawler Series B: effect of varying length-displacement ratio on effective horsepower, © and C_1

Series B—systematic variations in proportions

The new parent form was designed at Vickers-Armstrong's Experiment Tank, St. Albans, where all the later tests were carried out. The body plan is compared with that of the original form in fig. 343. It will be noted that the rise of floor has been reduced and the bilge radius increased so as to give a midship area coefficient of 0.885. At the same time, the U-shaped forward sections were replaced by V-shaped sections and the LCB was moved from 2.01 per cent. to 2.88 per cent. L aft of amidships. The form particulars are given in table 93 and it will be seen that the new model was slightly longer, and for the same displacement slightly finer. This resulted from a decision to take the length of 150 ft. (45.7 m.) between the after side of the rudder post and the fore side of the stem at the load water line instead of at the deck line as in the previous series. The corresponding length to the fore side of the stem at the deck would be 153 ft. (46.6 m.).

The resistance of the two parent models is compared in fig. 344. It will be seen that the new form has less resistance over the whole speed range, the difference amounting to 5 per cent. at low speeds and as much as 22 per cent. in way of the service speed between 11 and 12 knots.

This new form was then used as the parent for a methodical series of tests involving systematic changes in proportions using beam-draught ratio, B/T, and length-displacement ratio, $L/\nabla^{1/3}$, as the variables. This series was divided into two groups in which each of these form parameters was varied in turn while the other was maintained constant, that is, adhering to the philosophy of "one variable at a time".

Beam-draught ratio, B/T, variations. From the parent form with B/T=2.00 three new forms were derived with B/T ratios of 2.25, 2.50 and 2.75 by proportionate expansion and contraction of transverse and vertical dimensions respectively, so as to keep the displacement unchanged at 847 tons. This meant that the $L/\nabla^{1/3}$ ratio also remained unchanged at 4.85 throughout the group. The resistance results for the loaded 4 per cent. trim condition are shown in fig. 345. It will be noted that at speeds below about 11 knots there is a significant increase in resistance as B/T increases and this remark also applies at higher speeds above 13 knots. A most interesting and important feature, however, is that, at 12 knots in the neighbourhood of the service speed, the resistance appears to be peculiarly insensitive to change in B/T ratio.

Length-displacement ratio, $L/\nabla^{1/3}$, variations. Forms were then developed covering a range of $L/\nabla^{1/3}$ ratios as follows: 4.35, 4.60, 4,85 and 5.1, all with constant B/T ratio 2.25. These were again derived by proportional expansion or contraction of the linear dimensions as appropriate. The results for the loaded 4 per cent. trim condition are shown in fig. 346. In this presentation the group is regarded as a variation in length at constant displacement and, as would be expected, there is a steady reduction in resistance as length is increased. This shows very clearly the advantage in resistance to be gained by lengthening the form.

More recently, a group of models has been tested in which the block coefficient has been systematically varied above and below that of the parent form and maintaining the other geometrical characteristics. As one would expect, at constant displacement, the resistance progressively increased with increasing block coefficient.

Self-propulsion tests are now being carried out on certain models of Series B involving different propeller diameters appropriate to a range of shaft r.p.m. It is also intended to investigate special features on the parent form such as club-footing of the after sections.

Acknowledgments

The author is indebted to the Council and Director of Research of BSRA for permission to publish this paper and to members of BSRA staff for help in its preparation.

STATISTICAL ANALYSIS OF RESISTANCE DATA FOR TRAWLERS

by

D. J. DOUST

A statistical analysis of resistance data for trawlers, obtained from model experiments conducted in No. 1 Tank, Ship Division, National Physical Laboratory (NPL), was made. From an analysis of this type, a design method has been evolved, by means of which optimum resistance characteristics can be estimated for each trawler type, together with predictions of effective horsepower for any particular form.

These EHP calculations can be made by determining six parameters from the normal ship's lines plan, and to facilitate the computation of results a programme has been prepared for a digital computer (DEUCE), so that the NPL can provide an estimated EHP/speed curve very quickly for a given set of parameters. In addition, design diagrams have been prepared for practical use in design offices.

ANALYSE STATISTIQUE DES DONNÉS DE RÉSISTANCE POUR DES CHALUTIERS

L'auteur a effectué une analyse statistique des données de résistance pour des chalutiers, obtenues au moyen d'expériences sur modèles effectuées dans le Bassin No. 1, Division des Navires, Laboratoire national de Physique (NPL). On a élaboré une méthode de dessins d'après une analyse de ce genre, au moyen de laquelle on peut estimer les caractéristiques de résistance optimum pour chaque type de chalutier, en même temps que la prévision de la puissance effective pour chaque forme particulière.

Ces calculs de la puissance effective peuvent être faits en déterminant six paramètres d'après le plan normal des lignes du navire, et pour faciliter le calcul des résultats on a préparé un programme pour une calculatrice électronique (DEUCE) de façon que le NPL puisse fournir très rapidement une courbe estimée de puissance effective des vitesses pour un ensemble donné de paramètres. De plus, des diagrammes de projets ont été préparés pour l'utilisation pratique dans les bureaux d'études.

ANALISIS ESTADISTICO DE LOS DATOS DE RESISTENCIA PARA LOS ARRASTREROS

Se efectuó un análisis estadístico de los datos de resistencia para los arrastreros obtenidos por medio de experiencias con modelos efectuadas en el estanque No. 1, División de Barcos, Laboratorio Nacional de Física (LNF). Basándose en un análisis de este género, se elaboró un método de proyecto por medio del cual se pueden estimar las características óptimas de resistencia para cada tipo de arrastrero, junto con la previsión de la potencia efectiva para cada forma particular.

Estos cálculos de la potencia efectiva se pueden realizar determinando 6 parámetros a partir del plan normal de las líneas del barco y para facilitar el cálculo de los resultados se ha preparado un programa para una calculadora electrónica (DEUCE) de manera que el LNF puede dar muy rápidamente una curva estimada de potencia efectiva de velocidades para un conjunto dado de parámetros. Además, los diagramas de los proyectos se han preparado para su aplicación práctica en las oficinas de estudios.

A NEW design method which has been evolved to predict the form characteristics of trawlers for minimum resistance, together with the estimation of effective horsepower for any particular vessel has recently been completed in the National Physical Laboratory (NPL).

The method is thoroughly explained in a paper by D. J. Doust and T. P. O'Brien entitled: "Resistance and Propulsion of Trawlers", presented to the North East Coast Institution of Engineers and Shipbuilders in Newcastle-on-Tyne, U.K. on 3 April, 1959. The paper also contains a part dealing with propulsion and propeller selection for trawlers which is not covered in this paper and the discussion relevant to the whole paper. Complete copy with discussions to be had from the Institution, Bolbeck Hall, Newcastle-on-Tyne, U.K., price 10s. 6d.

This method consists basically in expressing the total ship resistance as a function of six form parameters, L/B, B/d, C_m, C_p, LCB and $\frac{1}{2}\alpha_e$) which are known from experience to be important in determining ship resistance at particular values of speed-length ratio. If we consider first a simple case where, say, ship resistance R in lb. is a function of only two form parameters, viz. LCB and $\frac{1}{2}\alpha_e$, then it may be written as

$$R=\sum_{0}^{n} a_n(LCB)^n+\sum_{0}^{m} b_m(\tfrac{1}{2}\alpha_e)^m+\sum_{n=1,m=1}^{n,m} a'_n(LCB)^n b'_m(\tfrac{1}{2}\alpha_e)^m$$

This polynomial expression for R may be considered as a surface as shown in fig. 347, and the variation of resistance for constant values of $\frac{1}{2}\alpha_e$ or LCB is then represented by the intersection of a plane, say ($\frac{1}{2}\alpha_e$=constant), with that surface. The case is now considered when n=m=2, which gives

$$\begin{aligned}R=\;&a_0+a_1(LCB)+a_2(LCB)^2\\&+b_0+b_1(\tfrac{1}{2}\alpha_e)+b_2(\tfrac{1}{2}\alpha_e)^2\\&+a_1'(LCB)b_1'(\tfrac{1}{2}\alpha_e)+a_1'(LCB)b_2'(\tfrac{1}{2}\alpha_e)^2\\&+a_2'(LCB)^2b_1'(\tfrac{1}{2}\alpha_e)+a_2'(LCB)^2b_1'(\tfrac{1}{2}\alpha_e)^2\end{aligned} \quad . (1)$$

which may be written as

$$R=A+B\,(LCB)+C(LCB)^2+D(\tfrac{1}{2}\alpha_e)+E(\tfrac{1}{2}\alpha_e)^2 +F(LCB)\,(\tfrac{1}{2}\alpha_e)+G(LCB)\,(\tfrac{1}{2}\alpha_e)^2+H(LCB)^2 (\tfrac{1}{2}\alpha_e)+I(LCB)^2(\tfrac{1}{2}\alpha_e)^2 \quad . \quad . \quad . \quad . \quad (2)$$

where A, B, C, etc., are coefficients, and is known as the regression equation of R.

If we have a series of observations,

$$\left.\begin{array}{l} R_1,\ LCB_1,\ \tfrac{1}{2}\alpha_{e_1} \\ R_2,\ LCB_2,\ \tfrac{1}{2}\alpha_{e_2} \\ R_3,\ LCB_3,\ \tfrac{1}{2}\alpha_{e_3} \\ ------ \\ ------ \\ ------ \\ R_n,\ LCB_n,\ \tfrac{1}{2}\alpha_{e_n} \end{array}\right\}$$

the values of the coefficients A, B, C, etc. may be calculated by the theory of minimal variance, provided the number of observations exceeds the number of coefficients by a reasonable extent. The number of observations required to solve a fixed number of coefficients in a regression equation is largely determined by the quality of the fit obtained in relation to the measured data.

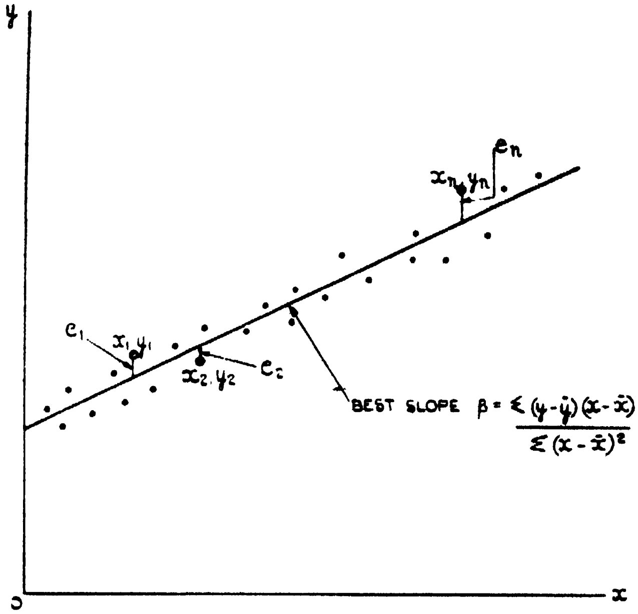


Fig. 348. Regression equation in the linear form

Theory of minimal variance

In the simplest case, consider a set of observations $y_1, y_2, y_3, \ldots, y_n$, and $x_1, x_2, x_3, \ldots, x_n$, and it is supposed that we have to choose the unknown values in a regression equation, so that the residual variation is a minimum. In this simple case it is assumed that the regression equation is linear and of the form, as shown in fig. 348,

$$y-y_0=\beta\,(x-x_0)+e$$

Where x_0 and y_0 are fixed values of x and y which normally vary, and it is required to find the best value of C_m such that the variance "e" is a minimum.

In particular choose $x_0=\bar{x}$ (the arithmetic mean of the observations).

Now since $\sum e^2=\sum\left[(y-y_0)-\beta(x-\bar{x})\right]^2=$ minimum,

therefore by differentiating with respect to C_m and y_0 we have

$$\sum\left[(y-y_0)-C_m(x-\bar{x})\right]=0 \quad . \quad . \quad . \quad . \quad (3)$$

and $$\sum\left[(y-y_0)-C_m(x-\bar{x})\right](x-\bar{x})=0 \quad . \quad . \quad . \quad (4)$$

From (3) $\sum(y-y_0)-\sum C_m(x-\bar{x})=0$

$$\sum y-ny_0=0$$

Therefore $y_0=\frac{1}{n}\sum y=y \quad . \quad . \quad . \quad . \quad . \quad (5)$

and from equation (4) $\sum(y-y)\,(x-x)=C_m\sum(x-x)^2$.

Therefore $C_m=\sum(y-\bar{y})\,(x-\bar{x})\Big/\sum(x-\bar{x})^2 \quad . \quad . \quad (6)$

In this way we can see that the theory of minimal variance gives the best straight line through the observations, passes through the point $(\bar{x}, \bar{y})$ and has a slope C_m, such that the residual variation is a minimum.

In a similar manner, the coefficients A, B, C, etc. in equation (2) may be determined and the argument extended to a larger number of coefficients provided there are sufficient observations.

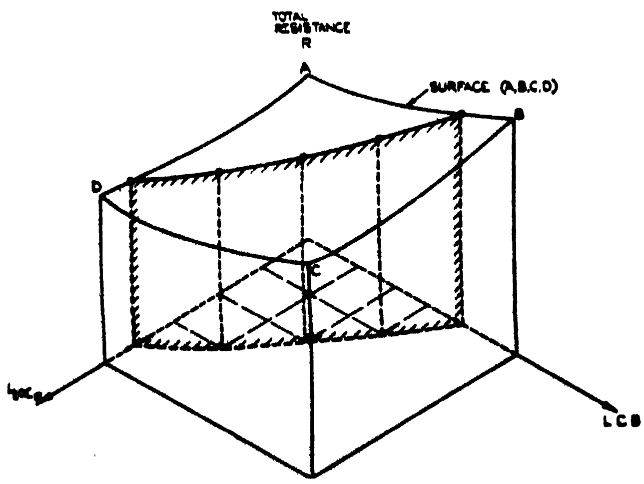


Fig. 347. Polynomial expression for R represented as a surface

Regression equation for trawler data

Certain facts are known from experience of trawler design, which assist in the formation of the regression equation.

(a) **LCB position is very important in determining ship resistance, the best position varying with prismatic coefficient.**

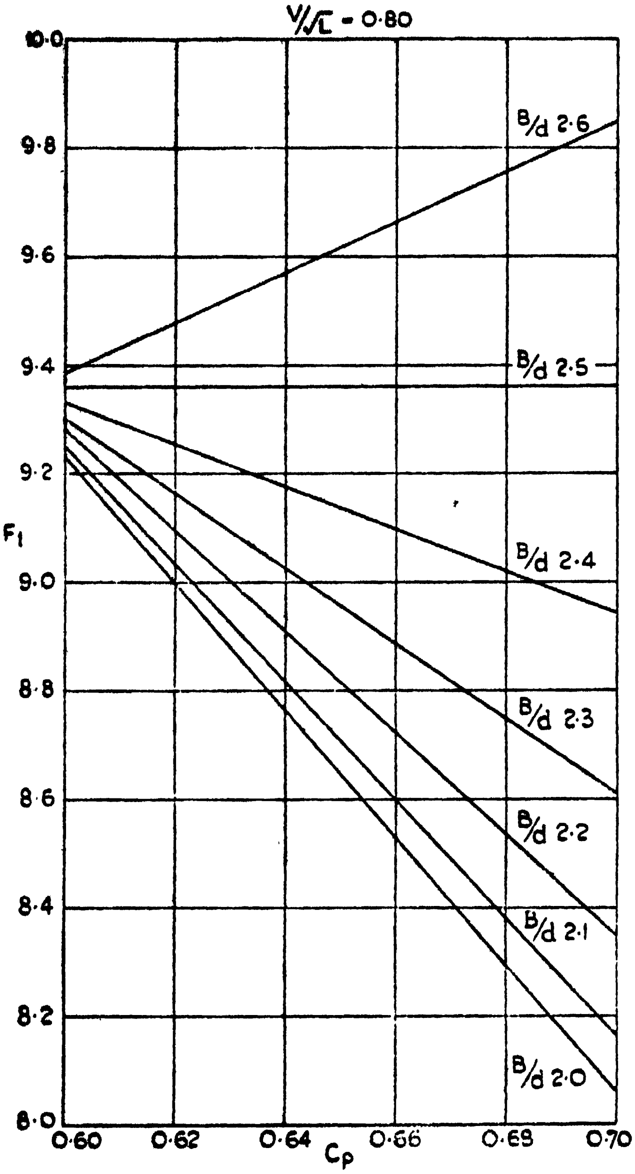


Fig. 349. Change in C_R due to C_p and B/d at $V/\sqrt{L}=0.80$

(b) Optimum values of $\frac{1}{2}\alpha_e$ for minimum resistance vary with prismatic coefficient and L/B ratio.

(c) Optimum values of B/d for minimum resistance vary with prismatic coefficient.

(d) Optimum values of L/B for minimum resistance vary with prismatic coefficient.

These facts suggest that cross-coupling of terms is required in the regression equation for resistance of these vessels, viz. terms such as $(C_p \times LCB)$, $(C_p \times L/B)$, $(C_p \times B/d)$, $(L/B \times \frac{1}{2}\alpha_e)$, $(C_p \times \frac{1}{2}\alpha_e)$.

The resistance data for some 130 trawler models which have been tested for industry in No. 1 Tank, Ship Division, NPL over a period of 30 years were available; the boundary layer flow being considered fully turbulent.

In cases where turbulence stimulators were not fitted to the models, corrections were made to the measured resistances based on model experiment data. These corrections seldom exceed 3 per cent. of the total resistance, due to the relatively high speeds of these vessels and the fineness of the forms. The data were computed in C_R form, $C_R = RL/\Delta V^2$, first proposed by Telfer (1922 to 23) for each speed-length ratio $V/\sqrt{L}=0.80, 0.90, 1.0$ and 1.10, and the six form parameters evaluated from the lines plans.

In order to establish the relative importance of individual parameters, a regression equation of the form

$$C_R = a_0 + a_1 L/B + a_2 B/d + a_3 C_m + a_4 C_p + a_5 (LCB) + a_6(\tfrac{1}{2}\alpha_e) \quad . \quad . \quad . \quad . \quad . \quad (7)$$

was first chosen, and the coefficients a_0, a_1, a_2, etc. determined by the theory of minimal variance. It was established that all parameters were significant, C_m being the least important. Evidence that cross-coupling of terms was essential was verified by plotting the residuals from equation (7) against terms such as $C_p \times LCB$ etc. and a definite variation detected. The term "residual" used here is defined as the difference between the observed and calculated values of C_R for any set of design parameters.

The final form of the regression equation for C_R.

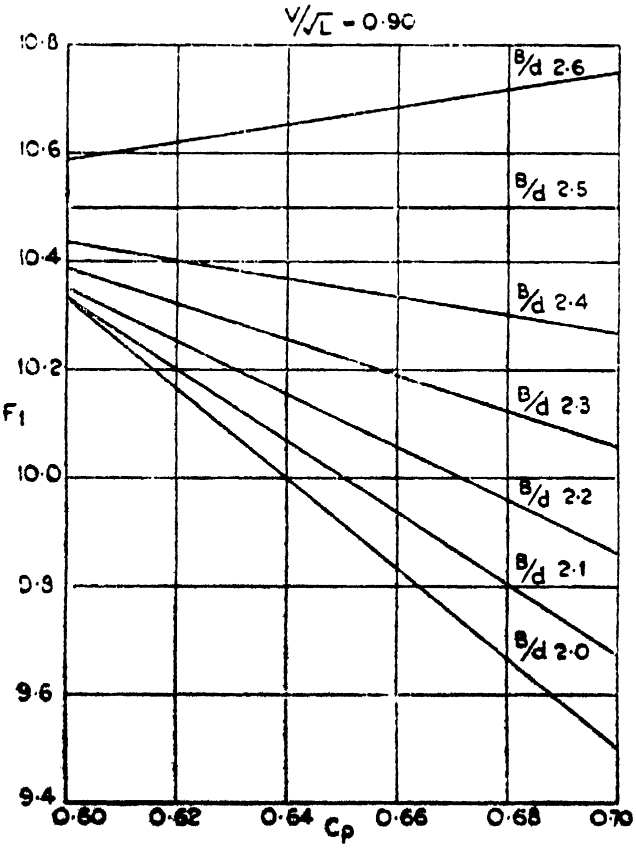


Fig. 350. Change in C_R due to C_p and B/d at $V/\sqrt{L}=0.90$

which includes the requirements (a), (b), (c) and (d), is as follows,

$$\begin{aligned} C_R = {} & a_0 + a_1 B/d + a_2 [B/d]^2 + a_3 LCB + a_4 LCB^2 + a_5 C_p \\ & + a_6 C_p^2 + a_7 L/B + a_8 [L/B]^2 + a_9 C_m + a_{10} \tfrac{1}{2}\alpha_e \\ & + a_{11} \tfrac{1}{2}\alpha_e^2 + a_{12} C_p LCB + a_{13} C_p LCB^2 \\ & + a_{14} C_p^2 LCB + a_{15} C_p^2 LCB^2 + a_{16} C_p \tfrac{1}{2}\alpha_e \\ & + a_{17} C_p \tfrac{1}{2}\alpha_e^2 + a_{18} C_p^2 \tfrac{1}{2}\alpha_e + a_{19} C_p^2 \tfrac{1}{2}\alpha_e^2 \\ & + a_{20} C_p L/B + a_{21} C_p [L/B]^2 + a_{22} C_p^2 L/B \\ & + a_{23} C_p^2 [L/B]^2 + a_{24} L/B \tfrac{1}{2}\alpha_e + a_{25} L/B \tfrac{1}{2}\alpha_e^2 \\ & + a_{26} [L/B]^2 \tfrac{1}{2}\alpha_e + a_{27} [L/B]^2 \tfrac{1}{2}\alpha_e^2 \\ & + a_{28} C_p B/d + a_{29} C_p [B/d]^2 \qquad . \quad . \qquad (8) \end{aligned}$$

It can be seen that individual design parameters have been included up to the second order, the cross-coupled terms therefore being of the fourth order. The coefficients a_0, a_1, a_2, etc. have been determined by the method already described. It has been established that equation (8) fits the majority of the data such that the speed pre-

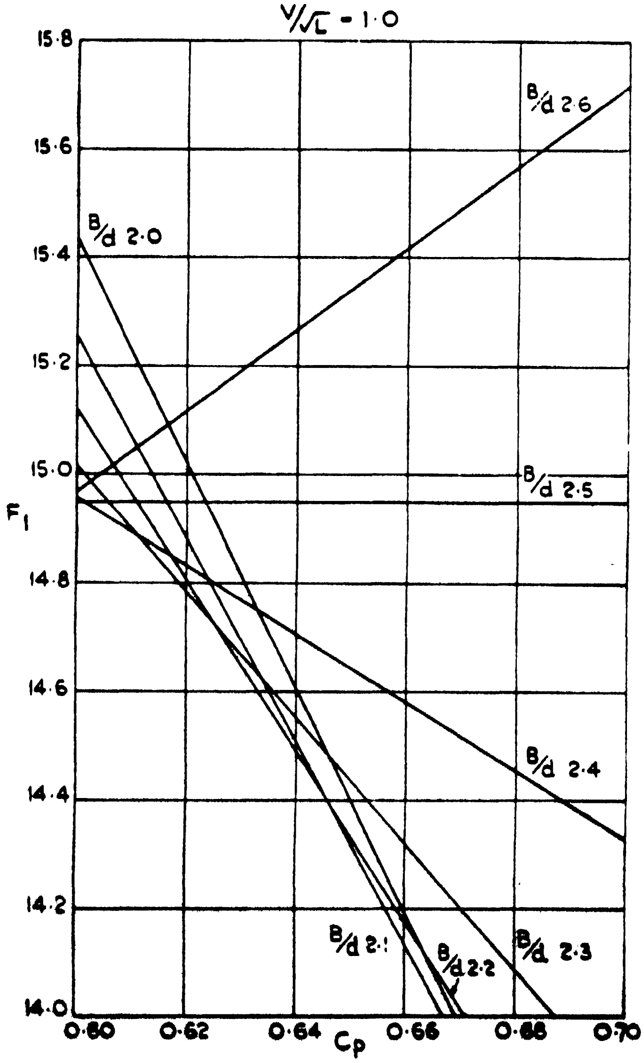


Fig. 351. Change in C_R due to C_p and B/d at $V/\sqrt{L}$=1.00

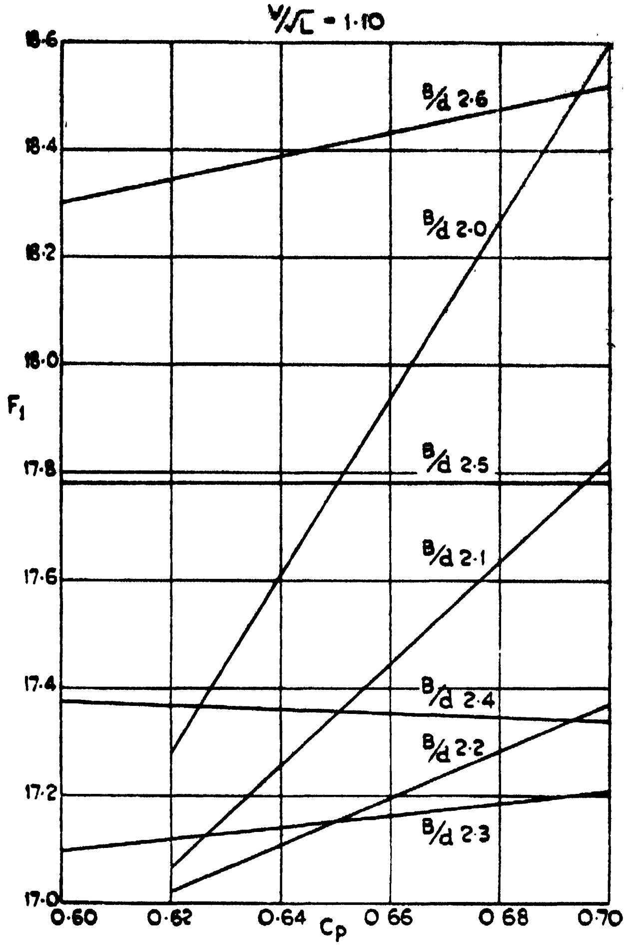


Fig. 352. Change in C_R due to C_p and B/d at $V/\sqrt{L}$=1.10

dicted from this equation is within $\pm\frac{1}{10}$ knot in an individual case, compared with that obtained using the measured tank results. Subsequent to the completion of the analysis, an additional 15 models were tested for the fishing industry and the measured results compared with those predicted from equation (8). It was found that each model was predicted to the same degree of accuracy as that of the original analysis. It should be noted also that the variations in resistance coefficient C_R for the original data are as large as 100 per cent. at each speed-length ratio, and these large variations in C_R have been explained in terms of the six design parameters L/B, B/d, C_m, C_p, LCB and $\frac{1}{2}\alpha_e$.

In view of the closeness of the fit obtained between equation (8) and the measured tank results, it can be seen that terms such as C_p^3, C_p^4, C_p^5, etc. are not required in the regression equation, and this is supported by the fact that standard series results for other ship types seldom reveal variations in resistance with specific design parameters, higher than the second order.

We therefore have a means of predicting total ship resistance at constant speed-length ratio, in which the results for an individual form are conditioned by all the

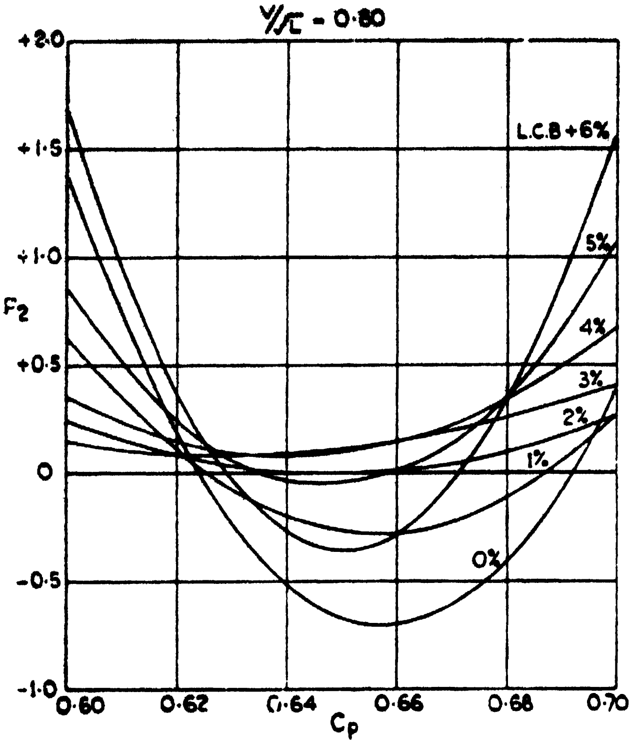


Fig. 353. Change in C_R due to C_p and LCB at $V/\sqrt{L}=0.80$

previously tested models for that particular type. It must be emphasized, however, that the data are applicable to certain limits and that a new regression equation would be required to predict individual freak results which might lie outside these limits of the form parameters.

viz., $C_p=0.60$ to 0.70, $B/d=2.0$ to 2.6, LCB=0 to 6% aft,
$L/B=4.40$ to 5.80, $\frac{1}{2}\alpha_e=5.0$ to 30.0, $C_m=0.81$ to 0.91.

Practical uses of the regression equation

(a) As a predictor of ship resistance. In the case of a new design it is required to find the variation of EHP with the ship speed. To facilitate computation of results, design diagrams have been prepared which depend on the values of the six form parameters L/B, B/d, C_m, C_p, LCB and $\frac{1}{2}\alpha_e$, the value of $C_{R(200\text{ ft.})}$ being obtained at each speed-length ratio by adding the values obtained by interpolation in each diagram.

Fig. 349 to 389 show four components of C_R, namely F_1, F_2, F'_3 and F_4 in diagram form, covering all the possible combinations of L/B, B/d, C_m, C_p, LCB and $\frac{1}{2}\alpha_e$ for the whole ranges of the experiment on these parameters, on the basis of four $V/\sqrt{L}$, namely 0.80, 0.90, 1.00 and 1.10.

These diagrams can be used either to calculate the $C_{R(200\text{ ft.})}$ value for a specific combination of the parameters or to estimate an optimum combination of the parameters for a given $V/\sqrt{L}$.

Here, further explanations will be presented for the case of $V/\sqrt{L}=1.10$.

Consider the case where for a new design the form parameters are:

$C_p=0.60$, $B/d=2.53$, LBC=+4.31% aft, $L/B=5.40$, $\frac{1}{2}\alpha_e=15.0$, $C_m=0.909$.

From fig. 352, 356, 386 and 389 we have

$$F_1 = +17.80$$
$$F_2 = -\ 1.20$$
$$F'_3 = -\ 2.50$$
$$F_4 = \ 0$$

therefore $C_{R(200\text{ ft.})} = 14.10$ at $V/\sqrt{L}=1.10$

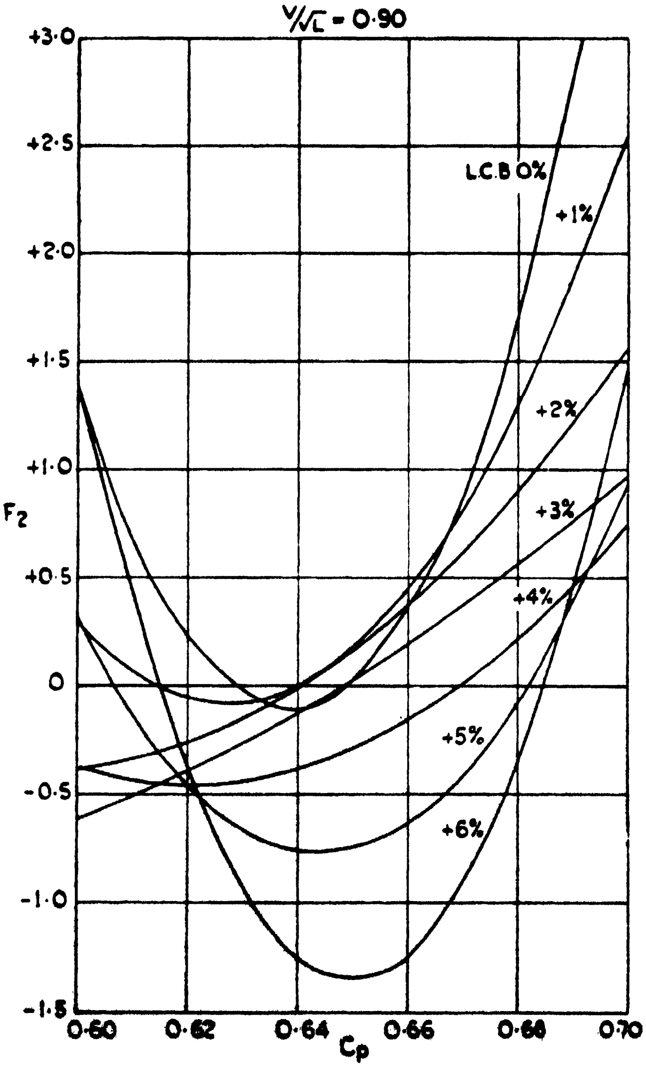


Fig. 354. Change in C_R due to C_p and LCB at $V/\sqrt{L}=0.90$

The C_R value for a ship 180 ft. (55 m.) L is therefore

$C_{R(180\ ft.)} = C_{R(200\ ft.)} + \delta_1$,

where $\delta_1 = \dfrac{152.5 \times (SFC)}{\Delta^{1/3}_{(200\ ft.)}}$ and

(SFC) = Froude skin friction correction from 200 ft. to 180 ft. L.

$\Delta_{(200\ ft.)}$ = Extreme displacement of 200 ft. L vessel (35 cu. ft./ton).

In this case $\Delta_{(200\ ft.)} = 1{,}710$ tons and (SFC) = 0.012.

Hence $\delta_1 = \dfrac{152.5 \times 0.012}{11.97} = 0.153$

Hence $C_{R(180\ ft.)} = 14.10 + 0.153 = 14.253$

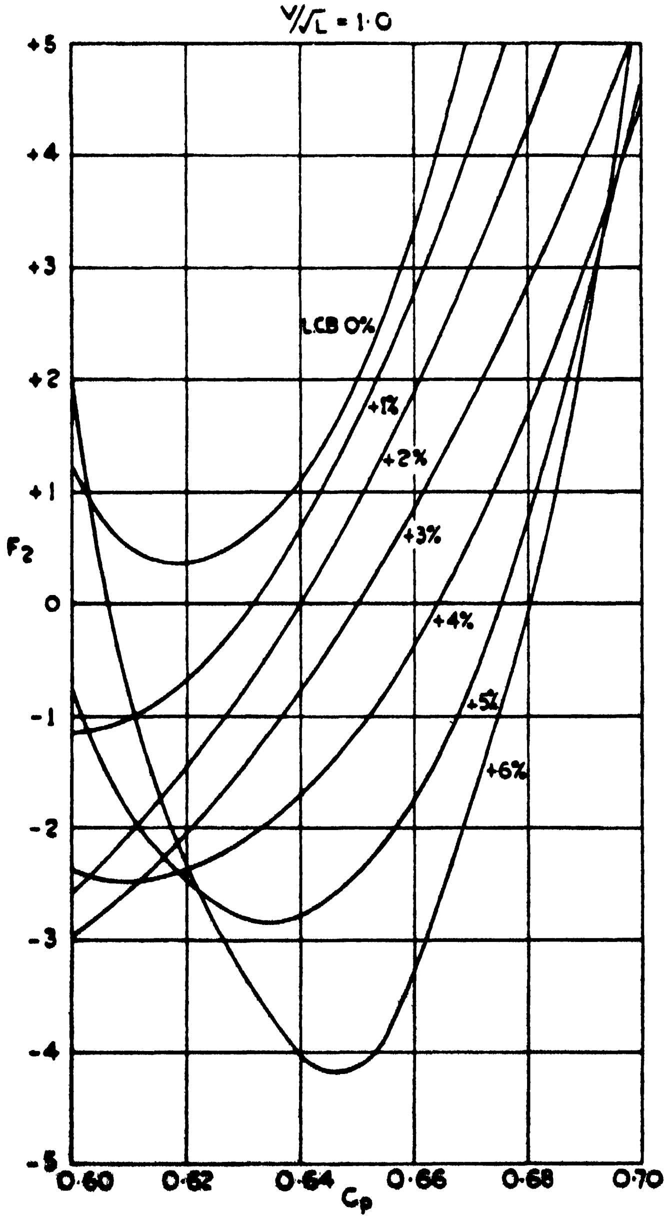


Fig. 355. Change in C_R due to C_p and LCB at $V/\sqrt{L} = 1.00$

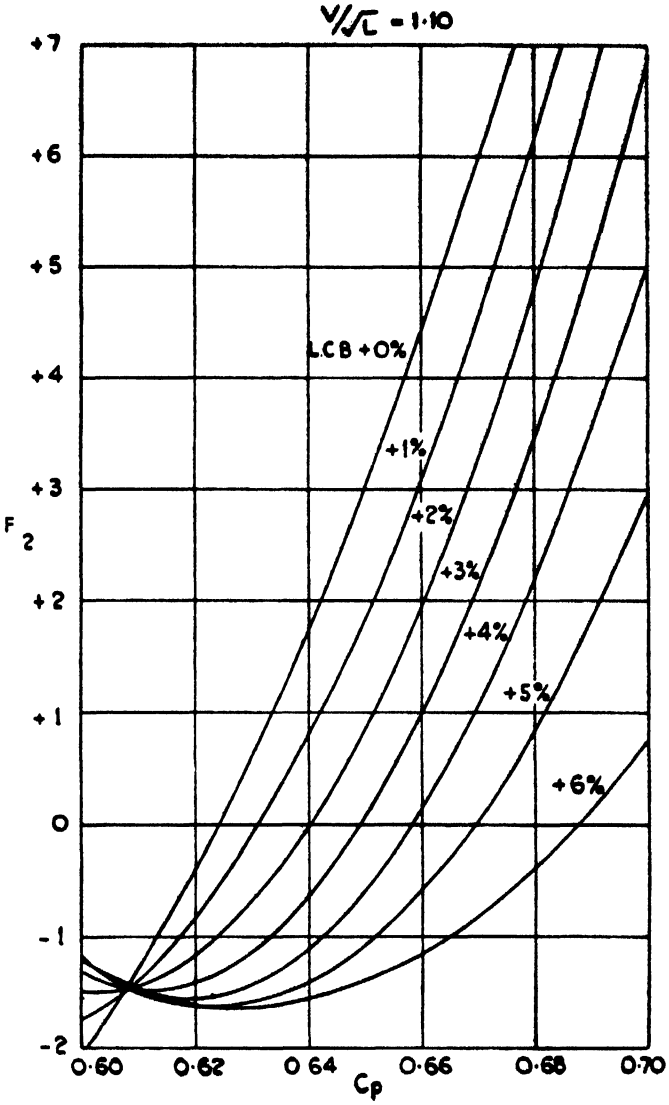


Fig. 356. Change in C_R due to C_p and LCB at $V/\sqrt{L} = 1.10$

and EHP (Froude) $= \dfrac{C_{R(L)} \times \Delta_{(L)} \times V^3}{325.7 \times L}$

$= \dfrac{14.253 \times 1250 \times (14.76)^3}{325.7 \times 180}$

therefore EHP (Froude) = 975

In a similar manner the EHP values at other ship speeds can be calculated to deduce the EHP-speed curve for the ship.

(b) As a design method. By referring to the design diagrams, certain optimum form characteristics are revealed. It can be seen from fig. 352 that minimum resistances are obtained in the region B/d = 2.25 over most of the range of prismatic coefficient C_p 0.60 to 0.70.

The beneficial effect of moving the LCB position further aft, up to 6 per cent. from amidships, can be seen in fig. 356, the reduction in resistance being greater

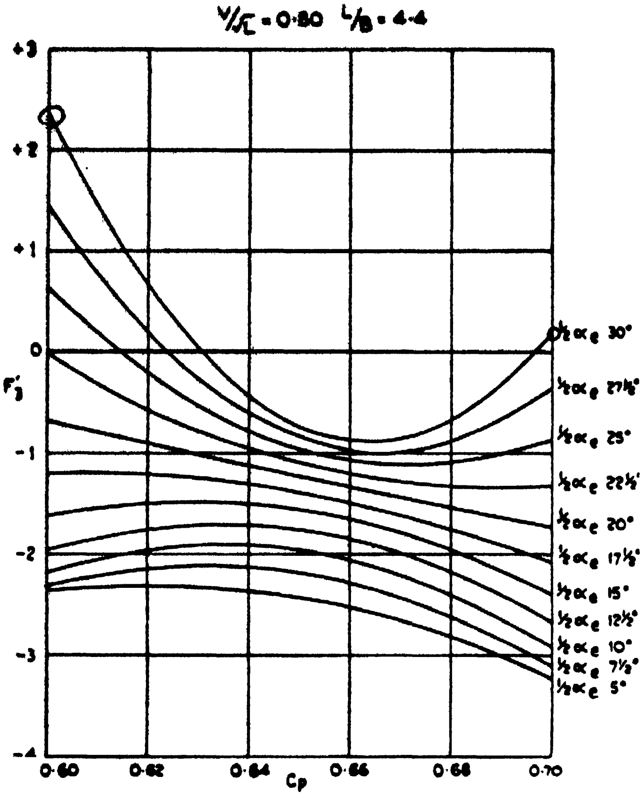


Fig. 357. Change in C_R due to C_p and ½α_e at $V/\sqrt{L}$ = 0.80 and L/B = 4.4

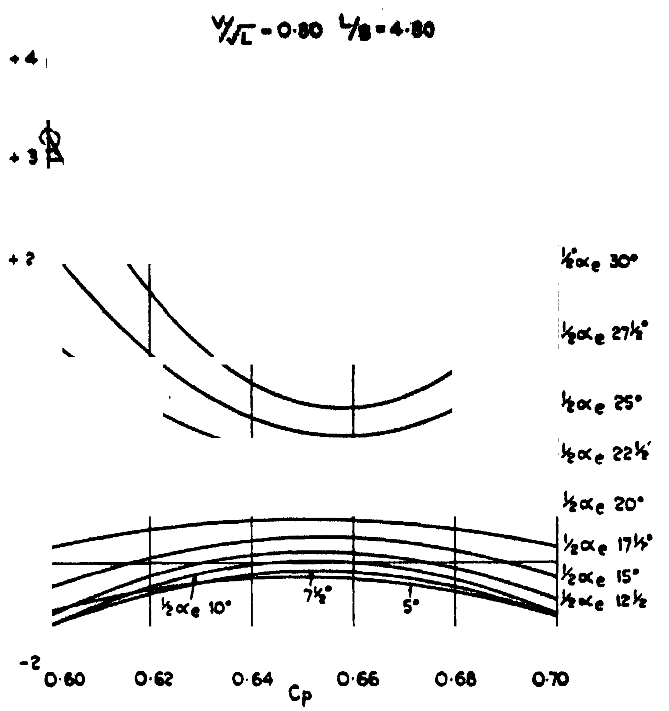


Fig. 359. Change in C_R due to C_p and ½α_e at $V/\sqrt{L}$ = 0.80 and L/B = 4.8

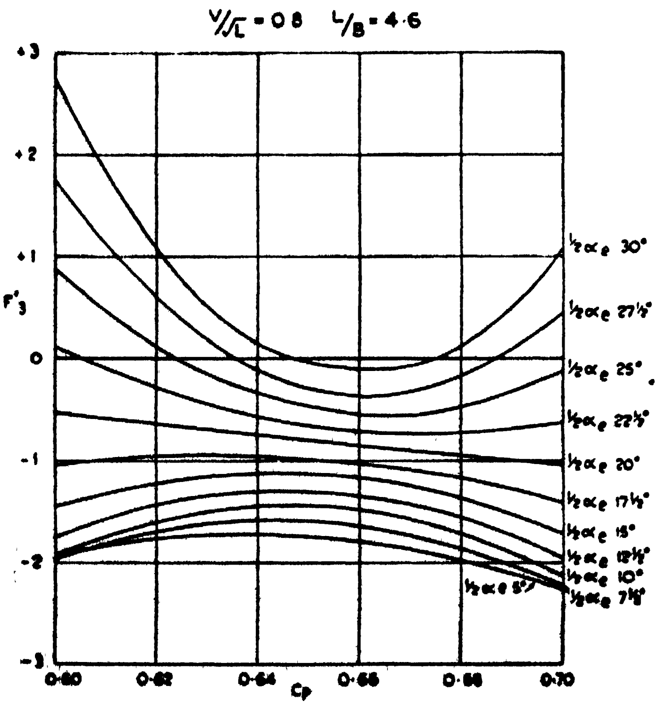


Fig. 358. Change in C_R due to C_p and ½α_e at $V/\sqrt{L}$ = 0.80 and L/B = 4.6

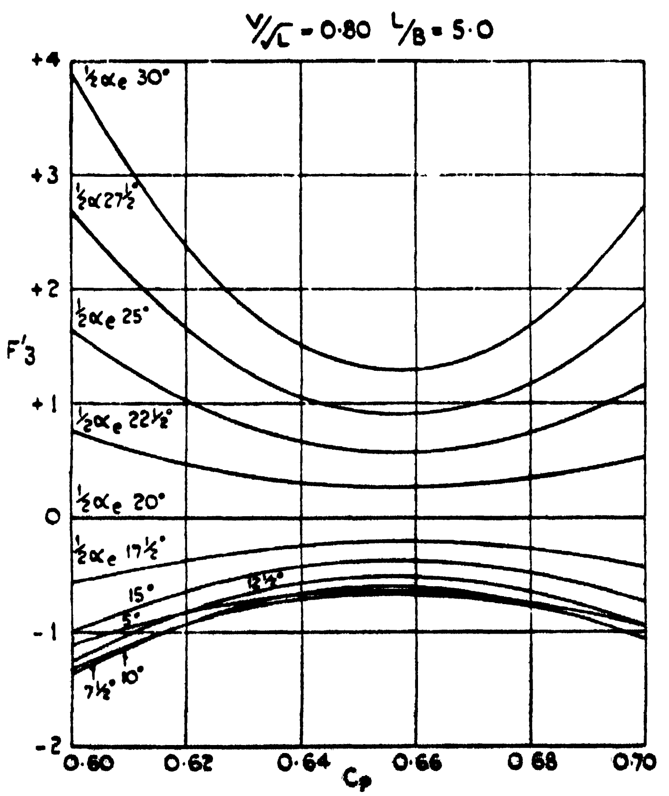
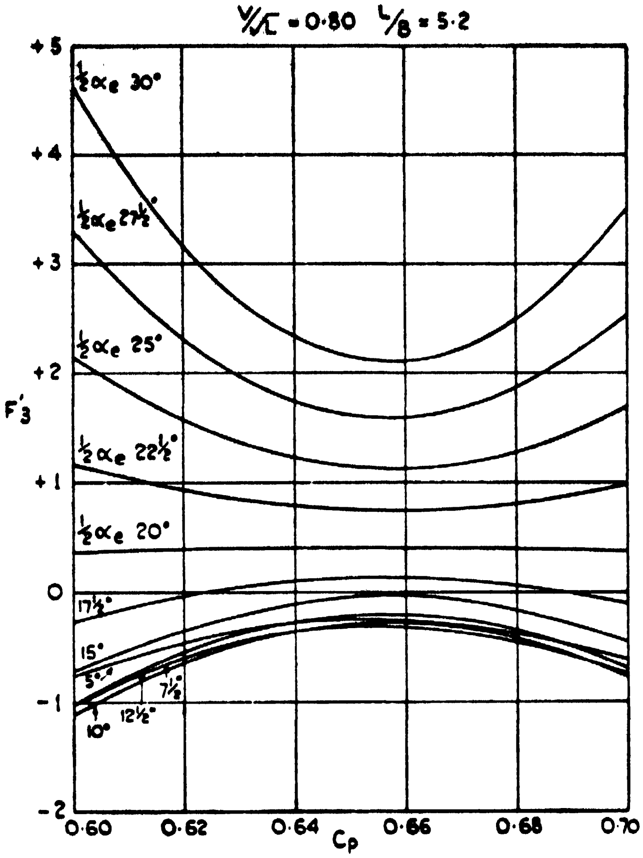
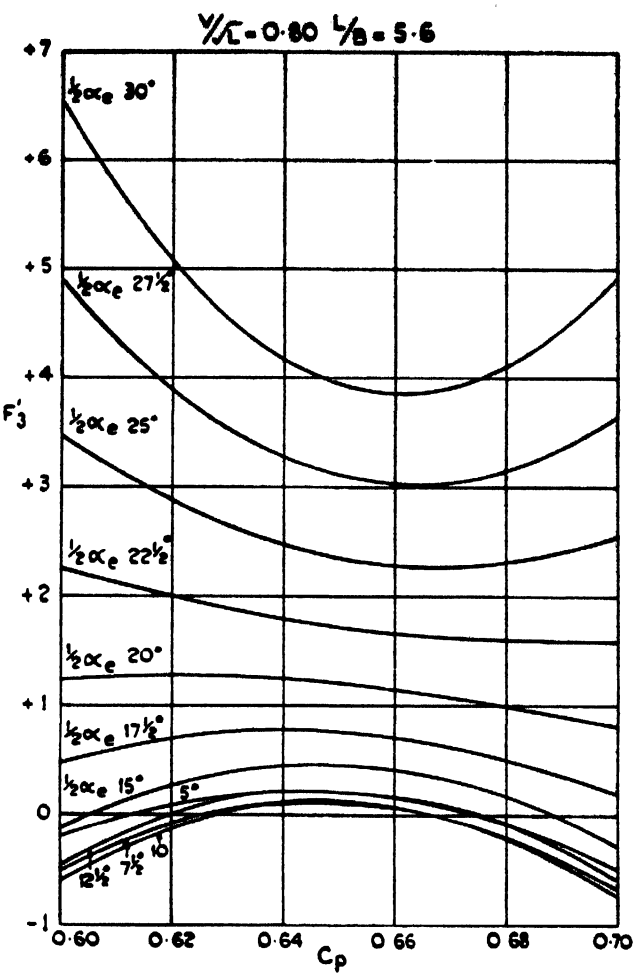
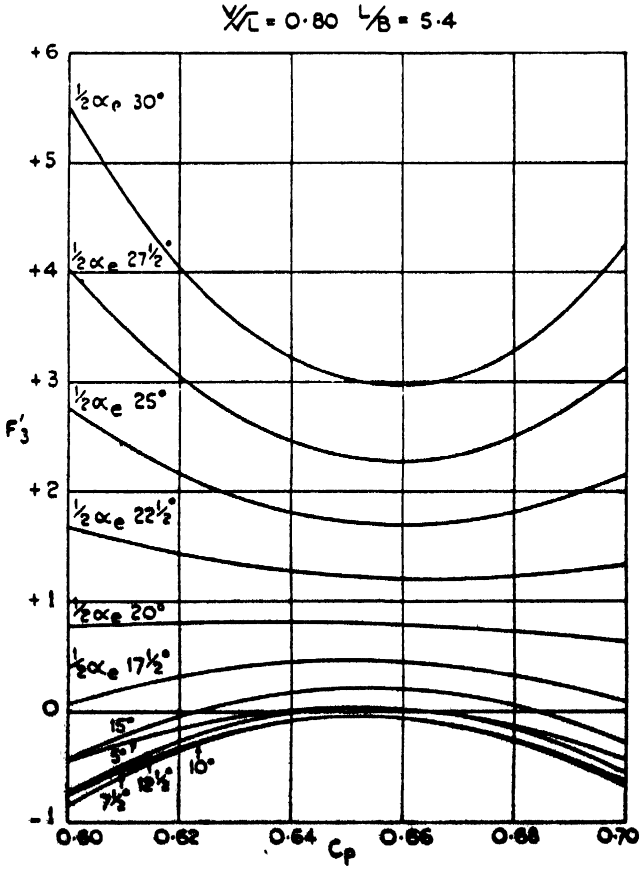


Fig. 360. Change in C_R due to C_p and ½α_e at $V/\sqrt{L}$ = 0.80 and L/B = 5.0







TOP LEFT

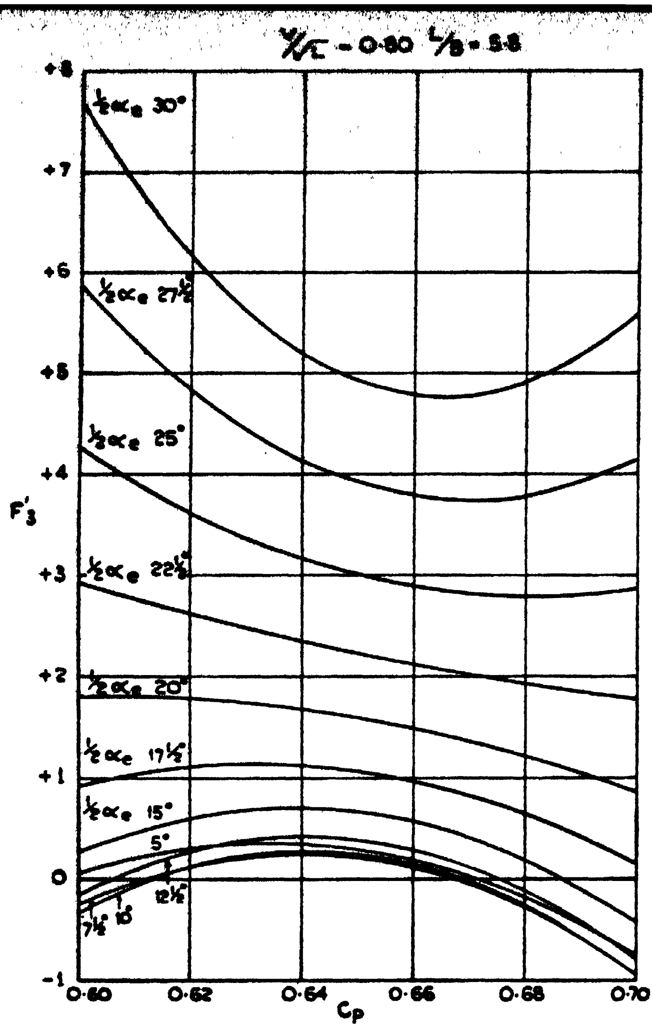
Fig. 361. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L}$ 0.80 and L/B 5.2

LEFT

Fig. 362. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L}$ 0.80 and L/B 5.4

ABOVE

Fig. 363. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L}$ 0.80 and L/B 5.6



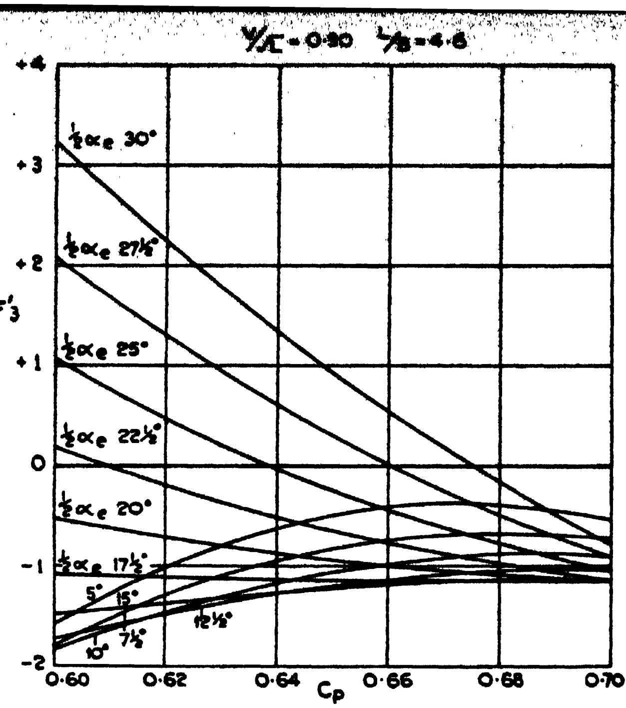


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Fig. 364. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L} = 0.80$ and $L/B = 5.8$

LEFT

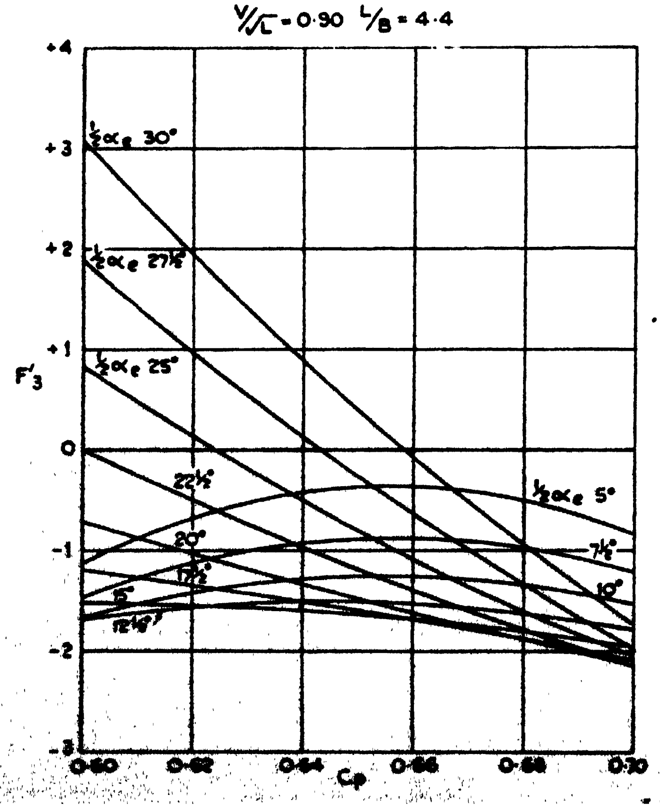
Fig. 365. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L} = 0.90$ and $L/B = 4.4$

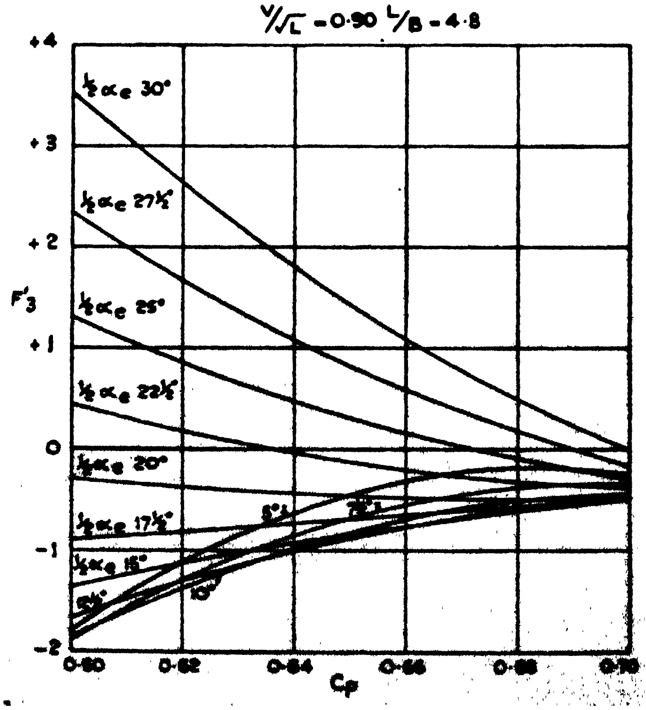
ABOVE

Fig. 366. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L} = 0.90$ and $L/B = 4.6$

BELOW

Fig. 367. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L} = 0.90$ and $L/B = 4.8$





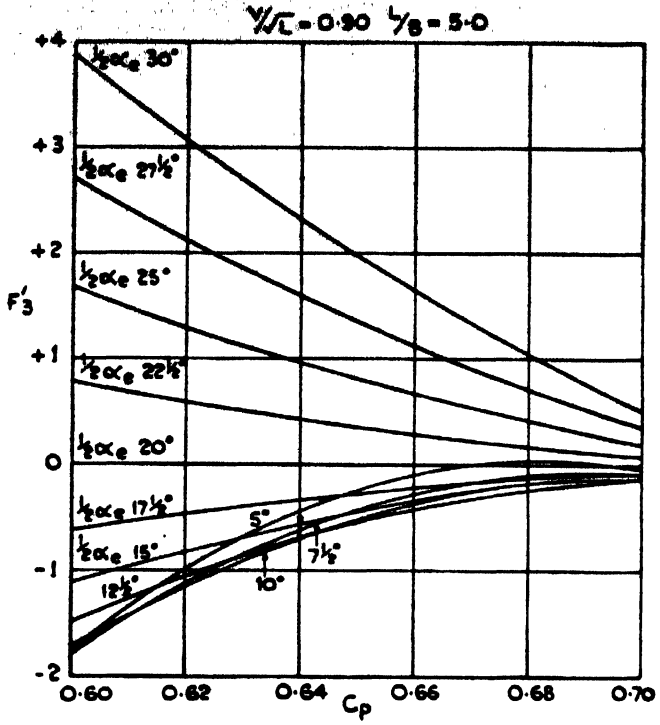


Fig. 368. Change in C_R due to C_p and ½α_e at $V/\sqrt{L}$ = 0.90 and L/B = 5.0

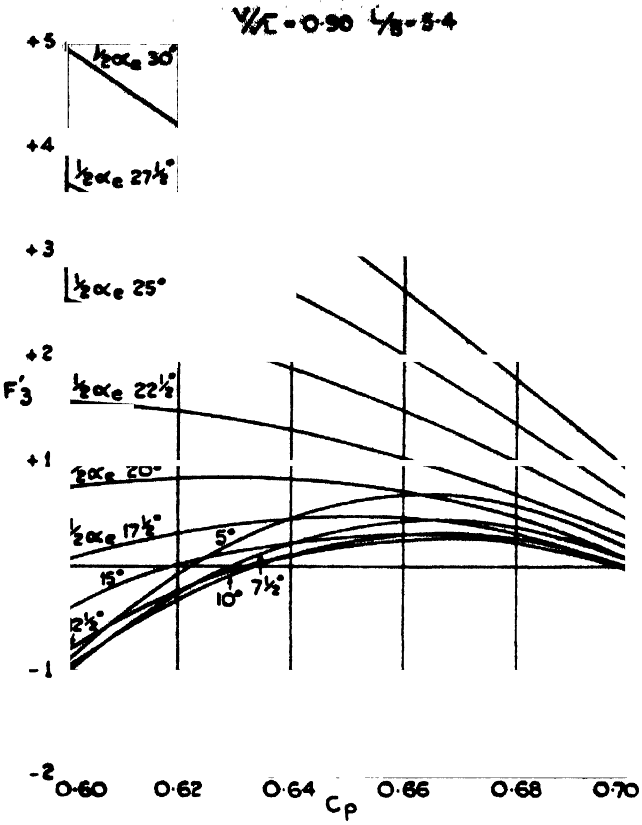


Fig. 370. Change in C_R due to C_p and ½α_e at $V/\sqrt{L}$ = 0.90 and L/B = 5.4

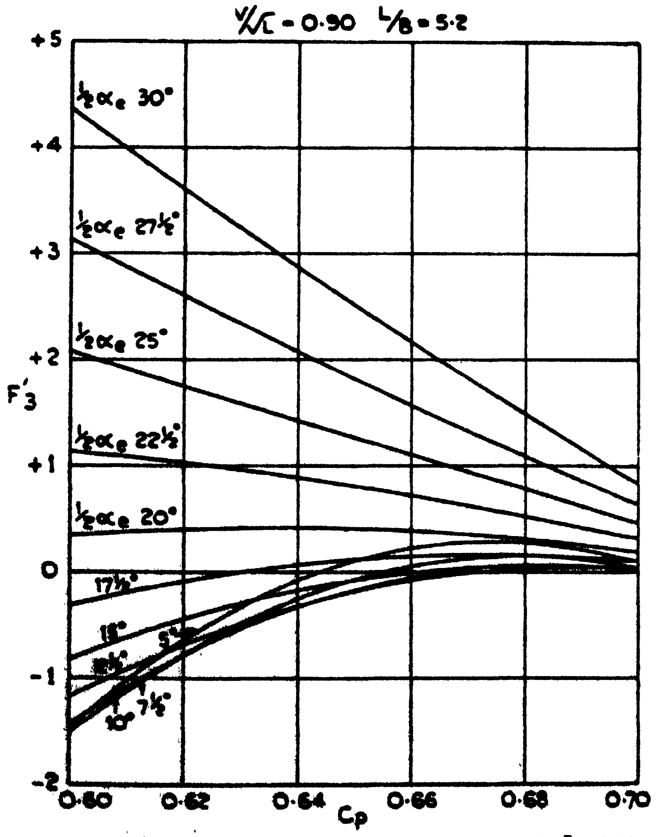


Fig. 369. Change in C_R due to C_p and ½α_e at $V/\sqrt{L}$ = 0.90 and L/B = 5.2

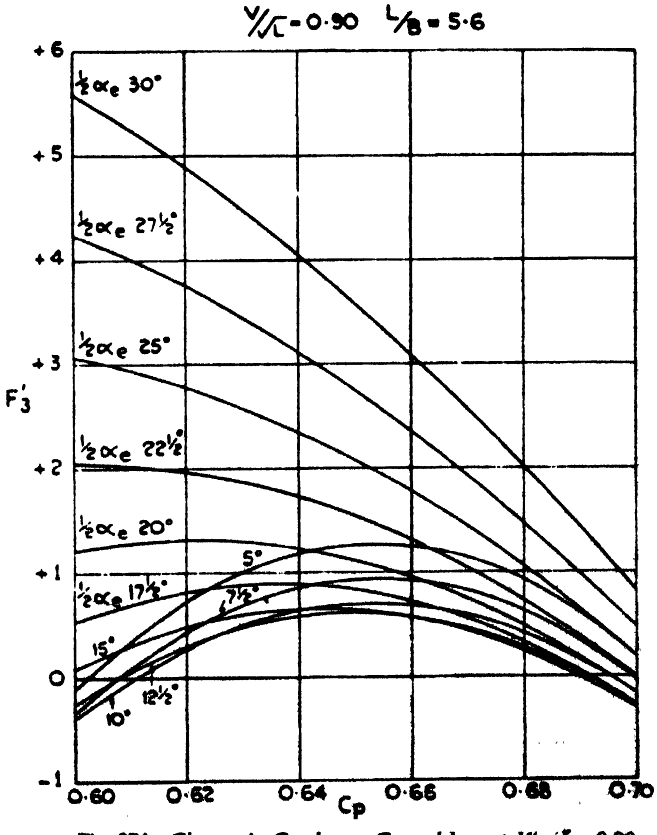


Fig. 371. Change in C_R due to C_p and ½α_e at $V/\sqrt{L}$ = 0.90 and L/B = 5.6

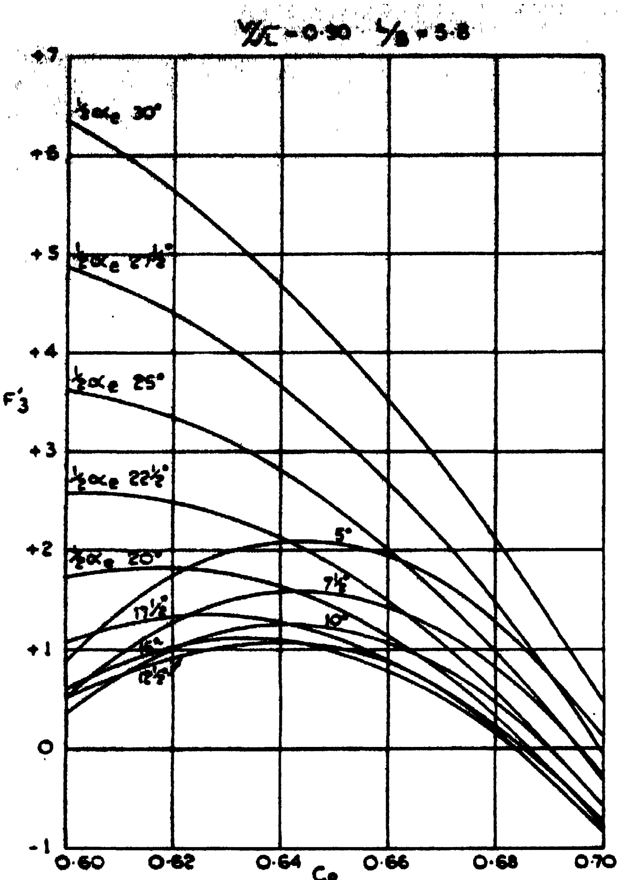


Fig. 372. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L}=0.90$ and $L/B=5.8$

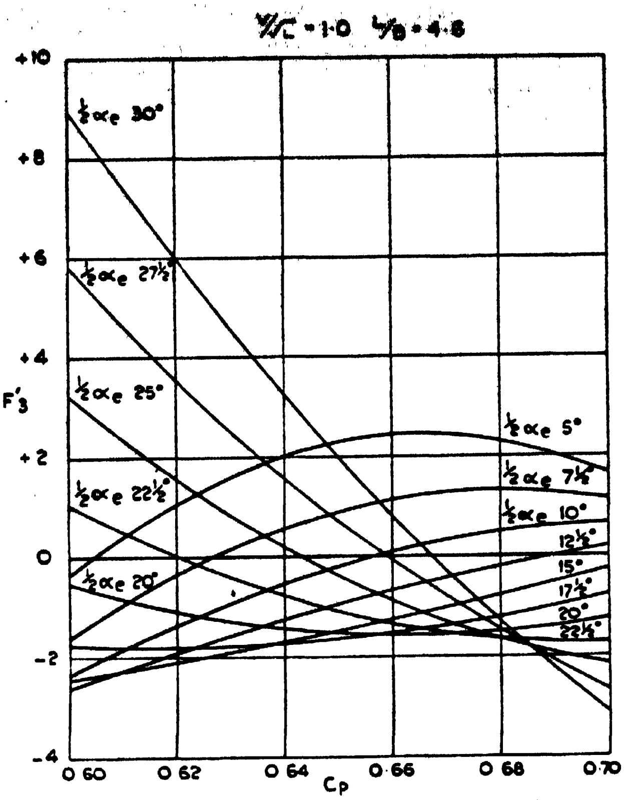


Fig. 374. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L}=1.00$ and $L/B=4.6$

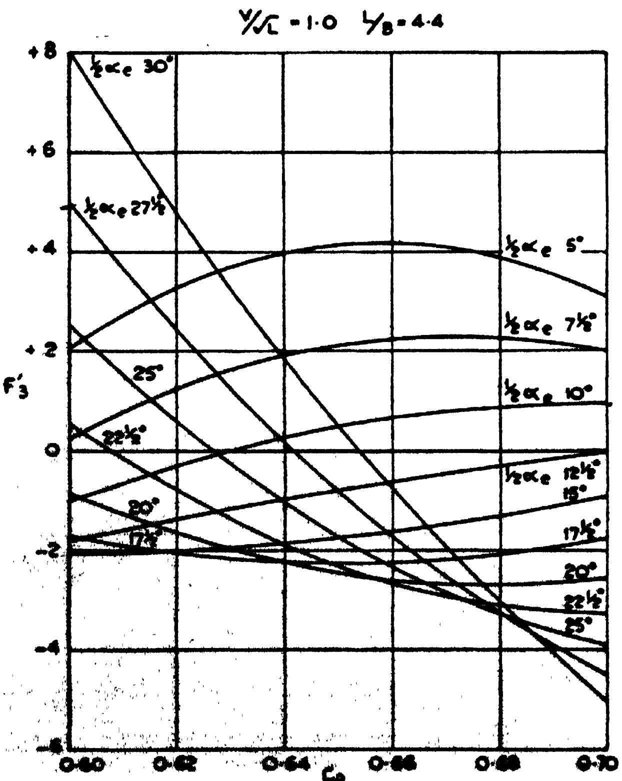


Fig. 373. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L}=1.00$ and $L/B=4.4$

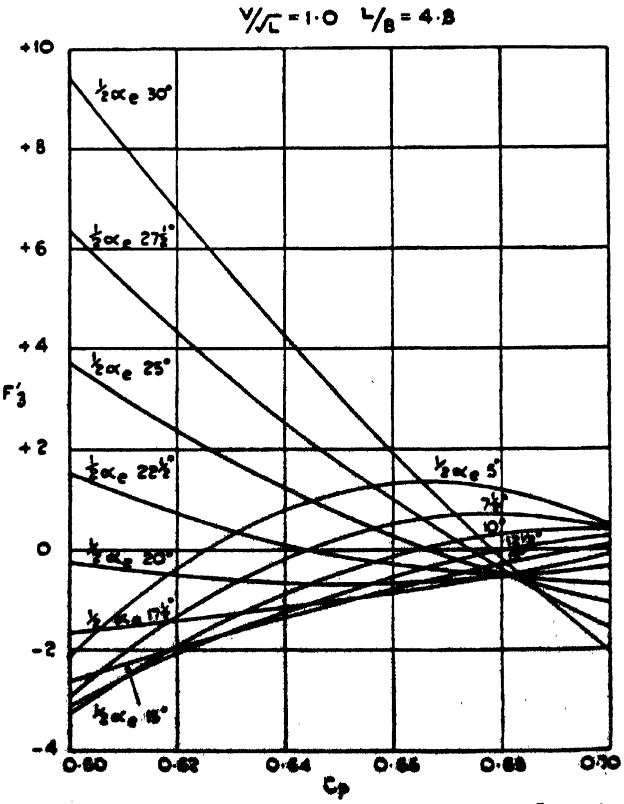


Fig. 375. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L}=1.00$ and $L/B=4.8$

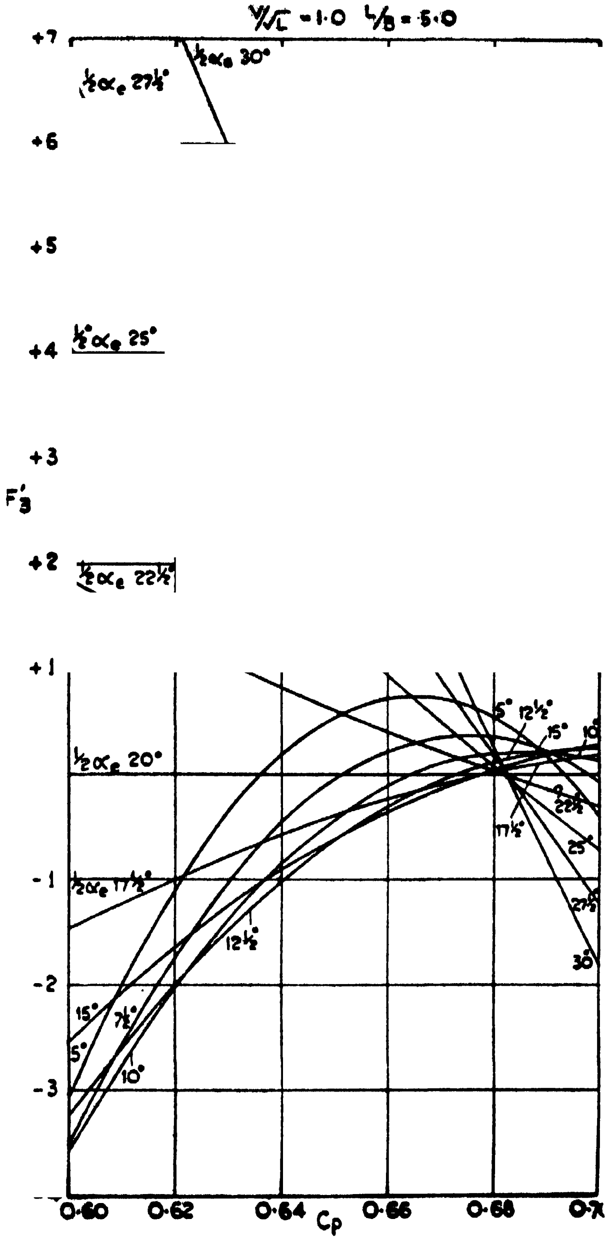


Fig. 376. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L}=1.00$ and $L/B=5.0$

for the forms of high prismatic coefficient. Optimum values of $\frac{1}{2}\alpha_e$, the half angle of entrance of the load waterplane, depend on the values of C_p and L/B, and for each combination of these parameters the best value of $\frac{1}{2}\alpha_e$ can be obtained from the relevant diagram. The effect of increasing the maximum area coefficient C_m is generally beneficial in reducing resistance, although at $V/\sqrt{L}=1.10$ it is relatively unimportant. As far as the effect of changes in prismatic coefficient on resistance is concerned, it can be seen that this depends on the magnitude of B/d, LCB, $\frac{1}{2}\alpha_e$ and L/B and is difficult to present in a single diagram, since the number of practical combinations of these four parameters is almost infinite. General trends may however be inferred, by considering each trawler type and choosing representative parameters for each (see worked example).

The effect on resistance of changes in L/B ratio is dependent on the values of $\frac{1}{2}\alpha_e$ and C_p for each speed-length ratio. For fixed values of $\frac{1}{2}\alpha_e$ it will be seen in fig. 381 to 388 that the effect on resistance of changes

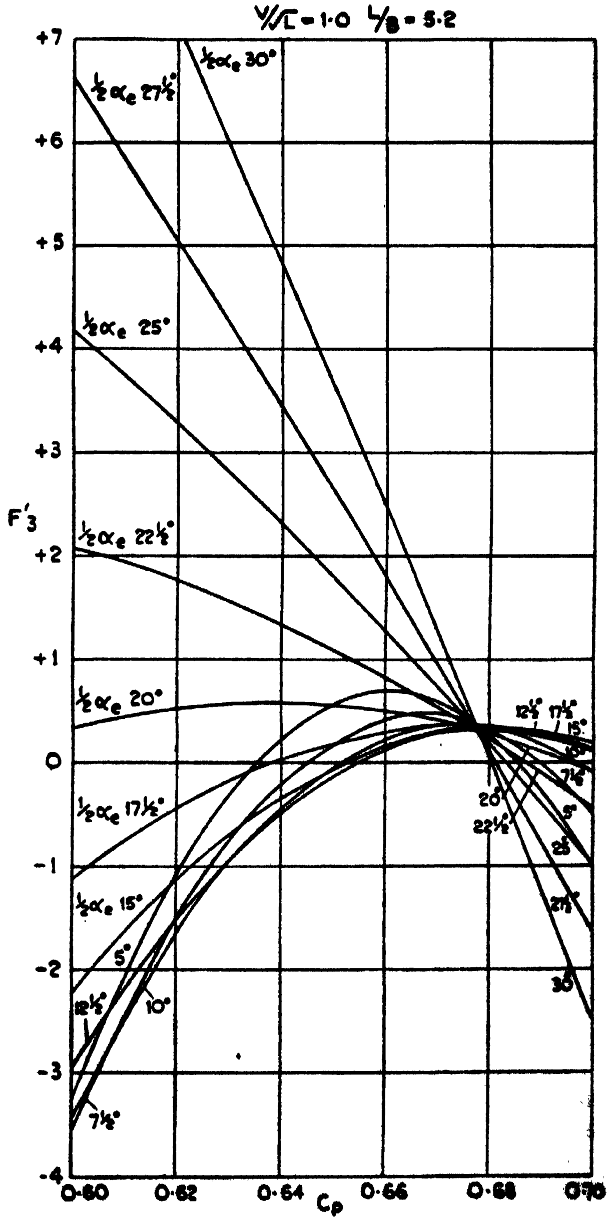


Fig. 377. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L}=1.00$ and $L/B=5.2$

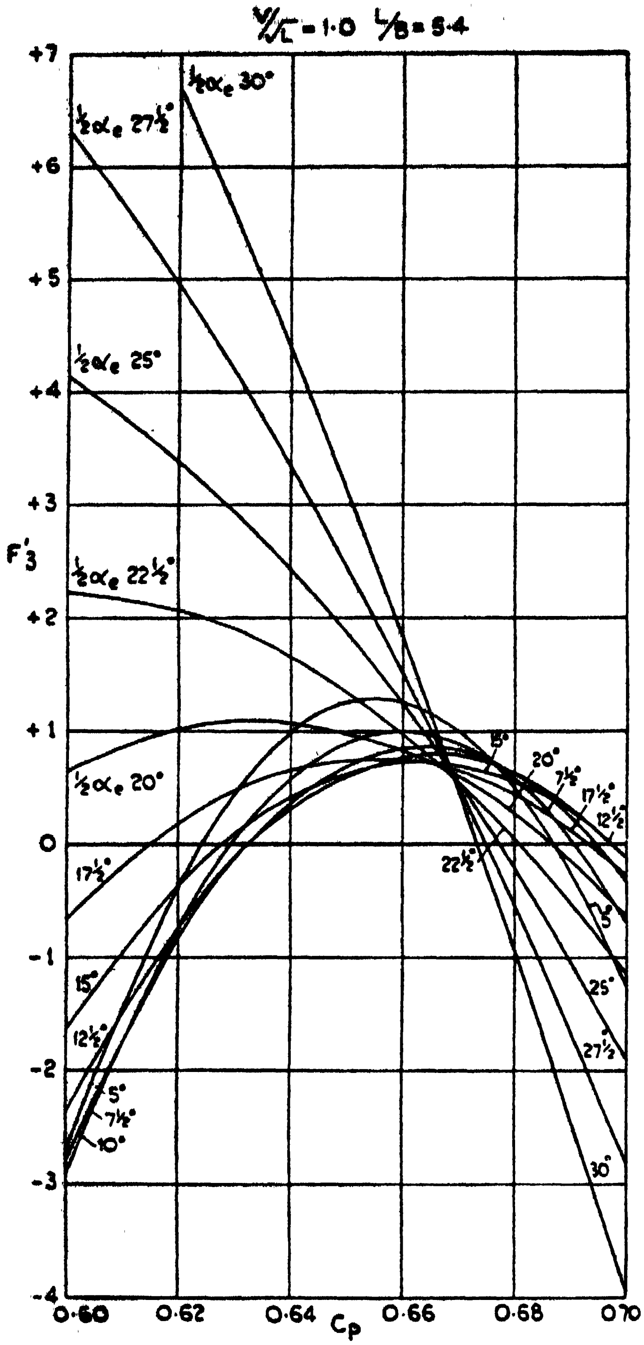


Fig. 378. Change in C_R due to C_p and ½α_e at $V/\sqrt{L}=1.00$ and $L/B=5.4$

in L/B ratio is more marked with the forms of high prismatic coefficient. For L/B ratios in the region 5.6 to 5.8 there is a marked reduction in resistance, whilst maximum resistances usually occur in the range L/B 4.4 to 5.0.

In addition to these design diagrams, a programme has been prepared for a high-speed digital computer (DEUCE), so that values of C_R may be obtained very quickly for any required combination of design parameters. Table 94 has been prepared, and shows the effects on C_R of systematic changes in the form parameters of a typical deep-sea trawler. For this form, at $V/\sqrt{L}=1.10$, the following form parameters give the best results.

viz. ½α_e=5°
LCB=2.5% aft of amidships
C_p=0.60
C_m=unimportant
B/d=2.20
L/B=unimportant

In this way the EHP-speed characteristics can be evaluated for each combination of design parameters, and the best form deduced.

Again, supposing that non-optimum characteristics have to be accepted due to other design considerations, the penalty in resistance may be calculated for these non-optimum conditions relative to the minimum values.

Conclusions

- By using the method described, the resistance-speed curves of trawler forms can be calculated from their lines plans with sufficient accuracy for practical purposes

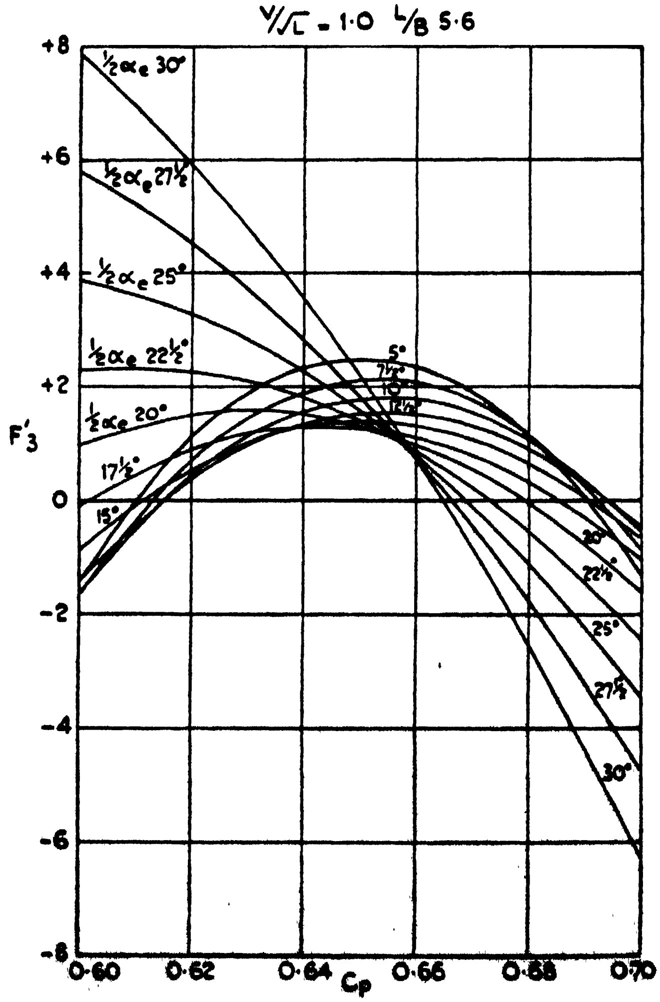
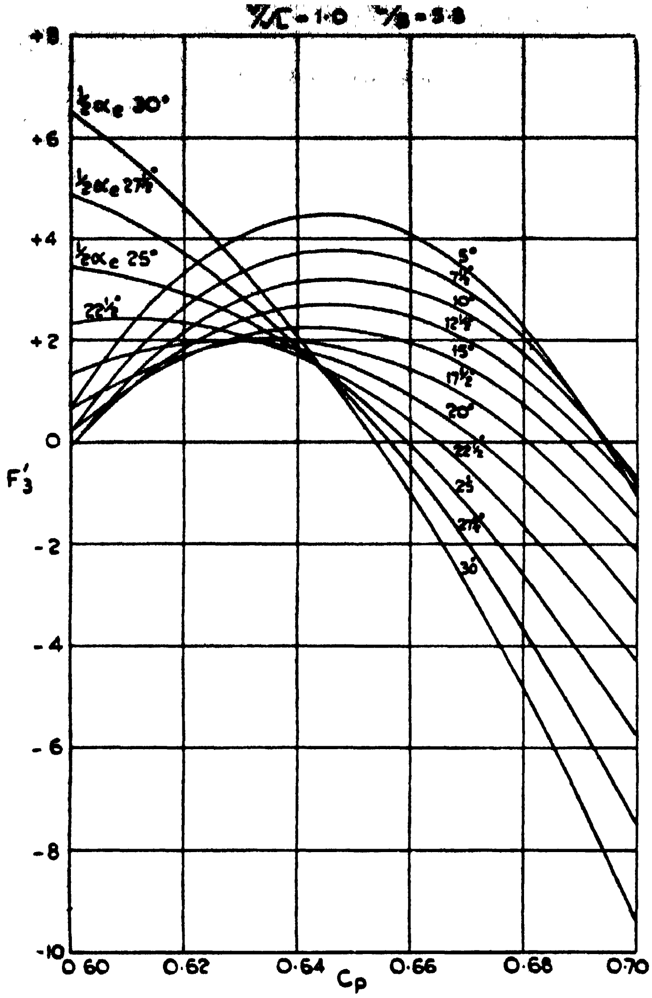
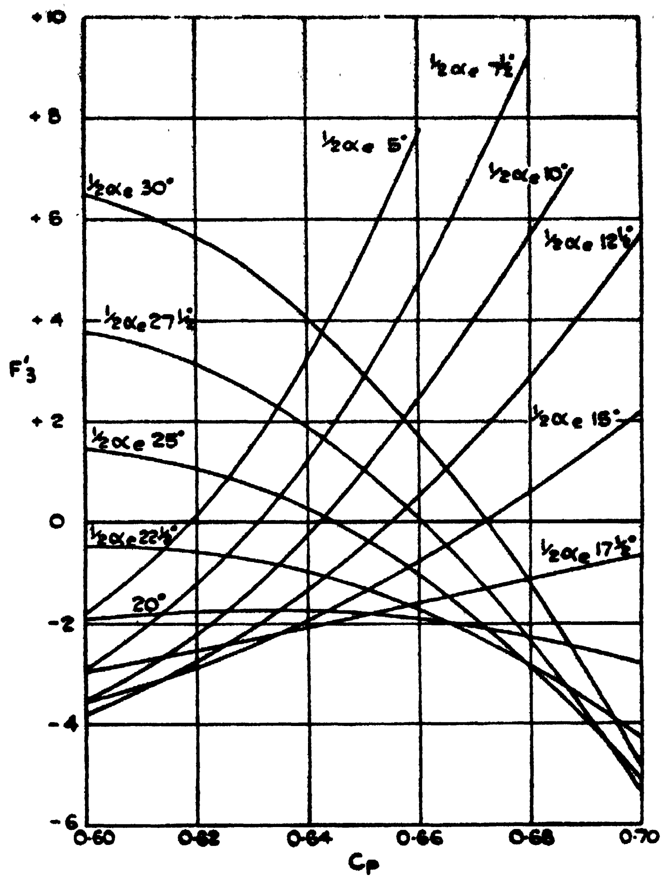
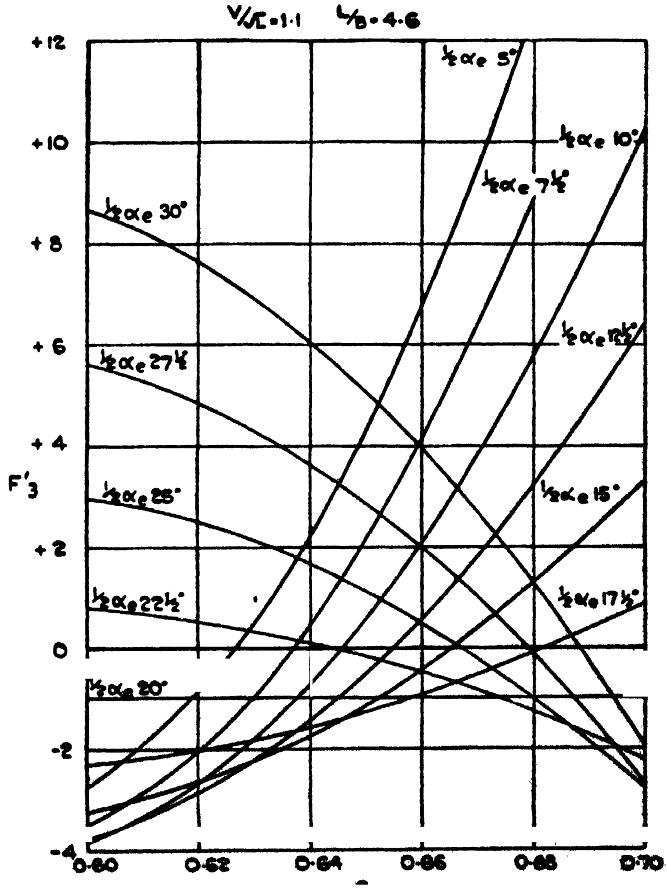


Fig. 379. Change in C_R due to C_p and ½α_e at $V/\sqrt{L}=1.00$ and $L/B=5.6$







ABOVE

Fig. 380. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L} = 1.00$ and $L/B = 5.8$

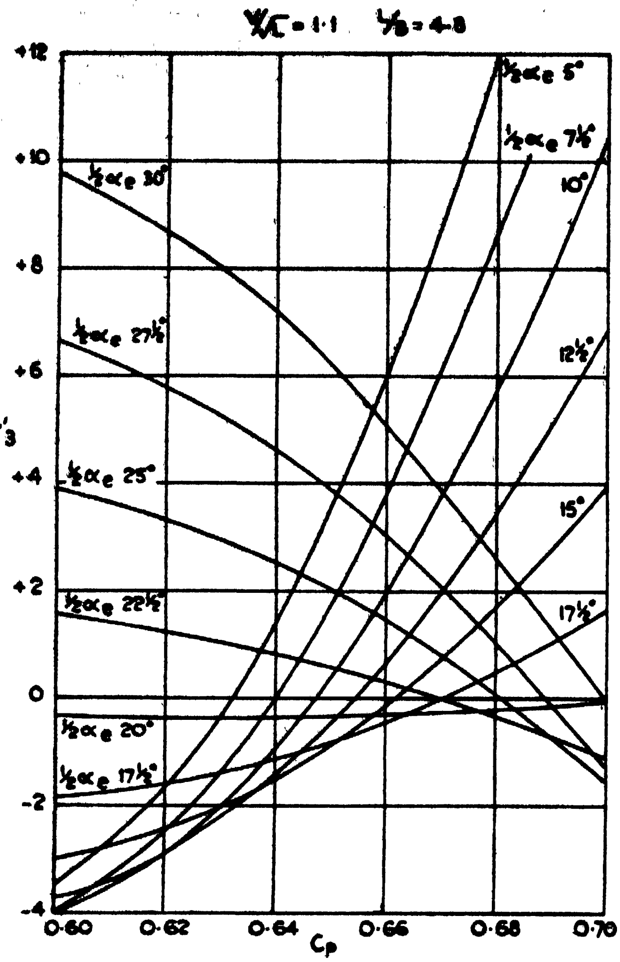
TOP RIGHT

Fig. 381. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L} = 1.10$ and $L/B = 4.4$

RIGHT

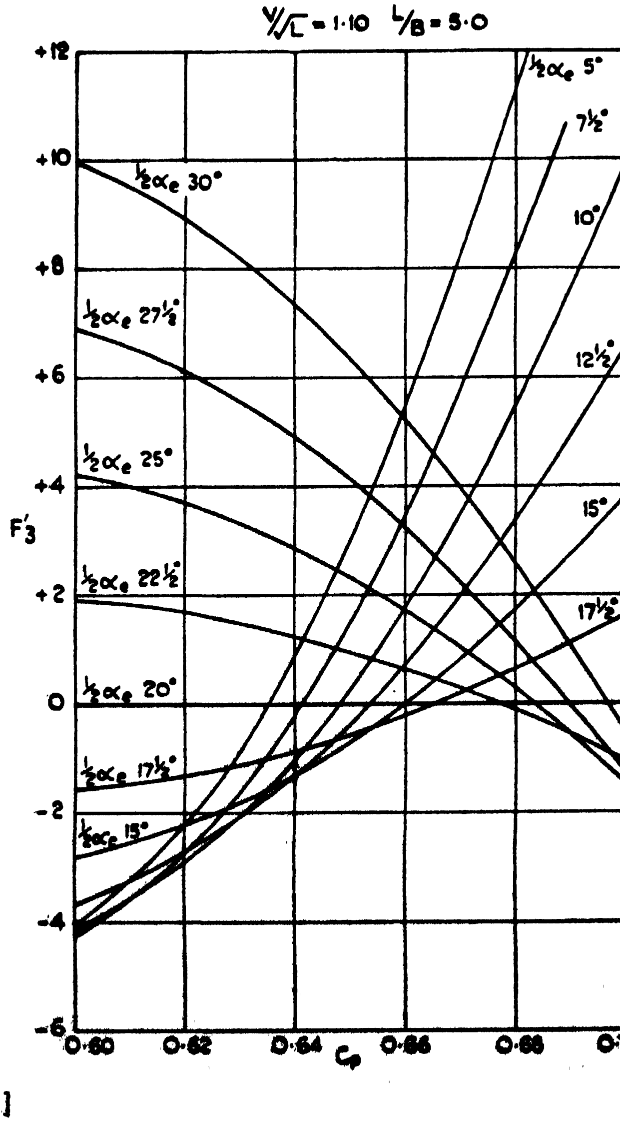
Fig. 382. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L} = 1.10$ and $L/B = 4.6$

- **Optimum design parameters can be determined either for general or particular cases and penalties in resistance estimated for non-optimum conditions**
- **The analysis has confirmed the high importance of LCB position in determining the resistance of trawler forms, and also the relative importance of the other form parameters**



LEFT
Fig. 383. Change in C_R due to C_p and ½α_e at V/√L = 1.10 and L/B = 4.8

RIGHT
Fig. 384. Change in C_R due to C_p and ½α_e at V/√L = 1.10, and L/B = 5.0



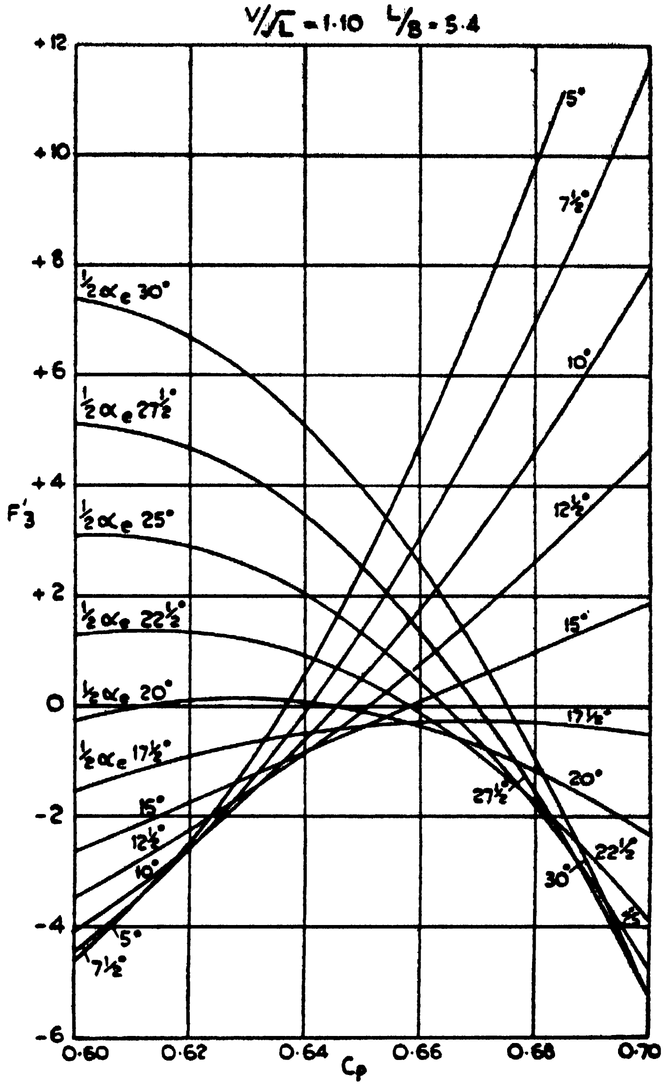


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Fig. 386. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L}$ - 1.10 and L/B - 5.4

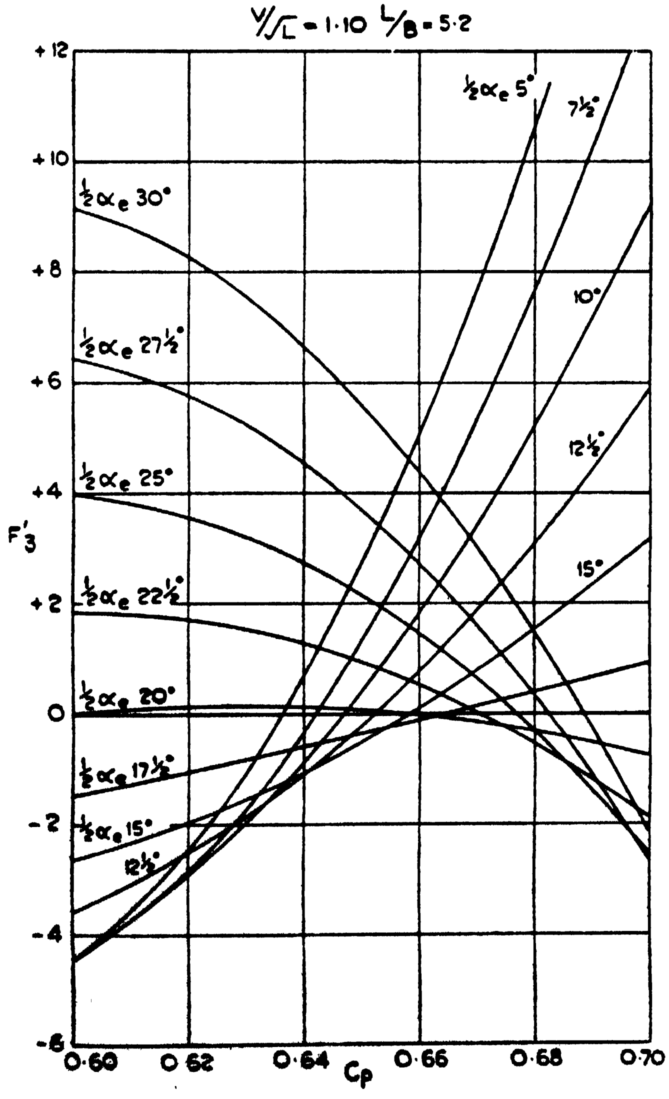

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Fig. 385. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L}$ = 1.00 and L/B = 5.2

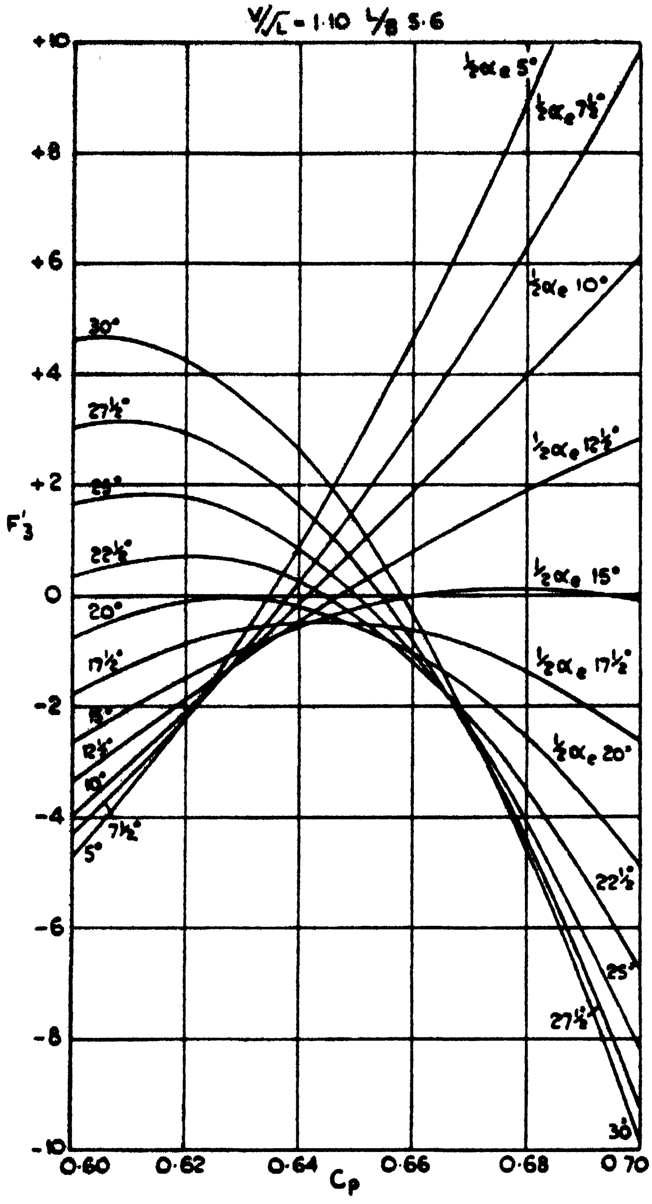

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Fig. 387. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L} = 1.10$ and $L/B = 5.6$

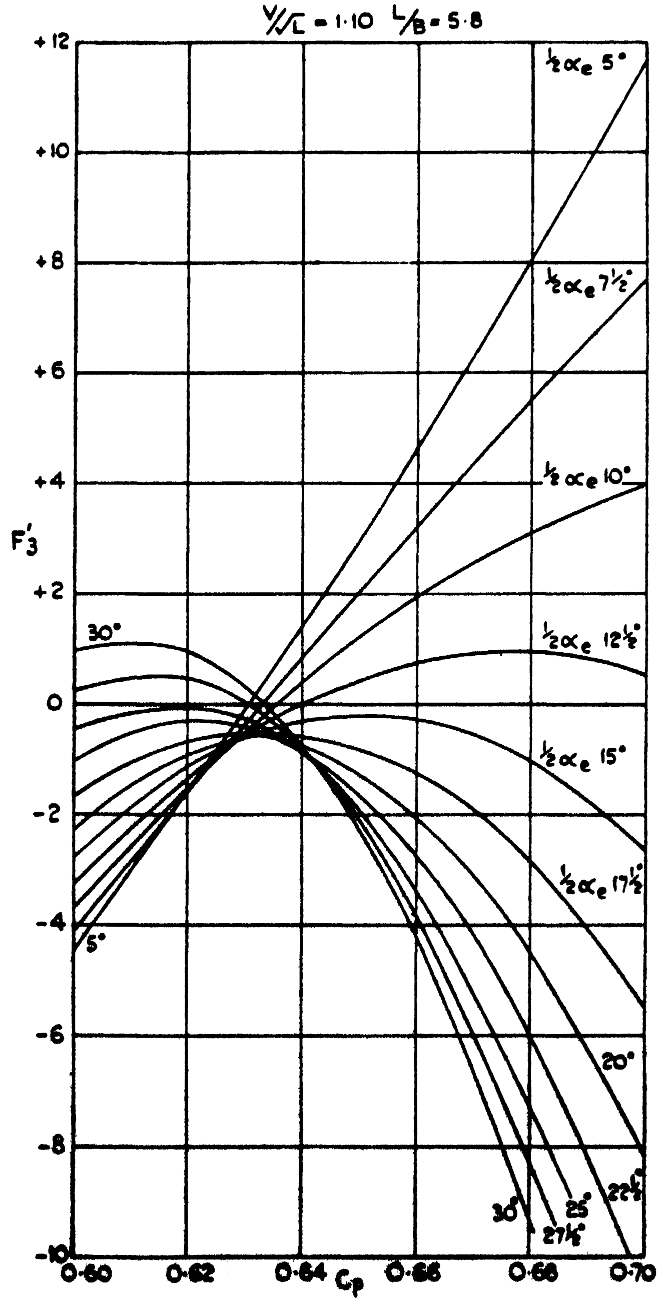

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Fig. 388. Change in C_R due to C_p and $\frac{1}{2}\alpha_e$ at $V/\sqrt{L} = 1.10$ and $L/B = 5.8$

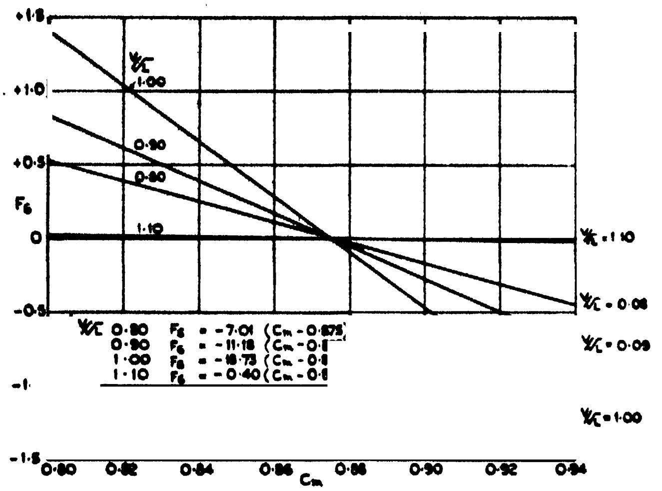


Fig. 389. Change in C_R due to C_p

- The method is considered to have a more general application to other ship types for which the variation in total resistance, due to changes in form parameters, are generally smaller in magnitude compared with trawler forms

- Finally, a cautious approach to the use of this type of analysis is recommended and more experience is necessary before it can be unconditionally recommended. There is no suggestion at this stage that the various expressions derived are the final word on the subject. They may have to be improved or modified in the light of new results. However, the method can be used for estimating purposes and to suggest modifications in the hull form of trawlers but, at the present time, these should be checked by model experiments. The method must not be used for values of parameters outside the range of those in the data, or estimates may be grossly in error. Eventually, tank-testing may not be necessary except for designs which are clearly revolutionary in concept.

This work forms part of the research programme of NPL and is published by permission of the Director of the Laboratory. The author wishes to acknowledge the assistance given by Mathematics Division, NPL, in computing the results, particularly Mr. J. G. Hayes who determined the required regression coefficients and advised on the statistical work. Thanks is also due to the North East Coast Institution of Engineers and Shipbuilders for permission to reproduce fig. 347 to 389.

TABLE 94

The effects on C_R of systematic changes in form parameters

L/B	B/T	C_m	C_p	LCB%	$\frac{1}{2}\alpha_e$	Resistance coefficient $C_{R(400 ft)}$ $V/\sqrt{L}=0.80$	$V/\sqrt{L}=0.90$	$V/\sqrt{L}=1.00$	$V/\sqrt{L}=1.10$
VARIATIONS IN C_p									
5.40	2.53	0.909	0.61	+4.31	15.0	9.23	9.59	11.06	14.26
			0.62			9.29	9.68	11.53	14.62
			0.63			9.35	9.75	12.11	15.17
			0.64			9.41	9.91	12.78	15.90
VARIATIONS IN B/d									
5.40	2.20	0.909	0.60	+4.31	15.0	9.08	9.34	10.85	13.10
	2.30					9.11	9.38	10.76	13.27
	2.40					9.14	9.43	10.70	13.55
	2.60					9.19	9.58	10.70	14.46
VARIATIONS IN LCB									
5.40	2.53	0.909	0.60	+2.50	15.0	8.85	9.18	9.75	13.89
				+3.00		8.84	9.12	9.68	13.97
				+3.50		8.91	9.18	9.86	14.03
				+4.00		9.05	9.35	10.29	14.08
				+4.50		9.27	9.64	10.97	14.10
				+5.00		9.56	10.04	11.91	14.10
VARIATIONS IN L/B									
5.20	2.53	0.909	0.60	+4.31	15.0	8.87	9.12	10.12	14.04
5.30						9.02	9.31	10.37	14.08
5.50						9.34	9.75	11.06	14.09
5.60						9.51	10.00	11.49	14.07
VARIATIONS IN $\frac{1}{2}\alpha_e$									
*5.40	2.53	0.909	0.60	+4.31	15.0	9.17	9.52	10.68	14.09
					12.5	8.87	9.16	9.98	13.24
					10.0	8.76	8.96	9.56	12.62
					7.5	8.85	8.92	9.44	12.23
					5.0	9.14	9.02	9.61	12.08
VARIATIONS IN C_m									
5.40	2.53	0.89	0.60	+4.31	15.0	9.31	9.73	11.04	14.10
		0.92				9.10	9.40	10.48	14.09
		0.93				9.03	9.28	10.29	14.08
		0.94				8.96	9.17	10.10	14.08

*Basic form

THE LOADS IMPOSED BY TRAWLING GEAR

by

W. DICKSON

Between the extremes of speed trials on the one hand and the occasional bollard pull test on the other lies the case recording of towing performance—the essential criterion of a trawler. The towing performance of two trawlers of very different size, an Arctic trawler and a pocket trawler, is set out in tabular form. The loads measured are the drag on the trawling gear and the horsepower developed by the engine. Propeller data are given.

The loads vary with speed. The large trawler does not use all the available horsepower when towing, while the small one sometimes does. There are notes on the effect of changing the warp-to-depth ratio and on the effect of depth. The towing performance of the small trawler is given for white-fish and herring trawling practice. In the latter case the net is much the same size as the Arctic trawlers but made of light-weight synthetic material.

Spot measurements are given when heaving up the Arctic trawler's gear and this includes the power developed by the steam winch. There are notes and observations for the situation when the trawl becomes fast on the bottom, particularly as it applies to small motor trawlers of high freeboard.

LES CHARGES IMPOSÉES PAR L'ENGIN DE CHALUTAGE

Entre les extrêmes des essais de vitesse, d'une part, et l'essai (peu courant) de traction au point fixe, d'autre part, on trouve le cas de l'enregistrement du rendement pendant le remorquage—critère essentiel d'un chalutier. Un tableau montre le rendement pendant le remorquage pour deux chalutiers de tailles très différentes: un chalutier arctique et un chalutier de poche. Les charges mesurées sont la traction sur l'engin et la puissance développée par le moteur. L'auteur présente les données pour l'hélice.

Les charges varient avec la vitesse. Le grand chalutier n'utilise pas toute la puissance disponible pendant le trait, alors que le petit chalutier le fait parfois. Il y a des notes sur l'effet de la variation du rapport longueur de funes-profondeur et sur l'effet de la profondeur. Le rendement du remorquage par le petit chalutier est donné pour la pratique du chalutage de fond et du chalutage du hareng. Dans ce dernier cas, le filet est de dimensions beaucoup plus voisines de celles du chalut utilisé par le chalutier arctique, mais il est en fibres synthétiques légères.

L'auteurdo nne des mesures individuelles effectuées pendant le relevage de l'engin du chalutier arctique et qui comprennent la puissance développée par le treuil à vapeur. Il donne aussi des notes et observations concernant la situation dans laquelle le chalut se bloque sur le fond, en particulier avec les petits chalutiers à moteur ayant un franc-bord élevé.

LAS CARGAS IMPUESTAS POR EL ARTE DE ARRASTRE

Entre los extremos de los ensayos de velocidad, por una parte, y el ensayo (poco corriente) de tracción a un punto fijo, por otra, se encuentra el caso del registro del rendimiento durante el remolque, que es el criterio esencial de un arrastrero. Una tabla muestra el rendimiento en pesca de 2 arrastreros de tamaño muy diferente: el arrastrero que pesca en el Artico y el arrastrero de bolsillo. Las cargas medidas son la tracción sobre el arte y la potencia desarrollada por el motor. Se dan datos sobre la hélice.

Las cargas varían con la velocidad. El gran arrastrero no emplea toda la potencia disponible durante el arrastre, mientras que el pequeño lo hace algunas veces. Hay notas sobre el efecto del cambio de la relación longitud de cable-profundidad y del efecto de la profundidad. El rendimiento de remolque del arrastrero pequeño se da para la prática del arrastre cuando se pesca en el fondo y cuando se pesca arenque. En el último caso la red es de dimensiones muy próximas a las empleadas por los arrastreros del Artico, pero se hace de fibras sintéticas ligeras.

Se dan medidas individuales efectuadas al halar el arte del arrastrero del Artico, comprendida la potencia desarrollada por la maquinilla de vapor. Hay notas y observaciones relativas a la situación creada cuando se embarra el arte, particularmente en lo que concierne a los arrastreros pequeños de motor con mucho francobordo.

A TRAWLER has to do her speed trials, and these can be more or less comprehensive, and occasionally a test of bollard pull is made. This paper is an attempt to provide some information on the towing performance between the extremes of full speed and dead stop. It cannot be said that no information on towing performance exists, but rather that there is not very much of it. Trawlers fishing commercially can rarely be spared for the purpose of taking such measurements and a few spot checks taken while fishing are interesting but of limited value. Research vessels are only suitable when the hull design, propulsion and fishing gear conform with commercial practice.

The tests were made on two research vessels: *Explorer*, 183½ ft. (55.93 m.) LBP, powered by a 1,200 h.p. triple expansion engine, and *Mara*, 73½ ft. (22.40 m.) LOA powered by a diesel engine developing 204 BHP at 600 r.p.m. These vessels correspond in essentials with the biggest and smallest, other than inshore craft, classes of U.K. trawler.

TABLE 95

***Explorer*: towing performance in relation to engine speeds (mean of two double runs)**

Engine speed	r.p.m.	70	80	90
Towing speed	knots	3.2	4.0	4.7
Slip . .	%	59	56	54
Trawl load .	tons	5.4	6.6	8.0
Warp declination	.	26°	24°	22°
Warp sag .	.	6.5°	4.5°	2.5°
Trawl drag . (horizontal component)	tons	4.9	6.0	7.4
Power to pull trawl	EHP	106	163	236
Shaft horsepower	SHP	278	406	584

The tests were made as part of a general programme on the design of fishing gear. Some of the details appertaining only to gear performance have been omitted here. The essential measurements are: (i) the r.p.m. of the propeller, (ii) the speed of towing, (iii) the h.p. developed by the engine, and (iv) the tension in the trawl warps together with (v) some records of their declination.

Instruments used

Certain measurements, such as warp tension and towing speed require to be continuously recorded because of their fluctuations; for others a direct reading will do. Ultimately, there is quite a good argument for recording all measurements.

Warp tension. The instrument for measuring warp tension works on the principle of one wheel deflecting the warp a small lateral distance between two outside wheels. The deflecting wheel is mounted on a strain gauge load cell in the form of an electrically balanced bridge, whose unbalanced voltage due to the load is fed to a recording instrument.

Speed. The UCWE low speed log is an electric log, recently developed by the Admiralty, adapted to work on the same recorder as the tension measuring instrument. The log is towed from a boom 5 ft. (1.52 m.) clear of the ship's side and 15 ft. (4.57 m.) below the surface.

Horsepower. On the trials with *Explorer* the SHP was measured by an electric torsionmeter clamped to the propeller shaft. Measurements of SHP were made at 5-min. intervals.

Declination of warp. The declination of the warps was measured with a pendulum instrument with oil damping. It was clamped to one warp below the towing block. By means of an alternating current magslip repeater, working on the synchronous link principle, the angle of the pendulum could be read in the instrument laboratory amidships.

Method adopted during trials

Measurements of towing load, towing speed and engine power are required over a range of engine speeds. The procedure has been to start at low r.p.m. towing in one direction and increasing the r.p.m. in steps. When the readings were complete, the r.p.m. were stepped up a little and the vessel brought about on the opposite course. Once there, r.p.m. were reduced to the topmost value of the former series and the measurements made in descending order. The mean of means was calculated for two such double runs. Naturally, the case is avoided where the turn of the tide would coincide with the turn of the ship.

The reason for working up and down the r.p.m. scale and for increasing r.p.m. above the recorded values is that mechanical hysteresis due to friction, such as at the pulley wheels of the tension recorder and indeed over the trawl gallows sheaves themselves, would give rise to error if this method was not adopted to average it out. The same argument applies for the trials on *Mara*, where the engine BHP was determined from the readings of exhaust temperatures according to the engine manufacturer's curves. There is some little time lag in the exhaust temperature reaching its new value, consequently it is better to take the readings both in the direction of increase and of decrease.

Explorer towing trials

1. **Normal condition.** These trials shown in table 95 were all made during good weather, towing over even bottom in 67 fm. (122 m.) of water and with 200 fm. (366 m.) of warp out. The warp-to-depth ratio was the usual 3:1. The gear towed was the large Aberdeen trawl of 96 ft. (29.3 m.) headline length with 15 fm. (27.4 m.) sweep wires between otter boards and net.

The engine speed at which *Explorer* normally tows is 90 r.p.m. On the one occasion when the engine speed was raised to 100 r.p.m. the vibration in the ship became considerable and the power transmitted by the shaft rose to 783 SHP. There are several other points worth noting:

(a) Under normal towing conditions only about half the available horsepower is being used. A factory ashore having half the plant idling for a considerable proportion

TABLE 96

***Explorer*: propeller data**

4-bladed solid R.H. manganese bronze propeller designed for 12 knots at sea developing 1,160 IHP at 126 r.p.m.

D .	Diameter 10 ft. 8 in. (3.25 m.). Boss diameter 23½ in. (600 mm.)
P_m	Mean pitch 11 ft. 3 in. (3.43 m.) (also as used for mean effective pitch in calculations)
$\pi D^2/4$	Disc area 89.35 sq. ft. (8.30 sq. m.)
A_p	Projected area (4 blades) 33.06 sq. ft. (3.07 sq. m.)
A_d	Developed area (4 blades) 39.48 sq. ft. (3.67 sq. m.)

of the working day would be a matter for some concern, yet such is apparently the case on large trawlers.

(b) As little as 20 per cent. of the available engine h.p. is effectively used in pulling the trawling gear, and of that between a third and a half is spent on the otter-boards. Trawling therefore cannot be regarded as highly efficient from the mechanical point of view.

(c) The increase of towing load with speed is in fact not much more than proportional to the first power of the speed. This is presumably because of the part played by friction on the sea bottom.

(d) The 3:1 warp-to-depth ratio would mean a declination of 19½° if the warp were straight, but there is an appreciable sag resulting from the heavy 3¼ in. (83 mm.) circumference warp. The warp is straightened out somewhat with increased towing speed.

For making thrust and SHP calculations, the propeller data are given in table 96.

2. **Effect of warp lengths.** Tests were made to determine the effect of differences in warp-to-depth ratio, since the 3:1 rule is not invariable. The details can be omitted but one or two points are relevant as they affect the loading on the ship:

The warp tension recordings showed a marked decrease in peak-to-peak variation as the warp-to-depth ratio was increased

- Between the limits of 3:1 and 5.3:1 warp-to-depth ratio, there was no very marked change in the horizontal component of trawl drag or SHP at constant r.p.m.
- The sag of the wire below the straight line given by the warp-depth ratio increases but the actual angle of declination appears only to decrease towards a limiting value. At 67 fm. (123 m.) depth the limiting value of declination was 19° when at 5.3:1 the sag had risen to 8°

TABLE 97

***Explorer*: Towing performance in deep water (single run)**

Engine speed r.p.m.	*Towing speed knots*		*Trawl load tons*
70	3.1	2¼	7.5
80	4.1	3¼	8.5
90	5.2	4¼	9.4

It is not a rare thing to see mistakes made in ship construction, and more particularly in ship conversion, where a little knowledge or appreciation of the angle of warp declination would have enabled the after gallows and towing block to be positioned sufficiently far apart so that the warps do not work in the slip hook.

If the after gallows are too close to the towing block or too high, then the after warp rides too high for the towing block; if the after gallows are too far away from the towing block, then it becomes unnecessarily difficult to bring the two warps into the block. Other considerations in locating gallows and towing block are their position in relation to the propeller and ensuring that when hauling the trawling gear over the broadside with engines stopped the ship will not tend to fall off the wind. Another point is that the nearer the gallows are together the greater the chance of foul shot gear. In small trawlers it is often found more convenient to clip the warps together at the top of the after gallows than to use a towing block and this allows the after gallows to be positioned somewhat further aft than would otherwise be the case.

3. **Effect of deep water.** It is known that trawling in deep water imposes greater loads on ship and engine. Facts about the magnitude of the loads seem to be few.

TABLE 98

***Mars*: towing performance with small otter trawl (mean of two double runs)**

Engine speed	r.p.m.	450	500	550
Propeller speed	r.p.m.	222	246	271
Towing speed	knots	3.5	3.9	4.6
Slip	%	55.7	55.0	52.5
Exhaust temperature	°F	529	616	717
	°C	276	324	381
Engine horsepower	BHP	98	127	156
Trawl load	tons	1.1	1.3	1.7
Trawl drag (horizontal component)	tons	1.1	1.2	1.6
Power to pull trawl	EHP	25	33	48
Propeller thrust (calculated)	tons	1.3	1.6	1.9
Shaft horsepower (calculated)	SHP	74	100	131
Pitch throughout		43 in. (1,090 mm.)		

Theoretical estimates of the drag of the increased length of trawl warp can be made but there is not yet sufficient practical data against which to check these estimates. Recently when *Explorer* was over deep water the opportunity was taken to make some drag measurements. Unfortunately time was short and the weather bad, but nevertheless table 97 does indicate that the increase in load is appreciable. The measurements were made with 600 fm. (1,100 m.) of warp at 200 fm. (366 m.) depth and the same net was in use. The run was made once in one direction only. The towing speed readings should be treated with caution. The first column gives the speed as determined by the low-speed log already described and the readings look high, perhaps because with the roll of the ship the path of the log towed from a towing boom is greater than the mean path. The second column gives the speed as determined by the ship's electric log which only reads to the nearest ½ knot.

In this case 6 tons of warp are out, and even in water this weighs 4¾ tons. The greater the declination of the warp, the greater is its drag per unit length. In principle the less able a ship is to develop the necessary thrust to straighten the sag in the warps due to their weight, the more heavily is it penalized. A discrepancy in towing speed between an under-powered and an adequately powered vessel will be more noticeable in deep water than in shallow.

Mara towing trials

Common requirements for this type of vessel are towing a small otter trawl made of medium gauge twine as would be done for white-fish on rough ground, and towing a big Vinge or wing trawl made of lightweight nylon as for herring.

In tables 98 and 99, line 6 is derived from the engine maker's curves, and line 10 and 11 from the propeller maker's curves. Line 8 is derived from line 7 on the basis of the warp-to-depth ratio and, since no allowance is made for wire sag, line 8 will be slight over-estimates. The first set of tests was made at depths between 20 and 33 fm. (37 and 60 m.) with 100 fm. (183 m.) of 1½ in. (38 mm.) circumference wire, the second set at 50 fm. (92 m.) with 250 fm. (457 m.) of wire. When white-fish trawling, normal engine speed would be between 500 and 550 r.p.m.

Herring trawling is done as fast as is reasonable and the maximum figures in table 99 are therefore in order.

- In the small trawler the available engine power is much more fully utilized when towing
- The large trawler appears to make somewhat better use of the actual engine power in that a higher percentage of it is transmitted to the fishing gear, a point in favour of a big screw turning slowly
- The lightweight nylon trawl towed by the pocket trawler is not very different in fishing size from the heavy trawl towed by the Arctic trawler.

Propeller data for *Mara* are given in table 100.

TABLE 99

Mara: **towing performance with herring trawl (mean of one double run)**

Engine speed	r.p.m.	500	550	575
Propeller speed	r.p.m.	246	271	283
Towing speed	knots	3.7	4.2	4.4
	%	58.3	57.0	56.7
Exhaust temperature	°F	615	709	757
	°C	324	376	403
Engine horsepower	BHP	127	155	168
Trawl load	tons	1.7	1.8	1.9
Trawl drag (horizontal component)	tons	1.6	1.8	1.8
Power to pull trawl	EHP	41	50	55
Propeller thrust (calculated)	tons	1.7	2.0	2.2
Shaft horsepower (calculated)	SHP	103	136	155
Pitch throughout		43 in. (1,090 mm.)		

TABLE 100

***Mara:* propeller data**

3-bladed controllable-pitch. Reduction gear ratio: 2.03:1

D	Diameter 60 in. (1.52 m.). Boss diameter 15 in. (380 mm.)
P_m	Mean pitch 47 in. (1.194 m.) (maximum setting as used in sailing condition)
BAR	Blade area ratio 0.35

Hauling trial

Measurements of warp tension and winch hauling speed were made on *Explorer* in good weather and, though representative of the power developed by the winch, they do not represent the greatest warp tensions ever met. The warp tension was measured in the after warp only and it is assumed that the tension in the fore warp is the same for the purpose of calculating winch horsepower.

However, steaming ahead at 80 r.p.m. but with 10° starboard helm as she came round, the tension in the after warp rose to 5.5 tons with the winch at full throttle and heaving at 244 ft. (74.4 m.) per min. This represents 182 BHP at the winch. When heaving over the broadside with the ship stopped, warp tension fell to 4.4 tons while the hauling speed rose to 390 ft. (120 m.) per min., representing 234 BHP at the winch.

Information on coming fast and warp tensions in rough weather is available in data collected on *Explorer's* predecessor, an old-fashioned trawler of 590 IHP. The old *Explorer's* trawl load was about 3 tons at normal towing speed. On coming fast and with the winch heaving very slowly the tension in the after warp alone rose to 4.6 tons. Another record shows that on heaving up over the broadside in a moderate sea and force 6 to 7 wind, the tension in the after warp varied from 1.4 to 2.8 tons. It seems reasonable that, if these figures are scaled up or down in proportion to the mean trawl load, they would give the sort of figures to be expected on bigger or smaller trawlers; but the unexpected is also liable to happen and since it is not unknown for one of the warps to snap, much higher warp tensions must sometimes occur.

Perhaps the most dangerous situation is having to heave up over the broadside in bad weather with the trawl fast on the bottom and in a strong tide. A winch with dog clutches would tend to jam under the heavy load and this may add to the difficulties. Now that some of the Scottish motorboats of the 75 ft. (22.9 m.) class are fitting out with lightweight trawls, they may have to face this situation. They can fish the Danish seine net in most weathers because the worst that can happen is for the ropes to part, but a trawl warp suspended from the top of the gallows on a boat of considerable freeboard is a different matter. The traditional Swedish type of motor trawler has come in for some hard criticism by naval architects on account of its being so stiff as to be thoroughly uncomfortable. Yet in the trawlerman, who occasionally has to face a situation with the trawl fast on the bottom, the type inspires confidence. This should not be read as a criticism of the Scottish type of wooden motorboat, but it has evolved on the basis of drift-netting, longlining and Danish seine netting (fly-dragging style) and not at all on the basis of trawling. If the practice of trawling from MFV's is developed further in Scotland it will be interesting to watch whether the hull design will be modified.

It should be possible to postulate a set of severe conditions of tide strength, winch hauling speed and wave height, and test them in a tank. Tests might even be made at sea with bigger models under more realistic conditions and not necessarily at any greater expense.

Conclusion

If the fishing gear engineer can use the naval architect's data on propeller thrust to match the drag of the trawls he designs, he will later be able to provide performance data. The scope of cooperation is, however, becoming wider and the fisheries biologist is involved too. Evidence is gradually accumulating on the catching rates of different types and sizes of fishing gear and how the catching rates depend on the fish stock. A knowledge of the performance of modern fishing gear, and the thrust, power and facilities required to handle it at the boat, cannot fail to provide a more rational background for the design of fishing craft and the planning of fishing fleets.

NEW PERSPECTIVES IN SEA BEHAVIOUR

by

G. VOSSERS

A review is given of the main developments in the theoretical study of ship behaviour in a seaway. The concept of the energy spectrum or spectral density, which is introduced in the study of irregular motion, is explained.

The behaviour of a ship in a regular seaway is discussed. The influence of the main dimensions, the weight distribution and shape of the sections is illustrated with the results of some theoretical and experimental investigations.

Some remarks are made on speed loss in waves. The author also considers some possible future developments.

NOUVELLES PERSPECTIVES DANS LE COMPORTEMENT EN MER

L'auteur passe en revue les principaux développements dans l'étude théorique du comportement des navires par mer forte. Il explique le concept du spectre d'énergie ou densité spectrale, qui est introduit dans l'étude de mouvements irréguliers.

Le comportement d'un navire par mer forte régulière est examiné. L'influence des dimensions principales, de la distribution du poids et de la forme des sections est illustrée par les résultats de quelques recherches théoriques et expérimentales.

La perte de vitesse dans les vagues fait l'objet de quelques remarques. L'auteur considère aussi quelques possibilités de développements futurs.

NUEVAS PERSPECTIVAS EN EL COMPORTAMIENTO EN EL MAR

Se reseñan los principales adelantos en el estudio teórico del comportamiento de un barco en mar gruesa. Se explica el concepto del espectro de energía o densidad espectral que se introduce en el estudio de los movimientos irregulares.

Se examina el comportamiento de un barco en mar gruesa regular. La influencia de las dimensiones principales, la distribución de pesos, y la forma de las secciones se ilustra con los resultados de algunas investigaciones teóricas y experimentales.

Se hacen algunas observaciones sobre la pérdida de velocidad en las olas. El autor también examina algunas posibilidades de mejoras futuras.

WHAT is a seaworthy ship? Kent's (1949/50) well-known and lyrical definition allows a good deal of freedom in its interpretation. Seaworthiness cannot be expressed by one quantity: a vessel should ship little water, should pitch and roll only moderately, and should be easy to control; there must not be, particularly in following seas, any danger of capsizing. The accelerations must be moderate; the vessel must not lose much speed in head seas, etc. The importance of each of these factors has to be balanced one against the other. Research will not automatically lead to the design of a seaworthy ship, but the results will enable the designer to weigh the factors on a scientific basis.

Without theoretical knowledge, it is impossible to understand a ship's behaviour, because of the many variables. And it is only through theory that it has become possible to predict the influence of the main dimensions, of the form coefficients, and of the distribution of weights.

Data from the study of irregular phenomena have been applied to the motions of ships. One of the characteristic aspects of the sea, viz., its irregularity, has been investigated, and the degree of this irregularity can be expressed by one or a number of figures. Precise instruments have been designed for use on board ships to determine motions, power, revolutions of propeller, speed, and wave height.

Research has commenced into the forces acting on a ship in waves. In particular, the bending moment amidships has been measured in model scale, and the pressures when slamming have also been determined, both in model and full scale, and compared with theoretical findings.

Since the 1953 FAO Fishing Boat Congress, model experiments have been made more realistic. Many model basins have been equipped with wave generators able to produce both regular and irregular waves. Experiments can also be carried out with waves meeting the model from any given direction, even in an irregular pattern. A few such facilities are in existence or are being constructed in England, Japan, Netherlands, U.S.A. and U.S.S.R.

This subject is reviewed under three headings:

- Waves—with a description of irregular phenomena, as some new conceptions require explanation
- Ship motions
- Resistance increase and the loss of speed in waves

Two recent books (Korvin-Kroukovsky, 1960; Vossers, 1959) deal with the general aspects of the behaviour of a ship in a seaway. In this paper only a short account of some of the results is given.

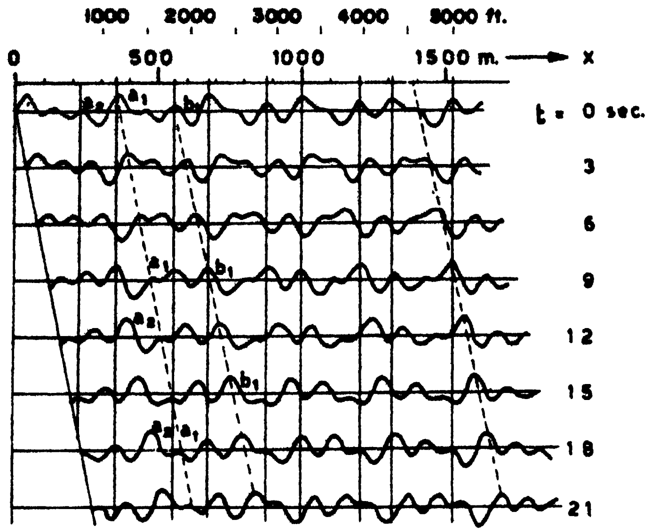


Fig. 391. Wave pattern obtained by super position of three regular waves

Waves—irregular phenomena

The irregularity of the sea has been the obstacle to its precise description. The sea has generally been described by idealized wave types, such as the trochoidal wave which rarely, if ever, exists in nature. Yet great importance has been placed on the trochoidal wave which is still used in strength calculations.

Tests with models have generally been restricted to single, regular waves. Important conclusions can be drawn from comparative testing of models in regular waves, but difficulties will arise when the quantitative results are extrapolated to the full scale ship's "irregular" behaviour.

The sea waves can be assumed to be built up of a large number of regular waves of different lengths, heights and directions. This imitates the characteristic behaviour of an irregular sea, as is clearly demonstrated by the super position of three regular sinusoidal waves, all of which are, for convenience sake, running in one direction (see fig. 391) (Neumann, 1952). With variations in time of 3 sec., the wave elevation of the following system is represented as a function of place:

$$h = h_1 \cos(k_1 x - \mu_1 t) + h_2 \cos(k_2 x - \mu_2 t) + h_3 \cos(k_3 x - \mu_3 t) \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where h_1, h_2 and h_3 represent the amplitudes of each composite wave; k_1, k_2 and k_3 the wave numbers, dependent on the wave length as follows: $k = 2\pi/\lambda$ (λ = wavelength); and μ_1, μ_2, and μ_3 the wave frequencies, dependent on the wave period as follows: $\mu = 2\pi/T$ (T = wave period).

For waves in deep water, there is a specific relation between the wave-length λ and wave period T:

$$\lambda = \frac{gT^2}{2\pi} \quad . \quad . \quad . \quad . \quad (2)$$

where g is the acceleration due to gravity.

Fig. 391 shows that the height of wave a_1, being at X = 1,150 ft. (350 m.) when t = 0 sec., decreases rapidly, as indicated by the dotted line drawn obliquely downwards. Wave a_2, on the other hand, rapidly gains in height. This rapid vanishing and appearance of separate wave crests is characteristic of an irregular seaway.

For more general consideration, a large number of regular waves of different periods can be presumed to be present. The height of each regular wave is an important quantity because it indicates the amount of energy belonging to each wave length and wave direction.

Since the energy is proportional to the square of the wave height, the quantity $\frac{1}{2}h^2$ of all waves present in the frequency interval from the μ to $\mu + d\mu$, can be added and, by definition, this sum is assumed to be equal to the product of $d\mu$ and a quantity $f(\mu)$, which is called the energy spectrum or spectral density:

$$\Sigma \tfrac{1}{2} h^2 = f(\mu)\, d\mu \quad . \quad . \quad . \quad (3)$$

The function $f(\mu)$, therefore, indicates the amount of energy present in each of the component waves.

Fig. 392 gives an instance of the curve of the spectral density as a function of the wave frequency at different wind velocities. The figure is based on a hypothesis by Neumann (1954). It shows that, with increasing wind force, the frequency at which the maximum amount of energy is present decreases, i.e. that with increasing wind force, the height of the longer waves increases.

Therefore, at a given wind force, a large number of different wave lengths, and not one wave length only, are present simultaneously.

The equation (3) is, in fact, only applicable to waves running in one direction. The consideration may, without any difficulty, be extended to waves running in different directions, which is more common. A three-dimensional spectral density $f(\mu, \theta)$ will then be obtained,

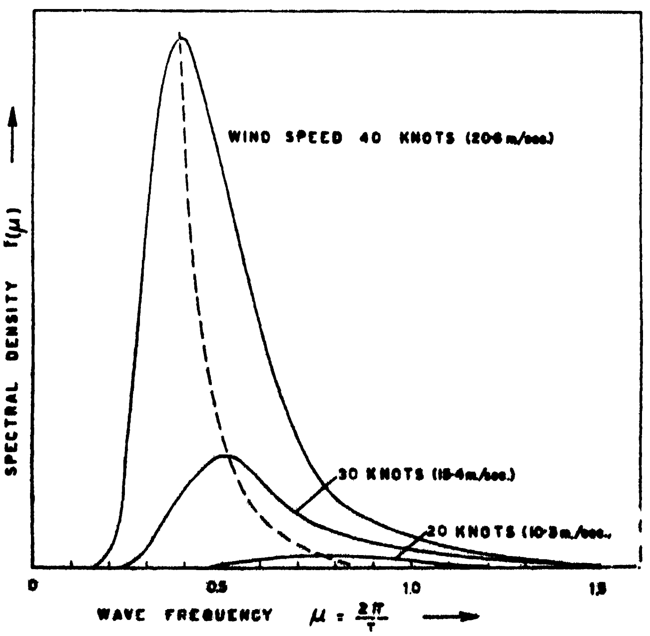


Fig. 392. Hypothetical spectral density as a function of wave frequency at different wind velocities

a theoretical example of which is given in fig. 393 (Marks, 1954).

Oceanographers disagree as to the shape of the curve of spectral density. However, it is hoped that the elaborate measurements which will be made in the next few years will clarify this matter. With the aid of the spectral density distribution, the irregular wave pattern can be completely characterized and comparison with two different wave patterns can be made.

It is not always necessary to know exactly the curve of the spectral density, but the area below the curve is of importance because it indicates the total amount of energy present in the wave pattern. Other parameters, which have been adopted for describing the shape of the curve, such as the position of maximum energy, the "width" of the spectrum, etc., are discussed in Korvin-Kroukovsky (1960) and Vossers (1959).

In the case of a narrow spectrum, the area below the curve of spectral density appears to be a measure of the visible features of an irregular phenomenon. One is, for instance, the significant wave height, indicated by $(h_w)_{1/3}$. This is the average of the apparent height of a third of the highest waves. An apparent wave height is indicated by h_w in fig. 394. It can be seen that height is not a constant quantity, and a large number of different apparent wave heights are found in one record.

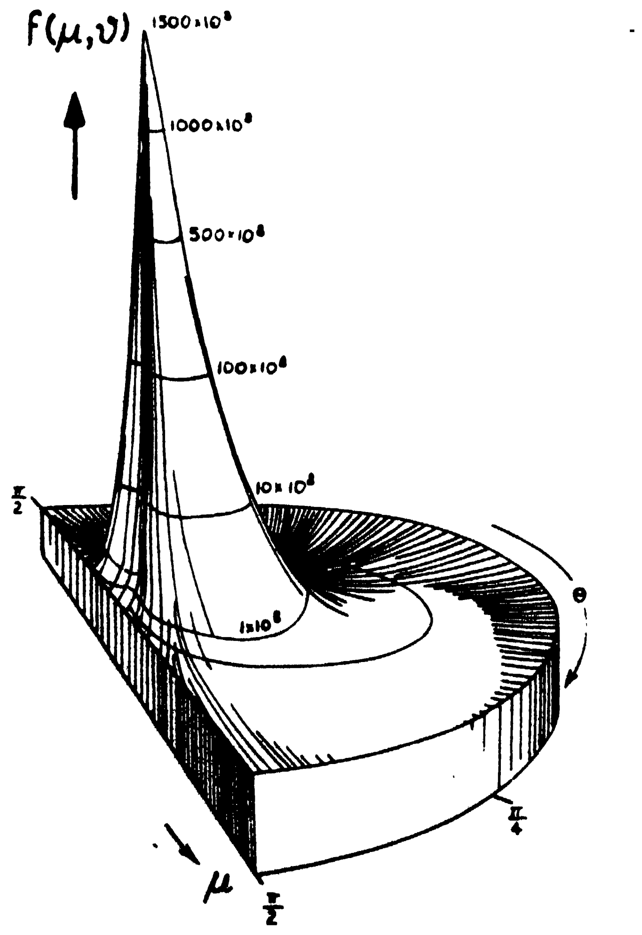


Fig. 393. Hypothetical spectral density as a function of wave frequency and wave direction at a wind velocity of 35 knots

Experience shows that, in general, the significant wave

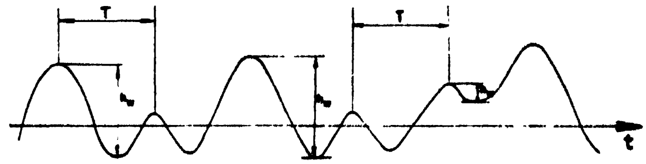


Fig. 394. Record of an irregular wave

height $(h_w)_{1/3}$ corresponds to the wave height that is visually estimated on board ship.

A significant wave period and a significant wave length can also be defined. These features also appear to depend on the curve of spectral density, though in a somewhat more complicated manner. From this it follows that the relation between the significant wave period and the significant wave length of an irregular wave pattern, is, in general, different from that between the wave period and the wave length of a regular wave, as given in equation (2). For an irregular wave pattern, the relation is:

$$\lambda = C_1 \frac{g\,T_{1/3}^2}{2\pi} \quad . \quad . \quad . \quad (4)$$

where C_1 is a coefficient dependent on the shape of the spectrum and varying between 0.6 and 1.0. The practical consequence is that care should be exercised in calculating the wave length from the estimates made of the wave period.

The estimates of wave heights and periods at sea are generally given as estimates of the significant value. Fig. 395 gives the frequency distribution of such a wave height estimate in the North Atlantic, the observation period being six years. The figure shows, for instance, that the chance of the significant wave height exceeding 20 ft. (6 m.) at the position of the weather ship is approximately 6 per cent. (Brooks and Jasper, 1957).

Ship motions are increasingly recorded on magnetic or punched tape, and the data analysed on an electronic computer. A large number of data can be recorded simultaneously. This considerably increases the reliability of the measurements and the possibilities of determining curves of spectral density.

It is important, but also difficult, to obtain a reliable recording of the wave height when a ship is under way. Many instruments are available for recording the wave height at a fixed point, and Tucker (1956) has evolved one for recording the wave height from a relatively slowly moving ship. Further developments may be expected.

The wave generator in a model basin can produce waves of different lengths and/or directions successively by varying the r.p.m. of the driving motor. Highly realistic sea patterns can be imitated, which considerably enhance the value of model experiments.

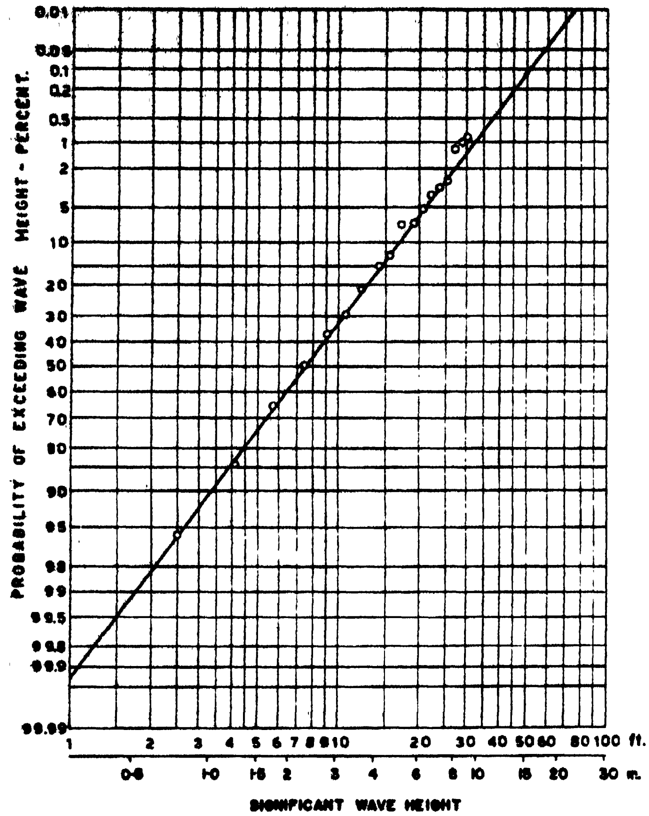


Fig. 395. Significant wave height for the weather ship J in the North Atlantic

Ship motions

A ship has six degrees of freedom—three displacements in a rectangular system, and three rotations about these axes (fig. 396). The motions are:

x: surging	ψ: pitching
y: swaying	φ: rolling
z: heaving	χ: yawing

Pitching and heaving result in shipping of water and loss of speed, while rolling and, to some extent, swaying, also play a prominent part in the ship's stability and safety. Yawing particularly affects steering, especially in following seas.

To study a ship's motions, it has been found convenient to study a simplified model (fig. 397). It shows the motion of a mass M under the influence of an exciting force F, a restoring force supplied by a spring with spring constant B, and a damping force with damping coefficient N. With displacement s as a function of time, speed is given by the differential ds/dt and acceleration by d^2s/dt^2. Four different forces are acting simultaneously: the inertia force $M\,d^2s/dt^2$, equal to the product of mass and acceleration; the damping force N ds/dt, equal to the product of damping coefficient N and speed; the restoring force Bs, equal to the product of spring constant B and the displacement s; and, finally the exciting force F. These four forces have to be in equilibrium at any moment, so that

$$M\,d^2s/dt^2 + N\,ds/dt + Bs = F \quad . \quad . \quad (5)$$

From this equation the magnitude of s can be determined as a function of M, N, B, and the force F. Should the force F be of a sinusoidal character as a function of time, say, $F=\bar{F}\cos\omega t$, the displacement s will vary as $\bar{s}\cos\omega t$. The amplitude $\bar{s}$ can easily be determined.

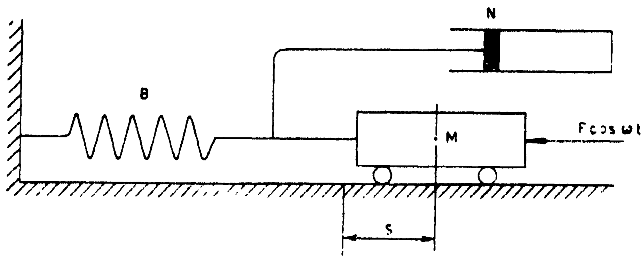


Fig. 397. Mechanical model of mass with spring and damping to illustrate mathematical expression for pitching

This amplitude can be represented by the product of two factors:

$$\bar{s}=\frac{\bar{F}}{B}\cdot K \quad . \quad . \quad . \quad . \quad (6)$$

The first factor $\bar{F}/B$ represents the displacement of the mass under the influence of a constant force $\bar{F}$; the force divided by the spring constant then gives the displacement. The second factor K depends on the frequency ω and indicates the increase or decrease of the amplitude, if a sinusoidal variable force $\bar{F}\cos\omega t$, instead of a constant force, is acting on the mass. K is, therefore, also called the magnification factor.

In fig. 398 the magnification factor has been plotted as a function of ω/ω_r, and a dimensionless damping parameter $\nu=N/\sqrt{BM}$.

For $\omega=\omega_r$ very large values of $\bar{s}$ are found, for which reason ω_r is called the natural frequency.

It is found that

$$\omega_r=\sqrt{B/M}\,(=2\pi/T) \quad . \quad . \quad . \quad (7)$$

and, consequently, that for the whole period,

$$T=2\pi\sqrt{M/B} \quad . \quad . \quad . \quad (8)$$

Fig. 398 also shows that the damping is principally of importance in the neighbourhood of the resonance frequency.

Fundamentally, the considerations with regard to the

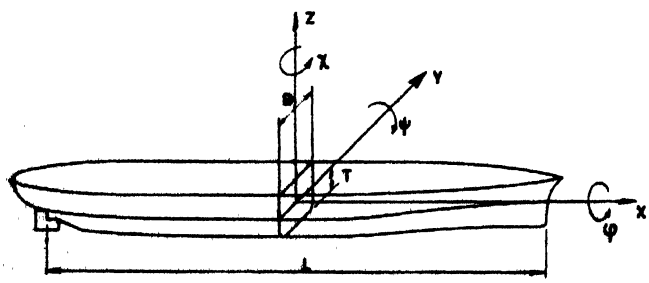


Fig. 396. Definition of ship motions

motion of a mass attached to a spring are also applicable to the motion of a ship in waves. The inertia forces or moments are dependent on the mass and the mass moment of inertia of the ship. Besides the inertia forces of the ship itself, the inertia of the entrained water must also be taken into account, so that an increase of the mass or the mass moment of inertia of the ship must also be considered. This increase may be negligible in the case of rolling, whereas it generally totals 50 to 100 per cent. in heaving and pitching.

The damping forces are caused by generation of waves which run in every direction and carry energy with them. Friction damping appears to be of minor importance. The restoring forces and moments arise from the rolling and pitching. Finally, the wave motions generate the exciting forces and moments.

However, there is a considerable difference in the motion of the mass with a spring (fig. 397) because the coefficients M, N, B and F are generally constant whereas they are variable for a ship.

Research during the last decade has given a clearer insight into the way in which the coefficients M, N, B and F are dependent on the main dimensions, the ship form, the ship speed and the wave length.

The influences of the main dimensions, the ship speed and the wave length are the most important, the ship form is only a secondary consideration. Therefore the behaviour of a ship in a seaway must be considered at the very early design stage because the main dimensions have such a large influence. At a later stage in the design close attention must be given to the smooth water performance. Relatively small changes in hull form may

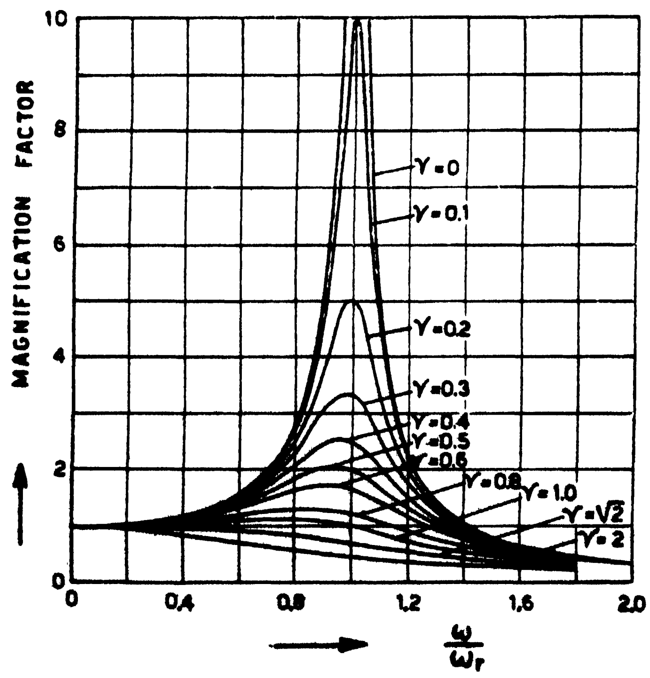


Fig. 398. Amplitude of motion as a function of frequency and damping

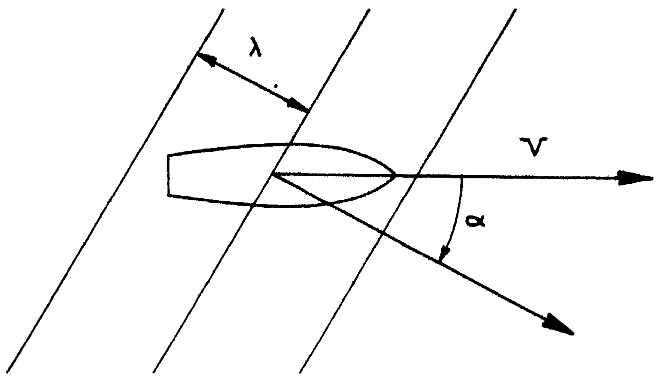


Fig. 399. Definition of wave direction with respect to ship

have important effects on the behaviour in still water. The effect of such small changes on the behaviour in a seaway will in general be very small, though there may be a greater possibility of slamming.

Actually, a sufficient freeboard and sheer is more important for obtaining satisfactory sea behaviour than the ship form (Numata and Lewis, 1957).

Some practical applications of these investigations are given below.

Influence of main dimensions

First, it is important to determine when resonance of motion will occur. The frequency of the exciting force is then equal to the natural frequency (fig. 398) and depends on the wave length, the wave direction and the ship's speed.

Fig. 399 shows how the wave direction is defined, this being the angle between the propagation of the waves and the ship. $\alpha = 0°$ corresponds with the following seas, and $\alpha = 180°$ with head seas.

Diagrams can be prepared to indicate the values of a ship's speed, wave length and wave direction at which resonance will occur. Fig. 400 gives such diagrams for natural periods of 3, 4, 5, 7, 9 and 11 sec. For a ship with a natural pitching period of, say, 5 sec., pitching resonance will occur in oblique head waves ($\alpha = 135°$) of 230 ft. (70 m.) at a speed of 10 knots, while a ship having a natural period of roll of 9 sec. will get into a rolling resonance in obliquely following waves ($\alpha = 45°$) of 295 ft. (90 m.) at a speed of 5 knots. These diagrams are not only useful for design, they also enable a skipper to determine the influence of speed and course alterations on the ship's motions.

A ship's natural period can be calculated by formula (7). The period of roll, T_r, and of pitch, T_p, is:

$$T_r = \frac{2\pi k_t}{\sqrt{g.GM_t}} \quad . \quad . \quad . \quad . \quad (9)$$

$$T_p = \frac{2\pi k_l}{\sqrt{g.GM_l}} \cdot \sqrt{1.7} \quad . \quad . \quad (10)$$

where k_t and k_l are the transverse and longitudinal radii of gyration respectively, and GM_t and GM_l are the transverse and longitudinal metacentric heights.

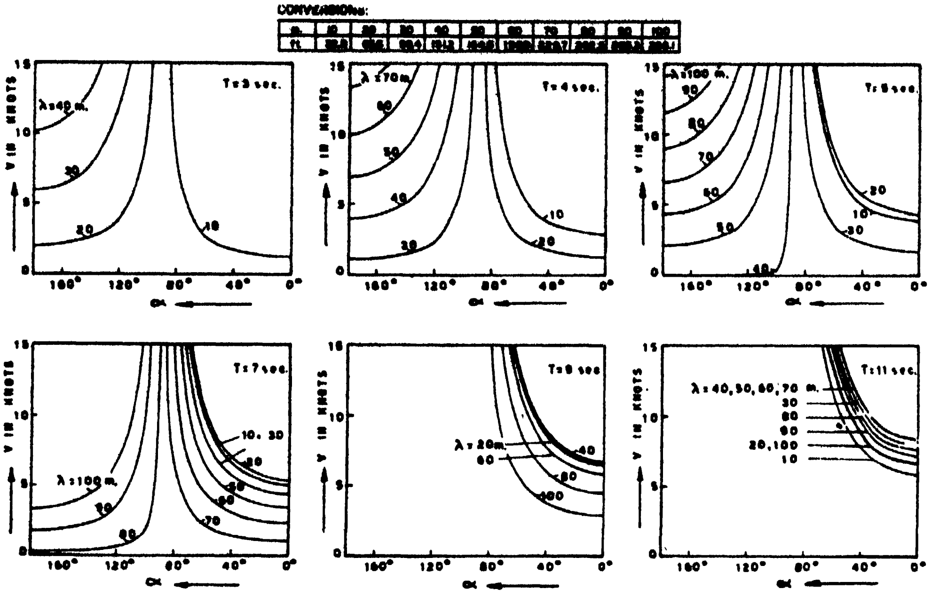


Fig. 400. Resonance diagrams for the natural periods of pitch and heave 3, 4, 5, 7, 9 and 11 sec. as a function of ship speed, wave length and wave direction

The factor $\sqrt{1.7}$ has been introduced in (10), because the moment of inertia of the added mass has to be taken into account for pitch (a mean value of 70 per cent. of the moment of inertia of the ship itself is appropriate) while it may be ignored in rolling.

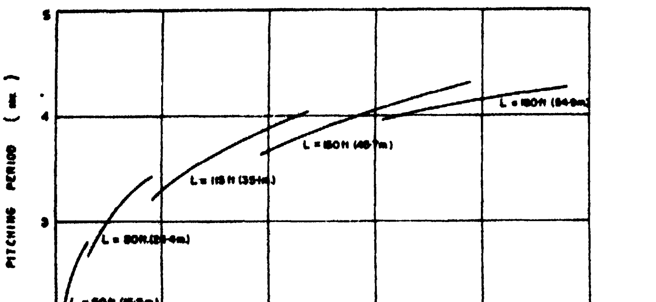


Fig. 401. The effect of displacement and ship's length on the natural pitching period

The radius of gyration is usually given as a percentage of the breadth or of the length of the ship. For rolling, however, it is more logical that

$$k_t = c\sqrt{B^2 + D^2} \quad . \quad . \quad . \quad (11)$$

where D is the depth at the side, B is the breadth, c varies between 0.33 and 0.39.

The radius of gyration for pitch varies between 0.23 and 0.26 L. The extreme cases are a rectangular distribution of weight, $k_l = 0.29$ L, and a triangular distribution of weight, $k_l = 0.20$ L. The distribution of weights of ships always lies between these values.

An elaboration of (10), in which greater allowance is made for the added moment of inertia, is given in fig. 401 (Lewis, 1955). The natural pitching period can be read as a function of the displacement and the length of the ship: a mean value of 0.25 L has been assumed for the radius of gyration while the figure is further based on an L/B ratio, varying between 5 (for $L/\nabla^{1/3} = 4.6$) and 6 (for $L/\nabla^{1/3} = 5.5$).

To obtain a short natural pitching period, the ship must have a great length and small displacement, i.e. a high value of $L/\nabla^{1/3}$. With fig. 400 and 401, the conditions for pitching resonance can now be estimated. One should also know how the exciting forces and moments are dependent on the wave length, the wave direction, the ship speed and the main dimensions and shape of the ship. In the first calculations, the influence of the ship speed can be ignored. The changes in the amplitude of the exciting moment are given in fig. 402 for pitching in head waves (wave direction = 180°) for different waterplane finenesses, α, as functions of the wave length/ship length ratio, λ/L. Similar diagrams can be drawn for different wave directions and for other ship motions. Fig. 402 shows that, for a wave length/ship length ratio between 1.0 and 2.0, the exciting moment for pitching is a maximum. If this wave length should also coincide with resonance, very large pitching angles can be expected.

Fig. 400 showed the relation between the natural pitching period and wave length, fig. 401 the relation between displacement, ship length and natural pitching period, and fig. 402 the relation between wave length and large pitch exciting moments. Fig. 403 combines these data to illustrate the case when waves meet the ship head-on; as a function of the length-displacement ratio, $L/\nabla^{1/3}$, the Froude number, $v/\sqrt{gL}$, has been determined, at which, with wave length/ship length, λ/L, between 1.0 and 2.0, resonance occurs. Fig. 403, originally developed by Lewis (1955), shows how, for avoiding violent pitching and, consequently, shipping water, the length-displacement ratio, $L/\nabla^{1/3}$, as a function of Froude number, $v/\sqrt{gL}$, has to be chosen. The critical range, indicated by hatching, should, therefore, be avoided. With increasing speed, a higher length-displacement ratio, $L/\nabla^{1/3}$, has generally to be selected. Fig. 403 also shows various values of modern ships. The speed reduction necessary for easy behaviour in rough weather for some of the ships is indicated. Fishing vessels seem to fall exactly in the middle range. The main dimensions have to be drastically altered to avoid excessive ship

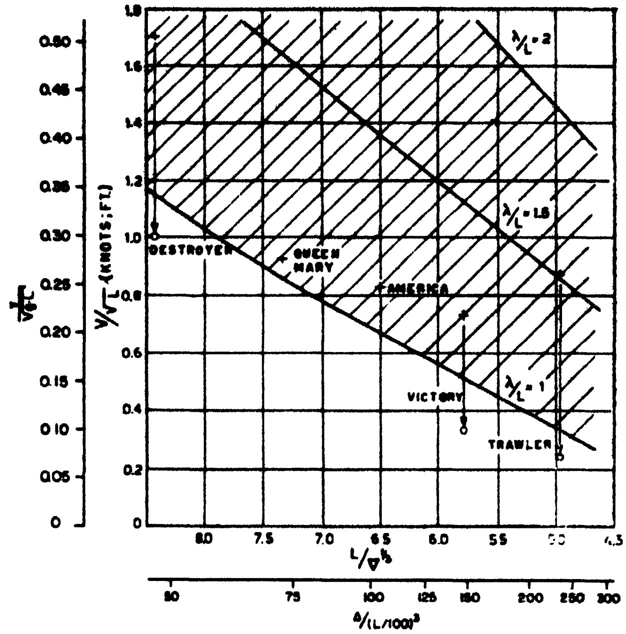


Fig. 403. The effect of speed-length and length-displacement ratios on large pitching motions and deck wetness (Lewis, 1955) for ships in head-on waves

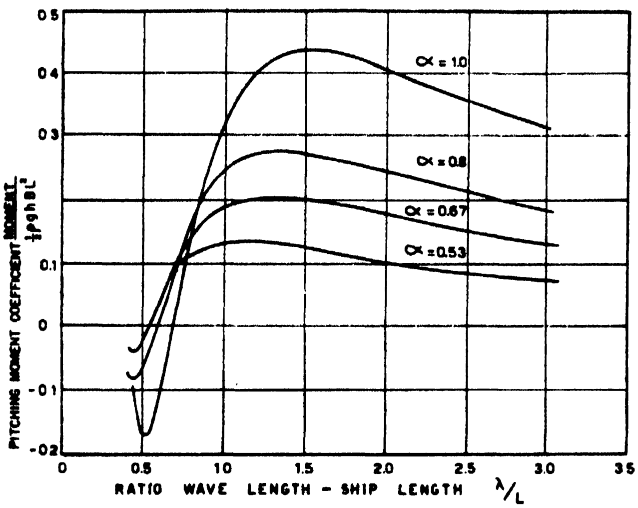


Fig. 402. The effect of wave length ship length ratio on the pitching moment coefficient for different waterplane finenesses

motion, and these alterations must be made to the area below the critical range as fishing boats frequently run at low speeds.

Influence of longitudinal radius of gyration

From formula (10) it will be evident that a short longitudinal radius of gyration results in a short pitching period. Therefore there is a relation between longitudinal radius of gyration and resonance. Fig. 404 shows the influence of changing the longitudinal radius of gyration on the pitching angle as a function of the Froude number, $v/\sqrt{gL}$, at a wave length/ship length ratio $\lambda/L = 1$. It will be seen from fig. 404 that a long radius of gyration gives resonance at a lower speed than a short radius of gyration. As boats must fish at low speeds a short longitudinal radius of gyration is always preferable. This is, therefore, in agreement with the discussion on choosing the main dimensions.

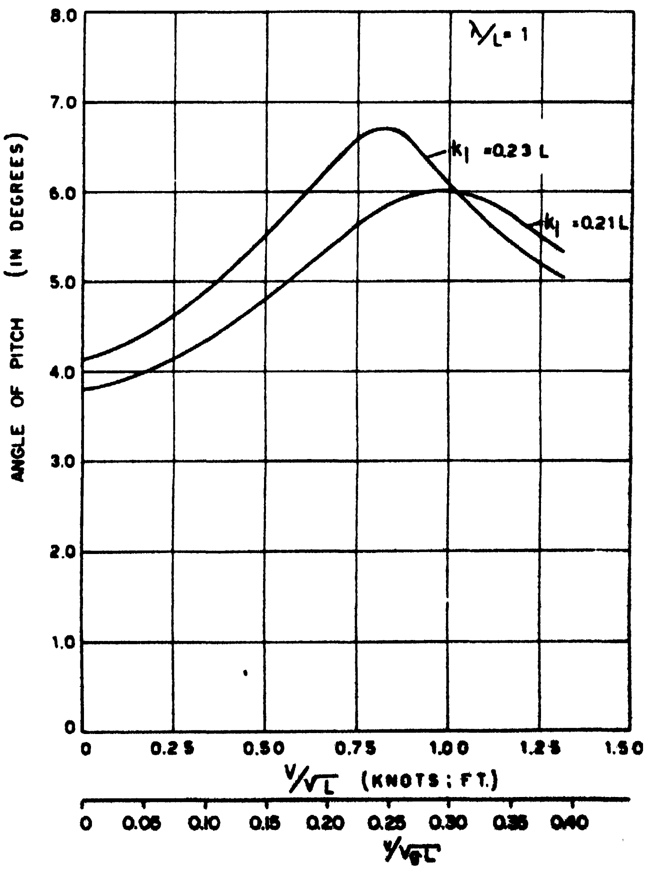


Fig. 404. Effect of the longitudinal radius of gyration on pitching

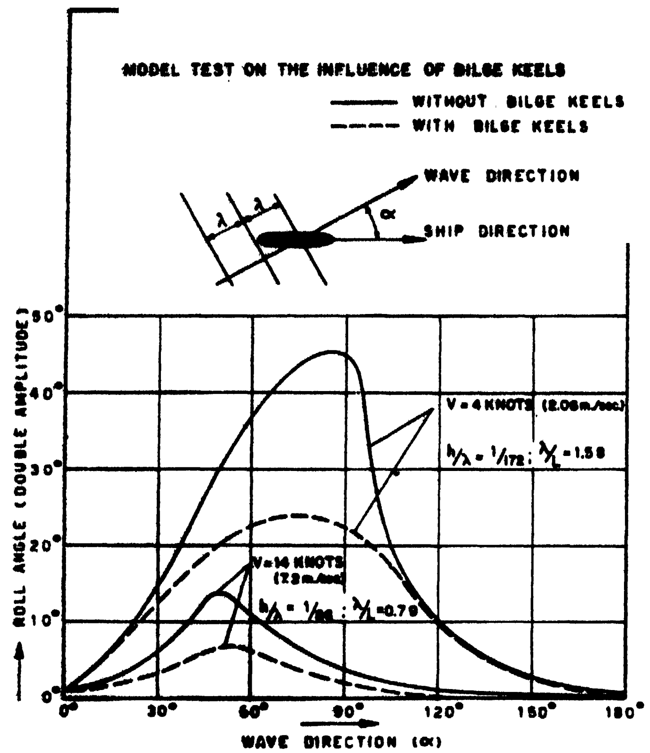


Fig. 405. Effect of bilge keels on rolling

Influence of bilge keels

The influence of bilge keels on rolling is illustrated in fig. 405, which gives the results of a model test. The shape of the curve corresponds with the resonance curve of fig. 398. Bilge keels reduced roll angles from 45° to 24° in this case.

The shape of the body sections and the ratio B/T also affect roll damping. For a midship-section coefficient β=0.80 with a B/T=3, a higher degree of damping is generally found than with a B/T=2.

Influence of the shape of sections

A fishing boat running in the critical zone of fig. 403 will be seaworthier with V-shaped than with U-shaped sections. This is perhaps not only due to the shape of sections. A V-shape hull has a higher waterplane coefficient, and fig. 402 shows this to be of influence on the exciting forces; moreover, the influence of the waterplane coefficient on damping must also be considered. This is illustrated in two figures, taken from Ochi (1957). Fig. 406 shows, as a function of the Froude's number, v/√gL, the vertical acceleration in the forepart of the ship for both U-shape and a V-shape of sections at two different draughts and a wave length/ship length ratio λ/L=1. Fig. 407 shows for the same ship forms, as a function of Froude's number, the draught-length ratio below which slamming will occur.

These figures show that at low speeds V-shaped sections will result in lower vertical accelerations, and give less trouble from slamming. At higher speeds, U-shaped sections may sometimes be advantageous, though not in the case of fishing vessels.

The vertical accelerations in the bow can also be reduced by a bulb, which acts as a damping mechanism; care should be taken, however, that the bulb is not too large. A 4 per cent. bulb (reckoned in percentages of the midship area) seems to give the best results.

Influence of freeboard and sheer

If a fishing vessel cannot be designed to operate outside the critical zone of fig. 403, the possibility of very large pitching angles has to be expected. Considerable sheer and freeboard are therefore necessary.

Absolute recommendations are difficult to give but it is hoped that accurate measurements at sea and model tests will be made, so that a rational base for choosing the proper freeboard and sheer can be arrived at. Statistics will have to be utilized and a percentage of probability fixed. This will be possible with the aid of the spectral densities of the motions.

A ship's behaviour in following seas must also be considered when determining freeboard and sheer. With oblique seas, a rather large amount of water will be shipped in the region L/3 from the stern. In following seas the velocity of the waves may be about as high as the ship speed, and large volumes of water may sweep the aft deck. It is easy to determine when this will occur, and it is shown in fig. 408. The zone in which the wave length/ship length ratio, λ/L, lies between 1 and 2 may be particularly prone to such a situation. The risk may be minimized by providing sufficient sheer aft, or may be avoided completely by proper manoeuvring, as, for example, by reducing speed.

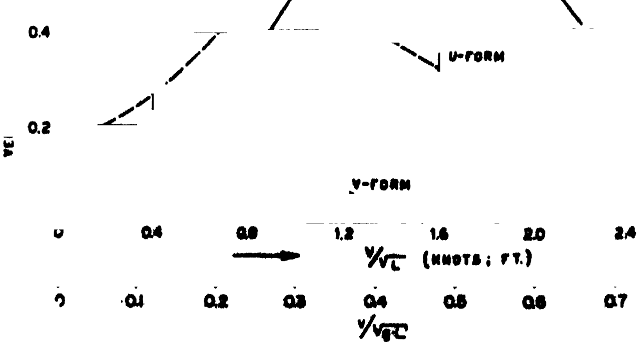


Fig. 406. Effect of the shape of sections or waterplane area on vertical acceleration in the fore part of a ship

Influence of metacentric height

The longest rolling periods should be chosen to obtain best behaviour in waves. Fig. 400 shows that, for a long rolling period, the range of wave directions in which resonance may occur is smaller than for a short rolling period. Moreover, a longer period will generally lead to smaller vertical accelerations.

It then follows that the largest possible radius of gyration (formula 9) and the lowest possible metacentric height, have to be chosen. The minimum metacentric height must, however, be determined by considerations of stability, a subject beyond the scope of this paper. It should be borne in mind that when a ship is on a wave crest her stability may be considerably reduced. This may, particularly in following seas, give rise to a critical situation and dangerous rolling motions may start.

Vertical accelerations

Vertical accelerations, as well as shipping water, affect "habitability" on board ship. These vertical accelerations may be caused by rolling, heaving, and pitching. The influence of accelerations on man's comfort on board ship has been investigated and reported on in a recently published thesis (Nieuwenhuysen, 1958). It appears that not only accelerations but also the frequency of motion is of importance. From fig. 409 (compare fig. 427) it can be seen that, for a pitching and heaving motion with a frequency of 0.25 c.p.s., the vertical accelerations become decidedly unpleasant at 0.25 g, whereas for a rolling motion with a frequency of 0.1 c.p.s. they become unpleasant at 0.35 g.

An acceleration of 0.25 g for pitching and heaving is easily reached for and aft for a quarter of the ship's length, whereas for rolling, even at the side of the ship,

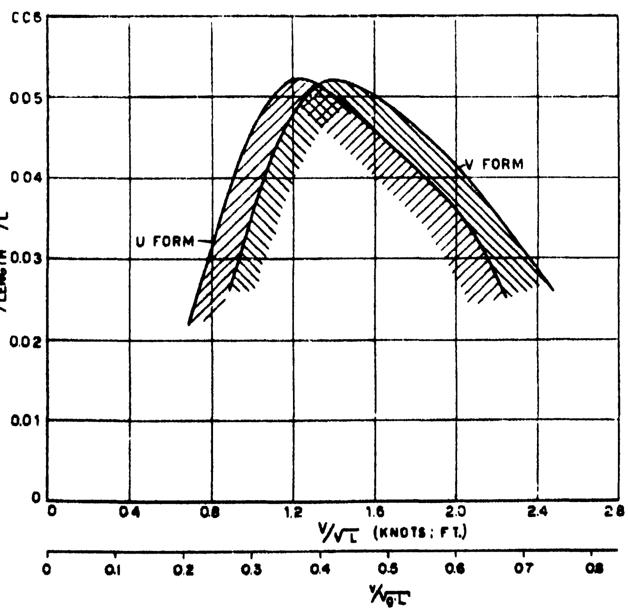


Fig. 407. Effect of the shape of sections on slamming

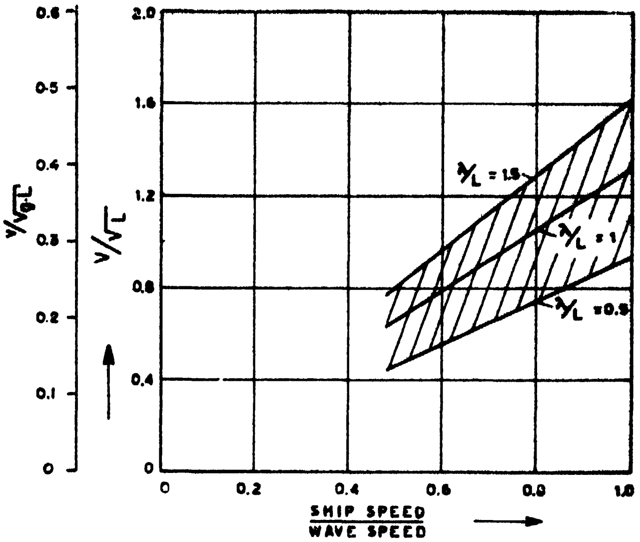


Fig. 408. Relation between Froude number and the ratio of ships speed to wave speed for different wave length/ship length ratios in following seas. The dangerous range is hatched

this acceleration seldom occurs. It is therefore clear from this figure that only pitching and heaving cause seasickness. If, from model tests or from measurements at sea, values of periods and accelerations are known, this figure can be used to judge the discomfort of a ship.

Motion of irregular seas

As a spectral density can characterize the irregular waves, so a spectral density may also be found for ship motions. The data in the upper part of fig. 410 shows, for instance, the spectral density of the sea surface at a certain point, while those in the lower part represent the spectral density of the pitching and rolling movements of a ship. There is a certain relation between the spectral density of the sea and that of pitching and rolling. This relation is determined by a ship's behaviour in regular seas; for example, that for pitching being:

$$f_{\psi\psi}(\mu) = [Y(\mu)]^2 f_{hh}(\mu) \quad . \quad . \quad (12)$$

where $Y(\mu)$ represents a function of the frequency, actually having similar shape to that given in fig. 398, $f_{hh}(\mu)$ the spectral density of the waves, and $f_{\psi\psi}(\mu)$ the spectral density of the pitching motion. $Y(\mu)$, therefore is the pitching of a ship in regular waves, and formula (12) indicates the manner in which, with its aid, the spectral density for pitching can be found. The wave direction, too, can be taken into account in formula (12). Details are given by Vossers (1959) which also show that, for the sake of accuracy in computation, it is preferable to start from a relation different from (12), which, however, does not contradict the line or argument taken above.

A relation similar to that for pitching is naturally applicable to rolling, but as damping is much less in rolling, the curve of spectral density will generally be much "narrower".

For an irregular sea with a wide spectrum, the peak of

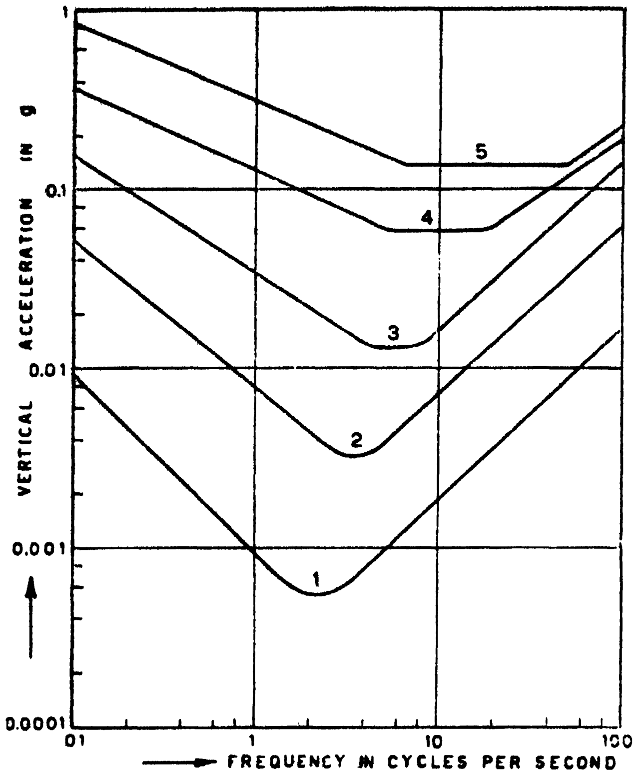


Fig. 409. Effect of vertical accelerations on comfort on board ship. Zone 1: only just noticeable. Zone 2: clearly noticeable. Zone 3: very clearly noticeable, just becoming inconvenient. Zone 4: decidedly unpleasant. Zone 5: unbearable (compare fig. 427)

the curve of spectral density for rolling will be in the neighbourhood of a period corresponding to the natural period of the period of roll. Then a measurement of the rolling period of a ship in a seaway will correspond to that of the natural rolling period. If, on the other hand, the spectrum of the sea is very narrow as, for instance, in the case of a regular swell, the peak of the curve of spectral density for rolling may correspond to the period of encountering the swell, and will not correspond to the natural rolling period. It is, therefore, advisable when determining a ship's metacentric height from the rolling period, to do so in a relatively irregular seaway, or, to make the rolling test in smooth water, when the natural rolling period will be found directly.

There are various possibilities as to when to apply the method of the spectral density; it may be used to indicate the probability at which values, such as pitch angle, submergence of the bow, or roll angle, are surpassed. This will enable a comparison between different ships in an irregular seaway.

Loss of speed

In the last few years, theoretical investigations have given a better understanding of the causes of loss of speed and of resistance increase in regular and irregular waves. One of the most important depends on a phase difference between the exciting forces and moments and the ship's motion, through which a certain mean resistance increase is obtained. The formula for the resistance increase in regular waves is:

$$R_1 = C\, h_w\, \psi \cos \epsilon \quad . \quad . \quad . \quad (13)$$

where: R_1 = the mean resistance increase, due to pitching: C is a coefficient dependent, for instance, on the ship form. A similar term is valid for the influence of heaving on the resistance increase.

It will be seen that, in principle, the increase in resistance is proportional to the product of the wave height and the pitching angle, or since the pitching angle is proportional to the wave height, to the square of the wave height. It further follows that, with large pitching angles, there will be a considerable increase in resistance.

This is illustrated in fig. 411, where the loss of speed as a function of the wave length/ship length ratio has been plotted for two different wave directions. The r.p.m. of the engine has been kept constant but, naturally, similar curves may be drawn for which the torque or the power is constant. It appears that for head-on waves ($\alpha = 180°$), with a wave-length equal to the ship length, where the pitching angles are generally maximum, the loss of speed, too, is greatest. With oblique seas on the bow ($\alpha = 135°$), the maximum loss of speed occurs with a smaller wave-length. The influence of the reflection of the waves against the ship, though present, appears to play a subordinate part.

The theoretical investigations have surprisingly shown a decreased resistance at small wave-lengths in head seas compared to the smooth water results. This phenomenon has also been observed in model tests in the seakeeping laboratory of the NSMB (van Manen, Vossers and Rijken, p. 422). The effect may total 5 to 10 per cent. of the power and cannot therefore be neglected, particularly in the interpretation of ship trials in small wave-lengths which are not generally considered to influence resistance.

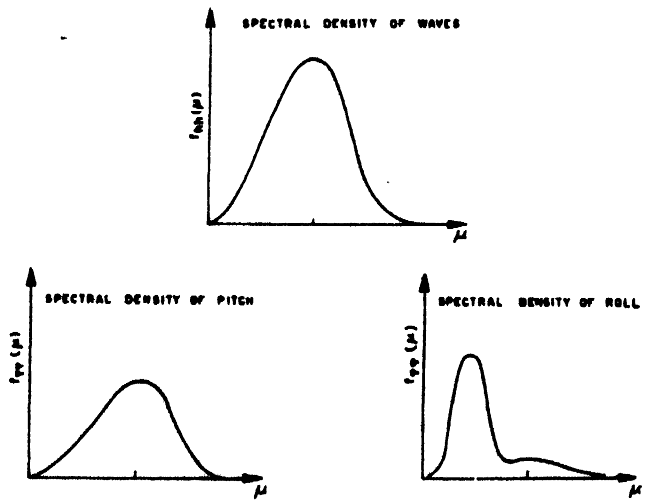


Fig. 410. Spectral density of pitching and rolling motions in a given irregular sea

The general pattern of the resistance increase in a seaway is, therefore, well known, but detailed information is not available, such as on the influence of the block coefficient and ship form, the behaviour of the propeller with or without a nozzle, and the advantages of using a controllable-pitch propeller in a seaway. Elaborate model tests will be carried out in the future, particularly now that accurate measurement of torque and thrust in a seaway is possible. Earlier measurements are unreliable, partly because the apparatus was unsuitable for taking dynamic measurements, and partly because theoretical and experimental investigations in the past few years have shown that wall effect plays a part in the conventional model basin which is only able to produce head-on waves.

Future developments

Now that a number of specially equipped seakeeping laboratories have been completed, a considerable advance has been made in the technique of model experiments in a seaway. Experiments cover both regular and also irregular waves, and thus the practical value of model tests is greatly increased.

It is impossible to predict to what extent research on the influence of shape and main dimensions of a ship will affect the new designs. It promises considerable contributions to the design of the optimum ship in a seaway. The use of electronic computers by the ship model basins has greatly simplified the numerical calculations involved.

The introduction of the conception of spectral density enables exact measurements on board ships to be made; and, in the future, instruments will be used on board ship to record motions and wave heights to permit a simple determination of the spectral density.

The conception of spectral density is also important when testing models in irregular seas. It will now be possible to carry out realistic experiments in any kind of sea.

In judging seaworthiness it is necessary to adopt statistical statements, such as the probability that such

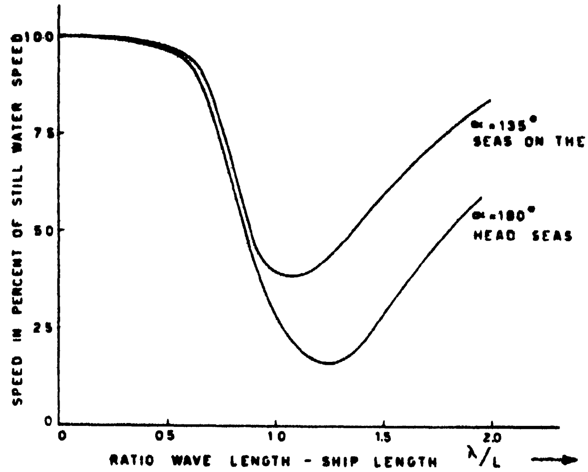


Fig. 411. Effect of wave length on loss of speed

and such a value will be exceeded in a certain situation. Ship research provides a still almost unexplored domain in this respect.

Finally, it is to be expected that in the seakeeping laboratory the nautical aspects of a ship's behaviour in a seaway will also come under review. This is, in any case, necessary in carrying out accurate seakeeping model tests because the human element plays a prominent part in seaworthiness. An incompetent skipper can easily make a good seagoing ship unseaworthy, but even the most competent man cannot turn a bad vessel into a good one.

BEHAVIOUR OF TRAWLERS AT SEA — II

by

WALTER MOCKEL

The behaviour of four trawlers, 167 to 182 ft. (51 to 55.5 m.) between perpendiculars, were investigated during fishing trips and shaft horsepower, ship's speed, warp pull, angle and period of roll and pitch, apparent angle of roll, vertical acceleration, and wind speed were measured.

It was found that the power requirement, when trawling, was almost the same for the four vessels and that the shape scarcely affected the power requirement, resistance of the ship being about 4 per cent. of that of the gear. Power was only partly utilised when trawling in good weather. In bad weather, the torque reserve and not the power reserve is the limit, due to the loss in r.p.m.

Increase of power is not the only way to increase speed; refined hull design and, above all, increase in length are important factors.

Trawlers require much additional power to maintain steaming speed in bad weather, 37 per cent. at Beaufort 5 and a speed of 13 knots. Loss of speed is less with a low block coefficient. Trawlers steaming at the same ratio of wave length to ship length as cargo ships lose comparatively more speed.

The comfort of the crew is directly related to acceleration. Almost 50 per cent. of the passengers were seasick at an acceleration of 2.6 ft./sec^2 (0.8 m./sec^2) on a large liner. The maximum acceleration found on the four trawlers investigated was about 1 g = 32 ft./sec^2 (9.81 m./sec^2) so they had about 12 times greater acceleration without a single case of seasickness.

The metacentric height should not be reduced below 2.3 ft. (0.70 m.) for motor trawlers to prevent risks arising from icing and shipping water. Crews complain not only about short periods of roll but also about long periods which convey a feeling of insecurity. Trawlers shipping much water soon have to stop fishing. Values and diagrams of natural periods of roll in relation to the beam of the ship, stability figures, data on the behaviour of the ship and the reaction of the crew, are given.

The point of minimum motion was deduced from measurements of acceleration. Vertical acceleration is greater forward than aft and is lowest in a following sea.

LE COMPORTEMENT DES CHALUTIERS EN MER—II

Pendant des sorties de pêche de quatre chalutiers, dont la longueur entre perpendiculaires était de 167 à 182 pi. (51 à 55.5 m.), on a fait des recherches sur leur comportement et on a mesuré la puissance sur l'arbre, la vitesse du navire, la traction sur les funes, l'angle et la période du roulis et du tangage, l'angle apparent du roulis, l'accélération verticale et la vitesse du vent.

On a trouvé que la puissance nécessaire pendant le chalutage était presque la même pour les quatre navires et que la forme du navire affecte à peine la puissance nécessaire, la résistance du navire étant environ 4% de celle de l'engin. La puissance était utilisée partiellement seulement pendant le chalutage par beau temps. Par mauvais temps, le couple et non la réserve de puissance forme la limite, par suite de la perte de t.p.m.

L'augmentation de la puissance n'est pas le seul moyen pour augmenter la vitesse; le dessin raffiné de la coque et, par dessus tout, l'augmentation de la longueur sont des facteurs importante.

Les chalutiers nécessitent beaucoup de puissance supplémentaire pour conserver la vitesse de route par mauvais temps: 37% pour un vent de force 5 à l'échelle de Beaufort et une vitesse de 13 noeuds. La perte de vitesse est moindre avec un faible coefficient de remplissage. Des chalutiers, naviguant au même rapport: longueur de vague—longueur du bateau, que des cargos, perdent comparativement plus de vitesse.

Le confort de l'équipage est en relation directe avec l'accéleration. Presque 50% des passegers avaient le mal de mer à une accélération de 2.6 pi./sec^2 (0.8 m./sec^2) à bord d'un grand paquebot. L'accélération maximum trouvée sur les quatre chalutiers en question était d'environ 1 g soit 32 pi./sec^2 (9.81 m./sec^2); ils avaient donc une accélération douze fois environ plus grande sans un seul cas de mal de mer.

La hauteur métacentrique ne doit pas être réduite au-dessous de 2,3 pi. (0,70 m.) pour les chalutiers à motuer pour prévenir les risques dus au glacage et à l'eau qui embarque. Les équipages se plaignent non seulement des courtes périodes de roulis mais aussi des longues périodes qui amènent un setiment d'insécurité. Les chalutiers qui embarquent beacoup d'eau doivent bientôt s'arrêter de pêcher. L'auter donne les chiffres et les diagrammes des périodes naturelles de roulis en relation avec la largeur du navire, les chiffres de stabilité, des données sur le comportement du navire et la réaction de l'équipage.

Le point de mouvement minimum a été déduit des mesures de l'accélération. L'accélération est plus grande à l'avant qu'à l'arrière et est la plus faible par mer venant de l'arrière.

COMPORTAMIENTO DE LOS ARRASTREROS EN EL MAR—II

El comportamiento de 4 arrastreros que tenian una eslora entre perpendiculares de 167 a 182 pies (51 a 55,5 m.) se investigó durante varios viajes de pesca y se calcularon la potencia en caballos al árbol, la velocidad del barco, la resistencia de los cables de remolque, los ángulos y periodes de balanceo y cabeceo, el ángulo aparente de balanceo, la aceleración vertical y la velocidad del viento.

Se observó que las necesidades de fuerza motriz durante la pesca eran casi iguales en los 4 barcos y que la forma del barco apenas influye en esas necesidades. La resistencia de los barcos era, aprox., el 4% de la ofrecida per el equipo de pesca. La fuerza motriz sólo se empleaba parcialmente cuando se pescaba en buen tiempo, pero en mal tiempo el par motor y no la reserva de potencia, marca el límite debido a la pérdida en r.p.m.

El aumento de fuerza motriz no es la única manera de incrementar la velocidad del barco; los cascos de formas más finas y, sobre todo, el aumento de la eslora, son factores de importancia.

Los arrastreros necesitan mucha potencia adicional para mantener la velocidad cuando el tiempo es malo: 37% con viento 5 de la escala Beaufort y una velocidad de 13 nudos. Se pierde menos velocidad cuando el coeficiente de bloque es bajo. Los arrastreros que navegan con la misma relación de longitud de onda-eslora que los barcos mercantes pierden relativamente menos velocidad.

La comodidad de la tripulación está en relación directa con la aceleración. En un gran transatlántico a una aceleración de 2,6 pies/seg² (0,8 m./seg²) casi la mitad de los pasajeros se mareó. La aceleración máxima encontrada en los cuatro arrastreros objeto de investigación fué, aprox., 1 g=32 pies/seg² (9,81 m./seg²) o sea, unas 12 veces más que en el transatlántico, no obstante lo cual no se dió ni un solo caso de mareo.

Para impedir los peligros que representan la formación de hielo y el embarque de mucha mar, la altura metacéntrica de los arrastreros de motor no se debe reducir a menos de 2,3 pies (0,70 m.). Las tripulaciones no sólo se quejan de los balanceos de período corto, sino también de los de período largo, por la sensación de inseguridad que crean. Los arrastreros que embarcan mucha mar no tardan en dejar de pescar cuando el tiempo se endurece. Se exponen valores y diagramas de los períodos naturales de balanceo con relación a la manga del barco, datos relativos a la estabilidad, datos sobre el comportamiento del barco y la reacción de la tripulación.

El punto de movimiento mínimo se dedujo de los cálculos de la aceleración. La aceleración vertical es mayor a proa que a popa y es mínima con mar de popa.

PERFORMANCE data for trawlers under actual operation are essential for improving their design. The mere subjective reactions of the crew make no contribution, because a naval architect must deal in measured quantities in his design calculations.

With financial support from the Minister for Traffic, the "Hamburgische Schiffbau-Versuchsanstalt" (Hamburg Ship Model Basin) has, in addition to researches undertaken earlier, carried out investigations of operational conditions on three trawlers, F, G and H. Data are also available for a steam trawler J. Although the information about J is less complete than for vessels F, G and H, it is adequate for purposes of comparison and will accordingly be taken into consideration.

Vessels F and G are motor trawlers, while H and J are steam trawlers. All of them are modern craft built during the last seven years. The voyages of the two motor trawlers took them to the area of the Lofoten Islands.

TABLE 101

Average displacements and draughts when leaving and arriving at port

Ship		*F*	*G*	*H*	*J*
T, leaving port	ft.	13.75	14.3	14.8	16.25
	m.	4.19	4.35	4.52	4.95
T, arriving port	ft.	14.5	15.25	13.32	—
	m.	4.45	4.65	4.06	
Δ, leaving port	ton	1,060	1,120	1,148	1,290
Δ, arriving port	ton	1,170	1,267	985	—

The steam trawler H was on a herring trip to the Fladengrund, whilst J went to Iceland. The bottom of the ship H had been painted just before the start of the voyage. The other three vessels had been bottom painted about ten months before the trip.

The ships have a length between perpendiculars of from 167 to 182 ft. (51 to 55.5 m.) and a breadth of from 28 to 30 ft. (8.6 to 9.2 m.). Table 101 shows the average draughts and the relevant displacements as measured on leaving and on arriving at port.

The pitch and disc-area ratios of the propellers are as follows:

Ship	*F*	*G*	*H*	*J*
Pitch ratio P/D	1.118	0.976	1.050	1.029
Disc-area ratio DAR	0.543	0.510	0.570	0.480
r.p.m. at sailing speed	110	120	109	109
Maximum r.p.m.	115.5	126.9	120	116.4

Some ship's data relevant to the investigations are plotted in fig. 412 against the angle of entrance.

PROGRAMME OF INVESTIGATIONS AND MEASURING INSTRUMENTS

The following measurements were taken several times each day throughout the fishing trip:

(a) shaft horsepower
(b) ship's speed
(c) warp pull
(d) angle and period of roll and pitch
(e) apparent angles of roll and vertical acceleration
(f) wind speed.

(a) The power was measured with a Maihak torsion meter aft of the thrust block on the shaft. An electric impulse counter was connected to the meter in order to determine the r.p.m. of the screw.

(b) The ship's speed was determined by a HSVA resistance-log calculated with the use of calibration curves from the measured resistance of a small metal cone towed behind the vessel.

(c) The warp pull was determined by means of two dynamometers fixed to the warps in a simple manner. Thus the annoying stopping of the warps with chains was avoided, although it is inevitable if ordinary spring dynamometers are used.

(d) The angles of roll and pitch were determined as before (Möckel, 1955). The periods of roll and pitch were found by using a stop watch, a long series of measurements being taken. Each day the GM was calculated with a fair degree of accuracy from the period of roll, thus permitting a representation of the variation of GM throughout the voyage.

(e) The devices for determining the apparent angles of roll and the vertical pitching accelerations were developed by Dr. Grim. Those mercury instruments give only the maximum obtained during the time of observations. Six instruments indicating the apparent angle of roll were distributed between the keel and the top of the wheelhouse, and seven accelerometers were distributed over the whole length of the ship.

(f) The wind speed was determined by means of an anemometer calibrated in a wind tunnel.

Owing to their sensitivity, some of these instruments e.g. the dynamometers were calibrated both before and after the voyage. The zero setting of the torsion meters was similarly checked. No change of the zero setting was noticed on any of the instruments during the voyages, so this source of error is thus excluded.

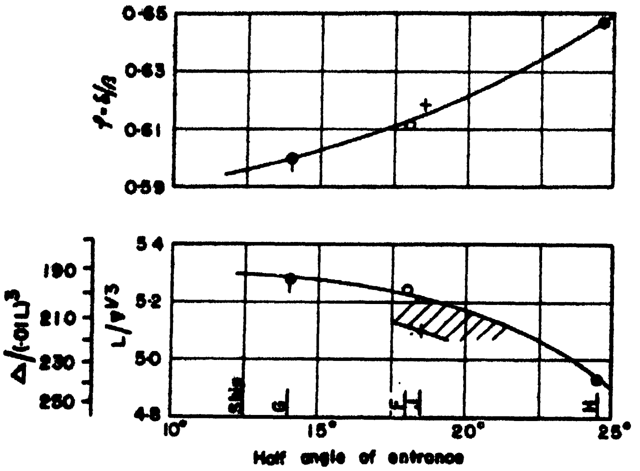


Fig. 412. Data of the forms of the trawlers investigated

POWER OUTPUT AND SPEED DURING GOOD WEATHER

Progressive trials were made on each ship in a calm sea at the beginning and the end of the voyage to determine the shaft horsepower, the propeller speed, and the speed of the ship. The results are plotted in fig. 413, 415 and 416, where the ship G is taken as an example. The curves for the other three vessels follow the same trend.

Fig. 413 shows the measured power versus r.p.m.^{3} In this diagram, which serves to check the measurements, the power curve forms a straight line as long as the torque coefficient is constant, $K_q = Q/\rho n^2 D^5$. This is generally true for vessels with comparatively low Froude numbers, e.g. freighters. However, as trawlers have higher propeller loads, because they sail at comparatively high Froude numbers, the gradient of the power curve increases at somewhat greater power than r.p.m.^{3}.

Fig. 413 shows the power curve at different wind forces, when sailing and when trawling. The torque coefficients K_q were calculated from these measurements and plotted against Froude numbers in fig. 414. The sailing point and the value determined at full load are shown on each curve. In the case of the two motor trawlers, which travel at higher Froude numbers than the steam vessels H and J, the torque coefficients under sailing conditions lie in the area where the curve rises sharply.

The torque coefficients increase with the pitch ratio of the propellers. Where this is low for example in ship G they remain constant up to high Froude numbers. As it rises, the coefficient also shows a tendency to increase, which is more pronounced at higher Froude numbers. However, in the case of ship H, the curve is too high in relation to the pitch ratio when compared with the results for the other three ships. The relatively high disc-area ratio of 0.57 may be a contributing factor. The effective pitch, which is unknown for all four propellers, in the case of ship H might be comparatively greater than that for the other ships, thus the effective pitch ratio will also be greater.

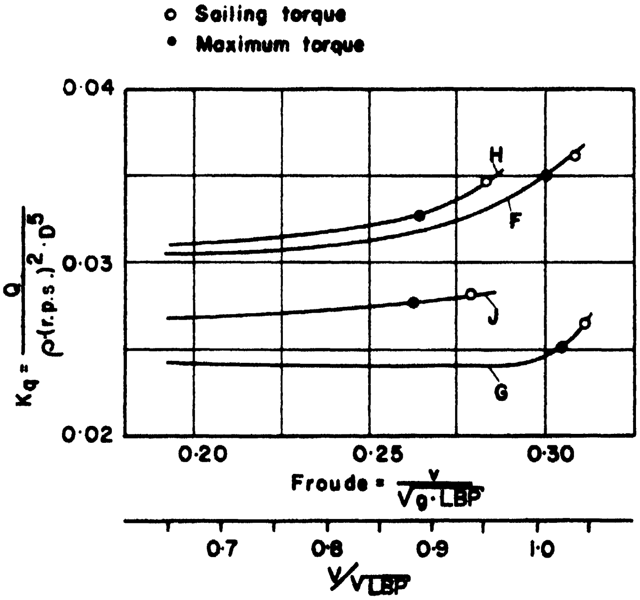


Fig. 414. Torque coefficients for trawlers

Since the power was determined several times a day throughout the voyage and the measured power always fell easily on the curve valid for the existing weather condition, the different torque coefficient found for ship H cannot be attributed to a measuring error.

Owing to the greater propeller load, the coefficients are higher when trawling than when sailing. In table 102 they are compared with the data obtained at sailing speed and at maximum speed.

Thus the torque coefficient when trawling is about 75 to 93 per cent. greater than when sailing. The trawling data given in table 102 for ships F, G and J represent power output at 3.5 knots. It is only the data for ship H that refer to the trawling speed of 4.5 knots usual when fishing herring.

A complete diagram is given in fig. 415 for trawler G,

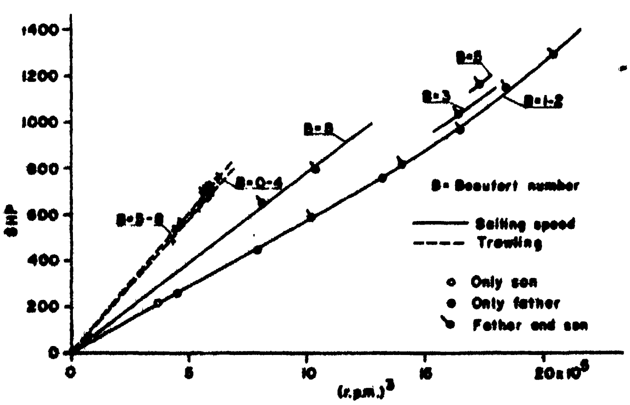


Fig. 413. SHP values for trawler G at different wind forces

where the values for shaft horsepower, ship's speed and trawl pull are plotted against r.p.m. It shows the curves obtained under different weather conditions, when sailing and when trawling. It can be seen from the diagram that the power requirement related to r.p.m. is the same on the outward and on the return voyage. The resistance, which varies with the displacement, has an effect only on the speed.

The trawling power, given below, is practically the same for all the vessels investigated:

Ship	*F*	*G*	*H*	*J*
SHP	568	570	630	572

As the ship H trawled one knot faster than the other vessels, its power was about 11 per cent. higher.

Differences in the hull form do not affect the power requirement at the low trawling speeds. At 3.5 knots, the resistance of a trawler of the type of ship G can be assumed to be about 0.5 ton, i.e. approximately 4 per cent. of the measured resistance of the gear, which was about 12.5 ton.

The measurements of warp pull, which were taken behind the gallows, appear at first sight somewhat high. Yet they were determined with much care by a long series of readings taken from two dynamometers on each trawl warp. The figures for warp pull were also supported by measurements by other investigators using ordinary dynamometers including the G's sister ship. These figures ran up to a maximum of 13 ton including the weight of the warps in water—about 2.4 ton.

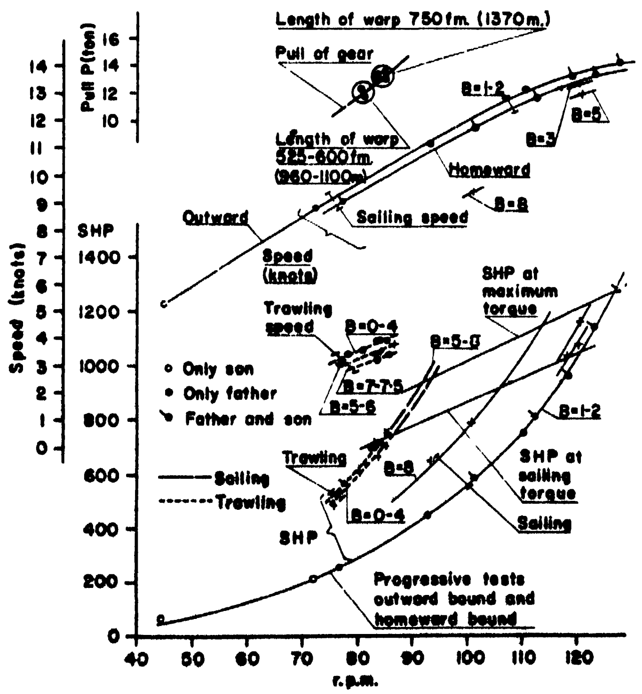


Fig. 415. Performance data versus r.p.m. measured on board trawler G under different weather conditions when sailing and when trawling

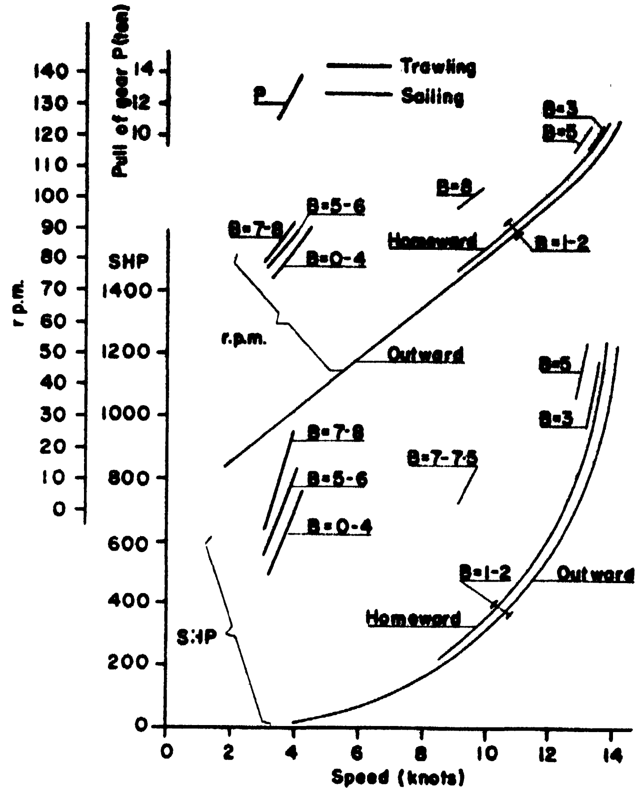


Fig. 416. Performance data versus speed measured on board trawler G under different weather conditions when trawling and when sailing

The efficiency of trawl pull can be expressed:

$$\eta_t = \frac{P\,(\text{kg.}) \times v\,(\text{m./sec.})}{\text{SHP} \times 75} = \frac{6.88\,P\,(\text{ton}) \times V(\text{knots})}{\text{SHP}}$$

The results are:

Ship	*F*	*G*	*H*
η_t	0.480	0.472	0.456

No measurements of pull were taken on ship J.

Although, under the influence of the seaway, the current and the ship's movements, some scatter is apparent in the warp pull figures, the efficiency shows very little difference; and it can be assumed that this is very close to reality.

The speed-power curves in fig. 416 are based on fig. 415.

TABLE 102

Comparison of torque coefficients at trawling and sailing speeds

Ship	*F*	*G*	*H*	*J*
K_{qs}	0.0350	0.0252	0.0329	0.0278
K_{qm}	0.0363	0.0266	0.0349	0.0281
K_{qt}	0.0611	0.0487	0.0591	0.0494
K_{qt} as percentage of K_{qs}	+75	+93	+75.5	+78
K_{qt} as percentage of K_{qm}	+68	+83	+69.0	+76

(where K_{qs} = coefficient at sailing speed; K_{qm} = coefficient at maximum output (maximum speed); and K_{qt} = coefficient at trawling speed.)

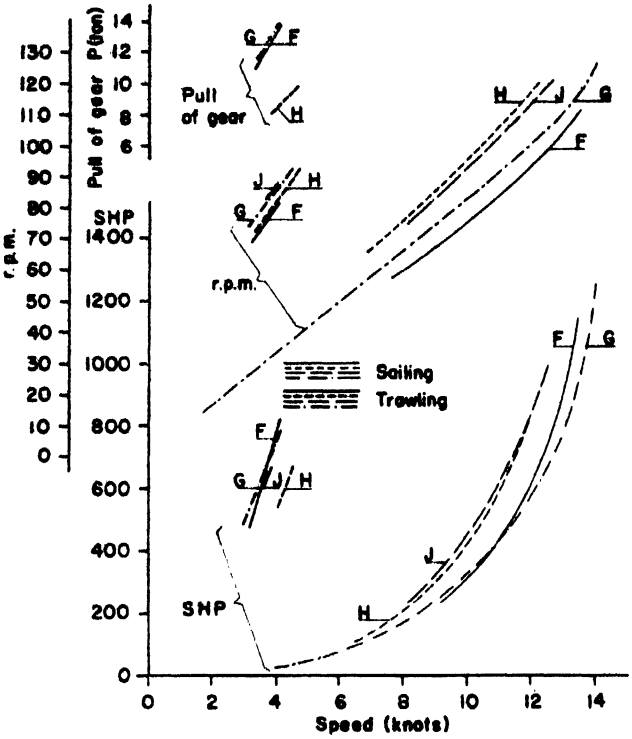


Fig. 417. Comparison of power requirements and trawl pull for the four trawlers under fair weather conditions

The fair weather curves for the four ships are assembled in fig. 417 for comparison.

In dealing with the question of power requirement it is important to know precisely what power and torque reserve are required when trawling in bad weather. It must first be ascertained to what extent the full sailing power output is needed for trawling in good weather.

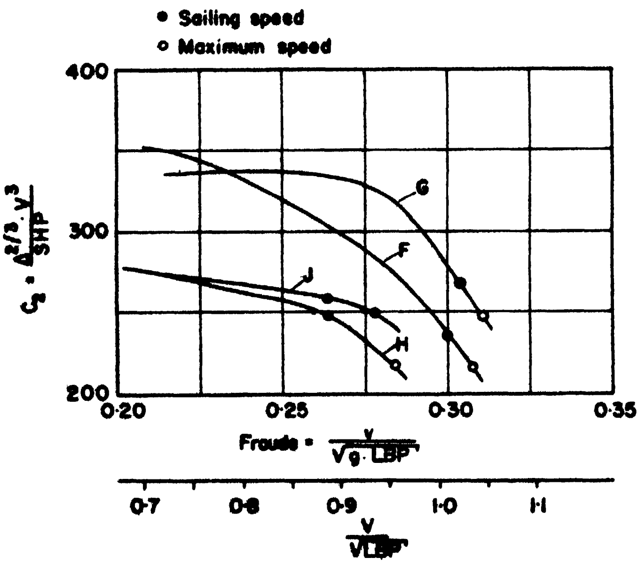


Fig. 418. Admiralty constants for the four trawlers

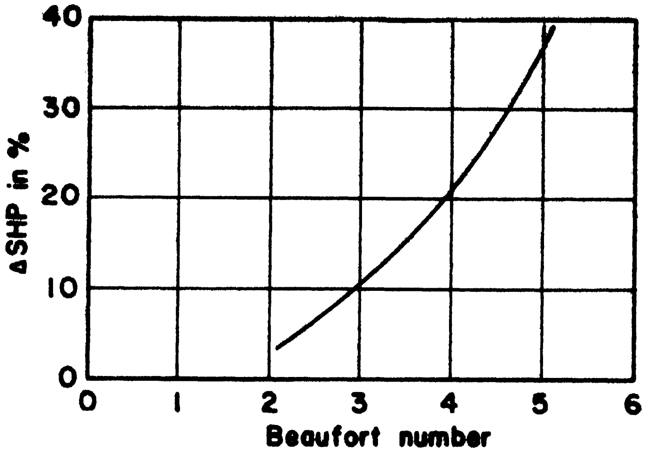


Fig. 419. Additional SHP for sustained 13 knots speed for ships F and G

The total power in good weather of the four trawlers was utilized as follows:

Ship	*F*	*G*	*H*	*J*
SHP when trawling as percentage of				
Sailing speed SHP	51.0	57.5	97.5	76.0
Full power SHP	43.0	46.0	69.0	63.0

Ship H was trawling at 4.5 knots and therefore required more power than the other vessels, trawling at 3.5 knots. At 3.5 knots, ship H would use about 57 per cent. of sailing speed power and 40 per cent. of the attainable maximum output. The reserve output cannot, however. be fully utilized at higher propeller loads owing to the decrease in r.p.m. It is not, therefore, the reserve of power but the reserve of torque which is decisive for the loading capacity of the engine. These reserves are notably smaller than the output margins indicated above:

Ship	*F*	*G*	*H*	*J*
Trawling torque as percentage of:				
Sailing speed torque	78	86	119	0
Full power torque	68	73	93	90

Thus, when trawling herring, ship H had already exceeded the sailing torque by 19 per cent. and used up 93 per cent. of the maximum torque. At 3.5 knots about 68 per cent. of the sailing torque and 53 per cent. of the maximum torque was required. On the other hand, ship J at 3.5 knots used all the sailing torque and up to 90 per cent. of the full power. In such cases it would be worth considering whether the use of a controllable-pitch propeller or multiple gear might be advantageous for economic reasons.

The steep rise of the power curves in fig. 417 shows that no further major gains of speed are to be expected from increase of power. The same tendency is apparent from trial measurements on most trawlers. Increased speed can only be attained by still better hull designs and increased length.

Judging from the C_2 curves (Admiralty constant $C_2 = \Delta^{2/3}V^3/SHP$) in fig. 418 it seems that for economical propulsion the ships should not travel at Froude numbers higher than:

	$V/\sqrt{L}$	$v/\sqrt{gL}$
Ship F . .	0.974	0.290
„ *G* . .	0.942	0.280
„ *H* . .	0.907	0.270
„ *J* . .	0.890	0.265

However, considerations, such as the marketing situation, also determine a ship's economic speed.

Fig. 418 was plotted from measurements taken at the beginning of the trips when the load conditions show a certain uniformity. These loads are very unequal on the homeward voyage.

THE SHIP IN THE SEAWAY

The seagoing qualities are determined by the loss of speed, by the additional power required to maintain speed and by the rolling and pitching condition. Only observations recorded when the wave pattern corresponded to the wind force, have been used.

Since good weather predominated during the short outward voyage of ship H, no investigations of the seagoing qualities of the unladen vessel could be made. However, the wind increased on the fishing grounds, so that some measurements could be taken.

The ship en route

The influence of wind and weather can be deduced from fig. 416 for trawler G. Such diagrams are available for all trawlers investigated. The shape of the hull of ships F and G differs only slightly, and the seagoing

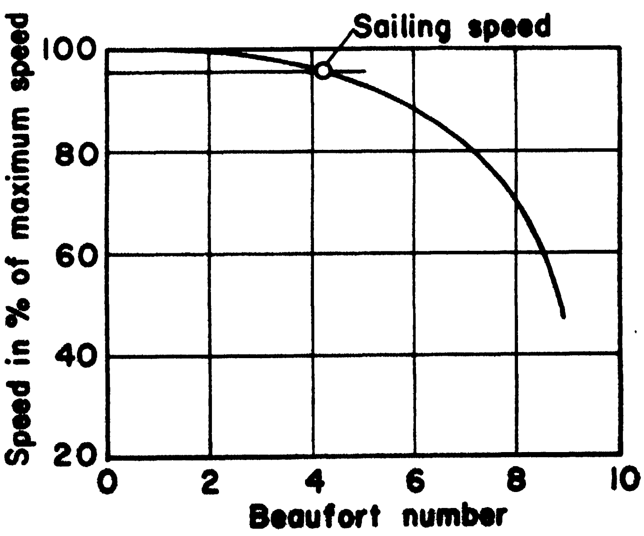


Fig. 420. Speed obtainable with maximum torque in per cent. of maximum speed for trawlers F and G

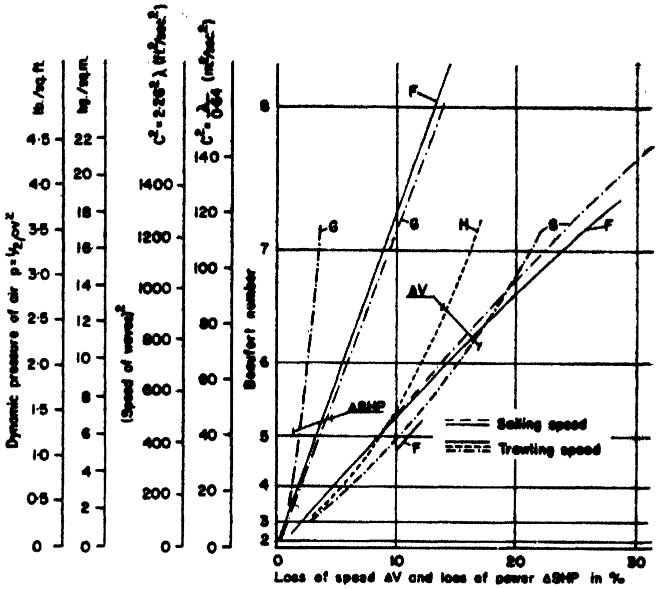


Fig. 421. Loss of speed and loss of power in per cent. of fine weather performance for trawlers F, G and H

qualities are practically the same. Fig. 419 shows that both ships require the same additional power to maintain their speed. The increase is quite considerable. It amounts to 37 per cent. at Beaufort 5 and a speed of 13 knots. The vessels still have that reserve of power. But they could only maintain 13.5 knots—corresponding to the sailing speed—up to about Beaufort 4, even at maximum torque. The possible speeds with maximum

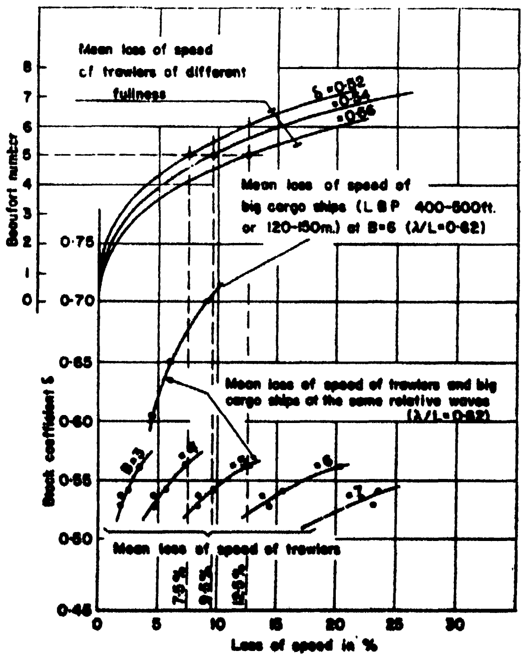


Fig. 422. Influence of wind and block coefficient on speed

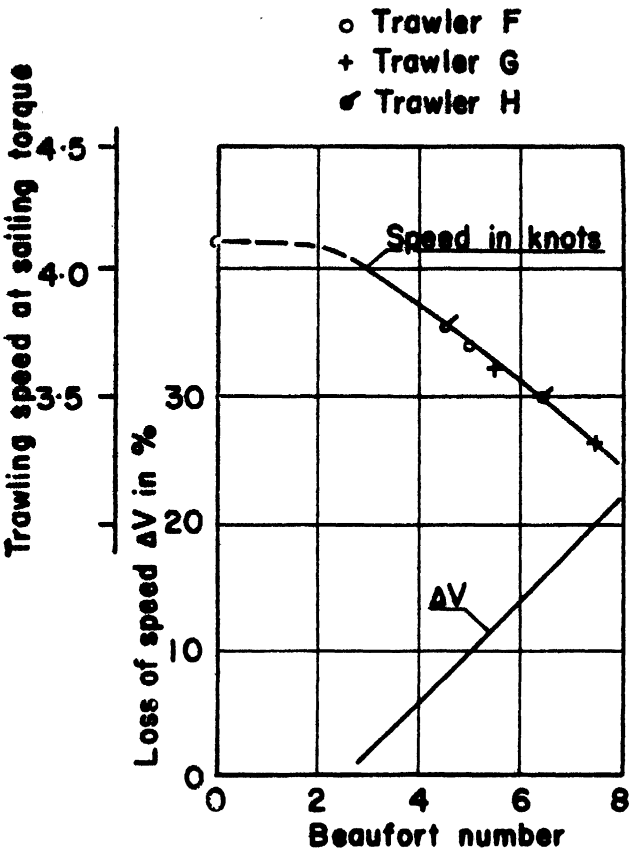


Fig. 423. Trawling speed at sailing torque in relation to wind force

torque are plotted in relation to the wind force in fig. 420, the speed in good weather taken as 100. For ships F and G, the sailing speed is about 3 per cent. less than the highest speed obtained with maximum torque. The diagram shows that the sailing speed could be maintained at Beaufort 4 with maximum torque. At greater Beaufort numbers the speed drops below sailing speed.

Fig. 415 also shows the power curve with uniform maximum and sailing torque. From this, fig. 421 gives the loss of speed, ∇V, and loss of power, ∇SHP, when travelling against the wind and the sea. The difference in losses for ships F and G are so slight that they may well be neglected and the two trawlers may thus be considered as equivalent.

The wind force ordinate of the diagram is divided to correspond to the dynamic pressure of air $p = \rho v^2/2$ and p to the square of the speed of the waves $c^2 = \lambda/0.64$. The percentage loss of speed remains proportional to p and c^2 up to about Beaufort 6. At higher Beaufort numbers, however, the loss of speed increases more rapidly.

Fig. 422 shows the influence of the shape of the hull on loss of speed under identical weather conditions. The loss increases with the block coefficient. At Beaufort 5, for example, it was found:

δ	ΔV
0.52	7.5%
0.54	9.5%
0.56	12.5%

Fig. 422 also shows the loss of speed for cargo ships at Beaufort 6. The loss of speed of trawlers is considerably

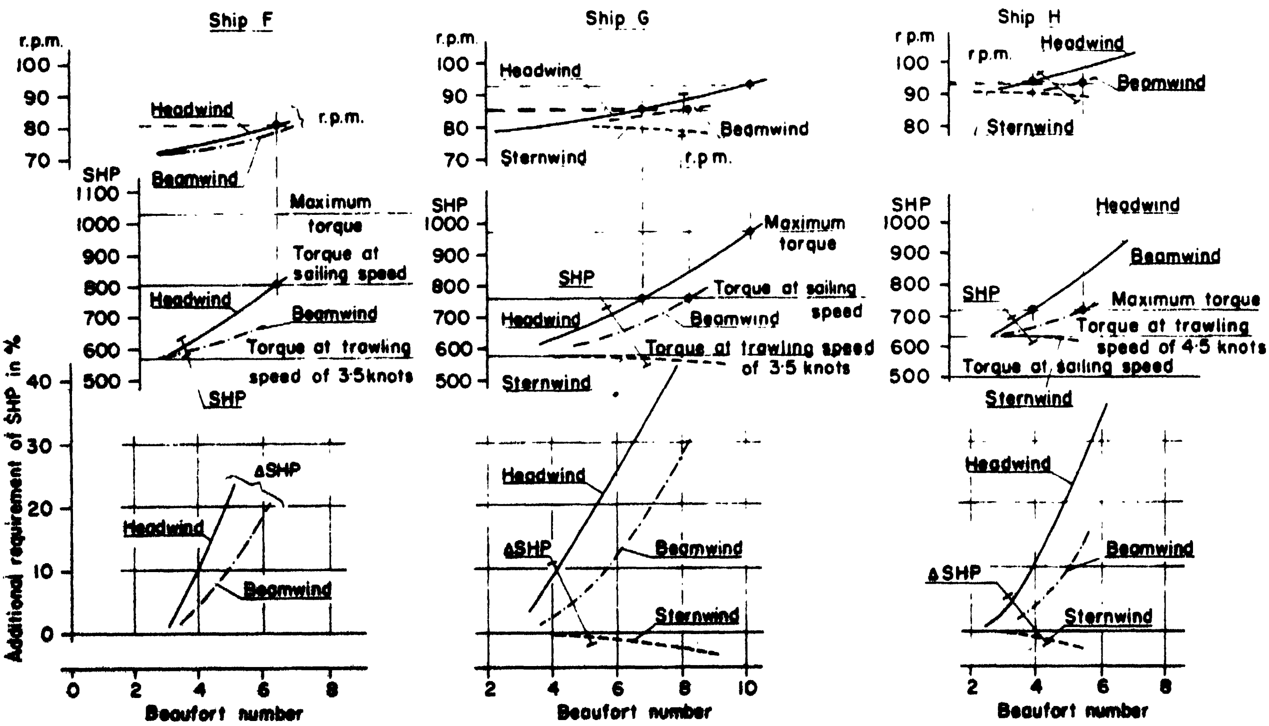


Fig. 424. Additional power requirement for trawler F, G (trawling at 3.5 knots) and H (trawling at 4.5 knots) at different wind forces

more than that of deep-sea cargo ships, although the latter are fuller, and their power per ton displacement, SHP/∇, from 0.3 to 0.6 is less than that of trawlers. The ratio for larger trawlers ranges between 0.8 and 1.0, and for smaller trawlers it is about 0.6.

It must be the larger pitching movements—being considerable in comparison with those of deep-sea cargo ships—which are responsible for the high losses of speed. The ratio of wave length to length of ship, λ/L, under identical weather conditions is also different. At Beaufort 6, trawlers in the northern part of the North Sea travel at a wave length / ship length ratio of from 0.9 to 1.1, which causes heavy pitching into the head seas. At the same Beaufort number, the λ/L ratio for cargo ships in the North Atlantic lies between 0.55 and 0.70. A trawler would meet corresponding waves at Beaufort 5. Fig. 422 indicates that loss of speed is considerably more for trawlers in the seaway than for big cargo ships, even if the λ/L ratio is the same.

The ship when trawling

The influence of wind and waves is notably less when trawling. The maintenance of 85 r.p.m. of trawler G at wind force 8, when sailing, requires an increase in power of 36 per cent. and when trawling, an increase of only 4 per cent. In this case the loss of speed amounts to about 20 per cent. when sailing, but only about 4 per cent. when trawling.

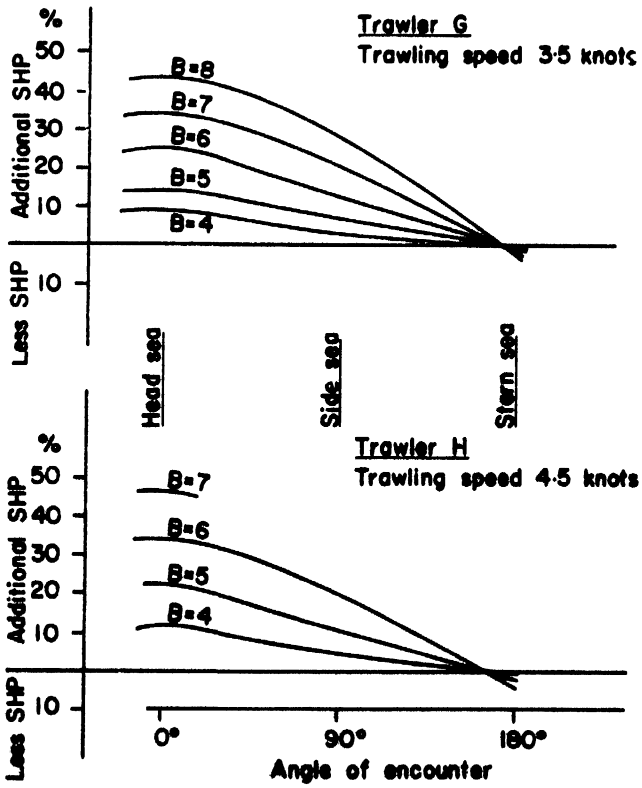


Fig. 425. Percentage of additional SHP for maintaining trawling speed in relation to wind force and angle of encounter (head seas 0°)

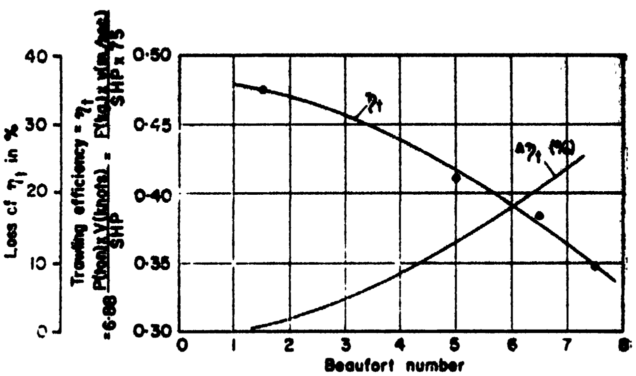


Fig. 426. Efficiency of warp pull for trawlers F, G and H

Fig. 421 indicates that for ships F and G the losses of speed when sailing and when trawling at Beaufort numbers up to 6 differ only a little, whilst the increase of power when trawling is considerably less than when sailing. The losses of speed and power are related to the sailing torque when sailing and to the good weather trawling torque when trawling.

Ships F and G are practically equivalent both when trawling and sailing. The loss of speed of ship H is somewhat less than that of both ships F and G, the reason being that the power of ship H—trawling faster—at a trawl pull of 8.5 ton was 11 per cent. greater than that of vessels F and G. The trawl pull of F and G was about 12 to 13 ton. It may be assumed that ship H, trawling with a light gear, regains speed much quicker after pounding into the waves than vessels F and G.

Fig. 423 shows that, with good weather sailing torque, ships F, G and H can all attain a trawling speed of 4.1 knots. The trawling speeds with this torque are also the same for all three vessels at the various wind forces. Up to Beaufort 6, they can maintain the usual white-fish-trawling speed of 3.5 knots with sailing torque. At higher wind forces, the engine must possibly be operated at maximum torque. Fig. 424, illustrating this point, shows for various angles of encounter and r.p.m., the power development and additional power needed to maintain the trawling speed (for F and G, 3.5 knots; for H, 4.5 knots) at different wind forces. With maximum torque, ship G can maintain 3.5 knots up to Beaufort 10. No observations at such high forces are available for the other vessels. Since, as a matter of fact, continuous overload of the engine is impossible, trawling has to be stopped before that limit is reached. Modern trawlers cease fishing at wind forces of 8 to 9. With maximum torque in good weather the three vessels reach a trawling speed of 4.7 knots.

The torque reserve of modern trawlers permits trawling at high wind forces. Therefore, it is important to improve the sea-going qualities and the gear to take advantage of this possibility without danger to the crew.

In fig. 424 there is a partial extrapolation of the power curves. This was made by the r.p.m.* curves of fig. 413. Since the power curves form a straight or almost straight line, notable deviations may rarely occur.

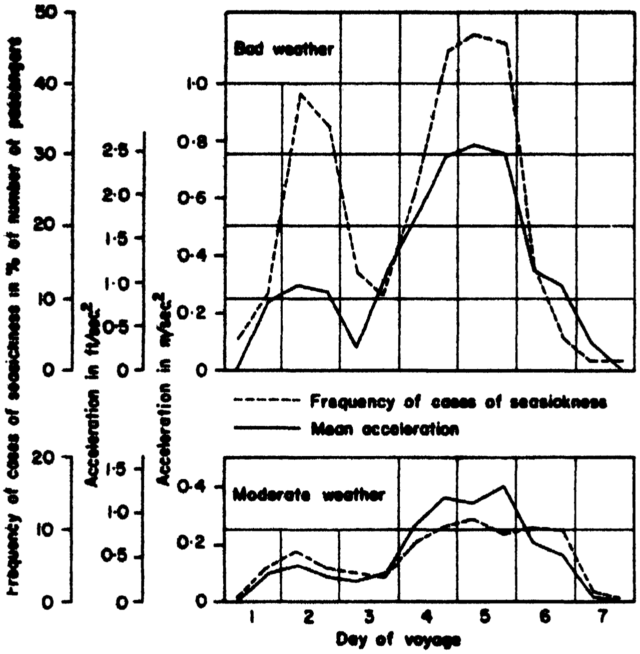


Fig. 427. Influence of acceleration on the comfort of people on board ship (compare fig. 409)

As far as possible, curves for head, beam and following wind were included. Up to Beaufort 2, the vessels maintain the trawling speed with the trawling torque required in good weather. At head wind of Beaufort 2 to 3 and corresponding sea, the power requirement starts to increase. The corresponding r.p.m. for a particular power can be ascertained from the upper curves in fig. 424. The r.p.m. of ship G, when trawling in good weather is 78, it rises to 85 with sailing torque for Beaufort 6 to 7 and to 92 with maximum torque for Beaufort 10. In a calm sea, ship F trawls with 73 r.p.m. With sailing torque, the r.p.m. is 82.

The lower diagrams of fig. 424 show the additional power requirement, plotted against wind force with the angle of encounter as parameter. Cross-curves are given in fig. 425, showing the power increase to maintain trawling speed at any angle of encounter. With a following wind, there is a slight gain in power.

Under the influence of wind and sea both power and efficiency of the trawling pull are affected, as shown in fig. 426. At the same Beaufort number, the efficiency of the three ships is so close that it can be represented by a single curve. Thus, at Beaufort 5 and 7, the reduction in the efficiency of the trawling pull amounts to 13 and 24 per cent. respectively.

THE STABILITY

Rolling is governed by the stability. The reactions of the crew to the ships' motion are determined by the accelerations. The greater the period of roll

$$T_r = \frac{2\pi k_t}{\sqrt{gGM}} = \frac{1.108mB}{\sqrt{GM}} \text{ in ft.} = \frac{2mB}{\sqrt{GM}} \text{ in m.}$$

the less unpleasant the ship's movements are felt to be. It is, therfore, important to design a ship with a stability giving a maximum period of roll without endangering its safety.

It is well known that the comfort of those on board is determined, as a rule, by the extent of the acceleration. Statistical evidence of this fact was first published by Dr. Geller in the "Klinische Wochenschrift", No. 51 of 21 December 1940. Dr. Geller was for many years a physician on big passenger liners. He measured the accelerations several times each day with instruments designed by himself. At the same time he recorded the number of cases of seasickness among the passengers. Fig. 427 (compare fig. 409) shows the frequency of cases of seasickness for bad and moderate weather compared with daily accelerations. The diagram indicates impressively the parallelism between acceleration and frequency of seasickness, and gives a very good idea of the stresses to which fishermen are exposed in the pursuit of their profession. During the voyage of the liner where bad weather predominated, the maximum acceleration noted was 2.6 ft./sec² (0.8 m./sec²). At this figure, almost 50 per cent. of the passengers were seasick. The maximum acceleration for trawlers, as established by the Hamburg Ship Model Basin, is in the neighbourhood of 1 g= 32.19 ft./sec² (9.81 m./sec²). Thus this acceleration is about twelve times larger than the value for the liner and not even a single case of seasickness did occur.

It is sometimes recommended that, in order to reduce

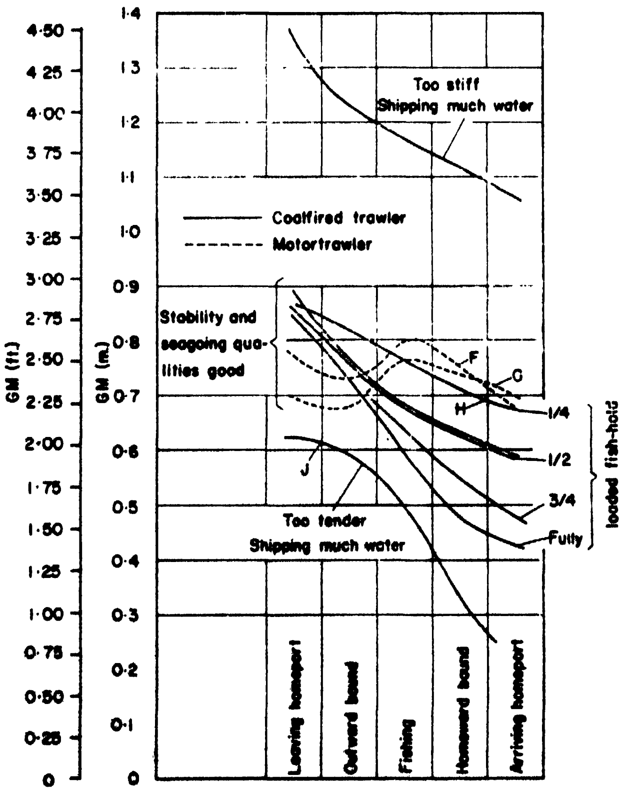


Fig. 428. Stability changes during the trip plotted from the daily averages

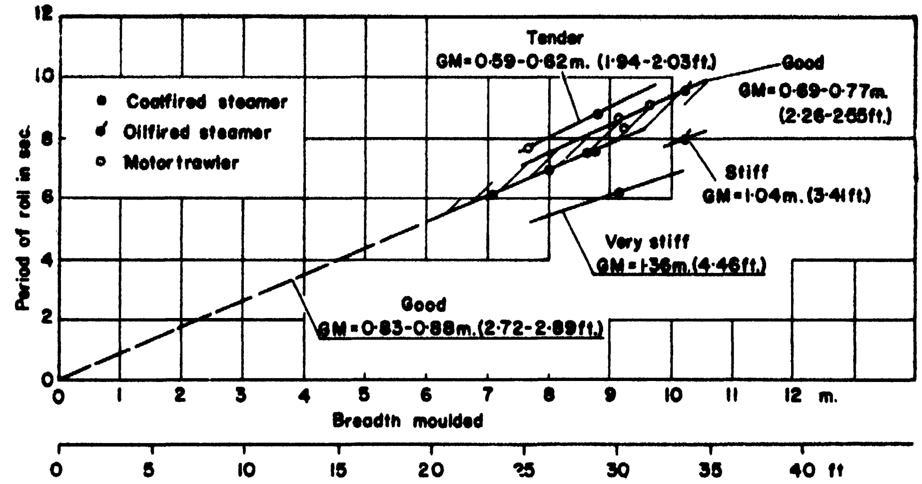


Fig. 429. Influence of stability on sea-going properties

rolling motions, there should be a reduction in the metacentric height. It is then necessary to study the crew's reactions to the motions of trawlers of different stability and consider the shipping of water when trawling in bad weather. The quantity of water shipped is decisive for work and for the safety of the crew.

It is difficult to determine a trawler's metacentric height by an inclining experiment (which has to be confined to the stay in port) because the short turn-around periods are fully taken up with unloading, equipping and essential repair work and the necessary time for the experiment is, therefore, seldom to be found. It is thus simplest to determine the metacentric height from measurements of the natural period of roll. The demands of adequate reliability are met if the period of roll is carefully ascertained by a long series of measurements and if the m-value for calculating the radius of gyration from the ship's breadth, B, corresponds to actual conditions. Inclining tests and simultaneous measurements of the natural period of roll have been done by several workers independently to determine those m-values and results have largely concurred. Nickum's (1955) investigations of tuna clippers in the U.S.A. gave m-values being between 0.385 and 0.415. The values obtained in Germany are in the same order of magnitude. From the results of investigations at various stages of the voyages they can be taken to be as follows:

Leaving port	m=0.400
Average outward bound. .	„ =0.395
Average trawling . . .	„ =0.390
Average homeward bound .	„ =0.387
Arriving port	„ =0.385

These values are for a normal fishing trip lasting about three weeks. The metacentric height determined by these values from the period of roll generally agreed very well with the stability calculations of the shipyards. It may be regarded as accurate enough for the present purpose.

During the trips the periods of roll were carefully determined several times each day and the mean GM was calculated from the daily average. The average metacentric height for the individual stages of the trip obtained from these daily averages are plotted in fig. 428. They give a fair idea of the variation in GM over the whole voyage. The results of more recent experiments have been used to complete the diagram, which has already been published (Möckel, 1955; p. 329, fig. 429).

The steam trawlers investigated generally start the voyage with a GM of about 2.8 to 2.9 ft. (0.55 to 0.89 m.). Naturally, on return to port, there are considerable differences. The bigger the catch, the less the metacentric height on arrival in port. The hold of ship H was loaded only to about a quarter; it returned with a GM of 2.3 ft. (0.70 m.), while another, almost exactly similar, trawler with a full fish hold had a GM of only 1.38 ft. (0.42 m.). Between these extremes, the stability curves of the other vessels fit in naturally according to the load condition. Ship J, starting its trip with a GM of 2.07 ft. (0.63 m.), was tender compared with the other ships and it was felt to be so by the crew. As a result of serious complaints by the crew, who had a feeling of insecurity, more solid ballast was put into the vessel.

The curves for the motor trawlers are quite different from those of the steam trawlers. After an initial decrease during the outward trip, they rise again when trawling, whilst the GM of the steam trawlers show a continuous decrease over the course of the trip. This is due to the different weight distribution of water and fuel and the difference in daily consumption. The steamers consume about 11 ton of coal and 2.3 ton of water daily, while the daily fuel consumption of a motor trawler is only about 6 ton. The influence of the fish is assumed to be about identical. The GM of the motor trawlers investigated were approximately 2.3 to 2.53 ft. (0.70 to 0.77 m.). When leaving port, they were somewhat less than those of the steam trawlers, and on return had a GM between 2.23 and 2.3 ft. (0.68 to 0.70 m.), showing that there was little difference in GM at the beginning and the end of the trip.

Trawlers often ship large quantities of water and in cold weather are subject to icing. Thus, on one occasion off the Greenland coast, trawling had to be suspended on ship F due to all-over icing. The vessel had become so tender that the captain had to stop and remove the ice.

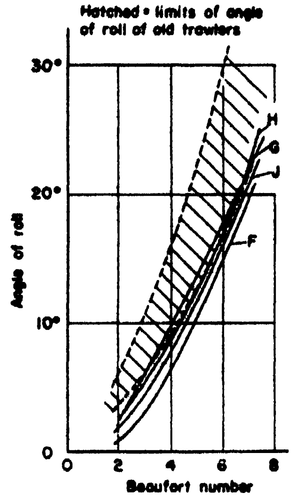


Fig. 430. Angle of roll of old and modern trawlers

Ship G, too, was so iced up at the start of the voyage that the GM was only 1.84 ft. (0.56 m.). When the ice had melted in warmer air after two days the GM rose to 2.1 ft. (0.64 m.). Calculation with the help of the stability curves indicated a GM of 2.66 ft. (0.69 m.) on leaving port, when there was no icing.

At the end of a voyage with full hold the metacentric height of steam trawlers was only from 1.41 to 1.48 ft. (0.40 to 0.45 m.). Motor trawlers also might suffer from lack of stability.

It is not necessary to increase the period of roll, because the crews, being accustomed to the violent motions of these small ships, seldom complain about rolling as long as the stability is normal within the limits explained below.

The periods of roll on departure were plotted against the ship's breadth in fig. 429. The trawlers are then uniformly laden, whereas on arrival in port there may be considerable differences in load and stability. The views of the principal members of the crew (captain, mates, engineers) supplement the curves represented in fig. 429. The ships within the hatched area did not give rise to any serious complaints. Their behaviour in a seaway was normal and, when trawling in bad weather, they shipped scarcely any, or only a little, water so that the handling of the trawl and the catch was not seriously affected. On the other hand, the ships outside the hatched area shipped so much water in bad weather that fishing was seriously hindered and it often had to be stopped when other vessels continued trawling. These experiences show that trawlers are more sensitive to stability than is commonly supposed—not so much with regard to safety against capsizing as in respect of the safety of the crews when working the net and the catch. The GM of the ships defined as "stiff" in the diagram could be reduced—but not that of any other ship.

From the investigations of stability so far carried out and from fig. 429. the following summary gives a preliminary conclusion:

GM	*Crew's view of stability and behaviour of ship*
(a) 4.46 ft. (1.36 m.)	Much too stiff; jerky rolling; vessel ships much water predominantly windward; deck work impossible; trawling has to be stopped early.
(b) 3.41 ft. (1.04 m.)	Too stiff: jerky rolling; much water on deck.
(c) 2.72 to 2.89 ft. (0.83 to 0.88 m.)	(Steam trawler). Movements are felt to be normal.
2.3 to 2.62 ft. (0.70 to 0.80 m.)	(Motor trawler). Vessel ships little or no water; no serious complaints.
(d) 1.94 to 2.03 ft. (0.59 to 0.62 m.)	Ship is too tender; heels under a beam wind sharply to leeward and ships much water by the lee rail; fishing becomes difficult; the crew have a feeling of insecurity.

The ships listed under (c) may be regarded as normal. Ships having a GM as set out under (a), (b) and (d) showed unsatisfactory behaviour; water was shipped in bad weather and trawling became difficult. Fig. 429 is only to be regarded as a preliminary result. Definite conclusions must be supplemented by further accurate measurements.

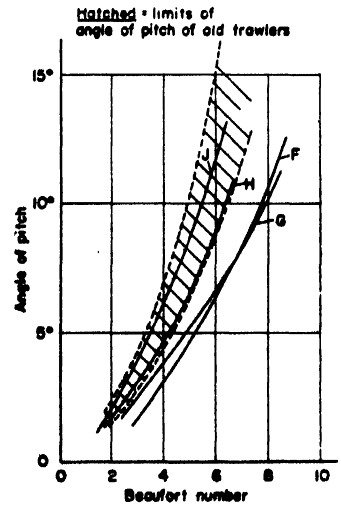
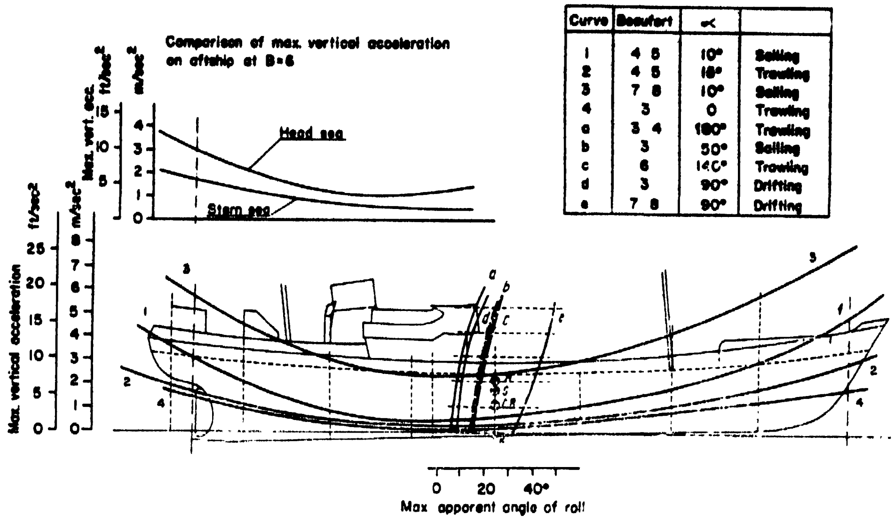


Fig. 431. Angle of pitch of old and modern trawlers

ROLLING AND PITCHING

Experienced fishermen feel that the rolling motions of modern trawlers are on the whole somewhat less

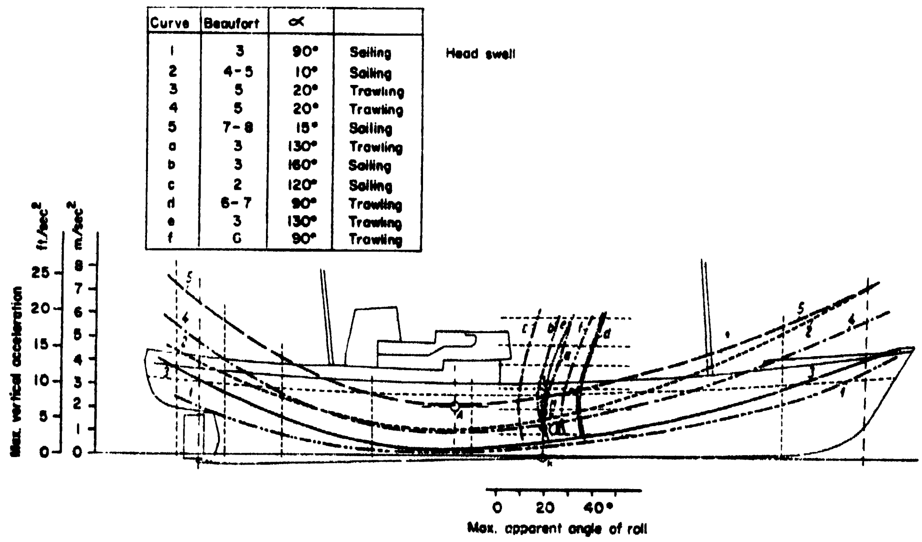


Curve	Beaufort	∝	
1	4 5	10°	Sailing
2	4 5	15°	Trawling
3	7 8	10°	Sailing
4	3	0	Trawling
a	3 4	180°	Trawling
b	3	50°	Sailing
c	6	14C°	Trawling
d	3	90°	Drifting
e	7 8	90°	Drifting

Fig. 432. Angles of roll and accelerations as measured on the trawler F in loaded condition

unpleasant than those of the older vessels. This subjective reaction is also confirmed by the measurements of the angle of roll in fig. 430; trawlers F, G, H and J have on the average smaller angles of roll than the older trawlers. This is mainly due to their considerably greater breadth. Also the rise of floor and bilge radius are greater in the older types. The differences in rolling hardly depend on the GM, which are approximately the same. The only exception is ship J with its relatively low GM. Even so, its angles of roll are nearly the same as those of the other ships investigated but they might be misleading because, being a tender ship, it rolled about a greater prelist when there was a beam wind. This prelist is not included in the measurements of the angle. The greatest total angles between the reversion points experienced are shown in table 103.

The natural periods of pitch were in the order of 4.2 to 4.4 sec.; according to calculation they should be 4.7 to 4.9 sec. Fig. 431 shows that at the same Beaufort number the angles of pitch of the loaded ships H and J were considerably larger than those of the more slender motor trawlers F and G, which had practically the same amplitudes up to Beaufort 9 head wind. The angles of pitch of F and G are less than for the old steam trawlers investigated earlier, while ships H and J lie within the hatched area. The crew complained about the unpleasant pitching of ship J. They felt it to be normal only when the fish hold was 70 per cent. full. This reaction follows from the decrease of vertical acceleration because of the greater radius of gyration, the greater natural period of pitch, the decrease of the angle of pitch due to the smaller reserve displacement of the



Curve	Beaufort	∝	
1	3	90°	Sailing
2	4-5	10°	Sailing
3	5	20°	Trawling
4	5	20°	Trawling
5	7-8	15°	Sailing
a	3	130°	Trawling
b	3	160°	Sailing
c	2	120°	Sailing
d	6-7	90°	Trawling
e	3	130°	Trawling
f	6	90°	Trawling

Fig. 433. Angles of roll and accelerations as measured on the trawler G in loaded condition

forebody, and a shift forward of the centre of buoyancy.

The notable changes in the motion of the ship brought about by the load in the fish hold is also shown by the difference between the fore and aft accelerations. When the hold is empty, accelerations are considerably greater forward. This difference becomes less as the load increases, as shown by measurements on trawlers with a heavy catch. On ship G, fig. 433, which returned home with a full cargo of fish, the maximum acceleration was greater at the forward perpendicular by the following percentages:

Measurement	*Load*	*At forward perpendicular*
1	Fish hold empty . . .	+75 per cent.
2	Fish hold empty . . .	+85 „ „
3	Fish hold about ½ to ¾ loaded .	+31 „ „
4	Fish hold ¾ loaded . . .	+23 „ „
5	Fish hold fully loaded . .	+14 „ „

Owing to the character of the wave pattern at the time, these percentages show a certain scatter. The tendency towards less difference between the accelerations fore and aft is evident as the fish hold is loaded. The curves for trawler F in fig. 432 show the same trend. At the start of the trip, the maximum vertical accelerations at the fore perpendicular were found to be 61 to 67 per cent. greater than those at the aft perpendicular but towards the end of the voyage only 35 to 38 per cent. That the pitching of a trawler varies with the load condition is a fact known to every fisherman. The figures only serve to show the extent of the variation and, at the same time, give an idea of the men's reactions. They also show that there is a distinct advantage if the crew is accommodated aft.

Curves 1 and 2 in fig. 432 show that, with a head wind of Beaufort 4 to 5, accelerations both forward and aft are about 60 per cent. greater when sailing than when trawling. The maximum acceleration at the fore perpendicular was found to be about 24 ft./sec² (8 m./sec²)

TABLE 103

The greatest total angles of roll and pitch and periods of roll

Ship		*F*	*G*	*H*	*J*
Breadth moulded	ft.	30.2	29.9	28.2	28.9
	m.	9.20	9.10	8.60	8.80
Angle of roll, φ . .		30°	37°	38°	46°
Angle of pitch, ψ . .		20°	17°	8°	15°
Periods of roll—T_r					
Leaving port . (sec.)		8.40	8.77	7.56	8.90
Average outward „		8.69	8.72	7.58	9.09
Average trawling „		8.06	8.20	7.78	9.78
Average homeward „		8.26	8.32	8.02	12.03
Arriving port . „		8.58	8.36	8.23	14.17

when travelling full power against wind of Beaufort 7 to 8. Accelerations resulting from the long periods of pitch with a following sea have the lowest values. The special diagram in fig. 432 shows the accelerations at Beaufort 6 on the aft body. Handling the catch and repair of the nets made it impossible to pass on to the foredeck and read the instruments arranged there. Yet even this partial measurement indicates the effect of the angle of encounter on the acceleration. The measurements were taken at half-hour intervals before and after hauling and shooting the net. Fig. 435 also offers a curve measured with a following wind of Beaufort 4 to 5. It shows that with a following sea the accelerations are somewhat greater at the stern than at the bow. The point of minimum motion which coincides with the minimum point of the curve is located forward. Thus in a following sea the ship pitches about an axis further ahead.

Curve	Beaufort	∝	
1	3 - 4	90°	Trawling
a	1 - 2	100°	Trawling
b	3 - 4	100°	Trawling
c	3 - 4	80°	Trawling
d	3 - 4	70°	Trawling
e	4 - 5	90°	Trawling

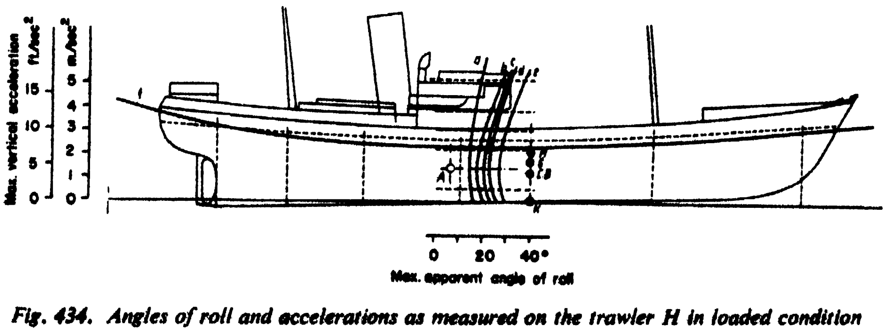


Fig. 434. Angles of roll and accelerations as measured on the trawler H in loaded condition

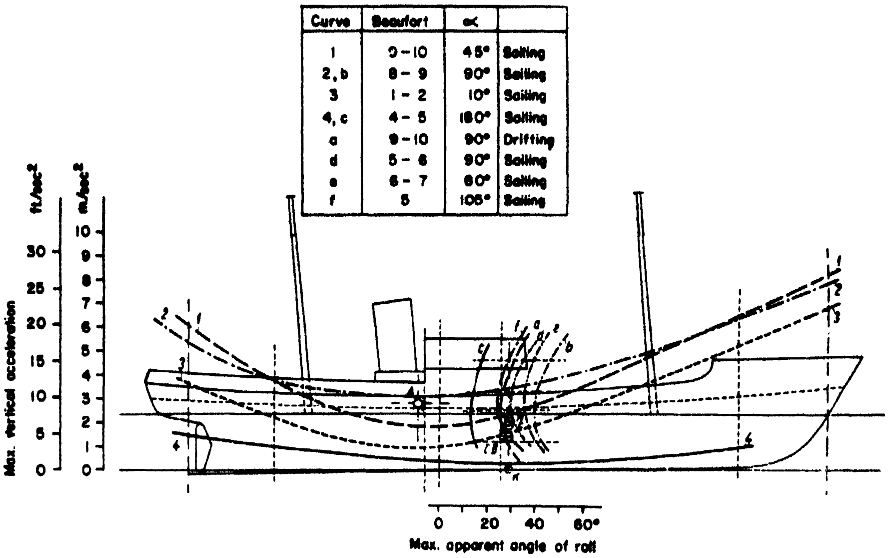


Fig. 435. Angles of roll and accelerations as measured on the trawler J in loaded condition

The position of the point of minimum vertical motion is indicated in each diagram. In the case of ships F, G and J, when sailing against the sea, it is situated about 0.36 LBP from the aft perpendicular. The position of minimum pitching motion of ship H lies at 0.43 LBP. Owing to the good weather, only one measurement could be taken, and that with a beam swell. Its presence is clearly apparent from the high level and flat course of the curve. This reading is therefore unsuitable for determining the point of minimum motion. There is evidence of relatively considerable heaving accelerations and only slight pitching accelerations.

The diagrams also include the maximum apparent angles of roll. They are greatest at the top of the wheelhouse. It has its minimum below the deck and again increases as the keel is approached.

The point, A, the intersection of apparent minimum angle of roll and of minimum vertical acceleration, is the steadiest point of the ship.

TABLE 104

Heights of points of minimum roll above keel—KA—in relation to height of centre of gravity—KG

Ship	*KA*		*GM Departure*		*KA/KG*
	ft.	m.	ft.	m.	
G	11.8	3.59	2.26	0.69	1.15
H	11.1	3.38	2.79	0.85	0.80
J	12.4	3.78	2.03	0.62	1.47

The point, A, was omitted for ship F because the curves indicated it to be in or even beneath the keel, which was confirmed by all measurements. There is no explanation for the trend of the curve from the stability data of ship F when compared with the other vessels. Such curves might occur in the case of a very stiff ship. The metacentric height as found by the rolling period is about the same as for the other trawlers and was in very good agreement with the stability calculations of the shipyard. The reason might be that the lowest instrument had failed.

The position of the steadiest point is to a large extent dependent on the weight distribution, i.e. on the stability. No definite conclusions concerning the relation between this position and the stability can be drawn from the results of only three vessels. The values should therefore only be regarded as preliminary. Table 104 gives the height of the point of minimum rolling motion (KA) with reference to the distance (KG).

The point of minimum rolling motion is highest for the most tender of the three ships (J) and lowest for the stiffest (H). The figures can, however, only be regarded as approximate values since, owing to the flat course of the curves for the apparent angle of roll in the range of minimum motion, the position of minimum rolling motion cannot be fixed with precision.

It should be noted that investigations during fishing trips are subject to unwanted influences and the results, therefore, represent only approximate values. But, for practical purposes, they provide an idea of the behaviour of ships in a seaway and stimulate basic research to be carried out with models.

REMARKS ON THE SHAPE OF DUTCH COASTAL FISHING BOATS

by

W. ZWOLSMAN

After World War II, the Dutch fishing fleet was entirely reconstructed. The most successful vessels were of the *GO* 28 and *HD* 12 types. This paper describes their speed, seakindliness and fuel oil consumption.

Some comparisons are made with two finer boats, one of which suffered from lack of buoyancy in following seas, while the other behaved like a drunken man. Comparisons are also made with fuller boats of the *RE* 212 type, which showed a tremendous increase in resistance.

REMARQUES SUR LA FORME DES BATEAUX DE PÊCHE CÔTIERS HOLLANDAIS

Après la seconde guerre mondiale, la flotte de pêche hollandaise a été entièrement reconstruite. Les types de bateaux *GO* 28 et *HD* 12 ont donné les meilleurs résultats. Cet article renseigne sur leur vitesse, leur tenue à la mer et leur consommation de carburant.

Ils ont été comparés à deux bateaux plus fins, l'un d'eux souffrait d'un manque de flottabilité par mer venant de l'arrière, alors que l'autre se comportait comme un homme ivre. Ils ont aussi été comparés avec des bateaux à formes plus pleines du type *RE* 212 qui montraient une énorme augmentation de la résistance.

OBSERVACIONES SOBRE LAS FORMAS DE LOS BARCOS DE PESCA COSTEROS DE LOS PAISES BAJOS

La flota pesquera de los Países Bajos se reconstruyó totalmente después de la segunda guerra mundial. Los tipos que dieron mejores resultados fueron el *GO* 28 y *HD* 12. Se describen su velocidad, navegabilidad y consumo de combustible.

Se hacen algunas comparciones con dos barcos de formas más finas, uno de los cuales no tenía suficiente flotabilidad con mar de popa y el otro se portaba como un ebrio. También se hacen comparaciones con barcos de formas más llenas del tipo *RE* 212, cuya resistencia había aumentado extraordinariamente.

THE post war reconstruction of the Dutch fishing fleet provided an opportunity to revise and experiment with the hull shape of the boats. The *GO 28*, fig. 436, and the *HD 12*, fig. 437, are typical examples of the latest developments. The *GO 28*, 68.9 ft. (21 m.) LOA and 17.7 ft. (5.40 m.) beam is equipped with a 3 cyl. 190 h.p. engine running at 750 r.p.m., with a reduction gear of 2½ : 1. The *HD 12* has a 250 h.p. 4 cyl. engine running at 750 r.p.m., with a reduction gear of 2½ : 1. Both boats are among the most economical in the Dutch fishing fleet, as shown during the annual examination made by the Dutch Fisheries Department. This examination has revealed that skipper-owned boats with 190 to 250 h.p., in the main, give more favourable results than boats with engines of less than 150 h.p. or larger boats with engines of 300 to 350 h.p. While these successful boats have not been model tested, the shape as shown in fig. 438 has been developed on the basis of model tests made by others and on practical observations. Their principal dimensions are:

LOA = 73.3 ft. (22.35 m.)
LBP = 63.9 ft. (19.50 m.)
B = 18.4 ft. (5.60 m.)
D = 9.0 ft. (2.75 m.)

Speed and seakindliness

During the last five years boats of 70 to 85 ft. (21 to 26 m.) LOA have been built on these lines with only slight variations. The speed results are favourable, as can be seen by fig. 439, comparing the power curve of *HD 12* and *RE 212* with those of an average and an optimum fishing boat given by Traung (1955). The optimum anticipated has practically been reached. The waterline length is the same, but the beam and the displacement of Traung's examples are 10 per cent. larger.

The average metacentric height of the Dutch fishing boat of standard shape, with full fuel and water tanks and all gear on board except ice, is 2.56 ft. (0.78 m.). The vessels are praised by the crew as very seakindly compared with the boats built before the war.

Vessels of the same dimensions and shape have been in service for some years in Denmark, Belgium, France, the regions around the Mediterranean, West African countries and in the Far East, and they have proved seaworthy and seakindly in both the short waves of the North Sea and the eastern part of the Mediterranean and in the longer waves of the Atlantic and the Pacific oceans.

Comparison with finer boats

A few vessels, deviating from the standard shape shown in fig. 438, have been working from the northern ports of Denmark in the upper part of the North Sea. They have a longer aft body and a finer shape. This sharper form is not favourable when the boat is laden with fish and sailing in a following sea. The lifting capacity is insufficient.

A whaleback has improved conditions on board because far less water is shipped and the crew has a shelter when nets, etc., are repaired during the trip. With the Danish boats, when deep laden in a following sea, water not only came aboard, but even stowed under the open whaleback, where there was no possibility of discharge. The problem was overcome by making a closed whaleback.

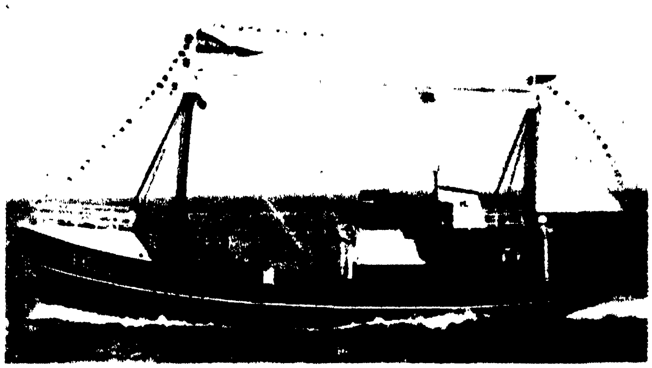


Fig. 437. Modern Dutch trawler

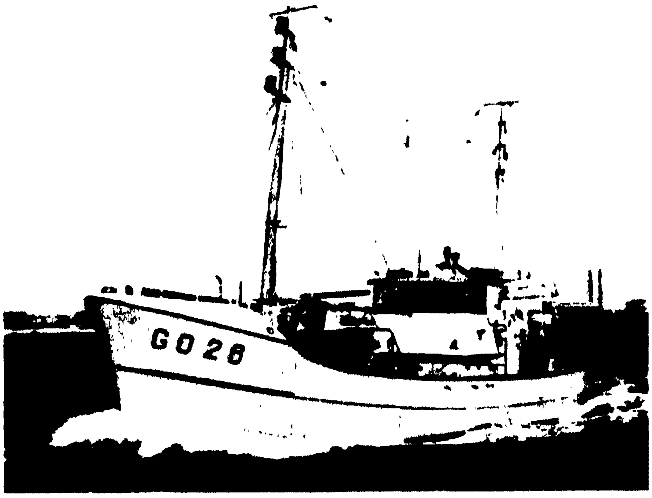


Fig. 436. Modern Dutch trawler

It might be possible to reduce resistance by using finer ends, but experience has shown that this makes the vessels less seakindly. Before World War II, a fishing cutter with very sharp ends was added to the Dutch fishing fleet. It behaved like a drunken man as soon as the sea became a little rough. The boat was built in the transitional period of the flat-bottom type with rounded ends, and, as the lines drawing in fig. 440 shows, it possessed all the properties required to behave unpleasantly, such as a large beam, a short but broad and flat midship section, and sharp ends with a concave

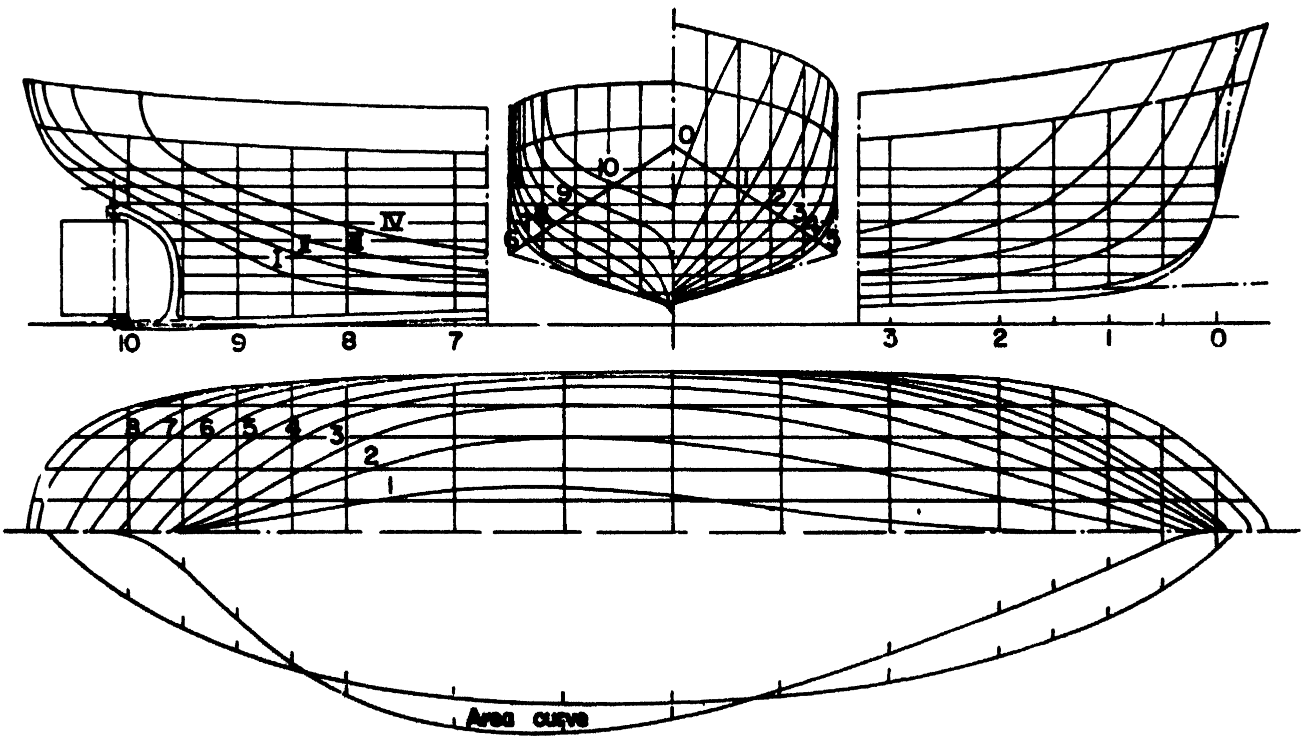


Fig. 438. Lines plan of HD 12 developed from study of model tests and practical observations

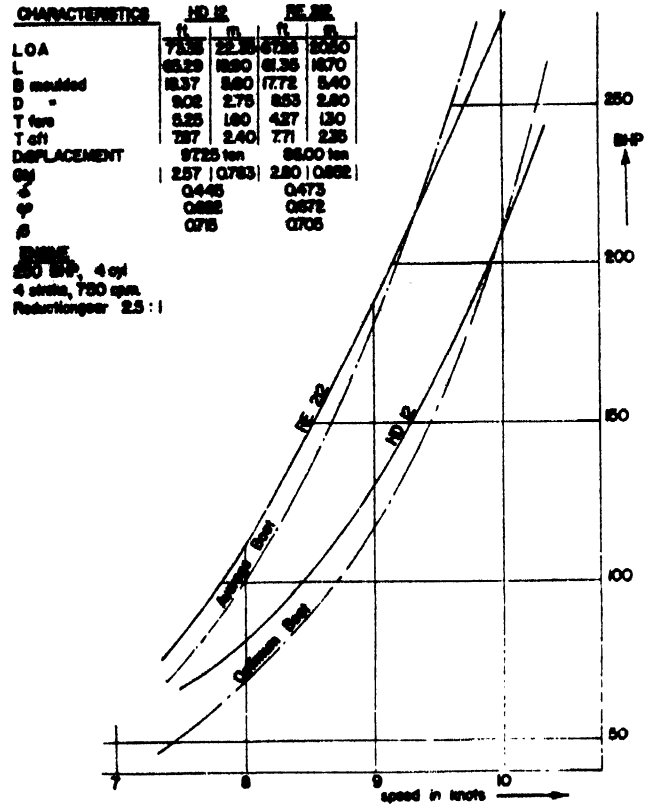


Fig. 439. Comparison curves for HD 12 and RE 212 and an optimum and average boat as given by Traung (1955)

waterline. The staggering motions were later partly suppressed by heavy ballasting which resulted in fuller water lines but, of course, this entailed other consequences.

Comparison with fuller boats

In 1954 Iceland started to use steel fishing cutters, six of which were built in Holland. These 60 to 70 GT boats sometimes enter port with 40 ton of herring on deck, stacked 4 ft. (1.20 m.) high, and the designers feared that the stability of the standard shape would not be sufficient. Therefore, without modifying the main dimensions, a somewhat fuller waterline was introduced, as shown in fig. 441 and 442. The particulars of this boat are also given in fig. 439, together with the speed and power curve. It shows the enormous increase in resistance resulting from a relatively small modification of the shape.

Speed is very important in several Icelandic ports in order to be the first at the best spots on the fishing grounds. The 9.55 knots reached by *RE 212* and by her five sister vessels was a disappointment, and was supposed to threaten their earning efficiency. However, now that the boats have been in service for two to three years, the contrary appears to be the case because, compared with some boats of a finer shape, the vessels can carry more fish on deck, can stay at sea longer when the weather becomes worse, and can go to sea earlier when the weather improves. This experience indicates that the boat with theoretically the best shape is not always the best. The particular circumstances always need to be fully considered.

However, this statement does not affect the need to strive for minimum costs in fuel and lubricating oil, by operational considerations when possible. Fig. 439 shows that good results were already attained in this respect. For example, the power required for a 70 ton boat of the *HD 12* type at 9 knots, was reduced from 180 to 130 h.p. or by about 28 per cent. The difference in the curves in fig. 439 is probably caused by the difference in the beam, which is somewhat less in the Dutch boats. The speed tests with *HD 12* in open sea were made during the trip from Den Helder to Cuxhaven without cargo, and the tests with *RE 212* were made in the canal between Amsterdam and Ymuiden. If the trials with *HD 12* had been repeated in that same canal, the results would probably have been still more favourable. The course of the curve at the bottom end shows this. The engines of *HD 12* and *RE 212* were of the same type

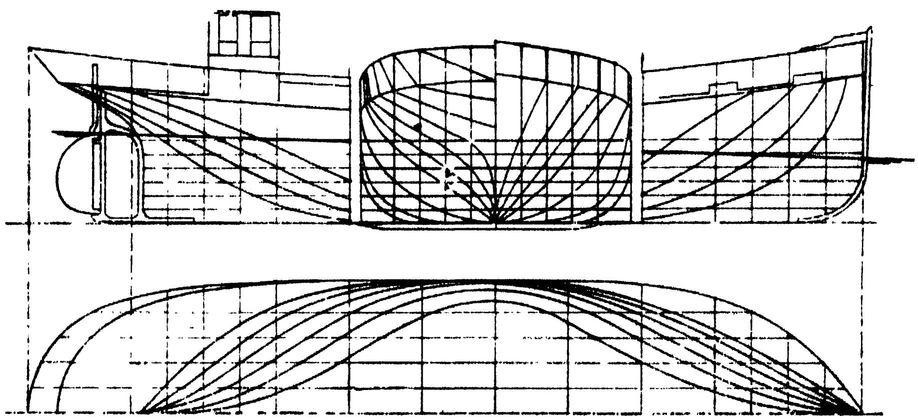


Fig. 440. Dutch fishing cutter built before World War II, having rather unfavourable sea-going properties. LOA = 59 ft. (18.00 m.), L = 51 ft. (15.60 m.), B = 18.8 ft. (5.75 m.), D = 7.85 ft. (2.40 m.)

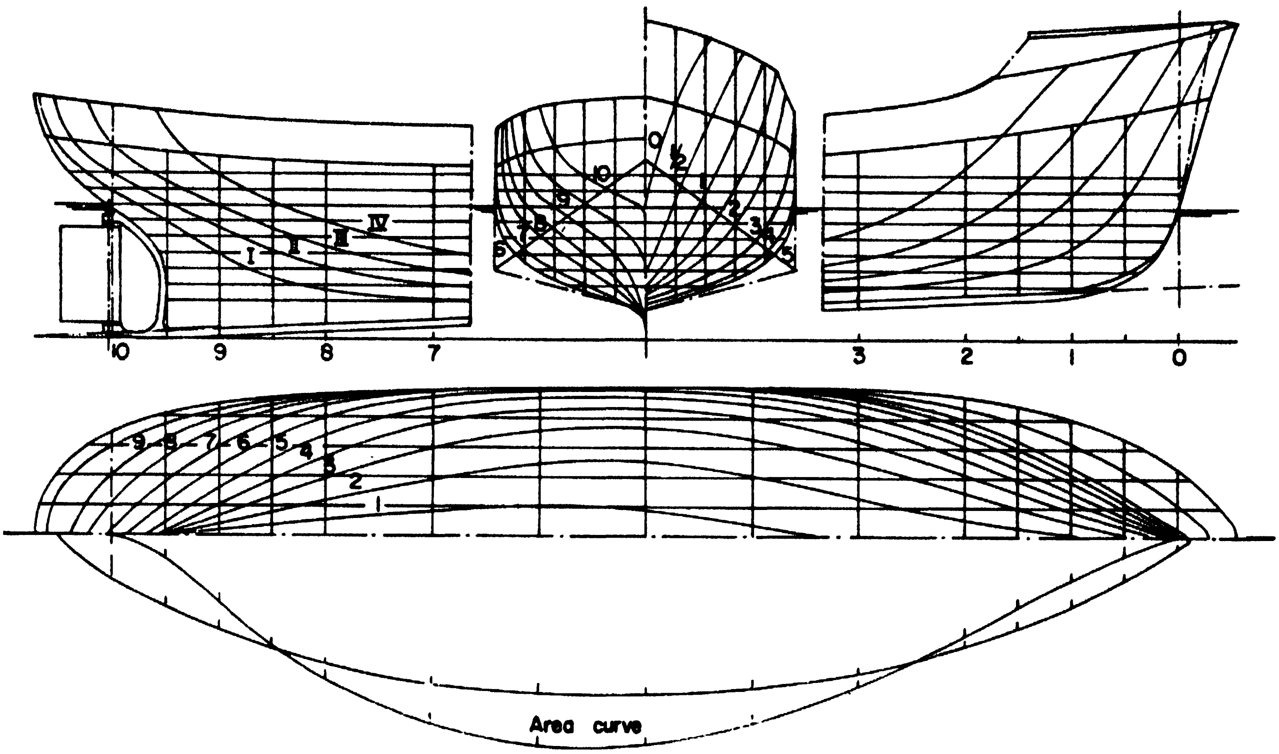


Fig. 441. RE 212: Icelandic fishing boat with great fullness due to the need for large carrying capacity. For main particulars see fig. 439

and make, and could not have caused any practical difference in the establishing of the power curve.

Fuel oil and lubricating oil consumption

The fuel and lubricating oil costs of a good engine in a good boat such as *HD 12* only amounts to 10 per cent. of the revenue from the catch. *HD 12* is equipped with a 4-cyl., 4-stroke diesel with a continuous output of 250 h.p. at 750 r.p.m., but usually the engine is not loaded above 200 h.p. Her fuel consumption in 1957 was 24,000 Imp. Gal. (109,800 l.) and oil consumption 189 Imp. gal. (840 l.) for 196 sailing days. The number of sailing days is not very high because Dutch fishing boats of this kind do not stay at sea on Sundays. This means, in practice, that the boats operate from Monday to Friday. The cost of the fuel and oil for the 196 sailing days was Fls. 15,000 (£1,420), while the catch for the past two years has reached Fls.150,000 (£14,200) per year.

Investigations of 30 post-war vessels equipped with post-war diesels all sailing from the same ports, usually leaving and entering at the same time, showed that in some boats fuel and oil consumption may be 20 per cent. or even more than 30 per cent. higher than that of *HD 12* — 12 to 13 per cent. of the catch. The annual investigation made by the Dutch Fisheries Department shows that fuel and oil costs sometimes amount to 17 per cent. of revenue from the catch, although the average catch does not differ much from that of *HD 12*.

In view of these differences in fuel consumption between post-war diesels, it seems likely that the cost of semi-diesels will be even more unfavourable.

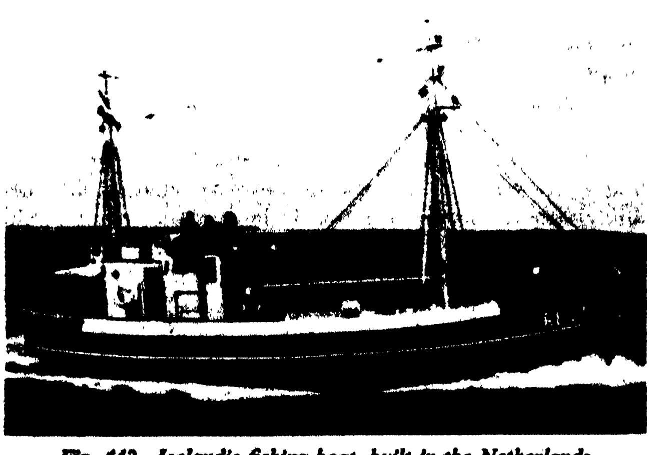


Fig. 442. Icelandic fishing boat, built in the Netherlands

Conclusion

The differences in fuel and lubricating oil consumption between one engine and another may easily have a greater influence on the economy than differences arising from the form of a vessel, which may constitute 3 per cent. to 4 per cent. of the revenue from the catch. The difference between one engine and another may amount to 5 to 6 per cent., a saving or loss which may determine her economic success or failure of the vessel.

TESTS WITH A TRAWLER MODEL IN WAVES

by

J. D. van MANEN, G. VOSSERS and H. RIJKEN

Tests with a trawler model with and without nozzle in still water and in waves are described. The model was tested in the free-running condition (0 to 11 knots) and when towing (4 to 6 knots). It appears that the addition of a nozzle for trawler propulsion when towing in still water can be recommended. This also applies to towing in waves, except in head seas, where unfavourable tendencies were found.

ESSAIS D'UN MODÈLE DE CHALUTIER DANS LES VAGUES

L'auteur décrit des essais d'un modèle de chalutier avec et sans tuyère, en eau calme et dans les vagues. Le modèle a été essayé en route libre (0 à 11 noeuds) et en pêche (4 à 6 noeuds). Il apparaît que l'addition d'une tuyère pour la propulsion du chalutier en pêche par mer calme peut être recommandée. Cela s'applique aussi à la pêche par mer forte, sauf en cas de mer debout où on a trouvé des tendances défavorables.

ENSAYOS CON UN MODELO DE ARRASTRERO EN OLAS

Se describen los ensayos de un modelo de arrastrero con tobera ys in ella en agua tranquila y en olas. El modelo se ensayó en ruta libre (0 a 11 nudos) y remolcando el arte (4 a 6 nudos). Parece ser recomendable la adición de una tobera al arrastrero cuando se remolca el arte en agua tranquila. Lo mismo es verdad cuando se remolca en olas, excepto si vienen de proa, en cuyo caso se encontraron tendencias desfavorables.

SINCE the successful improvement of the towing capability of tugs with the Kort nozzle (nozzle propeller or shrouded propeller), a steadily increasing number of fishing boats, particularly trawlers, are fitted with nozzle arrangements. The advantage when trawling in still water is well known; charts on performance and methods of design have been published (van Manen, 1956; van Manen and Superina, 1959).

Sometimes reference is also made to the beneficial effects of a nozzle propeller on the behaviour of a trawler in waves. The resistance increase in head seas is claimed to give the nozzle propeller an advantage; furthermore, it is said to increase the damping, thus reducing pitching. In order to verify these claims, a typical trawler model was tested in the Seakeeping Laboratory of the Netherlands Ship Model Basin with and without a nozzle propeller in still water and in waves.

Particulars of ship and model test conditions

The lines of the trawler are based upon one of Gueroult's (1955) designs. A paraffin wax model, scale 1:13 with bilge keels, was used. The propellers were designed for trawling at 5 knots, with 940 SHP and a propeller r.p.m. of 160. The Wageningen B-series charts were used for the normal propeller with a diameter of 9.84 ft. (3.00 m.) which was a compromise for the trawling and sailing conditions.

The diameter of the nozzle propeller was 93 per cent. of that of the normal propeller. The dimensions and the profile of the nozzle were similar to No. 18, the open-water test results of which were published by van Manen and Superina (1959). The dimensions of the nozzle propeller were chosen in accordance with the ideas presented in the same publication, and Kaplan-type blades were selected.

Particulars of the ship and propellers are given in tables 105 and 106. Body plan, profile and nozzle arrangement are shown on fig. 443 and 444.

The still-water trawling tests revealed that the propeller did not absorb exactly 940 SHP at 5 knots and 160 r.p.m. The resulting r.p.m. for the normal propeller were 160.5, and for the nozzle propeller 157.3. These values were used in the subsequent analysis.

Because no friction correction can be applied to a model in waves, the assumption was made that the differences in torque and r.p.m. between still-water and wave tests could be calculated for full size according to Froude's law. These differences were added to the still-water torque and r.p.m. for the ship. The still-water conversion from model to ship was made with the 1957 ITTC friction formula with an allowance of 0.0004 added for roughness.

The model was tested in 0 to 13 knots sailing, and 4 to 6 knots trawling. Trawling was simulated by

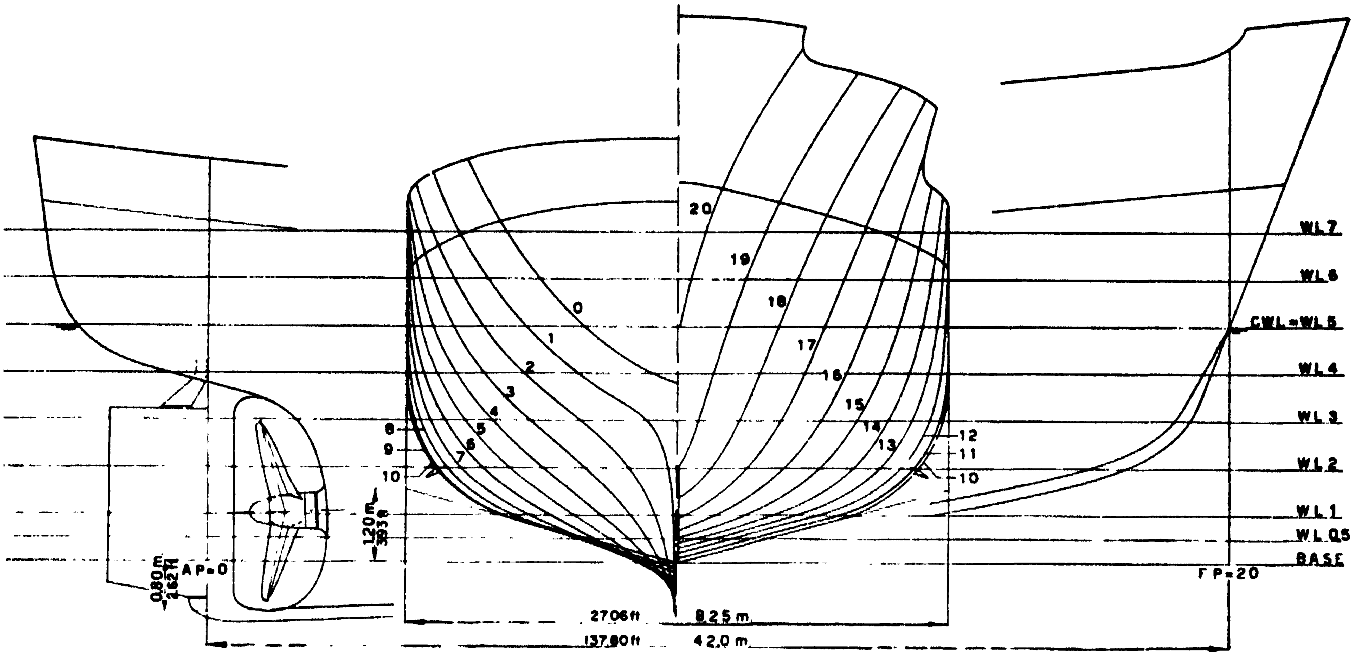


Fig. 443. Model 1779z based on a trawler design by Gueroult (1955)

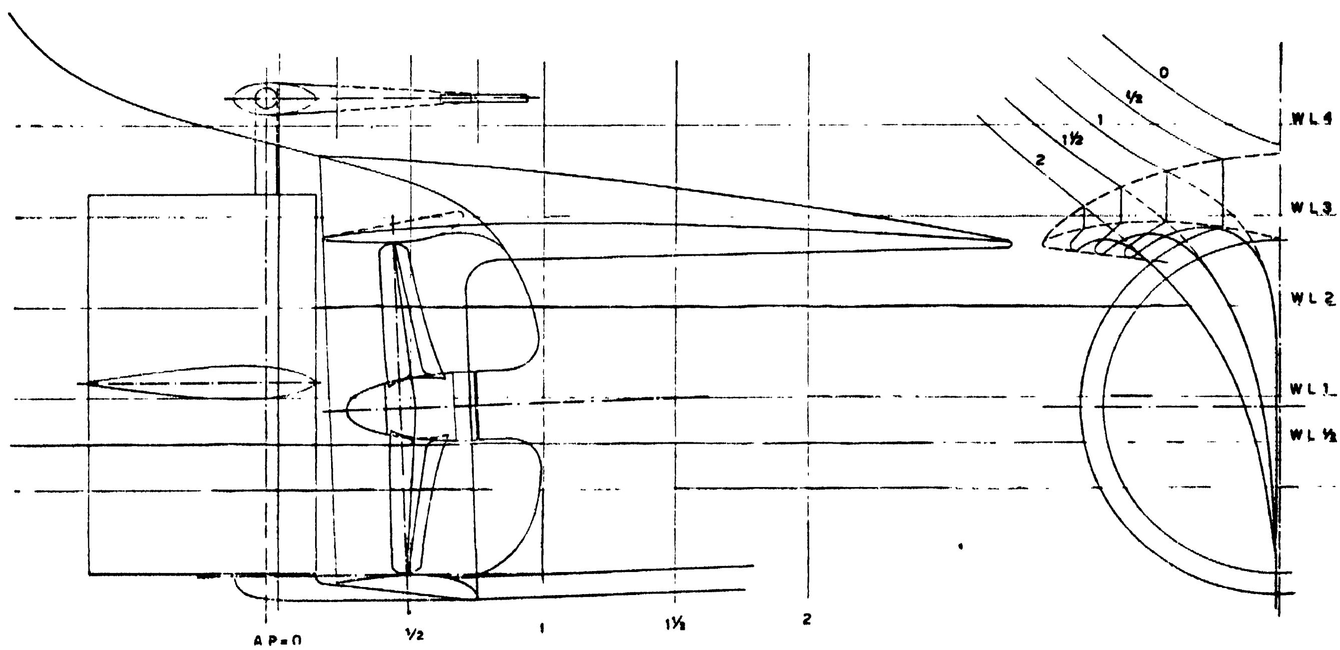


Fig. 444. Nozzle arrangement of model 1779z based on results by van Manen and Superina (1955)

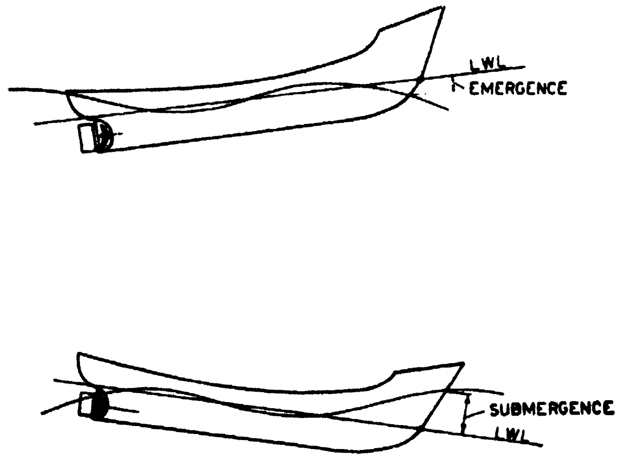


Fig. 445. Measurements of maximum emergence and submergence of bow in relation to waves

applying a resisting force to the model. The wave conditions were:

Directions: nearly head seas ($\alpha = 170°$), nearly following seas ($\alpha = 10°$), quartering seas ($\alpha = 45°$).

Lengths: wave length/ship length ratio: $\lambda/L = 0.75$, 1.00, 1.25

Heights: wave height/wave length ratio: $h_w/\lambda = 1/50$ and 1/30.

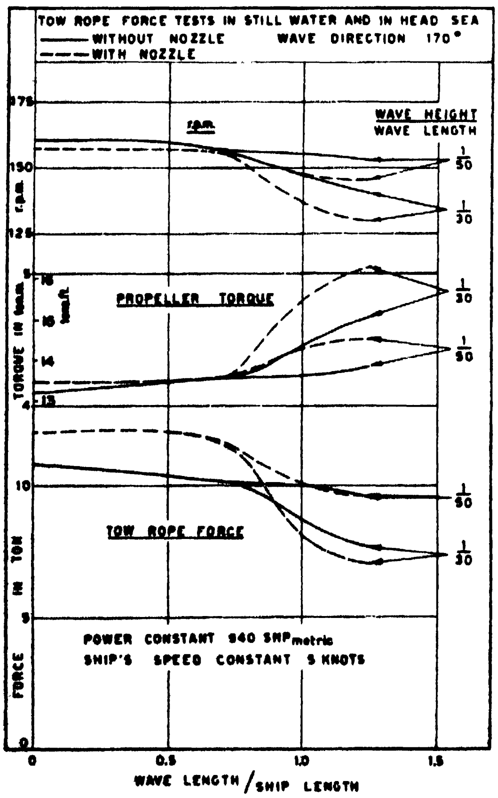


Fig. 446. Trawling performance data for constant power and speed

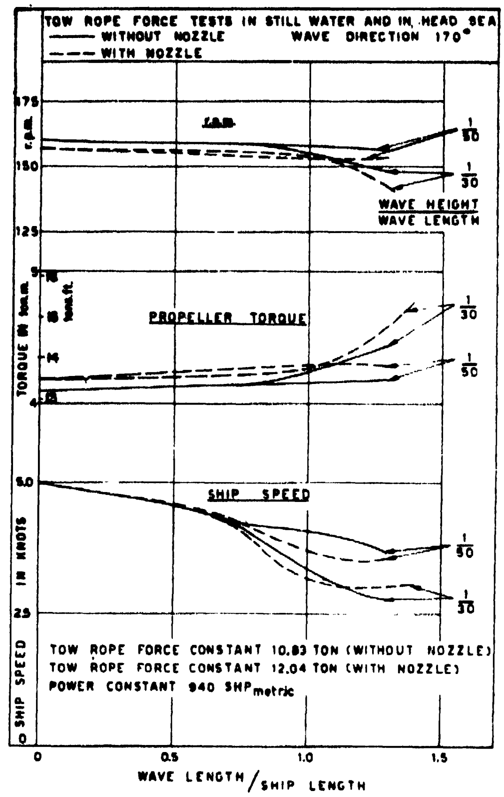


Fig. 447. Trawling performance data for constant power and tow rope force

The recordings taken were:

(a) Pitch angle (through the centre of gravity)
(b) Heave (of the centre of gravity)
(c) Angle of roll (through the centre of gravity)
(d) Maximum emergence and submergence of the bow in relation to the waves (fig. 445)
(e) Acceleration at bow and stern
(f) Shaft torque
(g) r.p.m.
(h) Speed

Results when trawling

The results of the still-water and head-seas tests when trawling are given in fig. 446 to 448. Quartering seas and following seas results differed very little from those in still water and are therefore omitted.

The tests when trawling in waves were analysed for three operating conditions:

- Trawling with constant speed and constant power; the changes in pull, propeller torque and r.p.m. as a function of the wave length/ship length ratio are given in fig. 446.
- Constant power and constant pull; the resulting speed of the ship, propeller torque and r.p.m. as a function of the wave length/ship length ratio are given in fig. 447.

- Constant speed and constant pull; the resulting SHP and r.p.m. are shown in fig. 448.

In still water, at 5 knots, the nozzle propeller gave a pull of 12.04 ton, while the normal propeller produced one of 10.83 ton. The same values were found in following and quartering waves. Therefore it can be concluded that the nozzle propeller gives a considerably increased pull (11 per cent.).

In head seas, however, an unexpected phenomenon was found. The differences between the propellers became smaller; in several conditions it was even found that the nozzle propeller gave a lower pull as shown in fig. 446 or a lower speed as shown in fig. 447, or required more SHP as shown in fig. 448. This was contrary to expectations as it should give better performance at higher loads. One explanation might be the greater sensitivity of the nozzle propeller to changes in the direction of intake velocity, which occur with heavy pitching and heaving. Another explanation might be the greater variation in efficiency of a nozzle propeller to rudder angles, although to keep the model on course in head seas, only small rudder angles of 4° to 10° were required. Further research is therefore needed.

Subsequent tests were carried out with two rudders, each placed a quarter of the nozzle's diameter from the centre line. Although very good steering resulted, there was no improvement in the nozzle propeller's performance when trawling in head seas.

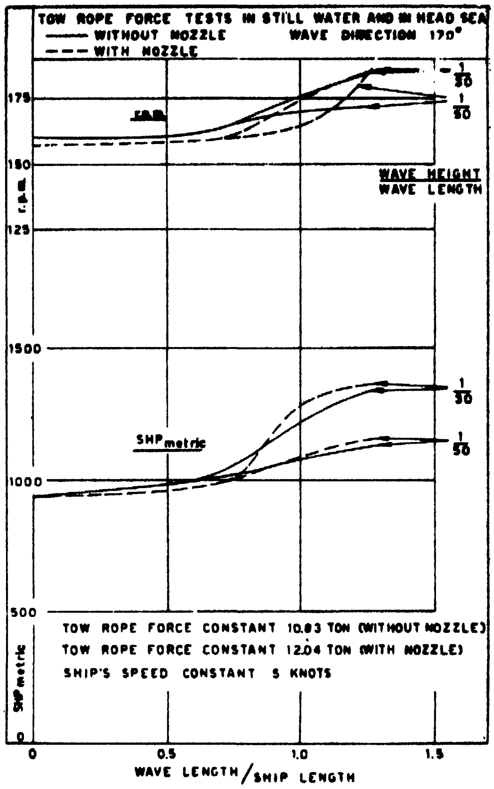


Fig. 448. Trawling performance data for constant tow rope force and speed

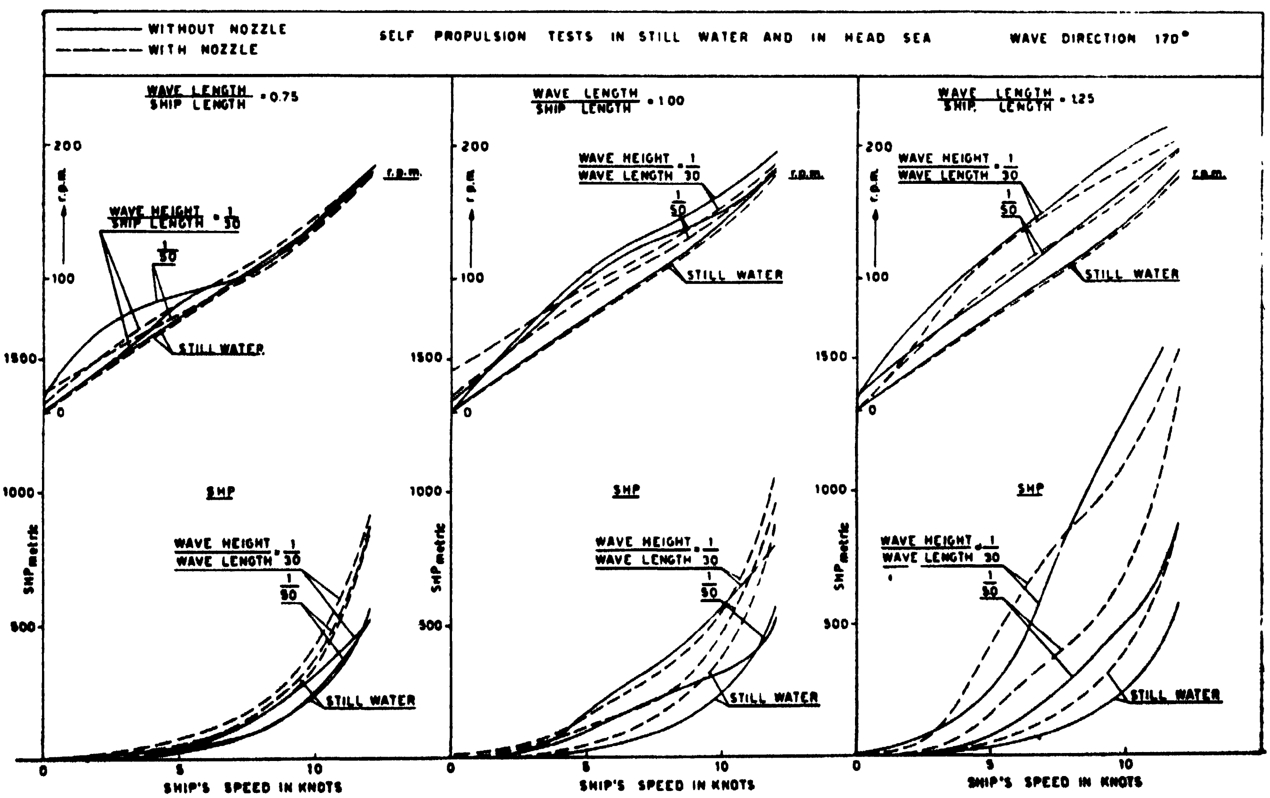


Fig. 449. Power requirement when sailing with and without nozzle

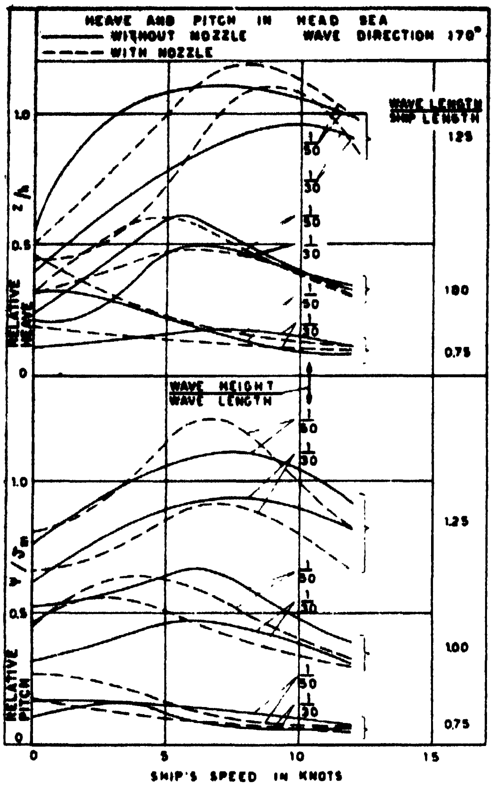


Fig. 450. Relative heave and pitch when sailing in head seas

Results when sailing

Fig. 449 to 452 show only the still-water and the head-seas results; the other tests produced very small differences. In fig. 449 the SHP and propeller r.p.m. are plotted against the ship's speed and the ratios of wave length/ship length and wave height/wave length. In still water the nozzle propeller required higher SHP, which was to be expected since the propellers were designed for heavy pulls; thus in the free-running condition with a small load, the nozzle propeller would be at a disadvantage.

In head seas, especially in high waves with a length equal to the ship's length or longer, where the resistance increase is high, the difference between the propellers became smaller, and in some conditions the nozzle propeller required less SHP. There, the advantage of the nozzle propeller working with a heavy load was demonstrated.

In general, the speed of the nozzle propeller is less sensitive to changes in load, which is of advantage for some types of propulsion machinery. When the design situation is at 160.5 r.p.m. for the normal, and 157.3 r.p.m. for the nozzle propeller, a high sailing speed can be obtained with the nozzle propeller, although it will require more SHP. However, there is sufficient SHP available in the free-running condition, due to the trawling requirements, as shown in table 107 compiled from fig. 449.

In certain conditions such as short wave length, small wave height and high speed, even in head seas, the SHP in waves is less than in still water. This was found on many occasions with different models. A theoretical explanation has recently been offered.

The motions in head seas are given in fig. 450 to 452. Heave and pitch are given in dimensionless form: the heave, by dividing the heave amplitude by the wave amplitude (wave amplitude = half the wave height); the pitch by dividing the pitch amplitude in radians by

TABLE 105

Particulars of ship and nozzle

Length between perpendiculars	LBP	42.00 m.	137.8 ft.
Length on the waterline	L	43.99 m.	144.3 ft.
Breadth	B	8.25 m.	27.06 ft.
Draught	T	3.85 m.	12.63 ft.
Displacement	∇	695.1 cu. m.	24.543 cu. ft.
Horsepower, propeller	SHP	940 h.p. (metric)	
Horsepower, motor	BHP	1,000 h.p. (metric)	
Speed of the propeller	r.p.m.	160	
Longitudinal radius of gyration (in percentage of LBP)	k_l	25%	
Metacentric height	GM	0.80 m.	2.62 ft.
Rolling period	T_r	8 sec.	
Bilge keels-Length in percentage of LBP		40%	
Height		0.20 m.	0.66 ft.
Nozzle diameter		2.80 m.	9.18 ft.
Length-diameter ratio		0.425	
Angle of the nozzle profile relative to the shaft line	α_i	8.5°	
Thickness-length ratio	s/l	0.15	

TABLE 106

Particulars of the propellers

		Normal propeller	Nozzle propeller
Propeller No.		2655	2656
Propeller type		B-series	K-series
Number of blades		4	4
Diameter	D	3.0 m. 9.84 ft.	2.8 m. 9.18 ft.
Pitch ratio	P/D	0.680	0.900
Blade area ratio	$\frac{A_d}{\pi D^2/4}$	0.502	0.540
Hub diameter ratio	d/D	0.167	0.184
Rake		10°	5°

TABLE 107

Sailing speeds and shaft horsepower for fixed r.p.m. for still water and in head seas

	Normal propeller 160.5 r.p.m.		Nozzle propeller 157.3 r.p.m.	
	V	*SHP*	*V*	*SHP*
Still water	11.09	363	11.12	580
$\lambda/L=0.75$; $h_w/\lambda=1:50$	10.88	357	11.10	563
$\lambda/L=0.75$; $h_w/\lambda=1:30$	11.09	422	10.67	551
$\lambda/L=1.00$; $h_w/\lambda=1:50$	10.83	363	10.65	588
$\lambda/L=1.00$; $h_w/\lambda=1:30$	9.73	533	10.23	586
$\lambda/L=1.25$; $h_w/\lambda=1:50$	9.60	455	9.73	610
$\lambda/L=1.25$; $h_w/\lambda=1:30$	7.50	755	7.75	825

the maximum wave slope, $\nu_m = \pi h_w/\lambda$, where h_w/λ represents the wave height/wave length ratio.

From fig. 450, with the pitch and heave amplitudes, no general conclusion can be drawn about the influence of the nozzle. Sometimes higher, occasionally smaller amplitudes were found. The same applies to fig. 452, where the emergence and the submergence of the bow is given in relation to the wave height. The influence of the nozzle on motions and taking water over the bow are of a secondary nature, and no definite trends can be discerned.

However, the measurements indicate that the nozzle reduces the vertical accelerations at the stern. The influence at the bow is negligible. It is therefore likely that the nozzle influences the phase angles between the motions by its damping effect, which, while not reducing pitch and heave, does decrease the vertical accelerations at the stern.

Conclusions

The following conclusions can be drawn from these tests:

- For a ship trawling in still water a nozzle propeller increases pull considerably.

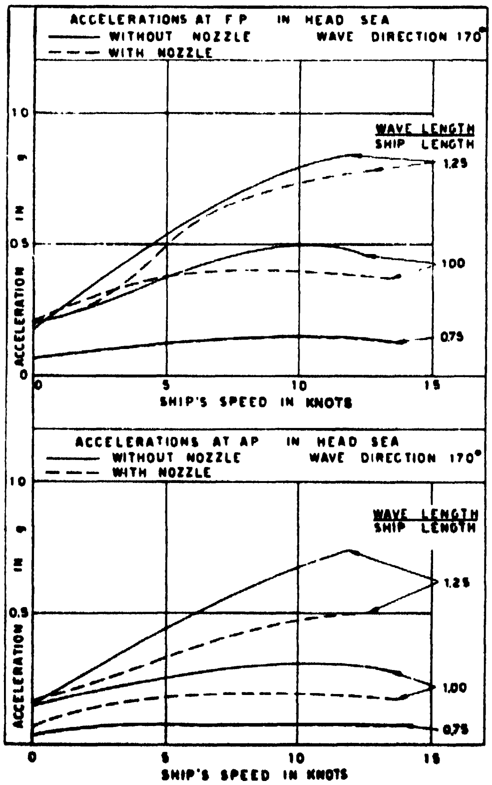


Fig. 451. Accelerations at FP and AP when sailing in head seas

- This remains true in following and quartering waves.
- When trawling in head seas, the nozzle propeller is unfavourable compared with the normal propeller. because it causes either a decrease in speed, a weaker pull, or an increase in SHP.

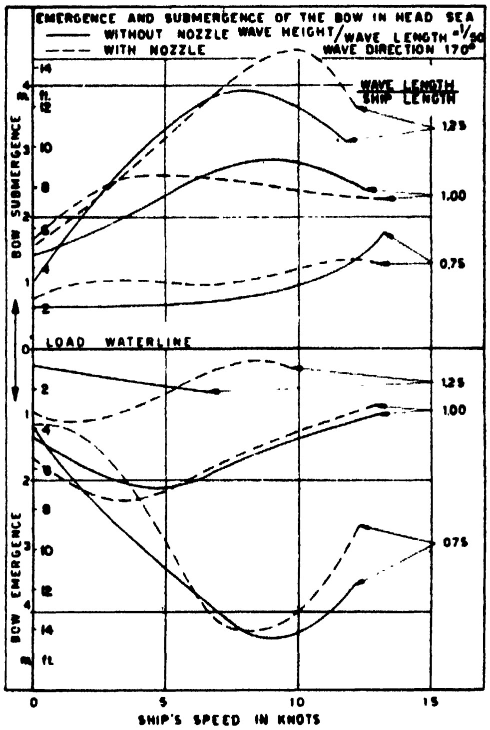


Fig. 452. Bow emergence and submergence when sailing in head seas

- In the free-running condition in still water the nozzle propeller requires a higher SHP, although at a lower number of revolutions, which is advantageous for certain types of propulsion machinery in attaining a higher free running speed.
- The same applies to the free-running conditions in following and quartering seas.
- In the free-running condition in head seas the differences between the propellers become smaller. and in high waves with a length equal to the ship's length the nozzle propeller is better.
- The influence of the nozzle propeller on the amplitude of pitch and heave and the wetness of the foredeck is negligible.
- The nozzle propeller, however, reduces the vertical accelerations at the stern.

THE PRISMATIC COEFFICIENT

by

JAN-OLOF TRAUNG

Tests with fishing boat models in waves indicate that those with a low prismatic coefficient require less power in a seaway and seem to have more agreeable motions. The trend in construction of large fishing vessels is to adopt a lower prismatic coefficient. A review is given and some preliminary conclusions reached of tests with four related models having prismatic coefficients of 0.525, 0.575, 0.625 and 0.675. Resistance tests were carried out with two versions, one being a true expansion of the lines according to the Lackenby method, and the other a more practical one, keeping the profile and the freeboard the same. In the "true" version, the differences between the models were not as great as in the "practical" version. This indicated that the fineness of water line endings has a great influence on resistance. Self-propulsion tests with the four models indicate that there was a tendency for the value of the optimum prismatic coefficient to decrease. The motions during the wave tests was considered to be equal for all models but from the powering point of view a prismatic coefficient of 0.525 seems to be the best.

LE COEFFICIENT PRISMATIQUE

Les essais de modèles de navires de pêche dans les vagues indiquent que oeux aui ont un coefficient prismatique faible nécessistent moins de puissance par mer agitée et paraissent avoir des mouvements plus agréables. La tendance dans la construction des grands navires de pêche est d'adopter un coefficient prismatique faible. L'auteur passe en revue les essais de quatre modèles de la même famille ayant des coefficients prismatiques de 0,525, 0,575, 0,625 et 0,675 et il donne des conclusions préliminaires. Des essais de résistance ont été effectués ave ceux versions, l'une étant un vrai développement des lignes selon la méthode de Lackenby, et l'autre, plus pratique, conservant le même profil et le même franc-bord. Dans la version "vraie", les différences entre les modèles n'étaient pas aussi grandes que dans la version "pratique". Cela a indiqué que las finesse des extrémités de lignes d'eau a une grande influence sur la résistance. Les essais d'auto-propulsion avec les quatre modèles indiquent que la valeur du coefficient prismatique optimum avait tendance à diminuer. Les mouvements pendant les essais dans les vagues ont été considérés comme étant égaux pour tous les modèles, mais du point de vue de la puissance, un coefficient un coefficient prismatique de 0,525 paraît être le meilleur.

EL COEFICIENT PRISMATICO

Los ensayos llevados a cabo con modelos de pesqueros en olas indican que los que tienen un coeficiente prismático bajo necesitan menos potencia propulsora en mar gruesa y paracen tener movimientos más suaves. En la construcción de pesqueros grandes se tiende a adoptar un coeficiente prismático más bajo. Se reseñan los ensayos con 4 modelos afines de coeficientes prismáticos de 0,525, 0,755, 0,625 y 0,675 y las conclusiones preliminares a que se ha llegado. Los ensayos de resistencia se realizaron con dos versiones distintas; una era la ampliación veradera de las líneas según el método de Lackenby, y la otra, más práctica, mantenía iguales el perfil y la obra muerta. En la versión "verdadera", las diferencias entre los modelos no eran tan grandes como en la "práctica", lo que indica que la finura de los extremos de las líneas de aguas influye mucho en la resistencia. Los ensayos de autopropulsión con los 4 modelos indicaron que existía una tendenoia a que disminuyese el valor del coeficiente prismático óptimo. Se consideró que el movimiento durante los ensayos con olas era igual en todos los modelos, pero desde le puntoode vista de la potencia propulsora un coeficiente prismático de 0,525 parece ser el mejor.

MANY tests in calm water with fishing boat models have been done over the years and a comparison of the results on a non-dimensional basis shows that resistance is governed by the same factors as with larger ships. Very few tests have, however, been done in waves. Still fewer comparative measurements have been taken on fishing vessels at sea; nothing has been published about smaller vessels.

Sharpness, as expressed by prismatic coefficient, seems to be an important factor influencing the calm water resistance. Fishing boats seldom travel at higher speed-length ratios than 1.1 ($v/\sqrt{gL}=0.33$) in spite of the fact that their often large engines could produce a higher trial speed (Traung, 1955). Therefore a low prismatic coefficient is the best. Further experiences from resistance tests in calm water show the advantages of a small angle of entrance, the centre of buoyancy far aft, and a transom stern instead of a rounded stern.

Because fishing vessels operate in rough water comparatively more than larger vessels, resistance in waves is naturally of great interest, and the object of this paper is to review some wave tests where the main variable was the prismatic coefficient. Furthermore, a summary is given of results of wave tests with four FAO models in the Fishing Boat Laboratory Tank of the Japanese Fisheries Agency.

Todd's steam drifter tests

Todd's (1938) steam drifter tests are well known. Reference is usually made to the calm water tests, but it might not be out of place to review the seaworthiness tests. The opinion had been expressed that the bow of a fishing boat should be full to ensure seaworthiness. This opinion had survived from the time of the old sailing ships but experience with other types of ships had shown that it was not correct. Todd pointed out in 1938 that several large trawlers built with a fine form, as suggested by model tests, had shown themselves more seaworthy than the conventional type with full bow.

The models represented typical pre-war drifters with steam propulsion, having a length between perpendiculars of 86 ft. (26.2 m.) and a displacement of 185 tons. The prismatic coefficient based on the actual length in the waterline was 0.652 for the standard design, and for the improved design 0.567. The wave test models were 4.75 ft. (1.45 m.) long and fitted with rudders, but no propellers, and they were towed simultaneously through the waves at a slight angle on the bow. During the preliminary tests the model representing the best calm water boat proved to have too low freeboard forward and a new model was made having the same freeboard forward as on the standard drifter. Table 108 gives a summary of the tests.

NPL motor drifter tests

Due to the success of the previous tests, the British Herring Industry Board requested the National Physical Laboratory (NPL) to make tests with smaller motor drifters made of wood (Experiments with . . . . . , 1938). One model was built according to the standard design and another of a modified design proposed by the NPL. The models represented 70 ft. (21.3 m.) vessels having a displacement of 85.9 and 88 tons in the loaded condition. The beam for the standard design was 18 ft. (5.5 m.) and for the modified design 19 ft. (5.79 m.). The models used for the wave tests were 4.7 ft. (1.43 m.) long and these tests were made in the loaded condition. The corresponding prismatic coefficients were 0.653 for the standard design and 0.630 for the modified design.

These experiments were also made by towing the models side by side and the speed corresponded to 8 knots through different degrees of rough water, each experiment being repeated with the models interchanged to eliminate any difference in the wave trains. Regular waves were used having the following dimensions:

Wave height	*Wave length*
7½ ft. (2.3 m.)	190 ft. (58 m.)
5 ft. (1.5 m.)	100 ft. (30 m.)
8 ft. (2.4 m.)	72 ft. (22 m.)
9 ft. (2.7 m.)	72 ft. (22 m.)

In 100 and 190 ft. waves the models rode easily and neither shipped any water. In the 8 ft. high and 72 ft. long waves with broken crests the modified model shipped very little water (less than 1 per cent. of its displacement) but the standard design shipped nearly four times as much, or 3 per cent. of the displacement. With the somewhat higher waves, the modified model shipped hardly any water, or about 1 to 3 per cent. of displacement, while the standard model shipped 4½ per cent. of displacement. The standard design threw the water up almost vertically and it fell back into the model. The modified design threw the water outwards more than upwards and was consequently drier. Had a wind been blowing in the direction of the waves, the standard design would have got more broken water than the modified design.

Confused seas were created by mixing wave lengths so that longer waves travelled through shorter waves, the general aspect of the water varying every second. In such waves of from 6 to 8 ft. (1.8 to 2.4 m.) in height the standard model shipped 13.5 per cent. water of its displacement and the modified design 6.6 per cent. In higher waves of 8 to 10 ft. (2.4 to 3 m.) the standard design shipped water equal to 18 per cent. of the displacement, and the modified design 5 per cent. It was concluded that the standard design, compared with similar experiments on trawler models, was a good design and that accordingly the modified one would be still better. Some simulated trawling tests were also made and the standard design shipped considerably more water than the modified one. No boats were built according to these results.

TABLE 108

Summary of Todd's steam drifter tests in waves

Wave type	*Standard drifter*	*Low prismatic drifter with low bow*	*Low prismatic drifter with same height of bow as Standard*
Regular waves of 125 ft. (38.1 m.) length and 8 ft. (2.4 m.) height (crest to trough).	A little water shipped over the bow and stern at beginning and end of run, but otherwise remained dry.	Shipped water over the bow, and sank after passing 62 waves.	No water shipped; quite dry at end of experiment.
Irregular sea, mainly composed of steep, short waves with a series of longer and lower waves passing through them on each run. The models passed through two very rough portions with comparatively smooth water between.	Took water over the bow and stern on first rough portion, and was about three-quarters full in the calm period. Model sank soon after entering second rough period.		Took a little water over the bow in each rough portion and was less than a quarter full after passing both rough portions.

Graff and Heckscher trawler tests

The Hamburg tank (Graff and Heckscher, 1941) investigated three similar trawlers having a length of 187 ft. (57 m.) with beams of 28.9 ft. (8.8 m.), 31.5 ft. (9.6 m.) and 33.8 ft. (10.3 m.). The displacement and the draught were kept the same, but the midship section area was enlarged and thus the prismatic coefficient was 0.657, 0.615, and 0.575 respectively. The resistance tests showed the superiority of the wide and low prismatic model which at 12 knots, or a speed-length ratio of 0.77 ($v/\sqrt{gL}=0.26$), only required 91 per cent. of the power taken by the narrow model. At 15 knots, or a speed-length ratio of 1.1 ($v/\sqrt{gL}=0.33$) the wide model only required 63 per cent. power compared with the narrow one. Self-propelled tests were made in waves of about the same length as the ship. The height corresponded to 6.55 ft. (2 m.) waves. The wide ship made these tests without any difficulty but the narrow one took the waves over the deck. Therefore the wave height was reduced to 5 ft. (1.5 m.) or a wave length/wave height ratio of 1: 37.5. The tests were only carried out up to a speed of about 11.75 knots, corresponding to a speed-length ratio of 0.76 ($v/\sqrt{gL}=0.255$). At lower speeds the wider model required somewhat more power and with the available 1,200 h.p. the narrow model would make 10.7 knots, while the wide model would only make 10.4 knots. However, the tendency was that at higher speeds than 12 knots, i.e. for speed-length ratios higher than 0.77, the low prismatic model would have the advantage. The movements of the models were also studied by means of a cine-camera and both the angle of pitch and heave were less for the narrow model. The wide model pitched 20 per cent. more and it was explained that this model, because of its more flaring bow, followed the waves more, thus having larger movements but on the other hand the ship was drier. The narrow model went more through the waves. The larger power requirements of the wider ship at moderate speeds were also explained by its greater front area.

Allan's drifter tests

After World War II the British Herring Industry Board again ordered model tests of wooden motor drifters (Allan, 1951). The models represented vessels of 62 ft. (18.9 m.) on the waterline and the original model had a beam of 17 ft. 10 in. (5.44 m.) and a prismatic coefficient of 0.645. A slightly modified design had the same beam and a prismatic of 0.612 and the extreme one had 1 ft. (0.3 m.) less beam and a prismatic of 0.501. The displacement for all models was 71 tons. The tests in still water showed the superiority of the low prismatic models. Self-propulsion tests were made in head seas of different lengths and heights at a speed of 7¾ knots and torque, thrust, revolutions, speed, heave and pitch were observed. The general conclusions were that in short seas of up to 50 ft. (15 m.) length the vessels plough through with very little pitch or heave. From 50 to 150 ft. (15 to 46 m.) length, the pitch and heave increases rapidly to maximum values around 100 ft. (30 m.) wave length and fall equally rapidly towards 150 ft. (46 m.) length. The big movements around 100 ft. length correspond to a tuning factor of 1, when the period of encounter between ship and wave is the same as the natural period of pitch and heave. At another speed there would be another period of encounter and also another length of wave, resulting in synchronous motion. The maximum increase in power occurs rather at the shorter waves of 80 to 90 ft. (24 to 27 m.) than at the point of maximum movement. Among the three models there was no material difference in the angle of pitch. The 0.501 prismatic model had appreciably greater heave than the other two. The general magnitude of power increase of the three models remained the same in head seas as in calm water, but as the modified designs required less power in calm water, they remained superior. The vessel with the full bow threw the waves higher above the gunwhale when pitching than either of the other two. The fan-flared bow of the lowest prismatic model threw the bow wave out and down when pitching and it was concluded that when meeting a head sea this model was the best one.

Later on a design was made which was a compromise between the 0.612 and the 0.501 models with a prismatic of 0.537. One boat was built according to these lines and another to the lines of the model with the 0.612 prismatic. These boats were tried out in commercial fishing and, surprisingly enough, the low prismatic type was later on re-built with a fuller foreship. The opinion was that she had too fine a forebody and was liable to trim too much by the bow when filled with herring. With 31 cran (12,200 lb., 5,530 kg.), the draught forward increased by 11 in. (0.28 m.), and with a catch of 106 cran (41,500 lb.. 18,800 kg.) the draught increased from 5 ft. 2 in. (1.57 m.) to 8 ft. 3 in. (2.51 m.) or by 3 ft. 1 in. (0.94 m.). This was due to the very sharp entrance, which had a half angle of 9° only. It was, however, reported that the performance of the vessel was excellent and if anything she proved a drier ship running into the wind than the higher prismatic one. The Board's reason for altering the forebody was that they had decided to dispose of the vessel and the new forebody was built to suit the prevailing orthodox ideas and to make the sale easier.

The conclusion from these experiments is that when designing fishing boats all possible loads should be taken into account, preferably by taking measurements at sea. and if a boat trims considerably due to its sharp forebody, this should be corrected by giving it a higher freeboard than a boat with a fuller waterline forward; in this case a 2 ft. (0.6 m.) higher stem would have been adequate and it would not have spoiled the conning-angle.

However, in 1952 the 0.612 prismatic type was accepted while the 0.630 was not before World War II.

FAO tests

The results from previous tests indicated that a low prismatic coefficient is also of advantage in waves. Since World War II there had been a distinct trend in the design of large trawlers in France, Germany and the United Kingdom to adopt a low prismatic coefficient and it was understood that skippers and operators found these ships to be superior. In view of this, FAO advises the adoption of a smaller prismatic coefficient, also for fishing vessels of less than 100 ft. (30 m.). However, scepticism is sometimes expressed since there are not as many results from wave tests as from calm water tests with models representing small fishing vessels.

In 1956 FAO decided to test four related models of an 88 ft. (26.75 m.) LOA fishing vessel with prismatic coefficients of 0.525, 0.575, 0.625 and 0.675. As the object of the tests was to investigate the influence of sharpness, and due to the fact that research (Lewis, 1955) had shown that the length-displacement ratio has an effect upon seakeeping behaviour, it was felt desirable to keep the displacement and the length constant as well as the centre of buoyancy. Thus it was necessary to vary the area of the midship section and a practical variation was to keep the B/T ratio and β the same, varying the beam and draught. This had the advantage that the metacentre, both transversal as well as longitudinal, was kept within reasonable limits so that each model would represent a ship with comparable periods of roll and pitch. It had the disadvantage that the low prismatic models with the greatest beam were penalised but, after all, the object was to compare models of some practical interest.

The parent form represents a development of model 206 c XXVI, FAO No. 6Cc, as published in *FAO Fishing Boat Tank Tests*, and it has a prismatic coefficient of 0.575. The variation was done with the help of the Lackenby (1950) method for ships without parallel middle body and with constant LCB, although some difficulties were encountered due to the design rake of the keel. Fig. 453 shows the profile and some typical sections of a "true" variation. The rake of the stem and the stern post were changed to obtain similar flow under water. According to this method, however, it was felt that the propeller aperture would be too small and lead to propeller-racing in waves for the high prismatic models and, furthermore, the increased freeboard of the small prismatic models would give them a certain advantage in waves which was only due to the method of variation and not to the difference in shape. The bow and stern over water of the high prismatic models would further be unnecessarily bluff and penalize those models.

Resistance tests

The models were ordered from the Fishing Boat Association of Japan and they were built by the Fishing Boat Laboratory of the Japanese Fisheries Agency to make them suitable for testing in their tank, being 213 ft. (65 m.) long, 13.1 ft. (4 m.) wide and 6.55 ft. (2 m.) deep. The model scale was 1 : 12.5, producing models 6.55 ft. (2 m.) in the waterline, as proposed by the tank staff. Turbulence was stimulated by using pins (Nevitt, 1957). Such pins have a rather high parasitic drag but Nevitt considered them to be satisfactory for small and beamy fishing boat models. The test results were expanded using the Schoenherr friction correction with 0.0004 allowance for roughness. Control resistance tests were

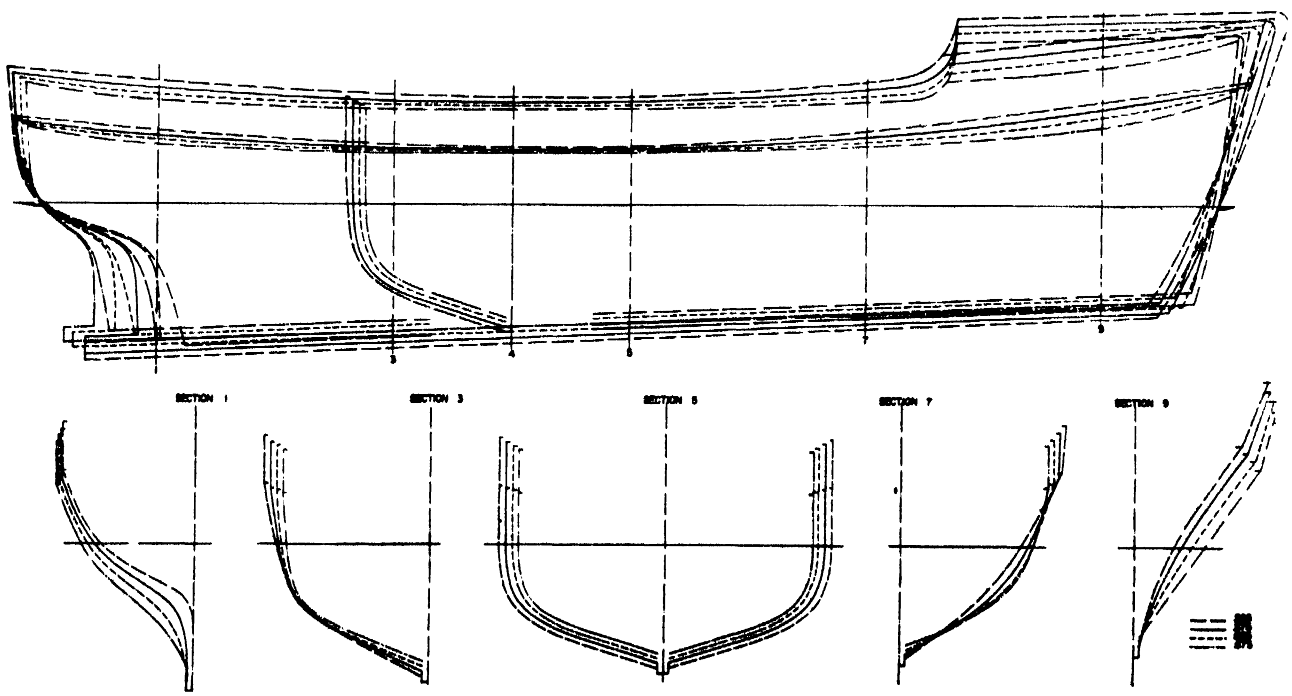


Fig. 453. True development of related models with the same displacement but different prismatic coefficients using the Lackenby method

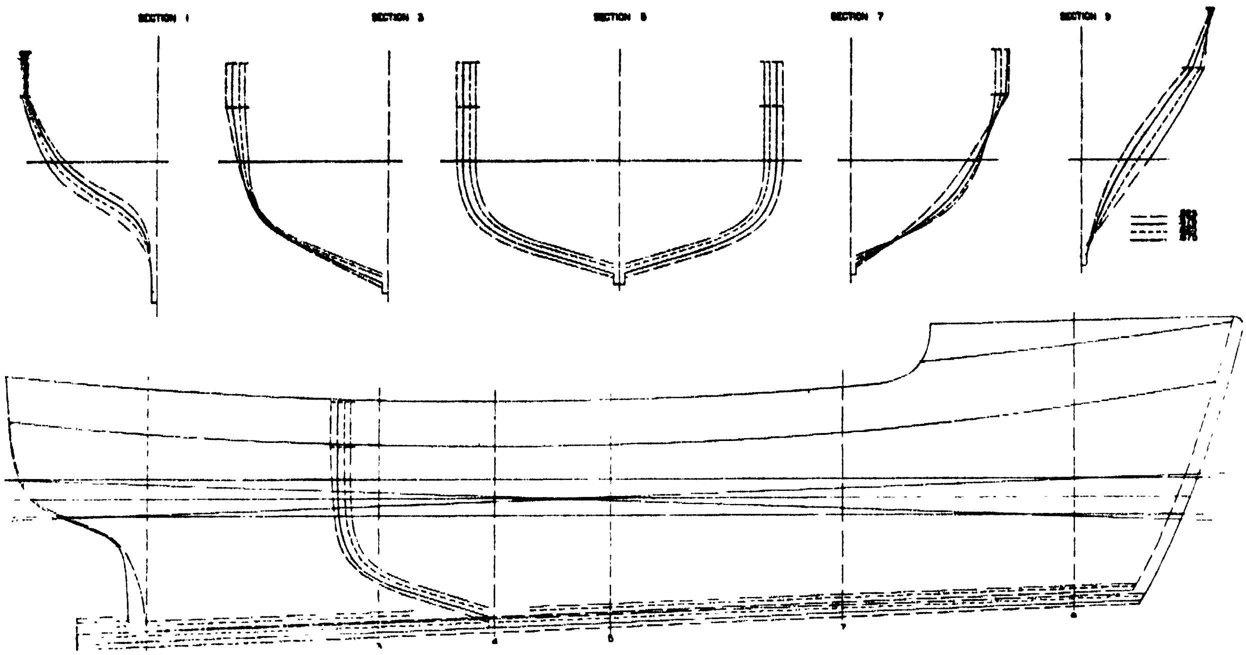


Fig. 454. Practical development of related models with different prismatic coefficients. Beam and draught are varied but displacement, midship-section coefficient and freeboard and profile kept the same

made with the 0.575 model in 43.5 and 61°F (6.4° and 16.1°C) water temperature in the Fishing Boat Laboratory Tank, and in the 26 ft. (8 m.) wide tank of the Japanese Transportation Laboratory in both 44.6 and 61.7°F. (7° and 16.5°C), the model speeds being from 1 to 6 ft./sec. (0.3 to 1.8 m./sec.). The results indicated that the tests were reproducible, that no disturbing laminar flow was present, and that there was no significant influence of side wall effect in the small tank during the resistance tests in calm water (Yokoyama and Kobayashi, 1948).

After resistance tests with the four models built according to the "true" method, the models were modified so as to have the same profile, the same freeboard and the same dimensions of stem, keel and stern timber, fig. 454. Table 109 gives the ship's data for the resistance tests in this version. Fig. 455 indicates the difference between sections ½, 1, 9 and 9½ of models 0.525, 0.625 and 0.675, the parent model 0.575 naturally being the same in both versions. Fig. 456 shows the body plans, section area curves and design waterlines of the models in the "practical" version.

The results from the resistance tests with the "practical" versions are given in fig. 457. The models were tested on three displacements and the design displacement with an

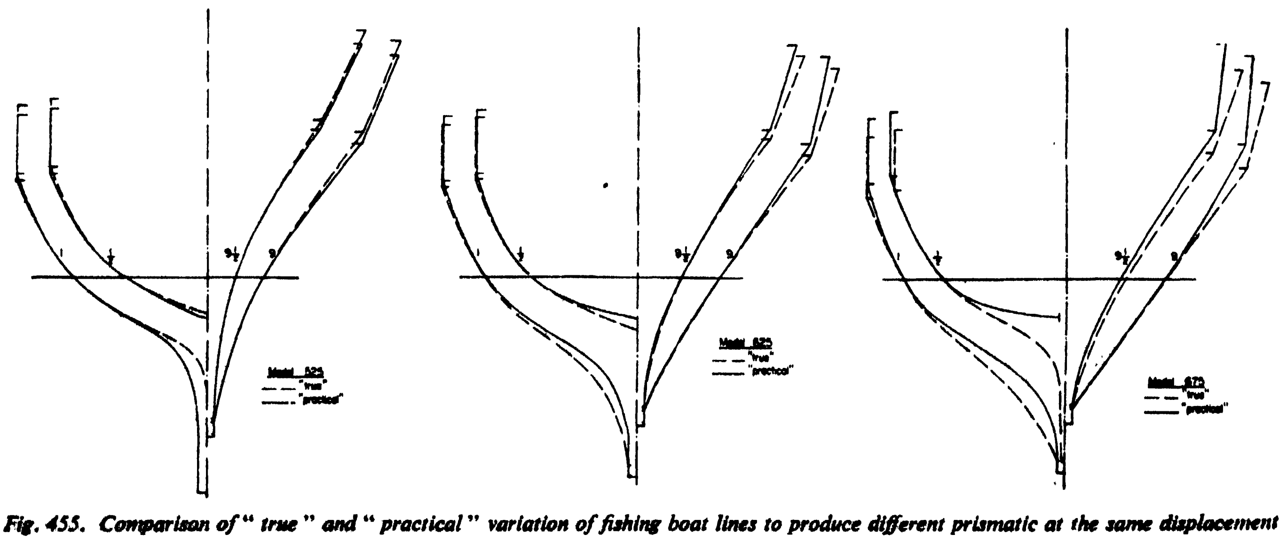


Fig. 455. Comparison of " true " and " practical " variation of fishing boat lines to produce different prismatic at the same displacement

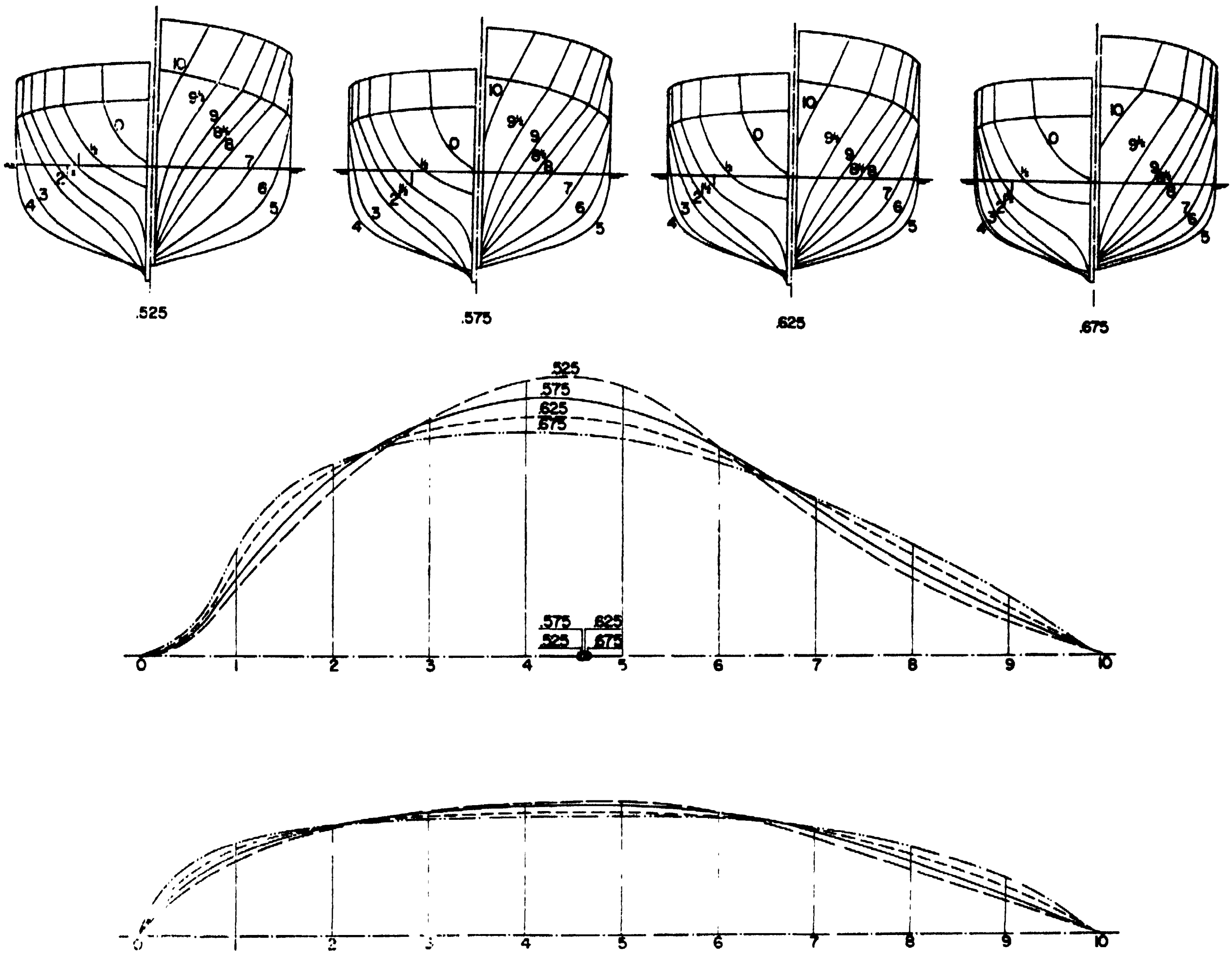


Fig. 456. Comparison of body plans, section area curves and water lines of four related models with different prismatic coefficients

additional two trims. Due to the finer underwater lines and the longer "displacement-length" of the "true" version, the differences were not as great as in the "practical" variations. The optimum prismatic coefficient seems to be about 0.575 and this is somewhat higher than is normally deduced from standard series. This might be due to the fact that the small prismatic models were beamier than the high prismatic models. Fig. 457 also shows the EHP for the trims on the design waterline displacement indicating that the selected LCB was reasonable from a resistance point of view.

Self-propulsion tests

The propeller was to absorb 300 h.p. at 300 r.p.m. and was selected from the standard series of the Ship Propulsion Division of the Japanese Transportation Technical Research Institute. The resulting propeller was of its B3-35 type, with a P/D ratio of 0.6 and a diameter of 71.5 in. (1.815 m.). The results of open water tests are shown in fig. 458 together with the corresponding results of a comparable Troost propeller.

The results from the self-propulsion tests at the design waterline and in calm water calculated by the tank are given in table 110 and in fig. 459. There is a considerable difference in propulsive coefficients between the models, the high prismatic one having the lowest. These differences might be due to scale effect but also to the fact that in the systematical variation, the lower waterlines of the high prismatic models turned out to be unnecessarily full toward the ends, thus restricting the flow to the propeller. In fig. 460 the propulsive coefficients for the four models have been plotted over the prismatic coefficient, together with the propulsive coefficients from the Allan (1951) drifter tests in calm water, where also only one propeller was used. In these tests there is also a tendency towards reduction in efficiency of the higher prismatic model. The reduction, however, is not so great, due to the fact that the models were designed individually and were not directly related, each thus having the best possible flow of water to the propeller.

To make a more "honest" comparison, it is tempting to split the propulsive coefficient into two components,

TABLE 109

Ship's data for the resistance tests

Model φ = 0.525		*I*	*II*	*III*	*IV*	*V*
L	ft.	82.00	79.70	82.50	79.00	83.80
	m.	25.00	24.30	25.15	24.07	25.46
B	ft.	23.35	23.35	23.35	23.35	23.35
	m.	7.12	7.12	7.12	7.12	7.12
T_a	ft.	11.05	9.55	12.42	9.78	12.52
	m.	3.37	2.91	3.78	2.98	3.81
T	ft.	9.35	9.35	9.18	8.07	10.82
	m.	2.85	2.86	2.80	2.46	3.30
T_f	ft.	7.62	9.25	5.97	6.37	9.12
	m.	2.32	2.82	1.82	1.94	2.78
A_m	sq. ft.	158.77	150.80	156.63	127.23	190.63
	sq. m.	14.75	14.01	14.83	11.82	17.71
∇	cu. m.	193.75	193.75	193.75	150.00	250.00
Δ_1	ton	198.59	198.59	198.59	153.75	256.25
∇_2	cu. ft.	6,842	6,842	6,842	5,297	8,829
Δ_2	tons	195.49	195.49	195.49	151.34	252.26
S	sq. ft.	2,091.0	2,109.7	2,077.5	1,862.2	2,378.8
	sq. m.	195.0	196.0	193.0	173.0	221.0
LCB % = $\pm \frac{1}{2}$L		−4.29	−1.40	−7.05	−4.42	−4.16
Non-dimensional: $L/\nabla^{\frac{1}{3}}$		4.32	4.20	4.35	4.53	4.04
δ		.415	.426	.421	.392	.449
φ		.525	.569	.520	.527	.555
L/B		3.51	3.41	3.53	3.38	3.57
B/T		2.72	2.71	2.77	3.19	2.32
$\frac{1}{2}\alpha_e$		18.2	15.7	14.0	13.9	23.0

Model = φ 0.575		*I*	*II*	*III*	*IV*	*V*
L	ft.	82.00	80.30	82.50	79.10	83.50
	m.	25.00	24.48	25.15	24.12	25.44
B	ft.	22.30	22.30	22.30	22.30	22.30
	m.	6.80	6.80	6.80	6.80	6.80
T_a	ft.	10.59	9.12	11.95	9.38	12.05
	m.	3.23	2.78	3.64	2.86	3.67
T	ft.	8.97	9.05	8.82	7.75	10.40
	m.	2.73	2.76	2.69	2.36	3.17
T_f	ft.	7.32	8.97	5.67	6.10	8.75
	m.	2.23	2.73	1.73	1.86	2.67
A_m	sq. ft.	145.10	140.03	148.54	118.40	177.50
	sq. m.	13.48	13.01	13.80	11.00	16.49
∇	cu. m.	193.75	193.75	193.75	150.00	250.00
Δ_1	ton	198.59	198.59	198.59	153.75	256.25
∇_2	cu. ft.	6,842	6,842	6,842	5,297	8,829
Δ_2	tons	195.49	195.49	195.49	151.34	252.26
S	sq. ft.	2,077.4	2,099.0	2,066.7	1,862.2	2,346.6
	sq. m.	193.0	195.0	192.0	173.0	218.0
LCB % = $\pm \frac{1}{2}$L		−4.14	−0.89	−7.24	−4.42	−3.86
Non-dimensional: $L/\nabla^{\frac{1}{3}}$		4.32	4.23	4.35	4.54	4.04
δ		.456	.461	.461	.430	.491
φ		.575	.608	.558	.565	.596
L/B		3.68	3.60	3.70	3.55	3.74
B/T		2.72	2.69	2.77	3.20	2.31
$\frac{1}{2}\alpha_e$		22.0	26.5	16.0	17.4	27.0

the open water efficiency of the propeller and a "rest" efficiency, containing both the relative rotative and the hull efficiency, plus any other influences, such as scale effect. If this "rest" efficiency from Allan's tests at 0.575 prismatic is set at 100, it will, on the average, for the 7½ and 9 knots test in calm water be: 96.5 per cent. at 0.625 and 88.5 (extrapolated) per cent. at 0.675 prismatic coefficient. A new modified propulsive coefficient could then be assumed for the self-propulsion tests with the 0.625 and 0.675 models, being the product of the open water efficiency at the specific speed from the test, the rest efficiency of model 0.575 at the specific speed and the correction for the specific prismatic.

In table 110 the modified propulsive coefficient and SHP for models 0.625 and 0.675 have also been listed. Fig. 461 shows the SHP plotted over the prismatic coefficient. A broken line represents the SHP as calculated directly from the model tests. The 0.675 model thus would require 82 per cent. more power to make 9 knots in calm water than the 0.575 model, instead of 122 per cent. more, as determined directly from the model tests.

It might be argued that the self-propulsion tests should have been made by individual optimum propellers. In this case, the fuller models should have propellers with smaller diameters. These would have been subject to additional risks of scale effect and variations in wake and thrust would also have been introduced, and it is not too certain that the results would have been more quantitatively correct.

Wave tests

FAO consulted a number of specialists before suggesting a programme for the wave tests. It was emphasized that wave tests cannot be too exact and only if the difference between two models is more than 5 per cent should a definite conclusion be drawn. In spite of the fact that wave tests are often carried out with 5 ft. (1.53 m.) models, there was a general recommendation that the models should not be too small due to the risks of laminar flow. A model length of 6.55 ft. (2 m.) was as large as the

TABLE 109 (*continued*)

Ship's data for the resistance tests

Model φ=0.625		I	II	III	IV	V
L	ft.	82.00	80.30	82.50	79.30	83.50
	m.	25.00	24.48	25.15	24.20	24.43
B	ft.	21.40	21.40	21.50	21.40	21.40
	m.	6.52	6.52	6.52	6.52	6.52
T_a	ft.	10.20	8.67	11.60	8.98	11.65
	m.	3.11	2.64	3.53	2.74	3.55
T	ft.	8.63	8.65	8.50	7.42	10.05
	m.	2.63	2.65	2.59	2.26	3.07
T_f	ft.	7.05	8.70	5.42	5.84	8.82
	m.	2.15	2.65	1.65	1.78	2.59
A_m	sq. ft.	133.58	128.95	138.43	108.61	165.12
	sq. m.	12.41	11.98	12.86	10.09	15.34
∇	cu. m.	193.75	193.75	193.75	150.00	250.00
Δ_1	ton	198.59	198.59	198.59	153.75	256.25
∇_2	cu. ft.	6,842	6,842	6,842	5,297	8,829
Δ_2	tons	195.49	195.49	195.49	151.34	252.26
S	sq. ft.	2,045.2	2,055.9	2,023.6	1,808.4	2,314.3
	sq. m.	190.0	191.0	188.0	168.0	215.0
LCB% = $\pm\frac{1}{2}$L		−3.90	−0.54	−7.27	−4.24	−3.75
Non-dimensional: $L/\nabla^{\frac{1}{3}}$		4.32	4.23	4.35	4.55	4.04
δ		.495	.504	.501	.468	.531
φ		.625	.661	.599	.614	.640
L/B		3.83	3.76	3.86	3.71	3.90
B/T		2.48	2.47	2.52	2.89	2.12
$\frac{1}{2}\alpha_e$		28.1	32.5	24.0	24.0	35.5

Model φ=0.675		I	II	III	IV	V
L	ft.	82.00	80.00	82.50	79.50	83.50
	m.	25.00	24.40	25.16	24.21	25.43
B	ft.	20.60	20.60	20.60	20.60	20.60
	m.	6.28	6.28	6.28	6.28	6.28
T_a	ft.	9.84	8.27	11.20	8.63	11.25
	m.	3.00	2.52	3.42	2.63	3.43
T	ft.	8.32	8.35	8.20	7.12	9.74
	m.	2.54	2.55	2.50	2.17	2.97
T_f	ft.	6.83	8.45	5.18	5.61	8.23
	m.	2.08	2.58	1.58	1.71	2.51
A_m	sq. ft.	123.68	120.56	129.49	101.07	155.32
	sq. m.	11.49	11.20	12.03	9.39	14.43
∇	cu. m.	193.75	193.75	193.75	150.00	250.00
Δ_1	ton	198.59	198.59	198.59	153.75	256.25
∇_2	cu. ft.	6,842	6,842	6,842	5,297	8.829
Δ_2	tons	195.49	195.49	195.49	151.34	252.26
S	sq. ft.	2,002.1	2,012.9	1,991.3	1,776.06	2,271.2
	sq. m.	186.0	187.0	185.0	165.0	211.0
LCB% = $\pm\frac{1}{2}$L		−3.64	+0.07	−7.54	−3.76	−3.38
Non-dimensional: $L/\nabla^{\frac{1}{3}}$		4.32	4.22	4.35	4.56	4.04
δ		.534	.545	.540	.509	.571
φ		.675	.709	.640	.659	.680
L/B		3.98	3.89	4.01	3.86	4.05
B/T		2.47	2.46	2.51	2.89	2.11
$\frac{1}{2}\alpha_e$		38.0	40.0	23.0	34.0	43.0

available tank would accommodate. One consultant was of the opinion that there would be a speed loss of 1.3 per cent. due to this small size.

There was a difference of opinion whether the wave tests should be carried out as self-propulsion or as pure resistance tests. As the tank staff considered self-propulsion tests to be simpler to conduct and at the same time more exact, it was decided to make self-propulsion tests. Thus the models would be completely free and be able to surge in the waves.

The tests were to be carried out both in head sea and stern sea, and it was decided to keep a constant wave height corresponding to 2.46 ft. (0.75 m.) high waves.

The tests could only be conducted in regular waves. Lewis stated (1955) that "qualitative comparisons of the motions of ships intended for rough-weather service can be made from the results of tests run over a wide range of speeds in a regular wave of length equal to ship length (i.e. the shortest wave component having major effects on motions)." Professor E. Lewis suggested that in this case three wave lengths should be used, one equal to the waterline length of the models and the two others $1\frac{1}{4}$ and $1\frac{3}{4}$ times the waterline length. The reason was that waves of the short length of a small fishing vessel are rather moderate and do not really represent normal weather. Furthermore, synchronous motions would take place at very low speeds. Professor Lewis felt that one should in this case compare the performance of the models on the longer wave length rather than on the shorter, as is standard for larger ships. It was comforting to know that quality comparisons can be made of tests in regular waves. Naturally, additional tests in irregular waves are necessary for any real quantitative comparisons.

Little information is available on the longitudinal radius of gyration for fishing vessels. Möckel (1955) gave an m-value of 0.275 for the outward voyage and 0.32 for the homeward one. The m-value contains both the longitudinal radius of gyration and a coefficient, taking into account damping from entrained water, etc. When suggesting the test procedure, the author wrongly speci-

TABLE 110

Results from self-propulsion and resistance tests

φ	V	N	t	w_T	PC	η_r	η_h	η_o	EHP	SHP	η_{rest}	$PC_{mod.}$	$SHP_{mod.}$
	3	63.6	.287	.648	.239	.272	2.026	.434	2.8	11.7	—	—	—
	4	86.0	.286	.522	.364	.452	1.493	.539	6.3	17.3	—	—	—
	5	117.8	.281	.406	.476	.677	1.210	.581	12.5	26.3	—	—	—
0.525	6	152.1	.273	.306	.554	.874	1.047	.605	22.4	40.5	—	—	—
	7	187.2	.264	.252	.586	.974	.985	.611	36.8	62.8	—	—	—
	8	219.9	.254	.241	.592	.992	.983	.607	60.0	101.5	—	—	—
	9	251.0	.223	.254	.573	.919	1.042	.598	96.0	167.5	—	—	—
	3	72.3	.257	.453	.232	.312	1.359	.547	2.6	11.2	.424	—	—
	4	99.3	.254	.362	.324	.473	1.170	.586	6.1	18.9	.553	—	—
	5	127.5	.258	.314	.427	.659	1.081	.599	12.8	30.0	.714	—	—
0.575	6	153.2	.260	.301	.489	.765	1.059	.604	22.5	46.0	.811	—	—
	7	185.0	.267	.294	.554	.894	1.038	.597	38.8	70.0	.928	—	—
	8	218.9	.291	.294	.584	.989	1.004	.588	61.9	106.1	.995	—	—
	9	249.5	.328	.305	.550	.984	.967	.578	91.2	166.0	.958	—	—
	3	77.4	.309	.340	.234	.382	1.047	.586	3.0	12.8	.965	.238	12.5
	4	103.0	.310	.280	.284	.485	.958	.611	6.4	22.6	—	.327	19.5
	5	131.5	.310	.244	.350	.622	.912	.617	13.3	38.0	—	.425	31.3
0.625	6	165.1	.310	.224	.400	.734	.889	.613	24.4	60.9	—	.480	50.9
	7	197.5	.310	.219	.457	.851	.884	.608	42.6	93.3	—	.545	78.3
	8	235.9	.317	.225	.489	.935	.881	.593	70.0	143.0	—	.570	123.0
	9	275.3	.369	.251	.469	.974	.843	.571	111.5	238.0	—	.525	219.0
	3	82.7	.494	.472	.240	.520	.958	.481	4.1	17.1	.885	—	—
	4	114.9	.494	.371	.282	.656	.805	.534	8.3	29.4	—	—	—
	5	148.3	.501	.323	.319	.793	.738	.545	15.3	48.0	—	.344	44.5
0.675	6	183.3	.514	.308	.338	.881	.702	.546	27.1	80.1	—	.391	69.3
	7	221.1	.531	.312	.341	.941	.682	.531	46.3	135.8	—	.436	106.0
	8	264.4	.550	.331	.327	.958	.673	.507	75.8	232.0	—	.446	170.0
	9	309.5	.564	.366	.326	1.002	.688	.474	120.5	369.5	—	.399	302.0

fied the radius of gyration to be 0.3L, instead of specifying an m-value of 0.3L. Thus the models have a period of pitch corresponding to 4.33, 4.21, 4.16 and 4.23 sec., which is longer than normal for boats of that size. A long radius of gyration is said to amplify movements (van Lammeren and Vossers, 1955), which has the advantage of separating the results for the models of different shapes but the disadvantage of giving them synchronous movements at too low speeds.

Fishing vessels sometimes sail at speeds which could be called supercritical, i.e. when the period of pitch is longer than the period of encounter. Supercritical speeds are at present impossible for large vessels, even if it is stated that some slender ones like the vessel *United States* sometimes operate at such. The fact that short fishing vessels sometimes operate at supercritical speeds might be the reason why a long period of pitch is advocated. Similarly, it has sometimes been said that a loaded fishing vessel is better in the seaway than an unloaded one. This could also be explained by the fact that the loaded vessel will be placed further into the supercritical zone. This is a problem which requires study.

Fig. 462 shows the arrangements for the wave tests. In addition, an acceleration meter was fitted in the bow. The tests were carried out on the design waterline with the displacement of 195 tons (193.75 cu. m.). Table 111 gives the results as reported by the tank and also for models 0.625 and 0.675, the modified SHP assuming the same factor as explained earlier. Fig. 463 shows the SHP for each model plotted over speed. Fig. 464 shows the SHP in head sea for the variations in prismatic coefficient and fig. 465 for the wave lengths. These diagrams suggest that the optimum prismatic coefficient in waves from the powering point of view is lower than it is in calm water. There is no indication that the best calm water hull form should lose its advantage in waves. Stern sea does not seem to have too great an influence on the power, as is evident from fig. 466.

Ships motions determine the maximum sustained sea speed. Fig. 467 shows the angle of pitch for the four models plotted on tuning factor. Only wave lengths 1½ and 1¾ times the ship's length give synchronous motion; but unfortunately reliable values were not obtained from the 0.525 model to allow the peak to be determined. The curves indicate that models 0.575 and 0.625 have almost identical maximum pitch angles, and that they are about ten per cent. lower than model 0.675. If the lower slope of the curves for model 0.525 is considered, the impression is also obtained that the peaks of this model would be somewhat lower than the other models. Fig. 468 compares the bow accelerations of the models, and here again the impression is that the 0.575 model is in no way worse than the high prismatic models. On the other hand, there is a clear indication that the peak responses of the 0.525 model are the highest. Heave

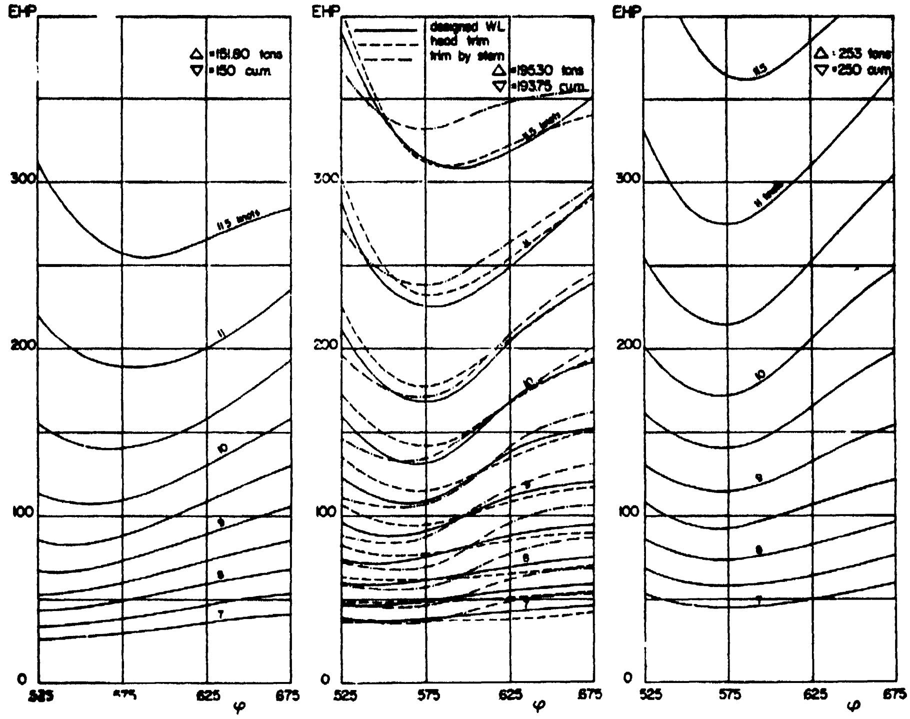


Fig. 457. Tow rope horsepower in calm water for light, medium load and full load conditions

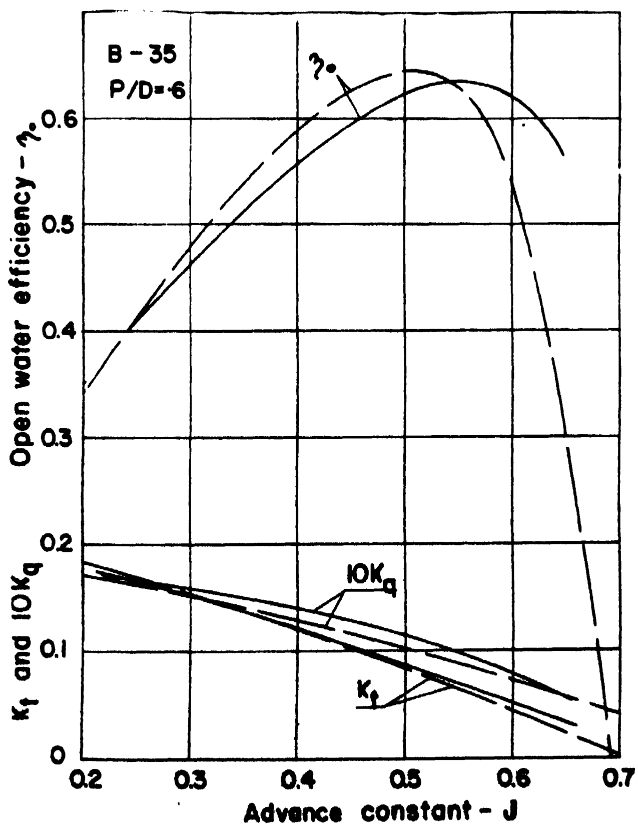


Fig. 458. Propeller characteristics

TABLE 111

Results from tests with four related models in waves and calm water

Model φ = 0.525

		V	EHP	SHP	PC	N	Ψ	Z	η_o	
Calm water .		3	2.8	11.7	.239	63.6	+.0120	−.021	—	
		5	12.5	26.3	.476	117.8	+.0122	+.015	.581	
		7	36.8	62.8	.586	187.2	+.0152	+.071	.611	
		9	96.0	167.5	.573	251.0	+.0174	+.145	.598	

		V		SHP	Δ_p	T_e	Ψ	Z	F_p''	Z''
Head sea .	1 L wave	3		19.0	1.49	2.90	.042	.238	2.40	.600
		5		35.0	1.72	2.53	.025	.150	1.90	.452
		7		79.5	1.92	2.25	.016	.113	1.73	.365
		9		177.0	2.14	2.02	.013	.088	1.76	.328
	1¼ L wave	3		25.0	1.17	3.71	.111	.619	6.46	.942
		5		62.0	1.25	3.21	.076	.456	5.30	—
		7		94.0	1.53	2.83	.054	.338	4.31	1.310
		9		189.0	1.72	2.53	.040	.250	4.06	1.040
	1¾ L wave	3		19.7	1.06	4.08	—	—	—	.490
		5		69.6	1.24	3.46	.116	.675	7.46	1.235
		7		140.2	1.42	3.05	.074	.538	6.66	—
		9		196.0	1.60	2.70	.056	.425	5.90	1.570
Stern sea .	1 L wave	3		14.2	.83	5.22	.0640	.229	1.07	.220
		5		27.8	.635	6.82	.0405	.139	0.52	.140
		7		66.0	.442	9.80	.0280	.100	0.38	.095
		9		189.6	.254	17.10	.0210	.088	0.23	.065
	1¼ L wave	3		13.0	.74	5.85	.0810	.348	1.14	.260
		5		27.8	.60	7.21	.0575	.250	0.70	.170
		7		69.7	.467	9.29	.0420	.184	0.30	.112
		9		184.0	.328	13.20	.0295	.129	0.12	.075
	1¾ L wave	3		14.0	.68	6.36	.0810	.438	0.99	.185
		5		30.0	.58	7.48	.0635	.351	0.56	.100
		7		64.5	.476	9.10	.0500	.285	0.38	.060
		9		177.0	.375	11.58	.0380	.226	0.37	.052

Model φ = 0.575

		V	EHP	SHP	PC	N	Ψ	Z	η_o	η_{rest}
Calm water .		3	2.6	11.2	.232	72.3	—	—	.547	.424
		5	12.8	30.0	.427	127.5	−.0020	+.053	.599	.714
		7	38.8	70.0	.554	185.0	−.0006	+.098	.597	.928
		9	91.2	166.0	.550	249.5	+.0050	+.166	.578	.958

		V		SHP	Δ_p	T_e	Ψ	Z	F_p''	Z''
Head sea .	1 L wave	3		28.0	1.41	2.98	.047	.263	2.56	.440
		5		47.8	1.67	2.52	.025	.150	1.98	.250
		7		83.2	1.94	2.17	.019	.100	1.89	.140
		9		181.0	1.98	2.11	.015	.081	1.74	.130
	1¼ L wave	3		38.0	1.10	3.82	.169	.738	4.37	.440
		5		88.0	1.16	3.63	.194	.862	5.31	.650
		7		148.6	1.215	3.46	.164	.988	5.60	1.010
		9		268.0	1.27	3.32	.140	1.123	5.33	—
	1¾ L wave	3		41.4	.98	4.30	.166	.750	3.68	.475
		5		83.2	1.04	4.04	.170	.838	5.48	.490
		7		117.5	1.115	3.77	.160	.913	—	.585
		9		224.3	1.18	3.57	.142	1.025	4.88	.945
Stern sea .	1 L wave	3		16.0	.815	5.16	.0645	.220	1.29	.160
		5		33.4	.650	6.48	.0420	.159	.68	.107
		7		12.6	.480	8.59	.0292	.125	.47	.078
		9		191.0	.329	12.76	.0195	.100	.43	.060
	1¼ L wave	3		15.5	.713	5.91	.0735	.359	.94	.208
		5		32.5	.590	7.12	.0555	.285	.68	.153
		7		79.7	.462	9.12	.0422	.233	.39	.118
		9		209.0	.342	12.30	.0315	.186	.20	.088
	1¾ L wave	3		18.0	.600	7.04	.0705	.469	.83	.200
		5		35.8	.518	8.13	.0560	.418	.64	.140
		7		77.4	.432	9.74	.0470	.375	.44	.105
		9		187.7	.354	11.90	.0390	.334	.35	.080

TABLE 111 (*continued*)

Model φ = 0.625

		V	EHP	SHP_{tank}	PC	N	Ψ	Z	η_o	$PC_{mod.}$	$SHP_{mod.}$
Calm water		3	3.0	12.8	.234	77.4	+.0014	+.014	.586	.238	12.5
		5	13.3	38.0	.350	131.5	+.0060	+.047	.617	.425	31.3
		7	42.6	93.3	.457	197.5	+.0095	+.081	.608	.545	78.3
		9	111.5	238.0	.469	275.5	+.0186	+.168	.571	.525	219.0
		V		**SHP**	**Λ_p**	**T_e**	**Ψ**	**Z**	**F_p''**	**Z''**	**$SHP_{mod.}$**
Head sea	1 L wave	3		48.4	1.32	3.15	.065	.325	2.99	.640	47.2
		5		75.6	1.62	2.65	.036	.181	2.52	.340	62.3
		7		113.5	1.855	2.27	.022	.115	2.34	.255	95.3
		9		264.0	2.09	1.99	.018	.086	2.27	.235	236.0
	1¼ L wave	3		36.0	1.06	3.92	.146	.703	3.16	.475	35.0
		5		130.4	1.15	3.62	.176	.813	3.38	.720	107.5
		7		225.2	1.24	3.36	.166	1.013	3.33	—	189.0
		9		336.0	1.32	3.15	.136	1.250	2.96	1.145	300.0
	1¾ L wave	3		30.5	.973	4.27	.160	.788	4.35	.50	29.7
		5		90.5	1.085	3.84	.172	.875	6.15	.75	74.5
		7		194.6	1.195	3.48	.139	1.088	6.69	1.28	163.5
		9		351.0	1.305	3.19	.116	—	5.62	—	314.0
Stern sea	1 L wave	3		14.0	.839	4.96	.0665	.175	1.87	.233	13.6
		5		43.5	.648	6.43	.0400	.123	0.86	.168	35.8
		7		116.0	.454	9.17	.0252	.099	0.70	.135	97.5
		9		240.5	.262	15.90	.0155	.089	0.57	.118	215.0
	1¼ L wave	3		14.8	.621	6.70	.0670	.319	1.62	.220	14.4
		5		43.9	.529	7.90	.0550	.258	1.22	.153	36.1
		7		110.7	.434	9.58	.0450	.213	.98	.122	93.0
		9		252.0	.339	12.28	.0370	.175	.83	.102	225.0
	1¾ L wave	3		23.5	.836	6.54	.0790	.409	1.10	.180	22.9
		5		45.8	.539	7.71	.0650	.346	.80	.120	32.7
		7		106.5	.442	9.44	.0535	.290	.59	.090	89.5
		9		269.0	.343	12.12	.0430	.243	.41	.070	240.0

Model φ = 0.675

		V	EHP	SHP_{tank}	PC	N	Ψ	Z	η_o	$PC_{mod.}$	$SHP_{mod.}$
Calm water		3	4.1	17.1	.240	82.7	—	—	.481	—	—
		5	15.3	48.0	.319	148.3	+.0055	+.033	.545	.344	44.5
		7	46.3	135.8	.341	221.1	+.0092	+.078	.531	.436	106.0
		9	120.5	369.5	.326	309.5	+.0154	+.156	.474	.399	302.0
		V		**SHP**	**Λ_p**	**T_e**	**Ψ**	**Z**	**F_p''**	**Z''**	**$SHP_{mod.}$**
Head sea	1 L wave	3		34.0	1.47	2.88	.058	.194	2.41	.602	—
		5		90.8	1.58	2.68	.037	.149	2.16	.485	84.1
		7		174.8	1.685	2.51	.031	.119	1.93	.415	136.5
		9		394.8	1.83	2.31	.028	.100	1.80	.375	323.0
	1¼ L wave	3		45.0	1.00	4.24	.132	.544	—	—	—
		5		130.0	1.11	3.80	.180	.668	4.85	.780	120.5
		7		250.7	1.25	3.45	.213	.838	5.08	1.590	201.0
		9		536.0	1.35	3.14	.150	.950	4.49	—	438.0
	1¾ L wave	3		24.0	0.97	4.36	.166	.750	—	.430	—
		5		103.5	1.042	4.05	.200	.825	6.49	.640	96.0
		7		270.8	1.15	3.76	.182	.938	7.05	.995	211.6
		9		471.9	1.205	3.51	.159	1.125	6.71	1.560	385.0
Stern sea	1 L wave	3		17.1	.795	5.31	.0520	.163	.98	.200	—
		5		49.3	.616	4.86	.0360	.128	.63	.140	45.7
		7		150.0	.448	9.45	.0260	.109	.50	.112	117.0
		9		380.0	.276	15.32	.0185	.094	.30	.096	310.0
	1¼ L wave	3		18.0	.738	5.74	.0660	.334	.80	.160	—
		5		52.2	.597	7.09	.0480	.250	.48	.105	48.9
		7		159.1	.460	9.20	.0355	.188	.32	.074	124.0
		9		403.0	.324	13.05	.0240	.125	.20	.052	329.0
	1¾ L wave	3		17.1	.613	6.91	.0750	.438	1.30	.250	—
		5		48.0	.523	8.10	.0640	.380	.85	.190	44.5
		7		142.0	.440	9.61	.0550	.328	.59	.153	111.0
		9		392.0	.354	11.96	.0465	.279	.42	.130	320.0

Note. For calm water Ψ denotes trimming and *Z* average sinkage. Ψ is given in radians and *Z* in m.

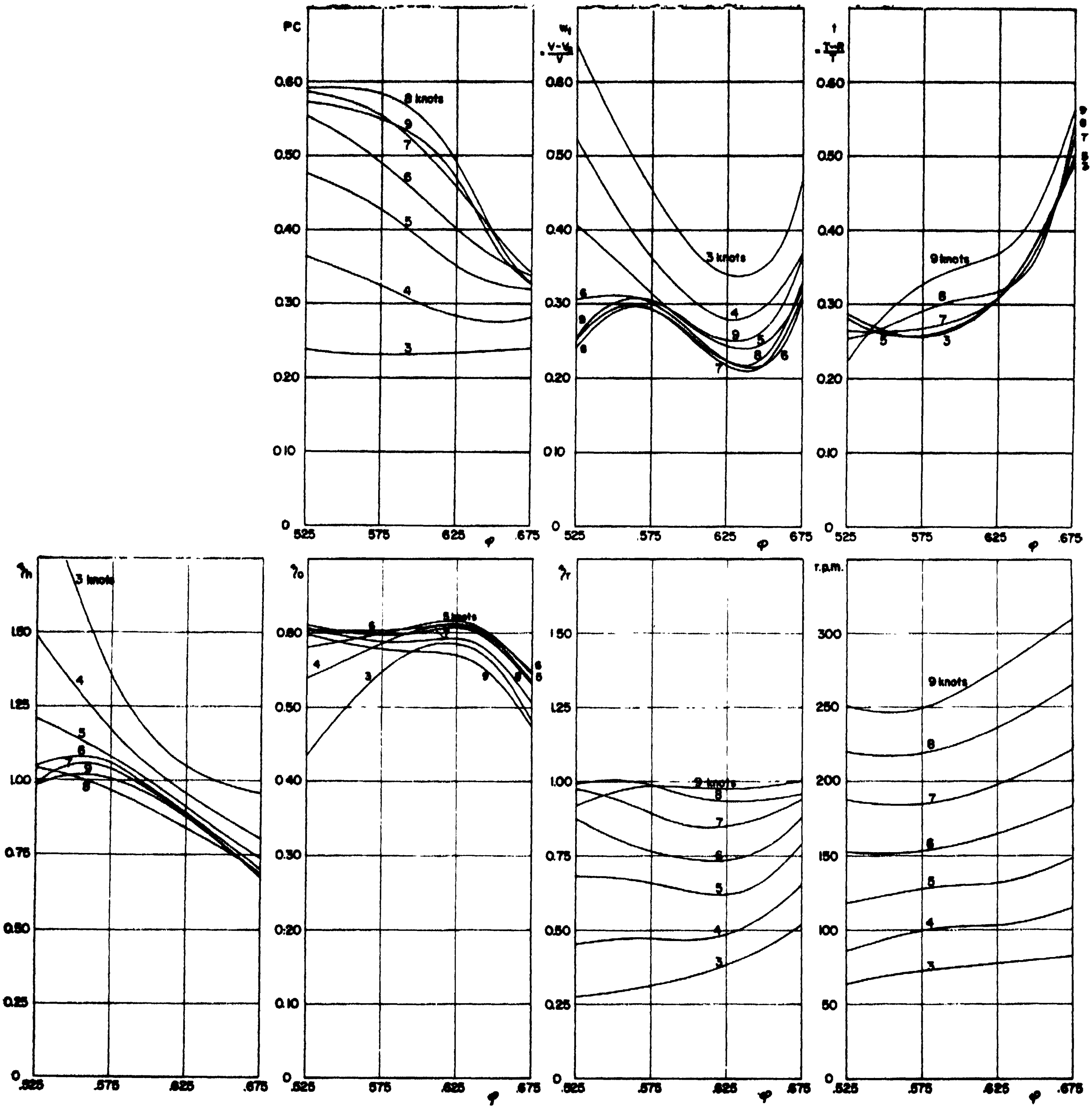


Fig. 459. Propulsive coefficient, wake, thrust, hull, open water and rotative efficiencies and revolutions in calm water

normally has little influence on fishing vessels, and in the tests heave seldom exceeded 3.3 ft. (1 m.). Fig. 469 gives the heave measurements, and from them it seems that all the models are equal, with, perhaps, 0.525 slightly the best. The tests were made in moderate regular waves. Tests in higher waves would probably have shown the influence of the more flaring bows of the smaller prismatic models.

Fig. 467, 468 and 469 also show the movements in the stern seas, and it is interesting to see how in some instances the curves for stern seas and head seas can be connected. If a ship can be considered as a balance it should not matter whether the upsetting forces come from the stern or the bow, and this might be the reason why the curves can be connected. No stern sea tests were made at speeds giving synchronous movements. All models must, for all practical purposes, be considered as equal so far as pitch, bow acceleration and heave in stern seas are concerned.

Trawling tests

The four models were also tested to simulate trawling at 3 knots.

The first test was made with the model dragging a

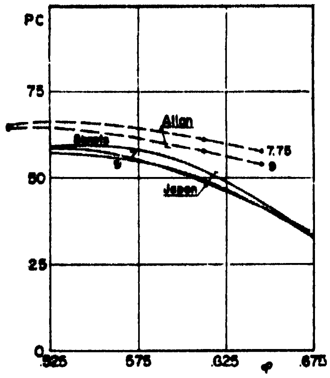


Fig. 460. Decrease of propulsive coefficient when the same propeller was used for models with different prismatic coefficient

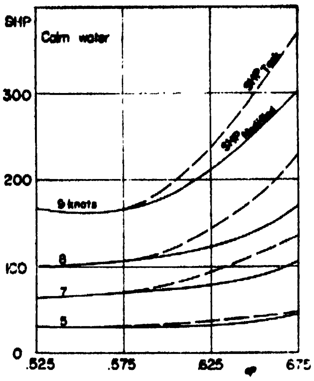


Fig. 461. Shaft horsepower as calculated and modified to take into account unnecessarily abrupt endings

weight on the bottom of the tank, the weight being selected, as near as could be, to produce a warp pull of 3 tons at 3 knots. But this was not satisfactory because great fluctuations in towing force were recorded—sometimes it was as high as 6 tons. By substituting a small net for the weight, the resistance remained constant. So the experiments were done with a net which was hung from the towing carriage to have the line of pull in the same direction as it would be when actually trawling. Fig. 470 shows the test arrangement, and table 112 gives the results from the tests. Both resistance and self-propulsion tests were made in calm water. As expected, the results from the resistance tests are practically equal, but the high prismatic models require more SHP due to their less favourable flow of water to the propeller. The trawling efficiency is from 0.389 to 0.323.

Fig. 471 shows the results from the trawling tests in waves as well as those from tests without a trawl, but at the same 3 knots speed. It appears as if the power increase is somewhat greater while trawling than when the boat is sailing free—and this in spite of the fact that the propulsive coefficient is larger while trawling. The motion data were plotted in many different ways to ascertain whether a ship while trawling has more agreeable motions than when sailing free. Table 113 sums up the results.

Generally it can be said that the models while trawling heave less and have a smaller angle of pitch. The heave accelerations are, however, the same and the bow accelerations slightly more. The latter probably is because the pitching centre has moved aft. The tests seem to confirm that the ship is damped by the trawl wire, and this might be the reason for the higher additional power required than when the ship is sailing free at trawling speed.

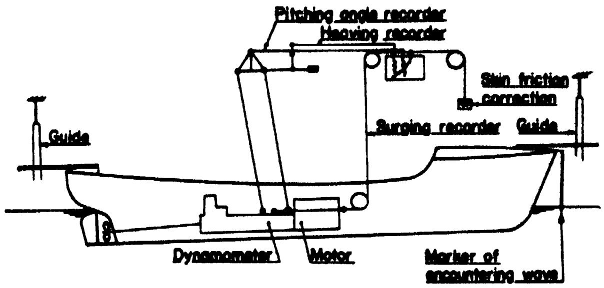


Fig. 462. Wave test arrangement

Future work

Model tests in waves are time-consuming. The research described was to a very large extent carried out by the Japanese Fishing Boat Laboratory, without remuneration from FAO. It is therefore not for FAO to specify what further work should be done, but it would be interesting if additional tests could be conducted with a shorter longitudinal radius of gyration, or perhaps with the same period of pitch for all models, so as to obtain comparable peak curves for the movements at somewhat higher speeds. Furthermore, it would be most interesting to study, at least with the three lowest prismatic models, the influence of different displacements and of higher wave heights. It would also be of value to study changes in the form itself, particularly the damping effect of a transom stern on the two lower prismatic models.

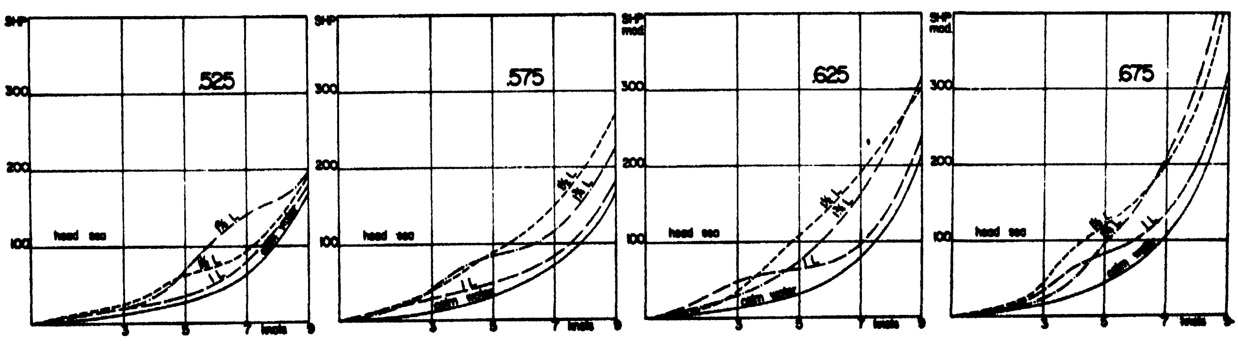


Fig 463. Shaft horsepower in calm water and head waves of different length, plotted for each model

TABLE 112

3 knots simulated trawling

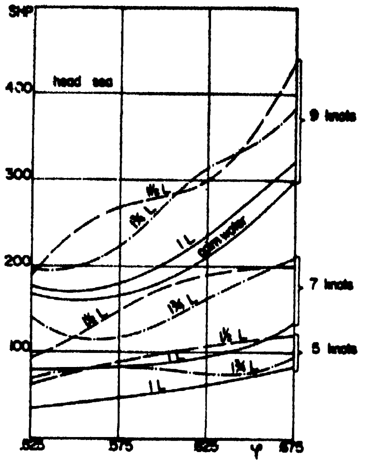
φ			*EHP*	*SHP*	*PC*	T_0	Λ_p	Ψ	*Z*	F_p''	*Z''*
0.525	Calm water	. . . .	64.4	159.8	.403	—	—	+.0169	−.016	—	—
	Head sea	1 L wave	—	180.5	—	3.15	.73	.0402	.211	2.48	.373
		1¼ L wave		205.0		3.83	.885	.0730	.554	2.88	.513
		1½ L wave		170.0		4.28	.99	.1650	.529	3.48	.388
	Stern sea	1 L wave	—	183.0	—	5.22	1.22	.0758	.139	2.15	.178
		1¼ L wave		177.3		5.89	1.36	.0930	.280	1.98	.296
		1½ L wave		159.8		6.47	1.50	.0718	.345	.96	.199
0.575	Calm water	. . . .	64.2	183.0	.351	—	—	+.0138	+.025	—	—
	Head sea	1 L wave	—	204.0	—	3.21	.763	.1320	.196	4.56	.525
		1¼ L wave		214.5		3.92	.931	.1419	.478	4.42	.484
		1½ L wave		193.6		4.36	1.033	.2070	.690	4.67	.467
	Stern sea	1 L wave	—	192.2		5.22	1.24	.0445	.213	1.46	.172
		1¼ L wave		179.8		6.18	1.47	.0649	.306	.86	.139
		1½ L wave		181.5		6.42	1.52	.0605	.313	.86	.177
0.625	Calm water	. . . .	64.6	192.0	.336	—	—	+.0097	+.039	—	—
	Head sea	1 L wave	—	210.0	—	3.02	.726	.0320	.086	1.77	.225
		1¼ L wave		218.0		3.81	.913	.1130	.569	5.17	1.072
		1½ L wave		189.2		4.51	1.08	.1560	.509	4.39	.507
	Stern sea	1 L wave	—	192.0	—	5.12	1.23	.0571	.138	1.42	.207
		1¼ L wave		196.8		5.94	1.43	.0820	.233	.96	.142
		1½ L wave		187.0		6.32	1.52	.0795	.353	.98	.130
0.675	Calm water	. . . .	65.7	190.0	.346	—	—	−.0102	+.025	—	—
	Head sea	1 L wave	—	237.5	—	3.14	.742	.0655	.196	4.14	.504
		1¼ L wave		226.5		3.[illegible]3	.905	.1070	.428	3.50	.461
		1½ L wave		192.0		4.[illegible]7	1.01	.0590	.425	2.25	.250
	Stern sea	1 L wave	—	232.5	—	5.16	1.24	.0580	.173	1.22	.212
		1¼ L wave		246.9		5.92	1.40	.0645	.161	.93	.118
		1½ L wave		240.7		6.7[illegible]	1.58	.0690	.388	.92	.199

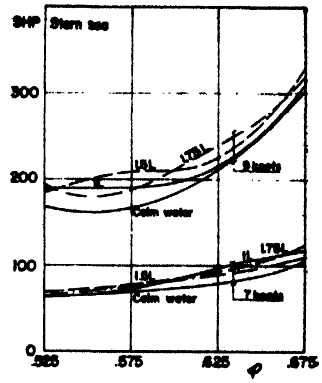
Note: For calm water Ψ and *Z* denotes trimming and average sinkage. Ψ in radians, *Z* in m.

TABLE 113

Movements while trawling, compared with those while sailing at 3 knots

Model	*Pitch angle*		*Pitch acceleration*		*Heave*		*Heave acceleration*	
	Head sea	*Stern sea*	*Head sea*	*Stern sea*	*Head sea*	*Stern sea*	*Head sea*	*Stern sea*
0.525	less	more	less	more	less	more	less	slightly more
0.575	±0	less	more	±0	less	less	more	less
0.625	less	more	more	less	less	less	more	less
0.675	less	±0	more?	±0	less	less	less	less
Average . . .	less	±0	slightly more	±0	less	less	±0	less





LEFT

Fig. 464. Shaft horsepower in calm water and head waves of different length, plotted over prismatic coefficient

RIGHT

Fig. 466. Shaft horsepower in stern seas

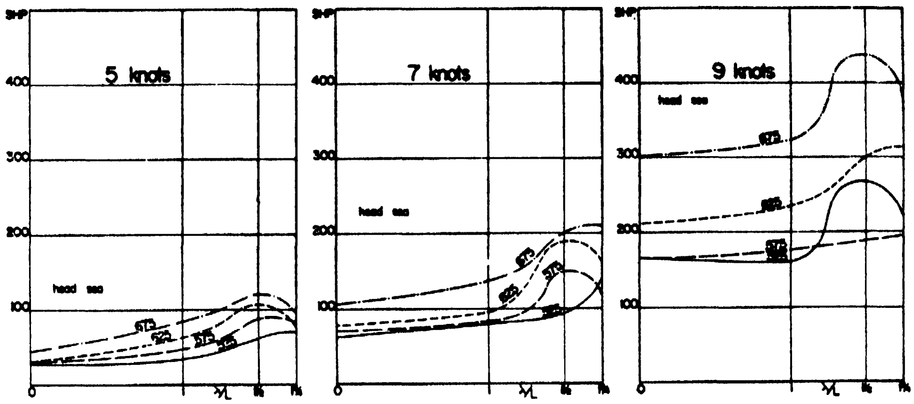


Fig. 465. Shaft horsepower in calm water and head waves of different length, plotted for each speed over wavelength

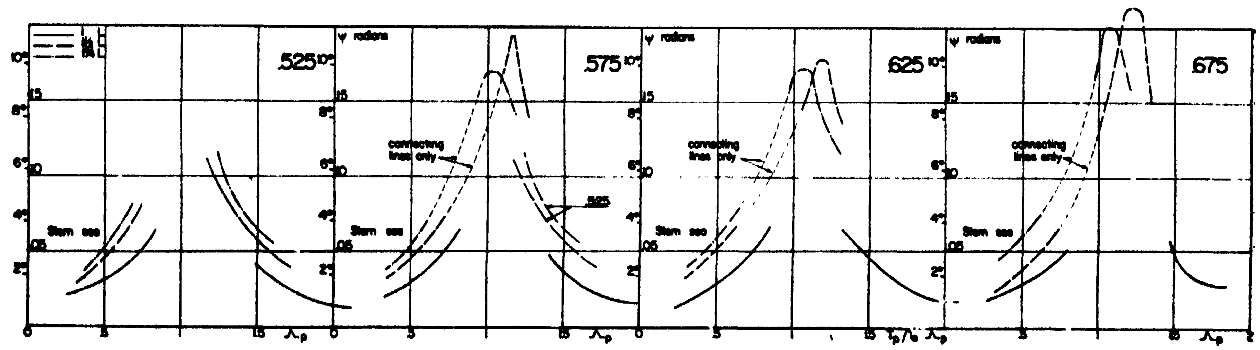


Fig. 467. Pitching angles for the four models

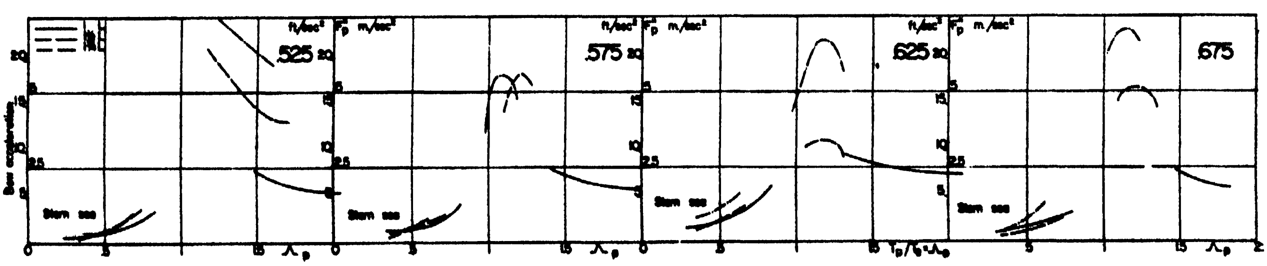


Fig. 468. Pitch accelerations for the four models

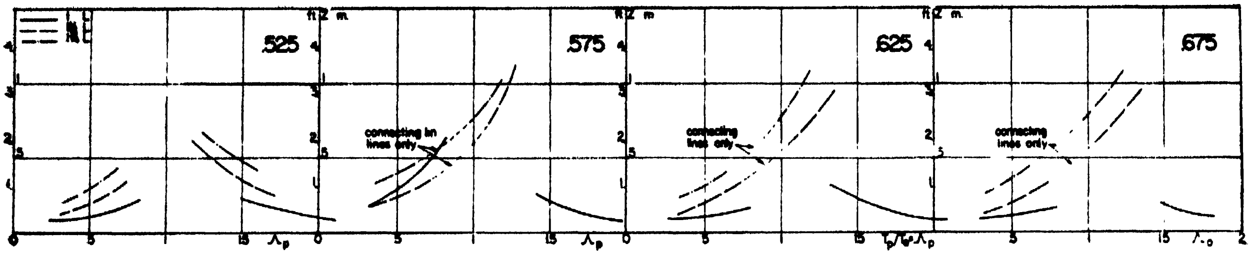


Fig. 469. Heave for the four models

While it is indicated from recent research that tests in regular waves must be considered to be conclusive and that head sea tests are important in themselves, it goes without saying that additional tests with larger models in oblique seas and in irregular waves, in one of the new establishments set up for this purpose, would be of great usefulness. The author hopes that the tests described will be considered important enough to stimulate such work. It would also be valuable if the tests could be done with somewhat different hull sizes and if careful measurements at sea could be correlated with the model tests.

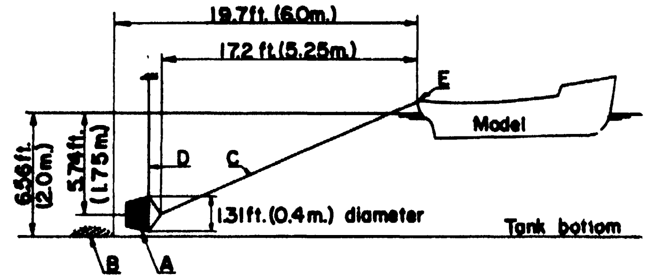


Fig. 470. At the trawling test a floating net was used to create a steady drag

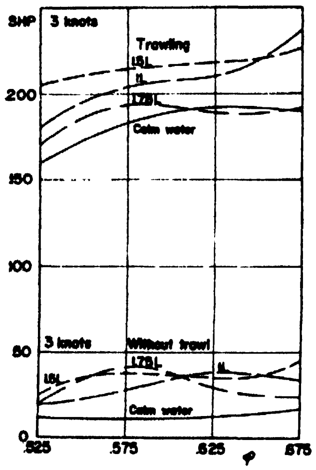


Fig. 471. Shaft horsepower at 3 knots when trawling and sailing

Conclusions

- Previous wave tests have shown that a lower prismatic coefficient than generally used is superior, provided the freeboard forward is not reduced.
- A prismatic coefficient of 0.575 seems to be the best in calm water from the resistance point of view
- A prismatic coefficient of 0.550 seems to be the best in calm water from the self-propulsion point of view
- A prismatic coefficient of 0.525 seems to be the best in waves

Acknowledgements

The author expresses his appreciation to the Committee on the Seagoing Qualities of Ships of the International Towing Tank Conference, especially Messrs. W. P. Walker and C. H. Hancock for valuable advice in planning the tests. Advice was also given by Mr. S. A. Vincent, Mr. Dwight S. Simpson, Dr. J. F. Allan, Captain W. Möckel, Professor Cedric Ridgley-Nevitt and Professor W. P. A. van Lammeren. Special thanks are due to Professor E. V. Lewis for detail recommendations regarding the testing technique and to the author's collaborators in FAO, Mr. Peter Gurtner and Mr. Norio Fujinami, for working out the programme and results. He is also indebted to Mr. Y. Kimura, Director-General of the Japanese Fishing Boat Association, Mr. Y. Otsu, Chief of the Fishing Boat Laboratory of the Japanese Fisheries Agency and his assistants, Mr. N. Yokoyama and Mr. T. Kobayashi for their co-operation.

TRAWLER FORMS WITH BULBOUS BOWS

by

D. J. DOUST

Resistance and propulsion experiments have been conducted in calm water over a wide range of speed with two models, one a conventional long distance trawler and the other a bulbous bow trawler having the same overall dimensions and displacement. Two propellers selected from the National Physical Laboratory (NPL) standard series, suitable for free-running and trawling conditions respectively, have been tested with each form. The results of these experiments indicate that overall reductions in power of the order of 10 to 15 per cent. may be obtained in the bulbous bow form, due to reductions in resistance and increased propulsive efficiency.

Additional experiments have been conducted to assess the relative performance of these forms in rough water. The bulbous bow design over the working speed range suffered a smaller reduction in speed than did the conventional design for the same resistance.

LES FORMES DE CHALUTIER AVEC AVANT A BULBE

On a effectué des expériences de résistance et de propulsion en eau calme, dans une large gamme de vitesses, avec deux modèles: un chalutier ordinaire pour la pêche dans les eaux éloignées et un chalutier à avant à bulbe, ayant les mêmes dimensions hors-tout et le même déplacement. Avec chaque forme, on a essayé deux hélices choisies dans la série standard NPL convenant respectivement pour les conditions de route libre et de chalutage. Les résultats de ces expériences indiquent que l'on peut obtenir des réductions totales de puissance de l'ordre de 10 à 15 pour cent avec la forme à avant à bulbe par suite des réductions de résistance et de l'augmentation du rendement.

Des expériences supplémentaires ont été effectuées pour établir le rendement relatif de ces formes par mer agitée. Le modèle à avant à bulbe au-dessus des vitesses d'utilisation subissait une plus faible réduction de vitesse que le modèle courant, pour la même résistance.

FORMAS DE ARRASTREROS CON PROA DE BULBO

Se han realizado ensayos de resistencia y propulsión en agua tranquila y en una extensa gama de velocidades con dos modelos, uno el arrastrero normal de gran altura y el otro un arrastrero con proa de bulbo de las mismas dimensiones y desplazamiento. En cada modelo se ensayaron dos hélices seleccionadas de la serie normal del NPL, adecuadas para la navegación en ruta y remolcando el arte. Los resultados de estos experimentos indican que mediante el uso de la proa de forma bulbosa se puede lograr una reducción general de la necesidad de fuerza motriz del orden de 10 a 15 por ciento, debido a disminuciones de la resistencia y a aumento del rendimiento propulsor.

Se han realizado otros experimentos para evaluar los rendimientos relativos de ambas formas en aguas agitadas. El modelo con proa de bulbo experimentó reducciones menores de la velocidad en toda la gama de velocidades empleadas, que el modelo normal de la misma resistencia.

IN THE past, a great deal of research has been conducted to determine the resistance characteristics of bulbous bow forms in calm water, as compared with those of the more conventional types (van Lammeren, 1948; Lindblad, 1944 and 1948; Dillon and Lewis, 1955; Fergusson and Parker, 1952; Wigley, 1935; Bragg, 1930). Most of this work has been concerned with speed-length ratios below $V/\sqrt{LBP}=1.0$ ($v/\sqrt{gLBP}=0.30$), and the published results indicate in general that reductions in total resistance in calm water can be obtained by good design over certain ranges of speed. Except in rare cases, however, the order of reduction in total resistance seldom exceeds 4 per cent. at the usual design speeds. It is not surprising to find therefore that opinions on the relative merits of bulbous bow forms and conventional ship forms have differed quite materially. This is reflected in the diversity of hull shapes which have been produced for substantially the same requirements for large ocean-going passenger liners, cargo liners, super tankers and naval vessels of all kinds (Dillon and Lewis, 1955).

In the case of trawlers, which operate, at relatively high speed-length ratios, up to $V/\sqrt{LBP}=1.20$ ($v/\sqrt{gLBP}=0.36$), the proportion of wave-making to frictional resistance is much greater, and on theoretical grounds it is to be expected that larger benefits in ship resistance should be possible with bulbous bow designs for this type of ship (Wigley, 1935). It is also apparent that the design of ship forms based on model experiments conducted in calm water does not always necessarily produce the optimum forms suitable for sea-going conditions, and considerable attention is now being given to the study of resistance and propulsion qualities in regular and irregular seas. It was therefore considered essential to ensure that the benefits obtained in calm water with these bulbous bow trawler forms were not offset by any undue penalty in rough water performance.

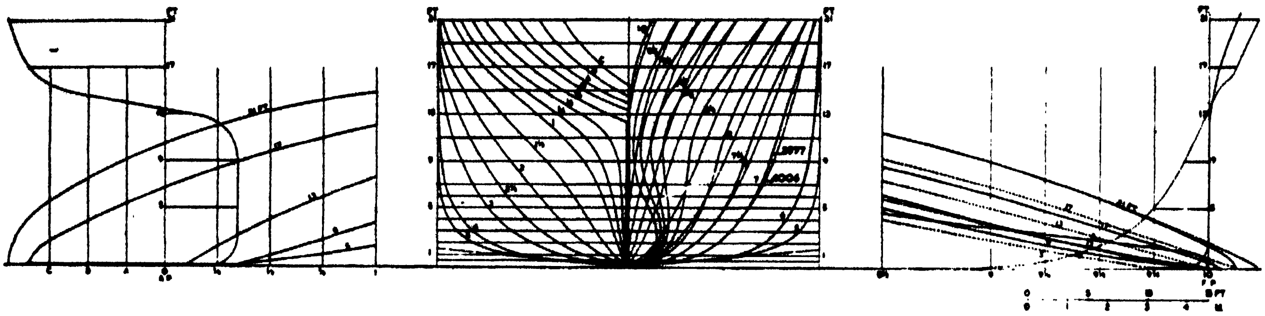


Fig. 472. Post-war British super trawlers have lines developed from the results of many model tests. The addition of a bulbous bow improves performance still more. Here are shown a normal form and one with bulbous bow

TABLE 114

Useful ranges of parameters in which the bulbous bow is most effective for trawlers

Parameter	*Most useful ranges*
$V/\sqrt{LBP}$ ($v/\sqrt{gLBP}$	1.05 to 1.20 (0.31 to 0.36)
LBP/B	>5.60
$\frac{1}{2}\alpha_e$	5° to 30°
φ	>0.63

It was hoped, indeed, that some improvement in rough water performance might be realized due to the pitch damping produced by the presence of the bulb.

Resistance characteristics in calm water

A statistical analysis of the resistance of trawler forms in calm water has recently been completed at the Ship Division of the National Physical Laboratory (NPL) (p. 370 and Doust and O'Brien, 1959). Many results for bulbous bow forms are included in the analysis, and the useful ranges of prismatic coefficient, speed-length ratio and other parameters in which these forms show up to advantage, relative to the conventional forms, are given in table 114.

The improvement is partly due to the reduction in the half angle of entrance which can be introduced in the bulbous bow form whilst retaining the same overall proportions and displacement as the conventional design, and partly to the specific effect of the bulb in introducing a pressure reduction in the region of the bow wave, thereby reducing the wave-making resistance of the form still further. This reduction of the normal bow wave system is particularly marked at $V/\sqrt{LBP}=1.0$ to 1.10 ($v/\sqrt{gLBP}=0.30$ to 0.33), and the main wave system is then observed to be generated at a section just forward of amidships. Fig. 472 and 473 show the body sections and non-dimensional area and waterline curves for the conventional and bulbous bow models investigated. They have been designated No. 4006 and 3977 respectively, and their resistance-speed characteristics were determined by conducting model experiments over a range of speeds corresponding to 4 to 16 knots for a 180 ft. (54.86 m.) ship. These models were made to the moulded lines and tested without appendages at the

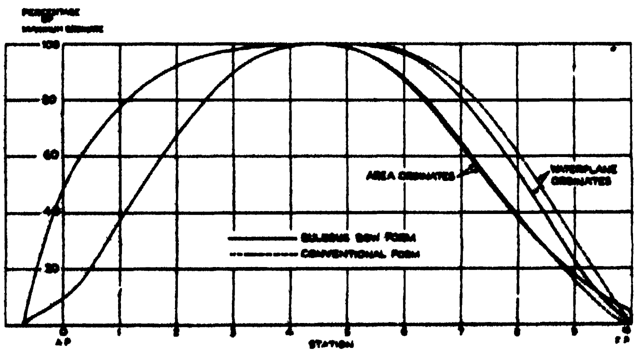


Fig. 473. Area and waterline ordinates for bulbous bow and conventional form

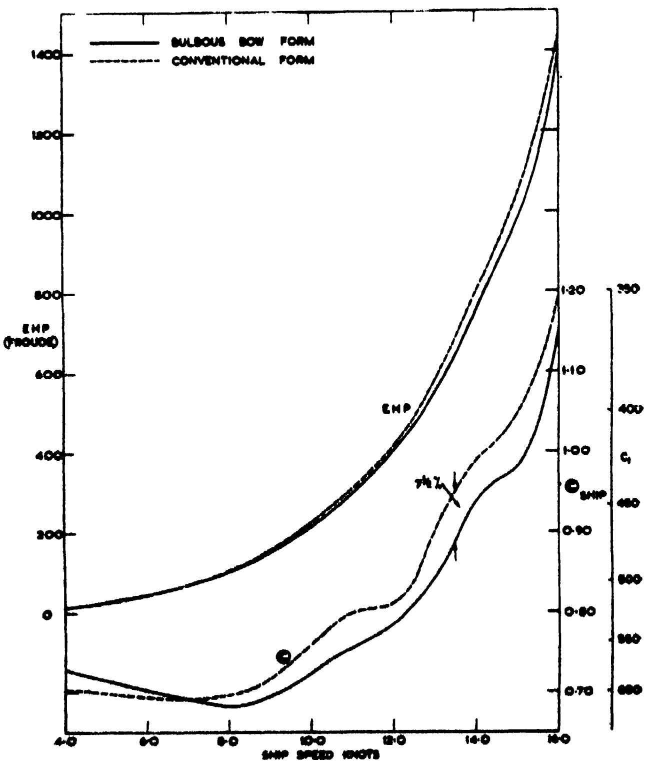


Fig. 474. ©, C_1 and EHP prediction

moulded displacement. Studs of ⅛ in. (3.2 mm.) diameter, $\frac{1}{10}$ in. (2.5 mm.) projection and 1 in. (25 mm.) spacing were fitted near the bow profiles to stimulate turbulent flow. The dimensions and form parameters are given in table 115, whilst the © and EHP predictions using the Froude method of extrapolation are given in fig. 474.

It will be seen that the after-bodies of both forms are identical, whilst the bulbous bow form is fuller forward, between stations 8½ and 10, and finer between stations 5½ and 8½ with the same overall dimensions and displacement. The effect of this type of modification is to shift the LCB position further forward as compared with the conventional design, and this is generally helpful in reducing the variation in trim in service conditions. The entrance is generally the same for each design, although considerable fining of the load waterline has been made with the bulbous bow form (fig. 473). The © and EHP curves indicate that a general reduction in power has been obtained in favour of the bulbous bow form, amounting to 5 to 7½ per cent. at the operating speeds of 12 to 14½ knots. In this speed range, the speed of the bulbous bow form is ½ knot greater than that of the conventional design for the same EHP.

TABLE 115

Principal ship particulars corresponding to conditions for which model tests were made

Hull model No.		3977	4006
Scale of model		1/12	1/12
Designed		bulb	conventional
Length between perpendiculars (LBP)	ft. (m.)	180.0 (54.86)	180.0 (54.86)
Breadth moulded (B_{mld})	ft. (m.)	32.0 (9.75)	32.0 (9.75)
Condition		loaded	loaded
Mean draft moulded (T)	ft. (m.)	15.1 (4.62)	15.1 (4.62)
Trim at rest, in LBP	ft. (m.)	5.9/stern (1.8/stern)	5.9/stern (1.8/stern)
Equivalent mean draft moulded at level trim	ft. (m.)	15.6 (4.76)	15.535 (4.74)
Designed rake of keel, in LBP	ft. (m.)	Nil	Nil
Displacement moulded (Δ_{smld})	tons	1,395	1,395
Displacement with shell (Δ_s)	tons	1,403	1,403
Wetted surface coefficient Ⓢ		6.054	5.881
Block coefficient (δ)		0.543	0.546
Midship-area coefficient (β)		0.910	0.910
Prismatic coefficient (φ)		0.597	0.600
LCB in trimmed condition aft of midships	ft. (m.)	7.8 (2.38)	8.2 (2.5)
½ angle of entrance of waterline (½α_e)	degrees	6.5	15.0
Length of entrance (L_e)	ft. (m.)	99 (30.2)	99 (30.2)
Length of parallel (L_p)	ft. (m.)	0	0
Length of run (L_r)	ft. (m.)	81 (24.7)	81 (24.7)
Bilge radius	ft. (m.)	not fixed	not fixed
Rise of floor	in. (m.)	18 (0.46)	18 (0.46)
Bulb area as % of maximum area (a/A_m)		5.0	0

1. Coefficients and LCB are for moulded displacement including cruiser stern, for moulded dimensions and level trim.
2. The trim is relative to the moulded base line and excludes designed rake of keel.
3. Density of water for ship taken as 35 cu. ft. per ton (specific weight 1.025).
4. Equivalent level draught used for coefficients was different from mean draft.

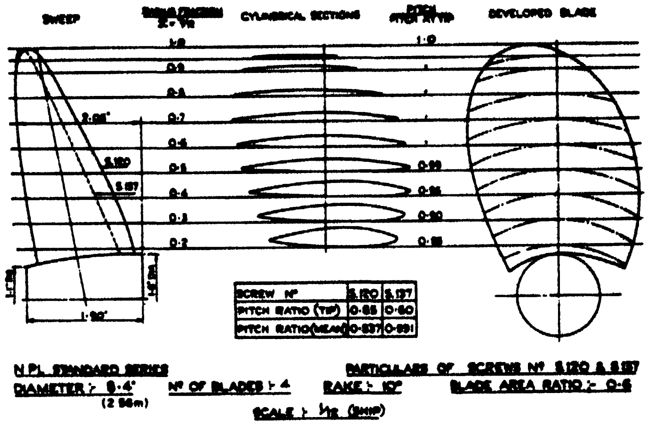


Fig. 475. Particulars of free-running propeller S.120 and trawling propeller S.137

It should be noted that the original design has near-optimum resistance characteristics for a conventional trawler of these proportions and fullness.

Propulsion characteristics when sailing in calm water

In order to ensure that unfavourable propulsion characteristics are not introduced as a result of modifications made to a particular form to improve its resistance qualities, it is necessary to conduct propulsion experiments for both the original design and any subsequent modifications. In the present instance, it is particularly important to establish whether the benefits of the bulbous bow form in regard to resistance are offset in any way from the propulsion aspect. Due to the marked differences observed in the wave profiles of the two forms, it might be anticipated that some changes in propulsive efficiency would occur due to the change in flow at the stern.

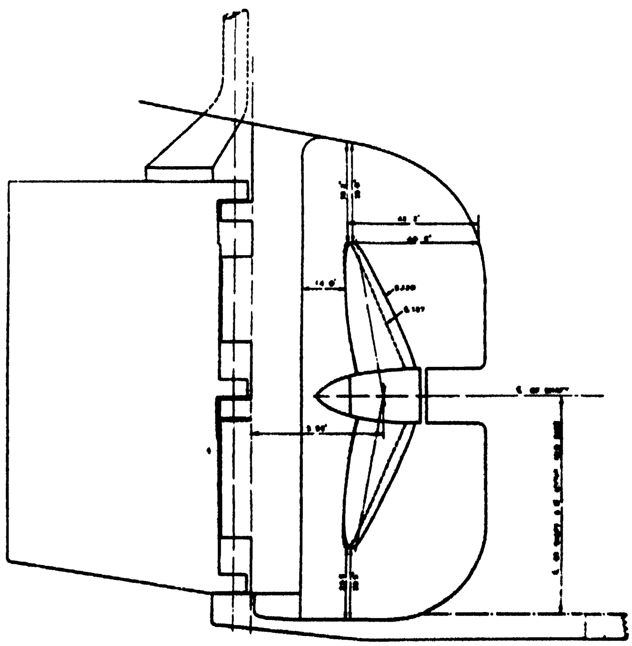


Fig. 476. Stern arrangements for the two propellers

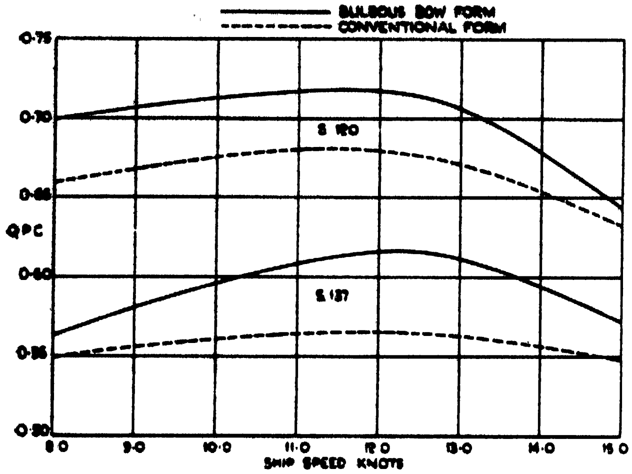


Fig. 477. QPC for bulbous bow and conventional trawler when sailing in calm water with free-running propeller S.120 and trawling propeller S.137

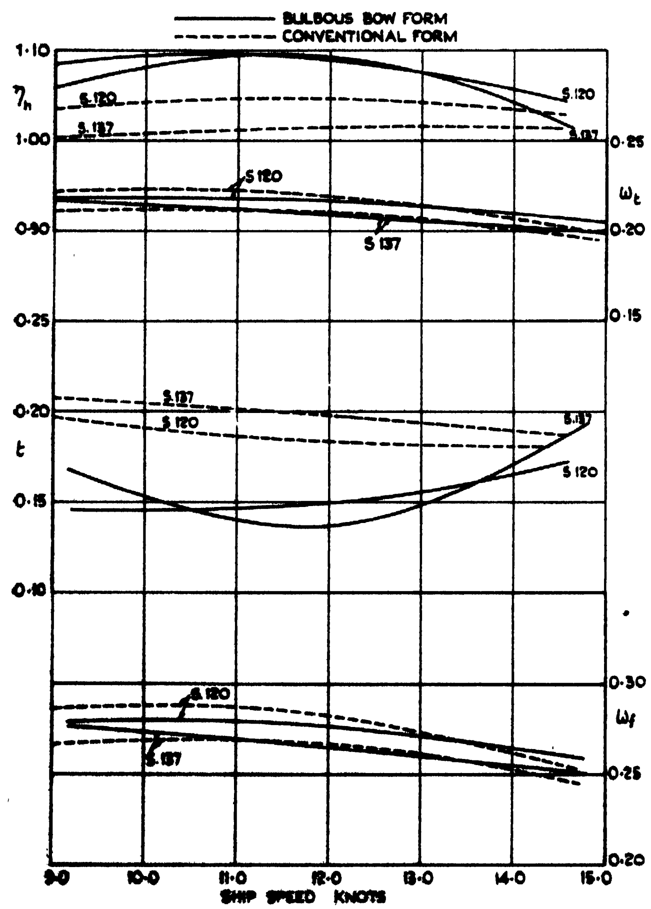


Fig. 478. Comparison of hull efficiencies. S.120 is the propeller designed for free-running and S.137 for trawling

Propellers S.120 and S.137 were selected from the NPL standard series to absorb 1,450 DHP at 250 r.p.m. in the free-running and trawling conditions respectively. The main propeller particulars are given in table 116 and the drawings in fig. 475. The efficiencies for both propellers when working behind the models have been determined over the range of 9 to 14.5 knots. In addition, overload tests at a speed corresponding to 4 knots have been conducted with both propellers under trawling conditions. The stern arrangements used in these propulsion experiments are shown in fig. 476, the

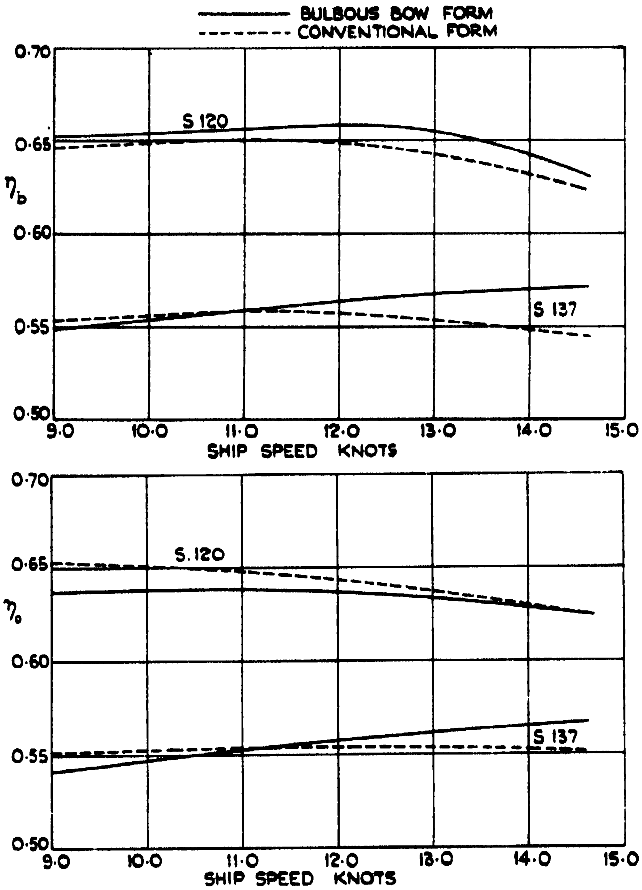


Fig. 479. Comparison of propeller efficiencies for free-running propeller S.120 and trawling propeller S.137

clearances of the screw in the aperture being representative of NPL practice. Fig. 477 shows the improvements in quasi-propulsive coefficient, QPC=(EHP × 1.10)/DHP, for the bulbous bow form in the sailing condition, over the speed range corresponding to 9 to 14.5 knots. At the service and trial speeds of 13 and 14.5 knots, these improvements amount to 5 and 3 per cent. with propeller S.120, and 8½ and 7½ per cent. with propeller S.137. Similar benefits in QPC for some twelve propellers tested behind eight bulbous bow forms have been obtained at the NPL in recent years. The average order of improvement in QPC relative to conventional designs is 4½ per cent. Fig. 478 and 479 show that the thrust deduction fraction is the component of QPC most affected by the presence of the bulb and re-designed forebody lines, the open and behind propeller efficiencies and wake fractions being only slightly influenced in favour of this design. The hull efficiency of the bulbous bow form is generally superior to that of the conventional trawler form, since the thrust deduction fraction is substantially reduced in this case. The average values of t which have been obtained at the NPL for bulbous bow and conventional trawler forms are 0.197 and 0.220 respectively. Fig. 480 shows the estimated powers and revolutions for each

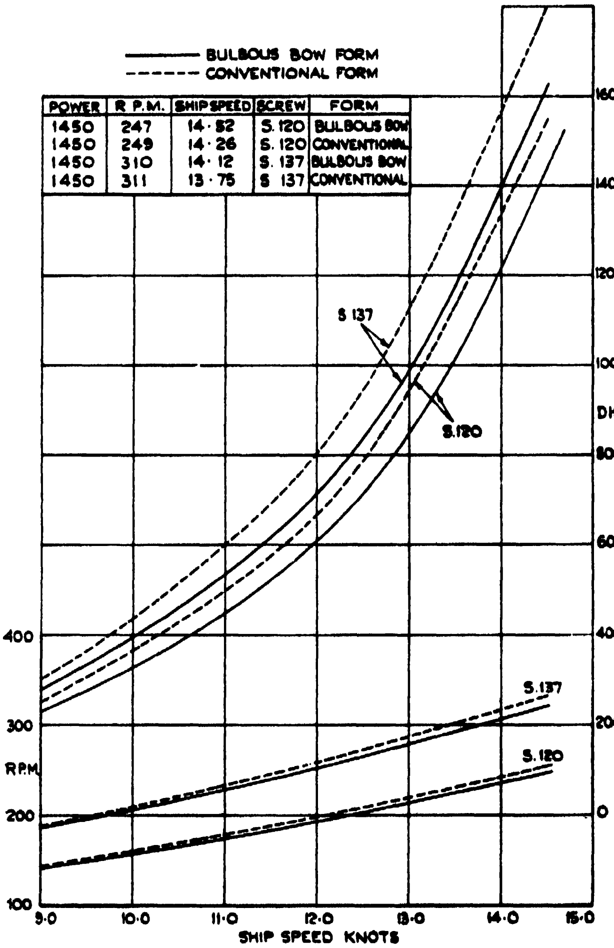


Fig. 480. Ship propulsion estimates with free-running propeller S.120 and trawling propeller S.137

form, in which DHP is defined as (EHP × 1.10)/QPC. With 1,450 DHP available, the bulbous bow form shows an increase in ship speed of 0.26 knot with propeller S.120, and 0.37 knot with S.137. When absorbing 1,200 DHP at the propeller, the increases in ship speed are 0.40 and 0.50 knots respectively.

Trawling conditions

For trawling conditions at 4 knots, it will be seen from fig. 481 that there is only a small difference in performance between the bulbous bow and conventional forms. The

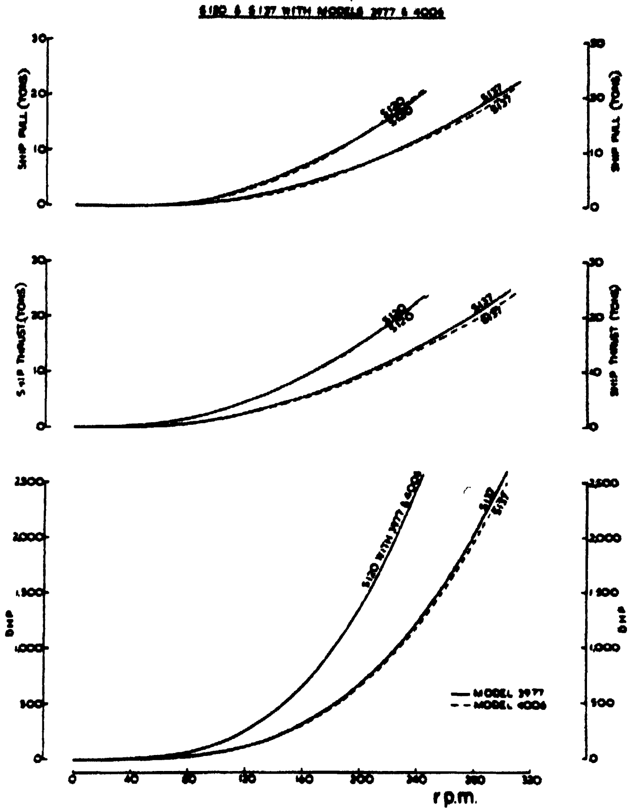


Fig. 481. Performance curves for trawling at 4 knots

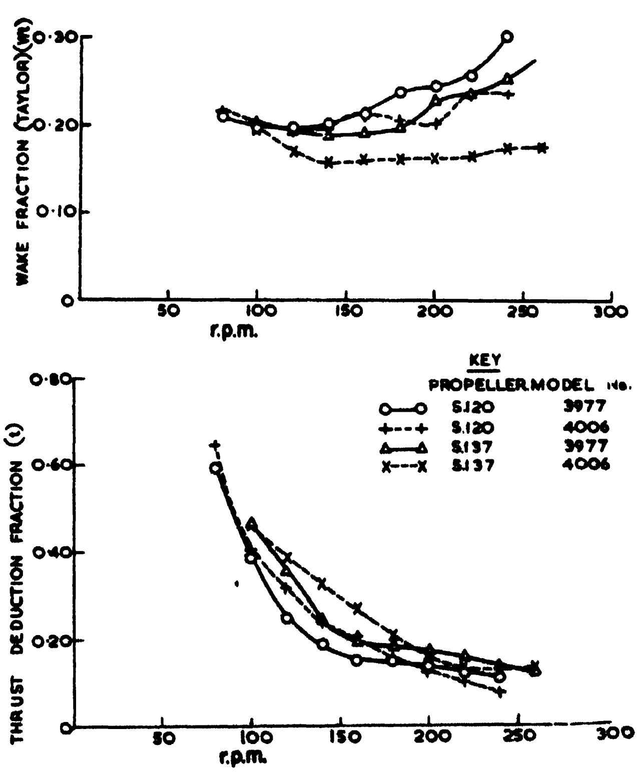


Fig. 482. Wake and thrust deduction fractions for trawling conditions at 4.0 knots

TABLE 116

Principal particulars of the selected ship screws to absorb 1,450 DHP at 250 r.p.m.

Screw model No.	S.120	S.137
Scale of model	$^1/_{18}$	$^1/_{18}$
Designed for	free-running	trawling
Type of boss	Solid	Solid
Material	Bronze	Bronze
Screw details		
No. of blades	4	4
Diameter (D) ft. (m.)	8.4 (2.56)	8.4 (2.56)
Boss diameter (max) in. (mm.)	18.0 (457)	18.0 (457)
Boss diameter at rake line (D_b) in. (mm.)	16.84 (428)	16.84 (428)
Designed face pitch (max) (P_f) ft. (m.)	7.14 (2.18)	5.04 (1.54)
Designed face pitch (mean) (P_m) ft. (m.)	7.03 (2.14)	4.96 (1.51)
Developed area outside boss (A_d) sq. ft. (sq. m.)	33.28 (3.09)	33.28 (3.09)
Cylindrical thickness at root (t_r) in. (mm.)	3.83 (97.3)	3.83 (97.3)
Thickness at shaft axis (t) in. (mm.)	4.54 (115)	4.54 (115)
Rake aft degrees	10°	10°
Boss diam. ratio (D_b/12D)	0.167	0.167
Mean face pitch ratio (P_m/D)	0.837	0.590
Blade area ratio (BAR=$4A_d/\pi D^2$)	0.60	0.60
Thickness ratio (t/12D)	0.045	0.045
Screw position		
Centre of propeller:		
forward of AP ft. (m.)	3.55 (1.08)	3.55 (1.08)
above mld. base ft. (m.)	6.0 (1.83)	6.0 (1.83)
Clearances		
Single screw:		
Trailing edge and leading edge of fin in. (mm.)	14.0 (356)	14.0 (356)
Top of aperture:		
above tips in. (mm.)	33.0 (838)	33.2 (843)
fwd. of tips in. (m.)	40.8 (1.04)	42.2 (1.07)
Bottom of aperture below tips in. (mm.)	23.5 (597)	23.5(597)

1. Mean face pitch is obtained by taking moments of pitch at equally spaced radii about the shaft axis.
   $P_m = \Sigma P_r r/\Sigma r$ where P_r = Face pitch at radius r.
2. Centre of propeller is taken at intersection of rake line and shaft axis.

r.p.m. of propeller S.137 designed to absorb 1,450 DHP when trawling at 4 knots, are 254 and 256 with the bulbous bow and conventional form respectively.

The corresponding pulls available for towing the trawl at 4 knots are 14.2 tons and 13.9 tons, giving an increased pull in favour of the bulbous bow trawler of some 2 per cent. The corresponding differences in pull, power and propeller revolutions for propeller S.120 designed for free-running conditions, are unimportant.

The wake fractions and thrust deduction fractions for trawling conditions are shown in fig. 482, and have been evaluated according to the principle of thrust identity. The main features of this presentation are the marked increases in thrust deduction fraction which occur at low propeller r.p.m. The small benefit in favour of the bulbous bow form with propeller S.137 already referred to is due to an increased hull efficiency offset by a smaller reduction in propeller efficiency behind the model.

Performance in rough water

Both models were ballasted to the conditions of loading and trim shown in table 115, and weights were adjusted longitudinally so that the radius of gyration about the LCB position was 23 per cent. of the length between perpendiculars in each case. Comparisons of speed, pitch and heave of these two models have been made

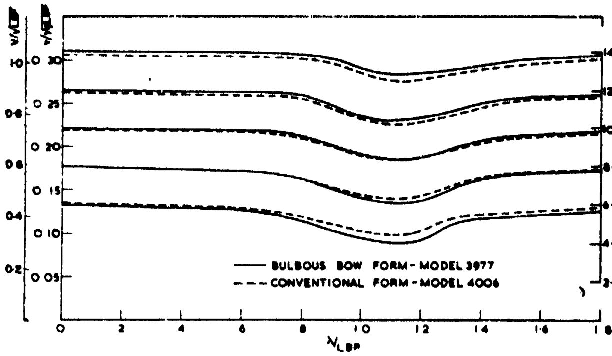


Fig. 483. Effect of wave length/ship length ratio on speed

in near-regular waves for the following head-to-sea conditions:

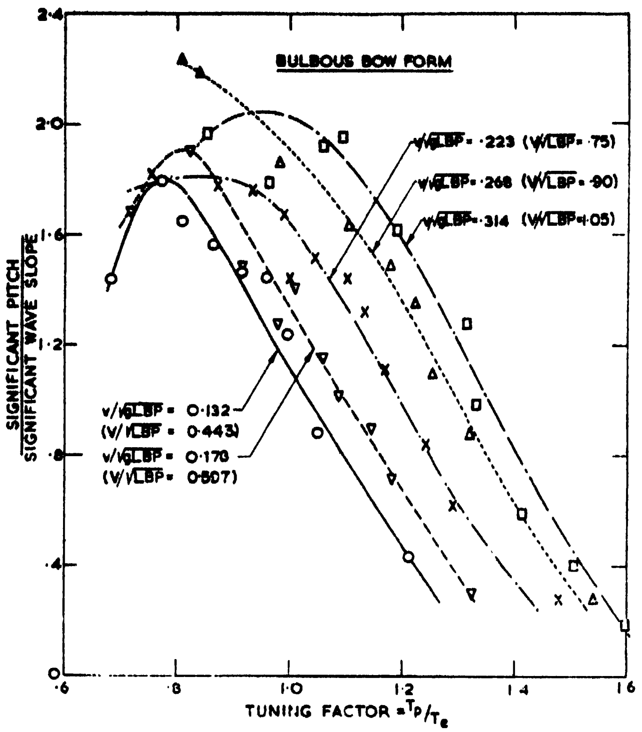
Wave length/LBP=0.80 to 1.80,
Wave height/LBP=1/45,
Ship speed=6, 8, 10, 12 and 14 knots.

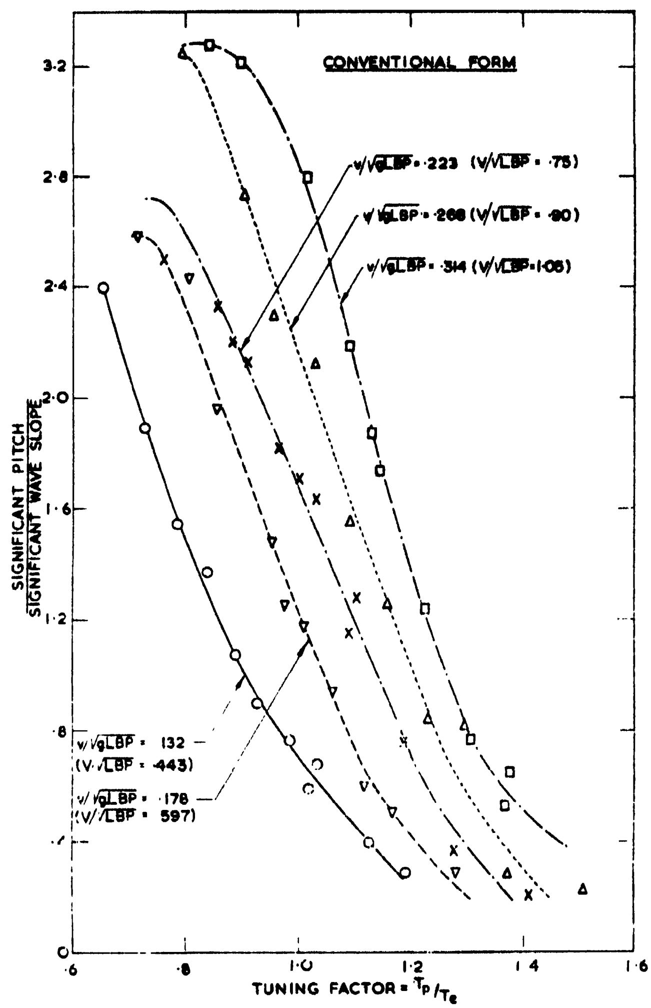
A description of the apparatus used to record the pitch, heave and resistance of the models under test is given by Gerritsma (1957), the wave height and period of encounter being recorded by means of a capacitance probe in conjunction with a frequency-modulated unit and pen recorder. The results of these experiments are shown in fig. 483 to 488. The sustained ship speeds given in fig. 483 have been determined for the condition at

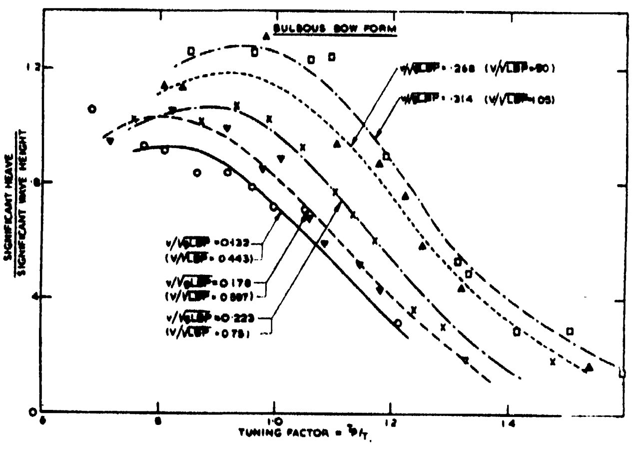
TABLE 117

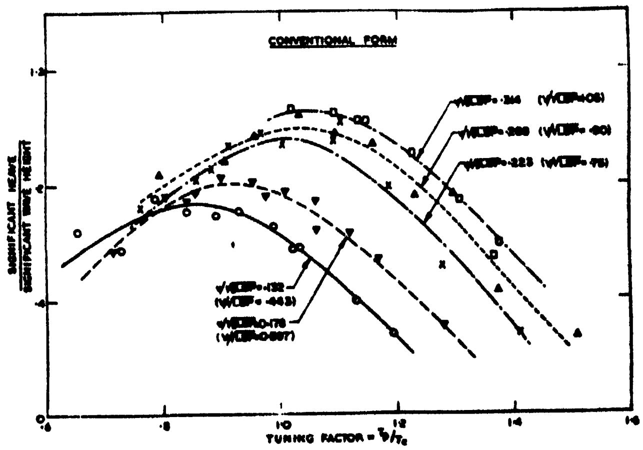
180 ft. (55 m.) LBP trawler—service speed 13.5 knots. Ranges of wave length and ship speed when the bulbous bow form is superior

Ship speed	*Wave length*	*Pitch amplitude*	*Heave amplitude*	*Sustained ship speed*
above 10 knots	Longer than 180 ft. (55 m.)	Less with bulbous bow form	Greater with bulbous bow form	Higher with bulbous bow form
above 10 knots	Shorter than 180 ft. (55 m.)	Rather more with bulbous bow form	Less with bulbous bow form	Higher with bulbous bow form
below 10 knots	Longer than 180 ft. (55 m.)	Greater with bulbous bow form	Greater with bulbous bow form	Lower with bulbous bow form
below 10 knots	Shorter than 180 ft. (55 m.)	Greater with bulbous bow form	Less with bulbous bow form	Rather lower with bulbous bow form









ABOVE
Fig. 484. Effect of tuning factor on pitch for bulbous bow form

BELOW
Fig. 485. Effect of tuning factor on heave for bulbous bow form

ABOVE RIGHT
Fig. 486. Effect of tuning factor on pitch for conventional form

BELOW RIGHT
Fig. 487. Effect of tuning factor on heave for conventional form

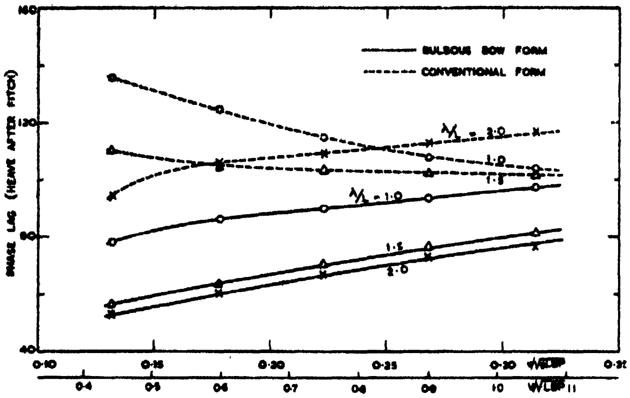


Fig. 488. Phase angles of conventional and bulbous bow forms

which the mean model resistance in waves is the same as that required to tow the bulbous bow model in calm water at speeds corresponding to 6, 8, 10, 12 and 14 knots respectively. It can be seen from fig. 483 that the loss of speed in all wave lengths covered by these experiments is less for the bulbous bow form at all speeds above 10 knots, below this speed it is greater than that of the conventional form. The free-running speed range of these vessels is about 12 to 14½ knots and the disadvantage of the bulbous bow form at the lower speeds is therefore relatively unimportant, since when trawling the normal motion of these vessels is usually damped by the restraining forces in the trawl warps. The non-dimensional pitch and heave amplitudes and phase angles may be compared by referring to fig. 484 to 488 in various wave conditions. Table 117 shows the ranges of wave length and ship speed in which the bulbous bow form is superior to the conventional trawler form.

The overall comparison of performance of these two forms in rough water may therefore be regarded as showing an advantage in favour of the bulbous bow form for all wave lengths in the range of ship speed greater than 10 knots ($V/\sqrt{LBP}=0.75$ or $v/\sqrt{gLBP}=0.223$). The effects of the bulb and re-designed forebody on the pitch and heave amplitudes are contradictory in some cases, but in the free-running conditions show a benefit in sustained ship speed.

Acknowledgments
The work described above has been carried out as part of the research programme of NPL, and this paper is published by permission of the Director of the Laboratory.

TESTS OF FISHING BOAT MODELS IN WAVES

by

KANAME TANIGUCHI

Self-propulsion tests on models of a tuna longliner and a fisheries training boat of approximately 370 gross tons were carried out in regular waves at the Nagasaki Experimental Tank in 1955.

- It was found that ship motions in waves are in proportion to the wave height, and the thrust increase is in proportion to the square of the wave height. This shows, experimentally, that, for practical purposes, the problem in waves can be treated on the assumption of linearity.
- For the hull forms tested, the thrust increase in waves is determined chiefly by the tuning factor for pitching and by the ratio of wave length to ship's length, but depends very little on heaving and ship speed.
- The mean wake in the self-propelled condition can be presumed to be the same as in still water and the relative rotative efficiency can be regarded as unity.
- The effects of the variation of the bow section form are not very noticeable. The magnitude of pitching is contrary to that of thrust increase. Of the three hull forms tested, that having a large flaring and a sharp entrance of the waterline is the most seakindly.
- Rolling was most violent when the waves approached the hull forms tested from 15° abaft the beam (75° from the stern).

ESSAIS AU BASSIN DE MODÉLES DE NAVIRES DE PÊCHE, DANS LES VAGUES

En 1955 on a effectué des essais d'auto-propulsion avec des modèles d'un palangrier-thonier servant à l'entraînement des pêcheurs, d'environ 370 tx. j.b., dans des vagues régulières au Bassin Expérimental de Nagasaki.

- On a trouvé que les mouvements du navire dans les vagues sont proportionnels à la hauteur des vagues et que l'augmentation de résistance est proportionnelle au carré de la hauteur de vagues. Cela montre expérimentalement que, pour des buts pratiques, le problème dans les vagues peut être traité sur la base de relation linéaire.
- Pour les formes de coque essayées, l'augmentation de résistance dans les vagues est déterminée principalement par le facteur de résonance du tangage et par le rapport de la longueur des vagues à la longueur du navire, mais très peu par la levée et la vitesse du navire.
- On peut présumer que le sillage moyen en auto-propulsion est le même qu'en eau calme, et le rendement de carène peut être considéré comme unité.
- Les effects de la variation de la forme de l'avant ne sont pas très importants. L'ordre de l'amplitude du tangage est inverse par rapport à l'augmentation de la résistance. Des trois formes de coque essayées, celle ayant un grand dévers et des façons de l'avant aiguës à la flottaison a la meilleure tenue à la mer.
- Le roulis était le plus violent quand les vagues arrivaient sur les formes de coques essayées en faisant un angle de 15° sur l'arrière par rapport au maître-couple (sous un angle de 75° par rapport à Larrière).

ENSAYOS EN ESTANQUES DE MODELOS DE PESQUEROS, EN LAS OLAS

En 1955 se efectuaron ensayos de autopropulsión con modelos de un atuenero palangrero de unas 370 tons brutas, que también se empleaba para la capacitación de personal. Los ensayos se realizaron con olas regulares en el estanque experimental de Nagasaki.

- Se observó que los movimientos del barco en las olas son proporcionales a la altura de éstas y que la resistencia aumenta proporcionalmente al cuadrado de su altura. Esto demuestra experimentalmente que, para los fines prácticos, el problema en las olas puede tratarse basándose en la relación linear.
- Para las formas de casco ensayadas el aumento de resistencia en las olas lo determina principalmente el factor de resonancia para el cabeceo y la relación longitud de la ola—eslora del barco, pero muy poco por las viradas y la velocidad del barco.
- Se puede suponer que la estela media en la autopropulsión es la misma que en agua tranquilia y el rendimiento de carena puede considerarse como unidad.
- No son muy importantes los efectos de la variación de la forma de la proa. El orden de amplitud del cabeceo es inverso al aumento de la resistencia. De las tres formas de casco ensayadas la más marinera fué la que tenía un abanico muy fuerte y una entrada muy aguda en la flotación.
- El balanceo era más violento cuando las olas llegaban a las formas de cascos ensayadas en ángulo de 15° a popa de la cuadra, (ángulo de popa de 75°).

SELF-PROPULSION and rolling tests were made, in regular waves, with models of a tuna longliner and fisheries training boat of approximately 370 GT. Four wave heights were used, the maximum being 0.072 LBP in order to test the validity of the linear relation between wave height and both ship motions and resistance increase. In the tests, thrust increase was actually measured. However, for the sake of simplicity the words "resistance increase" are sometimes used in this paper instead of "thrust increase".

Three pitching periods were chosen in testing the relation between thrust increase and pitching and heaving in waves. The relations between bow shape and seagoing qualities in waves were tested, one model with a Maier like bow form, and the other with a sharper waterline and a much increased flare. Investigations confirmed that, for the propeller performance in waves, the characteristics in smooth water can be used. So the results were analysed to find out the wake fraction factor and relative rotative efficiency.

The forced rolling angle was measured in regular waves approaching from six different directions while keeping forward speeds at zero. It is thought that the results of this investigation will be of value in both the study of fishing boats and of general ship form.

Methods and apparatus used in the experiments

The experiments were carried out in the larger tank, 41.01 ft. (12.5 m.) wide and 21.32 ft. (6.5 m.) deep—of the Mitsubishi Shipbuilding and Engineering Co. Ltd. (Allan, 1957). The ship models (scale $^1/_{16}$) were made of wood and lacquered, and equipped with bilge keels, rudder and fenders (starboard only). To simulate actual conditions as much as possible, the fore parts of the models—fo'csle, upper deck, bulwarks, hatches of fish holds, etc.—were similar in construction to those of the actual ship. Masts of steel pipe, 0.6 in. (16 mm.) diam. were set up at the bow and the stern as guides. To prevent the models from drifting, these masts were put between two piano wires fixed to the towing carriage. Ballast was adjusted to ensure that motions in full load conditions were similar to those of an actual ship. Displacement and trim were adjusted to a pre-determined value, and the height of the centre of gravity was checked by inclination test. The ballast was re-arranged so that the rolling and the pitching periods would be equal to the pre-determined values, giving the model a rolling or a pitching motion of small amplitude in smooth water. Table 118 shows the test conditions of the models and of the corresponding actual ship, but the value of the pitching period shown is the mean period of free pitching caused by pushing the bow or the stern of the model downward, so the effects of heaving may be included in these values.

Heaving periods were calculated from the difference between the heaving period obtained by pushing the bow downward and that obtained by pushing the stern downward, thus a high degree of accuracy cannot be assured. As a matter of fact, it is difficult to obtain accurate values of heaving and pitching periods, because of the large damping forces in these motions.

Wave lengths and heights were measured by an electric resistance recorder, which was fixed to the towing carriage at the forward quarter of the model. The actual wave length was determined by the period of encounter and the absolute speed. The value thus determined differed less than ± 0.3 per cent. throughout hundreds of measurements from that calculated on the basis of water level, amplitude and period of the wave-maker. The values of wave height, however, showed a variation of about ± 2 per cent. The values obtained from the wave recorder were used in analysing the results of the tests; the wave profile was regarded as a sine curve.

Thrust, torque, propeller r.p.m. etc. were measured by the Mitsubishi inductance type self-propulsion dynamometer (Taniguchi and Watanabe, 1956). The vertical accelerations of the bow and the stern and the longitudinal acceleration of the centre of gravity were measured by a strain gauge accelerometer and a penoscillograph. Pitching and rolling angles were measured by a small gyro-recorder with an inductance pick-up and by a penoscillograph. The natural period of the small gyro-recorder used as a pendulum was about 30 sec. Seaworthiness and ship motions in waves were recorded by a 16 mm. cine camera.

The sequence of tests was as follows: The wave maker was started and, when regular waves almost covered the whole length of the tank, the towing carriage was started. The model ran at the proper propeller speed, the towing carriage speed being adjusted to its mean speed. Necessary measurements were recorded during the adjustment run of about 160 to 260 ft. (50 to 80 m.). Electric wires connecting the model to the towing carriage were made as flexible as possible and arranged so as to have no influence on the motions of the model.

Fig. 489 shows the three hull forms. Table 118 gives the particulars. The after bodies of these models have the same form.

Confirmation of linearity

On the assumption that ship motions in regular waves can be expressed by linear differential equations of the second order, ship motions and resistance (thrust) increase in waves are given in the following equations.

Heaving: $Z/h_w = f(\Lambda_z, \lambda/L, v/\sqrt{gL})$ . . . (1)
Pitching: $\psi/\psi_m = f(\Lambda_p, \lambda/L, v/\sqrt{gL})$ . . . (2)
Thrust increase: $\Delta T/\rho g B h_w^2 = f(\Lambda, \lambda/L, v/\sqrt{gL})$. (3)

For the tuning factor Λ in the equation (3), both Λ_p and Λ_z should generally be considered, but it was found that only Λ_p has to be considered in this case. To confirm the validity of this linearity, the parent model No. 1234 was tested in four wave heights between 3.94 and 11.8 in. (10 and 30 cm.). On the assumption that thrust increase is proportional to the square of wave height h_w, the values of thrust increase thus obtained were recalculated for h_w=7.87 in. (20 cm.). In fig. 490, these recalculated values are plotted against the tuning factor for pitching, using the wave length/ship length ratio and speed as the parameters. The results for wave heights of 4.33 to 11.42 in. (11 to 29 cm.) are in good agreement with the results for the wave height of 7.87 in. (20 cm.), hence it is confirmed that the assumption of linearity holds good for practical use.

Pitching angles for various wave heights were analysed by using the equation (2) and plotted as shown in fig. 491. The plotted points fluctuated considerably, chiefly due to the inaccuracy of the pitching angle measurement; systematic errors could not be found. So the assumption of linearity is valid in this case, too.

At a wave height of 11.42 in. (29 cm.), the ship motions became so violent, especially at synchronism as shown in the photograph of fig. 492 that the water splashed over the fo'csle deck and fell on the deck when the bow was submerged. When the bow emerged, a considerable length of the fore part of the bottom could be seen. The assumption of linearity holds good in such an extreme condition.

Influence of pitching and heaving on thrust increase

The equation (3) can be re-written as follows:

$$\Delta K_t = \Delta T/\rho g B h_w^2 = f_1(\Lambda_p, \lambda/L, v/\sqrt{gL}) + f_2(\Lambda_z, \lambda/L, v/\sqrt{gL}) \qquad (3')$$

To see which of f_1 and f_2 in the equation (3′) has the greater influence, the parent model, No. 1234, was tested for three pitching periods, based on a period of an actual ship, and 20 per cent. larger and smaller. The thrust increase coefficients, $\Delta K_t = \Delta T/\rho g B h_w^2$, were calculated from these tests and plotted against Λ_p, in fig. 493. It can be seen that ΔK_t is influenced by Λ_p and λ/L only, independent of pitching period, when neglecting the small differences near 10 to 11 knots, which is also

TABLE 118

Particulars of models

		Ship		*Parent model M.1234*	*V-section bow M.1235*	*Flaring b[illegible] M.1236*
LBP × B × D	ft.	132.7 × 24.61 × 12.47		13.27 × 2.461 × 1.247		
	m.	40.45 × 7.50 × 3.80		4.045 × 0.7516 inc. skin × 0.380		
L	ft.	139.3		13.93	13.79	13.92
	m.	42.456		4.2456	4.2062	4.243[illegible]
T	ft.	10.15	in.	12.18	12.22	12.15
	m.	3.095	mm.	309.5	310.5	308.5
Displacement including appendages, ∇	ton	680.08	kg.	663.5	663.2	663.8
δ (naked)		0.7018		0.7018	0.6993	0.704[illegible]
Trim, aft	ft.	4.986	in.	5.984	5.984	5.984
	m.	1.52	mm.	152	152	152
Distance from water line to G	in.	7.716		0.7716	0.8268	0.7323
	mm.	196		19.6	21.0	18.6
LCB from FP in % of LBP		52.777		52.777	53.015	52.604
LCB above base line (KB)	ft.	5.741	in.	6.889	6.913	6.838
	m.	1.75	mm.	175	175.6	173.7
LCF from FP in % of LBP		54.63		54.63	54.43	5 4
Transverse metacentre above base line (KM_t)	ft.	12.14	in.	14.57	14.68	14.44
	m.	3.701	mm.	370.1	372.8	366.8
Longitudinal metacentre above base line (KM_l)	ft.	167.3		16.73	16.96	16.34
	m.	50.99		5.099	5.171	4.982
Metacentric height (GM)	in.	31.57		3.157	3.279	3.027
	mm.	802		80.2	83.3	76.9
Natural pitching period T_p	sec.	3.89		1.03 1.23 1.49	1.23	1.23
Natural rolling period T_r	sec.	6.24		1.973	1.956	2.099
Natural heaving period T_z	sec.	4.3		~1.36	~1.36	~1.36
Appendages:						
bilge keels, length × depth	ft. × in.	55.12 × 9.842			5.512 × 0.9842	
	m. × mm.	16.8 × 250			1.68 × 25	
rudder area/LBP.T		1/31.66			1/31.46	
Main engine (diesel)		650 BHP × 320 r.p.m.				
Propeller, diam. × pitch	ft.	6.299 × 4.035	in.		7.559 × 4.849	
	m.	1.92 × 1.23	mm.		192 × 123	

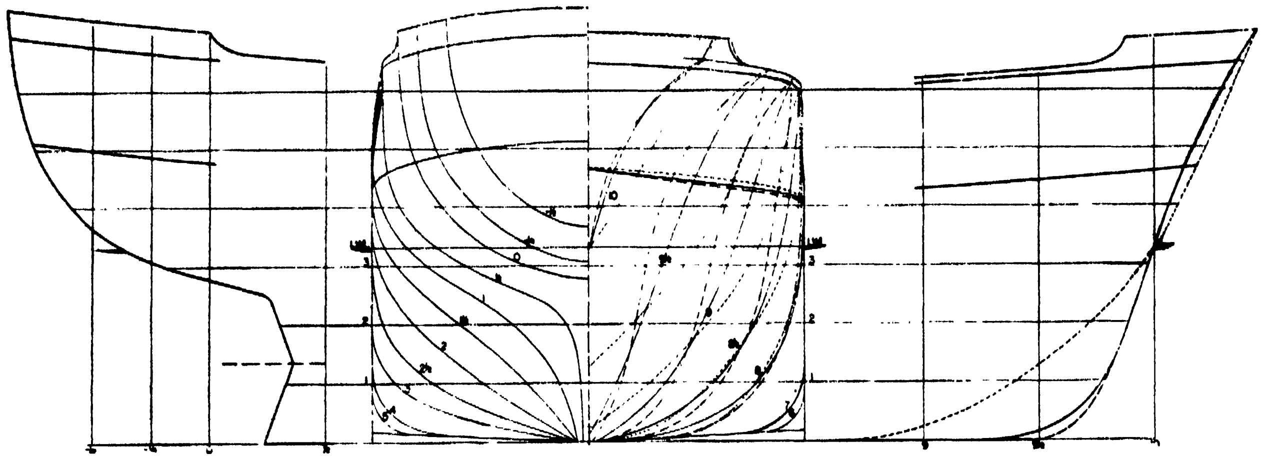


Fig. 489. A design of a tuna longliner and training vessel was tested with three different bows

found in fig. 491. If f_2 (as above) in the equation (3′) is considerably greater than f_1 (as above) synchronism must appear at $\Lambda_p = T_p/T_z$ when $\Lambda_z \sim 1$, i.e. $T_e \sim T_z$. As T_z is 1.36 sec., the peaks must appear at $\Lambda_p = 0.757$, 0.904 and 1.095 corresponding to $T_p = 1.03$, 1.23 and 1.49 sec., respectively. There are small "peaks" at $\lambda/L = 1.4$ and 1.7 corresponding to $T_p = 1.49$ and 1.23 sec. respectively, but these are not large enough to be taken into consideration. Therefore, it is assumed from this experiment, f_2 (as above) is much smaller than f_1 (as above), and, judging from fig. 493, the effect of $v/\sqrt{gL}$ is not great, so that for rough calculations (3′) may be taken as: $\Delta K_t = \Delta T/\rho g B h^2 \sim f_1'(\Lambda_p, \lambda/L)$.

Finally, it is concluded that, for the hull form used in this test, thrust increase is mostly determined by the tuning factor for pitching and the wave length to ship length ratio, and is not much influenced by heaving and ship speed.

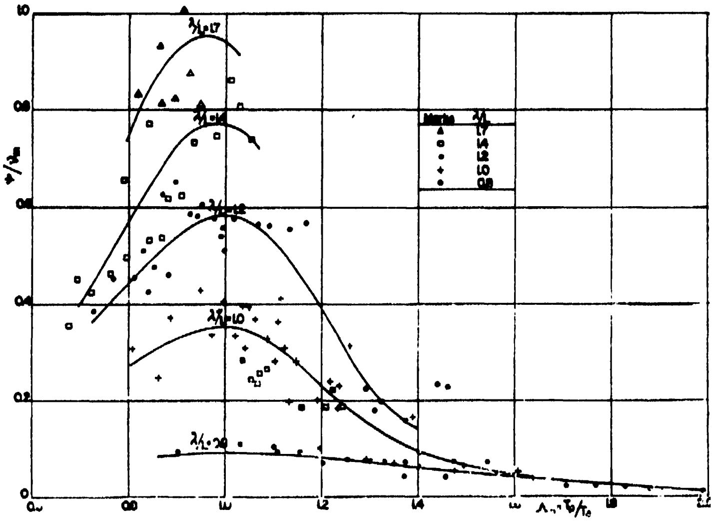


Fig. 491. Effect of tuning factor on pitch in regular waves

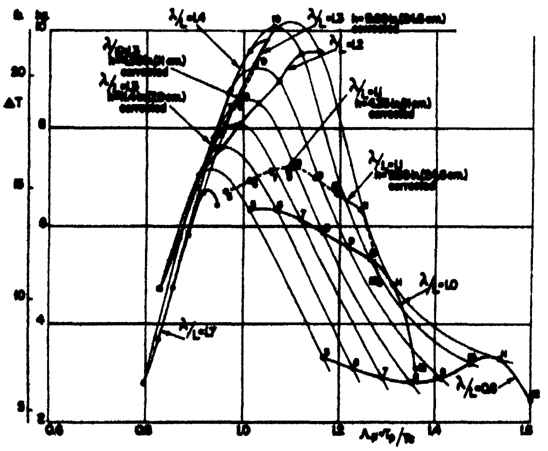


Fig. 490. Effect of tuning factor on thrust increase in regular waves on parent model, No. 1234, $T_p = 1.23$ sec.

——+—— *Original test 7.87 in. (20 cm.) wave height*

- - - - ɔ - - - - *Recalculated from 9.68 in. (24.6 cm.) wave height*

□ ,, ,, *4.33 in. (11.0 cm.) wave height*

■ ,, ,, *11.42 in. (29.0 cm.) wave height*

Wake fraction and relative rotative efficiency in waves

The characteristics of a propeller in waves, at a constant advance speed and r.p.m., can be regarded as quasi-steady when $\omega c/2U$ has such a low value as in the propulsion of a ship in waves ($\sim$0.02). Therefore, it is assumed from the aerofoil theory for non-uniform motion, that the mean characteristics in waves are identical with those in smooth water, as confirmed by experiment, and the effective wake factor, relative rotative efficiency, etc. were obtained from the thrust, the torque, the number of revolutions and the mean advance speed in waves using the open characteristics in calm water.

Fig. 494 shows the results of an analysis of about 200 self-propulsion tests on the parent model, No. 1234. The values of relative rotative efficiency are distributed in a narrow zone in the neighbourhood of unity; none of them passes over the 1.00 ± 0.08 lines and most of them lie between 1.015 ± 0.035. They should be regarded as

Fig. 492. Parent model, M-1234, at synchronism

close to unity rather than to the curve of the smooth water tests. The mean flow behind the ship in waves resembles the flow in open-water condition, because it is disturbed when the ship pitches.

The values of the wake fraction can be considered as lying near the smooth water values, except in the low speed range. When the speed is over 7 knots, most values are distributed in a zone ± 0.05 from the smooth water values. For the lower speed range, the scattered distribution of the wake fraction (Taylor), w_t, is not considered to be due to the inaccuracy of measurement, because the values of relative rotative efficiency, η_r, are not scattered. Considering that the ship speed is nearly equal to the orbital velocity of waves, the difference could be explained that the relation between the mean ship's speed and the relative velocity near the propeller varies to a large extent.

Thrust increase in waves amounts to 15 times the thrust in smooth water in a range of low ship's speed. No relationship is seen between this thrust increase and the scattered values of w_t and η_r.

From the foregoing it may be concluded, for all practical purposes, that w_t in waves is the same as in smooth water and η_r is unity. This conclusion simplifies the analysis in waves, and, if the propeller characteristics in smooth water and the thrust increase coefficient curves as shown in fig. 493 are known, the power and the number of revolutions in any given regular waves can be easily estimated. For irregular waves, mean thrust or mean power increase can be estimated by the method used in dealing with ship motions, if the energy spectrum of waves is given (Taniguchi and Iizuka, 1958).

Effects of bow section form

No. 1234 was the parent model; the forebody of No. 1235 had a V-shape, like a Maier form, and that of No. 1236 had an increased flare with a sharp entrance at the waterline. The aft bodies of all three vessels were unchanged. The comparison of the pitching angles is presented in fig. 495, and that of the thrust increase coefficients in fig. 496. The difference due to the bow is not so remarkable as is expected. The conclusion is that

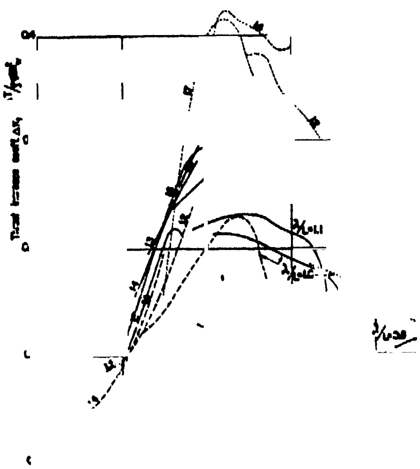


Fig. 493. Thrust increase coefficient in regular waves (M-1234)

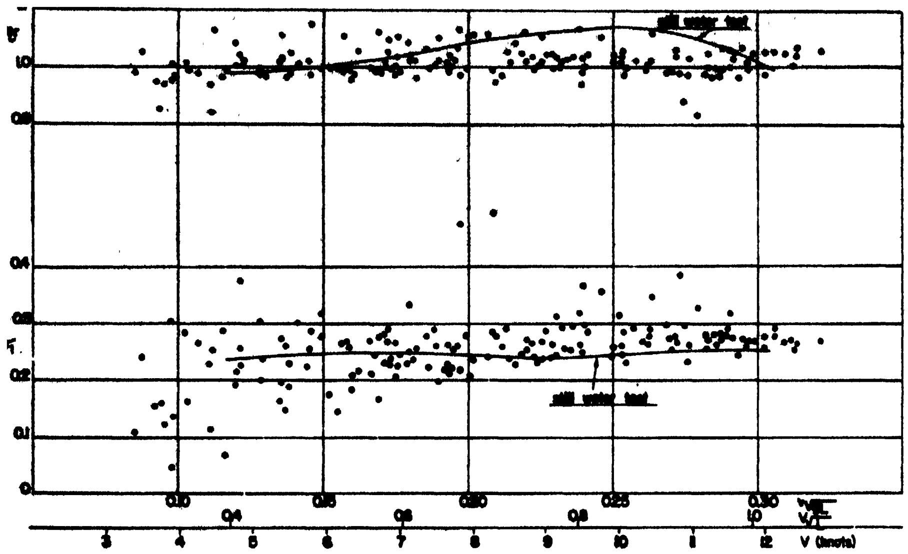


Fig. 494. Wake fraction and relative rotative efficiency in regular waves (M-1234)

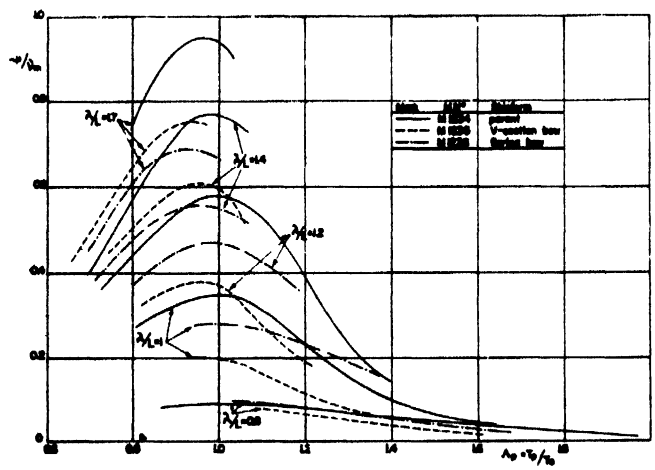


Fig. 495. Comparison of pitching amplitude where differences in bow sections have only small effect

the bow does not have much influence on the performance of a ship in head seas. The smallest pitching angles correspond to the largest thrust increases. No bow had both small pitching angles and thrust increases. If one of the three bows is to be chosen, the sharper of model No. 1236 is considered best.

Rolling due to the waves coming from any direction

Rolling tests are usually made with waves from abeam, but this does not ensure that the rolling angle reaches maximum. The following tests were, therefore, carried out.

The model was set to meet waves from several directions, the wave slope being kept constant at 6°. The angle between the ship and the waves was kept constant, the ship was allowed to drift freely with the waves. Fig. 497 shows the synchronous rolling angle due to the waves coming from each direction. Judging from this figure, rolling is most violent when the waves approach the hull from 15° abaft the beam (75° from the stern). The broken line in fig. 497 shows the values when the centre of gravity was lowered by 0.72 in. (18.2 mm.).

As many fishing boats are overturned by waves from abaft the beam, there is a need, as this result indicates, to investigate the problem further.

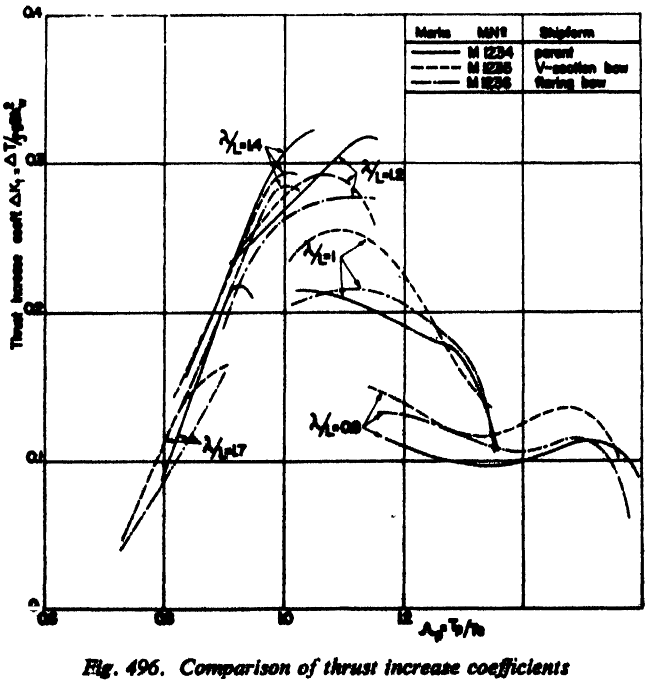


Fig. 496. Comparison of thrust increase coefficients

Conclusions

- Ship motions in waves are in proportion to the wave height and the thrust increase is in proportion to the square of wave height. For all practical purposes the problem in waves can be treated on the assumption of linearity.
- For the hull forms tested, the thrust increase in waves is determined chiefly by the tuning factor for pitching and by the wave length/ship length ratio, but very little by heaving and ship speed
- The mean wake fraction in waves can be assumed to be the same as in still water, and the relative rotative efficiency can be regarded as unity
- The effects of the variation of the bow are not very noticeable. The magnitude of pitching is contrary to that of thrust increase. Of the three bows tested, that having a flare and a sharp entrance at the waterline is the most seakindly
- Rolling is most violent when the waves approach the hull forms tested from 15° abaft the beam (that is 75° from the stern).

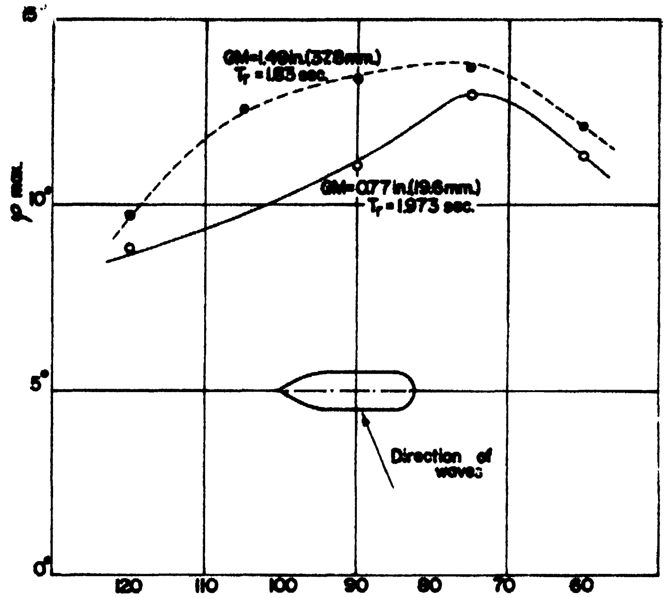


Fig. 497. Relationship between direction of waves and maximum angle of roll. M-1234. Wave slope = 6°

COMMENTS ON HULL DESIGN OF FISHING BOATS

by

H. I. CHAPELLE

For over 200 years the accepted approach to almost all problems in ship design has been through mathematics, and this has established in the minds of designers that apparent facts are less acceptable than a mathematical formula.

The trouble in the mathematical analysis up till now has been that there were many qualities that could not be measured, and the mathematical treatment had to be supported by approximations and assumptions which resulted sometimes in over-simplification, as in the case of resistance.

There are also certain forces not readily duplicated in model tests and trials, and which therefore naturally have not been explored, as in the case of seakindliness.

The intention is not to devaluate the mathematical approach, but to focus attention on the possibility that the optimum hull form for fishing boats could be a field for scientific study similar to that which the hull form of large ships has received. Too often fishing boat designers use rule-of-thumb, "art" and personal opinion, without much aid from mathematics or comparative and realistic model testing—in fact without well-formulated theories.

COMMENTAIRES SUR LA FORME DE COQUE DES NAVIRES DE PÊCHE

Depuis plus de 200 ans, il est admis d'employer les mathématiques pour résoudre presque tous les problèmes se présentant dans le dessin des navires, et cela a mis dans l'esprit des architectes navals que des faits apparents sont moins acceptables qu'une formule mathématique.

Jusqu'à présent, l'ennui dans l'analyse mathématique a été que beaucoup de qualités ne pouvaient pas être mesurées, et le traitement mathématique devait être appuyé sur des approximations et des suppositions qui amenaient parfois à une simplification trop grande, comme dans le cas de la résistance.

Il existe aussi certaines forces qui ne sont pas reproduites facilement dans les essais de modèles et les essais réels, et qui, ainsi, n'ont pas été explorées, comme dans le cas de la tenue à la mer.

L'intention n'est pas de dévaluer la méthode mathématique mais de concentrer l'attention sur le fait que la forme optimum de coque pour les navires de pêche pourrait constituer un domaine pour une étude scientifique similaire à celle dont la forme de coque des grands navires a fait l'objet. Ceux qui dessinent des navires de pêche actuellement utilisent trop l'empirisme, "l'art" et leurs opinions personnelles sans s'aider beaucoup des mathématiques ou d'essais de modèles comparés et réalistes—en fait, sans des théories bien formulées.

COMENTARIOS SOBRE LA FORMA DEL CASCO DE BARCOS DE PESCA

Desde hace más de 200 años ha sido normal enfocar casi todos los problemas de la construcción de barcos desde el punto de vista de las matemáticas, lo que ha creado entre los proyectistas la impresión de que las realidades aparentes son menos aceptables que las fórmulas matemáticas.

Hasta ahora la dificultad encontrada por el análisis matemático es que hay muchos factores que no se pueden medir, por lo que el tratamiento matemático ha tenido que apoyarse en la aproximación y la suposición, con el resultado de que en ocasiones ha habido una excesiva simplificación, como en el caso de la resistencia.

Existen también ciertas fuerzas muy difíciles de repetir en los ensayos y pruebas de modelo que no se han explorado, como en el case de la navegabilidad.

No se trata de restarle méritos al enfoque matemático, sino de destacar la posibilidad de que la forma óptima de los cascos de los pesqueros podría ser un terreno para la investigación científica análogo al que presenta la forma de los cascos de los barcos mayores. Los proyectistas de barcos de pesca recurren en demasía al empirismo, el "arte" y la opinión personal sin buscar la ayuda de las matemáticas o de los ensayos de modelos comparativos realistas, en fin, sin teorías bien formuladas.

FOR over 200 years the accepted approach to almost all problems in boat and ship design has been through mathematics. This has seemed to be the method by which the greatest precision in results might be obtained. So firmly has this approach been established in the minds of investigators that statements of apparent fact, with the necessary qualifications, are less acceptable than a mathematical formula. Nevertheless, there are areas where statements of apparent fact are more effective than any attempt at numerical valuation.

Now that a great deal of mathematical investigation data of problems in design have been accumulated, certain facts concerning this approach might well be stated. The basic one is that there are many qualities that have not been measured precisely, for good and sufficient reasons, and so the mathematical attack is supported by many approximations and assumptions that are far from precise. This has been the case in the long study of resistance, for example. The difficulties in measuring with precision the various factors making up hull resistance are too well known to all concerned with ship and boat design to require enumeration here.

The chief difficulty in placing precise numerical values on hull design elements is that few of these are unaffected, individually, by other elements. Thus, the numerical valuation may be based on an oversimplification of a problem. This produces an unsatisfactory result when the numerical value is applied in practical design, in which overlapping effects actually exist. This is one of the reasons for the difficulties in resistance measurements.

Another difficulty is that there are certain elements in the design problem that are the result of forces not readily duplicated in test conditions and which therefore are not well explored to date. The establishment of useful seakindliness factors in design seems to be an example of this.

Resistance and seakindliness are such important elements that success in design depends to a very great degree upon how well they are understood. If there is the slightest doubt as to the accuracy of the mathematical attack on these problems, it is necessary that some other approach be accepted for investigation.

RESISTANCE

That there are doubts as to the precision of certain mathematical approaches can be illustrated. For example the widespread reliance upon the prismatic coefficient as a practical guide to the value of resistance at the hull design stage might be referred to. The extreme view has, repeatedly been expressed that this single coefficient is for practical purposes, sufficient indication of the resistance factor in a design. However, model tests and actual trials have shown that for a given prismatic there may be quite a variation in actual resistance (Nevitt, 1956). It is usual to excuse this failure of prismatic coefficient by reference to "good or poor" hull design. How, then, can we attain knowledge of "good or poor" hull design so that we may have greater precision in results? Certainly, we all recognize that the prismatic coefficient is very useful but we must also accept the fact that the use of the optimum prismatic does not necessarily produce a hull design of the lowest resistance for this given prismatic range. It seems apparent that small prismatic variation is not indicative of a measurable difference in resistance in all cases.

The drawing-board attack upon this particular problem has not been a popular one among theorists. One investigator went so far as to express doubt that any manipulation in the lines drawing had appreciable influence on resistance; another thought a successful lines plan was firmly established by a few calculations on the back of an envelope. Few, if any, practical designers would accept such extreme views. However, it is fair to say that analysis of the lines plan, in basic design, is relatively neglected. Indeed, it has been rare to see anything in print on this particular subject. This field is that usually referred to as the "art" of design. The author considers this to be true only so long as the hull form is not examined as such, independent of other factors. Art should be a matter of beauty; a good hull form may or may not be "beautiful", depending upon hull requirements and the taste of the observer, or upon the artistic sense of the designer.

In regard to the comments that follow, it is necessary first to state that each of these is an opinion. They are offered to start discussion and, if possible, to raise questions that should be answered by testing of competitive models and full-size craft. The opinions are based on a long study of successful designs and upon practical experience, but without the opportunity for measured model tests. Hence they are no more than hypotheses and must be considered as such for the present.

Having determined, in the usual manner, the prismatic proposed in a design, its possible effects on the hull form can be considered. There seems to be a very strong possibility that the value of the prismatic is affected, so far as a precise indication of resistance is concerned, by the hull proportions intended or required in a design.

Length-depth ratio

Length-depth ratio seems particularly important. In a deep hull, such as that of an American wooden trawler, the length-depth ratio affects the steepness of the run and the camber of the bow and buttock lines. Simply stated, the proposition here is that the amount of camber in the buttock and bow lines has a definite relation to wave-making; the greater the camber, the greater the resistance in the higher speed-length ratios. Such a hull form, particularly with a large midship section, produces great camber when designed to a low prismatic; we have here a partial explanation of the apparent rise in optimum prismatic value for fast boats. The effect of wave-making caused in the very deep, fine-ended hull has been stated by Traung (1948) for fishing craft and Roach (1954) for tugs.

On the other hand, a length-depth ratio that appears in a shoal-bodied hull produces little or moderate camber in the buttock and bow lines and such a model can usually be driven without excessive wave-making at high speed-length ratios. However, the optimum prismatic may be high. This will normally result if a deliberate attempt is made to reduce buttock and bow line camber to a practical minimum, particularly at the stern. The latter, in a fast power-boat, becomes immersed in this case; therefore, the higher optimum prismatic becomes the logical result. It should be noted that the general assumption that fixed values of the prismatic are indications of suitability for certain speed-length ratios is thus brought into doubt, unless it is first determined that the hull proportions are in keeping with the prismatic.

Length-beam ratio

The length-beam ratio may also have a bearing on hull form design. One method of obtaining a desired prismatic is to employ relatively great beam, combined with fine entrance and run. Here again, objectionable wave-making resistance may result. In a beamy fishing boat hull, the entrance angle may prove excessive; if a hollow entrance is used, objectionable shoulders may appear a little forward of the midship section which will create wave-making resistance in the higher speed-length ratios, that is if the entrance is not abnormally long. In the wide shoal-bodied hull, the run can usually be formed with slight camber in the buttocks, but the midsection shape and the beam may sometimes produce heavy quarters, with excessive fullness in the waterline below, which create marked quarter waves in some instances, though this can usually be readily corrected by small changes in the aftermost sections or in the stern form. This matter arises most often when the displacement is relatively heavy.

Proportions are often imposed upon the designer by practical requirements of service. Hence the inherent restrictions on form and prismatic may not always be altered on grounds of low-resistance. With unsuitable proportions for high speed, neither optimum prismatic nor manipulation of form can produce the most efficient model for any appropriate speed-length ratio. This is a fact too often overlooked in prophesies of the speed of future fishing boats, of some types at least, where hull proportions cannot be changed very much.

Midship section

The form of the midship section is also a matter for careful consideration in design, although the size of the midship section may be fairly well fixed by service requirements. Generally speaking, the length-depth ratio should have a considerable influence on midship section form. Where the speed is to be high for a given length-depth ratio, the use of deadrise, or deadrise-and-hollow-garboards, is indicated: such a form makes relatively low-cambered buttocks and bow lines possible. In deep fishing boat hulls, deadrise in the midship section is thus vital if a very low-resistant form is desired. The necessary displacement can be retained by the judicious addition of beam; in design, this is the most practical dimension to be varied without running foul of service or cost limitations.

The position of the midship section in the waterline length is another factor of importance. Obviously, its position—as well as its form and area—may impose limitations on the length of run and the rise of the buttocks there; which is a matter of great concern, particularly in deep-bodied hulls requiring low resistance or high propulsive efficiency. Tugs and trawlers are examples. Likewise, the position of the midship section not only establishes the length of entrance but also, to a marked degree, the angle of entrance. This, of course, becomes most critical in a wide hull with a large midship section. The area of the midship section and its position, combined with the half-breadth form of the sheer or deck line, may restrict freedom in the design of the ends, in wide hulls particularly. The location of the midship section is not always the optimum, for weight distribution may control its position.

Before proceeding with the discussion of the details and analysis of hull form, the method employed to design to pre-determined hull form characteristics should be described. In general, the method of beginning a lines drawing established by Dixon Kemp (1875) seems very convenient and rapid. With the hull proportions established and the position and shape of the midship section known, the profile of the hull and half-breadth of deck are drawn. Next, the midship section form is designed. Then, in the half-breadth elevation, the shape of the forebody waterline is arbitrarily decided. In the sheer elevation, the quarter beam buttock profile is also arbitrarily established. The rabbet elevation and half-breadth are next drawn on sheer and half-breadth plans. Thus, for all sections in fore and afterbody, three control points are established through which each section outline must pass. These sections are sketched in with due regard to the form characteristics the designer has in view. At this stage, preliminary calculations of sufficient precision to establish control are possible before much labour is expended in fairing up the lines. If the calculations, or the examination of the sketched-in sections, do not produce the desired results, the designer can correct his control lines or manipulate the forms of the sketched sections, without wasted time and effort in useless drawing.

Shape of stern

These are only the initial considerations in hull form design. The selection of the suitable shapes for control lines requires some comment. Take the sheer elevation: the form chosen for the stern will have much influence on the shape of the afterbody. The "lifeboat" stern is generally unfitted for motor craft of high speed-length ratios, for the propeller cannot be so well "hooded", in the extreme afterbody, that air is not drawn in to the propeller at speed. Likewise, this stern will usually produce too round a run of the buttocks to permit any but a low speed-length ratio. The advantages of the canoe, or "cruiser" stern, over the counter of the tug-boat "fantail" have been the subject for discussion in the past, and opinion is that the canoe stern is the better for the higher speed-length ratios. This is probably true only because the canoe or cruiser stern, properly formed, allows the buttocks to be shaped with less camber as the stern is approached, compared with the usual high-tucked counter, or the round "fantail" of the tug and of some U.S. trawlers. The advantage of the cruiser stern would certainly be lost to some extent if compared with transom stern craft, which can have a longer run and can keep the buttock ends low and very near to the loadline. However, for high speed ratios, say above 1.2, the cruiser or canoe stern must be very full at deck or sheer in plan, and very flat in section, to give passable results—in general, the transom "square" stern, with bottom slightly immersed, gives better results. Here, again, a better run for relatively high speed, such as is now expected of small fishing craft, can be had with the square transom due to the inherent buttock form that is possible with this stern form alone.

Position of propeller

The position of the propeller is a considerable factor in the design of the stern. It seems to be generally accepted that the wheel should be well under the boat and forward of the after extremity of the loadline. "Hooding" the propeller, by carrying the inner buttocks out, say, to the quarter-beam, well abaft the wheel, is undoubtedly desirable in a fast boat. This matter is therefore of importance in the design of the stern form and, in planked-up stern deadwood hulls, in the form of the run inboard of the quarter-beam and must be considered early in design.

Bow profile

The bow profile is of relatively little importance in low-resistance design, except that the rather excessive rake, or cutting away of the forefoot, may shorten the effective length of entrance and thus increase the angle of entrance to no good purpose. The design logic of the extreme bow rake. so often seen in modern fishing boats is questionable both in the elements of resistance and seakindliness.

Sheer elevation

It can be seen that hull profile may limit design freedom as the hull form is developed. For that reason alone, it should be carefully considered in the early stages of hull design and not looked upon merely as a matter of appearance. Indeed, the establishment of the sheer elevation in the early stages of design should be tentative. Too often designers are inclined to establish the sheer elevation by temporarily fashionable criteria rather than by functional requirements, even in fishing craft.

Drag and length of keel

Drag and length of keel are also matters for careful examination. Designers of the older generation are inclined to be influenced by sailing hull elements of design. In power boats, a short keel may produce a hull that is unsteady on its helm, and cut-away ends may also produce this result.

Width of stern

Commonsense treatment of the deck or sheer in the half-breadth plan merely requires sufficient fullness forward to give a pleasing bow section. Aft, the width of the stern is obviously a matter of moment, depending upon the form of stern used, and the speed-length ratio required. Fast boats, unless very long and narrow, require a fairly wide stern, say, at least five-eighths the maximum beam; and the higher the speed-length ratio demanded, the wider the stern. The maximum is reached in some planing hulls and in the so-called "double-wedge" displacement models where the stern width may exceed the midship beam at waterline at least. Such extremes are not usually desirable in fishing boats.

Quarter-beam buttock profile

With the sheer elevation and midship section tentatively established, the form of the quarter-beam buttock profile can be considered. The position of the midship section will determine the length of the run, although the stern form, of course, will also be a factor. Kemp (1875) seems to have been the first writer to have considered this subject; he analyzed a number of fast English yachts and came to the conclusion that the quarter-beam buttock should take the form of half a parabola. In keeping with the fashion for mathematical valuation, he proposed a mathematical construction of the buttock profile. No proof was given, however, that such construction had special advantages. The camber of the buttock is fixed, obviously, by the depth at which it must intercept the midship section, and the height aft it must attain, to fair into the stern form. It is true that most fast boats of a given type, whether shoal or deep, show quarter-beam buttock profile characteristics that verify Kemp's report. However, the form is not a mathematical parabola, and in fact, there is much variation even in craft of comparable size and type. In general, this buttock becomes straight in profile as it goes aft; often it is dead straight as it crosses the load line in a counter or cruiser stern hull, or is straight before it reaches a "square" stern transom. In very fast shoal hulls of the launch type, the buttocks are often straight lines for about three-quarters of the total length of the run. Hence, the assumption might be made that the faster the hull is to be, the longer the straight-line part of the quarter-beam buttock. However, no determination has yet been attempted to show the relationships between the necessary lengths of straight buttocks for various speed-length ratios, and for the related length-depth proportions. Observation does suggest that straightness may have been carried needlessly far forward, giving an exaggerated flatness of run, in some fast hulls. The use of the straight-line buttock at the extreme stern, or where it crosses the loadline, appears to produce a much less disturbed wake than when the quarter-beam buttock is a continuous curve from midship section to stern or waterline intersection in any speed-length ratio above 1.0.

Thickness of stern deadwood

The thickness of the stern deadwood, if planked up, is apparently governed by speed-length ratio. In the lower ratios, up to about 1.0, the deadwood can be carried quite full, as long as it will fair into the sternpost easily. The result is that buttocks close to the hull centreline, inboard the quarter-beam, may take a reverse-curve profile. This is done in small trawlers to allow the engine to be placed as far aft as is possible, while retaining a good buttock at quarter-beam. In fast boats the skeg is usually thin, which, of course, is desirable for the propulsive efficiency that is then required. Towing power seems to require about the same stern design as low-resistance in this respect.

The curved quarter-beam buttock, carried rounded to the stern, is not seen in very low-resistant hulls. Reverse curve in the quarter-beam buttocks is very rarely seen in such hulls and appears only when the buttock crosses the load line straight and reverses above in the topside, as in some steamers. Reverse in the buttock, submerged, seems to have some disadvantage, so far as resistance is concerned, but may be useful in obtaining propulsive efficiency in some cases. The author has had only limited experience with this form; it evidently requires very gentle curves, connected to form reverse by a straight line for at least a short distance. If the camber in the profile of the buttock-bow-line is great, reverse is rarely desirable at the quarter-beam, below the loadline, so far as resistance is concerned, or where maximum tow-rope pull is desirable.

Entrance angle

A good deal of study has been given to the problem of the entrance angle and to the shape of the loadline. In practical design, these matters really depend more upon the length of entrance, beam-length ratio, and the desired position of the centre of buoyancy light and loaded, than upon optimum entrance angle and free design of the loadline shape. Obviously, the entrance angle should be as small as is practical for the given length of entrance. Hollow is rarely useful for it will usually produce shoulders, even though the entrance angle can thus be reduced. Hollow below the loadline at forefoot is common in low-resistant hulls, the emphasis on hollow depending upon how pronounced the forefoot is in the bow profile. While too large an entrance angle produces excessive bow wave, a shoulder at the end of the entrance will produce an even more objectionable wave formation in most fishing boat types. A hollow entrance should be considered only in a relatively narrow hull, say, under four beams to the length, where the entrance is longer than three-eighths the loadline length. In such a hull the shoulders can usually be worked out in fairing.

Manipulation of the position of the longitudinal centre of buoyancy in the design of the entrance need not be confined to alteration of the length and fullness of the load line. It can also be accomplished by increase and decrease of keel drag at rabbet, which will allow maintenance of a selected angle of entrance in many instances.

Loadline

In fishing boats, the loadline can usually best be formed by a straight line at the forward extremity, established at the desired angle of entrance. The reason for this is that the usual available length of entrance in these craft in relation to beam is not sufficient to permit a hollow form there, without marked shoulders developing further aft in the forebody. The straightness of the loadline can often be carried well aft, without shoulders appearing, unless the beam is large. However, the establishment of the entrance characteristics of the loadline should be tentative until the possible existence of shoulders is explored. At the speeds reached by most motor fishing boats of even the higher displacement-length ratios, a minimum of shoulder seems desirable. The appearance of shoulder in the loadline, and immediately above and below it, must be guarded against. The V-bottom, with high chine forward, is a very common offender.

It is quite easy to state what should be done in this instance but difficult to effect. It is here, as in the quarter-beam buttock design, that the initial effects of the hull proportions are brought home to the designer.

In following the Kemp method of drawing lines, the loadline in the afterbody and the quarter-beam bow-line in the forebody are not projected until the whole body plan is sketched in, or, at least, until the control sections are established. However, the designer might sketch a tentative afterbody loadline and a quarter-beam bow-line to guide in the formation of the body plan, particularly when he is well acquainted with the hull form type.

Therefore, some comments on the form of these lines are necessary. As to the profile shape of the quarter-beam bow-line in craft of the size and speed-length ratios of fishing boats, the buttock aft should merge into the bow-line in a rather long and easy sweep through the midbody and continue, as the bow-line, in a rather slack and easy curve to the height of the loadline, above which it may reverse somewhat, or run rakingly straight and forward to the sheer, as required by the intended flare in the bow sections. Hard curves in this bow-line, below the loadline, are unfavourable to speed in the usual size of boat under discussion. In passing, the form of bow-line profile recommended is also favourable to a seakindly hull form. It should be emphasized that the establishment of the quarter-beam bow-line, before the body plan is sketched in, produces only a tentative form, subject to some modification as the design progresses, particularly in final decisions as the waterline and the whole entrance.

Likewise, the tentative form of the loadline in the afterbody can be run in. Only very general comment can be given on the form to be developed. In fast and shallow-bodied hulls the loadline will usually hump sharply at the quarters, except in the case of most "square" transom-sterned hulls, with the bottom of the transom immersed. Here the loadline may run in a gentle curve through the quarters to end abruptly and "square" at the transom edge. In heavy displacement hulls, a sharp hump in the loadline at the quarters, combined with heavy buttock camber, is not usually favourable to a low resistance, and the hump should be made as moderate as the hull proportions and stern form permit, as has already been proposed.

Of necessity, comments on the forms of these lines cannot be extremely specific since there is an infinite variation in proportions and hull form involved. The author has rarely employed diagonals, as tentative control lines, in the initial stages of design because their form is controlled to a very great extent by their angle to the body plan centreline. However, a diagonal through the tuck-in of a planked-up stern deadwood is sometimes revealing to the designer when the after end is correctly projected (a task some designers avoid). Extreme fullness between the last station and the stern post, in this diagonal, is to be avoided.

Warp of plane

In sketching the sections afore and abaft the midship section, prior to final fairing of the lines, it is useful to examine carefully the relation of the sections, one to another. Take that portion of the deadrise of the midship section that is a straight line and consider this as a plane. Now, this plane must be carried fore and aft. At the stem, the plane will be narrow and vertical. It bends and warps as it approaches the midship section. It may continue to bend and warp in the same direction, as the stern is approached, becoming horizontal or nearly so in a fast displacement launch.

This constant warp can be seen in the bottom of many V-bottom launches. If a round-bottom hull section is drawn by a series of straight lines, a number of these warped planes are developed. Hence, in the so-called "simplified hull" designs, these warped planes are the result of section forms.

In some designs, the deadrise plane is warped very gently to the midship section and is then carried to the stern as an unwarped plane. In other words, the run is formed with sections having the same angle of deadrise right to the stern. This is seen in some fast V-bottom launches. In one type of V-bottom hull, without forefoot, in which the chine and keel rabbet in profile meet at the heel of the stem (this type is sometimes called a "modified sharpie"), the deadrise angle may be constant or nearly so in all sections, from stem to stern. In trawlers, and some steamers, the deadrise plane may show a double warp in the run; the deadrise plane amidships is first warped to allow increased angle of deadrise aft, and then the warp is slightly reversed well forward of the stern. Another variation is to have the deadrise plane warp toward the vertical so that the plane is first warped from the vertical forward to the deadrise amidships and then back again to the vertical in the run. Treatment of this plane, and of all planes in a simplified hull form, can be based upon a simple assumption that was once well expressed by the late Charles Nicholson, the noted British yacht designer: "Water does not like to be surprised". Apparently its distaste for surprise increases rapidly with the speed it moves. It is this last that makes the warp of the planes an important matter in design. This is another case in which it is easy to say what should be done: the warping should be very gradual and easy, but in actual design it is often abrupt by reasons inherent in the hull proportions. At any rate, the abruptness and direction of the warp seem to be a very important factor in the design of low-resistant fishing boat hulls.

A very gentle warp, with a gradual and constant increase from bow to stern, or the maintenance of constant angle of deadrise plane for the length of the run, or even for the whole length of the hull when possible, are all favourable to low resistance. Abrupt warping, or reversing the direction of the warp in the run, seem to be unfavourable to low resistance, judging by the study of hulls of known performance. These elements are, of course, of decreasing importance as speed is lowered, but in fishing boats, where the required speed is very high, these elements may be very important indeed to successful design.

The good results obtained in some simplified hull form models can be traced more to proper treatment of the warped planes in their hull form rather than to favourable prismatics or other factors. There seems to be a field for experimentation to determine the proper warping of these planes for given speed-length ratios, though probably great difficulties will arise in establishing even approximate numerical values.

The warped planes idea seems to apply with particular force to chine-built hulls, whether rectangular, V-bottom or "simplified hull form" type. A great many practising designers, who have had much experience with these models, are aware of what has been discussed. However, these matters are rarely considered in round-bottom hull design. The warping of the planes in such a design is far less obvious than in the "simplified hull form" or the V-bottom design.

With respect to "simplified hull form", as compared to V-bottom, it is probably safe to say the latter has the advantage in the higher speed-length ratios, as planing speeds are approached. However, if fore and aft camber in the chines, in profile, can be brought low, the V-bottom may compare favourably with the "simplified hull form" in the lower speed-length ratios. This is another matter that requires more examination than has yet been given to V-bottom hulls. It is the author's opinion, however, that water flow is controlled more by the "warped planes" than by coefficients or even by the use of chines of special form.

The use of chines in round-bottom hull forms is nothing new, for chines in the afterbody were employed in many high-speed steam yachts at the turn of the century and long before chines were employed in naval vessels of high speed. The chines were employed at the extreme afterbody to produce the "built-in squat-boards" or supporting plane areas over the propellers and abaft them to reduce squatting of a fine-lined afterbody. The use of chines in the afterbody might be useful in the design of fast fishing launches and in fishing boats requiring speed-length ratios above 1.3, where rough water performance is also a factor in design. In the design of this stern, the use of continuous warp from bow to stern seems to be desirable. The use of chines in the run has generally been confined to narrow hulls and little information is available on the performance of beamy hulls with this run.

Chine form forward and round bottom aft has been tried in spite of the very obvious lack of design logic in the idea. In all cases, the results were disappointing so far as speed was concerned for, as one might expect, squatting developed.

The use of increased width of the warped plane, as the stern is approached, is an obvious manipulation in high-speed hull design. This actually develops in the so-called "double-wedge" displacement hull, as well as in planing models, as a logical treatment of the run. It can often be utilized in less extreme hull forms where the possibility of squatting exists. In fact, it could be used in the cruiser stern, although it will cause slapping under the stern in any sea.

Shape of forebody section

There are other factors in hull form than the warped planes. The use of V- or U-shaped forebody sections has received attention so far as large vessels are concerned, with relation to both resistance and rough water performance. Less attention has been given to small craft in this matter. In general, small fishing boats seem to trend toward the use of V-sections, for with their relatively shoal forebodies the U-shape produces slamming and wetness. This will be true with the bulbous bow in small craft, but the latter is usually impractical in such boats due to their common lack of length and hollow in the entrance. There is not space here to discuss many other factors in hull form design: these are, however, of somewhat less importance, in the matter of resistance at least.

SEAWORTHINESS AND SEAKINDLINESS

The effect of hull form on seaworthiness and seakindliness is very important. These qualities depend upon distribution of weight and displacement, combined with proper hull proportions and hull form.

Length-depth ratio and length-beam ratio

It is generally true that the most seakindly fishing boats are those in which no one dimension is carried to an extreme in relation to the others. The norm appears to be somewhere around three to five beams to the length, and the draught one-quarter to one-half of the beam. Also, the more seakindly boats have trim by the stern, on the keel shoe at least, so that they draw more at the stern post than at the stem. This is an absolute requirement to prevent a tendency to broach in a following sea. No set proportions exist but the wider or more buoyant the stern form, the greater the drag of the keel bottom or skeg should be. The author has added to the drag of the skeg on some wide, "square" sterned motor cruisers and found that this stopped tendencies to broach, in spite of an unfavourable stern form.

The sharp or cruiser stern has no inherent advantage over the square transom stern or the counter, so far as rough water performance is concerned. The good qualities of any stern are less a matter of inherent design qualities. The choice in fishing boat design is usually a matter of prejudice and personal opinion.

Bow profile

The bow profile is of very limited influence on seakindliness in fishing boats. Generally, overhang bows are of little value in power boats, for in a head sea such bows throw spray. A straight, nearly upright stem, with good depth of forefoot and a fine entrance, produces a dry bow.

The clipper profile now seen in many fishing boats has no inherent advantage, except that it may make plating or planking the bow through the flared sections a little easier than with the straight stem rabbet or profile. A much rounded forefoot is of no real value insofar as seakindliness is concerned. It is usually justified on grounds of its usefulness in quick turning. However, with good drag to the keel, and a rudder of proper area, located as far aft as is practical, a hull with a rather deep and angular forefoot will steer very well. That is the author's experience, at least, and contrary to much professional opinion.

Shape of forebody section

Dryness in a head sea is accomplished by the design of the forebody, to give gentle pitching, without slamming or bringing up suddenly at the end of a dive, combined with a form that suppresses spray forming. Pitch is governed to a very great extent by weight and displacement distribution. Exclusion of weight in the ends of the hull is the easiest solution. The bow can be formed so that, as it dives, it picks up buoyancy at a gradually increasing rate. Such a bow requires only moderate flare; in fact, a straight-sided V-section will do. The forefoot is usually rather deep so that it does not lift out of water readily. There is no advantage in a very hollow flare and great fullness on deck, nor in the streamlined or "barrel" bow that now afflicts so many "modern" designs, so far as seakindliness is concerned.

Flare in topsides can often be carried far aft and makes for dryness; the amount of flare need not be great. In fact, excessive flare makes for uneasiness and a snappy roll. On the other hand, there is no advantage in tumble-home in small craft. Flaring the topsides is sometimes a working substitute for additional freeboard. Often flare and tumble-home are governed by aesthetics rather than really practical considerations.

Freeboard

Freeboard is governed by proportions and by requirements of use in most fishing craft. Since there are generally practical advantages in relatively low freeboard at the working positions in these boats, sheer can often be utilised to make up some deficiencies. Sheer is too often only a matter of aesthetics but it is quite important in fishing boats for dryness, as well as for range of stability. These matters pertain to hull form design and should be manipulated to the utmost.

Balance of fore and after body

Seakindliness is most common when the fore and after bodies are well balanced. A very wide buoyant stern, combined with a long, sharp and wedge-shaped bow, creates inherently unfavourable conditions. This matter of balance is often the basis for the preference for sharp or cruiser sterns in fishing boats. However, balance is usually a matter that can readily be obtained in a hull with both ends alike, but the advantage is not worth the speed and propulsive efficiency losses that are usually produced in such a model. In short, the balance need not be precise to obtain practical results. It can be obtained by drawing superimposed curves of area at various angles of heel and investigating the movement of the centres of buoyancy. In practice, a moderate movement aft is permissible as heel increases. The static condition represented in this check, of course, is not an actual service condition.

It may be well to repeat what has often been said by others—that a sharp-ended hull is usually seakindly; the only qualification is that there should be no abnormalities in hull proportions. However, any fishing boat driven at high speeds for her length will be wet and uncomfortable in a sea that is heavy for her size. The apparent dryness of full-ended boats is due to the fact that they cannot be driven at relatively high speed in a seaway, and not to their "dry hull form". The steady increase in the demand for speed in fishing boats has placed many boat types in critical speed ranges, so far as comfort, workability and dryness are concerned.

Shape of stern

The effect of the whole form of the stern on seakindliness is perhaps less than that of the whole bow. The stern form is most important in a following sea. This matter was brought up at the first FAO Fishing Boat Congress, where transom versus sharp or cruiser stern was discussed. Therefore it is only necessary to state that if a "square" transom stern is used, it should be at a good rake and not nearly vertical, or falling inboard, as in many of the Cape Island boats. A compromise between sharp stern and flat transom, that might be considered in some instances, is to employ the V-shaped transom, in plan view, which was once quite common in motor boats. In a fishing boat, flaring quarters are generally preferable, so far as seakindliness is concerned, to tumblehome. The latter has the sole advantage of reducing topside damage when alongside a wharf or another vessel.

Conclusion

This discussion of form is, of course, no more than a very general one, for the proper manipulation of hull shape depends upon the type of fishing boat, which is the result of service requirements and has firmly established proportions which usually must be adhered to in design. It is not supposed that the ideas that have been stated are totally unknown to practical designers, and the justification for stating them is to focus attention on the possibility that hull form is a field for scientific study similar to that which numerical values in hull design have received. No numerical values of real importance have been stated here, for to the author's knowledge nothing of a reliable nature is available that can be applied to hull form design in detail. There have been a few studies made on the value of hollow entrance and, of course, upon length of entrance. However, more extensive research is desirable before final acceptance of the numerical values that have been recommended. Likewise, a more extensive study of run characteristics is necessary. Once these are well explored, the other matters involved in hull form could be more readily examined and tested. As it is now, fishing boat designers are proceeding in hull form design by rule-of-thumb, "art" and personal opinion, without much aid from mathematics or model testing, and apparently without well formulated theory.

It may be practical to relate observations of flow tests of models to hull-form, this would make such information a most useful guide in the drawing-board stage of design. It is therefore encouraging to see the increasing interest in flow-studies in the model-testing field.

The necessity for manipulation in hull form is very great in the range of size of most fishing craft, for only by this means can the combination of service requirements and of speed demand be even approximated. So far as small craft design is concerned, there is a wealth of hull forms in existence that can be explored. The neglect of this seems to be due, to some extent at least, to excessive reliance upon the mathematical attack, in spite of its obvious shortcomings, in actual design.

A METHOD TO DETERMINE FREEBOARD IN RELATION TO STABILITY

by

OLGIERD JABLONSKI

The method for determining the minimum freeboard for merchant ships is not satisfactory for fishing vessels. There is also no established method to determine freeboard in relation to minimum stability.

A method is proposed to analyze the varying heights of the vessel's centre of gravity (KG) in relation to the displacement, namely two characteristic quantities:

- The maximum height admissible, considering the requirements of certain stability criteria—KG_s (index $_s$ = stability)
- The maximum height resulting from the operational conditions—KG_O (index $_O$ = operation)

The intersection of the two curves determines the maximum permissible displacement and, consequently, the minimum freeboard.

Some stability criteria refer to the curve of statical righting arms. A graphical method is proposed to determine rapidly the data necessary to construct the curve of KG_s. The methods of constructing a curve of KG_O is also explained.

A special diagram should be made to keep the skipper aware of the stability characteristics of his vessel. A survey of safety conditions of fishing vessels should be organized internationally. Inter-governmental agreement should be made to establish practical freeboard standards for fishing vessels.

UNE MÉTHODE POUR DÉTERMINER LE FRANC-BORD PAR RAPPORT A LA STABILITÉ

La méthode de détermination du franc-bord minimum pour les navires marchands n'est pas satisfaisante pour les navires de pêche. Il n'y a pas non plus de méthode établie pour déterminer le franc-bord par rapport à la stabilité minimum.

Une méthode est proposée pour analyser les hauteurs variables du centre de gravité (KG) du navire en relation avec le déplacement, à savoir les deux quantités caractéristiques suivantes:

- La hauteur maximum admissible, en tenant compte des exigences de certains critères de stabilité—KG_s (indice $_s$ = stabilité).
- La hauteur maximum résultant des conditions de fonctionnement—KG_O (indice $_O$ = fonctionnement).

L'intersection des deux courbes détermine le déplacement maximum possible et, par conséquent, le franc-bord minimum.

Quelques critères de stabilité se rapportent à la courbe des bras de redressement statique. On propose une méthode graphique pour déterminer rapidement les données nécessaires pour construire la courbe de KG_s. L'auteur explique aussi les méthodes de construction d'une courbe de KG_O.

Il faut faire un diagramme spécial pour informer le patron sur les caractéristiques de stabilité de son navire. Une enquête sur les conditions de sécurité des navires de pêche doit être organisée sur le plan international. Il faut qu'un accord intergouvernemental établisse des normes de franc-bord pratiques pour les navires de pêche.

METODO PARA DETERMINAR EL FRANCOBORDO CON RELACION A LA ESTABILIDAD

El método para determinar el francobordo mínimo para los barcos mercantes no da buenos resultados en el caso de los pesqueros. No existe un método establecido para determinar el francobordo con relación a una estabilidad mínima.

Se propone un método para analizar las alturas variables del centro de gravedad (KG) del barco con relación a las dos cantidades características:

- La altura máxima admisible considerando las necesidades de ciertos criterios de estabilidad—KG_s (índice $_s$ = estabilidad)
- La altura máxima que resulta de las condiciones de funcionamiento—KG_O (índice $_O$ = funcionamiento)

La intersección de las dos curvas determina el desplazamiento máximo permisible y, por tanto, el francobordo mínimo.

Algunos criterios de estabilidad se refieren a la curva del momento de adrizamiento estático. Se propone que se emplee un método práctico para determinar rápidamente los datos necesarios para construir la curva KG_s. También se explican los métodos para construir una curva de KG_O.

Debe prepararse un diagrama especial para que el patrón conozca las características de estabilidad de su barco. Debería hacerse una encuesta internacional de las condiciones de seguridad de los barcos de pesca, y formularse un acuerdo intergubernamental para fijar normas prácticas de francobordo para los barcos de pesca.

OVERLOADING beyond the limits fixed by safety considerations is common in fishing vessels and is due to several reasons. The designer finds it more and more difficult to balance the hold's capacity with the carrying capacity. The long range of operation and more powerful engines require large quantities of fuel in relation to displacement and deadweight capacity. For instance, small Polish vessels catch and salt herring as far as the North Sea. Fuel and water take up about 45 per cent. of the deadweight capacity.

The holds are designed to receive catches in relation to the weight of consumed fuel and water. If catches are more abundant than those assumed in the design, a deficiency occurs in deadweight capacity. This is usually disregarded by fishermen, and often results in serious overloading. There are no effective measures to make the fishermen take proper safety considerations into account. Some countries are seriously concerned with this problem. National regulations differ and vessels under various flags fish side by side and observe different standards of maximum loading.

No satisfactory solution to safety problems can be expected from national regulations, and a first requirement is to carry out an international safety survey on the fishing grounds. The simplest way to establish uniform standards of loading for fishing vessels is to determine the minimum freeboard.

Fishing vessels are little affected by the International Convention on Safety of Life at Sea, 1948, and not at all by the 1930 Loadline Convention, which is only applicable to large transport ships. It produces too low freeboard for fishing boats from the stability point of view.

Since the 1930 Convention many countries have introduced experimental stability regulations and scientific investigations have been carried out. Even so, it will probably take a long time before international agreements are made on stability criteria for all types of ships. There is a definite desire to establish a load line convention for fishing vessels.

With this possibility in mind, a method for combining freeboard standards with stability criteria is presented.

Principles of freeboard determination on the basis of stability criteria

In applying a stability criterion, such as that of Rahola (1939), to a ship, the problem can be considered as a question: Is there a critical height of the centre of gravity beyond which the minimum requirements of stability cannot be fulfilled?

Taking into account the various operating draughts (T_1, T_2, T_3, . . .) and displacements (∇_1, ∇_2, ∇_3, . . .), the critical heights of the vessel's centre of gravity (KG_1, KG_2, KG_3, . . .) can be determined and plotted on a curve KG_s called "the curve of maximum height of the centre of gravity" for a specific stability criterion.

If other stability criteria were used, different curves would result and such curves could also be used to compare various stability criteria.

In analyzing the operational conditions, it is necessary to examine a series of displacement values at various kinds and distributions of loads to determine the maximum operational heights of the centre of gravity. These values are corrected for free surface effect at the different displacements. The resulting values serve to construct the curve of KG_o.

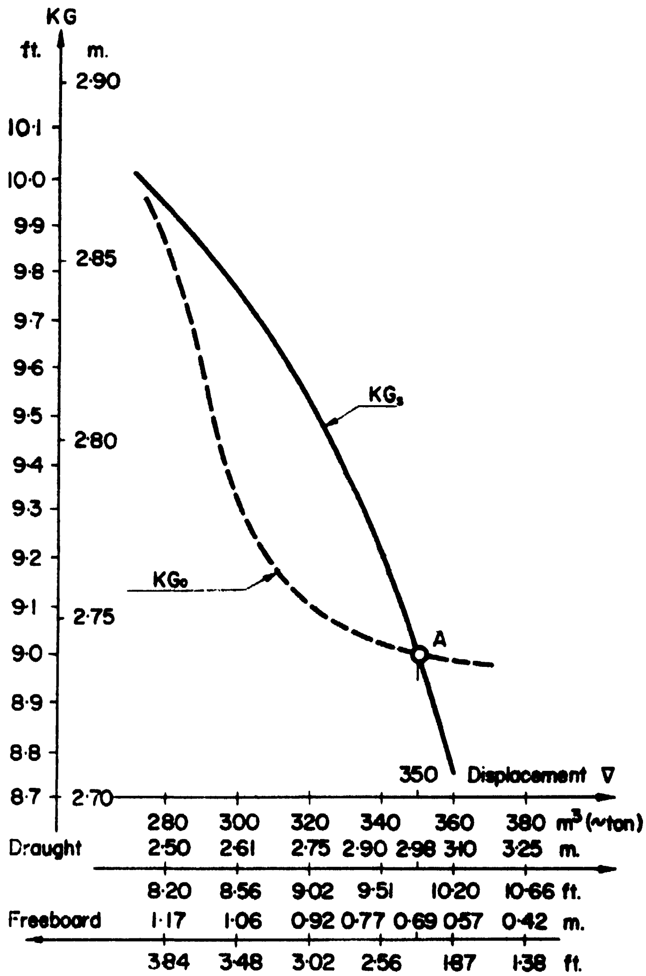


Fig. 498. Maximum height of gravity considering stability KG_s and normal operational height KG_o for various displacements

This curve is called "the curve of the maximum height of the centre of gravity" from operational conditions.

The intersection of the curve of maximum permitted KG_s, and the curve of operational maxima KG_o, A in fig. 498, determines the maximum admissible operational displacement for a given vessel and, consequently, the minimum freeboard. If A indicates a lower freeboard than the minimum of the Loadline Convention, the freeboard of the Convention should be used.

If curves KG_s and KG_o intersect in the region of small displacements, the vessel, when light, does not meet the criteria of stability, and ballast must be added.

Graphical method for determining the curve KG_s

Stability criteria based on curves of statical righting arms include those by the Germanischer Lloyd of 1933 and by Deutsche Schiffs Revision und Klassifikation of 1956. The Rahola system, as applied to Dutch fishing vessels, may also be included. The main condition of these criteria is the position and value of the maximum stability righting arms, as well as to their range.

In transferring the requirements into the maximum permissible heights of the centre of gravity (KG_s) for various displacements of a given ship, the work can be considerably speeded up by the use of a graph, called "the radial analyser of ship's stability".

The graph consists of radii as shown in fig. 499 from the point O, situated at any place on the abscissa of the cross-curve diagram for a given ship. The radii are

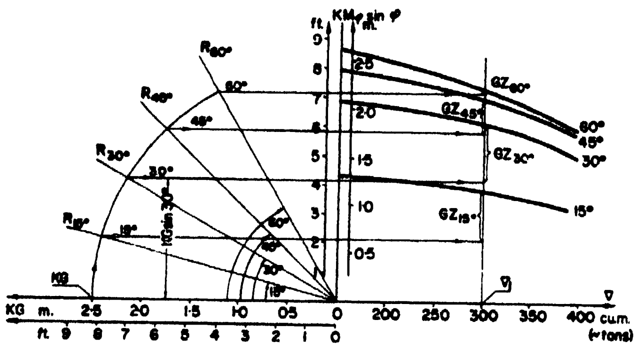


Fig. 499. Radial analyser of stability of ships

inclined towards the abscissa at angles of the corresponding cross-curves.

Any curve of statical righting arms for a given ship can be obtained by tracing from point O an arc with a radius corresponding to the actual height of the centre of gravity. Then it is possible to trace horizontal auxiliary lines, parallel to the cross-curve axis. The distance between them and the corresponding cross-curves, represent the intermediary values of righting arms, because each value fulfils the equation:

$$GZ = (KM_\varphi - KG) \sin \varphi \text{ (see fig. 500)}$$

Then the GZ curve is easily drawn (see fig. 501).

Choosing a simple criterion, the analyzer can be used as follows:

(1) $GZ_s \geqq 7.87$ in. (200 mm.) for $\varphi_s = 30°$, and

(2) $\varphi_r \geqq 60°$,

where

φ_s is the angle of heel at which the curve reaches its peak (maximum);

GZ_s is the ordinate at the peak point;

φ_r is the range of positive ordinates

According to condition (1) the diagram must be supplemented by an auxiliary cross-curve (see fig. 502) running 7.87 in. (200 mm.) lower and parallel to the 30° cross-curve.

It is necessary to determine for intermediary values of the displacement the maximum height of the centre of gravity (KG_s). The following displacement values come into consideration: $\nabla = 200$, 300 and 400 cu. m. (~ tons), Graphical operations of the analyzer will be discussed only with regard to the displacement = 200 cu. m.

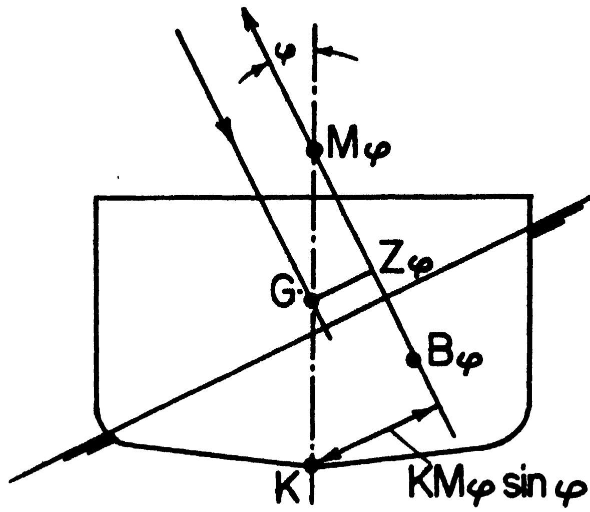


Fig. 500. Transverse section defining K, M, KMφ, etc.

From the point 1° on the auxiliary cross-curve and displacement = 200 cu. m., a line is drawn parallel to the abscissa, the so-called "departure course" 1. Along this course and across radii $R_{30°}$ and $R_{60°}$ a point is reached on the vertical line of displacement, 200 cu. m., corresponding to a heel of 60°.

In this case, the end point 1° appears above the 60° cross-curve. This means that, with a righting arm assumed to be 7.87 in. (200 mm.), condition (2) of the stability criterion will not be fulfilled. It may be stated, therefore, that the limiting condition in this case is the range of the stability curve.

The "return course" must then be drawn against the 60° radius, then by an arc down to the KG axis. This shows that, with 200 cu. m. displacement, the stability criteria will be kept only if the height of the centre of gravity is less than 9.74 ft. (2.97 m.).

On the "return course" are the cross-curves for 40°, 30° and 20°. The resulting righting arm values, $GZ_{40°}$ =

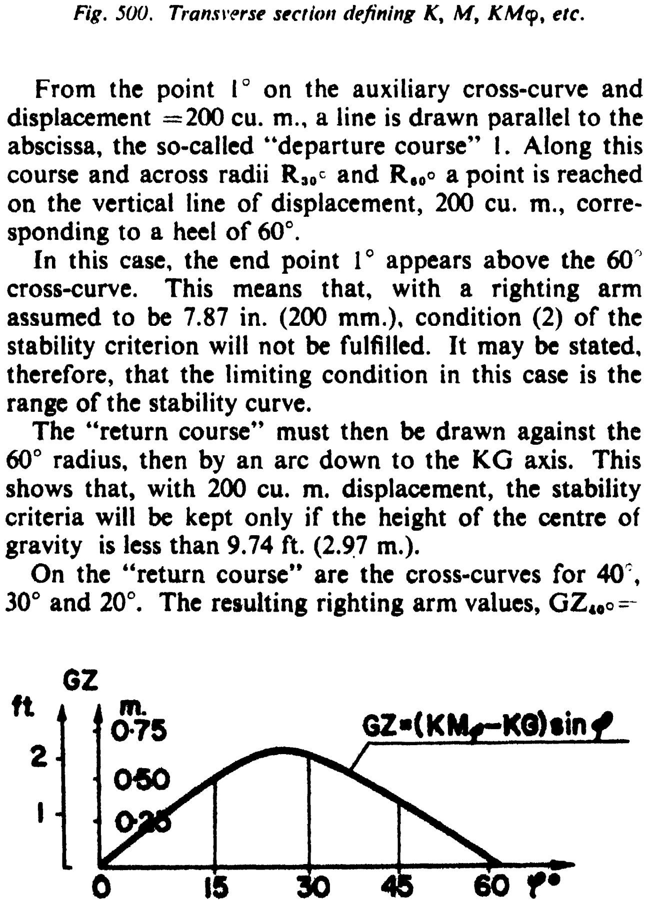


Fig. 501. Stability curve obtained from fig. 499

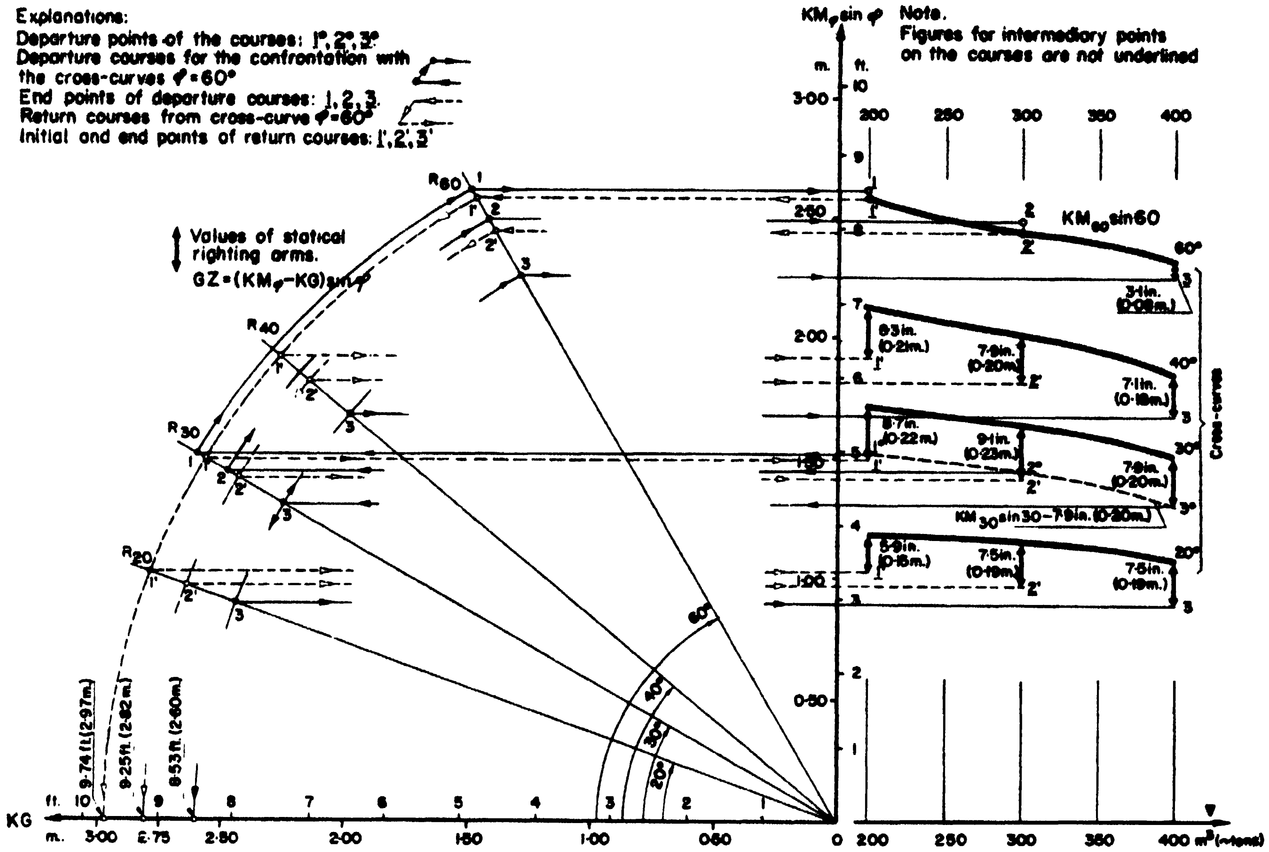


Fig. 502. Radial analyser of stability of ships considering a certain stability criterion

8.3 in. (210 mm.); $GZ_{30°}$=8.7 in. (220 mm.); $GZ_{20°}$= 5.9 in. (150 mm.) lead to the conclusion that the peak point of the stability curve is approximately at 30° heel; thus, the height of the centre of gravity as determined above will meet the criterion.

By applying similar graphical operations to the other displacements, the data for the construction of a curve of maximum permissible height of the centre of gravity, KG_s can be determined.

The curve of maximum height of centre of gravity from a specific stability criterion can be drawn directly on the radial analyzer as shown in fig. 503.

For both the criteria chosen, 1 and 2, separate curves can be drawn, namely KG_{s1} and KG_{s2}. From fig. 503 it can be concluded that the second criterion must be used for displacements up to about 300 cu. m., whilst above the first criterion must be used.

To the two above criteria, others may be added, each of which will have its own curve of KG_s.

Fig. 504 shows on an enlarged vertical scale, the two curves mentioned plus a third curve KG_{s3}, based on a dynamical criterion, as in the Russian stability regulations. This curve is drawn from the assumption that the dynamical action of the wind will not incline the ship to more than the critical limit.

Determination of critical loadings for fishing vessels in order to construct a curve of KG_0

In cargo vessels there is a large number of holds and tanks of different shapes, placed in various parts of the ship, and a wide range of cargoes may be carried, all of which contribute to a variety of loading conditions.

In order to compute a curve of KG_0 for such ships it may be necessary to assume conventional conditions, which, will only, if at all, be realistic for a short while.

The whole problem seems to be much simpler with fishing vessels. When computing a curve of KG_0 for a fishing vessel, a special method may be used, consisting of an analysis of operational states of loading.

The method is explained below for a trawler-drifter, 91.87 ft. (28 m.) long, fishing herring on distant grounds and salting the fish in barrels. This is a small vessel, operating up to 28 days per trip. The weight of stores, such as fuel, fresh water, food provisions, etc., on leaving port may be as much as 45 per cent. of the deadweight. These stores may diminish quickly and this calls for an estimate of "momentary cargo capacity", a fact never encountered in ordinary cargo ships.

When drift-nets are used, a fishing boat may have to take on board a very big catch quickly. When the fish is salted, put into barrels and placed in the hold, the hatches remain open and the deck load is considerable, thus increasing the height of the centre of gravity with due effect upon the vessel's stability.

In the determination of the operational loading combinations, the maximum available deck surface may be taken as the most disadvantageous from the stability point of view.

The following simplifies the considerations:

- The vessel has no ballast tanks of considerable size
- The greater part of the stores are placed in bottom tanks. The level to which the tanks are filled influences the height of the centre of gravity
- The transverse bulkheads that divide the hold to facilitate storage of the barrels, do not induce considerable variations in the height of the centre of gravity
- The weight of barrels, empty and filled with salt, is constant

Thus, the load distribution may be reduced to three variables: the amount of stores consumed, the net weight of fish in holds and the displacement of the vessel. Fig. 505 shows a selection of load combinations.

The percentage of stores on board, as compared with the maximum possible quantity on leaving port, has been assumed as the main factor. Its scale may be combined with another horizontal scale, showing, on the basis of the average daily consumption of fuel and water, the duration of the trip.

The total weight of stores on board (S) and of fish in the hold (F) are marked on the main ordinate scale. (S+F), expressed as a percentage of a certain, temporarily assumed, maximum total of these loads. The diagram shows two more vertical scales:

- The scale of the total displacement of the vessel (in tons)
- The stores scale (in tons)

The sloping straight line in the diagram connects the percentage and ton figures for stores and at the same time determines the percentage of actual stores, as compared with the assumed maximum value for $S+F_h$ (the maximum total of stores and fish in the hold).

Fig. 505 shows all the possible load distributions of importance. By drawing vertical and horizontal lines, the diagram is divided for further analysis. Each point of intersection of the auxiliary lines is marked with two figures. The first represents the percentage of actual stores, and the second shows the percentage of fish in the holds, as compared with the maximum total of stores and fish. Assuming that the actual stores rarely equal zero, these load combinations may be left out from consideration.

In order to trace a curve of KG_0 only the points underlined twice are necessary. Each point represents a height

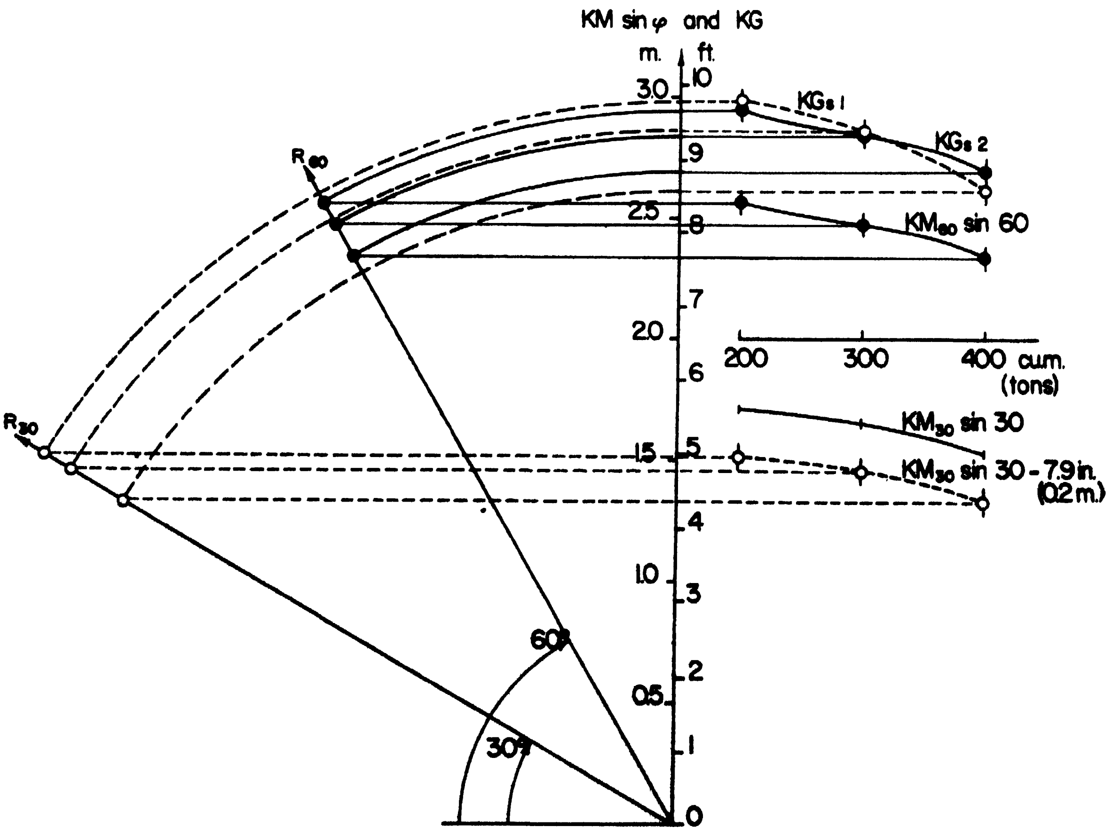


Fig. 503. Radial analyser with curves of maximum KG_s considering a certain stability criterion

of the centre of gravity which constitutes the maximum for the corresponding displacement.

Only six loading combinations are shown in fig. 505 after the final selection. A detailed computation of the height of the centre of gravity is necessary for these, and then a curve of KG_o according to fig. 498 can be drawn.

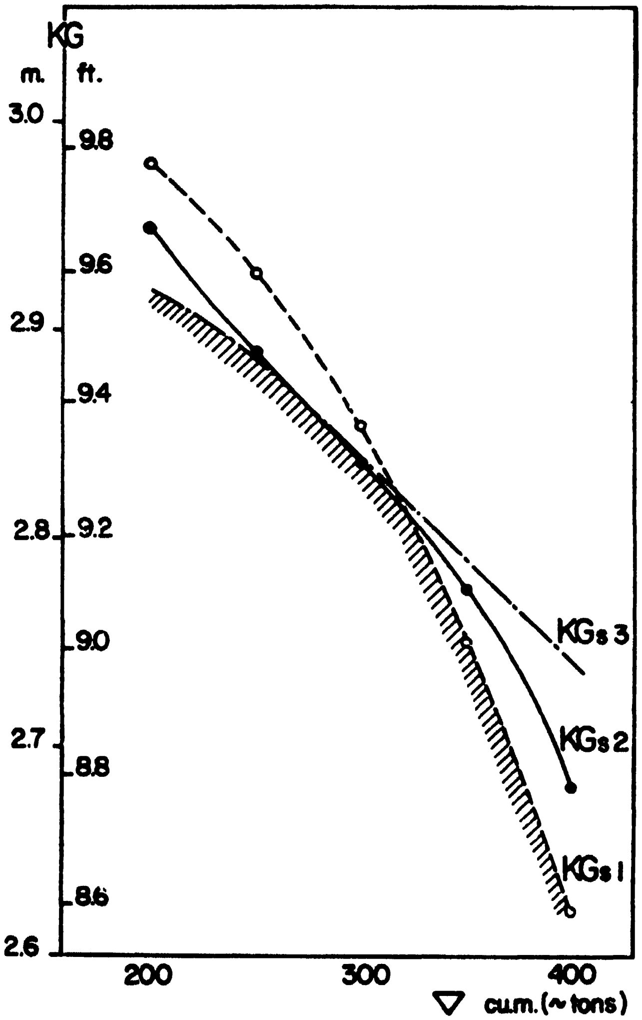


Fig. 504. Curves of maximum KG_S, the curve KG_{S3} based on a dynamical criterion

For the vessel discussed and for the selected criteria of stability the maximum operational displacement ought not to exceed 358 tons or 350 cu. m. in salt water.

This simple scheme of analysis may not, of course, always be suitable in the case of other types of fishing vessel, and necessary adjustments might have to be made. But, generally, variations in load distribution can be foreseen.

Additional use can be made of the curve of KG_o for "stability information" by skippers.

For this purpose the values of KG for all the control

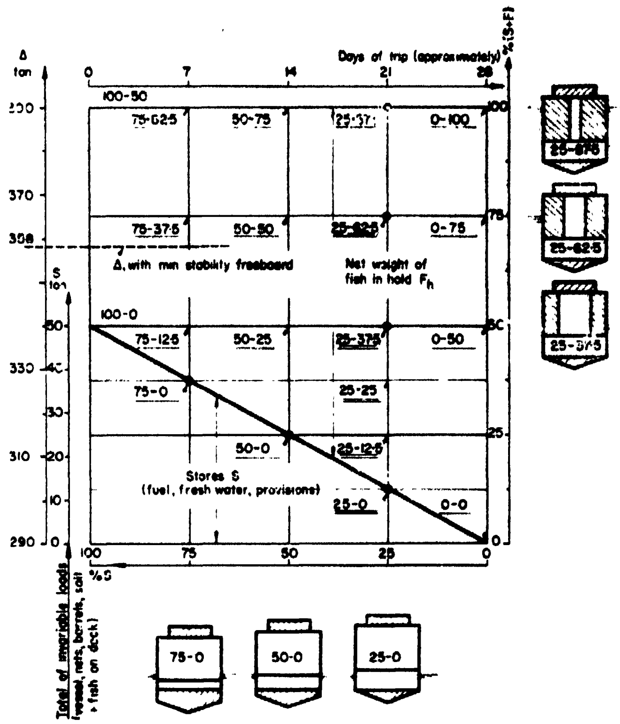


Fig. 505. Combinations of loading, where the left percentages represent stores, the right catch of fish

points in fig. 505 are calculated the displacement of which is less than "stability freeboard".

The value of KG is measured off from the corresponding points of fig. 505 perpendicular to the graph plane, i.e. to the plane fixed by axes (S+F) and (%S). In this way a relief surface is obtained, which for the discussed vessel has the shape shown in fig. 506.

Then the above surface is intersected by a series of

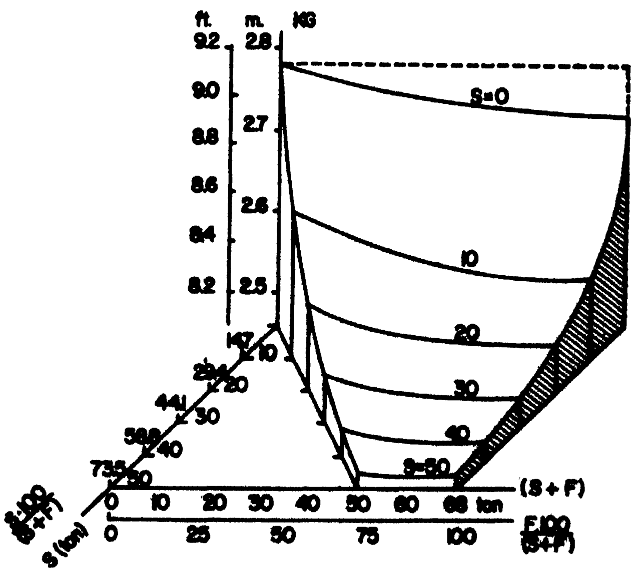


Fig. 506. Perspective diagram for ships' board control of stability

planes perpendicular to the base of fig. 505, as well as to the axis (%S).

Thus a set of "cross-curves for KG" is obtained, each of which corresponds to a constant value of stores (S).

The curve of KG_s is added to the set of "cross-curves for KG" (fig. 507). So the skipper has on a single graph all the "stability information" data necessary for the safety of the ship.

In making use of such "information" the skipper must first determine the amount of stores (S) on the ship and then find the corresponding curve on the graph.

When the catch begins, the left end of the curve should be studied, whereas in the final phase, the right end is the important one and the draught of the vessel approaches the freeboard mark.

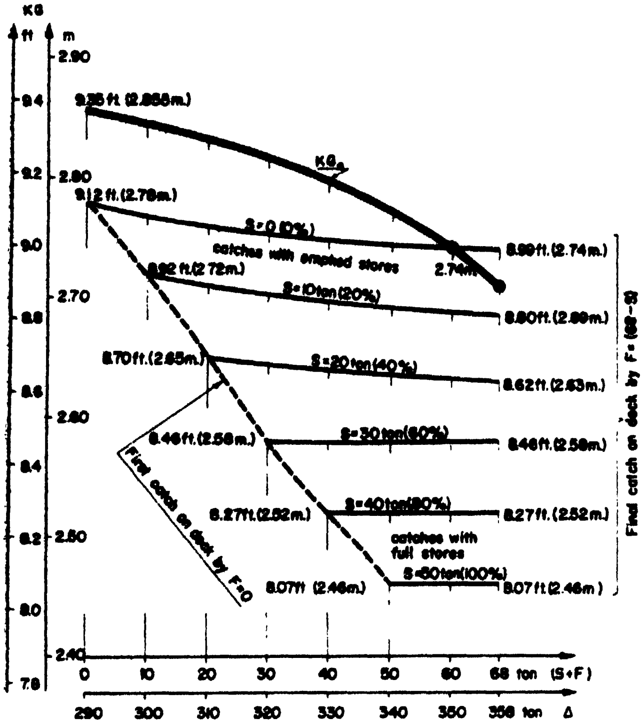


Fig. 507. Stability information for ships' board (obtained from fig. 506)

After locating the actual load condition on the graph the stability reserve of the ship is seen at a glance. It is the vertical distance from the KG_s curve.

If this distance is great the skipper may safely shift a part of the ballast or load upward, for example, for the purpose of decreasing violent rolling of the ship. Such a procedure is out of the question when the graph does not show a sufficient reserve of stability.

As can readily be seen, the interpretation of this proposed synthetic "stability information" is very simple. Without any additional calculation the skipper knows the actual stability characteristics of his ship. He needs only to know the amount of stores (fuel, water, provisions, etc.) he has on board.

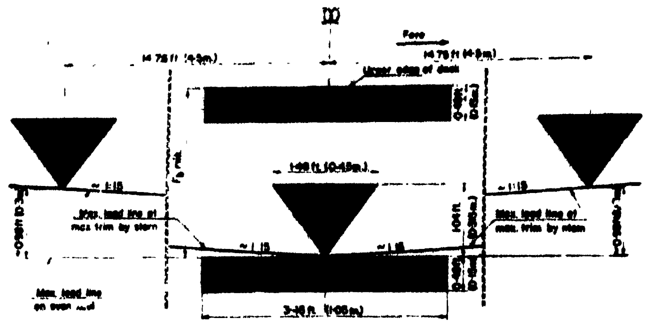


Fig. 508. Proposed freeboard mark for fishing vessels

Conclusions

The height characteristics of a vessel's centre of gravity are not directly useful when comparing the stability of various ships. However, a universal stability measure would open the way to finding the extent to which a given vessel in various states of loading fulfils the requirements of the stability standards in force.

The simplest measure for estimates of this kind is undoubtedly the height of the centre of gravity considered together with the displacement and compared with the maximum height permissible to meet the requirements of the stability criteria.

A clear and simple principle is proposed for determining the minimum "stability freeboard", i.e. a freeboard based on the stability criteria.

Generally speaking, it may be concluded that there are no methodical complications in the application of the stability freeboard principle to fishing vessels. It will be sufficient to adopt a suitable stability criterion.

As fishing vessels are overloaded on fishing grounds, the control of obedience to regulations should be made at the grounds and not in port. Inter-governmental organizations have been set up successfully for the protection of the living resources of the seas and there should be no insoluble reason why inter-governmental agreements should not also be reached regarding stability.

The first and most urgent step is a preliminary international compromise concerning the minimum stability requirements for fishing vessels. The next step is an agreement on the method for joint treatment of the minimum stability and freeboard standards.

Such agreements would pave the way for dealing with more detailed problems, such as the problem of the freeboard mark on fishing vessels being visible from a greater distance and when at sea. In this connection see fig. 508. It is proposed to introduce a single basic line for salt water with specific weight 1.025, as well as controlling marks for fore and after trim. This provides, of course, only a rough idea of the mark, which needs careful discussing in detail.

NOTES ON STABILITY

by

ATSUSHI TAKAGI

Statistics are given on the loss of Japanese boats. The principal dimensions and displacements of a selected number of recently built fishing boats are shown, based on L × B × D. Essential factors in stability of fishing vessels are discussed, including freeboard, trim and draught GM, KG/D, etc. Freeboard greatly affects the reserve buoyancy, length and range of righting arms. GM should be within a range of 1.48 to 1.97 ft. (450 to 600 mm.). GM and radius of gyration were investigated to determine the appropriate rolling period for the crew to work without becoming seasick.

Japan has regulations for the stability of passenger vessels and stability criteria have been proposed for smaller vessels, but not fishing vessels. The author recommends a criterion for all types of fishing vessels, i.e. a *safety index number*, which he hopes will be improved by further studies using data from all countries in which fishing boats are built.

NOTES SUR LA STABILITÉ

L'auteur donne les dimensions principales et le déplacement d'un certain nombre de navires de pêche construits récemment, en se basant sur L × B × D. Les facteurs essentiels pour la stabilité comprenant le franc-bord, l'assiette et le tirant d'eau, GM, KG/D, etc. sont examinés. Le franc-bord affecte beaucoup la réserve de flottabilité, la longueur et les limites d'action des bras de redressement. GM doit être comprise entre 1,48 et 1,97 pi. (450 et 600 mm.). On a fait des recherches sur GM et le rayon de giration pour déterminer la période appropriée du roulis pour que l'équipage travaille sans avoir le mal de mer.

Le Japon possède des règlements pour la stabilité des navires à passagers et on a proposé des critères de stabilité pour les petits navires, mais non pour les navires de pêche. L'auteur recommande un critère pour tous les types de navires de pêche, c'est-à-dire, un *indice numérique de sécurité* qui, espère-t-il, sera amélioré par de nouvelles études utilisant les données de tous les pays où des navires de pêche sont construits.

NOTAS SOBRE ESTABILIDAD

Se dan las dimensiones y desplazamientos principales de varios barcos de pesca construídos recientemente, basados en L × B × D. Se examinan los factores esenciales para la estabilidad de los barcos de pesca, inclusive el francobordo, el asiento y el calado, GM, KG/D. etc. El francobordo tiene gran efecto en la reserva de flotabilidad, longitud y limite de acción de los pares de adrizamiento. GM debe estar comprendido entre 1,48 y 1,97 pies (450 y 600 mm.). Se investigan GM y el radio de giro para determinar el período appropiado de balanceo para que la tripulación trabaje sin marearse.

Japón tiene legislación relativa a la estabilidad de los barcos de pasajeros y se han propuesto criterios de estabilidad para barcos más pequeños, pero no para los pesqueros. El autor recomienda un criterio para todos los tipos de barcos de pesca: un *índice numérico de seguridad* que confía será mejorado por estudios ulteriores en lo que se empleen los datos de todos los países donde se construyen barcos de pesca.

ACCORDING to Lloyd's statistics, losses of Japanese ships are comparatively higher than the average for the world. They are especially high for fishing vessels.

The statistics prepared by the Maritime Safety Board, table 119, shows that more than half the damages and losses are fishing vessels, although in tonnage, they are only 15 per cent. The actual figures for fishing vessels are probably much higher, because many small boats such as non-power driven fishing boats are not included in the statistics.

Table 120 classifies the causes. Engine trouble accounts for 40 per cent. The main causes are:

- Lack of navigation experience:
  - Improper steering
  - Insufficient knowledge of ship's position
  - Inadequate watch
  - Insufficient knowledge of channel
- Lack of skill in handling engine:
  - Inadequate maintenance
  - Errors in maintenance
  - Wrong operation
- Sea and weather conditions:
  - Misleading weather forecast
  - Forced navigation in rough weather
  - Insufficient refuge

Statistics of fishing vessel insurance

In 1937 owners of fishing boats of less than 1,000 GT organized an insurance system based on the locality and the type of fishing. Such cover is reinsured by the Government. The insurance risk is expressed in terms of percentage of the damages paid in relation to the total insurance coverage. Table 121 shows the statistics of this insurance.

The insurance risk for powered fishing boats from

TABLE 119

Reported damage or loss of Japanese vessels
(Based on the statistics by Maritime Safety Board of Japan)

Items	1954		1955		1956	
	Number of vessels	*Total GT**	*Number of vessels*	*Total GT**	*Number of vessels*	*Total GT**
Grand total . . .	3,699 (100%)	418.6 (100%)	3,670 (100%)	387.6 (100%)	4,132 (100%)	446.6 (100%)
Fishing boats total .	2,011 (54.4%)	53.4 (12.8%)	1,993 (54.3%)	53.9 (13.6%)	2,072 (50.1%)	76.4 (17.2%)
With power .	1,932	53.3	1,886	53.7	1,921	76.1
Merchant ships total	1,688 (45.6%)	365.2 (87.2%)	1,677 (45.7%)	333.7 (86.4%)	2,060 (49.9%)	370.2 (82.8%)
Large . . .	499	292.0	350	248.5	416	262.7
Small . . .	1,095	65.7	1,170	72.5	1,414	86.3
Others . . .	94	7.5	157	12.7	130	21.2

*Expressed in units of 1,000 tons

TABLE 120

Reported causes of damage or loss of Japanese vessels
(Based on the statistics by Maritime Safety Board of Japan)

Items	1954		1955		1956		*Remarks*
	Total	*Fishing boats*	*Total*	*Fishing boats*	*Total*	*Fishing boats*	
Grand total	3,699	2,011	3,670	1,993	4,132	2,072	
1. Errors in navigation	1,243	556	1,300	587	1,582	702	Main causes only
2. Improper engine handling . . .	786	457	883	580	885	548	
3. Foul weather or rough seas . . .			445	249	387	206	
4. Material fatigue	426	233	390	216	427	196	
5. Defects in construction or materials .			180	125	161	118	
6. Acts of God	392	278	131	71	224	133	

1950 to 1955 was, on a yearly average, 3.06 per cent.; average total loss was 1.79 per cent., and partial loss 1.08 per cent. The risk decreased with the increase in the size of ships. Vessels of 5 to 19 GT were the largest risk because many of them were old and were used on distant fishing grounds.

On the other hand, according to the unpublished statistics for merchant ships as prepared by the insurance companies, fishing boats of less than 1,000 GT represented less risk than merchant ships.

Losses have been attributed to the design of the boats rather than to lack of skill of the crew. Of course, even first-class seamanship cannot always overcome structural performance and other defects in a boat, and there is certainly a need to improve Japanese fishing boats to make them safer.

Table 120 indicates, however, that half the disasters to fishing boats is attributed to lack of skill in navigation and in engine handling, which stresses the need for better training of crews.

Trend in principal dimensions of various types

Improvements in design have been gradually achieved through experience gained over a long period. It can generally be said that when the principal dimensions of a vessel have been determined, more than half the problems in design have been solved.

Fig. 509 to 519 give values of L, B, and D indicated by $L \times B \times D$ based on the actual data of 1,500 existing vessels. Larger deviation of +5 per cent. from these

TABLE 121

Insurance risk (%) of power-driven Japanese fishing boats (1950-1955)
(Based on the Japanese fishing vessel insurance statistics)

By Year	*Risk total*	*Total loss*	*Partial loss*	*Rescue expenses*	*Collision damage*
1950 . . .	2.91	1.76	0.87	0.27	0.01
1951	2.96	1.51	1.15	0.30	
1952	3.07	1.95	0.92	0.20	
1953	3.03	1.58	1.27	0.18	—
1954	3.65	2.18	1.31	0.13	0.03
1955	2.75	1.74	0.93	0.08	—
Average	3.06	1.79	1.08	0.19	—
By size					
0 to 4 tons .	4.38	1.24	3.07	0.07	—
5 to 19 tons .	5.13	2.47	2.46	0.20	—
20 to 49 tons .	3.16	2.24	0.71	0.18	1.03
50 to 99 tons .	2.54	1.69	0.46	0.22	0.17
100 to 999 tons .	2.10	1.23	0.71	0.16	—

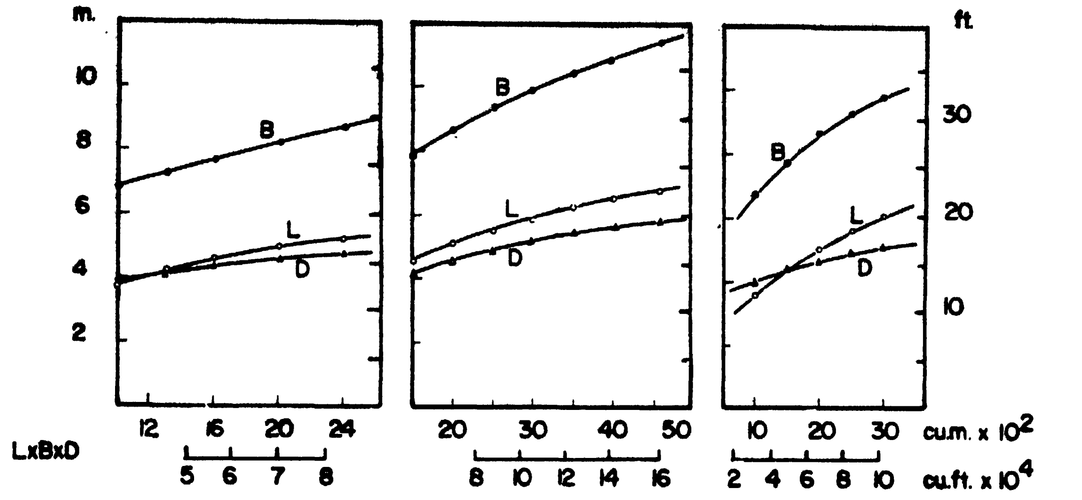


Fig. 509 *Fig. 510* *Fig. 511*

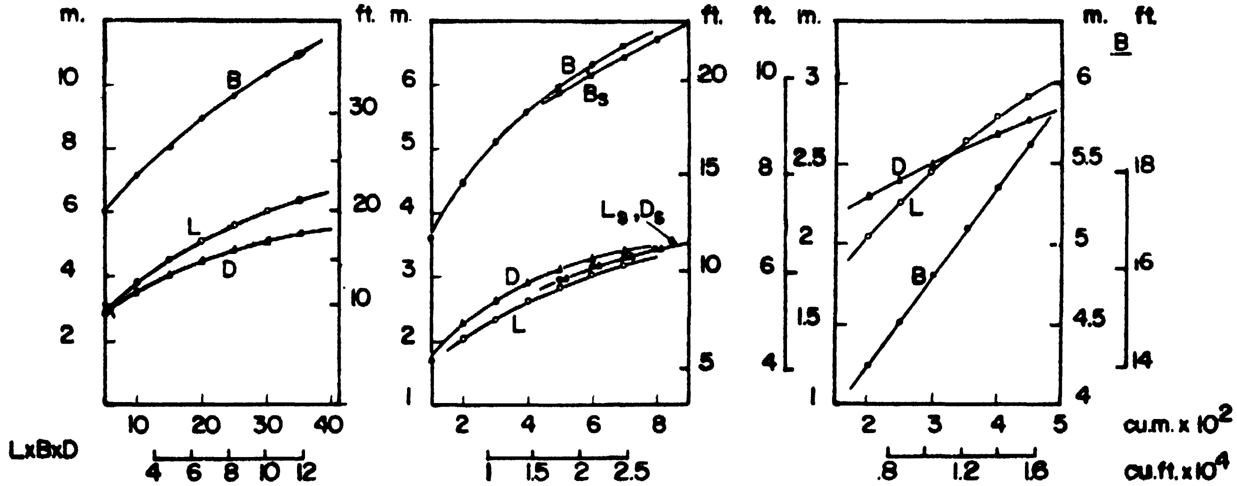


Fig. 512 *Fig. 513* *Fig. 514*

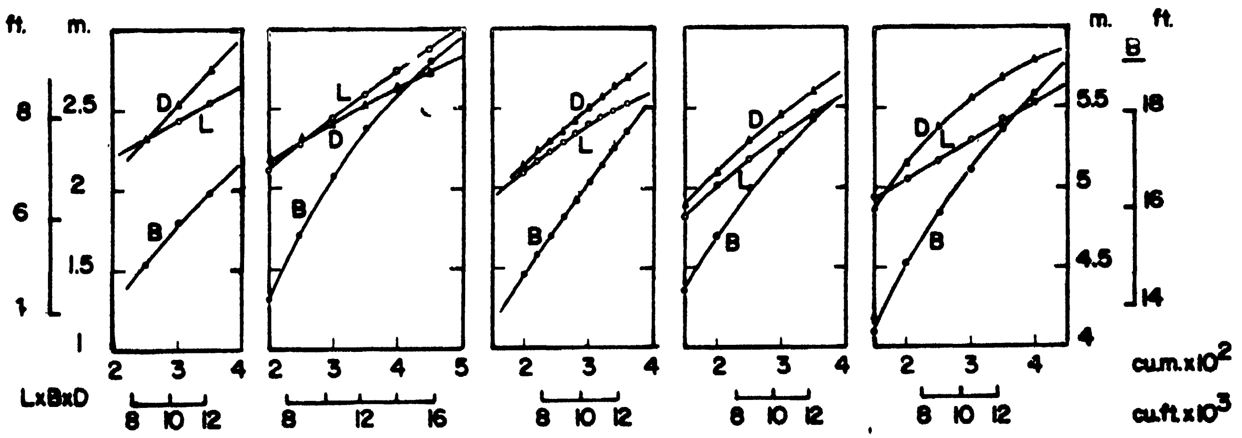


Fig. 515 *Fig. 516* *Fig. 517* *Fig. 518* *Fig. 519*

Fig. 509. Main dimensions of Japanese steam trawlers (steel) *Fig. 510. Main dimensions of Japanese diesel trawlers (steel)*
Fig. 511. Main dimensions of Japanese whale catchers (steel)
Fig. 512. Main dimensions of Japanese tuna longline fishing boats (steel)
Fig. 513. Main dimensions of Japanese skip-jack pole fishing boats (steel and wood). (Ls, Bs and Ds represent steel boat)
Fig. 514. Main dimensions of Japanese small pair trawlers (steel)
Fig. 515. Main dimensions of Japanese small pair trawlers known as Awa type trawler (wood)
Fig. 516. Main dimensions of Japanese salmon drifters and Pacific saury stick-held dipnet boats (steel)
Fig. 517. Main dimensions of Japanese salmon drifters and Pacific saury stick-held dipnet boats (wood)
Fig. 518. Main dimensions of Japanese purse seiners (wood)
Fig. 519. Main dimensions of Japanese mackerel pole fishing boats (wood)

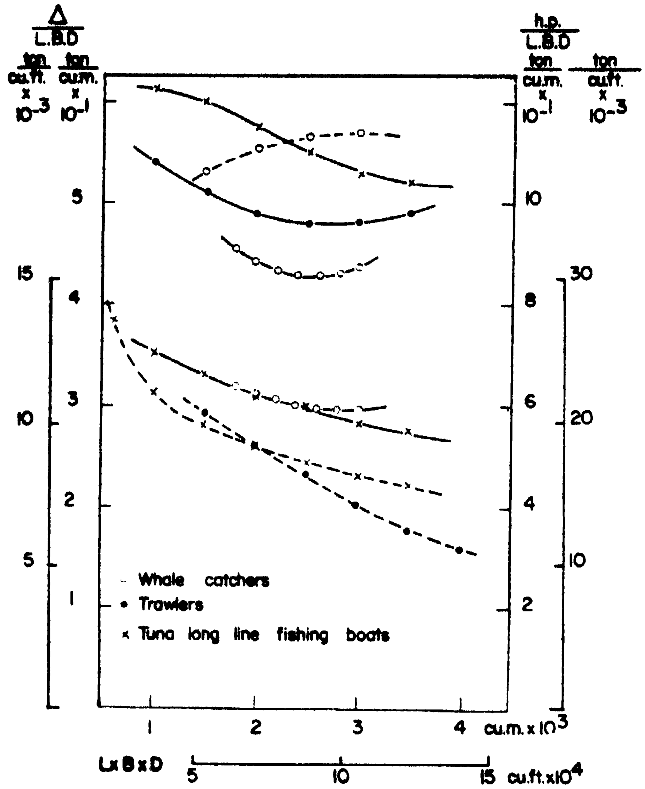


Fig. 520. Main particulars of Japanese whale-catchers, trawlers and tuna longline fishing boats (steel)

figures should only be made if there is a special and well-considered reason. Gross tonnage is the first decision and the basic factor in calculating the cost of a fishing vessel in Japan, and it can be conveniently used for the selection of L, B and D. Japanese regulations limit the gross tonnage in some types of fishing, which, of course, affects the principal dimensions.

Fig. 520 to 523 illustrate the relationship of L × B × D, the main engine output, and displacement for both light and load condition. This relationship varies according to the type of fishing. The principal dimensions shown in the figures influence to some extent the stability.

Stability

The problem of how to establish criteria for stability of specific vessels has been studied by specialists of many fishing countries. It remains, however, to make use of the experience of designers, builders and fishermen throughout the world to establish a common criterion for all fishing vessels. The problems can be illustrated by using Japanese fishing boats as an example.

The author has participated in the design of subsidized fishing boats since 1931. The results of the trial and inclining experiments for one vessel were used for the design of the next boat. Data were accumulated over many years, especially after 1947, when information on the advantages and disadvantages of the designs of 300 to 600 fishing vessels every year was provided through a new consulting system of the Government. Facts were also obtained about boats lost at sea. All this experience showed that stability is the most important safety factor in fishing boats.

Freeboard. Freeboard is measured midships from the waterline to the top of the deck. The international freeboard regulations do not apply to fishing boats. As Japanese fishing boats are built to operate in distant fishing grounds there is a danger that freeboard will be sacrificed for greater fish hold capacity. As it is, most Japanese fishing boats of, say, over 500 gross tons, could not meet the requirements of the Japanese freeboard regulations for merchant ships of this size. If freeboard, as required for merchant ships, provides the standard of measurement of safety, then fishing vessels are not up to standard, but this is not established as a fact.

The Japanese Fisheries Agency has the following freeboard requirements:

Wooden vessels: $f = D \times {}^1/_{15} + 0.66$ ft. (0.20 m.)

Steel vessels:

$D < 14.8$ ft. (4.5 m.), $f = D \times {}^1/_{15} + 0.49$ ft. (0.15 m.)

$D \geqq 14.8$ ft. (4.5 m.), $f = D \times {}^1/_{10}$

D is the depth midships. The sheer does not increase with the size of the ship in proportion to L and D. However, the larger the ship, the larger the superstructure. The freeboard requirements seem to provide a simple form for taking these factors into account. In the past, the rule was $0.10D + 0.66$ ft. (0.20 m.), regardless of the type of fishing boat. The change has been based on experience and after consideration of the buoyancy of the superstructures.

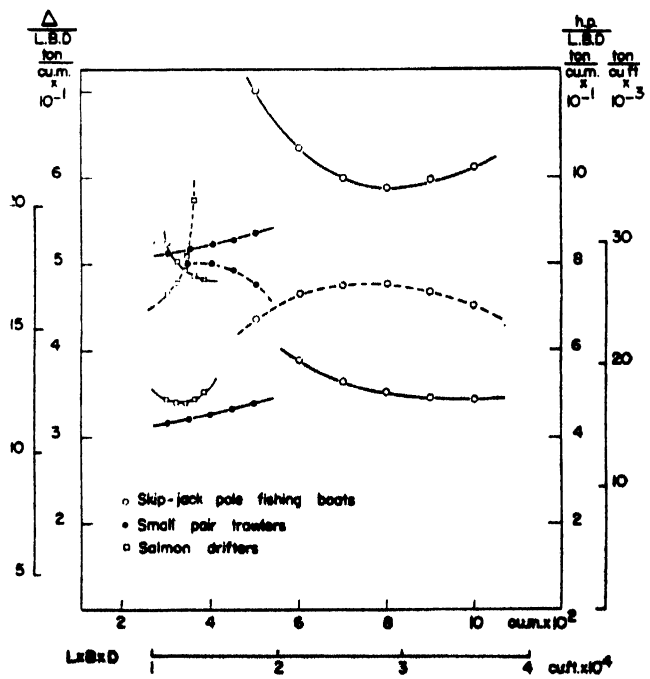


Fig. 521. Main particulars of Japanese pole fishing boats, small pair trawlers and salmon drifters (steel)

Freeboard varies with the type of fishing from 0.10D to 0.30D. A larger freeboard seems to have been adopted for new vessels. The larger the freeboard, the larger the angle at which the deck is submerged. This may be expressed:

$$\tan \varphi = f \Big/ \frac{B}{2} = 2f/B$$

in which φ represents the angle of inclination and f the freeboard. As the sheer increases, so does the angle of maximum stability, and the range of stability.

The safety of ships depends largely on the skipper, who, if careless, could endanger even those with adequate freeboard. It is desirable that the superstructures have few openings and that they be watertight. If not, superstructures could become dangerous to stability instead of adding to safety. Superstructure openings should not be placed on the side liable to exposure to waves. Unless unavoidable, no opening is made on the starboard of Japanese fishing boats, because this side is usually to wind and waves. The coamings should be as high as possible. There are many instances of boats being lost because of the apparently minor reason that water was shipped through low hatches, the covers of which were left open or had been washed away.

It is difficult to establish a freeboard criterion for fishing boats because their loads change during fishing. Skippers of boats with a sub-standard freeboard should be recommended to take precautionary measures in rough weather.

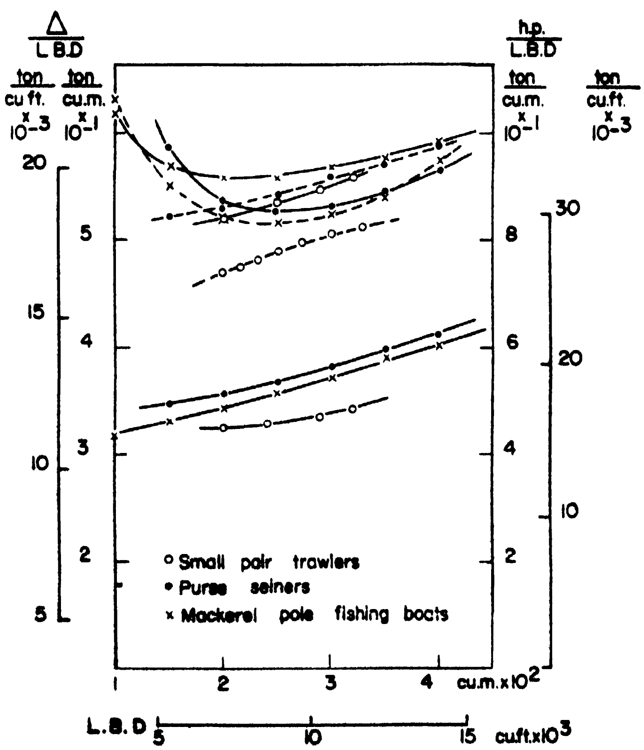


Fig. 522. Main particulars of Japanese small pair trawlers, purse seiners and mackerel pole fishing boats (wood)

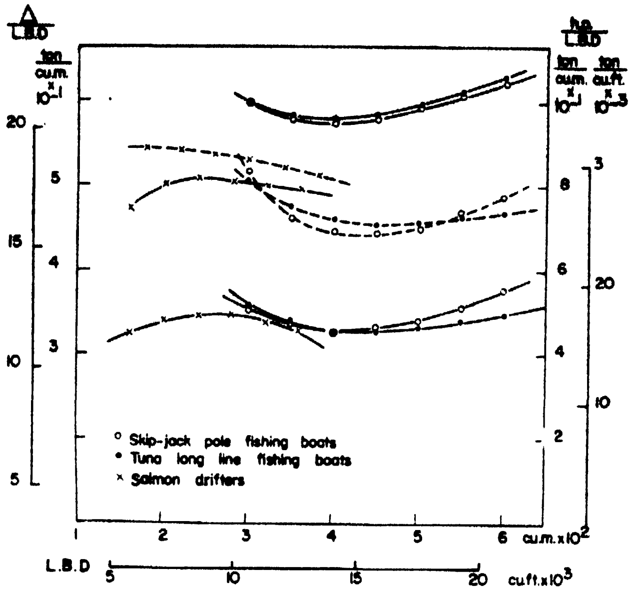


Fig. 523. Main particulars of Japanese skip-jack pole fishing boats, tuna longline fishing boats and salmon drifters (wood)

Draught and trim. Despite their small size, fishing boats need to make their way safely through wind, tide and waves, which calls for comparatively large power to produce the required speed at all loads. The stern has to be designed to maintain the draught to allow the screw to work effectively even in the light condition. With the increase of loads, the fore draught increases more than the aft draught. The aft draught in the light condition ranges between 0.85 and 1.05D, except for trawlers in which the range is 0.95 to 1.20D. Thus, deeper aft draught is necessary for trawlers, otherwise pitching would make the screws race. Once the ship is brought to a stop, the wind and waves would force her to turn round.

A deep draught is more important than a large freeboard in light condition for some fishing boats. For ease of navigation, vessels need to have proper trim by the stern. The fore draught, also, must be adequate to give directional stability in wind and waves.

GM. The metacentric height, GM, is used as a criterion for the stability. It is generally established that a trawler must have a GM value of over 1.25 ft. (380 mm.) in the light condition and over 2 ft. (610 mm.) in the load condition. It would be most desirable to determine a GM value for the worst condition in fishing. The minimum GM is established in Japan by the Fisheries Agency, and the value of GM in the load condition is required to be larger than those given below:

- **Purse seiners: The larger of the two values given by B/23+0.88 ft. (0.27 m.) or L/120+0.88 ft. (0.27 m.). If both values are less than 1.48 ft. (0.45 m.), 1.48 ft. (0.45 m.) is taken**

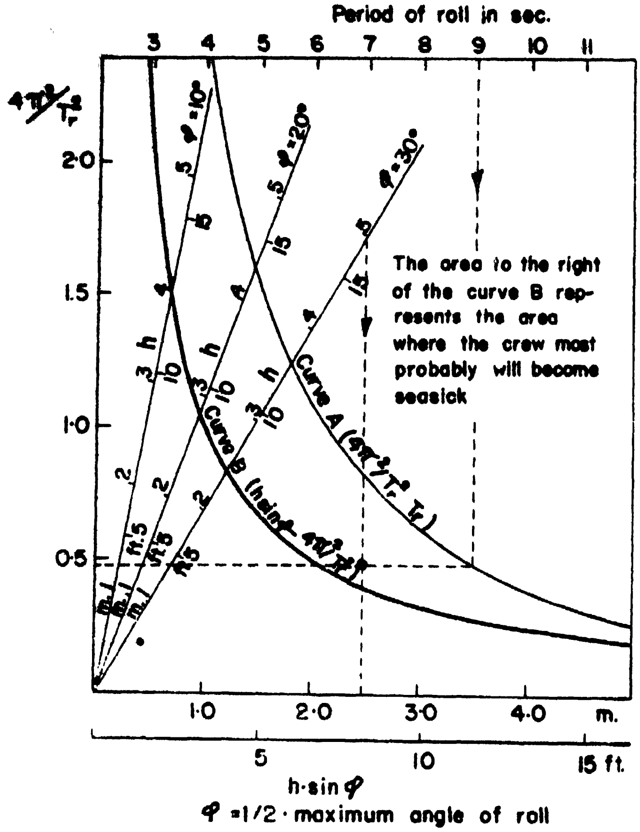


Fig. 524. Acceleration due to rolling

- Skipjack pole fishing boats: When B is smaller than 23 ft. (7 m.), the larger of the two values given by B/25+0.49 ft. (0.15 m.) and L/143+0.49 ft. (0.15 m.) or 1.41 ft. (0.43 m.). And when B is equal to or larger than 23 ft. (7 m.), the larger of the two following values is taken: [B-23 ft. (7 m.)]/12+1.41 ft.(0.43 m.) or [L-131.2 ft. (40 m.)]/70+1.41 ft. (0.43 m.)
- Other type boats: When B is smaller than 23 ft. (7 m.), the larger of the two values given by B/25+0.39 ft. (0.12 m.) or L/150+0.39 ft. (0.12 m.). And when B is equal to or larger than 23 ft. (7 m.), the larger of the two following values is taken: [B-23 ft. (7 m.)]/12+1.3 ft. (0.40 m.) or [L-138 ft. (42 m.)]/72+1.3 ft. (0.40 m.)

Until fishing boats reach the fishing grounds, their displacement decreases as fuel and other supplies are consumed, thereby changing the draught and trim and, naturally, the GM. The centre of gravity is highest and the GM smallest when the majority of the crew and catch are on the deck. The minimum value of the GM should then be 1.31 ft. (400 mm.). The value of the GM decreases in winter because of icing. Care must be taken to ensure that the GM never becomes negative. Japanese fishing boats keep the GM value between 1.48 ft. (450 mm.) and 1.97 ft. (600 mm.), depending on the type of ship. A GM value larger than necessary shortens the period of roll and increases acceleration, which has an unfavourable influence on the operational efficiency of the crew. In the load condition the distance of the metacentre from the keel, KM, increases and the GM tends to be excessively large. Such tendency could be prevented in the design.

KG/D. KG, the height of the centre of gravity above the keel, is determined by the distribution of the weight of the hull and the load distribution. KG must be fairly small even when the ship is loaded. In recent years, KG has increased because of larger superstructures, necessary to meet the need to fish on distant grounds. The ratio KG/D exceeds 0.80 in the light condition. In some vessels, however, KG/D exceeds 0.80 even in the load condition.

The superstructures influence a ship's stability unfavourably because of the exposure to wind and waves, but their buoyancy counteracts this to some extent.

Rolling period. The smaller the angle of roll and the longer the period, the more comfort for the crew. In general, the rolling period has the following relation to the stability:

$$T_r = \frac{2\pi\, k_t}{\sqrt{g.GM}} = \underset{\text{(ft.)}}{\frac{1.108 k_t}{\sqrt{GM}}} = \underset{\text{(m.)}}{\frac{2\, k_t}{\sqrt{GM}}}$$

The period of roll increases when the GM is small or the radius of gyration k_t is large. This means that the ship rolls more moderately. The GM cannot be too small. In order to increase k_t, the weights should be placed far away from the rolling centre. Side tanks filled with liquid have been proposed. Data on seasickness suggest that crews feel worse when the rolling acceleration exceeds 0.1 g, which equals 3.21 ft. (0.98 m.)/sec². This may be considered as 3.28 ft. (1.0 m.)/sec².

$$\frac{4\pi^2}{T_r^2}(h \sin \varphi) \geqq 0.1\ g \approx 3.28 \text{ ft. } (1 \text{ m.})/\text{sec}^2.$$

In the above φ is half the maximum angle of rolling. A 45° roll to one side may cause only a 15° incline to the other. The maximum angle of roll being 60°, φ is 30°. This is illustrated in a simple form in fig. 524, where the curve A is shown by the upper and left scale. From the period of roll $4\pi^2/T_r^2$ can be found, and h sin φ is indicated by the bottom scale and the three straight lines. The degree at which the rolling is accelerated can be seen by whether the co-ordinate expressed by $4\pi^2/T_r^2$ and h sin φ is on this side or on the other side of the curve B.

In estimating T_r from GM, or GM from T_r a problem is what value should be taken for k_t. With k_t=mB, the value of m ranges from 0.32 to 0.49. T_r of Japanese fishing boats is now being measured systematically. The measurements are taken when the ships are at anchor in a harbour and T_r includes the effect of the depth of water: therefore, the results can only be approximate. Few data have been obtained for the load condition. It is necessary, then, to use the figures obtained near the light condition. The range of m is between 0.32 and 0.54: from 0.39 to 0.45 for steel ships and from 0.44 to

0.51 for wooden boats. An approximate expression for $m = k_t/B$, by Kato (1956), is:

$$m^2 = \left(\frac{k_t}{B}\right)^2 = 0.125\frac{H^2}{B^2} + 0.020\frac{H}{T_0}\left(1 + 3.7\frac{T_1 - T_0}{T_1} + 0.027\right)$$

where $H = D + A/L$, T_0 = light draught, T_1 = load draught.

Comments on a few stability criteria

In the case of both trawlers and whale-catchers, the fishing techniques and the methods of construction of the vessels were introduced from Britain and Norway, and with this introduction came an established standard for GM and freeboard. GM was 1.25 ft. (380 mm.) in the light condition and 2 ft. (610 mm.) in the load condition. The freeboard was 2 ft. (610 mm.) or more depending on length. However, it was difficult to adopt this standard value of GM in trawlers with freezers in the superstructure and diesels instead of steam engines, having a larger KG/D. Designers and builders secretly installed costly ballast; this effort decreased load capacity. Bearing in mind how the fishing operation is actually carried out, designers should decide which is the more advantageous—to increase GM by changing the design or to carry ballast to lower the KG; the latter results in a smaller freeboard and decreases reserve buoyancy.

Many papers have been published on this problem, based on experience, especially in U.K. where so many fishing boats have been built. There are some indications that if 1.25 ft. (380 mm.) of GM is satisfactory in the light condition, a little less than 2 ft. (610 mm.) should be permissible in a load condition.

It has been discovered that a crew often operates a ship with half the GM value which the designer considered necessary. The ship has a longer period of roll and feels more comfortable, giving the crew a false sense of safety.

Rahola's (1939) work, based on extensive investigations, is valuable. It is very difficult, however, for Japanese fishing boats to fulfil a value greater than GZ=0.66 ft. (200 mm.) in the condition of 30° or even 40° of inclination. The vessels usually trim by the stern except when shipping a head sea or when a following sea submerges the stem and lifts the stern. It is unusual for the forecastle to be submerged for a long period, so that if this is included in the stability calculation, the GZ in some vessels is seldom as much as 0.66 ft. (200 mm.). Actually, the maximum value of GZ is generally only a little over 0.33 ft. (0.10 m.). Observation of larger cargo boats at sea proves that the forecastle should be included in stability calculations, which would permit, in the case of fishing boats, a lower criterion than proposed by Rahola.

De Wit (1955) states that the stability requirements of Dutch fishing vessels is based on Rahola's criterion. When compared with Japanese ships, these Dutch vessels seem to have somewhat larger freeboard and GM.

Japanese fishing boats of over 400 GT have freezers on deck and large fish holds, so it is difficult to give them as large a freeboard and value of GM as is considered necessary in Europe. Japanese trawlers operate in ice-free conditions.

Of the Japanese studies on stability, Kato's (1956) method was considered simple to judge the stability not only of fishing vessels, but of any other small ships. The method employs *safety index numbers* based on the data of ships which have the minimum permissible stability, according to Japanese experience. In considering this problem, an analysis has been made of the stability of small warships of the former Japanese Navy (Kawashima and Asakura, 1954).

Proposal for the assessment of fishing vessels' stability

In designing fishing boats, it is usual to look at similar vessels in operation. However, there are cases where operational requirements have resulted in less stability than desired. This made it necessary to carry ballast to lower the centre of gravity, which, in turn, resulted in too small a freeboard. However, the vessels were safely operated because the crew knew of the defects and counteracted them. But there have been ships which were considered to have maximum stability but which capsized.

In calculating the righting arms, the watertight superstructures—the poop, deckhouse and back—are included. For fishing boats, it is necessary to consider the changes when they trim by the stern. The author does not consider it reasonable to include a forecastle in the superstructure because it has effective buoyancy only when a ship lists considerably. In comparing ships, all conditions must be equal.

Tables 122 to 133 show the stability data of 96 Japanese fishing boats classified in six types of steel and six types of wooden boats, each represented by eight ships. The data are chosen at random. Both light and load conditions are given. "Light" means a ship without load, weight of the crew and fishing gear: it is the weight of the ship only. "Load" means a ship fully loaded, carrying the crew and effects, fishing gear, fuel, provisions, fresh water, fish bait, ice and other supplies. Sometimes a ship displaces a greater tonnage when leaving the fishing grounds than when leaving port but the two conditions are assumed to be the same in these tables. KM and KB were obtained from the hydrostatic curves. The breadth, B, does not include the thickness of shell plates, although they are quite thick in wooden boats. Consequently the real KB of the wooden ships in the examples is greater than that of steel ships.

In some ships the GM hardly reaches 1.48 ft. (450 mm.), although designed to be from 1.48 to 1.97 ft. (450 to 600 mm.), according to Japanese regulations. This defect is often compensated for by a large freeboard. GM could be increased by increasing B, but this might again produce a greater value of KG/D.

In discussing freeboard, the angle at which the deck is submerged is important. Up to this angle, GZ is increasing. Generally speaking, the larger the ship, the larger the value of 2f/B. When tan φ is from 0.12 to 0.22, φ is between 7° and 12° in the full load condition. The maximum arm in a statical stability curve are normally twice the angle to which the deck is submerged, or 14°

TABLE 122. Stability data of trawlers (steel)

Item		Taiyo Maru No. 55		Uji Maru		Kawachi Maru		Taiyo Maru No. 51		Taiyo Maru		Yamashiro Maru		Ikoma Maru		Taiyo Maru No 37.	
L×B×D	ft.	144.3×24.28×13.45		167.0×26.90×14.76		136.9×23.62×13.29		226.4×37.40×18.70		153.9×26.90×14.27		146.9×23.94×13.78		211.5×34.44×17.39		184.3×31.17×16.70	
	m.	44.00×7.40×4.10		50.90×8.20×4.50		41.74×7.20×4.05		69.00×11.40×5.70		46.90×8.20×4.35		44.80×7.30×4.20		64.46×10.50×5.30		56.17×9.50×5.09	
GT		369.79		535.06		300.21		1,489		495.22		349.21		994.83		744.42	
h.p.		700		1,000		700		1,800		850		700		1,200		1,200	
Built		1956		1956		1957		1957		1956		1955		1954		1954	
CN	cu. ft.	47,110		66,321		42,978		158,317		59,046		48,523		128,547		95,915	
	cu. m.	1,334		1,878		1,217		4,483		1,672		1,374		3,640		2,716	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	2.85	7.25	3.02	6.99	3.12	9.02	0.88	3.87	3.28	7.91	2.76	10.00	3.94	8.83	5.05	10.27
	m.	0.87	2.21	0.92	2.13	0.95	2.75	0.27	1.18	1.00	2.41	0.84	3.05	1.20	2.69	1.54	3.13
T_a	ft.	13.58	14.50	15.87	17.75	13.78	13.65	16.30	20.01	14.04	14.43	14.50	13.42	14.34	15.06	14.50	15.38
	m.	4.14	4.42	4.84	5.41	4.20	4.16	4.97	6.10	4.28	4.40	4.42	4.09	4.37	4.59	4.42	4.69
T	ft.	8.22	10.87	9.44	12.37	8.45	11.33	8.59	11.94	8.66	11.17	8.63	11.71	9.14	11.94	9.77	12.82
	m.	2.51	3.31	2.88	3.77	2.57	3.45	2.62	3.64	2.64	3.40	2.63	3.57	2.79	3.64	2.98	3.91
Δ	ton	433.51	654.17	718.47	1,052.78	415.23	630.40	1,151.04	1,795.67	553.36	795.33	469.07	714.79	1,068.20	1,509.03	327.44	1,198.06
f	ft.	6.07	3.44	5.94	3.02	5.47	2.59	10.17	6.82	6.43	3.94	5.90	2.82	8.92	6.13	7.55	4.56
	m.	1.85	1.05	1.81	0.92	1.67	0.79	3.10	2.08	1.96	1.20	1.80	0.86	2.72	1.87	2.30	1.39
KM	ft.	11.61	11.38	12.14	12.40	11.29	11.25	19.07	17.03	13.15	12.82	11.85	11.42	16.50	15.52	14.90	14.54
	m.	3.54	3.47	3.70	3.78	3.44	3.43	5.81	5.19	4.01	3.91	3.61	3.48	5.03	4.73	4.54	4.43
KB	ft.	4.42	6.86	5.12	6.89	4.43	6.24	4.73	6.66	4.69	6.14	5.06	6.53	4.99	6.53	5.51	7.19
	m.	1.35	2.09	1.56	2.10	1.35	1.90	1.44	2.03	1.43	1.87	1.54	1.99	1.52	1.99	1.68	2.19
KG	ft.	10.46	9.48	11.42	10.33	9.91	8.96	17.13	14.27	11.48	10.20	10.47	9.35	13.91	12.50	13.06	11.75
	m.	3.19	2.89	3.48	3.15	3.02	2.73	5.22	4.35	3.50	3.11	3.19	2.85	4.24	3.81	3.98	3.58
GM	ft.	1.15	1.90	0.72	2.07	1.38	2.29	1.94	2.76	1.67	2.62	1.38	2.07	2.59	3.02	1.84	2.79
	m.	0.35	0.58	0.22	0.63	0.42	0.70	0.59	0.84	0.51	0.80	0.42	0.63	0.79	0.92	0.56	0.85
BG	ft.	6.04	2.62	6.30	3.44	5.48	2.72	12.40	7.61	6.79	4.06	5.41	2.82	8.92	5.97	7.55	4.56
	m.	1.84	0.80	1.92	1.05	1.67	0.83	3.78	2.32	2.07	1.24	1.65	0.86	2.72	1.82	2.30	1.39
T_r	sec.	8.41	—	—	—	—	—	10.16	—	9.1	—	—	—	—	—	—	—
$m=k_t/B$		0.335	—	—	—	—	—	0.340	—	0.394	—	—	—	—	—	—	—
2f/B		0.503	0.285	0.442	0.224	0.464	0.219	0.545	0.365	0.480	0.293	0.495	0.238	0.517	0.354	0.488	0.293
GM/BG		0.19	0.72	0.11	0.60	0.25	0.84	0.15	0.362	0.25	0.65	0.25	0.73	0.29	0.50	0.24	0.61
2f/B×GM/BG		0.096	0.206	0.048	0.135	0.117	0.185	0.085	0.132	0.120	0.189	0.126	0.174	0.150	0.179	0.119	0.179
BG/f		0.995	0.76	1.06	1.14	1.00	1.05	1.22	1.11	1.05	1.03	0.92	1.00	1.00	0.97	1.00	1.00

TABLE 123. Stability data of whale catchers (steel)

Item		Katsu Maru		Seki Maru No. 17		Konan Maru No. 26		Konan Maru No. 18		Fumi Maru No. 17		Kyo Maru No. 11		Seki Maru No. 15		Konan Maru No. 8	
L×B×D	ft.	171.5×28.71×15.22		186.8×30.83×16.40		196.4×31.82×16.67		196.4×31.82×16.73		187.1×30.84×16.37		194.1×31.17×16.67		179.4×30.12×16.08		163.3×27.89×14.76	
	m.	52.27×8.75×4.64		56.95×9.40×5.00		59.85×9.70×5.08		59.85×9.70×5.10		57.04×9.40×4.99		59.15×9.50×5.08		54.69×9.18×4.90		49.78×8.50×4.50	
GT		494.83		650.07		743.48		741.61		647.18		696.94		598.65		471.34	
h.p.		2,700		3,000		3,280		3,280		3,000		3,500		3,000		2,200	
Built		1956		1956		1957		1956		1955		1956		1953		1952	
CN	cu. ft.	74,939		94,503		104,144		104,568		94,468		100,789		86,804		67,240	
	cu. m.	2,122		2,676		2,949		2,961		2,675		2,854		2,458		1,904	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	7.81	10.50	7.55	10.30	7.48	11.94	7.51	13.81	7.74	8.89	8.46	12.17	6.36	11.02	6.96	9.48
	m.	2.38	3.20	2.30	3.14	2.28	3.64	2.29	4.21	2.36	2.71	2.58	3.71	1.94	3.36	2.12	2.89
T_a	ft.	12.73	15.42	13.68	16.57	14.57	16.90	14.43	16.27	13.68	15.03	13.45	16.37	14.17	15.91	12.73	15.35
	m.	3.88	4.70	4.17	5.05	4.44	5.15	4.40	4.96	4.17	4.58	4.10	4.99	4.32	4.85	3.88	4.68
T	ft.	10.27	12.96	10.62	13.44	11.02	14.42	10.97	15.04	10.71	11.96	10.95	14.27	10.26	13.46	9.84	12.43
	m.	3.13	3.95	3.24	4.10	3.36	4.40	3.35	4.59	3.26	3.64	3.34	4.35	3.13	4.11	3.00	3.79
Δ	ton	643.91	926.19	772.97	1,113.80	897.44	1,335.35	885.52	1,407.04	781.61	927.81	815.49	1,248.38	720.29	1,066.27	604.06	859.00
f	ft.	5.28	2.59	6.07	3.24	5.94	2.53	6.04	1.97	5.74	4.49	6.07	2.76	5.87	2.66	5.18	2.59
	m.	1.61	0.79	1.85	0.99	1.81	0.77	1.84	0.60	1.75	1.37	1.85	0.84	1.79	0.81	1.58	0.79
KM	ft.	14.04	14.21	15.02	15.16	15.91	16.01	15.91	16.04	15.06	15.06	16.01	16.15	14.47	14.63	13.91	13.88
	m.	4.28	4.33	4.58	4.62	4.85	4.88	4.85	4.89	4.59	4.59	4.88	4.92	4.41	4.46	4.24	4.23
KB	ft.	6.30	7.91	6.46	8.20	6.82	8.79	6.79	9.12	6.56	7.32	6.96	8.86	6.30	8.10	6.04	7.55
	m.	1.92	2.41	1.97	2.50	2.08	2.68	2.07	2.78	2.00	2.23	2.12	2.70	1.92	2.47	1.84	2.30
KG	ft.	12.50	11.72	13.25	12.40	14.27	13.06	14.37	13.42	12.96	12.37	14.76	13.26	12.40	11.87	12.14	11.49
	m.	3.81	3.57	4.04	3.78	4.35	3.98	4.38	4.09	3.95	3.37	4.50	4.04	3.78	3.62	3.70	3.50
GM	ft.	1.54	2.49	1.77	2.76	1.64	2.95	1.54	2.62	2.10	2.69	1.25	2.89	2.07	2.76	1.77	2.39
	m.	0.47	0.76	0.54	0.84	0.50	0.90	0.47	0.80	0.64	0.82	0.38	0.88	0.63	0.84	0.54	0.73
BG	ft.	6.20	3.81	6.79	4.20	7.45	4.27	7.58	4.30	6.40	5.05	7.81	4.40	6.10	3.77	6.10	3.94
	m.	1.89	1.16	2.07	1.28	2.27	1.30	2.31	1.31	1.96	1.54	2.38	1.34	1.86	1.15	1.86	1.20
T_r	sec.	9.11	—	9.6	—	—	—	—	—	9	—	10	—	—	—	9.11	—
$m=k_t/B$		0.356	—	0.312	—	—	—	—	—	0.380	—	0.323	—	—	—	0.386	—
2f/B		0.369	0.181	0.394	0.211	0.373	0.158	0.380	0.124	0.373	0.293	0.389	0.177	0.390	0.177	0.372	0.188
GM/BG		0.25	0.65	0.26	0.65	0.22	0.69	0.20	0.61	0.33	0.53	0.15	0.65	0.34	0.73	0.29	0.61
2f/B×GM/BG		0.092	0.119	0.102	0.137	0.082	0.110	0.076	0.075	0.123	0.155	0.058	0.116	0.132	0.129	0.108	0.115
BG/f		1.18	1.47	1.12	1.29	1.25	1.69	1.25	2.18	1.11	1.12	1.29	1.60	1.04	1.42	1.18	1.62

TABLE 124. **Stability data of tuna long line fishing boats (steel)**

Item		*Eitai Maru*		*Kyowa Maru*		*Konpira Maru No. 11*		*Takatori Maru No. 11*		*Suijin Maru No. 1*		*Kinryu Maru*		*Sumiyoshi Maru No. 28*		*Koyo Maru No. 18*	
L × B × D	ft.	154.2 × 26.75 × 13.12		122.0 × 21.98 × 11.15		126.3 × 22.97 × 11.48		140.5 × 24.61 × 12.47		157.5 × 27.56 × 13.94		184.7 × 30.18 × 15.42		170.6 × 29.53 × 14.60		136.8 × 24.6 × 12.47	
	m.	47.00 × 8.00 × 4.00		37.18 × 6.70 × 3.40		38.50 × 7.00 × 3.50		42.81 × 7.50 × 3.80		48.00 × 8.40 × 4.25		56.30 × 9.20 × 4.70		56.00 × 9.00 × 4.45		41.70 × 7.50 × 3.80	
GT		457.26		232.95		276.26		361.09		498.12		748.48		647.75		349.21	
h.p.		850		650		550		650		1,000		1,200		1,000		650	
Built		1954		1956		1957		1957		1956		1956		1956		1958	
CN	cu. ft.	50,112		29,876		33,302		43,084		60,495		85,957		73,526		41,954	
	cu. m.	1,419		846		943		1,220		1,713		2,434		2,082		1,188	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	3.12	9.51	2.79	6.56	3.41	7.64	3.18	6.92	2.99	7.18	2.16	8.76	3.38	10.30	1.31	6.96
	m.	0.95	2.90	0.85	2.00	1.04	2.33	0.97	2.11	0.91	2.19	0.69	2.67	1.03	3.14	0.40	2.12
T_a	ft.	10.99	13.12	10.01	12.11	10.30	12.83	9.65	13.16	12.04	15.45	12.17	14.57	12.63	16.11	11.78	13.62
	m.	3.35	4.00	3.05	3.69	3.14	3.91	2.94	4.01	3.67	4.71	3.71	4.44	3.85	4.91	3.59	4.15
T	ft.	7.05	11.32	6.40	9.32	6.86	10.24	6.42	10.04	7.51	11.32	7.22	11.65	8.00	13.20	6.54	10.29
	m.	2.15	3.45	1.95	2.84	1.09	3.12	1.95	3.06	2.29	3.45	2.20	3.55	2.44	4.02	1.99	3.13
Δ	ton	489.03	904.83	293.58	471.00	351.00	600.00	384.63	680.72	553.00	951.00	713.36	1.286.10	662.30	1,263.70	405.11	701.37
f	ft.	6.36	2.10	4.69	1.77	4.89	1.51	6.27	2.62	6.73	2.92	8.50	4.04	7.12	1.94	6.40	2.66
	m.	1.94	0.64	1.43	0.54	1.49	0.46	1.91	0.80	2.05	0.89	2.59	1.24	2.17	0.59	1.95	0.81
KM	ft.	12.80	12.01	10.67	10.14	11.09	10.93	12.15	11.19	12.97	12.70	15.09	13.49	14.53	13.58	12.93	11.29
	m.	3.90	3.66	3.25	3.09	3.38	3.33	3.70	3.41	3.95	3.87	4.60	4.11	4.43	4.14	3.94	3.44
KB	ft.	3.97	6.40	3.71	5.25	3.97	5.91	3.58	5.61	4.40	6.63	4.07	6.50	4.36	7.25	3.81	5.87
	m.	1.21	1.95	1.13	1.60	1.21	1.80	1.09	1.71	1.34	2.02	1.24	1.98	1.33	2.21	1.16	1.79
KG	ft.	11.09	9.25	8.57	8.20	9.58	8.80	10.54	9.58	12.08	10.60	13.06	11.29	13.12	11.32	10.80	9.22
	m.	3.38	2.82	2.61	2.50	2.92	2.68	3.21	2.92	3.68	3.23	3.98	3.44	4.00	3.45	3.29	2.81
GM	ft.	1.71	2.76	2.10	1.94	1.51	2.13	1.61	1.61	0.89	2.10	2.03	2.20	1.41	2.26	2.13	2.07
	m.	0.52	0.84	0.64	0.59	0.46	0.65	0.49	0.49	0.27	0.64	0.62	0.67	0.43	0.69	0.65	0.63
BG	ft.	7.12	2.85	4.86	2.95	5.61	2.89	6.96	3.97	7.68	3.97	8.99	4.79	8.76	4.07	6.99	3.35
	m.	2.17	0.87	1.48	0.90	1.71	0.88	2.12	1.21	2.34	1.21	2.74	1.46	2.67	1.24	2.13	1.02
T_r	sec.	8.4	—	8.4	—	—	—	9.9	—	—	—	9.26	—	10.20	—	7.73	—
$m = k_t/B$		0.376	—	0.497	—	—	—	0.459	—	—	—	0.393	—	0.370	—	0.425	—
2f/B		0.485	0.160	0.427	0.163	0.421	0.132	0.507	0.213	0.487	0.212	0.564	0.268	0.482	0.130	0.520	0.216
GM/BG		0.24	0.96	0.43	0.65	0.27	0.74	0.23	0.40	0.15	0.53	0.23	0.46	0.16	0.55	0.30	0.62
2f/B × GM/BG		0.116	0.155	0.185	0.105	0.113	0.097	0.117	0.085	0.058	0.112	0.129	0.123	0.077	0.072	0.159	0.133
BG/f		1.12	1.36	1.03	1.67	1.15	1.91	1.11	1.52	1.14	1.36	1.05	1.18	1.23	2.10	1.09	1.26

TABLE 125. **Stability data of skip-jack pole fishing boats (steel)**

Item		*Konpir Maru No. 3*		*Azuma Maru No. 5*		*Katsuei Maru No. 5*		*Kyowa Maru*		*Kailin Maru*		*Wako Maru No. 2*		*Hiyoshi Maru*		*Shoichi Maru No. 11*	
L × B × D	ft.	103.0 × 20.34 × 10.17		108.3 × 21.00 × 10.83		108.2 × 20.34 × 10.33		122.0 × 21.98 × 11.15		124.7 × 23.62 × 11.97		115.94 × 21.98 × 11.15		113.4 × 21.65 × 11.15		111.7 × 21.98 × 10.99	
	m.	31.40 × 6.20 × 3.10		33.00 × 6.40 × 3.30		32.98 × 6.20 × 3.15		37.18 × 6.70 × 3.40		38.00 × 7.20 × 3.65		35.34 × 6.70 × 3.40		34.55 × 6.60 × 3.40		34.04 × 6.70 × 3.35	
GT		179.23		210.49		179.91		232.92		303.34		251.82		231.37		227.08	
h.p.		450		500		500		650		750		600		550		500	
Built		1955		1957		1957		1956		1957		1955		1954		1955	
CN	cu. ft.	21,295		24,579		22,743		29,876		35,244		27,616		27,369		26,980	
	cu. m.	603		696		644		846		998		782		775		764	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	3.48	6.46	5.25	8.79	4.23	7.54	2.79	6.56	3.02	7.55	2.76	7.38	2.06	6.42	3.97	7.68
	m.	1.06	1.97	1.60	2.68	1.29	2.30	0.85	2.00	0.92	2.30	0.84	2.25	0.63	1.96	1.21	2.34
T_a	ft.	10.24	11.84	7.09	10.76	8.56	11.22	10.01	12.11	11.65	14.70	9.84	11.84	10.63	12.75	8.50	11.15
	m.	3.12	3.61	2.16	3.28	2.61	3.42	3.05	3.69	3.55	4.48	3.00	3.61	3.24	3.89	2.59	3.40
T	ft.	6.86	9.15	6.17	9.78	6.40	9.38	6.40	9.33	7.33	11.12	6.30	9.61	6.34	9.58	6.23	9.41
	m.	2.09	2.79	1.88	2.98	1.95	2.86	1.95	2.84	2.23	3.39	1.92	2.93	1.93	2.92	1.90	2.87
Δ	ton	243.09	398.00	246.02	444.5	253.9	412.5	293.58	472.00	370.48	640.50	271.50	478.00	271.01	461.00	275.91	464.14
f	ft.	4.07	1.77	4.92	1.31	4.20	1.21	5.01	2.10	5.22	1.41	5.12	1.80	5.05	1.84	4.99	1.80
	m.	1.24	0.54	1.50	0.40	1.28	0.37	1.53	0.64	1.59	0.43	1.56	0.55	1.54	0.55	1.52	0.55
KM	ft.	9.84	9.68	10.24	9.97	9.38	9.38	10.67	10.14	12.10	11.05	10.99	10.43	10.33	10.00	10.69	9.71
	m.	3.00	2.95	3.12	3.04	2.86	2.86	3.25	3.09	3.69	3.37	3.35	3.18	3.15	3.05	3.26	2.96
KB	ft.	3.58	5.35	3.51	5.51	3.58	5.25	3.71	5.25	3.97	6.07	3.64	5.48	3.54	5.54	3.61	5.38
	m.	1.09	1.63	1.07	1.68	1.09	1.60	1.13	1.60	1.21	1.85	1.11	1.67	1.08	1.69	1.10	1.64
KG	ft.	8.07	7.45	9.19	8.20	8.33	7.42	8.57	8.20	0.33	9.38	8.86	7.94	9.18	7.90	8.56	7.97
	m.	2.46	2.27	2.80	2.50	2.54	2.26	2.61	2.50	3.15	2.86	2.70	2.42	2.80	2.41	2.61	2.43
GM	ft.	1.77	2.23	1.05	1.77	1.05	1.96	2.10	1.94	1.77	1.67	2.13	2.49	1.15	2.10	2.13	1.74
	m.	0.54	0.68	0.32	0.54	0.32	0.60	0.64	0.59	0.54	0.51	0.65	0.76	0.35	0.64	0.65	0.53
BG	ft.	4.49	2.10	5.64	2.69	4.76	2.17	4.86	2.95	6.36	3.31	5.22	2.46	5.64	2.36	4.95	2.59
	m.	1.37	0.64	1.73	0.82	1.45	0.66	1.48	0.90	1.94	1.01	1.59	0.75	1.72	0.72	1.51	0.79
T_r	sec.	—	—	—	—	10.1	—	8.4	—	8.1	—	7.7	—	7.9	—	—	—
$m = k_t/B$		—	—	—	—	0.523	—	0.497	—	0.411	—	0.460	—	0.352	—	—	—
2f/B		0.400	0.174	0.468	0.125	0.412	0.119	0.456	0.188	0.440	0.119	0.465	0.164	0.466	0.159	0.453	0.164
GM/BG		0.39	0.106	0.18	0.66	0.22	0.91	0.43	0.65	0.28	0.50	0.41	1.01	0.20	0.89	0.43	0.67
2f/B × GM/BG		0.158	0.185	0.086	0.082	0.091	0.108	0.197	0.123	0.123	0.060	0.191	0.166	0.095	0.141	0.195	0.110
BG/f		1.10	1.18	1.15	2.05	1.13	1.78	0.97	1.41	1.22	2.35	1.02	1.36	1.11	1.31	0.99	1.44

TABLE 126. Stability data of small pair trawlers (steel)

Item		Aoba Maru		Ebisu Maru No. 22		Akashi Maru No. 33		Taiei Maru No. 13	
L×B×D	ft.	95.93×17.72×8.86		86.25×16.40×8.53		86.94×17.72×8.37		81.92×16.73×8.20	
	m.	29.24×5.40×2.70		26.29×5.00×2.60		26.50×5.40×2.55		24.97×5.10×2.50	
GT		108.19		79.39		95.97		84.81	
h.p.		270		270		310		250	
Built		1956		1956		1956		—	
CN	cu. ft.	15,044		12,042		12,854		11,689	
	cu. m.	426		341		364		331	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	3.48	6.82	3.35	5.48	2.23	4.95	2.39	5.02
	m.	1.06	2.08	1.02	1.67	0.68	1.51	0.73	1.53
T_a	ft.	9.12	10.10	8.27	10.01	8.46	9.48	8.20	9.68
	m.	2.78	3.08	2.52	3.05	2.58	2.89	2.50	2.95
T	ft.	6.30	8.46	5.81	7.74	5.35	7.22	5.29	7.35
	m.	1.92	2.58	1.77	2.36	1.63	2.20	1.61	2.24
Δ	ton	155.20	241.25	111.33	175.36	118.25	188.24	101.92	169.55
f	ft.	3.31	1.15	3.44	1.51	3.74	1.87	4.04	1.97
	m.	1.01	0.35	1.05	0.46	1.14	0.57	1.23	0.60
KM	ft.	8.66	8.56	7.87	7.91	8.76	8.43	8.27	8.07
	m.	2.64	2.61	2.40	2.41	2.67	2.57	2.52	2.46
KB	ft.	3.38	4.40	3.15	4.33	2.76	3.90	2.89	4.10
	m.	1.03	1.34	0.96	1.32	0.84	1.19	0.88	1.25
KG	ft.	7.09	6.67	6.46	6.63	7.12	6.69	6.30	5.90
	m.	2.16	2.06	1.97	2.02	2.17	2.04	1.92	1.80
GM	ft.	1.57	1.80	1.41	1.28	1.64	1.74	1.97	2.17
	m.	0.48	0.55	0.43	0.39	0.50	0.53	0.60	0.66
BG	ft.	3.71	2.36	3.31	2.30	4.36	2.79	3.41	1.80
	m.	1.13	0.72	1.01	0.70	1.33	0.85	1.04	0.55
T_r	sec.	7.1	—	7.4	—	—	—	5.2	—
$B = k_t/B$		0.454	—	0.482	—	—	—	0.393	—
2f/B		0.373	0.129	0.420	0.184	0.421	0.211	0.478	0.235
GM/BG		0.42	0.76	0.32	0.56	0.37	0.62	0.57	1.20
2f/B × GM/BG		0.156	0.098	0.134	0.102	0.156	0.131	0.272	0.282
BG/f		1.12	2.06	0.96	1.52	1.17	1.49	1.85	0.92

Item		Nichibei Maru No. 12		Nichibei Maru No. 16		Akashi Maru No. 177		Nitto Maru No. 71	
L×B×D	ft.	88.58×17.88×8.73		91.86×17.88×8.69		91.86×17.88×8.69		87.83×19.36×9.35	
	m.	27.00×5.45×2.66		28.00×5.45×2.65		28.00×5.45×2.65		29.85×5.90×2.85	
GT		95.29		94.20		98.08		135.45	
h.p.		250		340		310		300	
Built		1956		1956		1957		1957	
CN	cu. ft.	13,808		14,267		14,267		17,728	
	cu. m.	391		404		404		502	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	2.10	5.31	2.17	5.45	1.80	6.36	3.14	5.12
	m.	0.64	1.62	0.66	1.66	0.55	1.94	0.96	1.59
T_a	ft.	8.33	9.58	8.20	9.58	8.83	8.86	9.08	11.67
	m.	2.54	2.92	2.50	2.92	2.69	2.70	2.77	3.56
T	ft.	5.22	7.45	5.18	7.51	5.31	7.61	6.11	8.44
	m.	1.59	2.27	1.58	2.29	1.62	2.32	1.86	2.57
Δ	ton	117.21	198.15	123.33	210.46	128.13	212.90	175.95	277.61
f	ft.	4.20	1.97	4.20	1.87	4.13	1.84	3.97	1.64
	m.	1.28	0.60	1.28	0.57	1.26	0.56	1.21	0.50
KM	ft.	8.63	8.27	8.66	8.30	8.60	8.30	8.83	8.79
	m.	2.63	2.52	2.64	2.53	2.62	2.53	2.69	2.68
KB	ft.	2.72	4.04	2.72	4.07	2.79	4.07	3.15	4.82
	m.	0.83	1.23	0.83	1.24	0.85	1.24	0.96	1.47
KG	ft.	7.25	6.83	6.82	6.36	6.86	6.33	7.58	7.58
	m.	2.21	2.08	2.08	1.94	2.09	1.93	2.31	2.31
GM	ft.	1.38	1.44	1.84	1.94	1.74	1.93	1.25	1.21
	m.	0.42	0.44	0.56	0.59	0.53	0.60	0.38	0.37
BG	ft.	4.53	2.78	4.10	2.30	4.07	2.26	4.43	2.76
	m.	1.38	0.85	1.25	0.70	1.24	0.69	1.35	0.84
T_r	sec.	6.23	—	6.06	—	6.46	—	8.3	—
$B = k_t/B$		0.371	—	0.416	—	0.430	—	0.432	—
2f/B		0.469	0.220	0.471	0.209	0.459	0.206	0.412	0.171
GM/BG		0.30	0.52	0.45	0.84	0.43	0.87	0.28	0.44
2f/B × GM/BG		0.141	0.114	0.212	0.176	0.197	0.179	0.115	0.075
BG/f		1.08	1.42	0.98	1.23	0.98	1.23	1.12	1.68

TABLE 127. Stability data of salmon drifters (steel)

Item		Okuni Maru No. 35		Kinsei Maru No. 8		Kyokko Maru No. 8		Hatto Maru No. 25	
L×B×D	ft.	85.30×18.04×8.53		86.97×17.88×8.20		85.30×18.37×8.20		85.30×18.37×8.20	
	m.	26.00×5.50×2.60		26.51×5.45×2.50		26.00×5.60×2.50		26.00×5.60×2.50	
GT		84.49		84.53		83.61		84.92	
h.p.		340		320		340		340	
Built		1956		1956		1956		1956	
CN	cu. ft.	15,102		12,749		12,855		12,855	
	cu. m.	371		361		364		364	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	13.54	4.17	3.51	4.10	3.35	4.59	2.82	2.53
	m.	1.08	1.27	1.07	1.25	1.02	1.40	0.86	0.77
T_a	ft.	8.30	10.73	8.10	10.76	7.64	9.58	7.81	9.42
	m.	2.53	3.27	2.47	3.28	2.33	2.92	2.38	2.87
T	ft.	5.92	7.45	5.81	7.43	5.49	7.09	5.31	5.97
	m.	1.80	2.27	1.77	2.26	1.67	2.16	1.62	1.82
Δ	ton	140.30	199.90	129.45	195.23	136.74	199.91	129.98	183.49
f	ft.	3.35	1.80	3.15	1.54	3.44	1.84	3.58	2.92
	m.	1.02	0.55	0.96	0.47	1.05	0.56	1.09	0.89
KM	ft.	8.56	8.56	8.76	8.60	9.18	8.76	9.45	9.09
	m.	2.61	2.61	2.67	2.62	2.80	2.67	2.88	2.77
KB	ft.	3.05	4.04	3.15	4.13	2.89	3.84	2.89	3.28
	m.	0.93	1.23	0.96	1.26	0.88	1.17	0.88	1.00
KG	ft.	6.95	7.41	7.32	7.25	6.76	6.96	7.74	7.74
	m.	2.12	2.26	2.23	2.21	2.06	2.12	2.36	2.36
GM	ft.	1.61	1.15	1.44	1.35	2.43	1.80	1.71	1.35
	m.	0.49	0.35	0.44	0.41	0.74	0.55	0.52	0.41
BG	ft.	3.90	3.38	4.17	3.12	3.87	3.12	4.86	4.46
	m.	1.19	1.03	1.27	0.95	1.18	0.95	1.48	1.36
T_r	sec.	—	—	6.9	—	5.5	—	7.0	—
$m = k_t/B$		—	—	0.416	—	0.420	—	0.448	—
2f/B		0.372	0.200	0.360	0.173	0.372	0.200	0.390	0.318
GM/BG		0.41	0.34	0.35	0.43	0.62	0.58	0.35	0.30
2f/B × GM/BG		0.152	0.068	0.126	0.074	0.231	0.116	0.136	0.095
BG/f		1.16	1.88	1.32	2.02	1.12	1.70	1.36	1.53

Item		Fuku Maru No. 6		Choei Maru No. 15		Tsune Maru No. 15		Konpira Maru No. 17	
L×B×D	ft.	83.46×17.39×7.87		83.37×17.72×8.53		84.35×17.72×8.04		81.36×18.37×8.37	
	m.	25.44×5.30×2.40		25.41×5.40×2.60		25.71×5.40×2.45		24.80×5.60×2.55	
GT		81.10		83.74		83.10		84.87	
h.p.		300		340		310		340	
Built		1956		1956		1956		1956	
CN	cu. ft.	11,407		12,572		12,007		12,431	
	cu. m.	323		356		340		352	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	2.30	3.51	3.28	4.43	2.62	4.27	2.39	4.17
	m.	0.70	1.07	1.00	1.35	0.80	1.30	0.73	1.27
T_a	ft.	7.15	9.12	8.14	9.74	8.01	9.45	9.42	10.79
	m.	2.18	2.78	2.48	2.79	2.44	2.88	2.87	3.29
T	ft.	4.72	6.32	5.71	7.09	5.31	6.86	5.91	7.48
	m.	1.44	1.92	1.74	2.16	1.62	2.09	1.80	2.28
Δ	ton	93.67	148.01	116.64	163.13	116.13	170.04	129.39	186.57
f	ft.	3.84	2.26	3.64	2.26	3.48	1.94	3.18	1.61
	m.	1.17	0.69	1.11	0.69	1.06	0.59	0.97	0.49
KM	ft.	10.43	8.76	8.92	8.82	8.89	8.40	8.86	8.86
	m.	3.18	2.67	2.72	2.69	2.71	2.56	2.70	2.70
KB	ft.	2.69	3.61	3.08	3.90	2.82	3.67	3.15	4.04
	m.	0.82	1.10	0.94	1.19	0.86	1.12	0.96	1.23
KG	ft.	7.38	7.09	7.02	7.54	7.15	7.25	6.99	7.09
	m.	2.25	2.16	2.14	2.30	2.18	2.21	2.13	2.16
GM	ft.	3.05	1.67	1.90	1.28	1.74	1.15	1.87	1.77
	m.	0.93	0.51	0.58	0.39	0.53	0.35	0.57	0.54
BG	ft.	4.69	3.48	3.94	3.64	4.33	3.58	3.84	3.05
	m.	1.43	1.06	1.20	1.11	1.32	1.09	1.17	0.93
T_r	sec.	5.0	—	6.8	—	6.2	—	6.1	—
$m = k_t/B$		0.451	—	0.476	—	0.415	—	0.408	—
2f/B		0.442	0.259	0.393	0.256	0.393	0.219	0.346	0.175
GM/BG		0.65	0.48	0.48	0.35	0.40	0.32	0.49	0.58
2f/B × GM/BG		0.287	0.124	0.190	0.090	0.157	0.070	0.170	0.101
BG/f		1.22	1.54	1.08	1.61	1.24	1.85	1.20	1.90

TABLE 128. Stability data of tuna long line fishing boats (wood)

Item		Fukuju Maru No. 8		Suzu Maru No. 3		Seiho Maru No. 5		Asahi Maru No. 7		Seiryo Maru No. 10		Sakae Maru No. 10		Shinmei Maru No. 8		Shofuku Maru No. 7	
L × B × D	ft.	71.69 × 16.14 × 8.04		81.49 × 18.11 × 9.32		73.62 × 16.57 × 8.04		81.07 × 18.18 × 9.16		96.72 × 20.93 × 10.20		90.22 × 19.42 × 9.84		97.44 × 20.93 × 10.56		102.5 × 20.83 × 10.63	
	m.	21.85 × 4.92 × 2.45		24.84 × 5.52 × 2.84		22.44 × 5.05 × 2.45		24.71 × 5.54 × 2.79		29.48 × 6.38 × 3.11		27.50 × 5.92 × 3.00		29.70 × 6.38 × 3.22		31.23 × 6.35 × 3.24	
GT		69.67		99.93		69.51		99.41		167.57		140.60		174.10		179.85	
h.p.		200		320		230		300		400		350		550		450	
Built		1957		1957		1957		1957		1956		1956		1956		1954	
CN	cu. ft.	9,288		13,738		9,535		13,455		20,623		17,233		21,542		22,037	
	cu. m.	263		389		270		381		584		488		610		624	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	1.90	3.94	1.93	4.00	2.36	6.33	2.76	5.25	3.97	6.27	2.82	5.81	3.18	6.66	3.87	8.37
	m.	0.58	1.20	0.59	1.22	0.72	1.93	0.84	1.60	1.21	1.21	0.86	1.77	0.97	2.03	1.18	2.55
T_a	ft.	7.87	10.17	9.77	12.99	8.20	9.25	9.78	12.86	10.66	14.14	9.35	12.57	10.60	13.94	10.60	12.50
	m.	2.40	3.10	2.98	3.96	2.50	2.82	2.98	3.92	3.25	4.31	2.85	3.83	3.23	4.25	3.23	3.81
T	ft.	4.89	7.05	5.85	8.50	5.28	7.79	6.27	9.06	7.32	10.20	6.09	9.19	6.89	10.30	7.24	10.43
	m.	1.49	2.15	1.78	2.59	1.61	2.37	1.91	2.76	2.23	3.11	1.85	2.80	2.10	3.14	2.21	3.18
Δ	ton	87.88	156.16	130.48	242.16	94.69	173.89	139.21	240.88	218.8	366.70	153.69	288.84	197.49	370.37	225.80	394.84
f	ft.	4.56	2.39	4.95	2.30	4.00	1.51	4.20	1.41	4.46	1.57	5.25	2.13	5.22	1.80	5.02	1.83
	m.	1.39	0.73	1.51	0.70	1.22	0.46	1.28	0.43	1.36	0.48	1.60	0.65	1.59	0.55	1.53	0.56
KM	ft.	8.43	7.51	9.18	8.60	8.30	7.84	9.09	8.46	10.40	10.04	10.01	9.19	10.69	10.04	10.63	10.04
	m.	2.57	2.29	2.80	2.62	2.53	2.39	2.77	2.58	3.17	3.06	3.05	2.80	3.26	3.06	3.24	3.06
KB	ft.	2.00	3.28	2.39	4.00	2.20	3.67	2.99	4.59	3.44	5.18	3.05	4.53	3.18	5.22	3.35	5.12
	m.	0.61	1.00	0.73	1.22	0.67	1.12	0.91	1.40	1.05	1.58	0.93	1.38	0.97	1.59	1.02	1.56
KG	ft.	6.59	6.46	7.44	7.48	5.87	6.10	6.70	7.31	8.36	8.30	8.07	7.88	8.59	8.30	8.86	8.73
	m.	2.01	1.97	2.27	2.28	1.79	1.86	2.04	2.23	2.55	2.53	2.46	2.40	2.62	2.53	2.70	2.66
GM	ft.	1.84	1.05	1.74	1.12	2.43	1.74	2.39	1.15	2.04	1.74	1.94	1.31	2.10	1.74	1.77	1.31
	m.	0.56	0.32	0.53	0.34	0.74	0.53	0.73	0.35	0.62	0.53	0.59	0.40	0.64	0.53	0.54	0.40
BG	ft.	4.59	3.18	5.05	3.58	3.67	2.43	3.71	2.72	4.92	3.12	5.02	3.35	5.41	3.08	5.51	3.61
	m.	1.40	0.97	1.54	1.06	1.12	0.74	1.13	0.83	1.50	0.95	1.53	1.02	1.65	0.94	1.68	1.10
T_r	sec.	6.6	—	7.0	—	6.0	—	7.3	—	6.7	—	6.36	—	7.3	—	8.2	—
$m = k_t/B$		0.500	—	0.460	—	0.511	—	0.479	—	0.412	—	0.412	—	0.458	—	0.473	—
2f/B		0.565	0.297	0.549	0.256	0.487	0.182	0.465	0.171	0.427	0.150	0.541	0.227	0.497	0.173	0.481	0.176
GM/BG		0.40	0.33	0.34	0.32	0.66	0.72	0.65	0.42	0.41	0.56	0.39	0.39	0.39	0.56	0.32	0.36
2f/B × GM/BG		0.226	0.098	0.189	0.082	0.322	0.130	0.301	0.072	0.176	0.084	0.209	0.089	0.194	0.098	0.154	0.064
BG/f		1	1.33	1.02	1.51	0.92	1.61	0.88	1.93	1.10	1.98	0.96	1.57	1.04	1.71	1.10	1.96

TABLE 129. Stability data of skip-jack pole fishing boats (wood)

Item		Asahi Maru No. 7		Myojyo Maru No. 1		Gyoei Maru No. 1		Kyoshin Maru No. 3		Koryo Maru No. 5		Sasano Maru No. 2		Kotoku MaruNo. 3		Sumoyoshi Maru No. 2	
L × B × D	ft.	81.07 × 18.18 × 9.15		68.50 × 15.26 × 7.71		97.83 × 20.24 × 10.33		86.71 × 18.63 × 9.58		69.55 × 15.75 × 7.81		95.11 × 19.03 × 10.50		68.11 × 14.53 × 7.15		82.58 × 17.62 × 8.92	
	m.	24.71 × 5.54 × 2.79		20.88 × 4.65 × 2.35		29.82 × 6.17 × 3.15		26.43 × 5.68 × 2.92		21.20 × 4.80 × 2.38		28.99 × 5.80 × 3.20		20.76 × 4.43 × 2.18		25.17 × 5.37 × 2.72	
GT		99.41		66.55		162.05		131.20		64.55		150.67		62.50		99.70	
h.p.		300		210		420		340		180		400		180		320	
Built		1957		1958		1955		1955		1957		1957		1956		1957	
CN	cu. ft.	13,455		8,052		20,447		15,468		8,546		18,999		7,063		12,925	
	cu. m.	381		228		579		438		242		538		200		366	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	2.76	5.25	2.10	5.77	3.31	6.92	4.63	7.91	2.92	6.03	2.89	7.91	2.59	6.00	2.72	6.07
	m.	0.84	1.60	0.64	1.76	1.01	2.11	1.41	2.41	0.89	1.84	0.88	2.41	0.79	1.83	0.83	1.85
T_a	ft.	9.78	12.86	8.50	9.48	10.07	13.16	8.23	9.81	8.04	9.60	10.89	12.30	7.84	8.72	9.02	11.12
	m.	2.98	3.92	2.59	2.89	3.07	4.01	2.51	2.99	2.45	2.93	3.32	3.75	2.39	2.66	2.75	3.39
T	ft.	6.27	9.06	5.30	7.62	6.69	10.04	6.43	8.86	5.48	7.81	6.89	10.10	5.21	7.36	5.87	8.59
	m.	1.91	2.76	1.61	2.32	2.04	3.06	1.96	2.70	1.67	2.38	2.10	3.08	1.59	2.24	1.79	2.62
Δ	ton	139.21	240.88	93.10	148.80	194.50	355.00	156.44	255.20	85.30	148.00	162.4	303.0	78.11	130.0	129.23	220.0
f	ft.	4.23	1.44	3.38	1.05	5.25	1.90	4.40	1.97	3.64	1.31	5.51	2.30	3.38	1.25	4.66	1.94
	m.	1.29	0.44	1.03	0.32	1.60	0.58	1.34	0.60	1.11	0.40	1.68	0.70	1.03	0.38	1.42	0.59
KM	ft.	9.09	8.46	7.25	7.55	10.17	8.79	9.48	8.73	8.27	7.74	9.61	9.06	7.22	7.15	8.93	8.23
	m.	2.77	2.58	2.21	2.30	3.10	2.68	2.89	2.66	2.51	2.36	2.93	2.76	2.20	2.18	2.72	2.51
KB	ft.	2.99	4.59	2.62	3.87	3.25	4.79	3.05	4.40	2.59	3.87	2.76	4.66	2.46	3.74	2.53	4.04
	m.	0.91	1.40	0.80	1.18	0.99	1.46	0.93	1.34	0.79	1.18	0.84	1.42	0.75	1.14	0.77	1.23
KG	ft.	7.35	7.31	6.39	6.17	8.30	7.41	8.63	7.48	6.43	5.84	8.76	7.55	6.30	5.58	7.42	6.10
	m.	2.24	2.23	1.95	1.88	2.53	2.26	2.63	2.28	1.96	1.78	2.67	2.30	1.92	1.70	2.26	1.86
GM	ft.	1.74	1.15	0.86	1.38	1.87	1.38	0.85	1.25	1.84	1.90	0.85	1.51	0.92	1.57	1.51	2.13
	m.	0.53	0.35	0.26	0.42	0.57	0.42	0.26	0.38	0.56	0.58	0.26	0.46	0.28	0.48	0.46	0.65
BG	ft.	4.36	2.72	3.77	2.30	5.05	2.62	5.58	3.08	3.84	1.97	6.00	2.89	3.84	1.84	4.89	2.06
	m.	1.33	0.83	1.15	0.70	1.54	0.80	1.70	0.94	1.17	0.60	1.83	0.88	1.17	0.56	1.49	0.63
T_r	sec.	7.3	—	10.5	—	7.3	—	10.2	—	7.3	—	—	—	7.5	—	8.1	—
$m = k_t/B$		0.477	—	0.570	—	0.445	—	0.455	—	0.565	—	—	—	0.445	—	0.508	—
2f/B		0.458	0.157	0.439	0.138	0.518	0.188	0.471	0.211	0.458	0.167	0.578	0.242	0.461	0.172	0.530	0.219
GM/BG		0.39	0.42	0.23	0.60	0.37	0.53	0.15	0.40	0.48	0.97	0.14	0.52	0.24	0.86	0.31	0.103
2f/B × GM/BG		0.183	0.066	0.099	0.083	0.192	0.100	0.070	0.085	0.220	0.162	0.082	0.126	0.111	0.148	0.164	0.226
BG/f		1.03	1.88	1.11	2.19	0.96	1.35	1.31	1.57	1.05	1.50	1.09	1.26	1.14	1.47	1.05	1.07

TABLE 130. Stability data of small pair trawlers (wood)

Item		*Ebisu Maru No. 23*		*Ebisu Maru No. 11*		*Jukichi Maru No. 13*		*Shinei Maru No. 1*	
L × B × D	ft.	75.69 × 14.83 × 8.73		80.94 × 15.72 × 8.96		77.36 × 14.57 × 7.55		80.08 × 15.72 × 8.43	
	m.	23.07 × 4.52 × 2.66		24.67 × 4.79 × 2.73		23.58 × 4.44 × 2.30		24.41 × 4.79 × 2.57	
GT		71.46		74.35		61.73		77.23	
h.p.		170		250		180		250	
Built		1955		1956		1956		1956	
CN	cu. ft.	9,782		11,371		8,476		10,595	
	cu. m.	277		322		240		300	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	3.12	7.48	2.59	4.43	4.27	5.15	2.26	5.97
	m.	0.95	2.28	0.79	1.35	1.30	1.57	0.69	1.82
T_a	ft.	7.84	8.86	7.91	9.42	7.58	9.81	7.78	8.99
	m.	2.39	2.70	2.41	2.87	2.31	2.99	2.37	2.74
T	ft.	5.48	8.17	5.25	6.92	5.93	7.48	5.02	7.48
	m.	1.67	2.49	1.60	2.11	1.81	2.28	1.53	2.28
Δ	ton	93.61	165.01	93.62	146.73	97.35	142.08	103.84	179.06
f	ft.	4.49	1.80	5.12	3.44	3.05	1.51	4.63	2.17
	m.	1.37	0.55	1.56	1.05	0.93	0.46	1.41	0.66
KM	ft.	7.55	7.25	8.43	7.58	6.79	6.86	7.94	7.35
	m.	2.30	2.21	2.57	2.31	2.07	2.09	2.42	2.24
KB	ft.	2.53	4.07	2.30	3.25	2.66	3.54	2.20	3.61
	m.	0.77	1.24	0.70	0.99	0.81	1.08	0.67	1.10
KG	ft.	6.20	6.10	6.07	6.23	5.71	5.71	6.43	6.30
	m.	1.89	1.86	1.85	1.90	1.74	1.74	1.96	1.92
GM	ft.	1.35	1.15	2.36	1.35	1.08	1.15	1.51	1.05
	m.	0.41	0.35	0.72	0.41	0.33	0.35	0.46	0.32
BG	ft.	3.67	2.03	3.77	2.98	3.05	2.17	4.23	2.69
	m.	1.12	0.62	1.55	0.91	0.93	0.66	1.29	0.82
T_r	sec.	7.2	—	6.2	—	8.0	—	—	—
$m = k_t/B$		0.508	—	0.547	—	0.515	—	—	—
2f/B		0.606	0.243	0.657	0.438	0.435	0.206	0.590	0.275
GM/BG		0.37	0.56	0.63	0.45	0.35	0.53	0.36	0.39
2f/B × GM/BG		0.224	0.136	0.413	0.197	0.152	0.109	0.212	0.107
BG/f		0.82	1.13	0.74	0.87	1.00	1.43	0.91	1.24

Item		*Showa Maru No. 1*		*Nikko Maru No. 3*		*Sumiyoshi Maru No. 23*		*Chowa Maru No. 12*	
L × B × D	ft.	79.99 × 16.08 × 8.83		79.75 × 15.75 × 8.43		80.47 × 15.88 × 8.63		80.02 × 15.58 × 8.14	
	m.	24.38 × 4.90 × 2.69		24.31 × 4.80 × 2.57		24.53 × 4.84 × 2.63		24.39 × 4.75 × 2.48	
GT		79.96		74.51		81.09		73.97	
h.p.		250		250		275		250	
Built		1956		1955		1956		1956	
CN	cu. ft.	11,336		10,559		11,018		10,135	
	cu. m.	321		299		312		287	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	2.53	4.82	1.97	5.74	3.64	7.81	3.05	6.43
	m.	0.77	1.47	0.60	1.75	1.11	2.38	0.93	1.96
T_a	ft.	8.86	10.14	8.20	9.22	7.97	8.83	8.17	8.73
	m.	2.70	3.09	2.50	2.81	2.43	2.69	2.49	2.66
T	ft.	5.70	7.48	5.08	7.48	5.81	8.32	5.61	7.58
	m.	1.74	2.28	1.55	2.28	1.77	2.53	1.71	2.31
Δ	ton	102.74	156.99	105.71	180.93	102.99	176.64	92.77	153.73
f	ft.	4.69	2.92	4.56	2.17	4.07	1.57	4.07	2.10
	m.	1.43	0.89	1.39	0.66	1.24	0.48	1.24	0.64
KM	ft.	7.91	7.51	1.84	7.35	8.89	8.14	7.74	7.28
	m.	2.41	2.29	2.39	2.24	2.71	2.48	2.36	2.22
KB	ft.	2.39	3.41	2.23	3.61	3.05	4.26	2.36	3.54
	m.	0.73	1.04	0.68	1.10	0.93	1.30	0.72	1.08
KG	ft.	6.27	6.17	6.53	6.40	6.66	6.30	5.90	5.77
	m.	1.91	1.88	1.99	1.95	2.03	1.92	1.80	1.76
GM	ft.	1.64	1.34	1.31	0.95	2.23	1.84	1.84	1.51
	m.	0.50	0.41	0.40	0.29	0.68	0.56	0.56	0.46
BG	ft.	3.87	2.76	4.30	2.79	3.61	2.03	3.54	2.23
	m.	1.18	0.84	1.31	0.85	1.10	0.62	1.08	0.68
T_r	sec.	6.5	—	—	—	5.7	—	6.23	—
$m = k_t/B$		0.469	—	—	—	0.483	—	0.489	—
2f/B		0.582	0.362	0.578	0.275	0.512	0.199	0.522	0.267
GM/BG		0.42	0.49	0.30	0.34	0.62	0.90	0.52	0.68
2f/B × GM/BG		0.247	0.177	0.173	0.093	0.317	0.179	0.271	0.181
BG/f		0.82	0.94	0.94	1.29	0.89	1.27	0.87	1.06

TABLE 131. Stability data of salmon drifters (wood)

Item		*Tomi Maru No. 8*		*Hayabusa Maru No. 5*		*Taisho Maru No. 5*		*Jyoyu Maru No. 21*	
L × B × D	ft.	72.31 × 15.19 × 7.41		59.12 × 13.06 × 5.87		75.59 × 16.04 × 7.84		69.20 × 14.40 × 7.09	
	m.	22.04 × 4.63 × 2.26		18.02 × 3.98 × 1.79		23.04 × 4.89 × 2.39		21.10 × 4.39 × 2.16	
GT		49.42		27.28		74.91		43.27	
h.p.		230		100		275		210	
Built		1957		1957		1956		1958	
CN	cu. ft.	8,122		4,520		9,450		7,063	
	cu. m.	230		128		269		200	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	2.76	3.61	1.64	1.54	2.36	4.46	2.30	4.33
	m.	0.84	1.10	0.50	0.57	0.72	1.36	0.70	1.32
T_a	ft.	7.48	10.43	6.69	8.43	8.46	9.84	7.81	8.40
	m.	2.28	3.18	2.04	2.57	2.58	3.00	2.38	2.56
T	ft.	5.12	7.02	4.17	4.99	5.41	7.15	5.05	6.36
	m.	1.56	2.14	1.27	1.52	1.65	2.18	1.54	1.94
Δ	ton	92.26	124.00	40.49	53.84	101.07	155.95	72.90	129.05
f	ft.	3.64	1.71	2.95	2.13	3.64	1.90	3.28	1.97
	m.	1.11	0.52	0.90	0.65	1.11	0.58	1.00	0.60
KM	ft.	8.20	7.65	6.63	6.33	8.23	7.45	7.48	7.12
	m.	2.50	2.33	2.02	1.93	2.51	2.27	2.28	2.17
KB	ft.	2.26	3.31	1.74	2.26	2.62	3.61	2.23	3.02
	m.	0.69	1.01	0.53	0.69	0.80	1.10	0.68	0.92
KG	ft.	6.03	6.53	4.89	5.41	6.62	6.30	5.31	5.64
	m.	1.84	1.99	1.49	1.65	2.02	1.92	1.62	1.72
GM	ft.	2.17	1.12	1.74	0.92	1.61	1.15	2.17	1.48
	m.	0.66	0.34	0.53	0.28	0.49	0.35	0.66	0.45
BG	ft.	3.77	3.22	3.15	3.15	4.00	2.69	3.08	2.62
	m.	1.15	0.98	0.96	0.96	1.22	0.82	0.94	0.80
T_r	sec.	5.8	—	5.3	—	6.8	—	5.0	—
$m = k_t/B$		0.505	—	0.484	—	0.485	—	0.461	—
2f/B		0.477	0.217	0.453	0.326	0.454	0.241	0.455	0.273
GM/BG		0.57	0.35	0.55	0.29	0.40	0.43	0.70	0.56
2f/B × GM/BG		0.274	0.075	0.250	0.095	0.181	0.103	0.320	0.153
BG/f		1.04	1.89	1.07	1.48	1.10	1.41	0.94	1.33

Item		*Hosei Maru No. 8*		*Shoun Maru No. 20*		*Ebisu Maru No. 12*		*Kaiko Maru No. 1*	
L × B × D	ft.	86.97 × 17.88 × 8.20		80.94 × 17.39 × 8.30		75.33 × 16.76 × 8.01		79.20 × 16.60 × 8.27	
	m.	26.51 × 5.45 × 2.50		24.67 × 5.30 × 2.53		22.96 × 5.11 × 2.44		24.14 × 5.06 × 2.52	
GT		84.98		84.74		74.13		84.85	
h.p.		320		300		275		280	
Built		1956		1956		1956		1955	
CN	cu. ft.	12,749		11,760		10,100		10,842	
	cu. m.	361		333		286		307	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	3.54	4.10	3.41	5.28	3.28	4.10	3.71	6.20
	m.	1.08	1.25	1.04	1.61	0.98	1.25	1.13	1.89
T_a	ft.	7.81	10.66	9.12	9.88	8.01	9.35	8.01	9.74
	m.	2.38	3.25	2.78	3.01	2.44	2.85	2.44	2.97
T	ft.	5.67	7.38	6.26	7.58	5.61	6.72	5.86	7.97
	m.	1.73	2.25	1.91	2.31	1.71	2.05	1.79	2.43
Δ	ton	130.07	195.85	142.95	191.56	107.93	149.19	114.51	182.73
f	ft.	3.35	1.64	3.44	2.13	3.77	2.66	3.58	1.48
	m.	1.02	0.50	1.05	0.65	1.15	0.81	1.09	0.45
KM	ft.	8.62	8.48	8.69	8.46	8.40	7.87	8.10	7.67
	m.	2.63	2.58	2.65	2.58	2.56	2.40	2.47	2.34
KB	ft.	2.39	2.31	2.89	3.67	2.43	3.22	2.79	4.00
	m.	0.73	1.01	0.88	1.12	0.74	0.98	0.85	1.22
KG	ft.	6.85	6.98	6.92	7.38	6.40	6.69	6.46	6.49
	m.	2.09	2.13	2.11	2.25	1.95	2.04	1.97	1.98
GM	ft.	1.77	1.48	1.77	1.08	2.00	1.18	1.64	1.18
	m.	0.54	0.45	0.54	0.33	0.61	0.36	0.50	0.36
BG	ft.	4.46	3.67	4.03	3.71	3.97	3.42	3.67	2.49
	m.	1.36	1.12	1.23	1.13	1.21	1.06	1.12	0.76
T_r	sec.	6.9	—	7.2	—	6.0	—	7.2	—
$m = k_t/B$		0.476	—	0.497	—	0.457	—	0.500	—
2f/B		0.347	0.193	0.397	0.245	0.450	0.315	0.430	0.176
GM/BG		0.40	0.40	0.44	0.29	0.50	0.34	0.45	0.47
2f/B × GM/BG		0.138	0.077	0.174	0.071	0.227	0.107	0.192	0.083
BG/f		1.33	2.24	1.17	1.74	1.05	1.31	1.03	1.69

TABLE 132. Stability data of purse-seiners (wood)

Item		*Fuji Maru No. 10*		*Inpaku Maru No. 1*		*Shinko Maru No. 2*		*Fuji Maru No. 6*		*Koyo Maru No. 11*		*Taiyo Maru No. 5*		*Hakuryu Maru No. 16*		*Soyo Maru No. 1*	
L×B×D	ft.	75.46×16.76×8.01		76.44×17.42×7.71		80.51×18.44×8.14		75.66×16.80×8.07		74.77×18.54×7.78		71.32×17.36×8.33		79.66×17.88×8.27		78.97×17.88×8.69	
	m.	23.00×5.11×2.44		23.30×5.31×2.35		24.54×5.62×2.48		23.06×5.12×2.46		22.79×5.65×2.37		21.74×5.29×2.54		24.28×5.45×2.52		24.07×5.45×2.65	
GT		79.03		59.98		80.97		78.78		59.96		59.98		84.89		87.14	
h.p.		250		320		330		250		320		280		300		340	
Built		1957		1957		1957		1957		1957		1956		1956		1957	
CN	cu. ft.	10,100		10,241		12,078		10,241		10,771		10,312		11,795		12,254	
	cu. m.	286		290		342		290		305		292		334		347	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	2.95	4.23	4.76	5.31	2.03	2.98	2.95	4.23	3.87	3.74	4.43	5.05	2.82	4.56	3.31	4.36
	m.	0.90	1.29	1.45	1.62	0.62	0.91	0.90	1.29	1.18	1.14	1.35	1.54	0.89	1.39	1.01	1.33
T_a	ft.	7.84	9.88	6.73	8.27	8.86	10.82	7.84	9.84	7.94	9.91	7.71	9.38	8.63	10.27	8.69	10.60
	m.	2.39	3.01	2.05	2.52	2.70	3.30	2.39	3.00	2.42	3.02	2.35	2.86	2.63	3.13	2.65	3.23
T	ft.	5.39	7.05	5.74	6.79	5.45	6.90	5.39	7.03	5.90	6.82	6.07	7.22	5.77	7.41	6.00	7.48
	m.	1.64	2.15	1.75	2.07	1.66	2.10	1.64	2.14	1.80	2.08	1.85	2.20	1.76	2.26	1.83	2.28
Δ	ton	96.13	149.11	104.78	138.51	112.69	168.31	96.13	149.11	119.95	155.41	114.06	154.18	105.46	165.47	127.40	182.80
f	ft.	3.90	2.23	3.44	2.39	3.97	2.49	3.94	2.30	3.28	2.36	3.35	2.20	4.04	2.39	4.06	2.59
	m.	1.19	0.68	1.05	0.73	1.21	0.76	1.20	0.70	1.00	0.72	1.02	0.67	1.23	0.73	1.24	0.79
KM	ft.	8.70	8.24	9.15	8.89	10.07	9.22	8.70	8.20	8.95	8.63	9.05	8.79	10.24	9.35	9.12	8.73
	m.	2.65	2.51	2.79	2.71	3.07	2.81	2.65	2.50	2.73	2.63	2.76	2.68	3.12	2.85	2.78	2.66
KB	ft.	2.49	3.48	2.43	3.12	2.56	3.48	2.49	3.48	2.62	3.22	2.69	3.31	2.92	3.90	2.79	3.58
	m.	0.76	1.06	0.74	0.95	0.78	1.06	0.76	1.06	0.80	0.98	0.82	1.01	0.89	1.19	0.85	1.09
KG	ft.	6.53	6.53	6.56	6.89	6.46	6.56	6.53	6.50	5.87	6.30	7.15	7.02	7.55	7.15	6.92	7.09
	m.	1.99	1.99	2.00	2.10	1.97	2.00	1.99	1.98	1.79	1.92	2.18	2.14	2.30	2.18	2.11	2.16
GM	ft.	2.17	1.71	2.59	2.00	3.61	2.66	2.17	1.70	3.08	2.33	1.90	1.77	2.69	2.20	2.20	1.64
	m.	0.66	0.52	0.79	0.61	1.10	0.81	0.66	0.52	0.94	0.71	0.58	0.54	0.82	0.67	0.67	0.50
BG	ft.	4.04	3.05	4.13	3.77	3.90	3.08	4.04	3.02	3.25	3.08	4.46	3.71	4.63	3.25	4.13	3.51
	m.	1.23	0.93	1.26	1.15	1.19	0.94	1.23	0.92	0.99	0.94	1.36	1.13	1.41	0.99	1.26	1.07
T_r	sec.	6.4	—	6.0	—	—	—	6.4	—	—	—	6.5	—	6.7	—	6.1	—
$m=k_t/B$		0.505	—	0.499	—	—	—	0.505	—	—	—	0.451	—	0.501	—	0.459	—
2f/B		0.465	0.266	0.391	0.274	0.431	0.272	0.471	0.274	0.354	0.251	0.387	0.253	0.451	0.268	0.453	0.290
GM/BG		0.54	0.56	0.63	0.53	0.92	0.86	0.54	0.57	0.95	0.75	0.43	0.48	0.58	0.68	0.53	0.47
2f/B×GM/BG		0.251	0.149	0.245	0.145	0.398	0.234	0.253	0.155	0.336	0.190	0.166	0.121	0.262	0.184	0.241	0.136
BG/f		1.03	1.37	1.20	1.58	0.98	1.24	1.02	1.31	0.99	1.30	1.33	1.69	1.15	1.35	1.02	1.35

TABLE 133. Stability of mackerel pole-fishing boats (wood)

Item		*Kyowa Maru No. 5*		*Toa Maru No. 1*		*Yawata Maru*		*Senyo Maru*		*Kyokuryu Maru*		*Sadaishi Maru*		*Matsu Maru No. 8*		*Kyowa Maru No. 8*	
L×B×D	ft.	80.38×17.72×9.02		79.00×17.22×8.63		62.14×14.34×5.94		62.11×14.11×6.20		62.17×13.81×5.94		62.93×14.01×6.73		77.00×17.22×8.23		88.19×19.03×9.88	
	m.	24.50×5.40×2.75		24.08×5.25×2.63		8.94×4.37×1.81		18.93×4.30×1.89		18.95×4.21×1.81		19.18×4.27×2.05		23.47×5.25×2.51		26.88×5.80×3.01	
GT		94.94		99.92		36.55		37.26		36.02		19.18		83.19		132.21	
h.p.		350		310		160		140		140		180		330		380	
Built		1956		1957		1957		1957		1957		1957		1957		1958	
CN	cu. ft.	12,819		11,725		5,262		5,403		5,015		5,898		10,948		16,563	
	cu. m.	363		332		149		153		142		167		310		469	
Conditions		Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full	Light	Full
T_f	ft.	3.15	6.59	1.77	3.84	1.67	4.04	2.95	3.05	2.23	3.74	1.25	4.04	4.06	4.76	2.53	4.82
	m.	0.96	2.01	0.54	1.17	0.51	1.23	0.90	0.93	0.68	1.14	0.38	1.23	1.24	1.45	0.77	1.47
T_a	ft.	9.71	10.73	9.22	10.26	7.91	11.06	6.50	8.46	7.31	7.55	7.71	8.07	9.41	11.84	11.12	12.33
	m.	2.96	3.27	2.81	3.13	2.41	3.37	1.98	2.58	2.23	2.30	2.35	2.46	2.87	3.61	3.39	3.76
T	ft.	6.43	8.66	5.50	7.05	4.79	7.55	4.72	5.75	4.77	5.64	4.48	6.06	6.73	8.30	6.82	8.57
	m.	1.96	2.46	1.67	2.15	1.46	2.30	1.44	1.75	1.45	1.72	1.36	1.84	2.05	2.53	2.08	2.61
Δ	ton	141.91	225.28	123.69	194.07	64.1	90.1	62.67	86.24	62.69	85.50	55.89	88.02	136.84	195.79	182.24	261.33
f	ft.	3.74	1.51	4.66	3.08	3.84	1.08	2.59	1.57	2.20	1.31	3.38	1.80	3.05	1.48	4.23	2.49
	m.	1.14	0.46	1.42	0.94	1.17	0.33	0.79	0.48	0.67	0.40	1.03	0.55	0.93	0.45	1.29	0.76
KM	ft.	9.12	8.59	8.50	8.04	7.34	6.93	6.89	6.53	7.05	6.72	7.12	6.66	8.73	8.43	9.91	9.41
	m.	2.78	2.62	2.59	2.45	2.24	2.11	2.10	1.99	2.15	2.05	2.17	2.03	2.66	2.57	3.02	2.87
KB	ft.	3.18	4.46	2.43	3.41	2.36	2.99	2.17	2.82	2.33	2.82	1.97	2.89	3.08	4.10	3.58	4.59
	m.	0.97	1.36	0.74	1.04	0.72	0.91	0.66	0.86	0.71	0.86	0.60	0.88	0.94	1.25	1.09	1.40
KG	ft.	7.41	6.72	6.89	6.66	5.08	4.83	5.28	5.15	5.48	4.95	5.48	5.12	7.45	7.51	7.94	7.54
	m.	2.26	2.05	2.10	2.03	1.55	1.47	1.61	1.57	1.67	1.51	1.67	1.56	2.27	2.29	2.42	2.30
GM	ft.	1.71	1.87	1.61	1.38	2.26	2.10	1.61	1.38	1.57	1.77	1.64	1.54	1.28	0.92	1.97	1.87
	m.	0.52	0.57	0.49	0.42	0.69	0.64	0.49	0.42	0.48	0.54	0.50	0.47	0.39	0.28	0.60	0.57
BG	ft.	4.23	2.26	4.46	3.25	2.72	1.84	3.11	2.33	3.15	2.13	3.51	2.23	4.36	3.41	4.36	2.95
	m.	1.29	0.69	1.36	0.99	0.83	0.56	0.95	0.71	0.96	0.65	1.07	0.78	1.33	1.04	1.33	0.90
T_r	sec.	—	—	7.6	—	5.2	—	—	—	6.5	—	—	—	7.67	—	8.2	—
$m=k_t/B$		—	—	0.488	—	0.492	—	—	—	0.531	—	—	—	0.454	—	0.545	—
2f/B		0.422	0.170	0.541	0.359	0.307	0.151	0.367	0.223	0.314	0.190	0.493	0.257	0.354	0.171	0.445	0.255
GM/BG		0.40	0.83	0.36	0.42	0.83	0.114	0.52	0.59	0.50	0.83	0.47	0.69	0.29	0.27	0.45	0.63
2f/B×GM/BG		0.170	0.142	0.195	0.152	0.255	0.172	0.189	0.132	0.157	0.158	0.230	0.177	0.103	0.046	0.200	0.162
BG/f		1.13	1.50	0.96	1.05	0.71	0.70	1.20	1.48	1.43	1.63	1.04	1.42	1.43	2.31	1.03	1.18

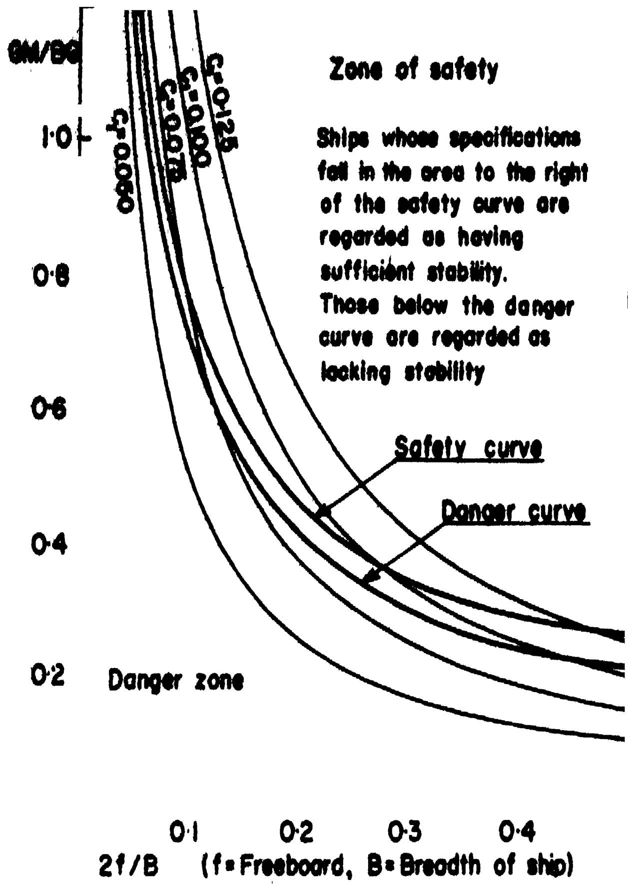


Fig. 525. Proposed criterion of stability for Japanese fishing boats

to 24°. The stability can be expressed in a simple form by GM × 2f/B up to a given angle of inclination.

In discussing the safety of fishing boats, external forces must be taken into account, such as the effects of wind and waves, ship's motions, etc. The effects of wind is a moment equalling the product of wind pressure, exposed area and the vertical distance from the centre of gravity of this area to half the mean draught.

The influence of external forces is considered as a function of BG. In a ship under the influence of wind and waves, the virtual centre of gravity is higher than that in a ship free from such influences. This decreases the GM and increases the value of BG. Among pre-war Japanese fishing boats not many had a hull shape exceeding a block-coefficient $\delta = 0.6$ in the full load condition. Among post-war ships more and more have a δ-value greater than 0.65 because of a trend towards larger fish holds, and such vessels seem to be more influenced by external forces than others. Vessels with a fine hull shape are seaworthy and have a large value of KB and a small value of BG.

Taking into consideration the various items mentioned, the author introduces the idea of the *safety index number* for fishing boats by:

$$C = (GM \times 2f)/(f(BG) \times B).$$

In the above equation, f(BG) can be represented by BG for the sake of simplicity, and the value of C is considered as a constant. Thus:

$$C_1 = (GM \times 2f)/(BG \times B)$$

Tables 122 to 133 and the experience of the author lead to the following conclusions:

$$C_1 = 0.075 \text{ in the load condition}$$

$$C_1 = 0.100 \text{ in the light condition}$$

There are vessels in operation which do not come up to this standard, and probably the value of C_1 is less than 0.100 in many.

It is possible to split the formula of C_1 into 2f/BG and GM/B; f/BG can also be written in the form of BG/f. Values for BG/f are given in tables 122 to 133. BG/f varies between 0.7 and 2.4. Only when BG/f remains nearly the same, can the stability be expressed by GM/B, as sometimes suggested.

The minimum stability of fishing vessels has to be studied further but a solution is proposed in fig. 525. This covers not only load and light conditions but also the worst conditions during operation. The form is GM/BG-2f/B, based on data for Japanese fishing boats. The four thin curves show lines of $C_1 = 0.050, 0.075, 0.100$ and 0.125, and the two thick curves show, respectively, a safety curve and a danger curve. If the GM/BG and 2f/B go below the danger curve, the ship is not safe. The value of C_1 is subject to change, according to the values of GM, BG and f; therefore, both designers and crews should always bear in mind the safety of the vessel.

It is hoped that the proposals will be improved when data on an international scale are collected. If agreement could be reached on international action along the following lines, it would lead to an improvement of fishing boats' safety throughout the world:

- An international standard for stability calculations of fishing boats
- All countries building fishing boats to publish the results of the tests of completed boats and to make this data available to all
- FAO to organize a standing committee to promote the safety of fishing vessels

TRANSVERSE STABILITY OF TUNA CLIPPERS

by

JOHN R. PAULLING, Jr.

The tuna clipper of the U.S. Pacific Coast is characterized by extreme dissimilarities in the form of the fore and after bodies. As a result of this difference, together with the method of operation, this class of vessel has been plagued with transverse stability problems perhaps more severe than those encountered in most other types of fishing vessels. A number of writers have on several occasions suggested that the conventional stability computations fall somewhat short of adequately describing the stability of these vessels.

A discussion is given of the shortcomings of the transverse stability diagram computed for a tuna clipper by the method of cross curves. It is shown that, as a result of the extremely low freeboard aft, tuna clippers trim by the stern as they heel, thus violating the basic assumption of no trim employed in the cross curve computation. This trim results in an actual calm water transverse stability which is appreciably less than that computed by the method of cross curves. A method is given whereby the transverse stability can be computed while permitting the vessel to trim, thus satisfying completely the conditions for static equilibrium. The method is only slightly more complicated than the usual computation and is much more general in its application. The computation is applied to two example vessels and yields righting arms substantially less than those obtained conventionally in both cases.

A significant extension of the computational technique is its application to the calculation of the transverse stability of a ship in a seaway. Under the condition described in 1953 by Möckel as most dangerous with regard to capsizing, i.e., running at high speed before a high following sea, it is shown that the transverse stability is greatly reduced when a wave crest is amidships. For the first example considered, the static stability curve, while showing reasonable values for the righting arms and range of stability in calm water, becomes almost entirely negative when a wave crest is admidships. For a second example, the very generous righting arms are reduced, in the wave crest, to only about one-half the values computed by cross curves or about two-thirds the exact still water values. Model test results are given which substantiate the computations.

It is concluded from these results that the proper assessment of the transverse stability of a tuna clipper requires somewhat more refined techniques than those usually used. Only when the proper computational procedure is known and applied to produce an accurate evaluation of the vessel's stability can stability criteria be formulated and incorporated in the design process. The procedure described here fulfils these requirements in providing the naval architect with a means of more closely approximating on the drawing board the actual behaviour of the vessel at sea.

LA STABILITÉ TRANSVERSALE DES TUNA CLIPPERS

Le "tuna clipper" de la côte du Pacifique des E.-U. est caractérisé par d'extrêmes dissemblances dans la forme de l'avant et de l'arrière. Il en résulte qu'avec la méthode d'utilisation, cette classe de navires a rencontré des difficultés de stabilité transversale peut-être plus sévères que celles affrontées dans la plupart des autres types de navires de pêche. En plusieurs occasions, un certain nombre d'auteurs ont suggéré que les calculs conventionnels de stabilité manquent quelque peu leur but, qui est de décrire convenablement la stabilité de ces bateaux.

L'auteur discute les insuffisances du diagramme de stabilité transversale calculé pour un "tuna clipper" et qui donne les courbes de stabilité aux grands angles d'inclinaison. Il est montré que, par suite du franc-bord extrêmement bas à l'arrière, les "tuna clippers" sont en différence quand ils gtent, violant ainsi le postulat fondamental de ne pas employer l'assiette dans le calcul des courbes de stabilité aux grands angles d'inclinaison. Cette assiette a pour résultat, en eau réellement calme, une stabilité transversale qui est appréciablement inférieure à celle calculée selon la méthode donnant les courbes de stabilité aux grands angles d'inclinaison. L'auteur donne une méthode selon laquelle la stabilité transversale peut être calculée tout en permettant au bateau d'avoir de l'assiette, satisfaisant ainsi complètement les conditions d'équilibre statique. La méthode est seulement légèrement plus compliquée que le calcul habituel, et son application est beaucoup plus générale. Le calcul est appliqué à deux navires servant d'exemples et donne des bras de redressement substantiellement inférieurs à ceux obtenus conventionnellement dans les deux cas.

Une extension significative de la technique d'évaluation est son application au calcul de la stabilité transversale d'un navire par mer forte. Dans les conditions décrites par Mockel comme étant les plus dangereuses en ce qui concerne le chavirement, c'est-à-dire faisant route à grande vitesse devant une mer forte de l'arrière, il est montré que la stabilité transversale est fortement réduite quand une crête de vague se trouve au milieu du bateau. Pour le premier exemple considéré, la courbe de stabilité statique, tout en montrant des valeurs raisonnables des bras de redressement et de la gamme de la stabilité en eau calme, devient presque entièrement négative quand une crête de vague se trouve au milieu du bateau. Pour un second exemple, les très généreux bras de redressement sont réduits dans la crête de vague, à seulement la moitié des valeurs estimées par les courbes de stabilité aux grands angles d'inclinaison, soit environ les deux tiers des valeurs exactes en eau calme. Il est donné des résultats d'essais de modèle qui appuient les évaluations.

L'auteur déduit de ces résultats que l'évaluation convenable de la stabilité transversale d'un "tuna clipper" nécessite des techniques quelque peu plus élaborées que celles utilisées habituellement. Les critères de stabilité peuvent être formulés et incorporés dans l'établissement du projet seulement quand on connait le procéde convenable d'évaluation et qu'il est appliqué pour produire une évaluation précise de la stabilité du bateau. Le procédé décrit ici satisfait ces exigences en fournissant à l'architecte naval un moyen de donner une approximation plus exacte sur la table à dessin du comportement réel du navire à la mer.

LA ESTABILIDAD TRANSVERSAL DE LOS CLIPERES ATUNEROS

El cliper atunero de la costa del Pacifico de los E.U.A. se caracteriza por la enorme desigualdad de las formas de sus cuerpos de proa y de popa. Debido a ello y a la manera en que es utilizado, esta clase de barco ha encontrado dificultades de estabilidad transversal posiblemente más severas que las que se presentan en casi todos los otros tipos de barcos de pesca. En diversas ocasiones vari os autores han sugerido que los cálculos normales de la estabilidad no son bastante exactos para describir adecuadamente la estabilidad de estos barcos.

El autor discute la insuficiencia del diagrama de estabilidad transversal calculada para el cliper atunero por el método de las curvas transversales. Se ha demostrado que, debido a lo bajo que es el francobordo a popa, los clipperes atuneros se asientan mucho por la popa cuando se balancean, violando así el postulado fundamental de no emplear el asiento en el cálculo de las curvas transversales. Este trimado tiene por resultado, en aguas totalmente en calma, una estabilidad transversal que es sensiblemente inferior a la calculada por el método de las curvas transversales. El autor propone un método según el cual se puede calcular la estabilidad transversal permitiendo que el barco tenga el asiento y satisfaciendo así por completo las condiciones de equilibrio estático. El método es sólo un poco más complicado que el cálculo habitual y mucho más general en su aplicación. El cálculo se aplica a 2 barcos que sirven de ejemplo y da brazos de adrizamiento bastante más pequeños que los obtenidos corrientemente en los dos casos.

Una extensión significativa de la técnica de la evaluación es su aplicación al cálculo de la estabilidad transversal de un barco que navega en mar gruesa. En las condiciones descritas por Möckel en 1953, como las más peligrosas en lo relativo al vuelco, es decir, navegando a mucha marcha con mar gruesa en popa, se demuestra que la estabilidad transversal se reduce mucho cuando la cresta de una ola se encuentra en la medianía del barco. Para el primer ejemplo considerado, la curva de estabilidad estática, aunque muestra valores razonables para el brazo de adrizamiento y la gama de estabilidad en agua tranquila, se convierte en casi enteramente negativa cuando la cresta de una ola está en la medianía. Para un segundo ejemplo, los muy generosos brazos de adrizamiento se reducen en la cresta de la ola a la mitad, aprox., de los valores estimados por las curvas transversales, o en unas 2/3 partes de los valores exactos en agua tranquila. Se dan los resultados de ensayos con modelos que confirman las evaluaciones.

El autor deduce de ellos que la evaluación adecuada de la estabilidad transversal de un cliper atunero exige técnicas algo más elaboradas que las que se emplean habitualmente. Sólo cuando se conocen los procedimientos de evaluación adecuados y se aplican para obtener una evaluación exacta de la estabilidad del barco, se pueden formular e incorporar en el establecimiento del proyecto los criterios de estabilidad. El procedimiento descrito aqui satisface estas exigencias al facilitar al arquitecto naval un medio de aproximarse más exactamente en el tablero de dibujo al comportamiento real del barco en el mar.

THE geometry, internal arrangements, and fishing method of the clippers of the Pacific Coast of the U.S.A. have led to a number of transverse stability problems which are peculiar to these vessels as a class. During recent years certain of these problems have been discussed by several writers, notably Snyder (1946), Dickie (1947, 1949) and Hanson (1955). In the discussion of Hanson's paper, for instance, it is pointed out that the conventional computational procedures yield an inadequate assessment of the transverse stability of this type of vessel. This results from the vessel's strong tendency to trim by the stern at angles of heel greater than that at which the deck edge is submerged. Consequently, the basic assumption of the usual cross-curve computation, i.e. no heel induced trim, is violated and the results so calculated will not accurately represent the actual behaviour of the vessel. This leaves in general a great portion of the final judgment of the vessel's stability to the experience and intuition of the designer. That this is not a desirable situation may be inferred from Hanson's noting the loss of some 75 of these vessels in a three-year period with the implication that a significant number of these losses is attributable to inadequate transverse stability.

In an attempt to partly offset this lack of analytic design knowledge, the underwriters have required multiple inclinings of the completed vessel in conditions representing, as nearly as possible, the loadings assumed during the various phases of operation. While such multiple inclining experiments yield valuable insight into the initial stability of the vessel, it must be remembered that ships, when capsizing, exceed by a considerable margin the range of heel angles for which the initial metacentric height governs the behaviour. Moreover, the low freeboard-to-beam ratio of tuna clippers results in submergence of the deck edge and consequent radically altered shape of the immersed volume at relatively small angles. Consequently, the initial metacentric height is even less valid as a criterion of stability than in the case of most other vessel types.

The general problem of transverse stability confronting the naval architect may be divided into three parts. First, the transverse stability must be expressible quantitatively from a knowledge of the vessel; second, the design of the vessel must be made so as to ensure adequate stability without impairing her function; and third, "adequate stability" must be defined in the same quantitative terms utilized in the first part. Thus it may be seen that in order to apply the *knowledge* implied in part three to satisfy the *requirement* expressed in part two, the *procedure* noted in part one must be known and must be valid. In other words, before stability criteria can be set up and before the design of the vessel can be made to conform to these criteria, what is meant by the stability must be defined exactly. It is in this definition that the conventional methods, which depend for their validity on extensive experience with more conventional vessels, fail in the special case of tuna clippers.

It is the purpose here to discuss in greater detail the shortcomings of the conventional methods when used in expressing the stability of tuna clippers and to show how they may be improved upon. Two separate situations are considered in which are obtained much closer approximations to the actual transverse stability of these vessels when operating at sea.

Effect of trim on transverse stability

In the conventional cross-curve computation, it is assumed that the vessel rotates about a longitudinal axis which is fixed in the ship and which always remains parallel to the water surface. As a result of fore and aft asymmetry this assumption is not, in general, satisfied by actual vessels, and the departure from this condition is exaggerated the greater the dissimilarity between the fore and after bodies. For seagoing vessels of normal merchant ship form, however, the fore and after bodies are sufficiently similar that significant errors in predicted righting arms are not introduced as a result of this assumption.

On the other hand, there are certain classes of vessels

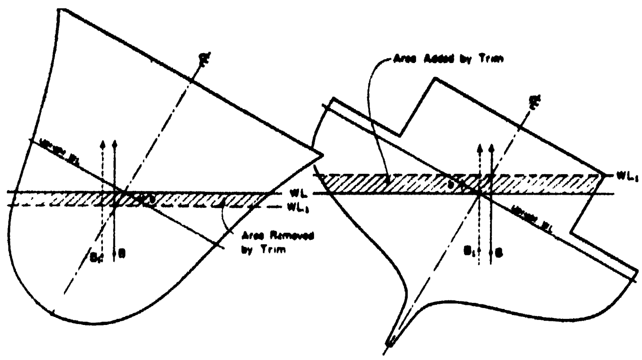


Fig. 526. Inclined fore and afterbody sections illustrating the effect of trim on local righting arms

that possess form peculiarities which render the stability calculations performed under this assumption practically meaningless. Such a vessel type is the tuna clipper characterized by great freeboard and somewhat V-shaped sections forward, combined with practically no freeboard and extremely broad flat sections in the afterbody. With such a freeboard distribution, an angle of heel sufficient to immerse the deck edge aft will invariably result in a trim by the stern. This may be deduced quite easily by reference to fig. 526, which shows typical forebody and afterbody sections of a tuna clipper inclined to a large angle of heel. The water surface marked WL is that assumed in the usual cross curve computation allowing no trim. In the forward sections it is noted that the area of the immersed wedge is larger than that of the emerged wedge because of the flare of the topsides. In the after sections, on the other hand, as a result of the extremely low freeboard, the immersed wedge falls far short of equalling the emerged wedge in area. Consequently, in the heeled condition there is a deficiency in volume in the afterbody and a surplus of volume in the forebody, resulting in a shift forward of the centre of buoyancy.

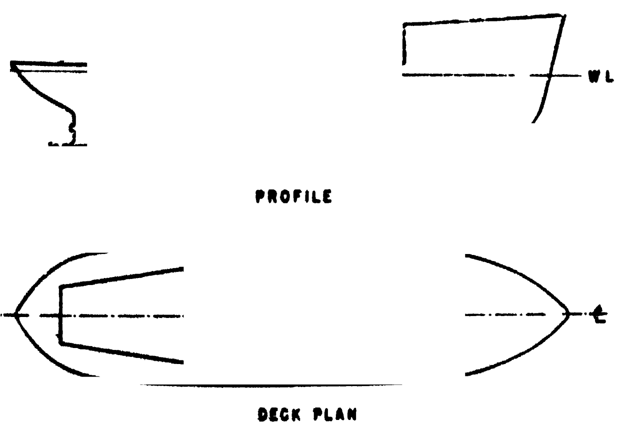


Fig. 527. Profile and deck arrangement plan showing areas assumed watertight. Vessel A

In order to maintain equilibrium the ship must trim by the stern until the centre of buoyancy again lies in the same longitudinal position that is occupied for the upright ship. This equilibrium waterline is shown in fig. 526 as WL_1. It will be below WL in the forebody and above WL in the afterbody. Noting the location of the centroid, b, of the increment of area, it is seen that the change in the local righting moments in both of these regions is negative. In the forward sections an area having a positive moment with respect to the total area is removed, while in the after sections the moment of the added section is negative. Thus, as a result of trim, displacement having a positive righting moment is lost in the forebody and displacement, which has a negative righting moment, is added in the afterbody. The vessel's trim by the stern, which results from the heel, therefore

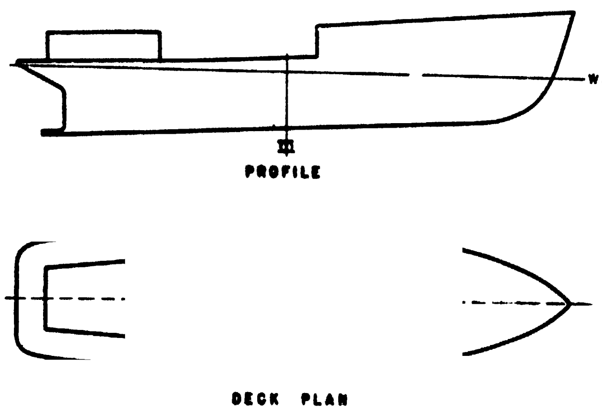


Fig. 528. Profile and deck arrangement plan showing areas assumed watertight. Vessel B

reduces the actual righting moment as compared with the righting moment computed by the conventional cross-curve method, assuming no trim.

The magnitude of this trim-induced error in the conventional stability computations has been determined for two tuna clippers, one representing the typical broad square stern form and the other incorporating somewhat different stern lines finished off with a semi-cruiser stern. Outboard profiles and deck arrangement plans of both vessels are given in fig. 527 and 528 showing the portions assumed watertight for the computations in each case. Table 134 lists the principal dimensions of these vessels.

The procedure which is used in performing the stability computations is illustrated by fig. 529. At each of ten stations, for a fixed angle of heel, the area and moment of area up to each of several parallel waterlines are obtained by means of an integrator in exactly the manner followed in the usual cross curve computation. These values, for each station, are then plotted as abscissae on an ordinate located at the appropriate station on a profile of the heeled ship. The resulting plots are heeled Bonjean curves and similar curves of transverse moment of area as in fig. 530.

If a waterline is superimposed on fig. 530, as denoted by WL, the area and moment of area of each station up to this waterline may be read (indicated, for example, at station 5 as d_1 and d_2 respectively). The condition of equilibrium requires that the displacement and the longitudinal position of the centre of buoyancy be the same for the heeled vessel as for the vessel in the original upright position.

Thus:

$$\left.\begin{aligned} \int_0^L A(x)\,dx &= \nabla \\ \frac{1}{\nabla}\int_0^L xA(x)\,dx &= x_B \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (1)$$

Here A(x) is the station area up to WL read for tabular integration by Simpson's Rule as d_1 at each station from fig. 530, x is the longitudinal co-ordinate of A(x); ∇ is the volume of displacement of the upright ship, x_B is the longitudinal position of the centre of buoyancy of the ship in the upright position. By trial and error, the heeled waterline, WL, is located so that conditions (1) are simultaneously satisfied. Once WL is so located, the transverse moment of area may be read at each station (noted on fig. 530 as d_2) and integrated over the length of the ship to yield the net righting moment. This procedure is repeated for several angles of heel and the results plotted as a curve of transverse stability in the usual manner.

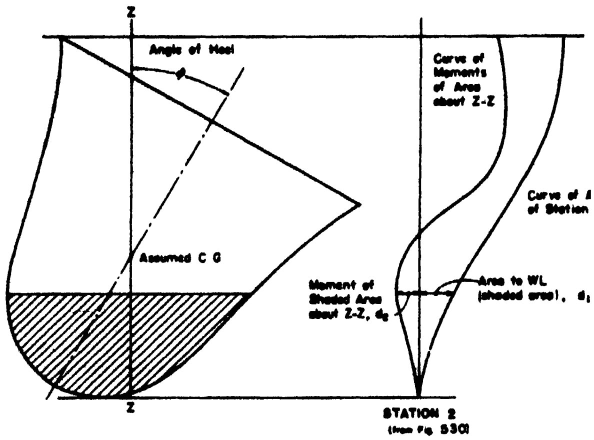


Fig. 529. Heeled section illustrating calculation and plotting of area and moment curves

A curve of transverse stability was so obtained for each of the subject vessels, together with a second curve computed by the usual method of cross curves. The results are given in fig. 531 and 532.

All four of these curves give values of righting arms corrected to an initial GM obtained from the stability booklet prepared for the actual vessels. The condition

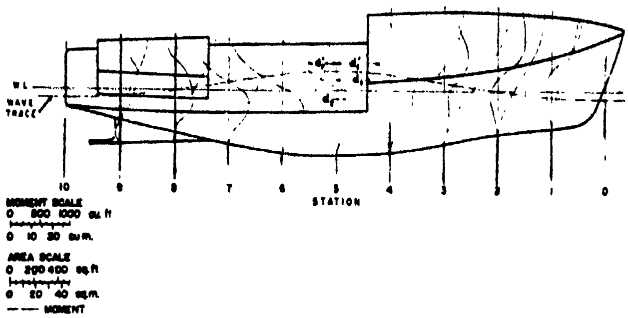


Fig. 530. Curves of heeled station areas and moments for φ=30° Vessel B

of loading in each case corresponds to that of the vessel full of dry frozen fish and with double bottom fuel tanks full. This loading, while not always the condition which results in minimum stability, generally results in a GM value near the minimum encountered in operation and is typical of the loading under which the vessel operates during an appreciable part of the time.

The most striking feature of the stability curves in fig. 531 and 532 is the markedly dissimilar behaviour of

TABLE 134

Principal dimensions of example ships

	Vessel 'A'	Vessel 'B'
LOA . .	99 ft. 0 in. (30.18 m.)	127 ft. 4 in. (38.81 m.)
B . .	25 ft. 0 in. (7.62 m.)	30 ft. 6 in. (9.30 m.)
T . .	11 ft. 11½ in. (3.65 m.)	12 ft. 6½ in. (3.82 m.)
Δ_s (∇) . .	475 tons (470 cu. m.)	693 tons (686 cu. m.)

the cruiser stern and the square stern vessel. The great disparity between the results with and without trim for the latter results primarily from the extreme difference in the shape of section fore and aft. In the cruiser stern design, the after sections have more nearly the same shape as the forward sections below the waterline and differ primarily in the amount of freeboard. The bait tanks located aft compensate for this lack of freeboard to some extent in both cases, however, so it is concluded that the more pronounced effect of trim in the case of vessel B is felt as a result of the very wide, flat sections.

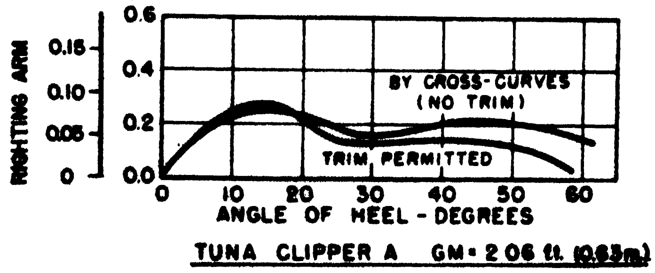


Fig. 531. Transverse stability in calm water

The transverse stability in longitudinal waves

The heeled Bonjean and transverse moment curves given in fig. 530 are not restricted in their use to stability computations in calm water. In general they may be used for computing the restoring moment acting on the ship at an angle of heel if lines of intersection of the water surface at all sections of the ship are parallel and therefore the buoyancy forces at all sections act in the same direction. Thus, the transverse stability of a ship in head or following seas can be computed using these curves, since when the ship lies normal to the wave crests the intersection of the water surface with each station is a straight line and all of these lines are parallel to the line of wave crests, hence parallel to each other. If the position of the vessel relative to the wave can be determined, and if an assumption of a hydrostatic pressure distribution throughout the wave can be made, the stability computation can be carried out as described in the preceding section by substituting a wave profile for the straight waterline. The first of these conditions requires a knowledge of the pitch-heave motion of the vessel as related to wave phase and geometry. Thus the problem is first of all one of ship-wave dynamics. However, a very important special case may be considered which requires no lengthy analysis of ship-wave dynamics. A number of writers, particularly Möckel (1955), observe that a small high-speed vessel finds itself in greatest danger of capsizing when running before a high following sea at a speed nearly equal to the wave speed. In this "most dangerous condition" the period of wave encounter is relatively large when compared with the ship's natural period of heave and pitch. Under such a condition, the heaving and pitching accelerations of the vessel are small, hence acceleration forces are small compared with static forces, and the vessel's orientation on the wave is consequently approximately that of static equilibrium in pitch and heave. In the limiting case, the ship speed equals the wave speed and the relative orientation of ship and wave is exactly static.

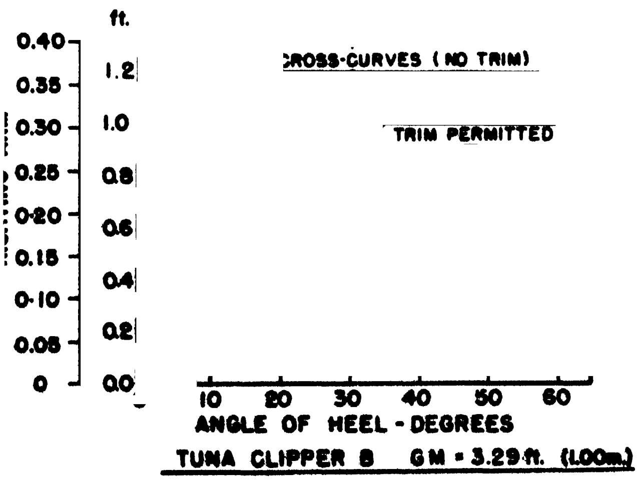


Fig. 532. Transverse stability in calm water

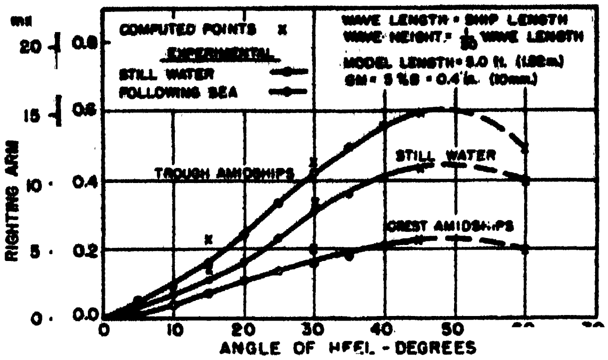


Fig. 533. Transverse stability in waves and calm water, Series 60, $C_b = 0.60$. Comparisons of computed and measured values

In this condition the sum of the vertical components of pressure forces over the immersed surface of the hull must equal the displacement of the ship. As a first approximation the pressure in a wave may be assumed to be hydrostatic. This is analogous to neglecting the "Smith Effect" in the conventional bending moment calculation, together with the assumption that the presence of the vessel does not appreciably disturb the pressure distribution. Under these assumptions, i.e. static equilibrium of ship on wave and a hydrostatic pressure distribution, the transverse stability in a following sea is computed as follows: A wave profile of desired length and height is superimposed on the heeled ship profile (shown dashed on fig. 530), the areas of stations up to the wave profile are read from the heeled Bonjean curves (co-ordinates d'_1) and the volume and longitudinal moment of the volume obtained by integration of these areas. By trial and error, the location of the ship on the wave is found such that the equilibrium conditions, equations (1) are satisfied. Thereupon the transverse moments (co-ordinates d'_2) are read at each station and integrated to obtain the righting moment. This process is repeated for several angles of heel at the same longitudinal position of ship on wave in order to obtain the complete curve of static stability. Such curves may be computed for several longitudinal positions of ship relative to the wave crest. However, Grim (1952) and Wendel (1954) show that, in general the minimum righting moments result when the wave crest is nearly amidships and the wave length is approximately equal to the ship length. The maximum righting moments occur when a wave trough is amidships.

Model experiments to measure the transverse stability of a ship in waves have recently been conducted in the Ship Model Tank of the Department of Naval Architecture of the University of California, Berkely, California, U.S.A. In these experiments the righting moment acting on a heeled model towed in following seas was measured. The purpose of the experiments was twofold: First, to test the applicability of the computational procedure described in the preceding paragraphs, and second, to determine experimentally the influence of variations in ship geometry on the wave-induced stability variations.

Fig. 533 taken from Paulling (1958) gives a comparison

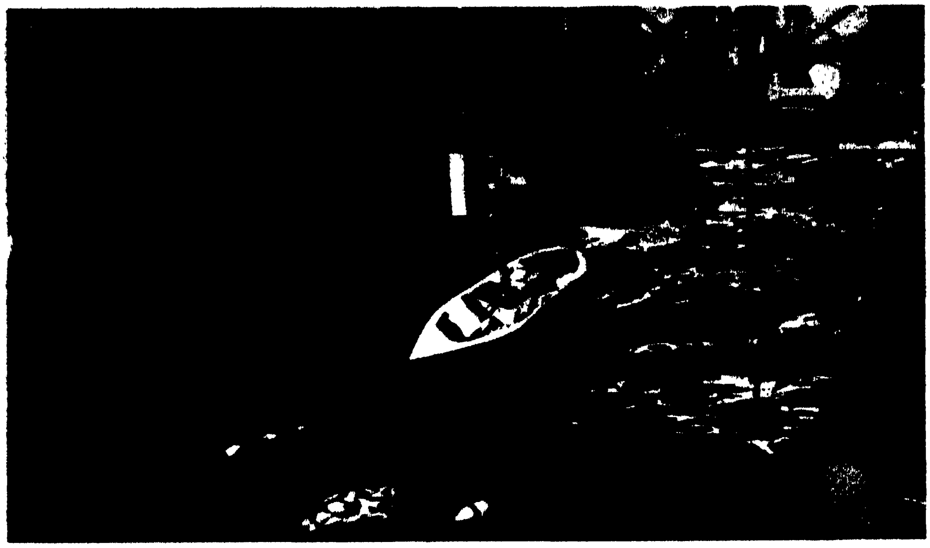


Fig. 534. Model being towed at an angle of heel to measure its transverse stability in a following seaway

of measured and computed righting arms for the basic model used in this study, a 5 ft. (1.525 m.) long model of the David W. Taylor Model Basin Series 60 Block 0.60 form having a scaled sheer and freeboard approximating that of a modern shelterdeck cargo vessel of about 400 ft. (122 m.) length. This model and several others incorporating variations in beam and freeboard were towed heeled at several angles over a range of speeds in following seas and the righting moments were continuously recorded. Fig. 534 is a photograph of one of these models being towed at a heel angle of 30° in a following seaway. The resulting records showed, in general, a maximum righting moment when a wave trough was amidships, while a minimum resulted when a crest was amidships. The upper and lower curves shown in fig. 533 are respectively the maximum and minimum model righting arms in waves, while the middle curve is the curve of the righting arms in calm water.

For these three cases, values computed by the procedure described in the preceding section are indicated, in addition to the experimental results. The agreement

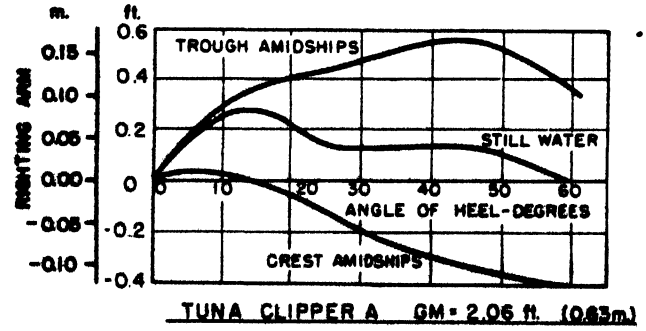


Fig. 535. Transverse stability in a following sea. Wave length = ship length, wave height = 1/20 wave length

between computed and experimental values is remarkable, especially in view of the extreme simplification of the problem inherent in the assumptions of hydrostatic pressures and static ship-wave orientation. Preliminary tests showed that the measured righting moments are independent of model speed for a range of zero speed up to a model speed equal to the wave speed. From the agreement between computed and measured values, it is therefore concluded that the assumption of static equilibrium and hydrostatic pressure distribution leads to results which are of acceptable accuracy in representing the following sea situation.

The results given in fig. 533 were obtained for a wave length equal to the model length and a wave height of one-twentieth the length. A series of tests conducted in waves of various lengths and of heights one-twentieth the length showed approximately constant maximum and minimum righting moments for wave lengths equal to or greater than the ship length. For lengths appreciably less than the ship length, the wave-induced stability changes become less pronounced and thus less important. Consequently, it is concluded that the wave of length equal to ship length and height of one-twentieth the length represents a reasonably attainable "worst situation" which may be adopted as a standard of comparison for computation of stability in waves.

On the basis of the preceding, the transverse stability in the standard L/20 waves was computed for the tuna clippers A and B described in the previous section. Resulting curves of righting arms are given in fig. 535 and 536 respectively. Here the same stability reduction in the wave crest shown by the Series 60 design is apparent, exaggerated to an extreme degree in the case of Ship A by the rather poor initial stability of this vessel. In the case of vessel B, while adequate righting arms are maintained in the wave crest, the maximum arm is reduced to about two-thirds of its value in calm water and only about one-half the value computed by the conventional method of cross curves. From these results, it will be concluded that the transverse stability of a tuna clipper at sea may bear little resemblance to the transverse stability of the same vessel on the designer's drawing board.

Conclusions

Two factors which may cause the transverse stability of a ship to differ from that predicted by the designer have been investigated. They are: (a) trim which occurs during heeling as a result of fore-and-aft asymmetry of the ship form and is neglected in the conventional cross-curve computation of stability; and (b) a longitudinal

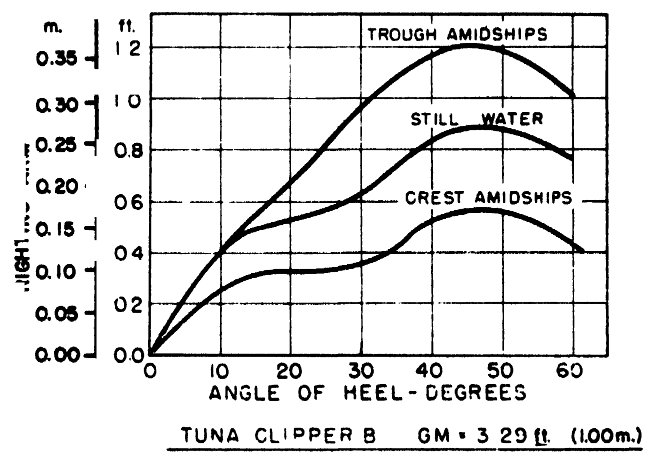


Fig. 536. Transverse stability in a following sea. Wave length = ship length, wave height = 1/20 wave length

seaway, in particular a following sea, which alters the transverse stability of the vessel by altering the shape of the immersed form as compared to the calm water situation.

As a consequence of peculiarities in the tuna clipper's geometry, heel-induced trim nearly always results in transverse stability appreciably less than that predicted by the cross-curve method of computation. This error in the predicted versus the actual stability is aggravated by the extremely low freeboard aft and wide shallow after sections of normal broad square stern tuna clippers. A cruiser stern with deeper and narrower sections would reduce this effect because there would be greater similarity between the fore and after sections. At the same time, it must be borne in mind that the narrower after waterlines associated with the cruiser stern increase the difficulty of obtaining adequate initial metacentric height.

When the vessel operates in a following sea, the transverse stability varies with time as the ship encounters succeeding waves. In general, the transverse stability is a minimum when a wave crest is amidships. If the initial metacentric height is sufficiently small—even though apparently adequate for calm water—the transverse stability of the ship in a wave crest may be reduced to a dangerously low value. The actual experience with vessel A is illustrative of this situation. In calm water, the metacentric height and righting arms, while relatively low, were considered acceptable, since the range of positive righting arms is fairly large. In waves, the righting arms, crest amidships, are vanishingly small or negative over the entire range. This vessel, having marginal stability to start with, capsized and sank on her maiden voyage. Perhaps fig. 535 and 536 contain a clue.

Tuna clipper B is one of the newest and most modern in the California fleet. With her rather generous initial metacentric height she possesses apparently adequate transverse stability both in calm water and in waves. However, it is interesting to note the appreciable error in her calm-water stability, as predicted by the conventional method of cross curves. In view of this large error, it is apparent that transverse stability curves computed in the conventional manner cannot be relied upon too heavily in the case of the usual broad, flat counter stern type tuna clipper.

Two recommendations to the designer are suggested by the foregoing discussion. As a result of the large trim-induced error contained in the transverse stability computed for the tuna clipper by the conventional methods, a more exact investigation of the still-water stability during the design process is indicated. The inclusion of a "generous margin" of unknown magnitude is no substitute for more exact knowledge. The procedure described in the first part of the present paper is only slightly more involved than the conventional method and yields results which are a much closer approximation of the actual situation.

As the second point, reference to fig. 535 and 536 shows the very severe stability reductions possible in a seaway. Here it is shown that the most dangerous situation occurs when a wave crest is amidships. In this case the immersion of the deck edge amidships occurs at a smaller angle of heel than is required in calm water, or, at the same heel angle, the deck edge is more deeply immersed in the wave crest than in calm water. The righting moment will be increased in this case by an increase in freeboard amidships. Consequently, it may be possible to serve the needs of the fishing method by keeping freeboard to a minimum aft and, at the same time, materially improve the "seagoing stability' of the vessel by raising the freeboard amidships.

Acknowledgments

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SAFETY FROM CAPSIZING

by

KURT WENDEL

Casualties in recent years show that even new ships are not safe from capsizing. Hitherto naval architects have used empirical data derived from statistics of casualties to determine stability. But these data are only useful for similar ships operating under nearly similar conditions. The only way to solve this important problem satisfactorily is to compare numerically the various simultaneously acting heeling moments with the righting moments. As there are uncertainties on some heeling moments and there are other factors which are neglected, the paper gives some information how to estimate them. The influence of a seaway in reducing the smooth water righting moments is also discussed in the light of some recent research. Finally, instruments to determine the actual stability on board ships are briefly described.

LA PROTECTION CONTRE LE CHAVIREMENT

Ces dernières années, les accidents ont montré que méme les nouveaux navires ne sont pas à l'abri du chavirement. Jusqu'à présent, les architectes navals ont utilisé des données empiriques provenant des statistiques d'accidents pour déterminer la stabilité. Mais ces données sont utiles seulement pour des navires similaires opérant dans des conditions presque identiques. La seule façon de résoudre cet important problème d'une manière satisfaisante est de comparer numériquement les moments de redressement. Comme il existe des incertitudes sur quelques moments de chavirement et que d'autres facteurs sont négligés, la communication donne des informations sur la façon de les estimer. L'influence des vagues qui réduisent les moments de redressement en eau calme est examinée aussi à la lumière de recherches récentes. Finalement, l'auteur donne une brève description des instruments pour déterminer la stabilité réelle à bord des navires.

LA PROTECCION CONTRA EL VUELCO

Los siniestros marítimos ocurridos en los últimos años demuestran que ni los barcos nuevos están a cubierto del peligro de volcar. Hasta ahora los arquitectos navales han determinado la estabilidad empleando datos empíricos deducidos de estadísticas de siniestros, pero estos datos sólo son de utilidad cuando se trata de barcos similares que trabajan en condiciones casi análogas. La única solución satisfactoria de este problema consiste en comparar numéricamente los varios momentos de escora y de adrizamiento que actúan simultáneamente. La ponencia explica la manera de estimar algunos momentos de escora sobre los que no se tiene seguridad y ostros factores de los que se hace caso omiso. Se examina a la luz de algunas investigaciones recientes el efecto de la mar gruesa en la reducción de los momentos de adrizamiento que existen en mar llana. Finalmente se describen con brevedad los instrumentos que existen para determinar la estabilidad real a bordo.

CAPSIZING occurs more frequently than is generally anticipated. In 1957 there were no less than 23 cases of capsizing, 19 of which led to total losses. By these accidents about 250 men lost their lives (Journal of Marine Catastrophies, 1958). Manley (1950 and 1958) has evaluated the losses of ships registered by Lloyd's Register since the beginning of this century. He shows that the number of small ships reported abandoned, foundered and missing is progressively increasing. Ships lost of 200 ft. (61 m.) and below amounted to 36 per cent. of the casualties in 1899 to 1913, 48 per cent. from 1919 to 1938 and 66 per cent. from 1946 to 1955. Only 20 to 30 per cent., however, of the world tonnage is of this size. The analysis of the disasters shows that:

- More than 70 per cent. of the casualties happened in winter, thus wind and sea play an important role
- Newly-built ships were as numerous as the older vessels, thus implying that wear and tear was not the important factor
- Most of the ships lost had one deck with short superstructures or raised quarterdeck and therefore had a small effective freeboard, thus it can be assumed that freeboard is one of the most important factors
- Most of the ships involved were carrying dry bulk cargoes, thus shifting of cargo plays an important role

It is worth noting that during the last 50 years the losses in the U.S.A. and the Netherlands were much below the average, from which follows that losses can be minimized by improving design or by complying with certain rules. Abandoned, foundered or missing are terms of wide scope, but disasters caused by collision or lack of strength are not included in these statistics.

Manley (1950) states: "It can be assumed that in the majority of cases of ships reported abandoned, foundered or missing, a major failure has occurred; that is, the ship has been overwhelmed by forces, the effect of which she was built to withstand".

A ship can go down either on an even keel, over the bow or the stern, or after capsizing. Most of the accidents reported may have happened by capsizing. Generally, capsizing is followed by sinking, this assumption being derived from the author's research on stability as well as from reports of survivors. The author does not know of any similar careful and extensive investigation of losses of fishing vessels; but based on many losses and numerous reports and discussions (Traung, 1955) about the dangers that fishing boats have withstood, he thinks that they are no safer than comparable sized merchant vessels, which Manley's investigations deal with. Some dangers may be of secondary importance in a fishing boat, e.g. shifting of cargo. Others, such as those from the sea and icing, are more serious in the Arctic fishing grounds than in the seaways used by merchant vessels.

Capsizing

Hitherto the naval architect has been interested only in the righting moments. It is known that these must be sufficient in order to counteract the heeling moments, but numerical comparison of heeling and righting moments has not yet become common.

The heeling forces can be found by calculation. Their

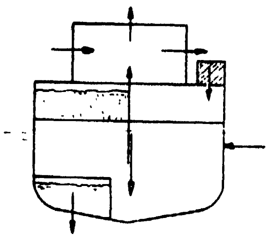


Fig. 537. Forces acting on a ship in upright position

moments can be plotted against the angles of heel. The points of stable or unstable equilibrium are the points of intersection between the curves of righting moments and heeling moments.

A free moving body is influenced by the amount, direction and point of application of forces, usually changing with the angle of heel as shown in fig. 537 and 538. It has been found more practical to draw curves of levers instead of moments. Fig. 539 shows a curve of righting levers GZ_r and some curves of the heeling levers. The equation

$$GZ_r - GZ_h = 0 \quad . \quad . \quad . \quad (1)$$

gives points of intersection or a point of contact. The equilibrium is stable only when

$$\frac{d}{d\varphi} GZ_r - \frac{d}{d\varphi} GZ_h > 0 \quad . \quad . \quad . \quad (2)$$

i.e. when the curve of heeling levers intersects the curve of righting levers from the top to the bottom going from

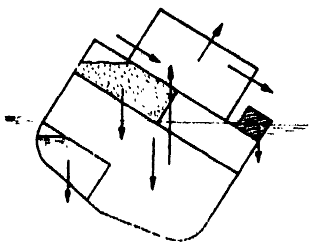


Fig. 538. Forces acting on a ship in inclined position

left to right. This condition is fulfilled in fig. 539 at φ_1. When heeling beyond the angle φ_1, the righting levers exceed the heeling ones and thus the ship will return to that angle.

The static upsetting angle is the angle beyond which a ship will capsize if "statical" heeling takes place, i.e.

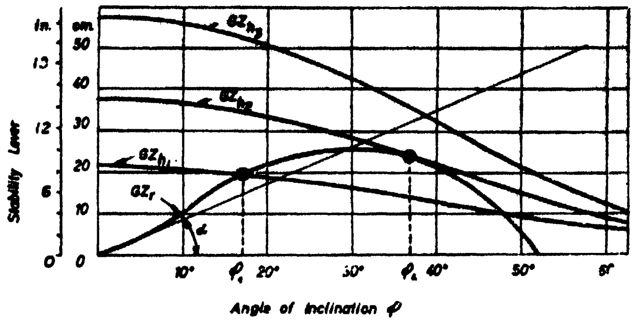


Fig. 539. Righting and heeling levers. GZ_r=righting levers, GZ_h= heeling levers, α=slope of GZ_r curve at φ=0, tan α=metacentric height

heeling without appreciable acceleration. Nearly all greater lists, which endanger ships, are of this type. Exceptions are inclinations caused by heavy rolling, but it is impossible to capsize a ship by rolling in transverse waves. The maximum angle up to which a ship may be inclined depends on the curves of righting and heeling moments.

In fig. 539 the maximum angle is φ_2 where the two curves are tangent. The static upsetting angle must not coincide with the angle of the maximum righting lever, as believed for a long time (Rahola, 1939); it can be located at any angle with a positive righting lever,

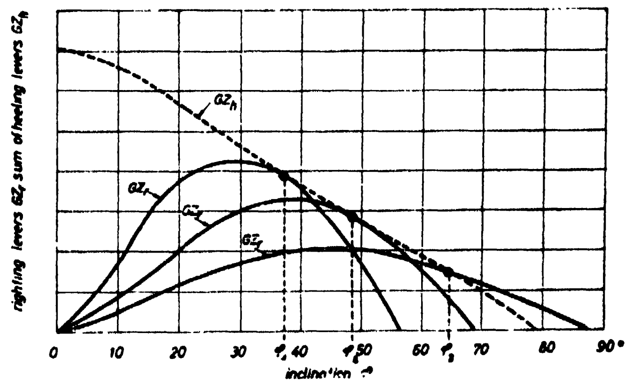


Fig. 540. Static upsetting angles and angle of stable equilibrium for three different curves of righting levers intersected by the same curves of heeling levers

depending only on the shape of the curves. Fig. 540 shows one curve of heeling levers and three different curves of righting levers. It can be seen that the same heeling moment can incline the two ships of curves 1 and 2 from the upright position to the static upsetting angles φ_1 and φ_2, although the curves have different maxima. It is merely the upsetting angles that are different. Curve 3 even has a point of stable equilibrium at φ_3, though the maximum righting levers are smaller.

Dimensioning of righting levers

The problem is now to dimension the righting levers in such a way that they are greater than the heeling levers at large angles of heel. The worst possible conditions must be considered; average conditions are of no use. As the righting and heeling levers can easily be added or subtracted they can be compared like items in a balance sheet. Such a balance sheet must be established

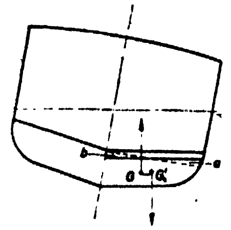


Fig. 541. Shift of centre of gravity —from G to G_1'—in a partially filled tank at small angles of inclination. a and b are wedge-shaped volumes of equal size and shape

at an early stage of design in order to ensure a safe ship. It has to contain:

Draught T
Volume of displacement, ∇
Total weight (displacement), Δ
Height of centre of gravity, KG
Height of metacentre, KM

and for the angles of inclination φ = 30°, 45° and 60°, the *heeling levers* caused by:

(1) Partially filled tanks
(2) Shift of cargo or other weights
(3) Additional weights, such as water on deck, water in holds and other compartments, icing
(4) Wind pressure
(5) Centrifugal forces when turning
(6) to (8) Extraordinary heeling moments, such as grounding, transverse pull, hanging weights
(9) Correction to righting levers for seaway
(10) Safety (amount of balance)

and the *righting levers* for:

(1) The load condition considered, including corrections for additional weights
(2) Watertight erections and deck cargo

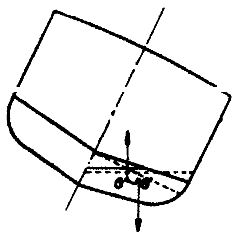


Fig. 542. Shift of centre of gravity at large angles of heel. With no tank top the fluid level would have reached the dotted line

Specification of moments

Partially-filled tanks. As a rule water and fuel tanks are not full, so the free surface effect must be considered. Provided the inclination is small, the liquid will shift so that the volume of the emerged and immersed wedges are equal (fig. 541). As soon as the level of liquids reaches the top or bottom of the tank (fig. 542 and 543) the shift of the centre of gravity will become smaller. The heeling moment will be

$$M_h = W (y \cos \varphi + z \sin \varphi),$$

where W=weight of the liquid, y=horizontal shift and z=vertical shift of the centre of gravity of the liquid, the co-ordinate axes being those of the ship. These moments have to be calculated for all partially-filled tanks, summed up and divided by the total displacement of the ship, thus giving the heeling lever of partially-filled tanks.

Shift of cargo or other weights. It is sometimes said that naval architects have nothing to do with the dangers caused by shift of cargo; in some cases, however, it is impossible for the seamen or stevedores to prevent this shift. If the calculation shows that the resulting heeling moments cannot be compensated by righting moments, alterations in the design of holds and coal bunkers must be made.

Additional weights. The quantity of water which will remain on deck after shipping a sea depends on the height and design of the bulwarks. Experiments on the effect of bulwarks (Wendel, 1954) on a coastal cargo vessel of 260 ft. (80 m.) length, showed that with a bulwark height

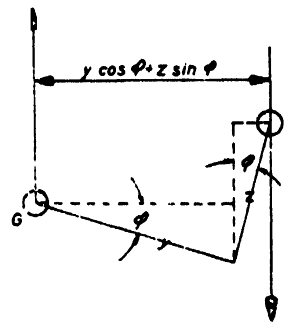


Fig. 543. Detail of Fig. 542. φ=inclination, y=horizontal shift of centre of gravity, z=vertical shift of centre of gravity

of 3.3 (1 m.) and freeing ports of 0.1 sq. ft./ft. (0.03 sq. m./m.) length, about 50 per cent. of the water coming on deck was still on the deck after 40 sec. Calculations for the same ship showed that if there is a period of encounter of 15 sec., and an average volume of water of 20 tons comes on the deck from each wave, there will remain:

10 tons after the passing of one wave;
25 tons after the passing of three waves; and
30 tons after the passing of five or more waves.

These values have been confirmed by experiments. Möckel (1949, 1955) reported that for a considerable time the whole deck of a trawler was filled with water nearly up to the bulwark rail.

Icing causes considerable heeling moments. The effects of icing have been shown by the BSRA (1957 and p. 511) model tests where a 180 ft. (54.8 m.) trawler of 1,115 tons displacement capsized due to 150 tons of ice. This report also gives detailed information about the distribution of ice. Two-thirds was stated to be on deck and the superstructure and one-third in the rigging.

Traung (1957) gives figures from the Russian stability rules which allow for 6.1 lb./sq. ft. (30 kg./sq. m.) of ice on deck and 3.35 lb./sq. ft. (16.4 kg./sq. m.) of ice on the rigging and spares up to a height of 33 ft. (10 m.). These figures may be somewhat high in the opinion of many naval architects. As these weights are additional, the displacement and the draught increase. The weights and levers of the added masses of ice must be estimated, multiplied by each other and, after division by the total displacement, put into the stability balance.

Wind pressure. The side wind moment on a ship in upright position is:

$$M_w = \rho_a/2 \cdot V_w^2 \cdot A \cdot d \cdot \zeta_w \qquad (3)$$

where

- ρ_a = density of air
- V_w = wind velocity; Beaufort 6, 8, 10, 12 means about 23, 35, 50, 58 knots, (12, 18 25, 30 m./sec.) respectively; a velocity of 115 knots (60 m./sec.) has sometimes been recorded
- A = lateral area including erections and rigging exposed to the wind
- d = distance between the centre of wind pressure and the centre of water pressure: in practice, this is taken as the vertical distance between the centre of the exposed area and a point at half draught
- ζ_w = wind pressure coefficient; according to model experiments (Horn, 1943) and full-scale experiments (Wendel, 1958) about 1.3

The wind moment has often been assumed to be constant at all angles of heel. There are even formulae based on the assumption that the wind moment is greatest at an angle where the ship has the largest exposed area (Rahola, 1939, gives an extensive list of papers). The assumption is wrong that the wind force (1) is proportional to the projected area, (ii) is acting in the centre of area, and (iii) is acting with the direction of the wind. Ships are box-shaped structures if masts, sails, rigging and rails are neglected. When a box is inclined, the distribution, magnitude and direction of pressure varies (fig. 544). According to fig. 544c and d, the moment decreases with inclination, although the projected area increases, this being confirmed by wind tunnel tests in Japan (Kinoshita, 1957). These experiments were conducted because some trawlers and ferry boats were lost in a strong gale. At 45° inclination the heeling moments were only half of those in the upright condition. The measured values can be approximated by the formula:

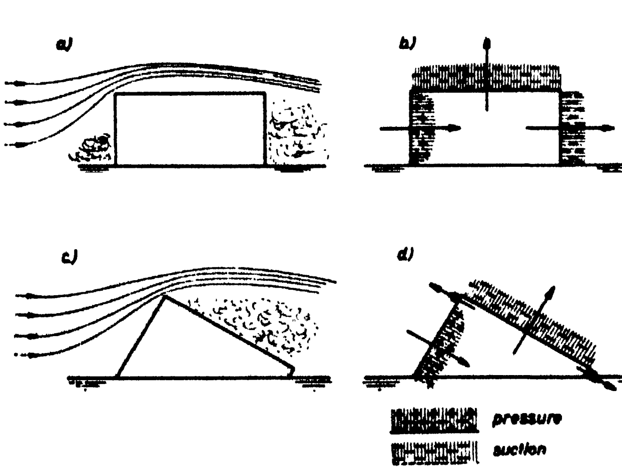


Fig. 544. Distribution of wind pressure on a prism

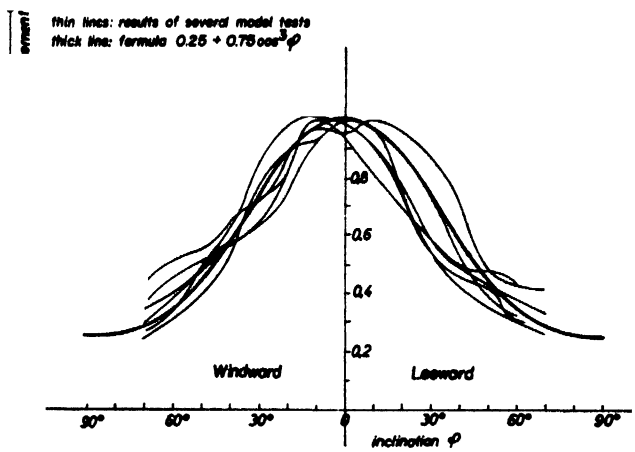


Fig. 545. Wind pressure heeling moments

$$f(\varphi) = 0.25 + 0.75 \cos^3 \varphi \qquad (4)$$

The constant term shows that a percentage of the wind moment is still acting at a list of 90°. Thus wind pressure results in the following heeling lever:

$$GZ_h = \frac{M_w}{\Delta} \cdot f(\varphi) \qquad (5)$$

Centrifugal forces when turning. An upright ship when turning is acted on by the moment

$$M_t = \frac{\Delta v^2}{g \cdot R}\, l \qquad (6)$$

resulting from a couple due to the centrifugal force $m.v^2/R$ and the reaction force of the water, where $m = \Delta/g$ = mass of the ship, v = peripheral velocity, and R = radius of the turning circle.

The centrifugal force is acting at the centre of gravity, the reaction force at a point about half draught, thus l is the vertical distance between these two forces. Trials carried out with a number of ships proved the moment not to be maximum at very small turning circles—because of the reduction in speed. The maximum moment was found at a circle diameter of about four times the ship's length, the speed then being about three-quarters of full sailing speed.

Extraordinary forces. Trawl warp pull and hanging weights may cause considerable moments, but as these are acting only in comparatively good weather when fishing, they can often be neglected. Ships lying at anchor in a heavy seaway require special considerations, because extraordinary moments are acting. On ships in an inclined position the immersed part of the hull is asymmetric and resistance has a component athwartships which causes a heeling moment. At normal speeds this moment is of secondary importance like those caused by the ship's wave pattern or by trim.

The righting levers

At any angle the righting lever in fig. 546 is:

$$GZ = c - BG . \sin \varphi \quad . \quad . \quad . \quad . \quad (7)$$

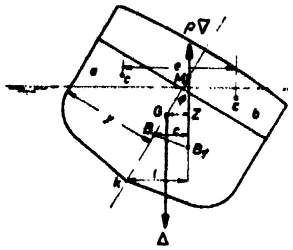


Fig. 546. Forces acting on inclined ship

If the ship is considered wallsided the immersed and emerged wedges have the same shape. Then

$$GZ = \left(GM + BM \frac{\tan^2 \varphi}{2} \right) \sin \varphi \quad . \quad . \quad (8)$$

This equation is valid as long as the sides can be considered parallel, not when the deck edge is immersed or the bilge emerged. To calculate the righting levers the ship may be divided into sections, and moment and volume of displacement calculated by numerical integration. The fraction moment/volume gives the lever $KM_t . \sin \varphi$ if the axis is put through the keel K. The righting lever is naturally smaller because the centre of gravity G is located above K.

$$GZ = (KM_t - KG) \sin \varphi \quad . \quad . \quad . \quad . \quad (9)$$

The calculation of the righting lever $KM_t . \sin\varphi$ is a geometric problem which many naval architects and mathematicians have dealt with, nevertheless the methods are very tedious. It can be facilitated by the use of mechanical or electronic computers.

As early as possible, at least approximate values of the righting levers must be known at greater angles of heel. There are some approximations, based on a comparison with finished ships (Krappinger, 1958); it is, however, advisable to draw a preliminary lines plan and to calculate the righting levers at angles of heel of 30°, 45° and 60°. The centre of gravity must be calculated for the most dangerous load condition.

There are different opinions as to whether erections are to be included. The implication that erections give greater safety is not always correct. Doors and openings may be forced open and water collected inside, resulting in additional heeling moments. Draining might be slow; in addition, the hull may be filled by more water from subsequent waves. An erection excluded from the stability calculation is not only "non-existent", but is also dangerous if flooded.

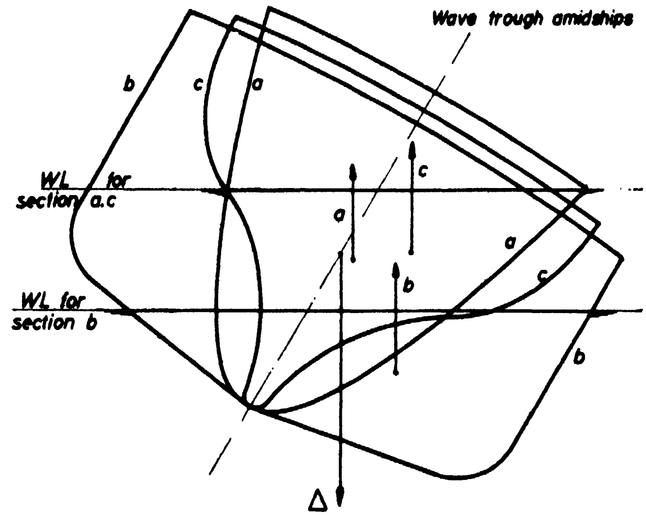


Fig. 548. Influence of seaway on the righting moment. a=section in the foreship, b=midship section, c=section in the aftship, Δ=ship's weight

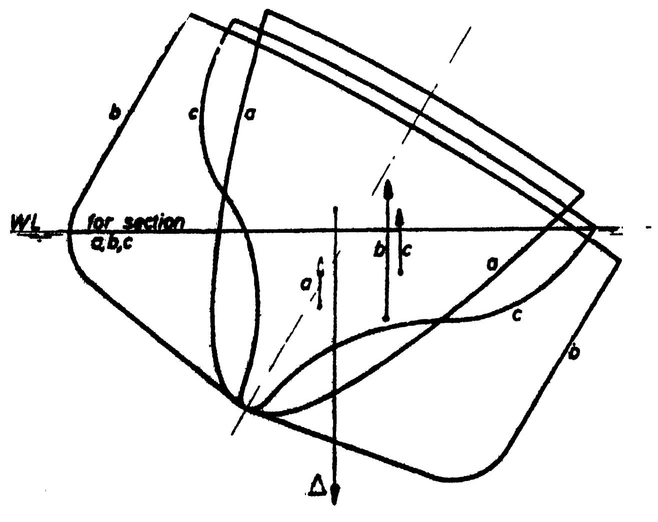


Fig. 547. Influence of seaway on the righting moment. a=section in the foreship, b=midship section, c=section in the aftship, Δ=ship's weight

Alterations of the righting levers due to waves

The lever $KM_t . \sin \varphi$ and the height of the centre of buoyancy vary considerably in heavy head or following seas. Waves generally decrease the righting levers, therefore the decrease is included as a part of the heeling levers, although the deduction can only be calculated at the same time as the righting levers.

The most unfavourable case occurs when a wave of the same length as the ship is slowly overtaking. Fig. 547 to 549 show three sections of a ship in smooth water and on or between wave crests. It will be found that the maximum lever occurs with the wave through amidships, this lever being even somewhat greater than that in smooth water because the ends of the ship produce larger righting levers (Arndt and Roden, 1959; Grim, 1952/3; Wendel and Platzoeder, 1958; Wendel, 1954). With the crest midships the righting lever is very much smaller because most of the hull sections do not produce righting levers. Fig. 550 shows a record taken during model tests. The model, inclined to 30°, was overtaken by waves of about the same length as the model with a height/length ratio of 1:20. The record not only shows that the righting lever varies during the overtaking period but also that the mean righting lever was considerably smaller than in smooth water. Every seaman knows a ship to be "soft" when riding on a big wave. There will generally not be enough time for the ship to capsize because the righting lever will soon increase. The mean reduction must, however, be considered in the stability balance.

This decrease of the righting lever in waves may be explained by a prismatic body having any shape, immersed to a displacement with maximum righting lever.

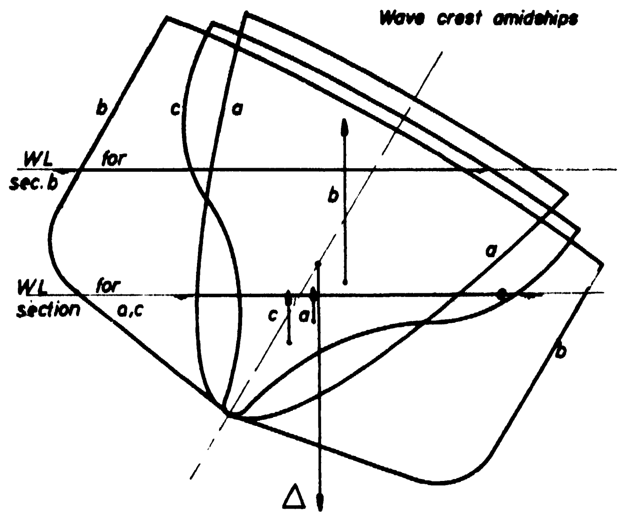


Fig. 549. Influence of seaway on the righting moment

When this condition is fulfilled for the body as a whole, it is also fulfilled for each of the sectional areas. If the immersion of some section areas is changed by a wave, the righting levers will be less.

The influences of the sea on stability are still not fully known, but the following can be stated: the deduction from the smooth-sea righting levers depends only on the shape of ship and wave; it is in no case proportional to the smooth-sea levers. If displacement, rate of heel, position and shape of waves are fixed, the deduction is constant and can be compensated for by larger smooth-sea righting levers.

Table 135 shows the righting levers of two ships in a seaway as calculated by Arndt and Roden.

Safety allowance

The safety allowance is the heeling lever which must be added. A ship may be considered safe when at angles of heel of 30°, 45° and 60° the balance appears on the left, i.e. in the heeling lever column. In the stability balance, unfavourable conditions should be investigated. All of them will rarely coincide. If the stability balance gives insufficient safety, the design must be changed or the master be instructed how to increase stability during voyages. This latter solution is unsatisfactory but difficult to avoid in some cases.

The moments resulting from free surface fluids can usually be decreased considerably by longitudinal bulkheads. Dry cargo or coal can be secured in the same way, generally with removable wooden boards. The accumulation of additional weights, e.g. water on deck or icing, can be avoided or decreased. There are various appliances for de-icing superstructures. Masts can be built without stays and shrouds. The BSRA researches (1957) showed

TABLE 135

Righting levers and their decrease in a seaway

		Ship No. 1	*Ship No. 2*			
Length, L	ft.	268.0	310.0			
	m.	81.60	94.49			
Beam, B	ft.	43.25	45.90			
	m.	13.20	14.02			
Moulded depth, D	ft.	25.90	27.80			
	m.	7.90	8.48			
Draught, T	ft.	17.90	—			
	m.	5.43				
Freeboard, f	ft.	8.10	—			
	m.	2.47				
Displacement, Δ	ton	4,575	6,420			
Wave length, λ	ft.	262	295			
	m.	80	90			
			Without erections		*With erections*	
Wave height, h_w	ft.	23.0	16.4	24.6	16.4	24.6
	m.	7.0	5.0	7.5	5.0	7.5
Maximum GZ	in.	8.65	10.25	10.25	16.55	16.55
	cm.	22.0	26.0	26.0	42.0	42.0
Angle of GZ_{max}	deg.	35	30	30	45	45
Decrease of GZ_{max}	in.	2.76	3.15 to 4.33	5.91 to 7.48	2.76 to 4.33	5.12 to 7.08
	cm.	7.0	8 to 11	15 to 19	7 to 11	13 to 18

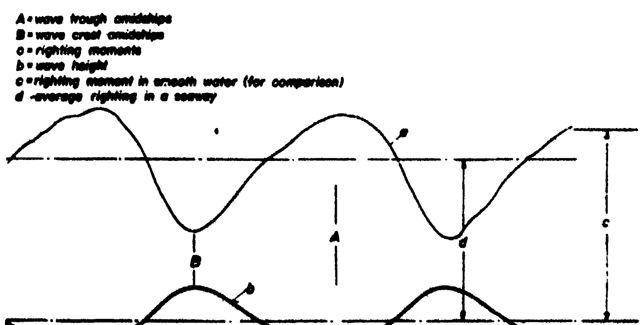


Fig. 550. Righting moments measured by model tests in a seaway

that a strut of 18 in. (46 cm.) diam. iced to only 27 lb./ft. (40.2 kg./m.), while a wire of 2 in. (51 mm.) diam. iced to 37 lb./ft. (55.1 kg./m.) under the same conditions. A bulwark with a continuous opening will clear the deck from water much faster than the old-fashioned freeing port. Such openings may not be desirable for conventional trawlers, where the catch is handled on the

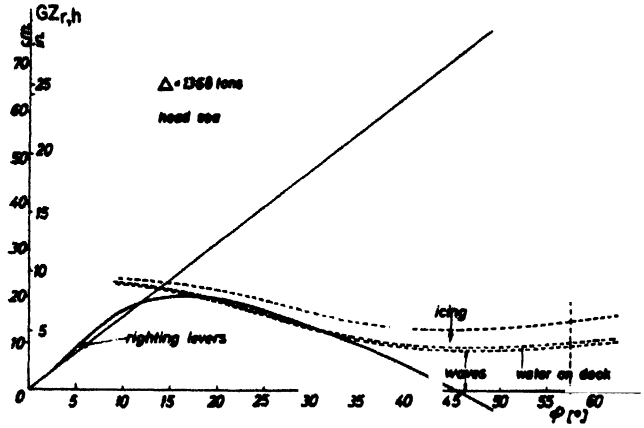


Fig. 551. Righting levers and heeling levers of trawler in head seas —according to Table 136. The ship is unsafe

weather deck, but on stern trawlers, where the catch is handled in the 'tween deck, side openings in the shelter-deck bulwarks should be used.

The heeling moment caused by the wind can hardly be reduced. The moment due to turning can only be reduced by lowering the centre of gravity. Further, it is almost impossible to reduce the loss of stability due to waves but it can be compensated for. The righting levers can be increased by solid or liquid ballast.

Alterations in the main dimensions may induce a considerable improvement: this is illustrated by considering the rectangular prism in fig. 554. The height of the centre of gravity above the keel may be constant. The curve "a" is valid for the dimensions given. At a list of 15° the deck edge becomes immersed and up to this point the equation (8) is valid. Curve "b" corresponds to a

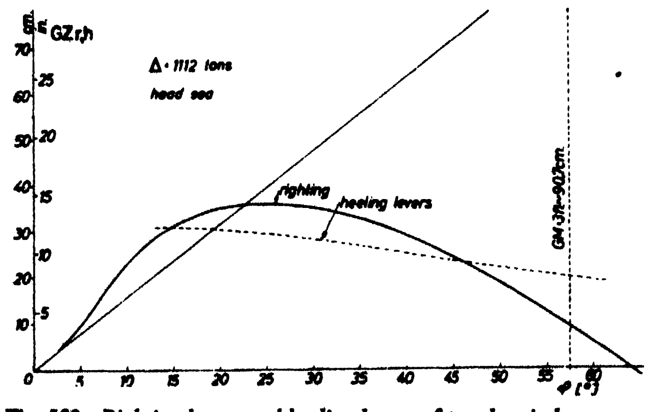


Fig. 552. Righting levers and heeling levers of trawlers in beam seas —according to Table 136. The ship is unsafe

prism 5 ft. (1.5 m.) broader, and curve "c" to one with freeboard increased by 3 ft. (1 m.). A higher freeboard gives the best improvement, especially at large angles of heel. Larger beam increases the metacentric height, which should not be too high for seakindliness, but it also increases the moments due to the shift of liquids in partially-filled tanks. Thus, in general, it is better to increase the freeboard. With increased freeboard, however, KG increases and thus the factor BG . sin φ causes a greater deduction in the equation (7); but as the increase of GZ is greater, the result is an improvement. A greater KG means a smaller GM and thus better seakindliness. The stability loss due to waves becomes appreciable at greater angles of heel, and to counteract this loss it is undoubtedly better to increase the freeboard than the beam.

The trawler of table 136 and fig. 551 and 552 is not safe. An increase of freeboard resulted in a safety allowance of 2⅝ in. (6.7 cm.) at 30° and ¼ in. (0.6 cm.) at 45° (table 137 and fig. 553). In this load condition the

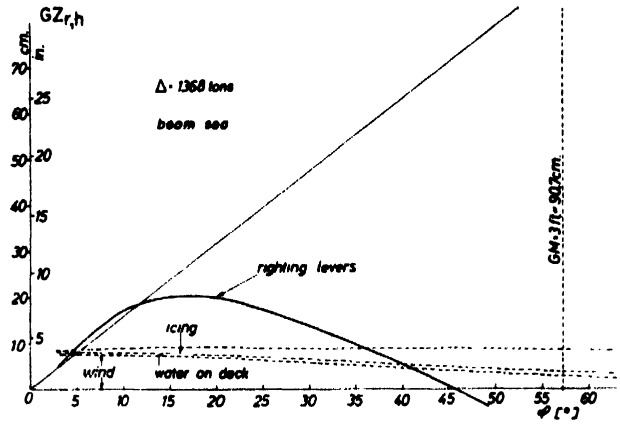


Fig. 553. Righting levers and heeling levers of trawler in the same case as fig. 551, but with increased freeboard—according to Table 137. The ship has sufficient stability. (Superstructure not included in calculation in all three cases.)

trawler will be safe when taking account of superstructure (forecastle, deckhouse) which were not included when calculating the righting levers.

Stability criteria

There are so far only empirical formulae and various criteria for minimum stability, and they are either not valid or are confined to special types of ships. In spite of the well-known and great influence of freeboard on stability, this was not considered at all when the international freeboard regulations were formulated.

The metacentric height (GM) is not sufficient for a detailed stability survey. Any search for a minimum righting lever or moment, which would be valid for all types of ships, is only a waste of time. It will not lead to any more satisfactory result than the search for a single formula for estimating the power of a ship of which only the displacement is known.

TABLE 136

Stability balance—Trawler

L = 174 ft. (53.00 m.)   B = 26 ft. 2½ in. (8.00 m.)
T = 15 ft. (4.59 m.)   f = 1 ft. 4 in. (0.41 m.)
Δ = 1,368 ton   GM = 3 ft. (0.91 m.)

HEADSEAS

		Heeling moment			Righting moment		
Heeling angle		30°	45°	60°	30°	45°	60°
Righting levers	in.	—	—	4.80	5.35	0.16	—
	cm.			12.2	13.6	0.4	
Influence of waves	in.	5.20	3.27	3.98			
	cm.	13.2	8.3	10.1			
Water on deck	in.	0.24	0.31	0.35	—	—	—
	cm.	0.6	0.8	0.9			
Icing	in.	1.10	1.58	1.89	—	—	—
	cm.	2.8	4.0	4.8			
Safety allowance	in.	—	—	—	1.18	5.0	11.05
	cm.				3.0	12.7	28.0
Total	in.	6.55	5.15	11.05	6.55	5.15	11.05
	cm.	16.6	13.1	28.0	16.6	13.1	28.0

BEAM SEAS

		Heeling moment			Righting moment		
Heeling angle		30°	45°	60°	30°	45°	60°
Righting levers	in.	—	—	4.80	5.35	0.16	—
	cm.			12.2	13.6	0.4	
Wind pressure	in.	2.28	1.58	1.07	—	—	—
	cm.	5.8	4.0	2.7			
Water on deck	in.	0.23	0.32	0.35	—	—	—
	cm.	0.6	0.8	0.9			
Icing	in.	1.10	1.58	1.89	—	—	—
	cm.	2.8	4.0	4.8			
Safety allowance	in.	1.73	—	—	—	3.32	8.1
	cm.	4.4				8.4	20.6
Total	in.	5.37	3.47	8.49	5.37	3.47	8.1
	cm.	13.6	8.8	20.6	13.6	8.8	20.6

Sufficient stability can be ensured only by balancing righting and heeling levers. The methods for calculating the heeling levers are not yet complete. Some of the heeling levers can easily be calculated, such as those due to internal free fluids or shift of cargo. Others require more complicated calculations. Even if single items are doubtful, this method should be used. In this paper a new concept is advanced regarding the wind moments, and some data on the loss of righting levers in a seaway are reported. Some full-scale and some model experiments seem to prove it, and detailed results are expected soon. The author succeeded in explaining some recent tragic cases of capsizing by the balance method.

When calculating the stability of a ship in a damaged condition, which is required for passenger vessels

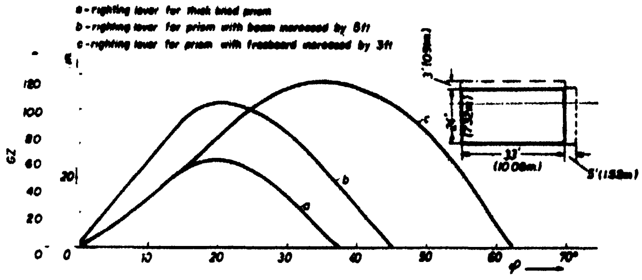


Fig. 554. Righting levers for a rectangular prism

according to the International Convention for the Safety of Life at Sea, 1948, the balance method is commonly used.

Something like table 138 is required, from which the curve of righting levers, giving adequate safety, can easily be determined.

Measuring stability

The righting levers of a given ship at a given displacement can be altered only by changing the position of the centre of gravity. The rise of the curve of the righting levers at the angle of $\varphi = 0°$ thus defines that curve throughout its whole range. As the KM value is defined by the displacement, the GM value defines, for a given ship at a given displacement, the whole curve of righting levers, although GM should not be used to compare the righting lever curves for two different ships or for two different displacements. Having calculated the righting levers required for a given ship, e.g. by the method indicated above, the result may be expressed by a table, showing the minimum values required against the draught. If the master was able to measure the metacentric height even while stowing, he could make sure that cargo was stowed so as to get sufficient stability; hence ships could be safe in all circumstances.

TABLE 137

Stability balance—Trawler
(Δ = 1,112 ton)

HEADSEAS

		Heeling moment			Righting moment		
Heeling angle		30°	45°	60°	30°	45°	60°
Righting levers	in.	—	—	—	13.90	9.57	2.44
	cm.				35.0	24.3	6.2
Influence of waves	in.	9.50	7.00	5.23	—	—	—
	cm.	24.1	17.8	13.3			
Water on deck	in.	0.28	0.39	0.43	—	—	—
	cm.	0.7	1.0	1.1			
Icing	in.	1.38	1.93	2.36	—	—	—
	cm.	3.5	4.9	6.0			
Safety allowance	in.	2.64	0.24	—	—	—	5.55
	cm.	6.7	0.6				14.1
Total	in.	13.80	9.57	8.0	13.8	9.57	8.0
	cm.	35.0	24.3	20.3	35.0	24.3	20.3

TABLE 138

Inclination, φ	*GM and GZ*		*in.*	*cm.*
0°	Metacentric height	GM	18	45.7
30°	Righting lever	GZ	10	25.4
37°	Maximum GZ		13	33.0
60°	Righting lever	GZ	2	5.1
62°	„ „	GZ	0	0

The metacentric height can be obtained either from an inclining or a rolling test. Both methods have advantages and disadvantages. As a rule, the inclining test is preferable. It can be carried out with water tanks at both sides of the ship which are filled alternately to a known volume. Measurement of the small angle of heel is not easy, but can be made by a sextant, or a water gauge. GM can be calculated with the aid of tables or curves.

An advantage of the rolling experiment is its simplicity, especially when dealing with smaller ships which can easily be made to roll. Measurements of the radius of gyration are published, so that this quantity can be estimated fairly accurately (Horn, 1953; Thode, 1954; Weiss, 1953). It is difficult, however, to determine the natural frequency of a ship among the forced oscillations caused by sea.

A self-acting instrument working on the principle of the inclining test has recently been developed by Arndt and Roden in the author's department (Boie, 1958; Hebecker, 1958). The test is carried out automatically in a few minutes. Fig. 555 shows this apparatus, which is the size of a wireless set. On the right panel are the draughts and the displacements in freshwater and seawater. On the centre panel, the value of GM is shown

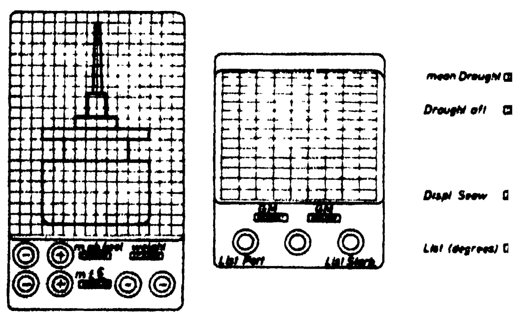


Fig. 555. Front of stability measuring and indicating instrument. Right panel: draught and displacement indicator. Middle panel: GM and righting lever indicator. Left panel: arrangement for calculating the influence on other weight distributions

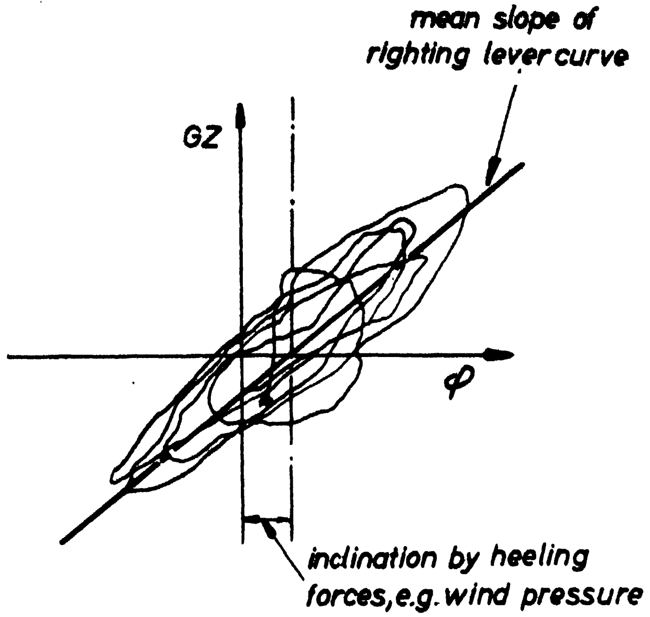


Fig. 556. Oscillogram from stability-at-sea recorder. The thick line represents the mean slope of fluctuating righting-lever curve indication

and the curve of righting levers in indicated by luminous points. The apparatus includes a computer with which the influence of the load can be calculated before stowage. With a knob, the master brings a luminous indicator to the point where the weight will be loaded or unloaded. After having inserted the weight with another knob, he immediately sees the righting lever curve and the GM value to be expected. This is based on exact measurement of the initial GM and exludes all calculation errors.

Another apparatus, also developed in the author's department by Roden and Baumann, is designed mainly for research. It presupposes motions of the ship, but it is not based on simple measurement of periods. According to the law of circular motions, the sum of moments acting is equal to the moment of inertia, multiplied by the angular acceleration. As the ship's moment of inertia can be assumed to be constant for a certain load condition, the measured angular acceleration allows calculation of the moments acting (Boie, 1958; Hebecker, 1958). This apparatus should help to determine accurately the decrease of righting levers at sea and those of other heeling moments. Fig. 556 is a typical result from this instrument as shown on its cathode-ray oscillograph screen.

The author wishes to express his appreciation to Deutsche Forschungsgemeinschaft for financial assistance given for the Stability in a Seaway investigation and the development of the stability-indicating instruments mentioned. He also wishes to acknowledge the valuable help of B. Arndt, C. Boie, O. Krappinger, S. Roden and U. Wagner in the preparation of this paper.

CAUSES OF ACCIDENTS

by

Wm. C. MILLER

The need for safety at sea is just as great as it is ashore or in the air, as nature is an immeasurably destructive force. Records of losses at sea however point out that the forces of nature are no more responsible than the failings of the crews. In the last six years, 29 California tuna clippers of more than 200 GT each have been lost, resulting in a financial loss of £4,650,000 ($13,000,000)—disregarding the loss of earnings. 37 per cent. of the accidents were caused by human failure, 7 per cent. by physical failure and 56 per cent. by a combination of both. The causes of the loss of five clippers were reported. A was lost because ballast tanks were not filled as instructed. B sank, losing two lives, because an internal bulkhead gave way. The reason for this loss was determined by the help of a plexiglas model. which could be filled at will by water in the various tanks. Vessel C was lost due to failure in the steering machinery in which, six years previously, an electrical safety circuit had been cut. D was at anchor, with her auxiliary engines stopped, awaiting better conditions. She was flooded, due to a leak, and because of the fact that the boat could not be pumped, she became a total loss. Vessel E developed a fire in the engine room when the engineer on watch was drinking coffee in the galley, and it had got out of control before it was discovered.

Training programmes must be established to give the seagoing personnel in the fishing industry the knowledge and experience required to prevent accidents. The task of designing and building a successful fishing vessel is difficult, but it seems to be still more difficult to introduce reforms in an industry that has been ruled by tradition and technical indolence for hundreds of years.

LES CAUSES D'ACCIDENTS

La nécessité de la sécurité en mer est tout aussi grande qu'à terre ou dans l'air, car la nature est une force destructrice incommensurable. Cependant, les relevés des pertes en mer font ressortir que les forces de la nature ne sont pas plus responsables que les défaillances des équipages. Pendant les six dernières années, il a été perdu 29 tuna clippers californiens de plus de 200 tx de jauge brute chacun, causant une perte financière de £4.650.000 (13.000.000$)—sans tenir compte de la perte de revenus. De ces accidents, 37 pour cent étaient dus à des défaillances humaines, 7 pour cent à des défaillances physiques et 56 pour cent à une combinason des deux. Les causes de la perte de 5 clippers sont rapportées. A a été perdu parce que les water-ballasts n'ont pas été remplis comme il était recommandé. B a sombré, en perdant deux hommes, à cause du lâchage d'une cloison interne. La raison de cette perte a été déterminée à l'aide d'un modèle de plexiglas. dont les divers réservoirs pouvaient être remplis d'eau a volonté. Le navire C a été perdu par suite d'une panne de la machine à gouverner dans laquelle, six ans auparavant, un circuit électrique de sécurité avait été coupé. D était ancré, attendant de meilleures conditions, et les moteurs auxiliaires étaient arrêtés, mais il a été perdu par suite d'une voie d'eau et du fait qu'il ne pouvait pas faire fonctionner les pompes. Il y a eu un incendie dans la salle des machines du navire E, pendant que le mécanicien de quart prenait son café à la cuisine, et l'incendie ne pouvait plus être maitrisé quand on l'a découvert.

Il faut que des programmes d'entraînement soient établis afin que le personnel des industries de la pêche prenant la mer ait la connaissance et l'expérience nécessaires pour prévenir les accidents. Le dessin et la construction d'un bon navire de pêche sont une tâche difficile. mais il semble plus difficile encore d'introduire des réformes dans une industrie qui est gouvernée par la tradition et l'indolence technique depuis des centaines d'années.

CAUSAS DE ACCIDENTES

La seguridad en el mar es tan necesaria como en tierra o en el aire, porque la naturaleza es una fuerza destructora inmensa. Sin embargo, los relatos de los siniestros marítimos ponen de relieve que las fuerzas de la naturaleza no causan más accidentes que las flaquezas de las tripulaciones. En los últimos seis años se han perdido 29 clíperes atuneros de California, de más de 200 tons. brutas cada uno. que han producido una pérdida financiera de £4,650,000 ($13,000,000) sin contar la pérdida de beneficios. El 37 por ciento de los accidentes se debieron a flaquezas humanas; el 7 por ciento a debilidad física y el 56 por ciento a una combinación de ambos. Se conocen las causas de la pérdida de 5 clíperes: A se perdió porque los tanques de lastre no se llenaron siguiendo las instrucciones dadas; B se fué a pique. con la pérdida de 2 hombres, por haber cedido un mamparo interno. La razón de esta pérdida se determinó con ayuda de un modelo de vidrio plexi, cuyos tanques se podían llenar de agua a voluntad: el clíper C se perdió por avería en el aparato de gobierno, en el que 6 años antes se había cortado un circuito eléctrico de seguridad. D estaba fondeado esperando que mejorasen las condiciones y tenía parados los motores auxiliares, pero se le abrió una vía de agua que lo anegó y se perdió porque las bombas de achique no se pudieron poner en marcha: en E se inició un incendio en la sala de máquinas mientras el maquinista de guardia estaba en la cocina bebiendo café, y para cuando se descubrió no se pudo dominar.

Deben establecerse programas de capacitación para que el personal que tripula las embarcaciones de la industria pesquera adquiera los conocimientos y experiencia necesarios para impedir accidentes. Es difícil proyectar y construir un buen barco de pesca, pero parece ser más difícil todavía introducir reformas en una industria regida por la tradición y la indolenica técnica durante cientos de años.

SAFETY of personnel and preservation of equipment and gear are important to the fishing industry. The physical and moral responsibility are undeniably the burden of the boat owners. The financial responsibilities are often borne partially, if not entirely, by insurance underwriters who compete for fishing vessel business.

Several basic facts should be considered:

- Where personnel and equipment are not insured, a single accident can result in financial failure for the owners
- Because of the frequency and financial severity of such accidents, insurance premiums are at a high level and may seem an overburdening load to the men who pay them
- Risks are unavoidable, but injuries, loss of life and damage to or loss of equipment can be kept to a minimum through safety practices and the full co-operation of crews.

Prevention of accidents, therefore, becomes the personal problem of each individual, but, as always, responsibility rests with the leaders, who must have the foresight and will to plan and put into effect a strong accident prevention programme based on technical details, experience, honesty and common sense.

Much good material is available to help plan such programmes, but this generally covers only usual conditions. It is necessary to prepare special precautionary requirements to cover local conditions and unusual circumstances. Then the success or failure of such a plan depends on how well the crews are trained to observe it.

The need for safety at sea is just as great as it is ashore or in the air. But at sea, the most imminent dangers would seem to come from the sea itself, combined with wind and storm and other natural elements, which are immeasurably destructive. Yet records of losses at sea point out, on a comparative basis, that the forces of nature are no more responsible than the failings of crews.

Thus, a destructive force equalling that of the powers of nature exists among the crews, and, although we have the intelligence, skill and organization to overcome the human failings, we rarely use them to the full extent.

Accident types

There have been numerous spectacular losses of all sizes of fishing vessels, which provide excellent material for the study of accident prevention. The California tuna clipper fleet has contributed its full share of serious financial losses. In the last six years, 29 vessels of more than 200 GT each have been lost despite the fact that they operated in ocean waters almost totally free from serious storm hazard.

Records show the loss percentage relative to cause to be as follows:

	Per cent.
Foundering	34
Fire	27
Stranding	17
Capsizing	10
Heavy weather	7
Collision	5

Based on insured value, these 29 losses have resulted in a financial loss of £2,710,000 ($7,595,000) to the industry and/or insurance underwriters, or an average yearly loss of £452,000 ($1,266,000). The industry has also suffered the loss of the difference in the amount recovered from the underwriters and the cost of new equipment, estimated to be £1,950,000 ($5,455,000) total or £67,000 ($188,000) per owner. The total combined loss for six years is £4,660,000 ($13,050,000). These figures do not take into consideration the loss of earnings.

Another aspect not dealt with here is that of partial loss due to equipment failure and breakdowns, which, in some years, has almost equalled the insurance premium and, in others, has exceeded it.

The figures show that fire, foundering and stranding comprise the most serious loss group but a study of the cause of loss records in official files shows that 37 per cent. of all accidents are clearly caused by human failure, 7 per cent. by physical failure and 56 per cent. by a combination of both, where the cause is not accurately determinable.

Thus in the past six years in Southern California alone, the annual monetary loss from total loss of vessels of more than 200 GT each has been as follows:

Losses caused by personnel failures, negligence, etc: £287,000 ($805,000).

Losses caused by physical failures of equipment: £54,000 ($152,000).

Losses caused by a combination or one or the other: £435,000 ($1,218,000).

If such losses are to be avoided the accidents must be prevented. A study of accident records must be made and every accident must be considered not only as a result important in itself, but also as a symptom of faulty condition. The results of such a study will form the basis for a sound accident prevention plan.

Some accidents and their causes

Two identical steel tuna clippers, 100 ft. (30.5 m.) in length overall, 210 GT and each with a crew of 14 men, were built in California in recent years. One capsized and sank suddenly during her maiden voyage. The other made one trip and then a false keel was installed containing ballast to add to stability. She operated successfully for several years and then sank, but a very different behaviour pattern was reported for her during sinking than for the earlier loss of her sister ship. Consider these vessels as A and B.

The loss of A was unquestionably due to failure of the crew to ballast the ship properly to provide minimum stability. Capsizing occurred in a calm sea, before any fish had been stowed in the freezing wells, while fuel oil was being transferred from a combination fuel and freezing well to the fixed fuel tanks. The side well's inboard longitudinal bulkhead was 2 ft. (0.6 m.) off the centre line. The well was shaped to the hull from the bottom to the weather deck and contained 22 tons of diesel oil. The loss was caused by filling this well without ballasting as specified by the written instructions for ballasting and loading, which were on board and available. Apparently, the captain felt that his past experience in similar vessels made it unnecessary for him to refer to the technical instructions for the ship's safety in this operation.

Vessel B, in sinking, took the lives of two of the crew. While cruising in calm water, with only a low flat swell running, this vessel suddenly took a hard port list which gradually became worse. Suddenly, she trimmed by the bow and disappeared. The survivors stated that, at the first list, her small boats were lost overboard so the crew were compelled to swim and cling to floating debris until the captain found a net skiff and managed to pick them up.

This loss was thought by the owners to be the result of failure of a recent hull repair but the technicians concerned thought that the sudden list came from an internal shifting of weights caused by a failure of the structure.

Investigation by model

In an effort to establish the facts, a model was built and tested, which revealed a trim condition affecting stability not previously recognized in the clipper class. These results can be useful in effecting greater stability in future vessels.

The model required to obtain precise results was accurate in all details. It was constructed of clear plexiglas so that all interior spaces and equipment were in view as shown in fig. 557.

Two basic considerations were kept in mind during construction and ballasting. The first was the form of the hull, which was reproduced with great accuracy: the second was the exact location of the centre of gravity. Other factors requiring attention were accurate reproduction of free surface, volume and surface permeability of liquids.

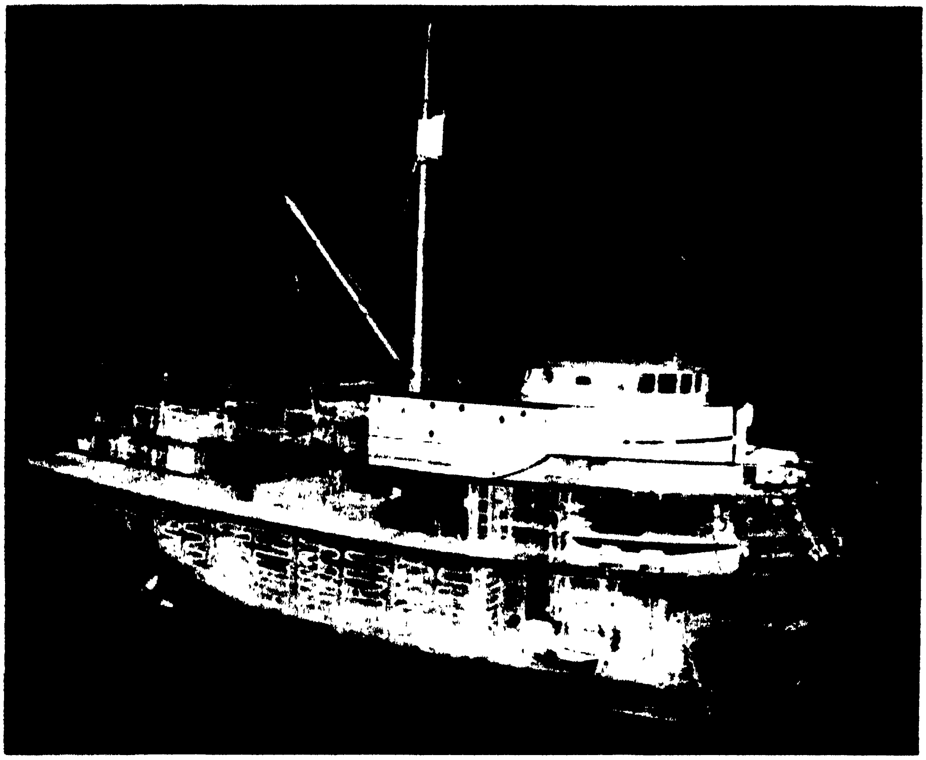


Fig. 557. Stability model of Vessel B

The model was approximately 5 per cent. lighter than the equivalent ship structure to avoid any chance of being overweight. The first step was to locate the centre of gravity of the model in the position corresponding to that of the subject vessel at the time of the disaster. By referring to the original inclining experiments of the ship and to the testimony of the crew regarding its load condition and other pertinent data at the time of loss, the centre of gravity of the ship was accurately determined.

The model was weighed in the light condition and, since the total displacement of the ship was known for her condition at the time of loss, the amount of weight required to be added to the model to duplicate the ship's condition was determined. The weights required represented crew and effects, frozen cargo, liquids, and useable stores. Sheet lead was used to represent crew and stores but the representative weight for frozen fish presented a problem because the volume of the wells had to be filled and the weight and density kept accurate and equally distributed in each well. After some searching, it was discovered that lead wool fulfilled the need. The remaining tanks were filled to the proper levels with water. This left approximately 5 per cent. more load to bring the model to accurate displacement. This deficiency was corrected by the addition of lead ballast which was experimentally moved about until the trim of the model represented that of the ship at the time of the disaster.

A series of inclining experiments were performed to position the centre of gravity accurately. Two methods of measuring the angle of heel during inclining were employed; one using high intensity light rays projected on to a small mirror on the hull side and reflected on to a vertical measuring scale; the other using the common pendulum as in full-size inclining experiments. The pendulum was suspended from the crow's nest to the top of the deckhouse where a small graduated scale was attached.

The scatter of plotted points when the model was inclined indicated an accuracy comparable to full-scale inclining experiments. Fourteen tests were completed during which many minor characteristics of the model were developed. But the centre of gravity was accurately placed and other factors of load and trim were satisfactorily obtained during the first five tests.

Every point considered

Since the sea was reported to be calm on the morning of the loss, it was felt that the tests should be held in static conditions only. The modelling laws to be satisfied in the case of purely static tests were those which stem from the geometry and condition of equilibrium of static forces and moments. On this basis, lengths scale by the first power, areas by the square and volumes by the cube of the linear ratio.

If a model is to float at a waterline, obtained by the application of these laws in a medium, the density of which differs from that of the medium in which the prototype floated, the displacement of the model and all static forces will be scaled by the volume ratio multiplied by the ratio of densities.

The dynamic effects involving flow of fluid from one location in the ship to another location are, in general, difficult to duplicate on a small scale because of the presence of viscous scale effects. However, such dynamic effects would be of minor importance so long as the time required for them to take place is large in comparison with the natural period of response of the ship to the mode of excitation in question. Evaluation of the testimony of the crew indicated that the movements of weight before sinking occurred over a period of minutes and, as the average period of roll of a typical tuna clipper is of the order of 10 sec., it was felt with a high degree of certainty that the situation could be considered static.

Several hypothetic conditions of flooding were investigated on paper, using both the lost buoyancy method and the added weight method, and it was significant to note that the model performance was in close agreement with calculated results at small angles of heel and trim.

At large angles of heel, the experiments frequently bore out the results of calculations but in certain areas discrepancies were noted. This is not to imply that the model impugned the results of the calculations or vice versa. Actually, the model was able to reveal certain phases of damaged stability which could be deduced only with great difficulty by calculations. In at least one condition of flooding the model showed a complete loss of stability and capsized, whereas calculations had indicated that stability would be maintained. However, because of the locations of the flooded spaces in this condition, the model assumed a trim by the stern which had not been considered in the calculations and the geometry of the hull resulted in considerably less reserve of stability than the calculations had indicated. The experiments with the model showed that certain nuances could be explored more readily in this manner than by calculations.

For example, effects of minor changes in loading could be determined in a few minutes experimentally, while to arrive at the same results by computation would require several hours of work. The variable factors affecting stability at large angles of heel, such as free surface and permeability, affected the results radically for small additional angles of heel. These effects are difficult to evaluate by computation and, in some instances, several trial and error approaches were used before the static angle of heel could be determined. An accurately built model obviates the necessity for computers and produces the results automatically. Such results as static angle of heel, moment to incline, trim and other criteria can be measured this way in a few minutes.

Cause of loss was found

The model accurately reconstructed every detail of the sinking as reported by the vessel's master and crew. By repeatedly sinking the model, it also proved without question the exact cause of the loss because the reported pattern condition occurred by only one shift of internal weights. In all other conditions of flooding, whether from internal tanks rupturing or from the hull opening to the sea, the model's behaviour pattern in sinking was radically different from the detailed testimony of the crew.

Before leaving this incident it should be noted that during the study of this loss it was determined that exterior hull and deck openings, vital to security, were open when the vessel's initial list occurred. Also, it was shown by the model test that had these openings been closed, as they were required to be by instructions to the master for maintaining stability, the vessel would not have been lost.

- **These hull openings were not the reason for the list. The court found that a bait well bulkhead below deck and/or its water supply lines broke, due to poor maintenance, allowing approximately 30 ton of water to empty into the shaft alley bilges. This started the list which submerged two of the hull openings**

A study of this kind is sometimes costly when considered in relation to a particular incident but when it results in knowledge to use in forestalling other accidents, such a cost is more than justified.

Another case investigated

Another loss concerned a vessel, C, a 90.4 ft. (27.5 m.) overall, 214 GT typical wood tuna clipper, carrying a crew of 15. She was lost within sight of her home port to which she was returning in ballast after discharging cargo elsewhere.

While cruising at approximately 8 knots and not fully down to her loaded line, C suddenly took a hard port turn, causing her to heel heavily to starboard. The captain stated that, in this condition, seawater entered through open engine room portholes and also through deck hatches and doors which, by instructions for maintaining stability, must be closed when under way. She continued to turn and so capsized and sank.

In the attempt to discover the cause of this loss astounding facts came to light.

The instructions for maintaining stability required that four fish freezing wells below the weather deck should be maintained at capacity flooding with seawater ballast, fish or fuel, at all times when underway and manoeuvring. The master stated that his wells had been leaking for some time and that in approximately 7 to 8 hr. the head of water in the tank would drop 10 to 12 in. (254 to 305 mm.), and would be 3 to 4 in. (76 to 102 mm.) below the top of the well, thereby establishing a substantial free surface effect of the water in the tanks. Displaced caulking and deteriorated bulkhead structure were responsible for the leak. It was also stated that, during the trip on which the loss occurred, bilge pumps were not kept in operation and that the circulating pumps, normally used to keep the tanks full, were not in operation. It was believed that the electric bilge alarm was not turned on.

The helmsman at the time of loss contended that the failure occurred in the steering system because the outside bridge wheel had been pulled so forcefully from his grasp that it could not be returned to neutral.

The steering equipment installed on C, although not all of one manufacture, made up a common electro-mechanical steering combination which affords the greatest amount of safety to any vessel, and is almost an essential system for vessels carrying valuable cargoes, plying inland waterways, or sailing in congested or treacherous waters. The system provides not only follow-up electric power steering, but also direct hand steering with the same steering wheel. The advantage of such a system is immediately apparent when one considers the steering difficulties which may occur during any operation. When being steered electrically, in the case of power failure or partial damage in the system, the clutch at the master wheel may be engaged by the helmsman without danger to himself, such as having his arm broken by a spinning wheel. He may take over manually, completely by-passing the electro follow-up mechanism.

The system on C consisted of the electro-mechanical steering column on the bridge, and a manually controlled steering stand and an electric controller forward of the pilot house. The controller was reported to be in operation at the time of the accident. With this controller activated, the outside wheel of smaller diameter followed the movement of the rudder control shafting, etc. This normally gives the helmsman the opportunity of grasping the wheel and following the motion of the system. The arrangement at the outside bridge wheel, however, would not allow the helmsman to take over from the electrical system in the case of failure as there was no manual clutch installed at that position. Even if the man could have taken over at the outside wheel, its circumference was too small to allow him to apply enough force to overpower the system. On the other hand, a manual clutch was originally provided at the main wheel inside the pilot house for just such occurrences, the wheel being smooth rimmed for safety. The helmsman, under conditions such as were reported, should have immediately entered the pilot house, engaged the manual clutch and taken over from the electrical system, applying opposite rudder to counteract the forces causing C to heel to port.

In C, however, six years before her loss and while undergoing some shipyard service, the electrical circuit to the pilot house wheelstand had been cut, therefore the only safety appliance in the system which allowed a man to take over and manually steer the vessel, was not operative. No counteracting rudder force could be applied. It was also learned that, during the previous six years, when manual steering was required for manoeuvring, such as docking, the engineer had broken the contacts at the steering motor in the engine room by using a screwdriver.

The turn which caused the loss of C resulted from corrosion in the steering motor contacts, which caused the motor to put the helm hard over.

The causes of loss of A, B and C were decided with certainty and proof established but there are many losses of which the causes are never clearly established.

Uncertain causes

Vessel D, a tuna clipper of 125 ft. (38 m.) length and 395 GT with a crew of 15, anchored in the lee of an island to await better fishing conditions. The sea was calm at 7.30 a.m. when the anchor was dropped and at 10.00 a.m. the auxiliary engine stopped and electrical power ceased. The man on watch went to the engine room and found it flooded beyond hope and without power for the pumps. D sank on her anchor in water too deep and in an area too remote to make salvage economical.

This situation has occurred many times, but generally with the vessel under way or moored in harbour and unattended. When the condition occurs at sea, vessels have been lost. In port, they have been salvaged and restored to use at high cost.

The losses at sea must be analysed in the light of immediate or recent sea and weather conditions and, where heavy seas can be ruled out, the causes can be compared with those of the vessels which sink in port.

Some of these causes are: deteriorated hull fittings, valves, pipes, etc., due to lack of maintenance or the owner's desire to extend the useful life of such equipment beyond reasonable limits. Another cause has been accurately identified as deterioration of the steel shell and deck plating and/or hull planking. In several cases, the hull planking has been so badly eaten by marine borers working from the inner surface that the timber could no longer withstand the pressure of the sea. Deterioration of steel shell plating from the inner surface has also been a cause.

It is not uncommon in the tuna clipper fleet to load the vessel until the fishing deck from amidships to the stern is submerged. A steel clipper, which recently sank in port, cost £75,000 ($210,000) for salvage and repairs, the salvage operations alone requiring 13 days. At the time of sinking, the deck aft was submerged and during repair this section was found to have many holes in it, under the bait tanks on the deck. Lack of proper periodic examination of the deck underneath the bait tank caused this loss.

Losses by fire

Fire has been a frequent cause of destruction and vessel E, of 125 ft. (38 m.) length and 390 GT, is only one of many lost through fire. While cruising, E was maintaining the customary ship's watches. The helmsman was intent on steering an itinerant course at the direction of the captain, who was scanning the sea to locate schools of tuna. The assistant engineer on engine room watch was drinking coffee in the galley and the others of the crew were turned in and resting.

The captain, going aft on the raised deck to scan an area for fish, noticed dense smoke pouring through the uptake vents of the funnel. He called the engine room watch from the galley but they found it impossible to enter the engine room door. The engine room was ablaze. The alarm was sound and the fixed full flooding inert gas extinguisher system was released after accessible deck doors with the compartment had been closed. While this was going on, the others of the crew launched the small boats and then the entire crew left the vessel. They went about a quarter mile off and watched until the fire became so bad that no hope of saving the ship remained. The crew was picked up by another clipper working in the same area.

This type of accident has its beginning in some very small fire, generally caused by generator or electrical motor brushes arcing or by some electrical short circuit. Such fires are very easily quenched with a small portable hand extinguisher if the man on watch is at the scene when the fire starts. In the history of accidents resulting in total loss from fire in the Southern California clipper fleet, it is common to find that the blaze was not detected until it could not be fought successfully with the equipment available.

Conclusion

The seagoing personnel in the fishing industry must be afforded the best available materials to work with and they must be taught the physical endurance limits of these products. Training programmes must be established to give them the knowledge and experience required to prevent accidents.

Some recommendations:

Training under qualified instructors in:

- **Principles of seamanship**
- **Safety aboard ship**
- **Lifesaving at sea**
- **Fire fighting on shipboard**
- **Damage control**

Planning:

- **Respect for advice of technical men ashore**
- **Planned and punctually executed maintenance programme**
- **Planned and properly executed operation of ship and equipment**

This paper has dealt with some of the accidents which resulted in the loss of 29 vessels of more than 200 GT each in 6 years (1953-58). During the same period, 56 smaller vessels in the Southern California clipper fleet have also been lost in similar circumstances.

Thus the tasks of the fishing boat designers, builders and maintenance technicians are not easy by any standards and the difficulties in building a vessel which is "worthy of the sea" in all respects and, at the same time, will make a profit in fishing, may seem at times to be insurmountable.

But they are almost trivial in comparison to the difficulties met in trying to introduce reforms which seek to eliminate the loss of life, boats and equipment due to human failure.

It calls for overcoming the prejudices in the minds of people in an industry that has been ruled by tradition and technical ignorance for hundreds of years.

FORMATION OF ICE ON TRAWLERS

by

H. LACKENBY

"Trawler-icing" came to the fore in 1955 with the loss of two trawlers in Arctic waters and the BSRA initiated an investigation to throw light on the problem. This took the form of icing experiments on a model in a climatic chamber from which the weight and distribution of ice accretion was determined for various attitudes to the wind and different rigging arrangements. The loss of stability due to the added ice was also determined. The tests have shown the importance of removing as far as possible ice-catching details such as shrouds and ratlines and cleaning up the rigging generally. This has been underlined by the better performance of the tripod mast arrangement as compared with conventional rigging. It is understood that this investigation has resulted in more attention being given to these matters. Attention has also been drawn to the importance of freeboard in this class of ship which has resulted in more adequate provision being made for this than had formerly been the practice.

In spite of improvements on the lines described above, it is pointed out that any advantage gained would be lost if ships remained long enough in icing conditions and it is stressed that the only sure protection is to withdraw from such conditions as quickly as possible.

LA FORMATION DE GLACE SUR LES CHALUTIERS

Le "givrage des chalutiers" est passé au premier plan en 1955 avec la perte de deux chalutiers dans les eaux arctiques, et la BSRA a commencé des recherches pour jeter la lumière sur ce problème. Ces recherches ont pris la forme d'expériences de givrage sur modèle dans une chambre climatique, d'après lesquelles on a déterminé le poids et la distribution de la croûte de glace pour diverses positions par rapport au vent et différents types de grément. On a aussi déterminé la perte de stabilité due à la formation de glace. Les essais ont montré l'importance de la suppression maximum des détails qui retiennent la glace, tels que les haubans et les enfléchures et, généralement, de la simplification du grément. Cette importance a été soulignée par le meilleur rendement du mât tripode comparé au grément conventionnel. Il va sans dire que le résultat de ces recherches a été de faire porter une plus grande attention à ces questions. L'attention a aussi été attirée sur l'importance du franc-bord dans cette classe de navires, ce qui a eu pour résultat de faire prévoir un franc-bord mieux approprié qu'on ne le faisait auparavant.

Malgré les améliorations des lignes, décrites ci-dessus, on fait ressortir que tout avantage gagné serait perdu si les navires restaeint assez longtemps dans des conditions de givrage, et l'on fait observer que le seul moyen de se protéger de ces conditions est de s'en éloigner le plus rapidement possible.

LA FORMACION DE HIELO EN LOS ARRASTREROS

La formación de hielo en arrastreros adquirió gran relieve en 1955 con la pérdida de dos de ellos en aguas árticas. A raíz del suceso, la BSRA inició una investigación para resolver el problema, basada en experimentos de formación de hielo en un modelo en una cámara climática, determinándose a partir de ellos el peso y la distribución del hielo acumulado con viento de diferentes direcciones y con diversas clases de jarcias. También se determinó la pérdida de estabilidad causada por el aumento de peso del hielo. Los ensayos demostraron la importancia que reviste el suprimir cuanta proyección y detalle, como obenques y flechastes, sea factible y simplificar la jarcia. De esto es prueba el mejor rendimiento logrado con el mástil de trípode en vez de la jarcia normal. Se entiende que uno de los resultados de esta investigación ha sido que se preste más atención a estos detalles. También se ha puesto de relieve la importancia del francobordo en esta clase de barcos, lo que ha culminado en la toma de medidas más adecuadas de lo que se acostumbraba anteriormente.

A pesar de las mejoras citadas, se hace hincapié en que cualquier ventaja lograda se perderá si los barcos permanecen tiempo suficiente en lugares en los que existan condiciones propicias para la formación de hielo. Se recalca que la única protección segura es alejarse de esos lugares con la mayor rapidez posible.

THE question of "trawler-icing" came very much to the fore early in 1955 with the loss of two trawlers in Arctic waters and, arising from this, BSRA initiated an investigation on the model scale with a view to throwing light on the problem. This took the form of icing experiments on a scale model of a British trawler in the climatic chamber of Vickers-Armstrongs (Aircraft) Ltd., Weybridge, England. The object was to ascertain the weight and distribution of ice accretion and the consequent loss of stability for various attitudes to the wind and different rigging arrangements.

The model represented to a scale of 1/12 a steam trawler of 180 ft. LBP × 30 ft. 6 in. beam (54.86 × 9.30 m.) and was complete with all superstructures, major deck fittings and permanent rigging. The above-water profile of the ship and the rigging is shown in fig. 558. It will be noted that the masts were supported by centre-line stays with shrouds and ratlines.

Test conditions

The model was floated in a tank of water in the icing chamber and ballasted to give the displacement and trim corresponding to the condition on the Arctic fishing grounds, viz.:

Displacement	1,115 tons
Draught amidships	13 ft. 7 in. (4.14 m.) moulded
Freeboard amidships	2 ft. 5 in. (0.74 m.)
Trim by stern	8 ft. 2 in. (2.49 m.)

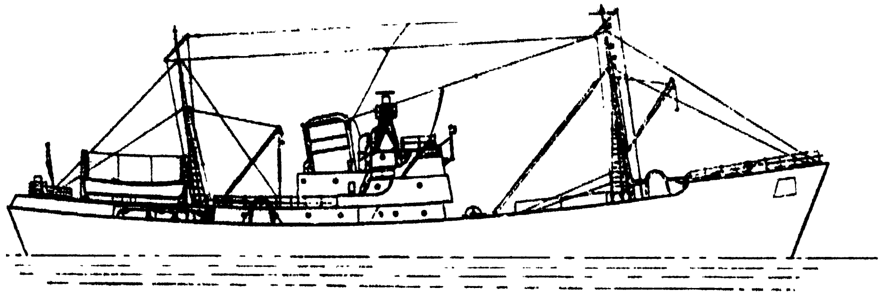


Fig. 558. Rigging arrangement of a typical British trawler 1948

Icing conditions were then simulated by subjecting the model to a cold air stream containing fine water particles injected by spray, but the water in which the model floated was kept above freezing point. The speed of the air stream reproduced, to scale, wind speeds of 45 to 55 knots (23 to 28 m./sec.) corresponding to Beaufort numbers 9 to 10 such as would be met in strong gales.

The following attitudes to the wind were tried:

- Head to wind
- Stern to wind
- Wind at 30 degrees on the bow

In the head to wind condition a tripod mast arrangement was tried in addition to the normal rigging with shrouds.

Results obtained

The ice accretion on the model for the ahead and astern conditions is shown in fig. 559 and 560 respectively. The patterns and relative weights of ice produced were considered to be fairly typical of those encountered on the full scale. On the other hand, the rate of icing on the model was not considered to have any particular significance as far as the ship was concerned. It was shown, however, that the rate of icing, which could be varied by changing the air speed and spray settings, did not affect the general distribution of the ice deposited.

The weight of the ice was determined from time to time by reading the draughts and calculating the increase in displacement. The centre of gravity of the ice was calculated from the loss of metacentric height (GM) determined from inclining experiments carried out at the same time.

The results, expanded to the full scale, are conveniently summarized in fig. 561, where the vertical centre of gravity of the ice and the loss of GM are plotted on a

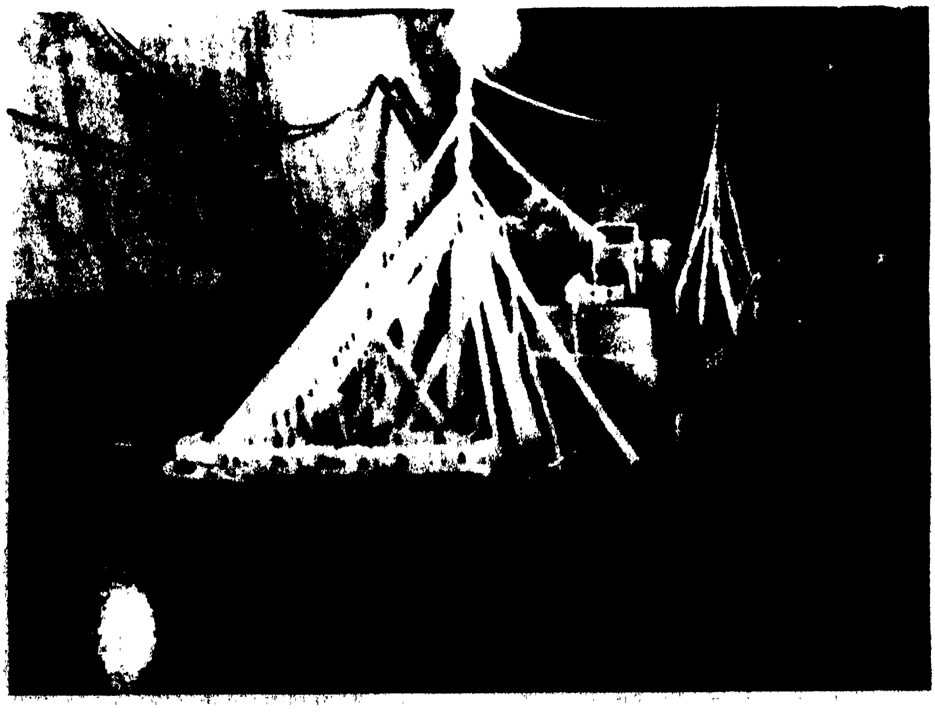


Fig. 559. Typical ice formation with model head to wind. Estimated ice weight equivalent to 140 tons

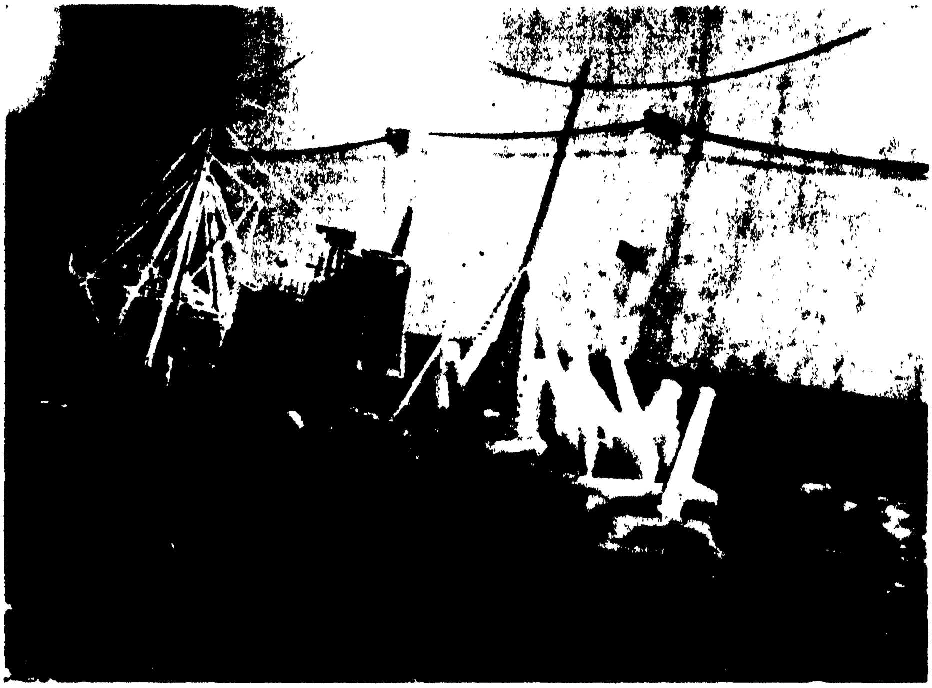


Fig. 560. Typical ice formation with model stern to wind. Estimated ice weight equivalent to 90 tons

base of weight of ice deposited for the different conditions. For a given weight of ice it will be seen that:

- Stern to wind the loss of stability in terms of GM is only about half that in the ahead condition, the centre of gravity of the ice being considerably lower
- With the wind on the bow the centre of gravity of the ice is highest of all and the loss of GM is about 50 per cent. greater than in the ahead condition
- Tripod masts are a distinct improvement on normal rigging when head to wind, the centre of gravity of the ice being significantly lower and the corresponding loss in GM about two-thirds that for normal rigging

The following observations will also be of interest:

Head to wind

In this condition the model iced steadily until it capsized and fig. 559 shows it just before this took place. The greatest weight of ice it was found possible for the model to carry and remain upright was equivalent to 150 tons on the full scale. In this condition the freeboard was reduced to 12 in. (30 cm.) resulting in a very small range of stability and the force of the airstream, although very fine on the bow, was sufficient to blow the model over.

It is pertinent to point out that about one-third of the total weight of ice was collected by the masts, derricks, rails, radar and rigging generally with a centre of gravity about 30 ft. (9 m.) above the deck edge.

Wind 30° on the bow

The ice settled largely on the windward side causing the ship to heel into the wind. This in turn caused more ice to be deposited high up in the rigging and the model eventually capsized with less than half the ice present in the head to wind condition.

Stern to wind

The foremast and its associated rigging were largely blanketed by the superstructure which, for the same weight of ice, resulted in the centre of gravity of the ice being about 7 ft. (2 m.) lower than for wind ahead.

General comment

The tests have shown the importance of removing as far as possible ice-catching details in the upper works, such as shrouds and ratlines, and the desirability of cleaning up the rigging in general. This has been underlined by the better performance of the tripod mast arrangement compared with conventional rigging in that the centre of gravity of the ice deposited was lower. This also points to the advisability of stowing derricks and tackle in the lowered position to keep the ice deposit as low as possible.

It is emphasized that while the removal of ice-catching rigging would improve matters considerably, the same loss of stability and freeboard would occur if the ship remained long enough in icing conditions. Accordingly it is stressed that when such conditions are encountered the only sure protection is to withdraw from them as quickly as possible.

A more detailed account of this work is given in BSRA Research Report No. 221, Trawler-Icing Research (1957). It is understood that the circulation of this report has resulted in more attention being paid by owners and

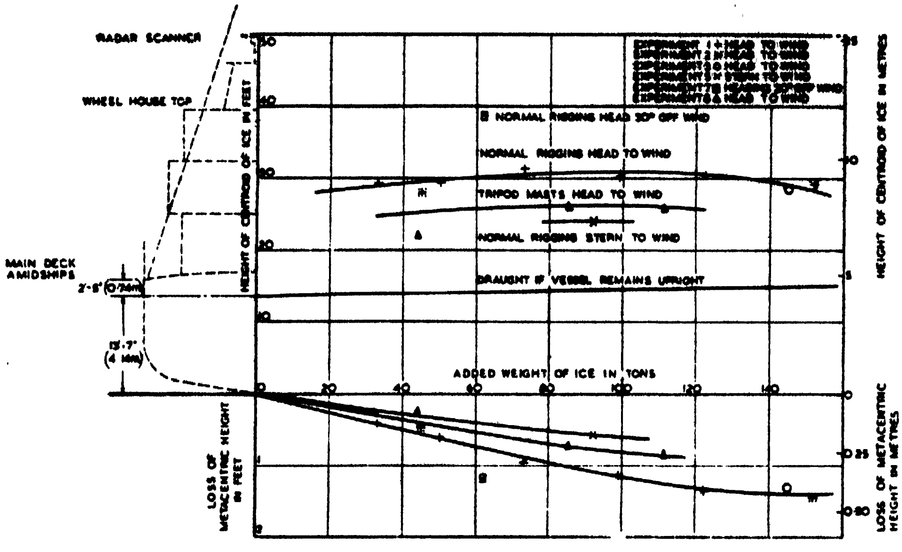


Fig. 561. Effect of icing

builders to certain aspects of trawler design. Action has been taken to streamline the mast structure and superstructures and to eliminate any unnecessary excrescences which could help the accretion of hard ice. The Ministry of Transport has assisted by accepting inflatable rubber dinghies as the main means of lifesaving with the addition of a single working boat stowed on the centre-line under a single arm davit. The attention drawn in the report to the importance of freeboard in this class of ship has resulted in more adequate provision being made than had formerly been the practice, dictated to a large extent by the fishermen's preference. It has been found that in several distant-water trawlers with characteristics improved along these lines, increased freeboard has no proved to be a handicap to successful fishing.

Fig. 562 shows the above-water profile for a more modern trawler than that in fig. 558 with the upper works cleaned up on the lines described above and including a tripod mast.

Acknowledgments

The tests were carried out for BSRA by Vickers-Armstrongs (Aircraft) Ltd., and Vickers-Armstrongs (Shipbuilders) Ltd., in the climatic chamber at Weybridge, England.

The author is indebted to the Council and Director of Research of BSRA for permission to publish this paper. He also wishes to express his thanks to Mr. Ambrose Hunter of Messrs. Cook, Welton and Gemmell Ltd. for advice in the preparation of the paper.

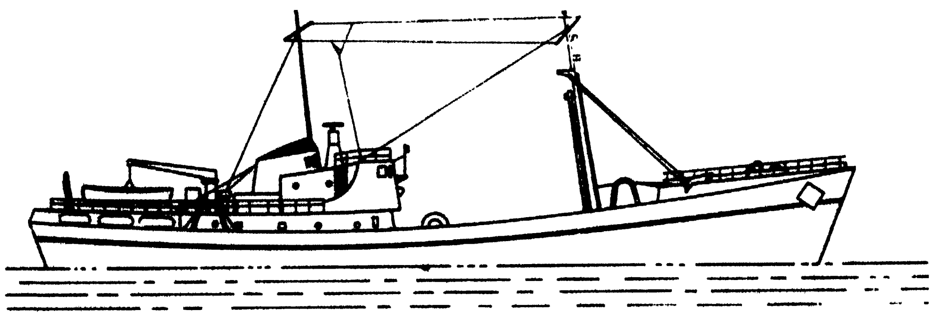


Fig. 562. Rigging arrangement of a typical British trawler 1958

SEA BEHAVIOUR — DISCUSSION

PROF. G. P. WEINBLUM—Vice-Chairman (Germany): Problems of resistance, propulsion and seaworthiness will be treated together. It is important to consider the experience of small boat designers and it is necessary to weigh the different requirements of a boat. Fishing vessels can be treated as large ships but proportions are different and therefore it is of great importance to discuss the peculiarities of fishing boat design.

SMALL BOAT RESISTANCE

MR. J. GARDNER (U.S.A.): The model tests of light displacement fishing launches carried out in 1958 by Gillmer are notable in several instances. The project is the first public and scientific investigation in the U.S.A. of hitherto neglected problems of small fishing boat design. Again, the project is organized as a voluntary co-operative endeavour with pooling of knowledge, skills, labour, and testing facilities. In this way the financial handicap is surmounted, which, more than any other factor, now retards small craft study.

Thirdly, this project, unlike some abstract theoretical studies, is directly practical. Its findings are already being taken account of in the industry. A new lobster boat built closely on the lines of the V-bottom, M-2, at Salem, will be powered according to recommendations from this study. If the performance measures up to expectations, its influence will be felt in the New England lobster industry. In any case it will be possible to check the model test findings with actual performance under fishing conditions.

So far, for obvious reasons, the project has been confined to hydro-dynamic testing. Within the limits of this design, the older, round model, M-1, was just as clearly superior. M-2, while good (hydrodynamically) gave "considerable promise" for improvement with "only slight modifications".

But the hydrodynamic factor is by no means the only one, nor the principal one, to be considered. At least three other major factors have to be taken into account: seakindliness, construction, and suitability for the specific fishing operation. To illustrate the close interaction of these components and how they all figure in making an economic and workable boat, it is enlightening to consider the background of the two designs, M-1 and M-2.

The 34 ft. (10.36 m.) M-1 was built by Frost in Portland, Maine, in 1946 for a Gloucester, Mass., lobster fisherman. The construction of this well-made, but lightly-built round-bottom carvel hull compared favourably with superior yacht work. In fact, a few years later a Gloucester builder copied this hull for a fast and very handsome sport fishing boat.

The year following the import of M-1 from Maine a small builder in a Cape Ann town adjacent to Gloucester built a V-bottom lobster boat of the same approximate length and displacement for a local fisherman. It probably did not cost half the price of the Maine boat. The construction was rough and heavy, and so poorly fastened that the bottom actually fell out within eight months of launching. The boat was beached at Swampscott where an inner chine was added and bolted in. The boat is still in service.

In spite of its crudity, the positive qualities of this V-bottom predecessor of M-2, more precisely its suitability for lobstering as it has recently developed in Cape Ann waters, has inspired a small fleet of similar V-bottom launches. The shortcomings of these V-bottom boats, on the other hand, as well as the fluid requirements of a fast-changing fishery, has occasioned no little experimentation of late, some not particularly successful. M-2 is the latest development in this line of experimentation, or to use Chapelle's term, "manipulation of design".

M-1, regardless of hydrodynamic superiority, is now obsolete so far as the local Massachusetts fishery is concerned. Its construction is relatively costly. Its slack-bilged, comparatively narrow hull has insufficient lateral stability, and does not afford optimum cockpit space for lobster traps tied in series on a single long buoyed line. Further, displacement is too small for new fishing requirements, in particular winter netting and longlining with which fishermen are finding it increasingly necessary to supplement summer lobstering.

The relatively low cost of building chine boats was and is the first point in their favour. Second, their great initial stability makes for easy, comfortable fishing, especially considering the increasingly long hours fishermen must stand at the winch due to growing competition and scarcity of lobsters. A steady boat also makes it easier to balance stacks of pots on the narrow side decks. In addition the chine boats have great cockpit capacity, of which there cannot be too much for modern fishing.

One chief fault of the first Essex County V-bottom boats was their excessive wetness in a head sea. This would seem to be due in part to a full, blunt entrance and in part to a rising chine that broke water at its intersection with the load waterline. These boats require a lot of power. The automobile engines with which these chine boats have been equipped could supply ample power but at the cost of excessive fuel consumption. Fishermen often cannot afford to run their boats at high speed.

By its comparatively fine entrance (14 degrees half angle) and its entirely submerged chine which fairs out completely in the forward sections, M-2 seeks to achieve an easy driving boat and a dry boat in a head sea. Her considerable flare carried well aft is also expected to help dryness. This flare also contributes to make the largest working cockpit of any of the local lobster boats so far, namely 17 ft. (5.2 m.) long by 8 to 9 ft. (2.4 to 2.7 m.) wide inside the coamings. M-2's extra ton of displacement (over M-1) is needed for netting and other winter fishing operations, as well as for carrying upwards of 60 soaked pots as is now sometimes required

M-2 is comparatively inexpensive to build, and would cost appreciably less than M-1 with steam-bent frames and shaped planking. Economy in construction is made possible by M-2's straight section lines and moderate longitudinal curves

Fig. 563. Existing Turkish fishing boats of the Taka type having marked forward shoulders

which allow fast, easy framing and planking. Minimum lofting is required: no moulds and no steam bending in any part of the boat. It is possible that the cross-plank bottom and other features of deadrise construction found in Chesapeake Bay work boats might be even more economical. However, such is not to be considered for New England fishermen and builders would never stand for it.

How M-2 will behave in a following sea remains to be seen. As insurance in this respect, the boat now building has been given nearly four more inches (100 mm.) of keel drag aft than the original lines called for. A rather large rudder should give additional help in this connection. However, there are other factors involved, and these are not so precisely understood as yet in their total interaction as to make forecasting a simple matter.

It might be that M-1 could be altered to give greater cockpit capacity, increased lateral stability in moderate weather, and additional displacement without reducing the model's hydrodynamic superiority, as well as its other excellent qualities. It is doubtful if its construction could be so simplified as to substantially reduce its building cost.

It would seem that by lines manipulation, derivative hulls from M-1 and M-2 could be brought rather close hydrodynamically, and this might also prove true for all other aspects except building costs. In this one department, Mr. Gardner was inclined to believe that the chine boat would always have the edge. But even in this respect the cost spread might be worked down to minor proportions.

For all their differences, including round hull versus V-bottom hull, M-1 and M-2 have much in common. The fact is that the form of M-2 was much influenced by M-1's prior design, as can be appreciated when the lines of earlier Essex County chine boats, the predecessors of M-2, are examined. The fine, gradual entrance, the flare, the run, all show a basic similarity in M-1 and M-2.

When the boat presently being built in Salem is in the water, and her performance under various conditions is known, there will be a much fuller basis, than is afforded by model tests alone, to see how she measures up to the present moods of Massachusetts lobstermen. There is no doubt at all that further manipulation of design will be required. It is certain that the fishermen are far from satisfied with any design used so far. This fishing situation steadily grows more critical, and this pressure bears directly upon the boats. With mounting costs and competition the factor of boat design grows increasingly important. So far, not enough has been done, or even considered, to help boat design and construction catch up with present needs. Gillmer's model test study is one step in the right direction.

Exploratory tests

Mr. H. I. Chapelle (U.S.A.): He had acted as an adviser in Gillmer's tests of fishing launches. The models used were of fishing launches whose plans were available, and the tests were primarily exploratory. These represented types that had not been tested. Fig. 311, hull M-1, represents a highly developed round-bottom launch-form that has become popular with many New England lobster fishermen. These launches are relatively fast and, if properly loaded, fairly good sea boats. They should be loaded aft, of course.

Fig. 312, hull M-2, is an experimental design and rather unusual for a V-bottom. Though theoretically a high-chine V-bottom, the entrance is so fine that the chine disappears in the fore sections, as close inspection of the body plan will show. This model is based on the Hatteras Boat type in the forebody. Fig. 313, hull C-1, was a composite design with the design feature that marked a great many modern Chesapeake Bay launches. The shoulder in the chine is perhaps a bit more marked in the model than in many of this type of launch, but the drawing represents a trend toward a fuller forebody that seems to be in process. These launches were heavily built, compared with M-1, but carry about the same cargo loads in service.

Fig. 314, hull C-2, was an old launch of a type no longer built, but which is still in service. This type is heavily built,

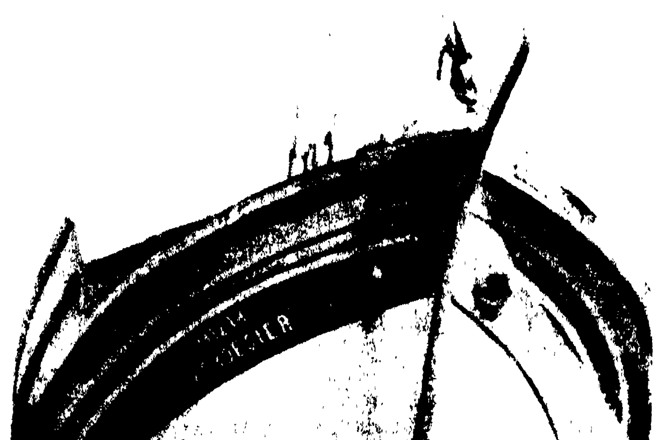


Fig. 564. The Turkish Taka type fishing boats having good seakeeping qualities

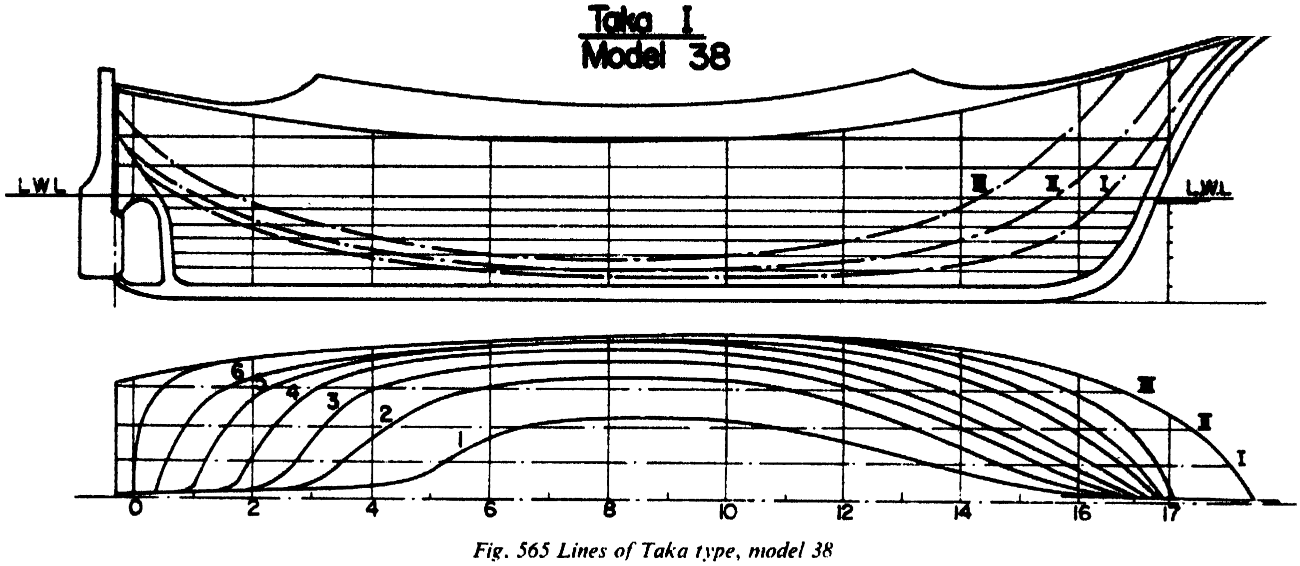


Fig. 565 Lines of Taka type, model 38

compared to M-1, but does not usually carry quite the loads. These launches are always rather narrow and the lines are typical in form and proportion.

Unfortunately, the launches are not of the same displacement, nor dimensions, and comparisons require care, since the design purposes of each model were not the same. However, it would be almost impossible to obtain such similarity using actual working or representative designs from widely-spread areas of the country.

As to the seaworthiness of these models it can be said that C-1 was used in the Bay winter and summer, and the Chesapeake could be very dangerous for small craft. C-1 is less seaworthy and comfortable; M-2 is as seaworthy as M-1: both require careful loading aft, and this is also true of C-2.

Mr. Chapelle emphasized that none of Gillmer's models had high chines and the angular shoulder, where the waterline crossed the chine, as seen in Colvin's drawings of the larger gillnet boats of the Great Lakes, that usually marked the V-bottom form. That was something for further testing, M-2 and C-1 did not show this particular and common feature.

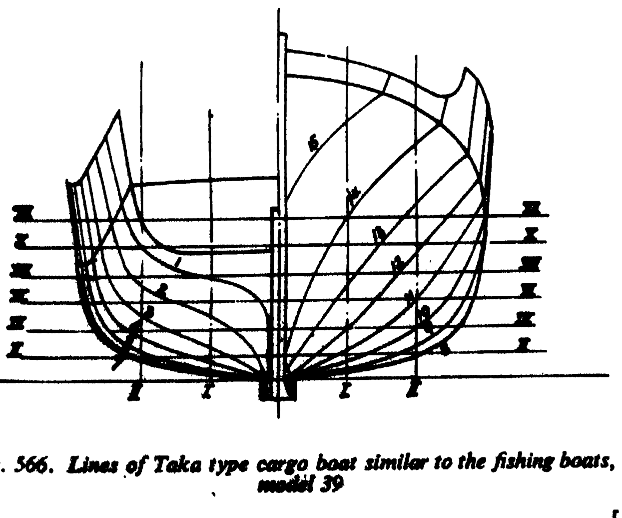


Fig. 566. Lines of Taka type cargo boat similar to the fishing boats, model 39

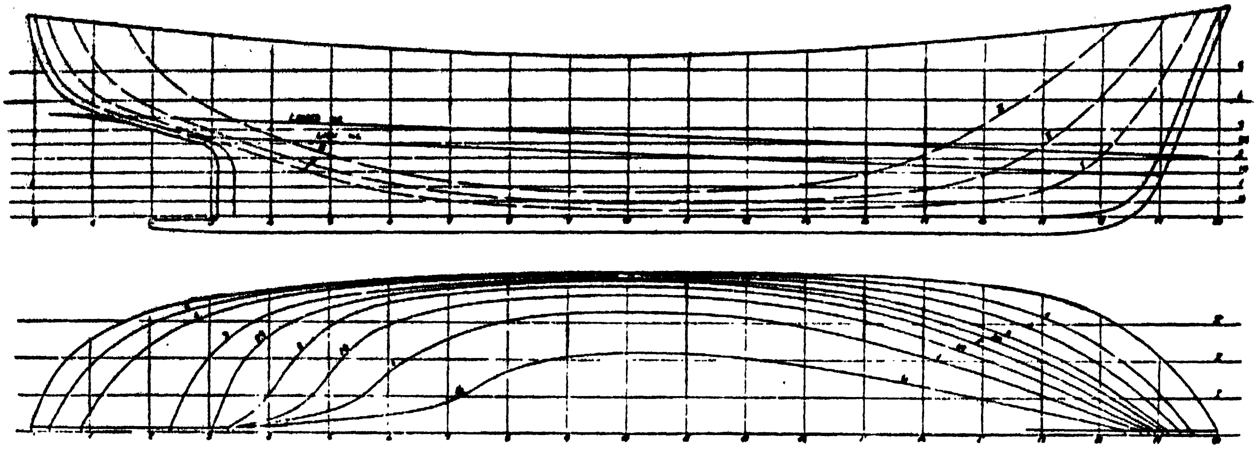
It was chance that three of the models were basically of the "double wedge" form, for selection was not on this basis, M-2 was the most extreme in this respect. He said it was rather difficult to see what marked improvement could be made in M-1, resistance-wise, without loss of desirable practical characteristics. She was a rather extreme model of her type. These boats were not well designed for much variation in load, of course; the practical and safe loading of each would surely increase resistance by immersion of unsuitable stern forms. Hence the conclusions should possibly be qualified. It was evident, however, that C-2 as well as M-2 could be improved. C-1 showed that the existing trend in this type was not going to produce a desirable boat as far as resistance characteristics were concerned.

Turkish experience

PROF. ATA NUTKU (Turkey): The popular Turkish Taka originated several centuries ago. The hull has a comparatively fine entrance and hollow waterlines forward, both in light and trimmed condition. There is a marked forward shoulder, and great sheer and flare forward, as shown in fig. 563 to 566. These characteristics are believed to contribute to the seaworthiness of the Taka. The waterlines aft are blunt and full. The buttocks are fair, bending up at the stern, and ending in a high, shallow transom. The sections aft are nearly flat, ending in a deep deadwood, which gives good directional stability in following seas.

The good sea-keeping qualities of these boats may be one of the reasons for the little interest from fishermen in any improvements in their form after their motorization. However, a first step has been the introduction of the cruiser stern, which gives longer waterline length and helps to prevent squatting. Many boats with transom stern are, however, still being built. It is claimed that transom sterns are better in following seas and do not cause pounding due to stern overhang. A high narrow transom helps to keep the boat stable in quatering seas and to prevent it capsizing while being beached in a surf.

Model tests were carried out in the Turkish Tank to investigate possible improvement in the hull forms of existing old craft. First, two Takas—one used for fishing, another for



Figs. 567. Local builders have themselves improved the Taka type—adopting a cruiser stern and reducing the forward shoulder and sheer. This type is called MG1 and a model No. 20 has been tested

cargo carrying—were selected as representative of their class. The lines of these boats are shown in fig. 565 and 566, models No. 38 and 39 respectively. No. 38 is called *Taka I.*

The second step was to test models of hulls which had been created by local builders by modifying the existing old types, in adopting a cruiser stern and reducing the forward shoulder and the sheer. These boats were typified as MG1 and MG3 respectively, models No. 20 and 21. Their lines are presented in fig. 567, 568 and 569, 570.

The third step was to design new hull forms, on the basis of experience obtained from sea trials and the model tests with these types of boats. The forward shoulder and aft shoulder were reduced, and the aft waterlines were fined; thus the *Taka II* form was produced. This is shown in fig. 571, model No. 28. Mr. H. I. Chapelle while on a FAO mission in Turkey made the design DG3, model No. 14, which is another boat in this category. The lines are shown in fig. 572. Another boat, designed by the Tank for fishermen, has a normal cruiser stern; her lines are presented in fig. 573, model No. 22.

The considerations determining the design of *Taka II*, No. 28, and model No. 22, were to attain hull forms for maximum economy up to 8 knots, with reasonable engine powers of 50 to 60 BHP, as previously tested models of existing craft have proved that engines of 150 to 200 BHP usually fitted in such craft were not justified from engineering and economy considerations.

In addition, a new type of form, being a combination of the Taka and Maier types, with straight parallel sections, has also been studied and the results are included in this contribution as a matter of interest. Two boats built with this form have had satisfactory service for years. The lines are given in fig. 574 and 575, model No. 29.

The dimensions and coefficients of all models are given in table 139. The great differences of the models have enabled a study of resistance of this type of boat. In fig. 576 to 582 the sectional area curves of the boats are given, which help to explain the resistance of the different models especially wave formation and wave resistance.

Fig. 583 shows for boat lengths of 46 to 49.3 ft. (14 to 15 m.) values of R_t/Δ (total resistance in kg. per ton displacement in salt water) and $C_t = \nabla^{2/3}V^3/EHP$. The R_t/∇ curves show that at $V/\sqrt{L}=0.90$ to 1.0 the normal form with cruiser stern (model No. 22) is slightly superior, the unit resistance being about 0.0007, which corresponds to SHP = 50 and V = 7 knots for the boat.

From $V/\sqrt{L}=1$ to 1.3, the modified *Taka II*, model No. 28, has the lowest resistance, both in light and loaded condition. But above $V/\sqrt{L}=1.2$ the resistance increases sharply.

The original *Taka I*, model No. 38, has the highest resistance up to 9 knots. She is fuller than the other models and her aft shoulder results in separation and considerable eddies. The position of the forward shoulder causes unfavourable wave resistance. Above $V/\sqrt{L}=1.32$ the original *Taka I* seems to improve. This is, however, an abnormal speed for fishing boats; in fact it would require about 3½ times as much power as is required at 8 knots for an economical boat type.

Trimming both by head and stern causes an increase in resistance. Heavy squatting occurs above $V/\sqrt{L}=1.2$ when the bow rises considerably.

Photographs of the models of *Taka I* and *Taka II*, showing the wave formations at a speed-length ratio of around 0.9, are given in fig. 584 and 585. The effect of the forward shoulder of the *Taka I* is easily recognised by the trough in the vicinity of the shoulder and the high bow wave. The *Taka II* has a

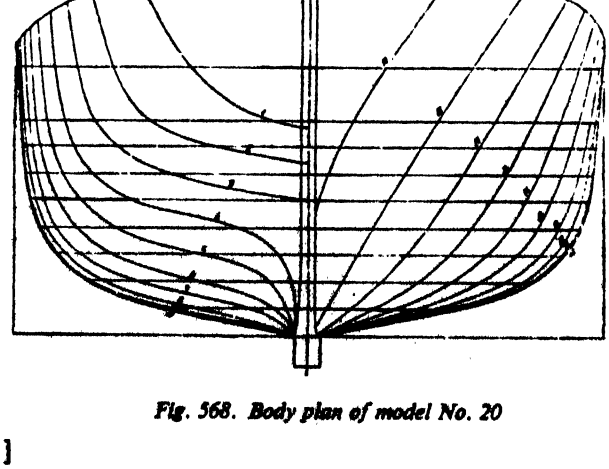
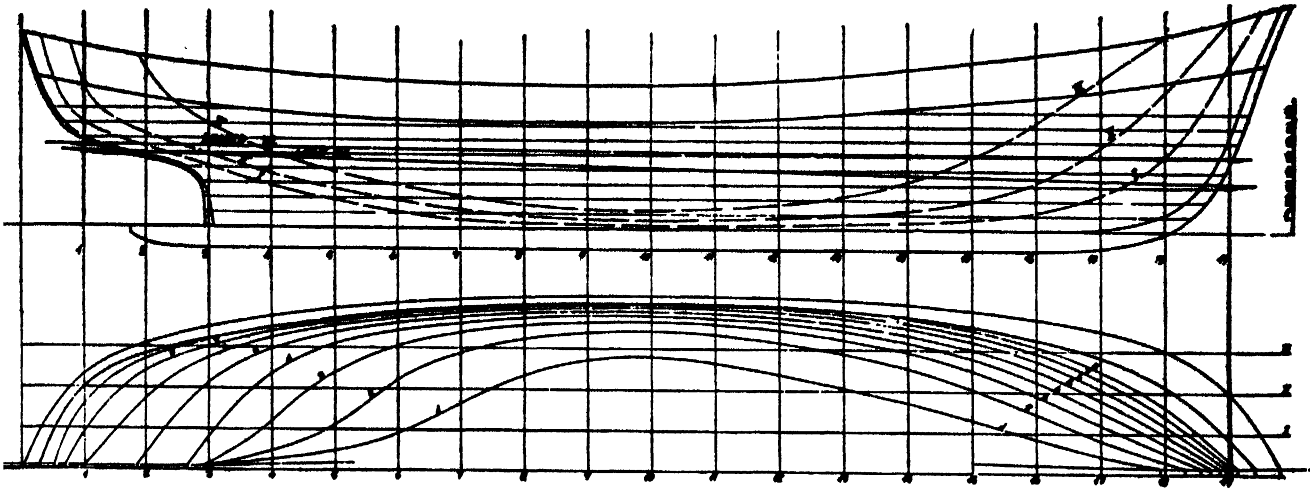


Fig. 568. Body plan of model No. 20



Figs. 569. Taka improved by local builder, type MG 3. Model 21

longer bow wave with a trough behind the midship section. The form still seems to suffer from abrupt changes in the waterlines and diagonals.

Residuary resistance per ton displacement are plotted over $F\nabla = v/\sqrt{g\nabla^{1/3}}$ in fig. 586, including model No. 39, which is a cargo-carrying Taka, the lines and particulars of which are not given in this contribution. Model No. 22 with cruiser stern has the least R_r/Δ up to her design speed of 7.5 knots ($F\nabla = 0.725$). The modified *Taka II*, model No. 28, is best up to $F\nabla = 0.825$, after which DG3, model No. 14, is superior up to $F\nabla = 0.95$. This is, however, not the case when the resistance results are compared on the basis of C_1 values, as shown in fig. 587. The wetted surface ratio of DG3 is $S/\nabla^{2/3} = 7.635$ against 6.5 of MG1. Therefore, she is better up to $F\nabla = 0.75$. At higher speeds, DG3 has relatively less residuary resistance, due to her fineness, $\Delta/(L/100)^3 = 281$ against 438 of MG1. But the unfavourable position of her LCB (+1.3 and 2.7%) may be the reason for the increased resistance at higher speeds.

Model No. 29 (fig. 574 and 575), with straight parallel sections, is a compromise between the Taka and the Maier form. It has harmony between length, prismatic and midship section coefficients. The flow around the hull is uninterrupted and uniform along the diagonals. The aft form with deadwood results in a high propulsive efficiency and directional stability in waves. The wave formation is shown in fig. 588. The resistance, according to fig. 583, is much lower than that of other boats. At $V/\sqrt{L} = 1.4$ the total resistance/displacement coefficient is 0.0025 against 0.0040 for the original *Taka I*, the best of the others at this speed. This corresponds to approximately 1.5 knots increase of speed with the same power. Two boats were built with the form of model No. 29, and full-scale trials confirmed the model tests. The boats have also proved themselves economical and good sea boats in service.

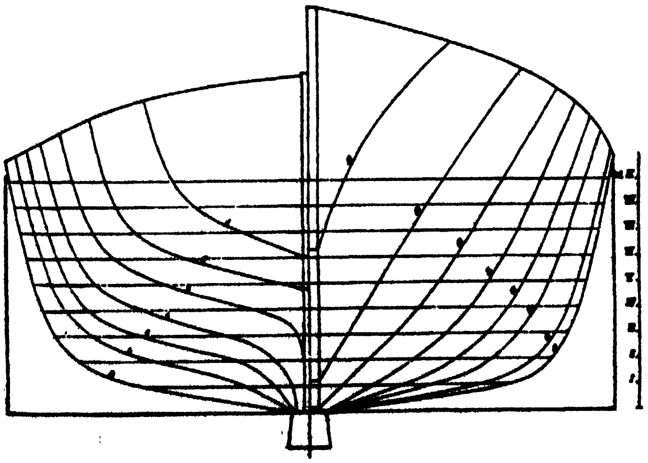


Fig. 570. Body plan of model No. 21

Turkish studies useful

MR. H. I. CHAPELLE (U.S.A.): The Turkish studies of their fishing craft, conducted by Nutku, are of great interest to small craft designers. The Taka type is extensively used in Turkey, and it was his opinion that the motorized version was decadent, at least when compared to the small sailing types seen on the Black Sea Coast in 1957.

He proposed an improved Taka type hull in that year, and it gave him great satisfaction to see that Nutku's improved form closely approximated his design—particularly in view of the improved performance reported.

With regard to the Maier type model, he felt chines might well be retained if wood construction were intended—for it would then be easier to build. The report on the Japanese model indicated that good results could be obtained in this chine modification.

Trawler

MR. J. PROSKIE (Canada): Tothill in his contribution on "trawler economics" did not make it clear what items of cost he included in "power costs". It is also quite obvious that his "net earnings" are "residual" after deducting power costs from gross earnings. In the absence of an assessment of other costs, Tothill's conclusions are subject to doubt.

Investigations indicate that fishermen usually want a higher powered engine than is normally recommended by naval architects and marine engineers. While this desire may not have scientific backing, some weight should nevertheless be given to the man who works the equipment and pays the bills.

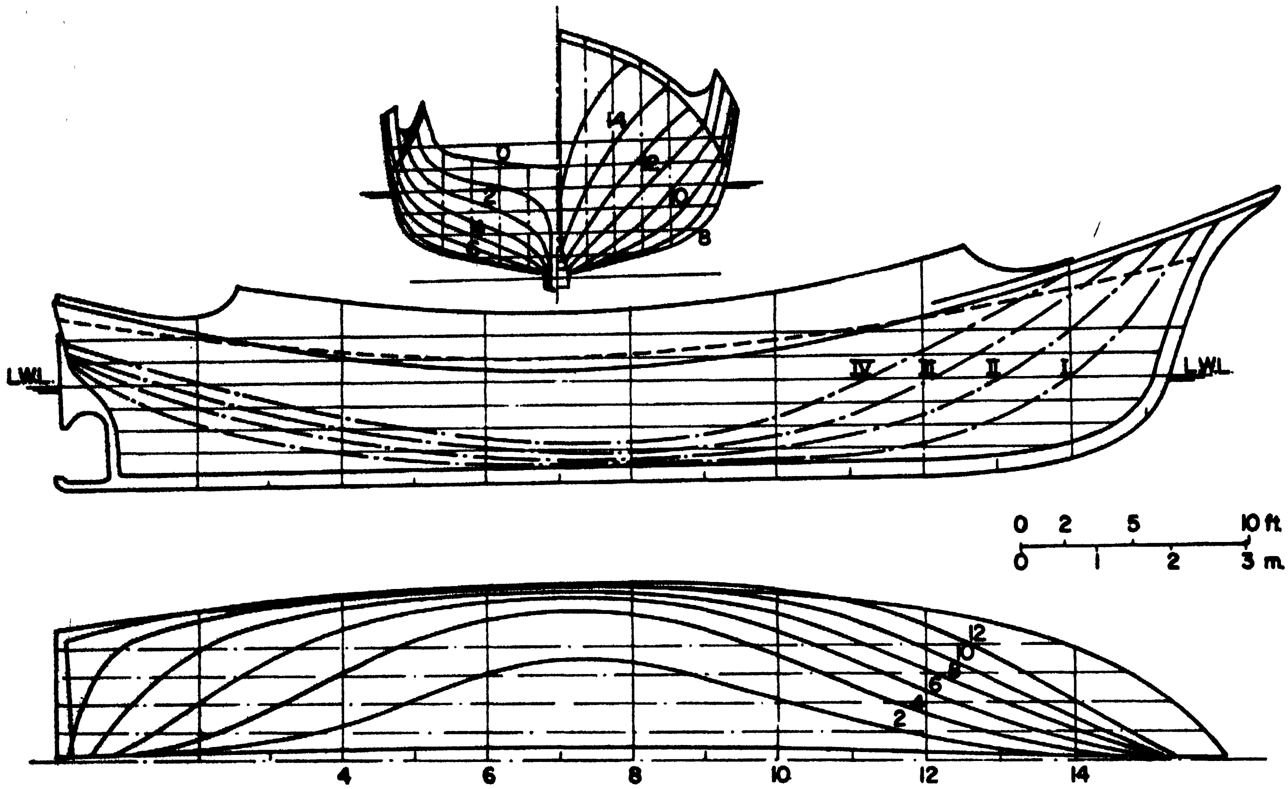


Fig. 571. Taka II designed by the Turkish Tank, model 28

During the past seven years the Canadian Department of Fisheries has made a study of 216 modern boats, of which 102 were longliners, and 114 trawlers under 70 ft. (21.5 m.) LOA. In general, the conclusions from this study indicate that higher powered boats usually have a better performance, higher productivity and profitability. There are exceptions to this generalization, of course. These differences may be accounted for, in part, by variations that exist in type of bottom and in hydrographic conditions generally on the fishing grounds adjacent to the shores of the Atlantic seaboard. The trawling technique, as known at present, is inapplicable on some grounds and on parts of others. This is accentuated by the species caught and landed. For these reasons, type and size of boat and horsepower of engine will vary from area to area for successful and profitable operation. While it is impossible to review the results of the investigation for all areas covered, one or two examples may be sufficient to illustrate the points under discussion.

Example I—compares two groups of trawlers operating in the Bay of Fundy: a 50 ft. (15.25 m.) LOA boat powered by a 200 h.p. diesel engine and a 59 ft. (18 m.) LOA boat powered by a 150 h.p. engine. The total average investment

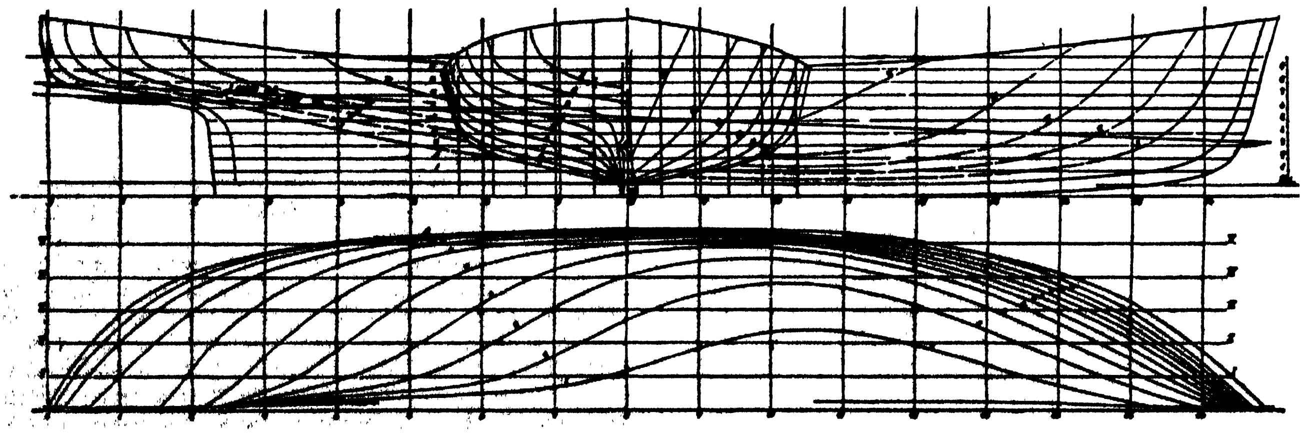


Fig. 572. Fishing boat, DG 3, designed by H. I. Chapelle while on FAO mission in Turkey, model 14

TABLE 139

Dimensions of model tested Turkish fishing boats

Condition	Models		*Taka I Transom*	*Taka II*	*Normal cruiser stern form*	*Taka-Maier combination straight form*	*MG1*	*MG3*	*DG3*
	Model No.		38	28	22	29	20	21	14
	Model scale		1:6	1:6	1:6	1:6	1:6	1:6	1:6
Light condition	L	ft.	44.3	46.2	44.75	52.25	42.97	43.10	42.97
		m.	13.5	14.08	13.65	15.45	13.10	13.16	13.10
	LBP	ft.	44.3	46.2	42.75	52.25	40.40	39.50	40.17
		m.	13.5	14.08	13.035	15.45	12.35	12.05	12.24
	B	ft.	14.90	13.27	14.05	12.63	13.29	12.43	13.65
		m.	4.54	4.045	4.284	3.85	4.05	3.79	4.162
	T_f	ft.	3.10	2.23	2.18	2.33	1.90	1.84	1.74
		m.	0.945	0.68	0.665	0.71	0.58	0.56	0.53
	T	ft.	3.10	2.72	2.85	2.33	2.76	2.43	2.46
		m.	0.945	0.83	0.870	0.71	0.84	0.74	0.75
	T_a	ft.	3.10	3.22	3.54	2.33	3.61	2.99	3.18
		m.	0.945	0.98	1.080	0.71	1.10	0.91	0.97
	∇	cu. m.	28.4	19.70	19.70	19.70	19.70	18.91	16.00
	∇_s	cu. ft.	1,004.0	695.0	695.0	695.0	695.0	667.0	565.0
	Δ	ton	29.0	20.20	20.20	20.20	20.20	19.38	16.41
	Δ_s	tons	28.6	19.90	19.90	19.90	19.90	19.08	16.17
	S	sq. ft.					559.0	536.0	508.0
		sq. m.					52.0	49.82	47.20
	L/B		2.98	3.49	3.19	4.0	3.05	3.18	2.94
	B/T		4.80	4.86	4.80	5.44	4.82	5.12	5.55
	$L/\nabla^{1/3}$		4.48	5.21	5.06	5.74	4.575	4.52	4.86
	$\Delta/(0.01L)^3$		334.0	204.0	222.1	141.5	304.0	314.0	253.0
	δ		0.464	0.417	0.392	0.465	0.468	0.56	0.419
	β		0.742	0.78	0.687	0.863	0.78	0.797	0.697
	φ		0.625	0.536	0.570	0.545	0.60	0.702	0.60
	LCB from FP (%)		52.88	57.0	50.0	52.8	54.37	52.3	47.3
	$\frac{1}{2}\alpha_e$ (degrees)		20.0	20.0	25.0	23.0	25.5	28.5	28.5
Loaded condition	L	ft.	46.50	47.00	48.70	52.95	46.40	44.60	45.70
		m.	14.20	14.34	14.85	16.15	14.17	13.60	13.94
	LBP	ft.	46.50	46.80	46.05	52.40	40.60	40.20	40.35
		m.	14.20	14.30	14.05	16.0	12.40	12.24	12.30
	B	ft.	15.26	15.03	14.43	12.88	13.78	12.83	13.72
		m.	4.65	4.58	4.40	3.928	4.20	3.91	4.182
	T_f	ft.	3.81	2.89	2.89	3.13	2.69	2.99	1.74
		m.	1.16	0.88	0.88	0.955	0.82	0.91	0.53
	T	ft.	4.13	3.39	3.54	3.13	3.54	3.15	2.66
		m.	1.26	1.035	1.09	0.955	1.08	0.96	0.81
	T_a	ft.	4.46	4.20	4.34	3.13	4.40	3.31	3.58
		m.	1.36	1.180	1.325	0.955	1.34	1.01	1.09
	∇	cu. m.	43.22	28.80	28.80	28.80	28.78	24.87	18.53
	∇_s	cu. ft.	1,527.0	1,018.0	1,018.0	1,018.0	1,015.0	878.0	654.0
	Δ	ton	44.34	29.50	29.50	29.50	29.50	25.50	19.00
	Δ_s	tons	43.60	29.05	29.05	29.05	29.05	25.15	18.72
	S	sq. ft.					657.0	639.0	575.0
		sq. m.					61.08	59.40	53.50
	L/B		3.05	3.14	3.38	4.11	2.95	3.13	2.94
	B/T		3.69	5.20	5.00	4.11	3.80	4.07	5.16
	$L/\nabla^{1/3}$		4.02	4.695	4.85	5.28	4.04	4.19	4.65
	$\Delta/(0.01L)^3$		440.0	285.0	252.0	197.5	438.0	393.0	281.0
	δ		0.52	0.43	0.405	0.475	0.512	0.542	0.445
	β		0.819	0.76	0.728	0.880	0.810	0.820	0.720
	φ		0.635	0.563	0.556	0.541	0.632	0.661	0.618
	LCB from FP (%)		54.86	55.9	55.9	50.0	53.47	50.0	48.7
	$\frac{1}{2}\alpha_e$ (degrees)		25.50	25.0	31.0	20.0	35.0	35.0	29.5

in the former (trawler A) was £11,450 ($32,032), of which the engine acounted for £5,380 ($15,102), and the latter (trawler B) had a capital investment of £17,000 ($47,614), of which the engine accounted for £4,500 ($12,603).

Comparison of performance, productivity and profitability of these two classes of vessels, based on two-year averages (1956 and 1957) was as follows:

Item		*Trawler A*	*Trawler B*
Days at sea		112	126
Hours trawling		773	735
Landings in tons		619	569
Landings per hour of trawling	in lb.	1,829	1,736
	in kg.	830	786
Gross stock in dollars		32,698	31,542
Rate of profit on capital invested in per cent.		20.1	12.0

It is apparent that the higher powered boat in this area has a definite advantage over the lower powered boat. Further data on these classes of trawlers can be examined in table 140. From these data it can be seen that the average fuel, oil and grease costs per trawler was less than 10 per cent. of the gross receipts in both cases, the figure for trawler A was 9.7 per cent. and for trawler B it was 9.3 per cent.

Example II—compares 60 ft. (18.3 m.) LOA trawlers operating in the Gulf of St. Lawrence for a three-year period, 1956-1958. The relevant data are summarized below:

Item			
SHP of diesel engine	114	120	152
Capital investment in $	40,897	40,830	47,106
Of this, engine cost $	11,827	12,734	14,672
Days at sea . .	113	130	111
Hours trawling .	1,298	1,441	1,228
Landings in tons .	299	383	327
Landings per hour of trawling in lb.	516	595	596
in kg.	234	269	270
Fuel, oil and grease costs as a percentage of gross receipts . .	9.1	10.6	8.0
Profit as a percentage of gross receipts	10.5	10.6	11.9

Additional information on costs and returns can be found in table 141. Although the results of this group of boats is not as clear cut as those in the first example, nevertheless, indications are that there is some slight advantage in the higher powered boats.

Conclusions: If other things were equal then the level of power costs would determine the proper size of boat and engine power as Tothill has concluded in his paper. However, other things are not always equal. For example higher power costs may be offset by higher volume of output and thus decrease fixed unit costs of production. Thus the rate of profit may be maintained or even increased. Again there are institutional factors. For example, Tothill's choice of a 75 ft. (22.9 m.) trawler for the Canadian Atlantic coast is not the best selection. Canadian fishing regulations prohibit trawlers over 65 ft. (19.8 m.) in length to fish within 12 miles of the coast in specific areas. On the other hand, 75 ft. (22.9 m.) trawlers based in Nova Scotia ports are too small for successful operation on the Grand Banks. In spite of all this, Tothill has made a valuable contribution in his paper, which should stimulate further thinking and research on the subject of his investigation.

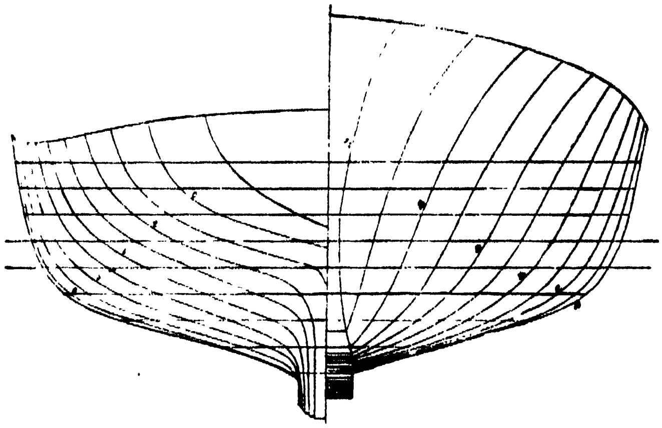


Fig. 573. Fishing boat, model 22, designed by the Turkish Tank

INFLUENCE OF NOZZLES

Dr. F. Gutsche (Germany): The very interesting design of a "fishing boat of the near future" by Tothill reveals some striking aspects of performance. Considering the real task of a fishing boat—to catch fish on the fishing grounds and bring them home in the shortest time—he thought the design has not yet been investigated in all service conditions the fishing boats have to endure. Tothill has developed a fine boat from only one hydrodynamic point of view, i.e. "fine weather speed". Several other points, and surely not of less importance, are the behaviour of the boat in normal sea conditions on the fishing grounds in a seaway up to Beaufort 7, including manoeuvring, especially when going astern. He felt that the design of the rudder nozzle, together with the contra guide stern skeg shown in fig. 332, has not yet solved the problems arising in steering astern, and he would be glad to hear what experience Tothill has had with the simple nozzle without fins and stabilizer, and also with the small clearance between nozzle and stern aperture.

The statement that today on the average, a 9-knot hull is powered by an 11-knot engine, is without doubt correct, but considering that this statement is based only on model tests it should be confirmed in practice under severe weather

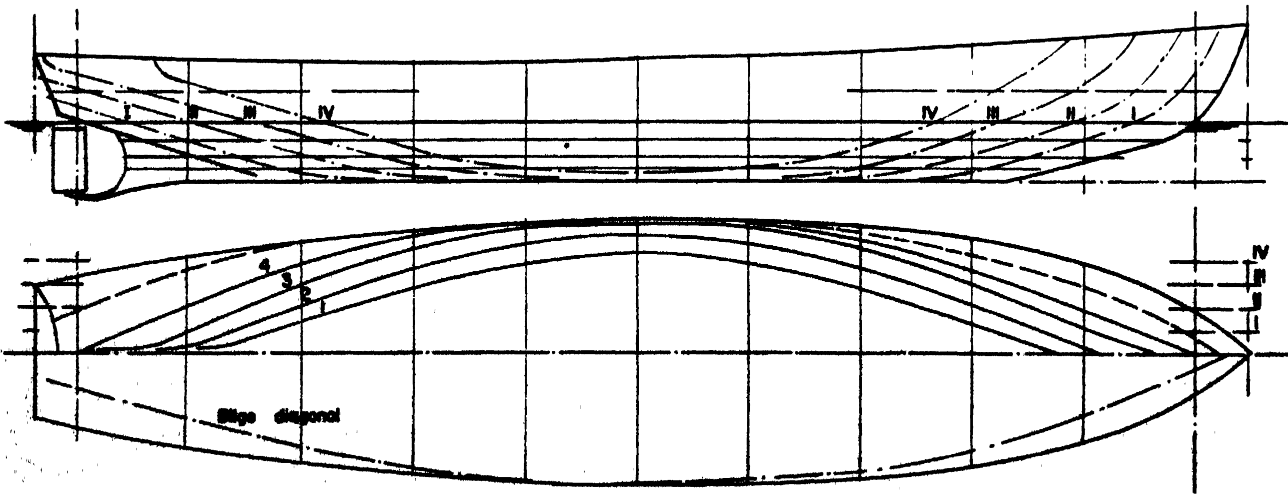


Fig. 574. Hull being a combination of Taka and Maier form, model 29

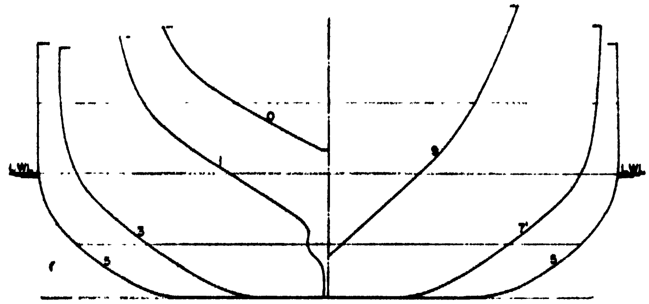


Fig. 575. Body plan of the combined Taka and Maier form

conditions, where it might be found necessary to have some margin of power.

The "seventh power law" used for fixing the point of "optimum speed" may have only a very limited value for this special boat design and it cannot be regarded as a general rule for the other vessels. "Optimum speed" has a special meaning in every case, influenced as it is by many factors, such as building costs, fuel consumption, distance to fishing grounds and many others.

The results of wake measurements within the nozzle without a working screw may hardly be regarded as an indicator for the homogenizing effect of the nozzle. The screw in the forward part of the nozzle with the contracting nozzle wall is the only source of this effect, and the heavier the load on the screw the greater will be the homogenizing effect; in the special case without a screw, the effect becomes very small or practically vanishes.

With regard to the pitch distribution of the screw, the proposal of Dickmann (1955) and van Manen (1957) to design the nozzle-screw in line with axial blow pump theory, so as to reach a constant pressure increase over the whole propeller disc, is, in the special case of a race without tangent velocities, fundamentally the same as Tothill's proposal to aim at a constant axial velocity within the tail race. The problem remains, how far can an approximation to this ideal state of race be expected by the proposed nozzle arrangement without any rudder or stabilizer in the rear part of the nozzle.

The last question is—what will happen with the pitching great nozzle in a heavy seaway? Only model investigations

TABLE 140

Average and Percentage Distribution of Gross Receipts of Bay of Fundy trawlers

Item	*Trawler A* 2-year Average $	*Trawler A* Percentage distribution %	*Trawler B* 2-year Average $	*Trawler B* Percentage distribution %
RECEIPTS				
Fish sales	32,698	100.0	31,542	97.8
Other receipts	—	—	710	2.2
TOTAL RECEIPTS	32,698	100.0	32,252	100.0
EXPENDITURES				
Maintenance and repairs				
Hull	1,244	3.8	273	0.9
Engine	853	2.6	639	2.0
Winch and gallows	75	0.2	12	—
Catching gear	1,797	5.5	2,220	6.9
Other equipment	142	0.5	400	1.2
Sub-total	4,111	12.6	3,544	11.0
Other operating expenses				
Fuel, oil, grease	3,164	9.7	2,996	9.3
Ice	134	0.4	367	1.2
Provisions	773	2.4	648	2.0
Wages	435	1.3	10	—
Wharfage and rentals	1,187	3.6	—	—
Miscellaneous	103	0.3	130	0.4
Sub-total	5,796	17.7	4,151	12.9
Fixed charges				
Marine insurance	193	0.6	386	1.2
Interest	240	0.7	1,130	3.5
Taxes and other	51	0.2	119	0.4
Depreciation	1,684	5.1	2,847	8.8
Sub-total	2,168	6.6	4,482	13.9
Crew shares	14,189	43.4	14,386	44.6
TOTAL EXPENDITURES	26,264	80.3	26,563	82.4
NET EARNINGS OF BOAT	6,434	19.7	5,689	17.6

TABLE 141

Average and Percentage Distribution of Gross Receipts of Gulf of St. Lawrence trawlers

SHP of Engine	114		120			
RECEIPTS	$	%	$	%	$	%
Fish sales	20,029	97.0	25,675	100.0	21,727	9.9
Other fishery receipts	623	3.0	—	—	15	0.1
TOTAL RECEIPTS	20,652	100.0	25,675	100.0	21,742	100.0
EXPENDITURES						
Maintenance and repairs						
Hull	480	2.3	810	3.1	589	2.7
Engine	503	2.4	837	3.2	299	1.4
Winch	169	0.8	387	1.5	166	0.8
Catching gear	1,210	5.9	1,425	5.6	1,143	5.2
Other equipment	104	0.5	171	0.7	45	0.2
Sub-total	2,466	11.9	3,630	14.1	2,242	10.3
Other operating expenses						
Fuel, oil and grease	1,882	9.1	2,732	10.6	1,733	8.0
Ice	584	2.8	714	2.8	715	3.3
Provisions	1,308	6.3	1,507	5.9	943	4.3
Wages	165	0.8	261	1.0	74	0.3
Wharfage and Rentals	12	0.1	6	—	6	—
Miscellaneous	175	0.9	166	0.7	59	0.3
Sub-total	4,126	20.0	5,386	21.0	3,530	16.2
Fixed charges						
Marine insurance	948	4.6	1,023	4.0	1,084	5.0
Interest	586	2.8	553	2.2	868	4.0
Taxes and other	20	0.1	30	0.1	19	0.1
Depreciation	2,509	12.2	2,544	9.9	2,921	13.4
Sub-total	4,063	19.7	4,150	16.2	4,892	22.5
Crew shares	7,830	37.9	9,776	38.1	8,499	39.1
TOTAL EXPENDITURES	18,485	89.5	22,942	89.4	19,163	88.1
NET EARNINGS OF BOAT	2,167	10.5	2,733	10.6	2,579	11.9

or practical experience in such a seaway can give a satisfying answer.

MR. H. KLAASSEN (Netherlands): Tothill attributed the homogenizing action to the wake created by the nozzle. This is not the right explanation because it neglects the fact that the mutual effect of the propeller and the nozzle materially changes the velocity field in the nozzle to such an extent that a comparison between the velocity fields cannot be made without the propeller action being taken into account. The homogenizing action of the nozzle is the result of the velocity field set up by the circulation around the nozzle airfoil profile. This velocity field is circumferentially equal for reasons of symmetry, and is superimposed on the wake behind the ship. The result is that the field must be circumferentially markedly more homogeneous than the field without a nozzle. In conclusion he stressed that the propeller and the nozzle should be treated as one means of propulsion and that the nozzle should not be taken as a part of the hull.

MR. A. HUNTER (U.K.): Tothill rightly endeavoured to obtain the best of all worlds in his project design. One might question the advantage of a bulbous bow in ships of the length he discussed. With the nozzle, the very fine clearances have to be remembered and also the very rapid erosion which will probably go right around the nozzle unless it is taken care of at regular intervals. Perhaps the metallurgists might be able to help there. A question might be raised about the advantage of the pronounced flare; it might lose considerable speed in bad weather. There again model tests in waves might help.

Closer turn with nozzle rudder

MR. W. ZWOLSMAN (Netherlands): If he had understood correctly, Tothill had not made any steering trials with the nozzle rudder yet, but thought that the rudder effect of the nozzle rudder is likely to be about the same as that of a normal rudder.

In 1945/46 he had built several steel fishing craft:

Five—55 ft. 9 in. (17 m.) LOA, with 70 h.p. engines
Seven—59 ft. (18 m.) LOA, with 80 and 100 h.p. engines
Four—65 ft. 8 in. (20 m.) LOA, with 120 h.p. engines.

Of each of these classes, one boat was fitted with a nozzle rudder, which made a good comparison possible. The 59 ft. boat with nozzle rudder was added to his own fleet, as well as one of the 65 ft. 8 in. boats, also with a nozzle rudder. The general design of the nozzle rudder is given in fig. 589.

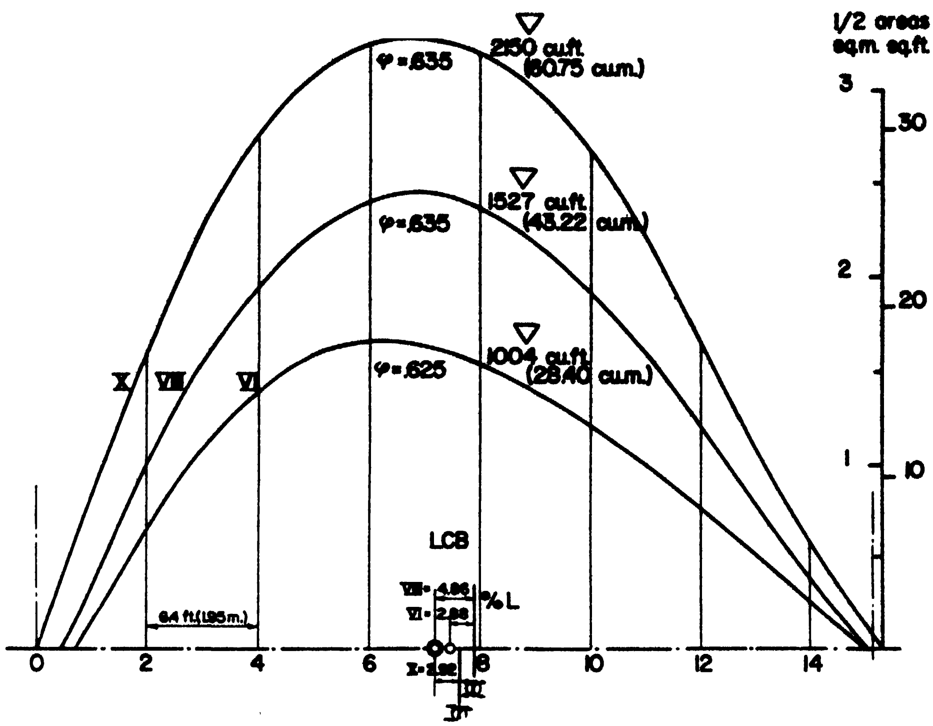


Fig. 576. Section area curves with LCB for fishing boat model 38 tested in the Turkish Tank

The steering effect of the nozzle rudder turned out to be much greater than that of a normal streamlined rudder. In a small fishing port, where the boat with normal rudder has to go several times ahead and astern in order to turn round, the boat with the nozzle rudder can turn without manoeuvring ahead and astern, occupying only half the distance required for the boat with normal rudder.

As the 59 ft. boat, which was equipped with an 80 h.p. two-cylinder 350 r.p.m. engine, fished for ten years from a harbour from where some other 59 ft. boats also fished—one of which was provided with a similar engine and the other with a 100 h.p. two-cylinder 320 r.p.m. engine—he also gained a clear impression of the improvement of the tractive efficiency of the nozzle rudder during this long period.

The 59 ft. boat with the nozzle and 80 h.p. engine made the same catches as the boat with the 100 h.p. engine, and left the boat with the 80 h.p. engine regularly 20 per cent. behind. This was not due to a better crew, because the crew was changed several times in the course of the ten years.

Another advantage of the nozzle rudder is that the propeller is protected from being hit by the trawldoors and that warps cannot get tangled in the propeller. When the boat was ten years old, she still had the same propeller which was undamaged.

Tugs get increased efficiency

Mr. P. Chardome (Belgium): Tothill raised one point which particularly had drawn his attention because he had also

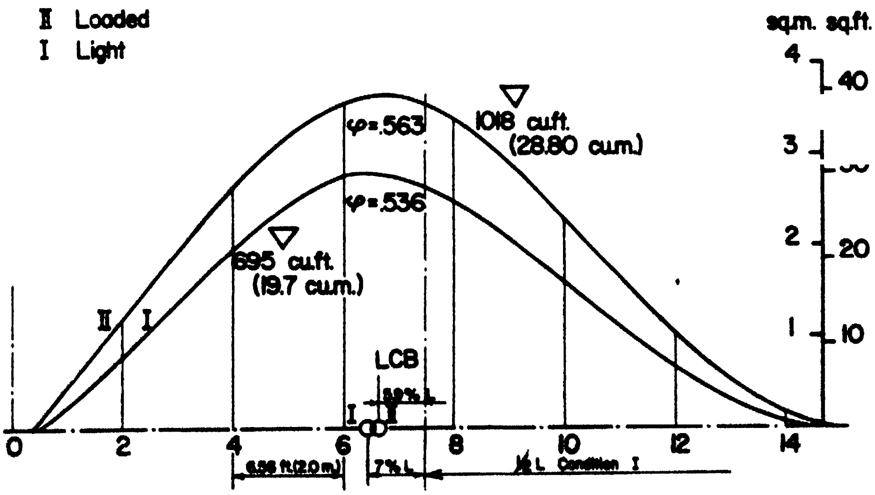


Fig. 577. Section area curves with LCB for fishing boat model 28 tested in the Turkish Tank

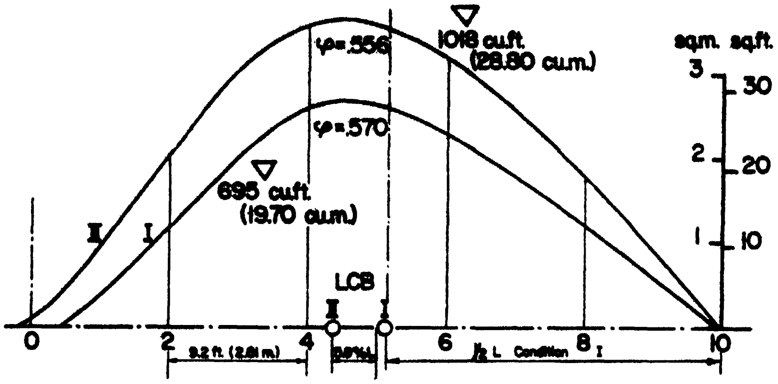


Fig. 578. Section area curves with LCB for fishing boat model 22 tested in the Turkish Tank

advocated for a long time the use of nozzles. This system was invented 25 years ago by the late Mr. Kort, and has been perfected since by Kort and his collaborators. However, Tothill based his suggestions merely on the studies made by van Manen in an experimental tank. Mr. Chardome wanted to support his view by reference to a few practical trials that he had followed.

As theoretical studies and very numerous tests and trials have shown, nozzles are most effective for tugs and especially for slow ones. In bollard pull tests, tugs showed an increase in efficiency of about 45 per cent. when equipped with a nozzle. However, the shape of a nozzle that gives such a high increase in efficiency is not favourable for sailing speeds; these are diminished rather than increased. For an ordinary tug this is not very important, whereas a trawler must have a high sailing speed. A nozzle should increase the speed of a trawler rather than diminish it.

However, trawlers also function as tugs when trawling and when sailing against rough seas. Consequently the design of a trawler nozzle should be a compromise between giving added thrust and increased sailing speed.

Regarding increased thrust or towing power, Mr. P. Chardome first mentioned the case of a 74.5 × 19 ft. (22.75 × 5.80 m.) trawler with 10 ft. (3.05 m.) draught aft, and an engine developing 120 h.p. at 375 r.p.m., where practical tests had shown:

Bollard pull test	*Without nozzle*	*With nozzle*
Power	103.5 h.p.	99 h.p.
r.p.m.	310	337
Towing force . . .	1.76 ton	2.035 ton (increased to 2.225 ton by modifying the propeller)
Towing force per 100 h.p.	1.7 ton	2.25 ton
Efficiency increase . .		32.2 per cent.

Sailing trials	*Without nozzle*	*With nozzle*
Power	110	119
r.p.m.	362	376
Average speed . .	7.59 knots	8.01 knots

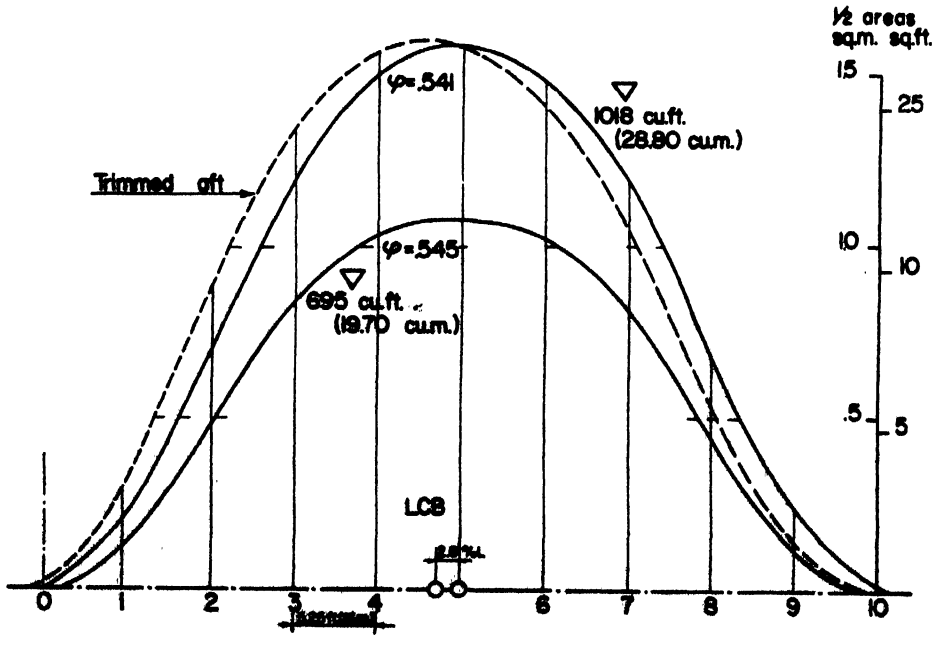


Fig. 579. Section area curves with LCB for fishing boat model 29 tested in the Turkish Tank

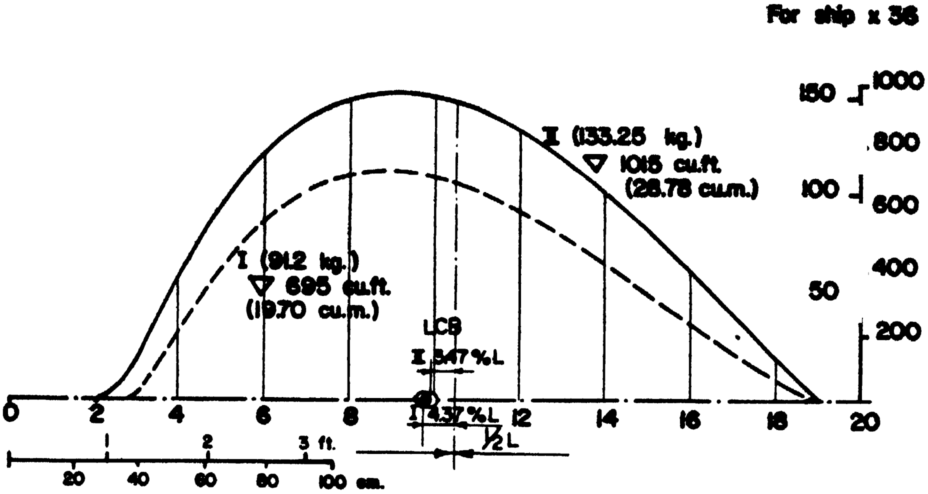


Fig. 580. Section area curves with LCB for fishing boat model 20 tested in the Turkish Tank

The nozzle proved particularly useful in rough seas, because one trawler with nozzle returned at the same time as another without nozzle, and which normally sailed 1 knot faster. The first was also able to keep up with the trawler without nozzle for 24 hours; the latter only picked up its higher speed in calm seas. Moreover, in the crew's opinion, pull when trawling was also increased, although no measurements with dynamometers had been taken.

Another instance was that of a trawler with 66 ft. (20.1 m.) length in the waterline, 19.7 ft. (6 m.) beam, 11.5 ft. (3.5 m.) draught aft and a 200 h.p. engine running at 300 r.p.m.

Bollard pull test	*Without nozzle*	*With nozzle*
Power	151.5 h.p.	171 h.p.
r.p.m.	231	230
Towing force	2.700 ton	4.072 ton
Towing force per 100 h.p.	1.775 ton	2.380 ton
Efficiency increase		34 per cent.

Sailing trials	*Without nozzle*	*With nozzle*
Power	185 h.p.	193 to 225 h.p.
r.p.m.	308	268 to 278
Average speed	9.05 knots	9.16 to 9.29 knots

Also these trials showed that the sailing speed was increased rather than decreased. The figures also give an idea of the necessary compromise. It is sufficient to compare the efficiency gained at the bollard pull tests (34 per cent.) with that normally obtained for tugs (45 per cent.). In other words, when using nozzles on trawlers, one sacrifices from 10 to 20 per cent. of the possible increase in thrust in order to maintain the sailing speed.

When one says that the sailing speed is maintained or is only slightly increased by nozzles, one strikes too pessimistic a note because fishing boats are among the type of craft that are most exposed to rough seas, their length being the same as that of the waves. As mentioned in the first case, a boat equipped with a nozzle can keep up with a rival in bad weather. Other observations have shown that a boat which can make 11 knots in calm water, may slow down to 5.6 knots in rough seas but when it is equipped with a nozzle it can maintain a speed of up to 7.9 knots. It is therefore not accurate to say that there is no change in the sailing speed as this depends on the weather.

He could give other examples but he merely wanted to

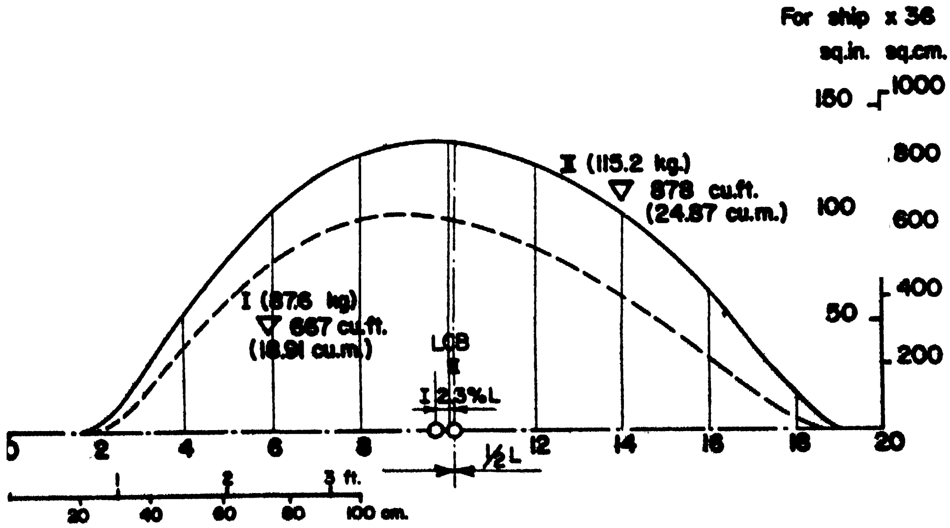


Fig. 581. Section area curves with LCB for fishing boat model 21 tested in the Turkish Tank

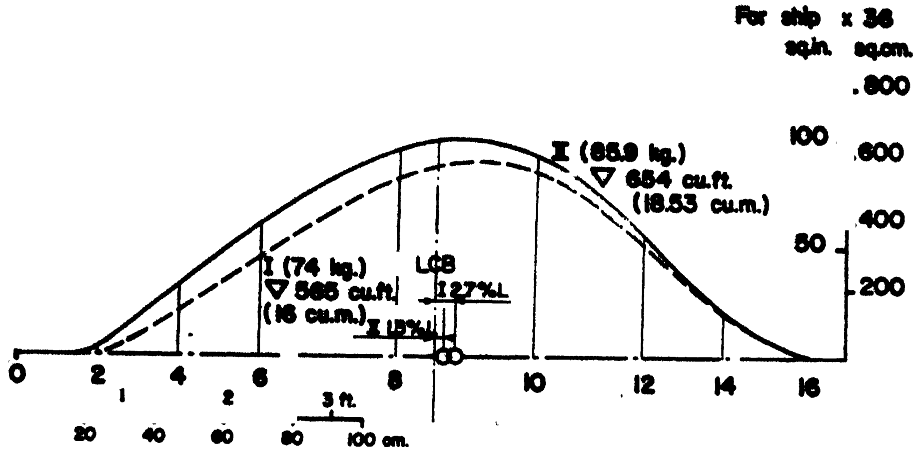


Fig. 582. Section area curves with LCB for fishing boat model 14 tested in the Turkish Tank

support Tothill's theoretical conclusions by a few practical examples. Nozzles will no doubt be an important feature in the perfect trawler of the future because they provide increased towing force, smoother running of the engine and increased speed in heavy seas and protection of the propeller.

2,500 vessels fitted

MR. E. K. ROSCHER (Germany) contributed a few comments on Kort nozzle propulsion for trawling. The Kort nozzle is a profiled ring shrouding the disc of the propeller turning therein. This ring either forms a fixed appendix to the vessel's stern or takes the place of the rudder. In the latter case it is connected to the rudder shaft, the centre line of which falls in line with the turning disc of the propeller. The purpose of the Kort nozzle is to increase materially the average sea speed. On trawlers this average will be about 1 knot during the year in Northern waters. It furthermore increases traction power when trawling between 30 or even 40 per cent. at equal propeller diameters and when using the full torque of the diesel engine.

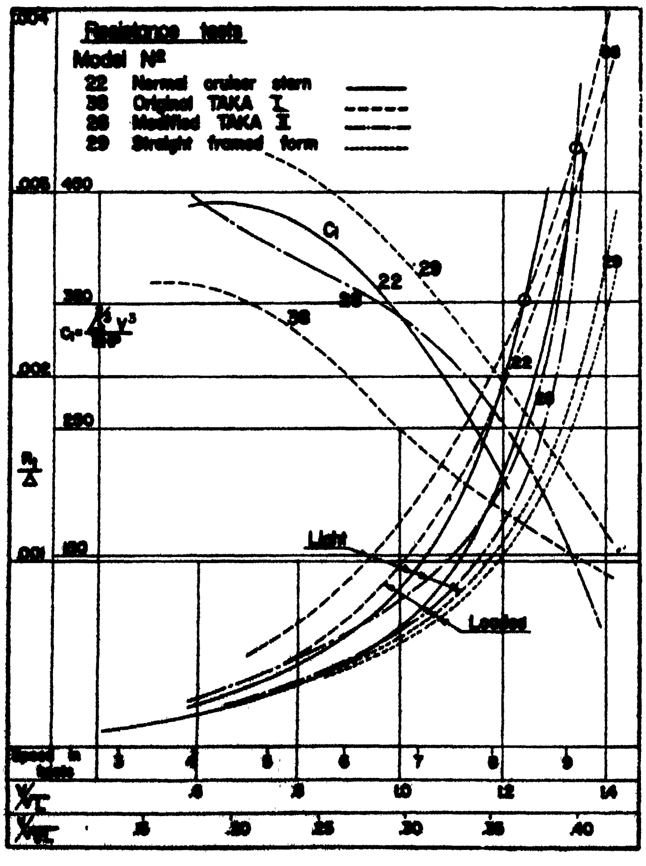


Fig. 583. Comparison of resistance/tons displacement and Admiralty constants

The nozzle rudder also allows positive steering ahead *and astern* even when the vessel is practically at a stand-still. This latter possibility has proved its advantage when setting out or hauling in the trawl and when emptying in partitions a great catch out of the codend.

The papers of Süberkrüb, Tothill and van Manen deal with the problem of the nozzle but all exclusively under the aspects

Fig. 584. Taka I, *model 38, tested at speed-length ratio 0.9*

of model tests. Van Manen's paper is noteworthy in so far as it gives trial data of a trawler model in artificial seaway.

Mr. Roscher said he had co-operated with the inventor of the Kort nozzle, Mr. L. Kort of Hannover, Germany, for more than 26 years. During this time about 2,500 vessels with powers up to 3,000 h.p. per unit have been fitted with the device all over the world. The majority of these vessels were tug boats used for service on rivers, in harbours *and* in the open sea. The duties of the latter can be compared with those of a trawler when trawling. Before World War II, 13 steam trawlers of about 400 IHP were equipped with the nozzle as well as 6 new boats of 750 IHP each. After the war, eight 1,000 h.p. motor trawlers of the "Pysbe" in Spain, one 300 h.p. trawler in Holland and twelve 600 h.p. drifter-trawlers in Germany, the latter in connection with propeller rudders,

Fig. 585. Taka II, *model 28, tested at speed-length ratio 0.9*

were fitted with fixed nozzles. Nozzle rudders were fitted in Holland to a 420 and a 700 h.p. trawler, in Germany to three 400 h.p. drifter-trawlers and to a 1,500 h.p. stern trawler. Another 1,200 h.p. side trawler with nozzle rudder is under construction in France. Negotiations are pending for a repeat of the 1,500 h.p. stern trawler. The post-war trawlers were all diesel driven.

With regard to van Manen's paper and his model tests with a nozzle fitted trawler in smooth water and in a seaway, Mr. Roscher felt that he could not accept the conclusions drawn. These conclusions were contradicted not only by quite a number of model test results from the Hamburg model tank, but particularly by the wide experience gained from actual practice with sea-going tugs and trawlers. If the van Manen statements were correct, there would be no reasonable explanation as to why the nozzle fitments have been accepted for a great many sea-going vessels for more than 20 years by owners and naval architects. It may be that his investigations were based on a shape of the nozzle ring designed on purely theoretical conceptions. The wall profiles of the van Manen rings are in many respects different from those of what might be called "the genuine Kort nozzles". Mr. Roscher conceded, however, that this explanation might not be sufficient.

About 20 years ago comparative trials with and without the nozzle in smooth water and in artificial seaway were made in the Hamburg tank with the free running model of the

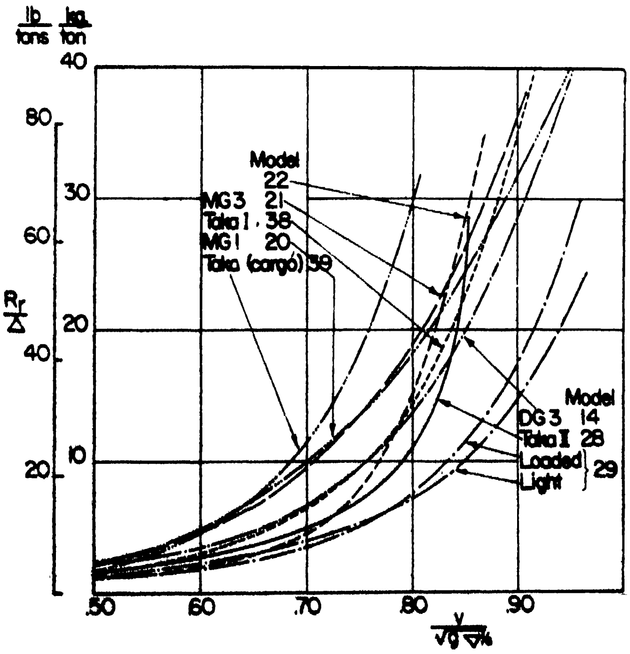


Fig. 586. Residuary resistance per tons displacement for fishing boat models tested in the Turkish Tank

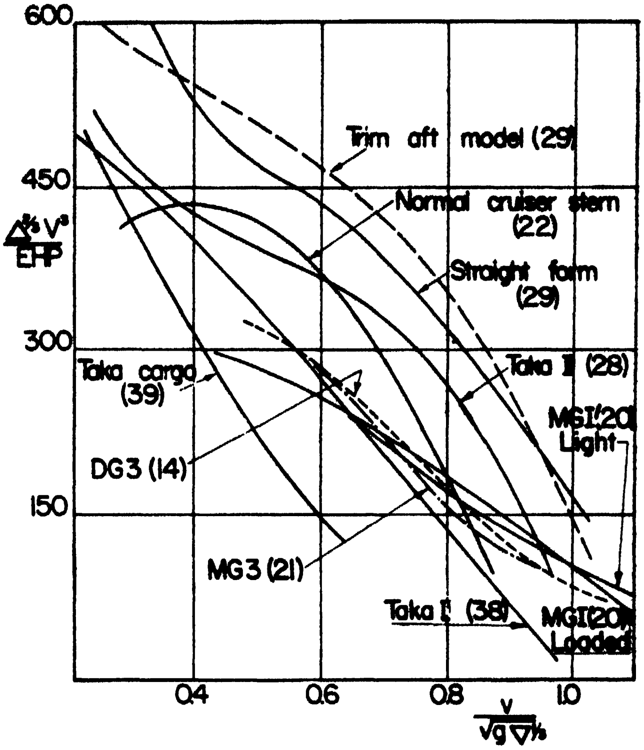


Fig. 587. Admiralty constants for Turkish fishing boat models

500 h.p. motor trawler *Volkswohl*, which had a length of 164 ft. (50 m.) and a propeller diameter of 8.2 ft. (2,500 mm.) In smooth water the speed was about 11 knots without and with nozzle. When going against a wave length of 112 ft. (34 m.) equal to about $^2/_3$ of the ship's length, the free speed without nozzle dropped to 5.6 knots at 512 SHP, while with nozzle 7.9 knots at 480 SHP were measured. The speed gain obtained by the nozzle in this seaway was thus about 40 per cent.

Another interesting comparison was made on a tug boat in Falmouth. For years this boat had been daily towing the same hopper barge out to open sea without a nozzle. Later a Kort nozzle was fitted. Carefully screened log-book data taken before and after fitting revealed as a mean result of a full winter season, that with nozzle the towing time was about 25 per cent. less than without nozzle and that in addition there was a saving in fuel consumption of 13 per cent.

In the light of his own experience and from similar examples, Mr. Roscher wished to state that:

- The free speed in smooth water will not decrease
- In seaway the yearly average speed gain will be at least between ½ and 1 knot
- The pulling power, when trawling at 4 knots in smooth water and applying the full torque of the diesel engine, will rise between 30 and 40 per cent.

Fig. 588. Model of a combined Turkish Taka and Maler type hull, No. 29 at speed-length ratio 0.9

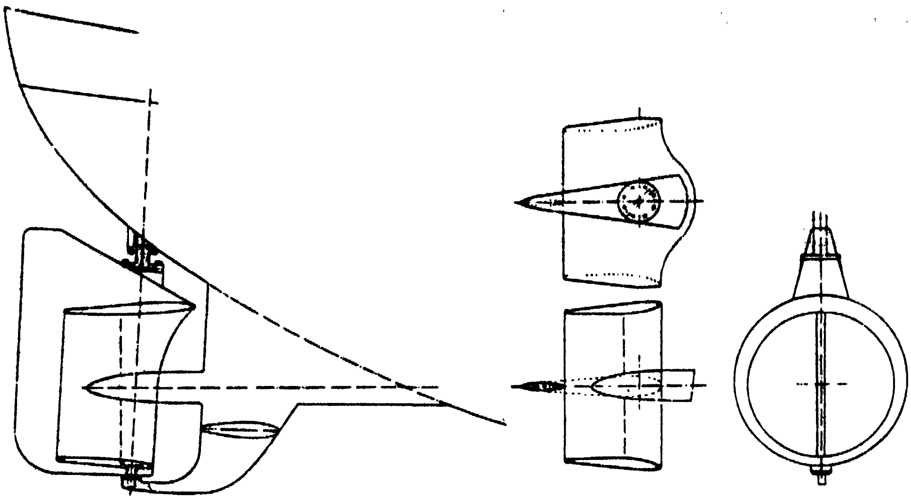


Fig. 589. In the Netherlands owners have had good experience with this type of nozzle rudders

- When trawling in bad weather, a nozzle fitted boat can keep up fishing much longer than the same boat with open propeller

The statement that such a big increase as 40 per cent. of pulling power is possible is explained not only by the increased thrust per h.p. but also by the increased r.p.m. and thus the developed power of the engine. By quite a number of model tests and also in practice it has been ascertained, that at constant torque the drop of r.p.m. between sailing speed and trawling speed is only about 50 per cent. of what is normal with an open propeller of same diameter. In other words, the nozzle performs in part as a two-speed reduction gear designed for full power at both sailing and trawling speed.

The captain of the 1,500 h.p. trawler *Carl Kämpf* (fitted with a nozzle rudder, and in service for about 2 years), when asked by his owner whether he would prefer a repeat construction of the boat without or with nozzle rudder, replied that he would not like to have another trawler without a nozzle.

BULBOUS BOWS

Mr. N. V. Johnsson (Sweden): From the autumn of 1955 and onwards tests have been conducted with bulbous bows on trawlers in the Swedish State Shipbuilding Experimental Tank (Johnsson, 1956; 1958) for reasons which are well explained in Doust's paper. The need is perhaps more urgent for Swedish conditions, as their trawlers are driven at a higher relative speed, right at or even above the squatting speed, which means a speed-length ratio of 1.2 or more. The tests were made as calm water tests as, unfortunately, there was no wave-making apparatus available. The effect of a bulb on the behaviour in waves could only be guessed on the basis of tests with similar types of ships. Therefore, Doust's paper was read with great interest and particularly the part concerning resistance and behaviour in waves. The parent form, fig. 590, of the Swedish models was of a type suitable for Swedish conditions, which meant a vessel of the following dimensions:

LBP . . .	82 ft. (25 m.)
B . . .	20.8 ft. (6.35 m.)
Mean draught, T .	9 ft. (2.75 m.)
Displacement . .	217 tons (215 cu. m.)

which gives ratios LBP/B = 3.95 and B/T = 2.31, i.e., a rather beamy boat.

This demanded a rather small midship section coefficient of .73. With a block coefficient of about .49 this resulted in a prismatic coefficient of about .67. This was, of course, a bit too big for good speed but it undoubtedly gives a more seaworthy ship. LCB is about 4 per cent. aft of midships. Fig. 590 to 593 shows how the bulbs were fitted to the hull. It was done in the way recommended by Taylor (1943), which results in constant displacement but a somewhat altered position of the LCB. The respective sizes of bulbs were, in loaded condition, 3.45 per cent., 6.36 per cent. and 9.18 per cent. The results of the tests are shown in fig. 594 to 597. Doust is of the opinion that bulbous bows would not result in gains for prismatic coefficients over .63. However, the Swedish tests have shown that gains of up to 12 per cent. in loaded condition and up to 19 per cent. in light conditions with 4 per cent. stern trim can be had. He thought the statement had to be restricted to the types which Doust had envisaged; that means forms of more slender design than the Swedish fishermen use. It was difficult to set up any general rules for the use of a bulb or a resistance decreasing device of any kind. The only thing to be said is that an optimum design from a speed point of view is the best. As soon as one has to depart from this design because of reasons such as stability, the use of a device as mentioned above might help, and the degree of this application is in relation to the degree of departure from the optimum design.

In the results of the trim curves it was found that the action of the bulb and the resulting shift in LCB meant an increase of the squatting speed. A constant gain in resistance above this speed was also found. It follows that for these forms there is no upper speed limit for the use of a bulb.

A certain influence of the bulb upon the stability characteristics is unavoidable but not difficult to control. Fig. 598 shows the decrease in metacentric height for growing bulb size. The biggest bulb shows a decrease of about 4 per cent. or 5 in. (127 mm.), but taking into account a lowering of the centre of bouyancy because of the bulb, a net reduction in metacentric height of 3 in. (7 to 8 cm.) occurs which can easily be compensated if necessary.

Mr. Johnsson regarded Tothill's design, on the whole, as a basis for discussion rather than as a final design. The flatness of the bulb would probably cause considerable slamming. He had himself (Johnsson, 1956; 1958) warned against this risk, and had also suggested some alterations to prevent it. He also felt that the above-water form was unsuitable. This had convinced him that Tothill's design was intended for tests in a towing tank rather than for rough seas. The lines were beautiful as such, and the attack on the pure flow problems appeared correct.

Detailed tests to be i

DR. D. CSUPOR (Switzerland): Tothill's endeavours to find a standard hydrodynamic solution to a wide range of sizes of fishing boats has led to a hull form with features remarkable at least for the size of the ships in question. They should be reviewed not only from the point of view of speed and power in calm water but also with regard to all phenomena which might influence the general service performance.

● The bulbous bow of the flat bottom type applied on the forebody has, according to Tothill, advantages with regard to the resistance characteristics under trial conditions. The sharp roundings at the sides of the bow bulb will contribute to the damping forces when pitching. However, there still remains

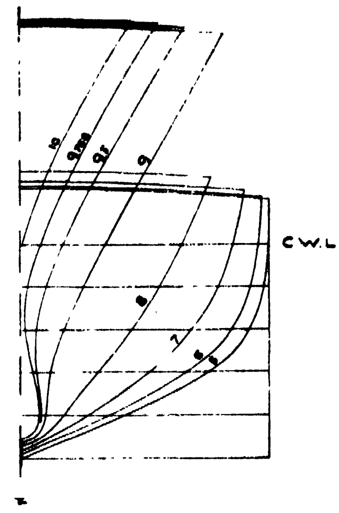


Fig. 591. 3.45 per cent. bulb on typical Swedish fishing vessel, model 729

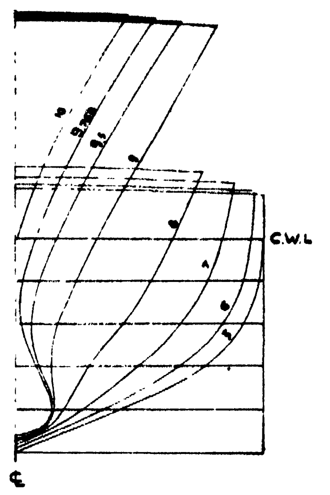


Fig. 592. 6.36 per cent. bulb on typical Swedish fishing vessel, model 727

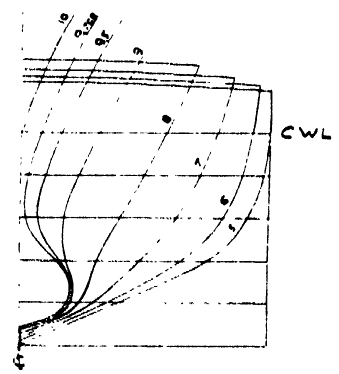


Fig. 593. 9.18 per cent. bulb on typical Swedish fishing vessel, model 728

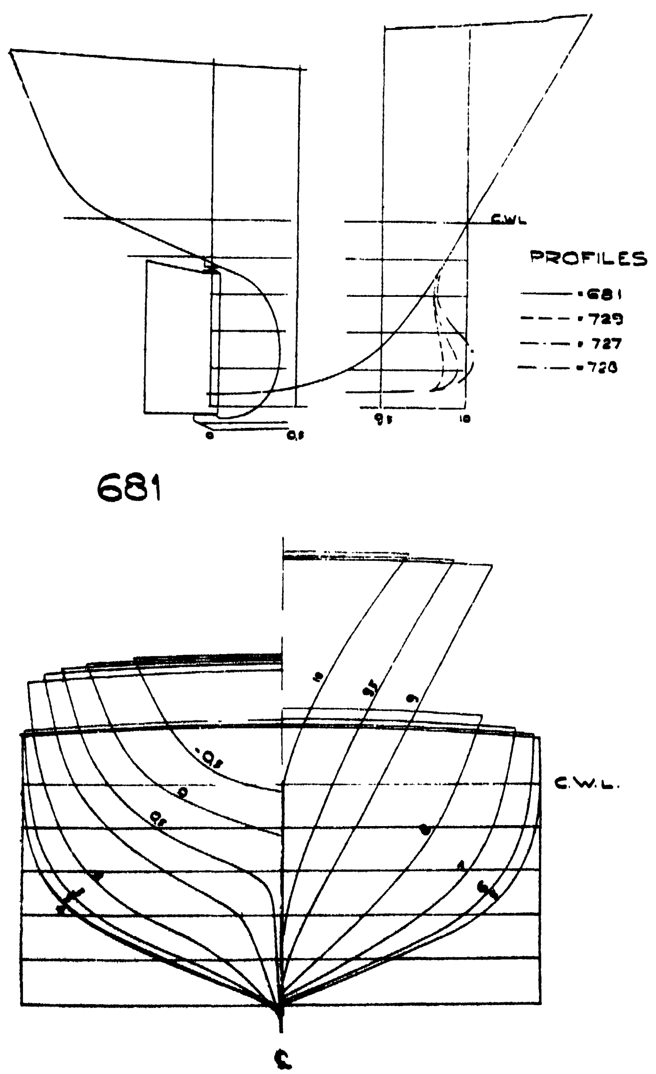


Fig. 590. A typical steel constructed Swedish fishing vessel having also been tested with the addition of bulbs

some problems to be solved and it would be interesting to know whether Tothill has investigated the following points:

(a) What type of structural construction is proposed for this bulbous bow? Will it be made of wood or steel? Certainly it would be possible to make a composite construction consisting of a wood or steel stem and a prefabricated bulb of glass fibre or of any other synthetic material. In the case of such a construction, what kind of structural connection should be provided to withstand the appreciably changing pressures acting on the bottom when slamming?

Even if the damping forces given by the flat type bulb were very high, under certain conditions in a heavy sea, slamming would be unavoidable. Szebehely (1952), Korvin-Kroukovsky (1958) and Kazuo Ochi (1958) have made an outstanding experimental and theoretical analysis of the problem. Of special interest are the comparative figures No. 6 and 7 of Ochi's paper, showing maximum slamming pressures measured on a series 60 model and a V-frame model. These very instructive diagrams show a relation of 6:4 between the maximum

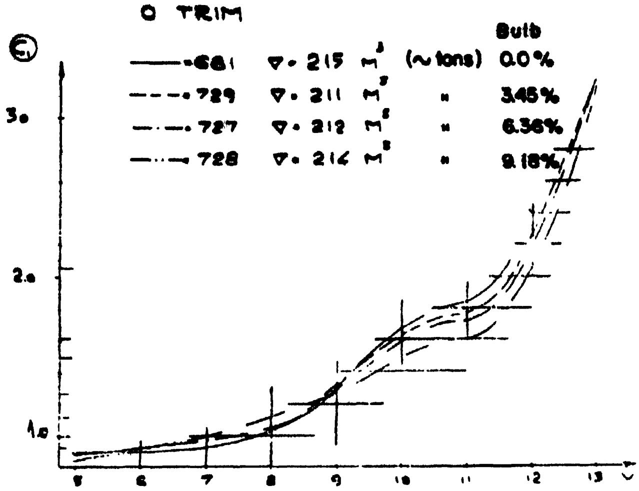


Fig. 594. Influence of bulb on resistance at average displacement

slamming pressures of the two models under the same conditions, the V-frame forebody with sharper stem and foreship bottom giving the lower values. As the bulbous bow of the Ottawa model has an even wider and flatter bottom than the series 60 ships, one should also expect higher slamming pressures on the flat type bulb.

Serious attention should be paid to this problem, keeping in mind that slamming not only can seriously damage the foreship bottom plates, but, as statistically shown, is also the main cause for intentional speed reduction in bad weather.

It would be of interest to know whether some measurements of the slamming pressures on the Ottawa model in an irregular heavy seaway are available. The results of such tests could give some new aspects to slamming research.

(c) In the light condition the flat type bulb is hardly submerged. Therefore, when the vessel is pitching, the bulb with its extremely broad waterline comes to the surface, thus, creating a new temporary floating waterline. Information on the results of any manoeuvrability measurements taken in this condition would be interesting.

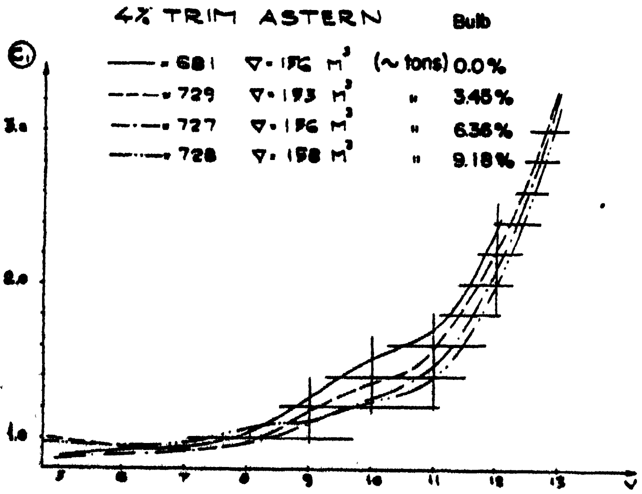


Fig. 595. Influence of bulb on resistance at light displacement and stern trim

● In the fully loaded condition the vessel is floating on an extremely hollow waterline which, together with the contraction of the foreship frame shapes builds up concave sidewalls. Such a design does certainly help to decrease the resistance at higher Froude numbers, but there are some further points to be clarified:

(a) Is the trimming of the ship not too sensible when loading and unloading?

(b) What is Tothill's opinion on the strength of a concave shell against ice pressure and on the general behaviour when sailing in ice?

● The pronounced flare of the frames in the foreship immediately below the main deck has been designed in order to give better damping characteristics when pitching.

(a) Is this hollowness not situated too high above the waterline to be effective during any longer fraction of the pitching period? In order to produce some appreciable energy dispersion the flare should start lower.

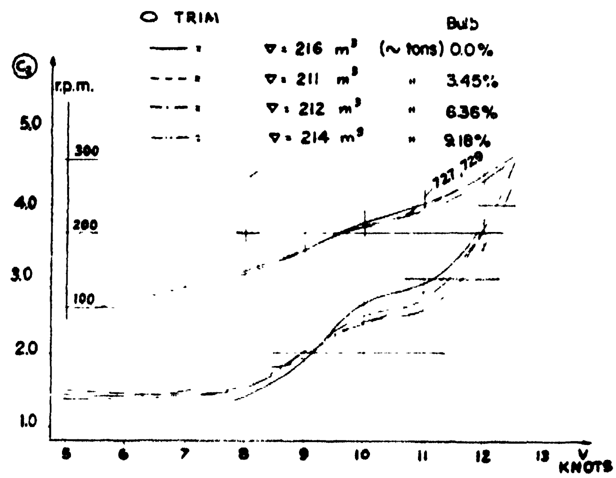


Fig. 596. Self-propulsion results for a model with bulbs of different sizes

(b) As stated by Korvin-Kroukovsky (1958), in some destroyer constructions greater slamming pressures occur on the above parts of the foreship. The frames of these vessels have a sharp curvature and a big flare situated in a position very similar to that in the Ottawa design. Has it been investigated whether the flare is not introduced too suddenly to promote such phenomena?

● It would be of interest to know whether Tothill made comparative tests with and without the contra guide stern skeg and how much is the relative rotative efficiency augmentation due to the application of this device. What happens when moving astern.

Tothill gives some information on the wake distribution, the wake fractions varying between 0 and 90 per cent. at different points of the propeller disc. This high degree of variability has always been observed behind this type of stern. This means that, applying a contra guide skeg, one should also take into account correspondingly strong oscillations of the hydrodynamic forces on the propeller which should lead to longitudinal and torsional vibrations of the shaft. It is not known whether the Ship Laboratory of Ottawa is equipped with instruments for the measuring of the oscillations of torque and thrust. Such measurements belong, in some of the European model basins to their standard tests. If they should have been carried out in Ottawa, measured data for this ship would be useful.

● Tothill used a two-bladed propeller in order to ensure high efficiency. Furthermore, the blade profiles of the two-bladed propeller, having the same area ratio as a screw with more blades, are finer, because of the lower thickness-length ratios which result in a better safeguard against cavitation. On the other hand, one must take into account that two-bladed propellers are suspected of being the source of strong vibrations, especially in such cases where the unequality of the velocity field is very pronounced and is of the same order as the number of blades. As the inequality of the wake behind the stern of a single screw ship has always a very strong component of the second order, the working together of a two-bladed propeller and a contra guide stern skeg must lead to extremely strong exciting forces. Had Tothill investigated this problem, and what type of damping would he advise to apply in order to save the gear, the thrust bearing and the shaft line? If this problem is solved in all details, the example of Tothill in applying a two-bladed propeller for a single screw ship would certainly be followed by the majority of naval architects.

● Most naval architects like to give trawlers stern forms, which give less resistance to waves coming from the stern and avoid strong transverse forces in irregular seas. The stern form applied by Tothill does not seem to fulfil this requirement, although, on the other hand, it certainly has some advantages, e.g. the preventing of greater dipping when trawling and the possibility of applying a bigger propeller. However, it is felt that manoeuvrability and coursekeeping could be disturbed when trawling at low speeds in a stern sea. Dr. Csupor has had no experience with the behaviour of such a type of stern under the above conditions and, therefore, he would like to have Tothill's opinion.

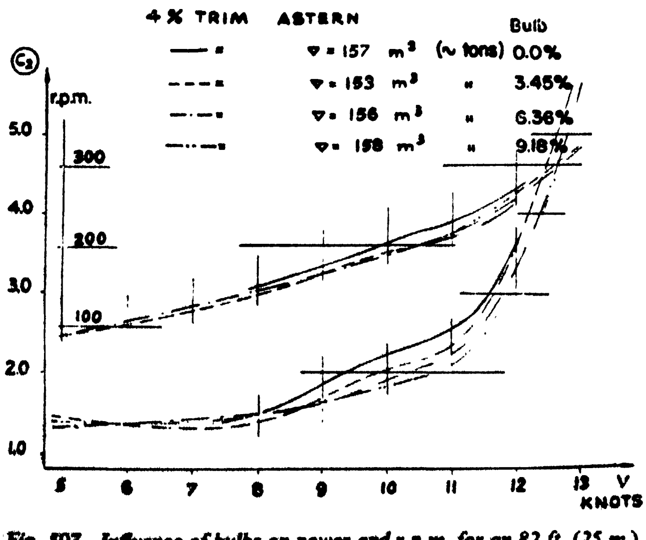


Fig. 597. Influence of bulbs on power and r.p.m. for an 82 ft. (25 m.) fishing vessel of Swedish type

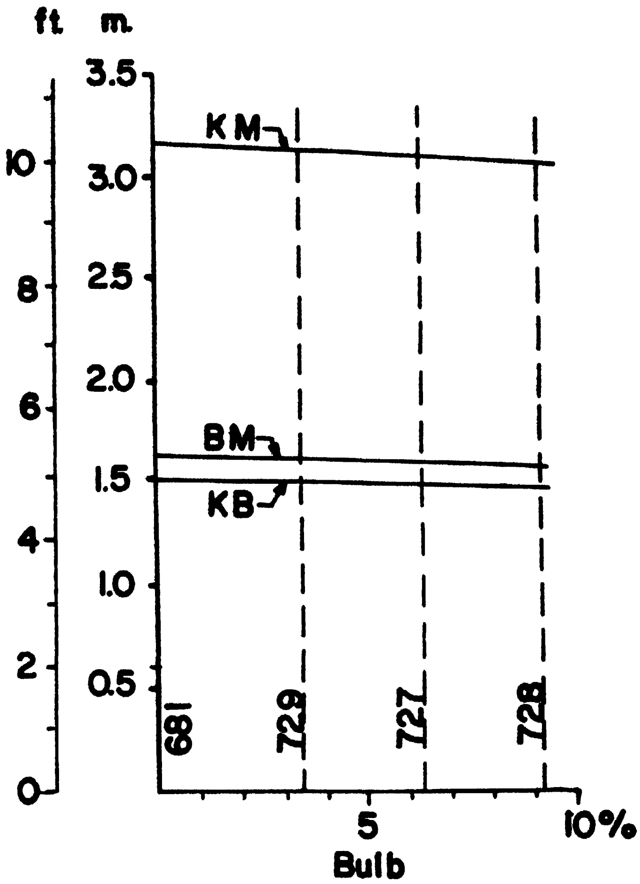


Fig. 598. Influence of bulbs on the height of the metacentre

● Tothill applied a nozzle rudder with a diameter of 90 per cent. of the draft and expects that during severe pitching, when the nozzle emerges from the sea, it will throw up a wave and remain full of water. It is felt that the crest of such a thrown up wave would be situated above the nozzle and not where suction forces are prevalent, but certainly it is a question which should be investigated in a wave pattern of heavy irregular seas.

One should raise the question whether the gain in propulsion by the application of so many unusual features is enough to justify the costs of building and operating such a vessel. To answer this question, fig. 331 of the paper can be referred to. In this Tothill gives a comparison of the propulsion curves for several vessels designed by outstanding naval architects. This comparison does not refer directly to the quality of the hull lines because they all have different main dimensions, propellers, numbers of revolutions and are designed for different Froude numbers. Some of these features are possibly "owners' requirements" which might have given some handicap to one or the other of these ships. However, a rough estimation can be made on the basis of this diagram. Dr. Csupor would especially refer to the power curve of model No. 85A being a Maierform model with a "saturation speed" of 10 knots, according to Tothill. The Ottawa model 149A has however, a "saturation speed" of 10.5 knots. These differences are self-explanatory, the Ottawa model being 4.6 per cent. longer than the Maierform model.

The power curves of the two models up to 9 knots speed,

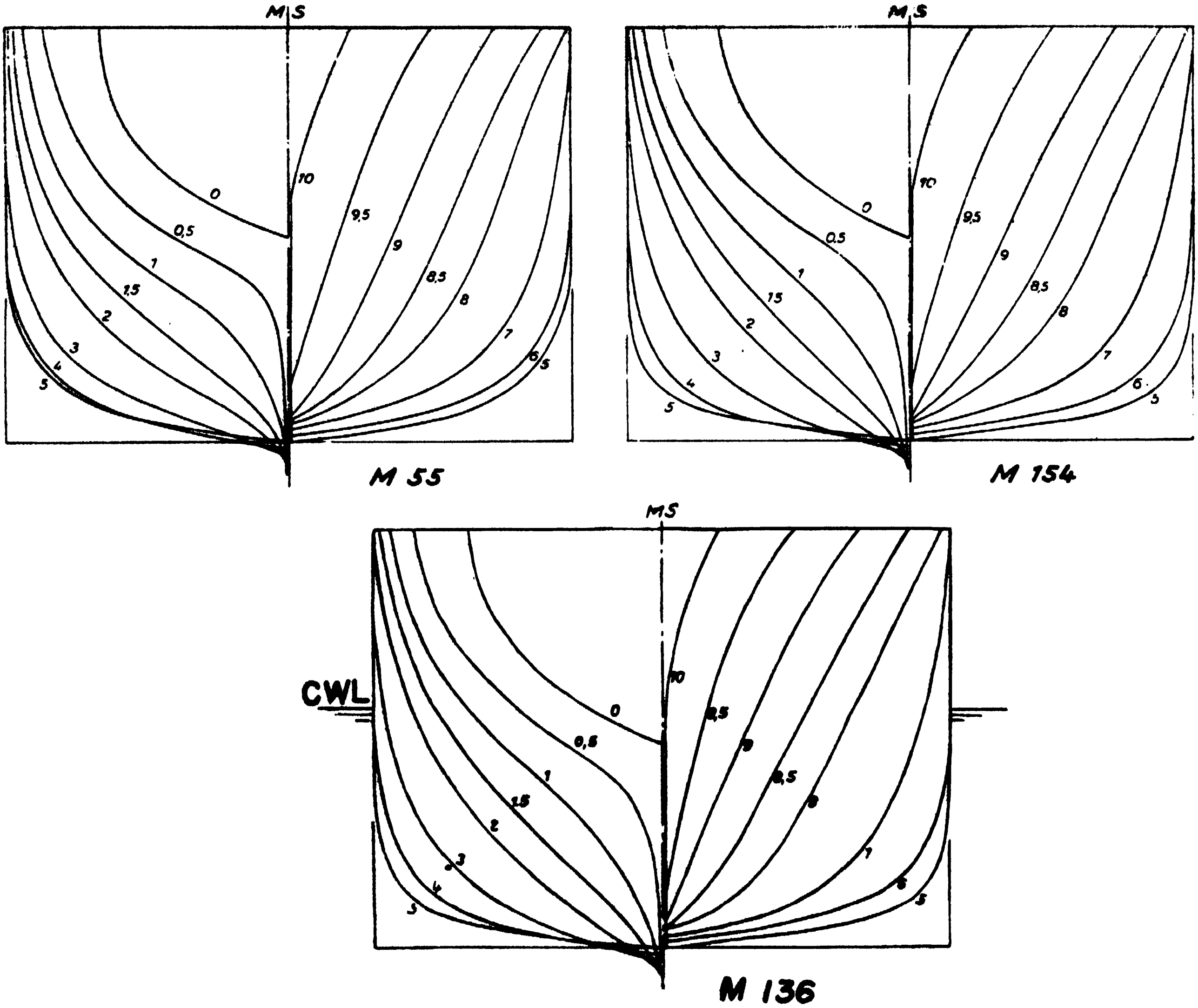


Fig. 599. Body plans of three 191.5 ft. (58.4 m.) trawlers with different midship section areas. Model 136 having the largest

which is about the average service speed of the Maierform model, are similar, i.e. up to this speed the special devices applied on the Ottawa model gives apparently no measurable gains. In the speed range over 9 knots the Froude number has increasing importance, and the Ottawa model becomes better with increasing speed. Being very familiar with the Maierform lines Dr. Csupor was confident that, based on the experience gained by the development of over 4,600 Maierform vessels, it would be possible to design a ship with a "saturation speed" of 10.5 knots with the same length as the Ottawa design, which would show such results that not only could many of the features proposed by Tothill be waived, but an additional gain in power could be achieved. So it would be interesting to develop such a design with the same main dimensions and the same power as the Ottawa model. Dr. Csupor's firm has decided to carry out tests with a model according to this description and to compare the propulsion results with those of another model built to the same scale and constructed exactly on the basis of the Ottawa design. These tests will be started in the autumn of 1959 at the Vienna Model Basin and the Fishing Boat Section of the FAO will be given full particulars on the results. The typical Maierform ship would avoid high slamming pressures, would better withstand ice pressure and would have best manoeuvrability and coursekeeping qualities in bad weather.

Special investigations

MR. W. HENSCHKE (Germany): Tothill's and Doust's papers showed trawler designs with bulbous bows and gave interesting results from model tests with them. In the tank at Berlin-Potsdam several 191.5 ft. (58.4 m.) LBP trawler models have also been tested; the body plan of the original model 55 is shown in fig. 599, together with those of two models (No. 154 and 136) having the same dimensions but larger midship area coefficients: thus they had smaller prismatic coefficients. At 10 knots model 154 was 3.5, and model 136, 7 per cent. better than model 55. At 15 knots model 154 was 13.5 and model 136, 19 per cent. better than the original model 55 with the high prismatic coefficient. Fig. 600 shows the EHP curves for models 55 and 136—but not model 154. In addition fig. 600 shows the EHP for a model 206.

Model 136 was then modified with four different bulbous bows having 1.65 to 6.55 ft. (.5 to 2 m.) width according to fig. 601. The results are given in fig. 602. At the light displacement the bulb reduced the resistance at speeds higher than 14 knots, and the largest of the investigated bulbs was the best. At mean displacement the bulb made no appreciable influence on the EHP and at loaded displacement the smallest investigated bulb was the best one. The largest improvement in resistance was about 5 per cent. and was achieved at the light displacement.

In order to check these results additional resistance tests were made with a model 206. This model was only different from model 55 as far as sections aft were concerned. The EHP curve is given in fig. 600 and it is similar to that of model 55 up to 13 knots. Model 206 was then modified with bulbs having widths from 1.65 to 6.55 ft. (.5 to 2 m.), fig. 603. Model 206 was, from the resistance point of view, not optimum and the addition of the bulb did not make the model any better than model 136 without bulb.

It was his opinion that for the time being it was best to give a trawler the best possible shape without bulb, because the improvements possible with a bulb are comparatively small and the influence of the bulb upon the sea behaviour is still a controversial matter. It would however be good if more resistance tests and especially tests in waves could be made soon so that this interesting problem could be clarified.

Practical experience good

MR. A. HUNTER (U.K.): His company had delivered four 185 ft. (57 m.) trawlers with bulbous bows, having a bulb area of roughly 5 per cent. of the midship area. They appeared to perform very well in practice and there had been no bad reports of slamming. Indeed, the comparison seemed to be a boom rather than the bang of the normal form. One advantage which had not been pointed out is that the LCB position can be moved forward with the bulbous bow, which should be of great advantage for some complicated machinery taking up more space than normally, with little penalty. Research was carried out with a very small bulb on one very good form which it was thought impossible to improve, the bulb being added without disturbing the rest of the form. Nevertheless it was found that there was a 5 per cent. reduction in resistance. The fact that pitching can be reduced seemed to be borne out in practice, and experience encouraged further research. But as Vossers said, it might be necessary to do more wave tests. In practical research, a gain in speed of ½ knot was obtained in a larger trawler with the same horsepower at a very small initial cost, notwithstanding the fact that, for stability reasons, full advantage could not be taken of the optimum bulbous bow characteristic.

PROF. G. P. WEINBLUM—Vice-Chairman (Germany): The results can be quite different with respect to the usefulness of the bulbous bow dependent on the prismatic coefficient, but it is not only the prismatic coefficient that is important. The shape of the section areas as such also has a great influence. Hence there is no contradiction between the results presented by Doust, Johnsson and Henschke.

MR. H. LACKENBY (U.K.): Fishing boats, and trawlers in particular, are generally quite highly driven, their speed-length ratio being about unity (in terms of knots and feet) and in this respect they are comparable to Atlantic liners. In the circumstances, there is scope for such devices as bulbous bows and transom sterns to ease the "over-driving", and he was very interested in the particular applications made by Tothill, together with the steerable nozzle, wide-tipped propeller and contra-guide skeg. From the results given the combined effect of these devices appears to have had a very beneficial effect indeed. He asked Tothill whether he could give a "breakdown" of the overall improvement and, in particular, what he would consider the improvement due to the nozzle and wide-tipped propeller would be worth as compared with a normal stern arrangement.

STATISTICAL ANALYSIS OF RESISTANCE

PROF. E. V. LEWIS (U.S.A.): Doust's paper is noteworthy having implications beyond the realm of trawler design alone. He has demonstrated that statistical methods provide the means of bringing orderly trends out of a large amount of trawler resistance data; perhaps they can do the same for the vast accumulation of model resistance test data on ships of other types as well.

Of course, the choice of form parameters and variables is a

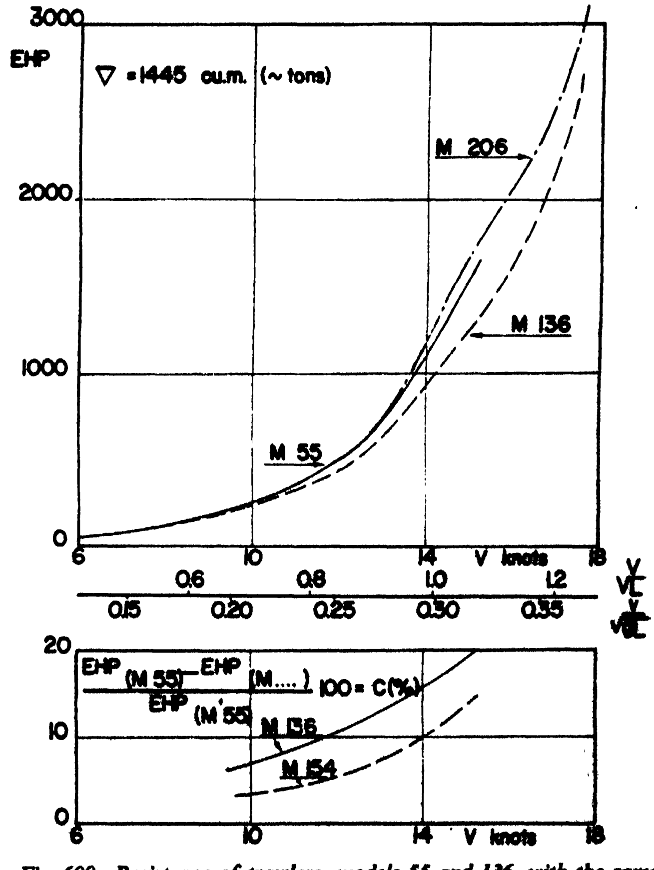


Fig. 600. Resistance of trawlers, models 55 and 136, with the same dimensions, but 136 having larger midship section area and smaller prismatic coefficient. Trawler 206 has the same forebody as 55 but other sections aft

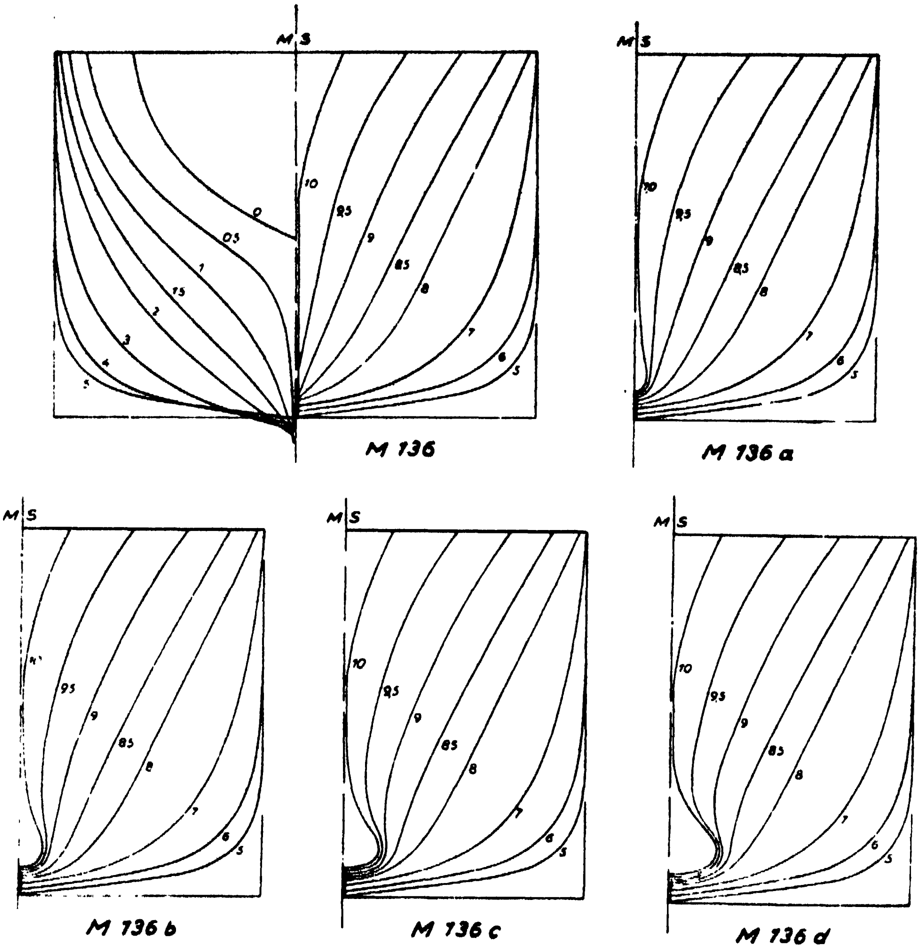


Fig. 601. Addition of bulbs with widths from 1.65 to 6.55 ft. (0.5 to 2 m.) to trawler 136

vitally important part of the whole procedure. The six parameters here seem to have been very well chosen, leading to significant and useful results. The use of cross-coupling terms is a refinement which appears to be worthwhile.

However, it appears that the quantities $RL/\Delta V^2$ and $V/\sqrt{L}$ may not be the optimum choices for the basic variables because they fail to show, when a particular speed is sought, the advantageous effect of increasing length on $V/\sqrt{L}$. The use of $V/\Delta^{1/6}$ or Ⓚ, on the other hand, focuses attention on the minimum resistance for a given size (Δ) and speed of the ship or boat. For the other variable, either R/Δ or Ⓒ is suitable. Perhaps $\Delta/(L/100)^3$ would then be a more satisfactory form parameter than L/B. Doubtless Doust has given the matter considerable thought already, but perhaps he can give further consideration to means of allowing for length. Professor Lewis wanted also to refer to his paper: "Optimum Fullness for Deadweight Cargo Ships in Moderate Weather Service", published in *Journal of Ship Research*, November 1957.

Some attempts at statistical analysis of model data at the Davidson Laboratory (Morrison, 1954) were handicapped by the necessity of using data from models of different sizes tested at different laboratories. Other form parameters included were vertical prismatic coefficients of entrance and run, and length of parallel middle body. It is hoped that Doust's paper will be given attention by the staff at model basins from the viewpoint of possibly more general application.

Mr. A. Hunter (U.K.): The form parameters taken by Doust in his resistance paper had always been found significant in trawler design. The plea was made that the application of Doust's paper should not eliminate model tests. Perhaps Doust could also lead in some reference to the effect of skin roughness.

Mr. N. Fujinami (FAO): Doust's paper is an outstanding contribution for two main reasons:

(1) The resistance of trawlers which have the six form parameters within the range of the experiment can easily be computed, either graphically or by an equation.

(2) The equation is set out in a form which allows fairly free selection of the parameters, and it is possible to check the influence of each form parameter on the ship's resistance; thus an idea of the optimum combination of the parameters can be obtained.

Here Doust's diagrams will be used to study item (2).

Fig. 349 to 352 show *the effect of the combination of C_p and B/d.*

For $V/\sqrt{L}$ of 0.80, 0.90 and 1.00 respectively: (a) when B/d is 2.5, different values of C_p have almost no influence on the resistance; (b) when B/d is more than 2.5, lower value of C_p results in less resistance, and (c) when B/d is less than 2.5, higher value of C_p gives less resistance. Generally the smaller value of B/d gives less resistance, with the exception of $v/\sqrt{L}$ of 1.00 when C_p is 0.60 to 0.64. For $V/\sqrt{L}$ of 1.10, lower values of C_p result in less resistance at any value of B/d, and the optimum value of B/d is around 2.25.

This analysis gives the impression that the B/d value should be between 2.2 and 2.3 for fishing vessels which usually have a rather high $V/\sqrt{L}$, and for such a low B/d value, higher value of C_p will result in lower resistance. However, the maximum difference of resistance caused by the lowest and

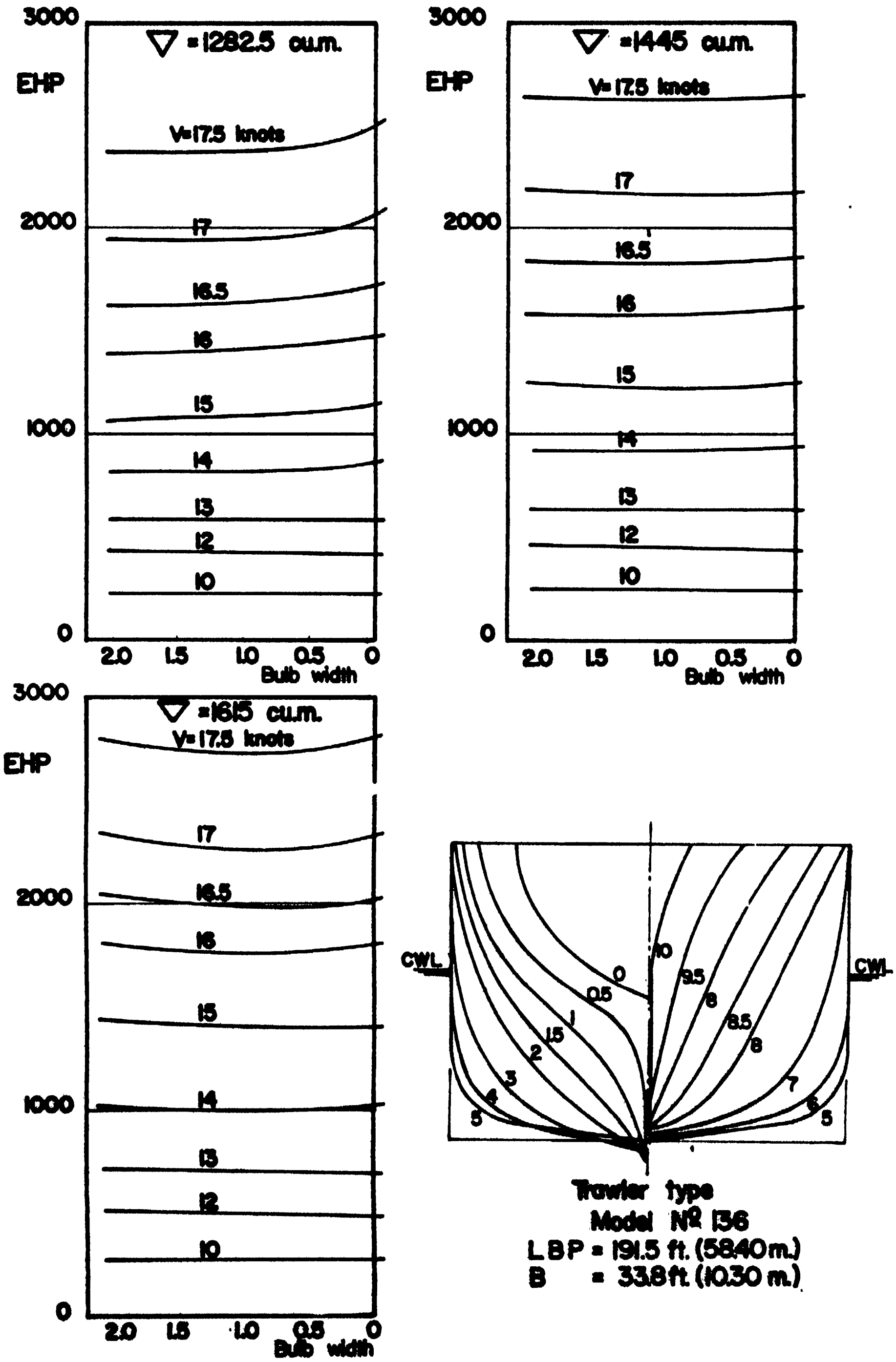


Fig. 602. Influence of bulb width on resistance of trawler 136

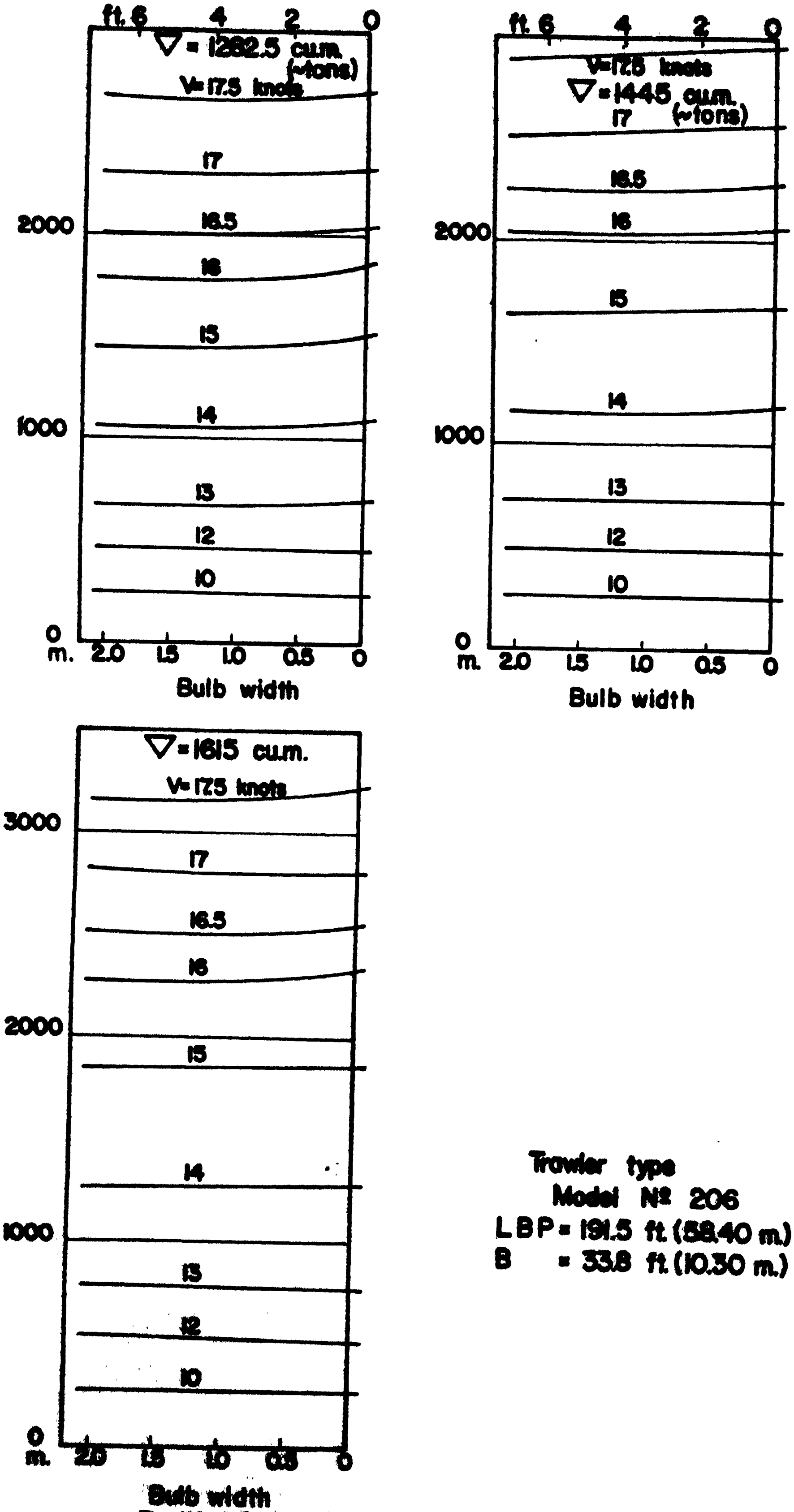


Fig. 603. Influence on bulb width on resistance of trawler 206

highest C_p has only little influence on the total resistance, namely 1.1 on F_t scale when B/d is 2.0 at 1.0 of $V/\sqrt{L}$, as shown in fig. 360.

Fig. 353 to 356 show *the influence of combined C_p and LCB on the resistance*. For any value of $V/\sqrt{L}$, each LCB has its own optimum combination with C_p to result in the lowest resistance, these optimum values of C_p usually being less than 0.65. The difference in resistance for the best and worst choice of C_p for a fixed LCB is fairly big, even when C_p is less than 0.65, namely about 6.3 on F_s scale at 1.0 of $V/\sqrt{L}$ and −6 per cent. of LCB in fig. 355. This difference becomes still greater if the whole range of C_p up to 0.70 is taken into consideration, namely 9.3 on F_s scale at 1.0 of $V/\sqrt{L}$ and +6 per cent. of LCB in fig. 355.

Thus the optimum C_p obtained here differs greatly from the optimum obtained in connection with B/d. More attention must be paid to the combination with LCB, because of its greater influence.

Fig. 357 to 388 show *the influence of the combination of C_p and $\frac{1}{2}\alpha_e$*. Generally speaking, at any value of $V/\sqrt{L}$, when $\frac{1}{2}\alpha_e$ is 17½° to 20°, different values of C_p have little influence on the resistance.

When $V/\sqrt{L}$ is 0.80 and $\frac{1}{2}\alpha_e$ is more than 17½° to 20°, the optimum value of C_p is around 0.66 to 0.67, and when $\frac{1}{2}\alpha_e$ is less than 17½° to 20°, it is 0.60 and 0.70, thus it has two extreme values, but in any case the difference caused by different values of C_p is not so great as in the cases of 0.90, 1.00 and 1.10 of $V/\sqrt{L}$.

When $V/\sqrt{L}$ is 0.90, 1.00 and 1.10, and $\frac{1}{2}\alpha_e$ is more than 17½° to 20°, higher value of C_p gives less resistance, and when $\frac{1}{2}\alpha_e$ is less than 17½° to 20°, lower value of C_p gives less resistance. This means that in most cases of $V/\sqrt{L}$, the optimum value of C_p is dependent on whether $\frac{1}{2}\alpha_e$ is smaller or larger than 17½° to 20°.

Moreover, the combination of C_p and $\frac{1}{2}\alpha_e$ has a very great influence on the resistance especially for big values of $V/\sqrt{L}$ over 1.00, and the best and worst combination results in a difference of resistance of about 16.0 on F_s scale at 30° of $\frac{1}{2}\alpha_e$ in fig. 380, and also at 5° of $\frac{1}{2}\alpha_e$ in fig. 382 to 386. It is interesting to note that a combination of 5° of $\frac{1}{2}\alpha_e$ and 0.60 of C_p often results in almost the same resistance as a combination of 30° of $\frac{1}{2}\alpha_e$ and 0.68 to 0.70 of C_p.

The above analysis indicates that there is no optimum value of C_p without taking $\frac{1}{2}\alpha_e$ into account; namely, the optimum value of C_p for any $V/\sqrt{L}$ and L/B, is dependent on $\frac{1}{2}\alpha_e$, and the best combination appears at the extreme value of C_p, namely 0.60 or 0.70, except when $V/\sqrt{L}$ is 0.80 and $\frac{1}{2}\alpha_e$ is more than 20°.

Which of these two extreme values of C_p should be chosen must be considered, together with other parameters.

Fig. 357 to 388 also show *the influence of L/B on resistance*. Generally, when $V/\sqrt{L}$ is 0.80, a smaller value of L/B (thus more breadth) gives less resistance regardless of the value of C_p, and the maximum difference of resistance for smallest and largest values of L/B at certain fixed $\frac{1}{2}\alpha_e$ reaches about 5.0 on F_s' scale, for example, the difference between F_s' value at 0.60 of C_p and 30° of $\frac{1}{2}\alpha_e$ in fig. 357 and 364.

When $V/\sqrt{L}$ is 0.90, the smaller value of L/B still gives the lower resistance, but the maximum difference of resistance resulting from the value of L/B becomes less, namely about 3.5 on F_s' scale; for example, the difference between F_s' value at 0.60 of C_p and 30° of $\frac{1}{2}\alpha_e$ in fig. 358 and 372.

However, when $V/\sqrt{L}$ is 1.10, the trend becomes contrary, and the bigger value of L/B (thus less breadth) generally gives less resistance, especially at the high value of C_p. This trend is quite remarkable around L/B of 5.0 to 5.8, and the maximum difference of resistance, between the best and worst choice of L/B, results in as much as 15.0 on F_s', for example, the difference between F_s' value for 0.70 of C_p at 30° of $\frac{1}{2}\alpha_e$ in fig. 384 and 388 and, on the other hand, the maximum resistance, usually appears in the range of L/B of 4.4 to 5.0.

The above analysis of the combination of C_p and L/B invites serious attention, especially if the vessels sail at 1.10 of $V/\sqrt{L}$.

The influence of C_m on the resistance is the most simple among the six parameters, as clearly shown in fig. 389, namely, higher value of C_m gives less resistance, but the maximum difference of the best and worst value of C_m gives only 2.8 on F_s scale at $V/\sqrt{L}$ of 1.00.

The preceding analysis, taken in conjunction with a study of the magnitude of the influence of each individual parameter, will give a clear indication of the best combination of parameters, i.e.

- C_m is as big as possible; on the other hand C_m has no serious influence on the resistance.
- It is preferable for B/d to be between 2.2 and 2.3, but the difference of B/d does not have any serious influence on the resistance
- L/B has no definite optimum value and serious attention should be paid to L/B if high values of C_p are applied
- The most serious consideration should be paid to the combination of C_p and $\frac{1}{2}\alpha_e$ in connection with LCB

When only the combination of C_p and $\frac{1}{2}\alpha_e$ is considered, there are apparently two different optimum combinations with contrary values of C_p and $\frac{1}{2}\alpha_e$; for example 0.60 of C_p and small value of $\frac{1}{2}\alpha_e$ and 0.70 of C_p and 30° of $\frac{1}{2}\alpha_e$. It must however be reminded that larger $\frac{1}{2}\alpha_e$ always gives more resistance under low $V/\sqrt{L}$ as shown in fig. 358 to 364.

On the other hand, from the LCB viewpoint, C_p value should always be less than 0.64, especially at high $V/\sqrt{L}$. Thus, the advantage of 0.70 of C_p and 30° of $\frac{1}{2}\alpha_e$, for example, is offset by the disadvantages of LCB.

Thus one may conclude that the lowest value of C_p, and accordingly smaller $\frac{1}{2}\alpha_e$ less than about 15° and +2 to +4 per cent. of LCB, is the best combination from a resistance point of view.

Based on the above conclusion of the optimum combination of the parameters, it is possible to reach more precise determination of their values.

Table 94 can be used for this purpose, as the original form parameters of L/B: 5.40, B/T: 2.53, C_m: 0.909, C_p: 0.60, LCB: 4.31% and $\frac{1}{2}\alpha_e$: 15° are quite near the optimum combination.

So far as the table is concerned, the best result appears in a combination of L/B: 5.40, B/T: 2.53, C_m: 0.909, C_p: 0.60, LCB: 4.3 per cent. and $\frac{1}{2}\alpha_e$: 7.5°, but a slight improvement may be reached by changing L/B and B/T.

Fishing vessels are often designed far from the optimum values of these parameters and the power loss may be great. It is amazing that parameters such as C_p, $\frac{1}{2}\alpha_e$, LCB, and C_m, which could have been selected from publications on resistance or from model tests, are far from the optimum values.

The results of Doust's investigations indicate that until now the design of fishing vessels has not always been optimum. What is now needed is a similar study for parameters typical for fishing boats of smaller size.

Mr. H. Lackenby (U.K.): He thought that it was fortunate that at about the service speed of 12 knots, the resistance was insensitive to the beam. Hence, if an increase in the initial stability is wanted, this could be done without unduly penalizing the resistance related, of course, to smooth water conditions.

Prof. G. P. Weinblum—Vice-Chairman (Germany): He thought that damping by increasing its beam would be slightly increased so that the motion of beamy vessels should be better. It is more difficult to say what happens to resistance, but since refraction is not too large he did not believe that it matters too much.

FISHING GEAR RESISTANCE

Mr. P. R. Crewe (U.K.): Dickson's experiments suggested that the resistance of bottom trawls varied almost proportionately to the towing speed. The towing pulls given in fig. 416 and 417 of Möckel's paper were obtained over a very narrow speed range, but they were not inconsistent with the assumption of being directly proportionate to speed. Was this type of variation of gear resistance with speed desirable in practice, or did it indicate a possibility of improving the gear, which if successful might make the present results unrepresentative?

Before enlarging upon this point he explained that his tank had been commissioned to make a survey of the extensive technical literature on the performance of trawls, and compare the reported findings with some analogous results in other fields involving the motion of bodies in fluids. Structural considerations were also being given serious attention. Later it was hoped to conduct some theoretical studies, and contribute some model and full-scale experiment results.

While much excellent work had been done, it would perhaps be agreed that it had not yet achieved the co-ordinated presentation and degree of co-relation between experiment and calculation that a scientific discipline demands.

In fact, as had already been mentioned, the development of a generally accepted fishing gear technology was at its beginning—a beginning that had been greatly assisted by the 1957 FAO Fishing Gear Congress, and the transactions (Kristjonsson, 1959) that had resulted from it.

As regards the technical point raised, if a trawl is moving, in midwater, its resistance would be expected to vary as the speed squared.

It might, however, show some departure from this behaviour if relatively large areas of net are inclined at fine angles to the direction of motion, for then forces equivalent to fluid skin friction become significant.

However, such fine angles limit the tendency of the net itself to produce water forces, which would hold it open, and so it seemed reasonable that a tendency for resistance to vary as speed squared should be an indication of satisfactory design.

Turning to the bottom trawl, the variation of resistance might tend to be nearer to a linear than to a speed squared condition, because of the frictional resistance between the otter boards and the sea bed, and also between the net and the sea bed. Such resistances tend to remain nearly constant or decrease as speed increases. Furthermore, if the spreading power of the otter boards increases with speed, too fast relative to the net forces, the net mouth will be overspread and its area will decrease, thus holding down the net resistance and accentuating a tendency which, depending on the way the fish are shoaling, might well be undesirable.

From this argument it might be tentatively concluded that the ground friction drag of a bottom trawl should be as small as possible, its mouth area should be kept large, and that in these conditions its resistance would vary more nearly as speed squared.

It might therefore be necessary to reconsider the power requirements for gear towing, if gear of generally greater efficiency can be developed.

It is, of course, possible that such gear would have the same resistance as now at the normal speed of trawling, but would be less at lower speeds. Even so, the transient loads on it at the momentarily greater speeds which occur in shooting or hauling, could be greater.

Therefore attempts to increase hydrodynamic efficiency are most likely to be disappointing unless due regard was at the same time paid to structural implications.

Mr. A. Hunter (U.K.): He wondered if Dickson was right in assuming that by towing with and against what he imagined to be the tide, he got the true answer. The strength of the tide could vary from the surface to the bottom, but methods used by oceanographers might give the truer effect. He suggested that delivered horsepower might be a better basis than shaft horsepower as this would take propeller efficiency into account. The powers given for hauling, too, would perhaps be of more interest for the designer, where he has to think of generator capacity, if it could be referred to the input end; in other words, the winch efficiency should be taken into account.

Mr. J. Tyrrell (Ireland): He regarded Dickson's information and remarks on the stability of smaller vessels as of the greatest importance. A vital factor in this matter was the height of trawl gallows, which was virtually the same in vessels of all sizes, and provided a serious heeling lever in vessels of the 50 to 70 ft. (15 to 21 m.) range.

SEA BEHAVIOUR THEORY

Mr. A. Hunter (U.K.): Almost every aspect of trawler design like other ships had to be considered in two conditions. thus:

- Speed in smooth water as compared with speed in waves
- Trawling in smooth conditions as compared with trawling in rough seas
- Clean smooth hull as compared with a fouled or roughened hull
- Vibration in calm seas and vibration as a result of working in waves
- Static loading conditions as compared with loads imposed in waves were perhaps of less importance in a trawler

There is little use designing only for smooth water conditions. Naval architects have perhaps done fairly well in designing seakindly forms and that this had been achieved without fundamental rough water research was perhaps a testimony to their skill.

General practitioners like himself would welcome the further knowledge which could accrue from the results of research in the seakeeping basins. Vossers' paper whetted this appetite. He suggested that trawlers deserved a high priority in rough water research and made the plea that the various seakeeping basins should combine to further this research at the earliest possible date.

MR. F. MINOT and DR. C. E. CARVER, Jr. (U.S.A.): It is only a few years since the marriage of naval architecture and oceanography, but they have been most productive years in regard to the understanding of the behaviour of ships operating in the ocean's irregular wave systems. Vossers' splendid paper clearly indicates some of the important strides which have been made in the statistical study of the characteristics of wind-generated ocean waves and how the motions of ships can be related to them.

The characterization of irregular wave patterns by energy spectra has been a truly significant step forward in bringing order out of the chaos that seemingly existed in the study of natural surface waves. The spectrum of a particular response of a vessel is then related to the spectrum of the waves by Eq. (12) of Vossers' paper. The complete description of an irregular wave system, as he has indicated, must embody both wave frequency and direction, and the resulting spectrum is then referred to as a directional energy spectrum.

Vossers is correct in his assertion that oceanographers are still "at sea" regarding the shape of the energy spectrum, and he pleads for more elaborate and numerous measurements to be made in the future in this connection. Such research is currently in progress at the Woods Hole Oceanographic Institution (WHOI), and a brief description of the wave investigations there should be of some interest.

The directional spectrum is customarily expressed as the product of a one-dimensional or point spectrum and an operator which is a function of wave frequency and direction. A point spectrum can be obtained from the wave-height measurements of a single detector with little difficulty; the more formidable experimental difficulties are associated with the characteristics of the operator. In 1954 a research programme entitled SWOP (Stereo Wave Observation Project) was undertaken by the U.S.A., in which a portion of the North Atlantic Ocean was stereophotographed and after a laborious process of data reduction a directional spectrum was obtained of an actual seaway. There are not more than three or four actual ocean directional spectra in existence today, and it is not surprising that little agreement exists concerning the shape of the curve.

A comprehensive programme of research was therefore instituted at WHOI, having as its initial objective the measurement of the directional spectrum of actual wind-generated ocean waves for a variety of wind conditions. For this purpose a steel-framed wave observation tower, 60 ft. (18.3 m.) in height, was installed in Buzzards Bay, Mass., in 40 ft. (12.2 m.) of water, and securely anchored to the bottom. Such a tower has the distinct advantage of providing a fixed platform from which wave height measurements can be made with great accuracy. Hence, the resulting point spectrum thus computed would also possess a high degree of accuracy.

A detailed discussion of the method of wave measurements from which the directional operator would be obtained is beyond the scope of this comment. It involves the use of a line array of wave detectors suspended from the tower in such a way as to be capable of being rotated at various angles with respect to the dominant wind direction. The distinct advantage of the experimental programme is that it provides a means of obtaining directional spectra for actual ocean waves under various wind conditions with good accuracy and rapidity. The data so obtained should prove especially valuable to towing tank personnel who want to reproduce in their towing tanks directional spectra comparable to those which exist in nature.

It is planned to continue the project to include the experimental measurement of the motions of a remote controlled, self-propelled model of one of the WHOI's existing research vessels. Such a model would be operated in the vicinity of the tower; the heave, pitch, roll and perhaps yaw would be recorded from telemetered data emanating from the model, and the necessary wave data obtained from the tower from which the directional spectrum of the seaway in which the model is operating could be computed. The motions of the model would be measured in this way for several different headings.

Having a model of an existing prototype also lends itself to some very important experiments concerning the nature of the scale factors involved in the prediction of prototype behaviour from model experiments. It is in the case of the irregular seaway that the nature of the scale factors for model and prototype seaway spectra is important. It is hoped to gain some insight into the nature of these scale factors by direct measurement.

The measurement of the motions of a full-sized vessel are not difficult to undertake; however, the measurement of wave heights aboard a vessel, it is felt, needs considerable refinement before the results can be considered accurate. The problem of wave interference by the vessel exists whether she is under way or not. Some devices depend upon double integration of the vertical acceleration of the vessel but suffers from the fact that the theory is better than the electronics. Nevertheless, it is probably quite safe to say that much more data of this sort is needed if it shall be possible to fully understand the complex nature of wave motion and its effect on the motions of ships.

COMDR. P. DU CANE (U.K.): Vossers has done well to describe the nature of the path of progress in describing the realistic or irregular short crested sea since 1953. As far as the design of trawlers is concerned this is mainly of value in an attempt to make model testing in waves of more value. Much of this technique has been derived from the processing of statistics and the mathematics of probabilities which has been developed in other branches of engineering, notably electricity and nuclear physics.

As mentioned by Vossers in the case of the narrow spectrum. which is on the whole the type of spectrum which is likely to interest the ship designer and operator, the significant waveheight, which is the average of the apparent height of a third of the highest waves, is the height of wave likely to be observed from the ship. It is probably a fair wave to assume for most design purposes, but it does not by any means represent the maximum likely to be met with in the course of a ship's life. It is important to bear this in mind, because no statistical methods will really supply the answer to the question as to what are the dimensions and frequency of the biggest wave a ship will ever meet and presumably survive.

Vossers and others mention the bulbous fore foot and claim for it a reduction in the vertical accelerations at the bow. This may be expected to apply to pitching, but there seems a strong possibility that once conditions are reached such that "slamming" is a possibility, the position may well be reversed and it may be found that the incidence of slamming is increased by the bulb.

Vossers' fig. 409 shows that liability to seasickness is dependent upon the magnitude and frequency of the vertical accelerations imposed on the human body. It is submitted for consideration that there is probably another factor which has to be taken into account here. It is well known that the liability to seasickness is much reduced in the planing type of fast patrol boat or rescue tender despite the fact that vertical acceleration up to 4 g and even more are occasionally recorded. Certainly 1.5 g to 2 g is quite common. This is approaching ten times Nieuwenhuysen's figure for normal types of vessel.

If one supposes that acceleration is the stimulus which excites the systems responsible for nausea and vomiting, it is unlikely that the responses of these systems are related to duration or intensity of exposure (to accelerations) in a linear manner. With vision, for instance, the relationship

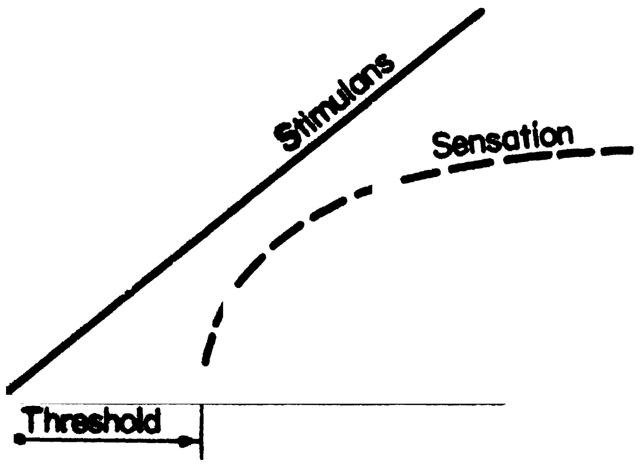


Fig. 604. Seasickness is perhaps not always dependent on the magnitude and frequency of the vertical accelerations

between stimulus and sensation is somewhat as represented in fig. 604.

Within reason it has been possible to express the relationship in the form:

$$\text{Sensation} = K \log I + C$$

where I is intensity of stimulus and C is threshold intensity or duration.

This indicated that if the stimulus, in this case of acceleration, is applied for a sufficiently short period to be within the "threshold" no sensation will result, or at least seasickness will not be caused. It is quite reasonable to suppose this explains why the short period acceleration experienced in the planing craft does not have the same effect as in a large ship whose motions are relatively deliberate. It can go some way, perhaps, towards explaining the influence of frequency demonstrated in Vossers' fig. 409. Of course, seasickness is not in fact much of a problem in fishing vessels as most members of the ship's company are quite inured to this distressing sensation.

DR. F. H. TODD (U.K.): He found Vossers' paper very interesting, especially the new facilities developed at Wageningen. At the NPL they were building a new towing tank, with a large wave-maker at the end, and also a square seakeeping basin with arrangements to make all types of waves, to run models at different angles to the sea and also in irregular sea patterns. They were trying to gather information on full-scale ships which could be used as a guide for testing models.

A co-ordinating committee comprising the BSRA, the Admiralty, the National Institute of Oceanography and the National Physical Laboratory (NPL) had been appointed. This committee was devising methods for taking measurements of sea state, ship motion, ship power and speed on full-scale ships, and correlating these data between the model and the ship.

He asked Vossers to give a definition of the significance of the height of the wave—was it from crest to trough?

OBSERVATIONS OF BEHAVIOUR AT SEA

CAPT. S. REMØY (Norway): He agreed with Möckel that GM should not be too low—below 2.3 ft. or .7 m.—for motor trawlers, but if too high, the ship will be working too heavily, shipping water and exposing herself to icing much faster than she would do if GM is kept to a minimum with regard to the conditions in which she is navigating.

Norwegian seal-hunters do not have a large GM, but they have a very high foremast and a comparatively heavy deckhouse structure which gives long rolling periods.

These ships are often exposed to heavy strain when riding strong gales in Arctic waters. With powerful machinery they also often suffer from damage to bulwarks and superstructures more often than when their engine power was much lower.

In order not to break down, they use sails, even today, so as to be able to keep the ship close to the wind and sea. In his opinion trawlers and ships up to 600 tons d.w. should—as on the seal-hunters—use sails to avoid heavy strain on the ships and machinery, and also to reduce icing.

Seal-hunters use a fore staysail, a three-hooked mainsail on the foremast and a mizzensail. All are close-hauled to keep the ship close to the wind and sea.

The engine is only used now and then if needed to bring the bow up again if it falls off. By doing this the strain on hull and engine is only a fraction of what it would be if the ship had to be forced against stormy weather by engine power only. In addition, the fuel consumption is also a fraction of what it would be with a forced speed.

A ship drifting freely in open sea—or attached to a longline or gillnet—or when processing fish, such as herring, can often reduce rolling and increase processing work considerably by hoisting a three-hooked sail on the foremast. It need not be a large sail, but kept tight by tacks amidship it is surprisingly effective, and costs very little. If the rolls are long and heavy it is possible to increase the work on deck with anything from 10 to 50 per cent., all according to conditions.

COMDR. P. DU CANE (U.K.): Once again Möckel has given us a wealth of valuable and detailed information based on practical sea-going tests of trawlers. It is not possible to quarrel with the figures given for GM as a measure of initial stability: that is to say, stability near the vertical. It will be appreciated, however, that in order to avoid excessive motion in the rolling plane or shipping of water while fishing, the same could be achieved with a GM of say 1 ft. (0.3 m.), provided damping was adequate and the freeboard could be increased.

In other words, the margin of stability required relates chiefly to the necessity to provide for a reserve of stability in case of icing and to allow for carrying water on deck due to shipping sea when handling the catch. Many naval architects will probably agree that a consideration of the curve of righting levers (GZ) is on the whole a superior criterion of safety than is GM, provided the ship remains intact. The work of Rahola will not be unknown to most.

All of this leads the observer to conclude that there must be very great advantages in fishing over the stern which would allow the ship to be designed to have adequate freeboard. Incidentally also the fitting of activated roll damping fins in such vessels should be quite practical either at the turn of the bilge or retracting vertically through the keel.

It cannot be denied that a low block or prismatic coefficient will lead to improved seakindliness, but it has to be remembered that the fine ended ship can be put down by the head easier in the course of filling the fish hold. This can lead to unpleasant behaviour in following sea conditions.

It is of interest to notice that most naval architects seem to discuss the prismatic coefficient in this context, whereas Möckel adheres to the block coefficient which seems less fashionable in these days.

Mr. A. Hunter (U.K.): Was Möckel satisfied that the skin roughness of the four trawlers investigated was comparable? Möckel brought out the advantage of longitudinal weight distribution and its effect on the longitudinal radius of gyration. Mr. Hunter also found that by putting the reserve fuel oil forward and discharging to amidships when about 1,000 kits (63.5 ton) had been taken into the fish room, a much easier motion of the ship could be obtained and the fish room placed in a much better position in the ship. He agreed with Möckel's observation on the effect of the metacentric height in fig. 429, although not long ago many fishermen would have objected to it. Designers would no doubt agree on the desirability of all operating personnel receiving more education in matters of trim and stability.

Dr. F. H. Todd (U.K.): He endorsed Möckel's plea for more objective information on the performance of the ship. Möckel's speed measurements were made by a resistance log and he felt that this was not very satisfactory in ships making large waves.

He found that the steep rise in power curves at high speeds would indicate that there was little point in further increase in power. What was needed was to reduce the resistance, by making the ships longer and finer. In Möckel's analysis of the behaviour of the three ships, F, G, H, having similar characteristics, there did not seem to be a strong case for the motor ship. If Möckel felt that the incidence of seasickness was attributable to the linear acceleration, this was in agreement with the work done by the U.S. Navy.

Mr. J. Tyrrell (Ireland): As regards the shape of the bow, he noted that Chapelle did not favour rake to the stem and flare to the bow. However the flare on Irish fishing boats designed by his company had been found useful in single boat operation. It permitted a finer entrance with reduced resistance, was drier in a head sea, gave greater reserve buoyancy and easier motion.

However, when they were asked to design vessels for use in pairs at ring-net fishing, where the boats come alongside each other at sea, it was recognized that the bow with normal flare would be vulnerable and easily damaged.

Therefore a knuckle was introduced in the bow at an appreciable distance below deck level, giving a vertical side from the knuckle line to the rail. This has given a very strong topside, immune to damage when the boats are lying together. Apart from this feature, it provides greater reserve buoyancy, allows a greater degree of fineness of the waterline, and provides increased internal space.

Vessels with this bow design preserve their trim when carrying loads in excess of 50 per cent. of their standard displacement.

Hunter's statement that a transom stern resulted in 20 per cent. more resistance he found it impossible to accept. The value of the transom stern was at deck level where great width was wanted. It was quite practical to design an efficient transom stern with a load waterline having an aft ending no fuller than normally shaped for a cruiser stern.

Mr. T. Tsuchiya (Japan) said that over the last ten years sea performance data of fishing boats had been collected in Japan. The results however were often unsatisfactory because of inaccuracy of measuring instruments, especially those for determining SHP. The importance of sea performance tests is however becoming recognized.

Referring to Möckel's contribution, Mr. Tsuchiya assumed that the important results reported were obtained only after overcoming difficulties concerned with the methods of measurement.

In Japan the various tests were at first made separately because there was no opportunity for simultaneous investigation of the boat's speed, r.p.m., SHP, net pull force and shape of the trawl used from two-boat trawlers. Recently, simultaneous measurements had been made on board the *Yagami Maru* (about 100 GT and 260 BHP diesel engine). The principal dimensions of the trawler are given in table 142.

The torque of the main engine was measured by an instrument consisting of an amplifier acting on the electric current taken from a cross type wire strain gauge fitted on the shaft. The instrument is easy to install and requires only 8 in. (200 mm.) free length of the shaft, and it can be used also in small fishing boats having a short shaft with limited space around it. One difficulty with the instrument is that the zero point is apt to shift. It is, therefore, necessary to calibrate the zero point of the instrument before and after measurements. In these experiments the zero point could not be checked after trawling because this would disturb the commercial operations. In addition, because of the diesel propulsion, torque fluctuation was so large that the torque records could not be amplified sufficiently, and thus the accuracy of SHP was not satisfactory.

The draught and displacement of the *Yagami Maru* and the results of SHP measurements are also shown in table 142 and fig. 605a and b.

η_t should normally include the hull resistance in spite of its comparatively small value, but it was calculated from the equation $\eta_t = 6.88P\ (\text{ton}) \times V\ (\text{knot})/\text{SHP}$ to compare it with Möckel's results. The result was as follows: $\eta_t = 6.88 \times (3{,}682 \times 1.85)/(2{,}204 \times 96) = 0.220$. This value of η_t seems small compared with Möckel's results, but it is not abnormal because Japanese two-boat trawlers generally have high r.p.m., low trawling speed, and a fixed-blade propeller, the pitch being selected at the request of the owners to give the highest efficiency when sailing.

Möckel's determination of the acceleration in waves on various places in fishing boats suggests that the efficiency of the crew should next be investigated.

TABLE 142

Principal particulars and sea performance

Principal particulars:					
LBP × B × D	ft. (m.)	91.86 × 17.72 × 8.86 (28.00 × 5.40 × 2.70)			
Main engine		260 BHP × 380 r.p.m. × 4-stroke diesel			
Propeller	in. (mm.)	58.31 (1,480) diam. × 37.43 (950) pitch; developed blade area ratio 0.350; 3 fixed blades.			
Sailing speed on trials:					
Draught	ft. (m.)	6.04 (1.84) fore; 10.37 (3.16) aft			
Displacement	ton	235.95			
Load of engine		1/4	2/4	3/4	4/4
Speed, knots		6.69	8.22	8.89	9.30
r.p.m.		240	302	345	380
SHP		62	132	199	263
$V/\sqrt{LBP}$		0.698	0.857	0.927	0.970
$(v/\sqrt{g.LBP})$		(0.208)	(0.256)	(0.276)	(0.288)
Data from trawling:					
Main engine output		96 SHP at 249 r.p.m.			
Speed of boat, knots		1.85			
Advance component of pull	lb. (kg.)	3,682 (1,670)			
Distance between boats	ft. (m.)	920 (280) Approx.			
Engine output		$\frac{\text{trawling SHP}}{\text{sailing SHP}} = 48.2\%$; $\frac{\text{trawling SHP}}{\text{SHP at full load of engine}} = 36.5\%$			
Torque		$\frac{\text{trawling Q}}{\text{sailing Q}} = 66.7\%$; $\frac{\text{trawling Q}}{\text{Q at full load of engine}} = 55.6\%$			

Möckel's proposal to measure the GM value during trips by measuring the natural rolling period, T_r, seems satisfactory when the small error caused by the scattered values of m is ignored. It is, however, difficult to measure the T_r value accurately on the open sea because of disturbance by waves. Fig. 605c shows both normal maximum and occasional maximum rolling periods measured from the *Yagami Maru* in irregular waves, and the values coincide fairly well with the T_r value of 6.97 sec. This can be proved by the rolling theory of ships in irregular waves.

Waves in port often cause difficulties during the inclination test, when measuring the accurate angle of inclination of small fishing boats. To overcome this, a glass tube clinometer was made, being about 8 in. (200 mm.) long, and having about 6.55 ft. (2 m.) radius. This instrument was designed so that the size of the air bubble in the clinometer could be controlled, thus the movement of the air bubble could be damped by changing the bubble size. It was possible to read the mean inclination, even when small waves were present. In order to increase damping further, a more viscous liquid can be used.

The measured conditions of the *Yagami Maru* for full load departure, fishing and arrival conditions, are shown in table 143, and the corresponding statical stability curves are shown in fig. 605d. These data show that the *Yagami Maru* has less stability than European trawlers, mainly due to its smaller freeboard. This boat might have had more stability on her maiden voyage. It is well known that the displacement of boats often increases with time because of the addition of unknown weights, often in a high location. This is thought to be the main reason for the small freeboard.

The problem is how to maintain sufficient stability of fishing boats. The introduction of minimum freeboard regulations is difficult because the freeboard is closely connected with the owner's economy. The data of European fishing boats give good evidence of this problem.

The majority of sea accidents of fishing vessels are considered to be due to lack of stability, and this factor was experienced also during the experiments in October 1957. One night, the *Yagami Maru*, under the condition of table 143, got a large quantity of water on deck, suddenly heeled 35 to 40 degrees to port side, and could not right herself for ten seconds. The condition of the sea at the time is given in table 143. The boat was drifting with the sea, with wind and waves from starboard. The crew were stowing fish into her holds. When the water came on deck, a part of the catch was swept overboard, and sea water flowed into the hold through the hatchways. Fortunately, the boat could be stabilized gradually because the crew started the engine immediately and turned her against the wind. The stability curve and heeling moment lever curves caused by the wind and sea water on deck are shown in fig. 605e. These curves show an apparently dangerous situation. It is quite clear that the direct cause of this critical heel was the great quantity of water on deck. There were no more similar incidents even when she was drifting under almost the same condition, and it is felt that such a dangerous situation happens only accidentally. However, sometimes ship owners report such happenings and they should be taken into account when considering stability.

Unfortunately, at present few fishing vessels are safe from a purely naval architecture point of view, and it seems that 100 per cent. safe fishing vessels are difficult to design, due to the commercial requirements of the owners; therefore, the safety of small fishing vessels has to be obtained through the seamanship of the crew. Fishing vessel design should be further improved and the onus on the crew reduced.

Möckel's work is very instructive and shows how the

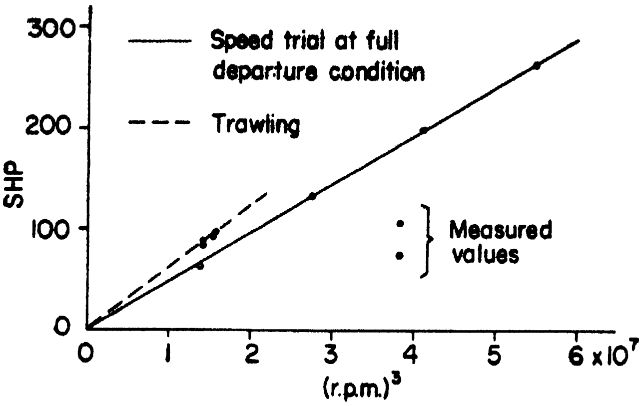


Fig. 605a. Yagami Maru: *SHP against cube of r.p.m.*

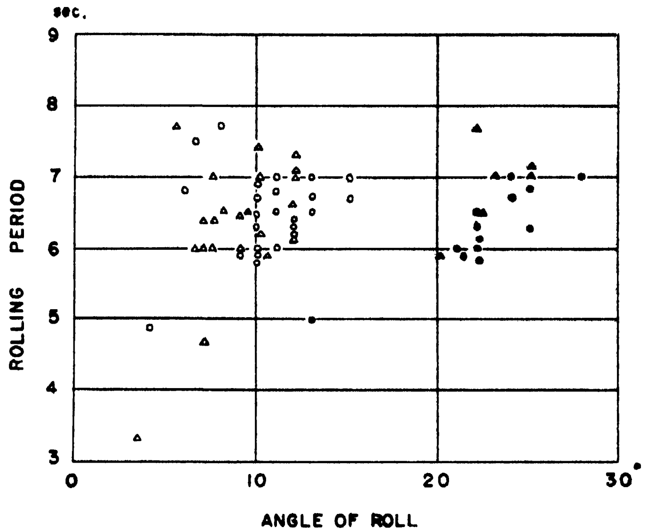


Fig. 605c. Relation between rolling angles and rolling periods when $T_r = 6.97$ sec.

Reference: O, ● *drifting;*
Δ, ▲ *running slowly against wind*
Black: occasional maximum rolling angle
White: usual maximum rolling angle

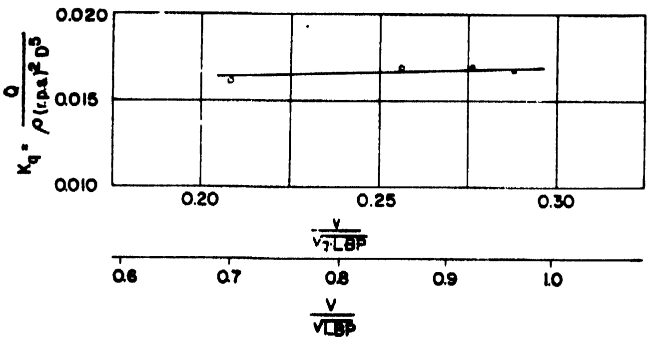


Fig. 605b. Torque coefficient against Froude numbers measured in speed trial at full departure condition

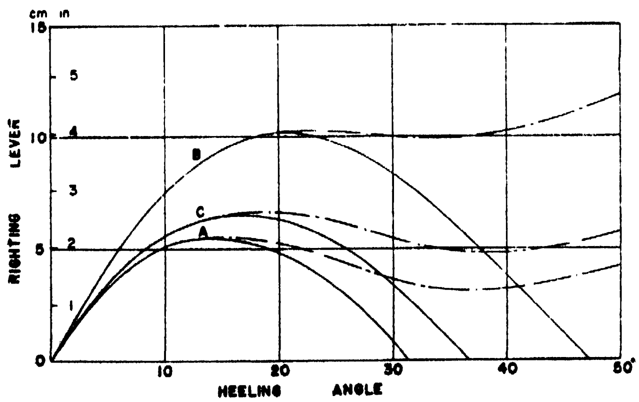


Fig. 605d. Yagami Maru: *Statical stability curves*

Reference: ———— *under deck only*
—· —· — *including deck house and forecastle*
Mark A, B & C (see Table 143)

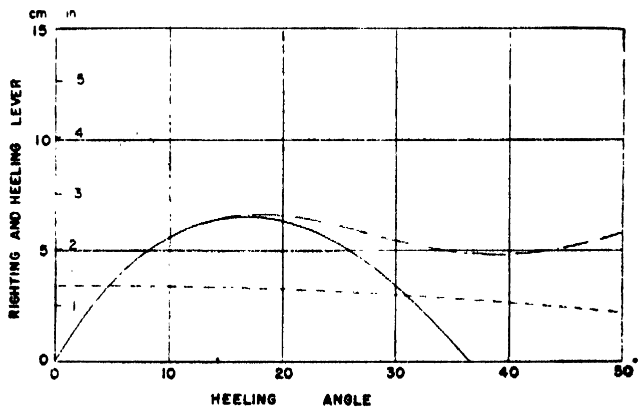


Fig. 605e. Yagami Maru: *Statical stability curve and heeling leve curves caused by deck water and 82 ft./sec. (25 m./sec.) beam wind*

Reference: ———— *Statical stability curve under deck only*
—· —· — *Statical stability curve including deck-house and forecastle*
— — — *Heeling lever caused by wind*
.... *Heeling lever caused by deck water*

research work of naval architects should be directed in the future.

MODEL TESTS IN WAVES

Mr. J. O. Traung (FAO): Taniguchi showed that three different bow types gave nearly the same behaviour in a seaway; thrust increase was about the same. The question arose as to what was the calm water power. If one bow required less power than another in calm water that bow plus thrust increase in waves would give the best ship.

Tyrrell mentioned that if care was taken, a transom could be better than a cruiser stern, this was also his experience. The problem with factory ships seemed to be that they need to have considerable body under the water to get the wide stern ramp close to the water. This might be the reason why a transom was not so good on a stern trawler with ramp.

Dickson emphasized the importance of investigating the behaviour of small fishing boats when the trawl comes fast. Scottish fishing boats (MFV) generally had a GM of 3 to 4 ft. (0.9 to 1.2 m.)—about the same as Swedish boats.

He was interested in Johnsson's statement that a high prismatic was good for boats making high sea speeds. During a fishing trip on a Swedish trawler of very recent design with a 500 h.p. engine, he found that seldom more than 250 h.p. was used when steaming, movements otherwise being too

Table 143

Stability properties for various conditions

		Full departure	*Full arrival*	*Fishing*
Mark in fig. 605d		A	B	C
Displacement	ton	238.9	230.2	233.0
KG	ft.	6.92	6.59	6.86
	(m.)	2.11	2.01	2.09
GM	in.	16.6	20.1	17.3
	(m.)	0.42	0.51	0.44
T_r (natural)	sec.	7.14	6.47	6.97
Freeboard	in.	10.6	12.6	12.2
	(m.)	0.27	0.32	0.31
Days after departure			30 days	7 days when serious heeling occurred.
Sea conditions:				
Wave length	ft.			160 to 230
	(m.)			50 to 70
Wave height	ft.			12 to 16
	(m.)			3.5 to 5.0
Wave period	sec.			6 to 8
Wind velocity: mean	ft./sec.			50 (approx.)
	(m./sec.)			15 „
maximum	ft./sec.			65 „
	(m./sec.)			20 „

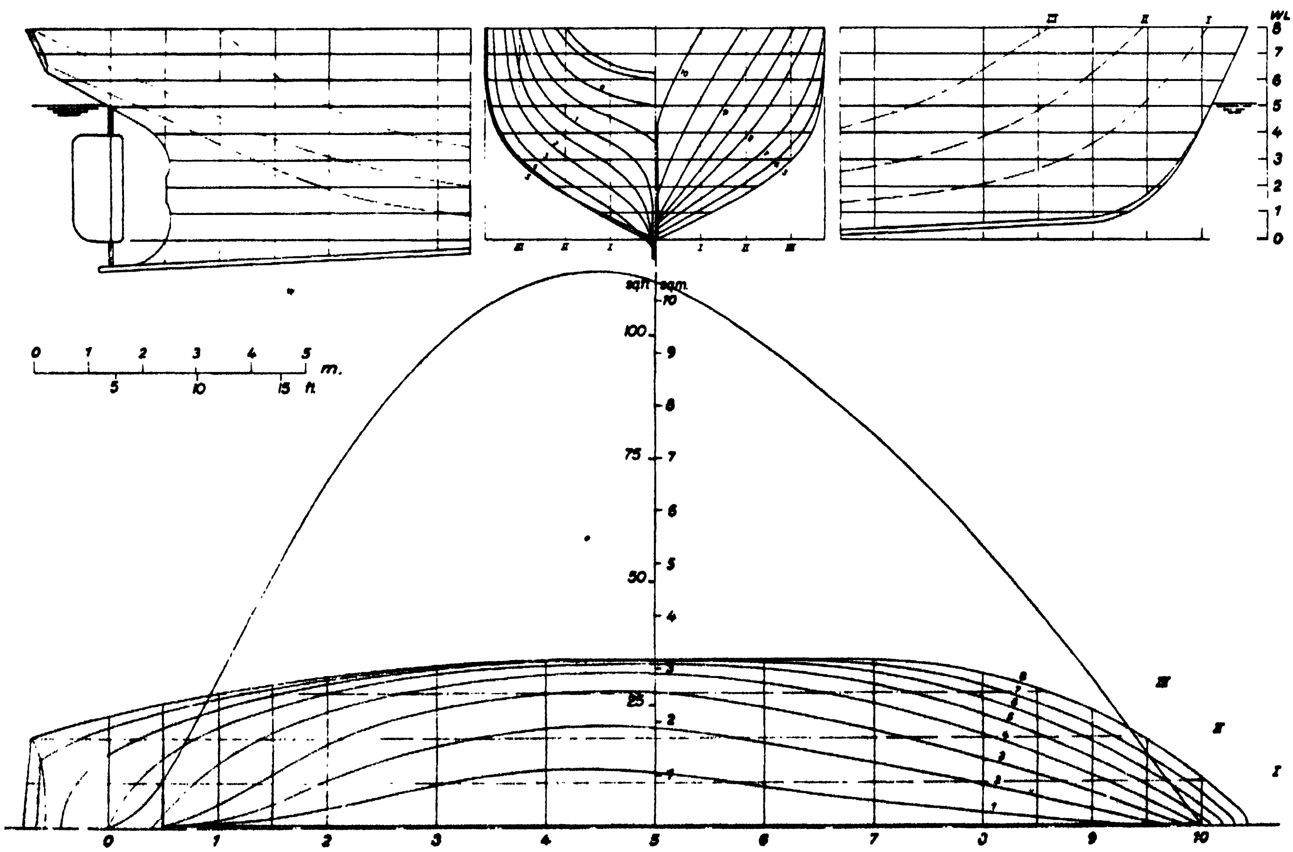


Fig. 606. 78.5 ft. (24 m.) German steel fishing boat, model 91, φ=.612

violent and fuel consumption too high, and that the boat seldom did more than nine knots, the average being eight knots. This boat operated well below the transition of 1.2 speed-length ratio when a low prismatic became advantageous.

Had Johnsson done any sea experiments since having received the report on this fishing trip, indicating that the sustained sea speed of any Swedish vessel was so high as to justify having the high prismatic coefficient he advocated? Johnsson stated that a high prismatic "undoubtedly gives a more seaworthy ship"; some elaboration on this statement would be highly interesting.

Traung believed that fishing boats sometimes operate in supercritical condition (Lewis, 1955). Möckel advocated, and Hunter agreed, that the main weights be distributed towards the ends of the ship. This was typical for supercritical condi-

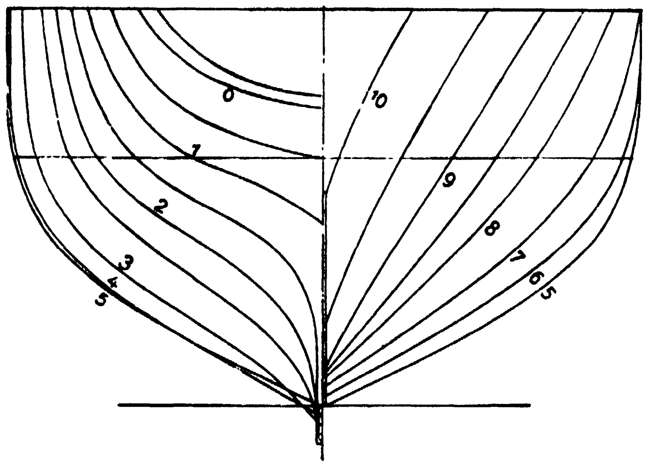


Fig. 607. 78.5 ft. (24 m.) German steel fishing boat model, $\varphi = .612$

tions since under subcritical conditions the weights would have to be concentrated amidships.

Mr. T. Mitsui (Japan): The answer to Traung is that the delivered horsepower at 10 knots in still water is as follows:

Condition	*Model No.* 1234 (*parent*)	*Model No.* 1235 (*V-section*)	*Model No.* 1236 (*flaring bow*)
Full load	100 per cent.	103.6 per cent.	104 per cent
Half load	100 „ „	102.4 „ „	96.3 „ „
Light load	100 „ „	118 „ „	97.8 „ „

Prof. G. Weinblum—Vice-Chairman (Germany): Möckel, Hunter and Traung have pointed out that fishing vessels may sometimes operate under *supercritical* conditions. This involves lengthening of the natural pitching period, essentially by increasing the pertinent mass moment of inertia. Dangers are herewith possible in the resonance zone because the exciting force is in general appreciably increased and the dimensionless damping slightly decreased as compared with corresponding conditions for a normal design. The appraisal of favourable ship parameters is greatly complicated by the possibility discussed.

Problems of transverse stability in a seaway obviously belong to the subject "sea behaviour". Möckel succeeded in establishing a fairly narrow band for the desirable values of trawlers, thus contributing valuable information to the difficult problem of stability standardization.

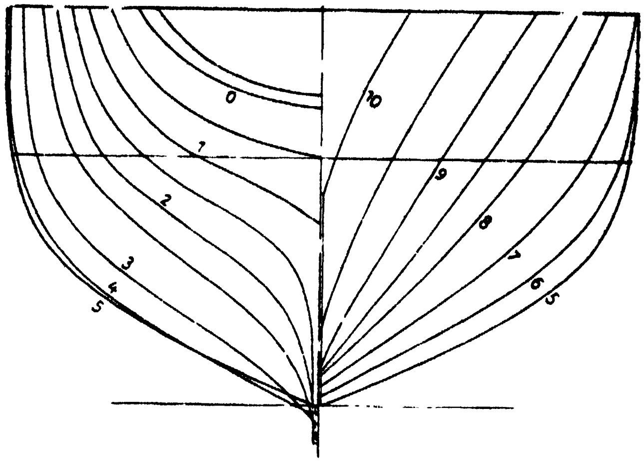


Fig. 608. 78.5 ft. (24 m.) German steel fishing boat model, $\varphi = .584$

The prismatic coefficient

Comdr. P. du Cane (U.K.): He wanted to congratulate Traung on a very fine paper, over which exhaustive research and much trouble has been taken. The conclusion that low prismatic coefficient will lead to optimum performance in a seaway, both from the viewpoint of propulsion and pitching motion in waves, is clear from this paper, and in fact seems to be a theme running throughout the papers.

Whether trawler owners as a whole will accept this conclusion and incorporate a low prismatic coefficient into their trawlers is another matter. His firm delivered a ship based on these principles about 18 months ago, and on the whole the low prismatic coefficient certainly resulted in outstanding performance. They had since carried out comparative model tests in waves in head and following seas, making use of this form and another form noticeably fuller at the ends. When at designed trim there was nothing much to choose between these forms, though, undoubtedly, the finer form was easier driven.

However, if a low prismatic is made use of it must be appreciated that it is relatively easy to put her down by the head in the course of loading the fish holds and as fuel is

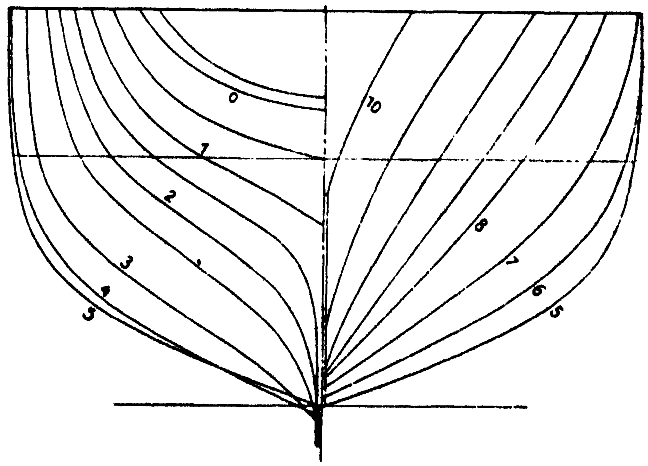


Fig. 609. 78.5 ft. (24 m.) German steel fishing boat model, $\varphi = .560$

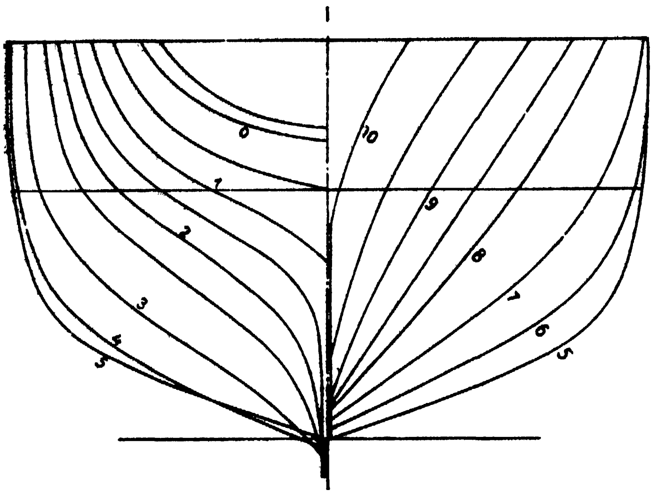


Fig. 610. 78.5 ft. (24 m.) German steel fishing boat model, φ = .539

used. If such a ship becomes substantially trimmed by the head she may become very unpleasant in a following or quartering sea. It is here that the fuller ship will score because the same load will not put her out of trim to a comparable extent.

DR. F. H. TODD (U.K.) felt that Traung's paper gave a good review of the whole subject of the design of small trawlers and the use of prismatic coefficient as a design parameter, and the conclusions corresponded generally with experience at the NPL as regards low prismatic, low half angle of entrance, and an aft position of the LCB in smooth water. He felt that the tests done in waves called for a still finer prismatic coefficient, but such wave tests were still in their infancy, and they should gain much more experience in the use of the new facilities before making any attempt at generalisation.

MR. W. HENSCHKE (Germany): The tank in Berlin-Potsdam has tested a number of fishing boat models in order to determine the influence of the prismatic coefficient on the resistance. The fishing boats had 78.5 ft. (24 m.) LOA, 67.3 ft. (20.5 m.) LBP, 21 ft. (6.4 m.) beam, 8.3 ft. (2.53 m.) draught and a displacement of 135 ton. This displacement-length coefficient $\Delta/(.1\ L)^3$ for the vessel was equal to 14.71. The parent model, M.91, fig. 606, had a prismatic coefficient of .612 and the four models in fig. 608, 609, 610 and 611 were designed so that length, beam, draught and LCB were kept the same, whilst the midship section was made fuller. In this way the following models resulted:

Model No.	φ	β	δ	*Fig.*
91	0.612	0.655	0.401	606–607
92	0.584	0.682	0.398	608
97	0.560	0.711	0.398	609
119	0.539	0.739	0.398	610
120	0.496	0.803	0.398	611

Fig. 612 to 614 give the results and the minimum EHP for each speed is joined up by a curve, thus giving the optimum prismatic. It is to be noted that the position of this curve is the same for all three displacements.

A study of these figures shows that the curve has about the

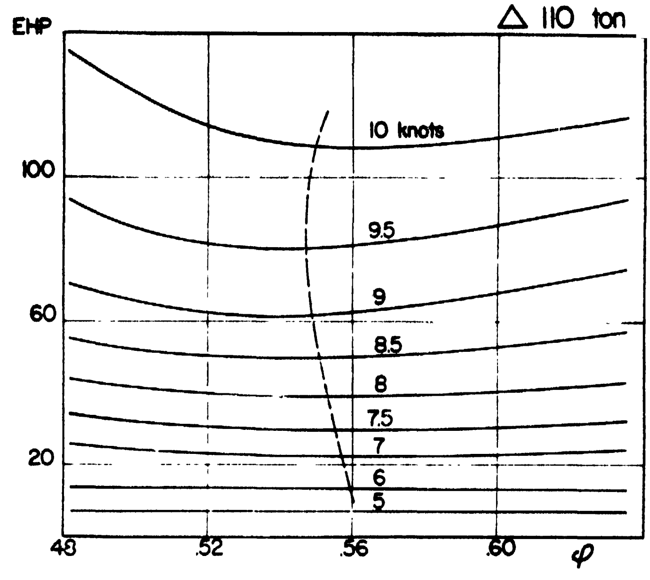


Fig. 612. Influence of prismatic coefficient on resistance—light condition

same tendency as that shown in fig. 457 of Traung's paper. For a displacement of 135 ton it is possible to determine from fig. 613 that the resistance increase in relation to the prismatic coefficient of .55 is:

V (knots)	φ = 0.50	φ = 0.62
7	10.2 per cent	6.1 per cent.
8	9.7 ,, ,,	11.4 ,, ,,
9	7.1 ,, ,,	14.2 ,, ,,
10	17.1 ,, ,,	5.9 ,, ,,

The optimum prismatic coefficient in this case seems to be between .55 and .56 and the results correspond very well with Traung's investigations if compared at the same relative speeds. Mr. Henschke did not, however, want to comment upon the influence of the prismatic coefficient upon the behaviour in the seaway, as his model tests in waves were only due to start.

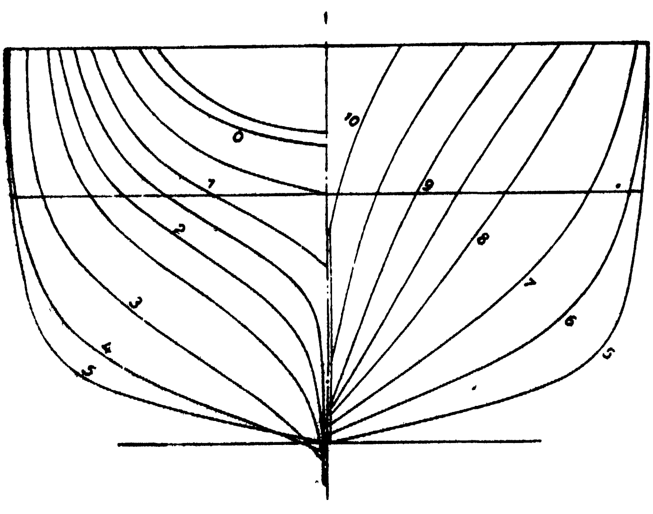


Fig. 611. 78.5 ft. (24 m.) German steel fishing boat model, φ = .496

PROF. E. V. LEWIS (U.S.A.): Traung's paper assembled a considerable amount of valuable evidence from both published papers and new FAO-sponsored model tests on the effect of prismatic coefficient on resistance, propulsion and sea behaviour of trawlers. His comments were confined to the FAO model tests in waves.

The final conclusion stated: "A prismatic coefficient of .525 seems to be the best in waves." He believed that this statement required some qualification, except from the point of view of power requirements. Perhaps the comparative performance of the four models in waves can be clarified by replotting the data in table 111 directly on a basis of speed instead of on tuning factor. Fig. 615 shows that the peaks of pitch amplitude occur at higher speeds as fullness increases. Although the tests were not made to low enough speeds to show the peaks for the 0.525 model the difference in heights of the peaks is not great. It seems apparent from this form of plotting that the most significant difference among the models is the speed at which the peaks occur. This in turn depends mainly on the natural pitching periods. Similarly, the most

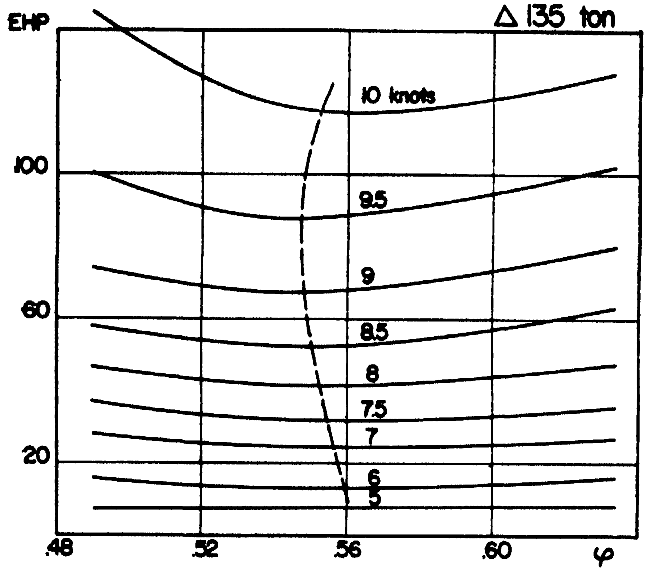


Fig. 613. Influence of prismatic coefficient on resistance—average load

significant difference in bow accelerations is the location rather than the height of the peaks (fig. 468).

What then is the significance of the location of these peaks? In irregular storm seas if there are no important wave components present longer than 150 ft. or 46 m. (1.75 L), the finest ship should be able to proceed comfortably in a *supercritical* condition at around 6 knots, whereas the other ships would pitch violently at this speed. The fuller craft might become comfortable at 8 to 10 knots, if such a high speed could be attained. On the other hand, if there are important wave components present 200 to 300 ft. (61 to 91 m.) in length, all of the craft would probably be subject to violent motions.

To confirm this it would be desirable to include tests in waves of 200 ft. or 61 m. (2¼ L) which would give synchronism at the top speed of 8 to 10 knots. (The recommended wavelengths were thus too limited in scope). In such waves, speed reduction would be necessary, and the advantage would shift to the 0.675 model which would be able to operate at a higher *subcritical* speed.

From the above, it is apparent that the question of relative superiority of the different hull forms depends mainly on the

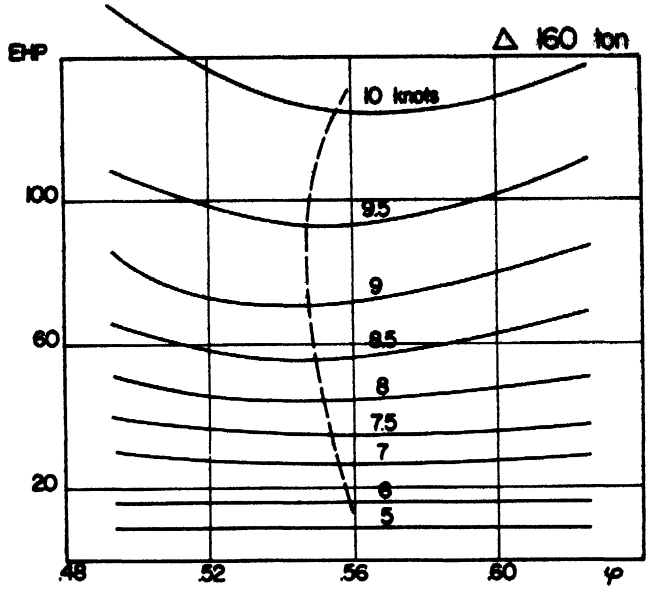


Fig. 614. Influence of prismatic coefficient on resistance—full load

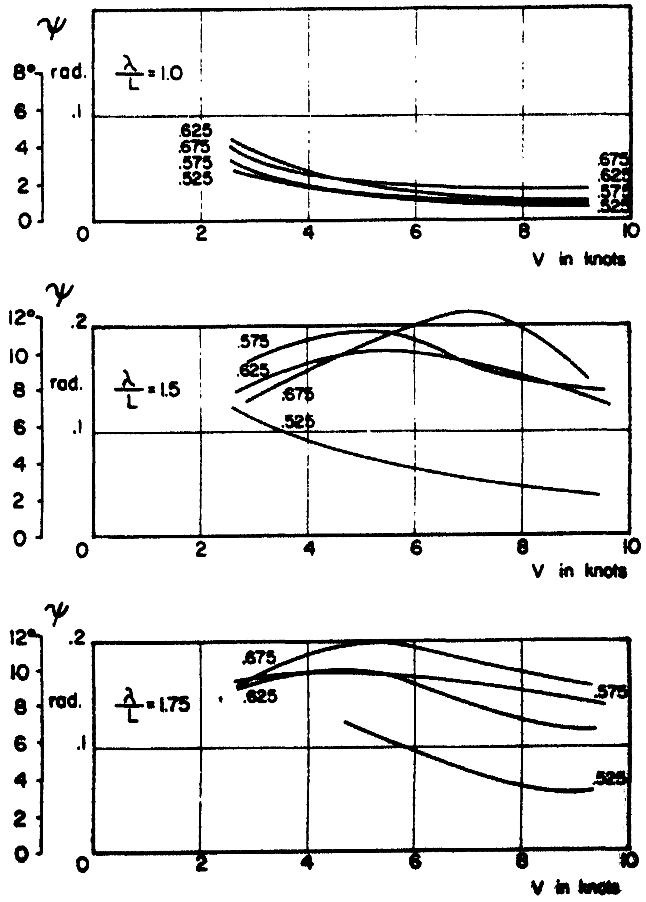


Fig. 615. Effect of prismatic coefficient on pitching angle

nature of the seas actually encountered. If wave components in the irregular seas are seldom larger than 150 ft. (46 m.), comfortable supercritical operation might be possible with the finest hull. If longer components are often present, the fullest ship (or a compromise) would probably be preferable in order to obtain better behaviour at low speed or hove to. One would expect the latter condition to be typical when the sea is rough with important long wave components present, except for the case of a very light sea or a very short fetch. Hence, Professor Lewis was doubtful that trawlers can operate in the supercritical condition in really rough seas.

On the other hand, Möckel stated in his paper that, "at Beaufort 6, trawlers in the northern part of the North Sea travel at a wave-length/ship-length ratio of from 0.9 to 1.1." He is speaking of trawlers of about 175 ft. (53 m.) length, and it certainly does appear that supercritical operation would be possible for these larger vessels in such short seas.

Because of the importance of the speed at which motion peaks occur and hence in the natural pitching period, the ballasting of the models is of considerable importance. Although the value of 0.3 L for radius of gyration may be somewhat high, it is believed that Traung was correct in assuming the same value for all models. To have worked to the same m-values would have vitiated the entire comparison, since the most important hydrodynamic factors affecting the comparative behaviour of the models in waves are those which determine their natural pitching periods.

It would be of interest to know the method used for determining the periods of pitch of the models. The value of 4.23 sec. for the fullest model does not follow the general trend and should perhaps be rechecked.

The FAO experiments in Japan

Mr. Y. Otsu (Japan): Model tests of fishing boats have been carried out in several Japanese commercial tanks. In addition, the Government Fisheries Agency have their own fishing boat laboratory with departments for ships, engines, echo sounders and structural tests of ships. The Ships Department uses the small tank described by Traung, and this tank is also used for experiments with fishing gear. In addition to the individual model tests, the Department has carried out several tests with model families. The results have been published in the Japanese fisheries literature, as well as in FAO's *Fishing Boat Tank Tests*, and some are also given in Mr. Otsu's paper, p. 348.

The prismatic coefficient has not been considered very much in the design of fishing vessels in Japan in the past, despite the fact that Takagi (1950) used it as a parameter in his fishing boat standard series. Owners and builders usually think in terms of block coefficient, probably because Japanese fishing boats have a very large midship section and there is little possibility of changing the midship section coefficient. However, in the design of larger Japanese vessels, such as round-bottomed tuna longliners and 100 GT pair trawlers, variations in the prismatic coefficients are possible. The prismatic coefficient is naturally a more refined way of defining longitudinal distribution of the displacement than the block coefficient, if one has a certain freedom in the shape of the midship section.

When therefore FAO proposed the tests described by Traung, staff of the Fishing Boat Laboratory devoted much of their time to refining the wave test technique. However the tank was rather small for such experiments, and some of the resulting test figures might include measurement errors. Traung had rightly said that the object was to find a qualitative rather than a quantitative comparison, or, in other words, establish a trend of development which could be utilized for further work and Mr. Otsu was sure that they were adequate for this. He noted from the discussion that contributors had kept closely to the issue, i.e. whether one could with advantage depart from the high prismatic coefficients used in many countries, Japan included, and had refrained from going into details of the test technique. The tests certainly showed that a reduction would result in advantage as regards fuel consumption, even if it brought about no definite improvement in the behaviour of the low prismatic models. Fuel consumption

Table 144

Calculation of modified SHP according to Otsu

φ	V	*EHP*	*SHP*	*PC*	η	η_{rest}	*Calculated* *PC*c	*Calculated* *SHP*c	*Per cent. of .575*
.525	3	2.8	11.7	.239	.434	.550	.239	11.7	83
	5	12.5	26.2	.476	.581	.819	.476	26.2	85
	7	36.8	62.8	.586	.611	.959	.586	62.8	92
	8	60.0	101.5	.596	.607	.975	.592	101.5	99
	9	96.0	167.5	.573	.598	.957	.573	167.5	105
.575	3	2.6	11.2	.232	.547	.424	.184	14.1	100
	5	12.8	30.0	.427	.599	.713	.414	30.9	100
	7	38.8	70.0	.554	.597	.928	.567	68.4	100
	8	61.9	101.6	.584	.588	.995	.605	102.5	100
	9	91.2	166.0	.550	.578	.952	.570	160.0	100
.625	3	3.0	12.8	.234	.506	.399	.173	17.3	123
	5	13.3	38.0	.350	.617	.567	.330	40.3	130
	7	42.6	93.3	.467	.608	.572	.460	92.5	135
	8	70.0	143.0	.489	.593	.825	.501	140.0	136.5
	9	111.5	238.0	.469	.571	.821	.491	227.0	142
.675	3	4.1	17.1	.240	.481	.499	.217	18.9	124
	5	15.3	48.0	.319	.545	.585	.340	45.0	146
	7	46.3	136.8	.341	.631	.641	.392	118.2	173
	8	75.8	232.0	.327	.507	.645	.392	193.5	189
	9	120.5	369.5	.326	.474	.687	.411	293.0	183

costs were, however, an important item and, as long as the result was not adverse behaviour, these possibilities should be exploited.

Mr. Otsu then commented upon a few points in Traung's interpretation of the test reports from his tank.

As regards the resistance tests, Traung found that the optimum prismatic coefficient for the four models was about .575, and he stated that this was higher than that shown by Taylor's and Takagi's standard series. This was also the case in the discussion presented by Henschke, whose optimum was between .55 and .56. Traung made his lower prismatic models wider and deeper and kept the midship section coefficient the same to keep the displacement the same, and he felt that the reason the optimum was higher than normal was because the small prismatic models were "beamier". Mr. Otsu thought that this was somewhat of a generalization and that the changes in draught and the angle of entrance were also responsible.

When discussing the self-propulsion tests, Traung said that the differences in propulsive coefficient might be due to scale effect. However, as there was only one propeller, there was no change in scale and the propeller would thus have the same scale effect in all the tests.

It was rather unfortunate that only one propeller was used in the tests with the four models, as it was no doubt more efficient in certain tests. Traung's effort at a more "honest" comparison was interesting because he had tried to take into account the full ends of the lower waterlines of the high prismatic models resulting from the Lackenby variation. Another way of making such a comparison would be to calculate the "rest efficiency" for each individual model and speed, and assume that different propellers could be designed for the individual models having the same open-water efficiency as the present propeller had for model .525. The modified propulsive efficiency would then be the rest efficiency for the individual model by the open water efficiency for model .525. The calculations are shown in table 144 and the results are plotted in fig. 616. This comparison shows roughly the same tendency as in Traung's fig. 461, the high prismatic models requiring considerably more power in high speeds.

It is difficult to compare model tests in waves. Mr. Otsu did not agree with Traung that one could use the modified SHP

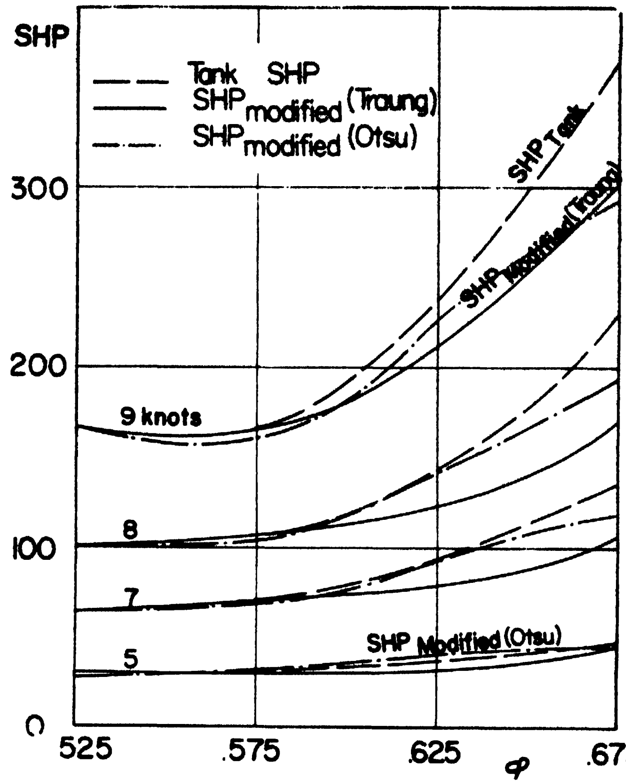


Fig. 616. Comparison of SHP derived from test with four models and one propeller, and modified SHP assuming individual propellers

for the high prismatic models in the wave tests, as no EHP had been obtained in waves. He had plotted the relation between the wave SHP (tank) and the calm water EHP in fig. 617, and had found that for the high speeds the SHP increase was proportional, so that the low prismatic models from the powering point of view were still of advantage as shown in Traung's fig. 464.

Mr. Otsu agreed with Lewis that it might be wise to plot the results from pitch and heave over speed instead of over

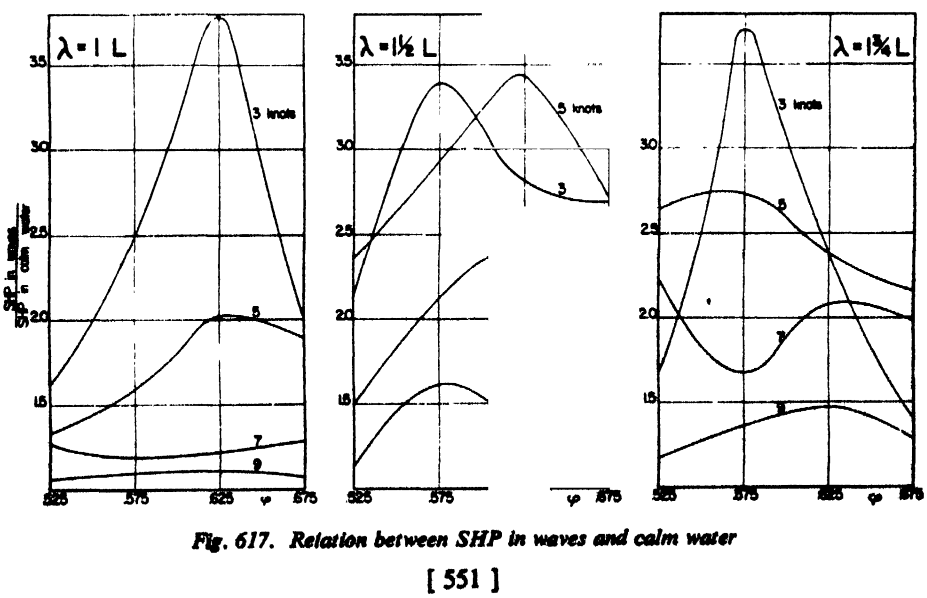


Fig. 617. Relation between SHP in waves and calm water

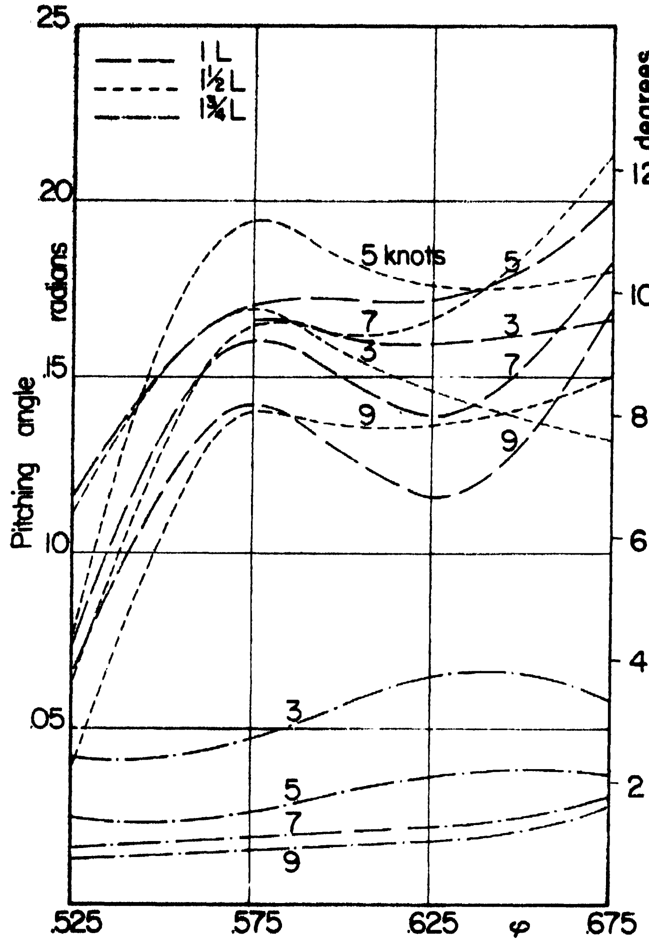


Fig. 618. Pitching angles of the four FAO models with different prismatic coefficients

tuning factor. Even if the natural period of pitch could be determined exactly, the period of encounter was more difficult to determine, and great errors could be introduced, as shown by fig. 467, where the peaks did not always correspond with tuning factor 1. In fig. 618 the pitching angle is plotted over the prismatic coefficients showing the variations for individual speeds. This is another alternative to Lewis' plotting in fig. 615. Fig. 618 confirms Traung's statement that there is little difference between the .575 and .625 models, and that they have some 10 per cent. less pitching angle than the .675 model. However, this plot indicates that model .525 not only has a "somewhat lower" pitching angle, as stated by Traung, but considerably lower angle of pitch.

Fig. 619 shows a similar plot for the bow acceleration, and this gives a rather confused picture. The .575 model has, with the exception of the 7 and 9 knots speed in the 1½ wave-length, the smallest accelerations. On the other hand, it seems that the .625 model has on an average the lowest bow acceleration. Again, the peak responses of the .525 model are rather high, possibly indicating that the low pitching angles of this model were caused by the high damping of its flaring bows, resulting in considerable acceleration, even though these accelerations might have been of short duration and would not necessarily be of great discomfort.

Fig. 620 shows a similar plot for the heave, and here again Traung's remark that .525 "being slightly the best" might be an under-statement. In this plot the .525 model has considerably less heave, and this seems to confirm Weinblum's statement that increased beam results in increased damping. Actually, the Allan (1951) low prismatic model with the smallest beam had greater heave than the other two (p. 430).

Answering Lewis's question about the method for determining the natural period of pitch, Mr. Otsu said that the models, each with a bowsprit, were placed longitudinally in the tank in calm water. A light beam was thrown athwartships through the bowsprit and was picked up by a photocell connected to an oscillograph. Pitching was started manually, and as the bowsprit cut the light beam, the pitch was recorded on the oscillograph. The periods were determined several times for each model and as they agreed well, it was difficult to explain why the period for the fullest model did not follow the general trend. A check of the period for the .675 model gave 4.21 sec., instead of 4.23 sec. which indicated a weight adjustment error of 2.5 per cent.

Mr. Otsu felt that tests with fishing boat models in a wave-length equal to ship-length were of minor importance, although

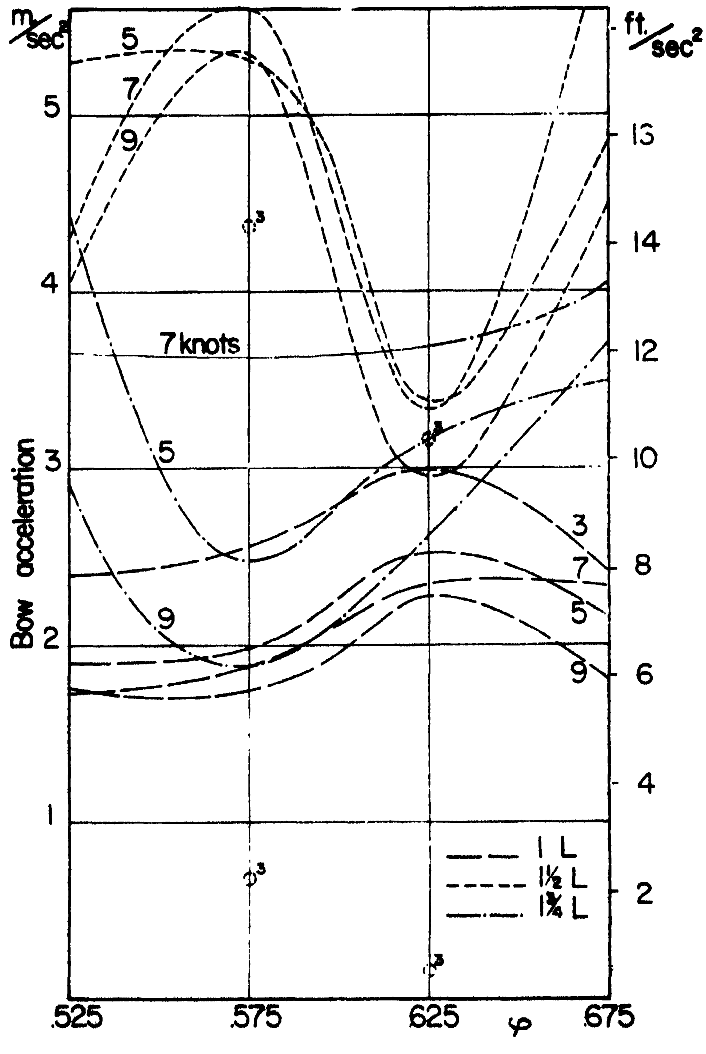


Fig. 619. Bow accelerations of models with various prismatic coefficients

they had a certain academic interest when comparing fishing boat behaviour with the large ships which were often tested in this wave-length, which for them was important. He felt that in comparing the models one should concentrate on the results from 1¼ and 1¾ wave-lengths, and he agreed with Lewis that additional tests in a wave-length of 2¼ L were needed. As the tendency now was for the magnitude of the accelerations to increase with increased wave-length, and as it was not certain that one would obtain a maximum, even with a 2¼ wave-length, he would even suggest tests also in a still longer wave-length, say 3L.

Any vessel must naturally be designed to avoid the predominant wave-length where it will operate. This can be done by changing length, speed, or perhaps prismatic coefficient. Unfortunately, there is today little knowledge of the predominant wave-length for the fishing grounds of the world; but with the advance of oceanography and the use of electronic computers, such predominant wave-lengths might soon be determined. The establishment of new international freeboard regulations will no doubt also bring clarification

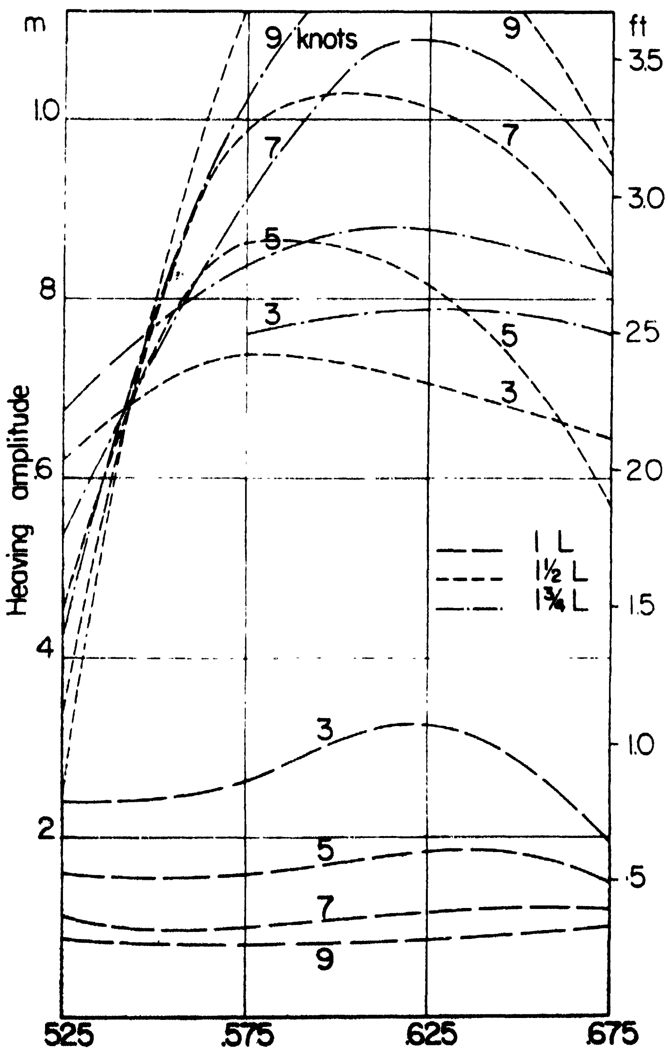


Fig. 620. Heaving amplitudes of low and high prismatic models indicating that the low prismatic models heave less

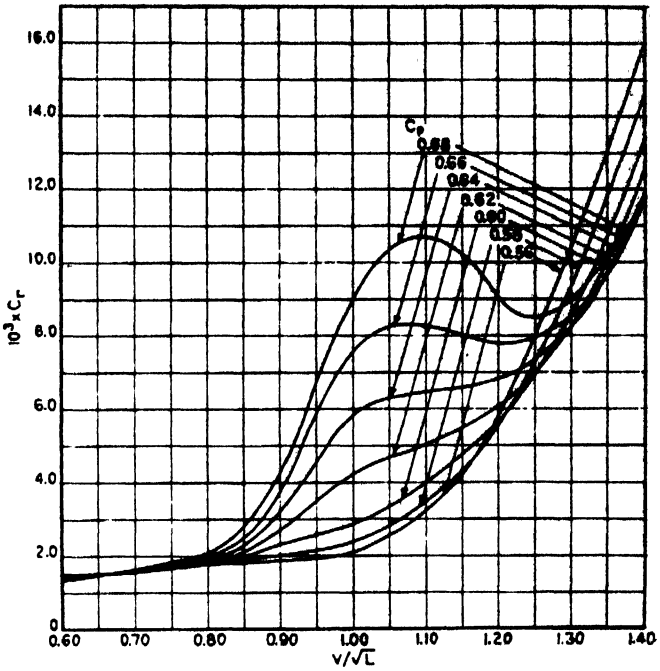


Fig. 621. Relation between residual resistance coefficient and Froude numbers for tugs of various prismatic coefficients and with a $L/\nabla^{1/3}=4.5$ (Roach, 1956)

about wave conditions. It is important to study now the responses of small craft so that when the wave-lengths have been determined it is at once possible to design the best ship.

Mr. Otsu felt that the order of priority of any further tests should be as follows:

- Resistance tests in waves, to establish the EHP in order to study the influence of the propulsive coefficient in waves
- Tests in a wave-length of 2¼ ship's length, or possible also in 3 ship's length
- Tests with a loaded displacement and bow trim, as the fish hold will be forward of midships, to find out the influence of the larger bow trim of the small prismatic models on behaviour and resistance, although it is realized that the freeboard forward can be corrected at the design stage to avoid shipping of water
- Manufacture of a model with still lower prismatic, possibly .475, to cover a longer range and make the fairing of individual plots more accurate
- Tests of at least the .525, .575 and .625 models in a higher wave height to study the influence of the differences in flare of the bow
- Tests with some of the models with transom sterns and bulbous bows

Such additional tests in regular waves, rather than a repeat of the present tests in irregular waves or oblique seas, would be of even more immediate interest to naval architects endeavouring to follow FAO's aim in producing seakindlier and more economical fishing vessels.

Mr. N. V. Johnsson (Sweden) felt that Traung had misunderstood his statement about speed and seaworthiness. Mr. Johnsson had said in his contribution that the prismatic coefficient should be less than 0.67 for the speed-length ratio 1.2. He would suggest 0.62, which Traung might find agreeable if he studied fig. 621 (Roach, 1954; Traung, 1955; and

Johnsson, 1958), and if the vessel's relative calm water speed were assumed as being between 1.2 and 1.3, say 1.25.

In rough weather all available power can be used up to a certain windforce, the speed decreasing with increasing seas. the speed loss is *due to increase in resistance*. At a certain condition of weather (about 6 Beaufort in the North Atlantic for ordinary merchant vessels), the movements of the ship become violent, so the skipper must cut the speed, and a decrease of power output will be necessary.

The reduction of power depends upon the type of waves and also upon the type of ship. The fishing vessels referred to by Traung were probably in a sea state in relation to the ship type giving violent motions. Mr. Johnsson did not, of course, envisage a trawler steaming, with full power, head on into waves of 6 to 7 Beaufort! But he knew that Swedish fishermen used full engine output whenever they could. Recently he had met with fishermen who wanted to build a vessel of his design only if it could make 12 knots, that is a speed-length ratio of 1.32. He was therefore convinced that the fishermen wanted speed, if they could have it without sacrificing stability and seaworthiness.

Mr. Johnsson then commented on Traung's request for clarification of his statement that a prismatic coefficient of 0.67 gives better seaworthiness. It is well-known that a fuller waterline gives more damping of the motions than a finer one. This is confirmed theoretically by Weinblum and St. Denis (1950). A fuller waterline will however result in a higher prismatic coefficient, unless one gives the hull an almost unrestricted amount of V-form. To a certain extent a V-form would improve the damping qualities, but it will increase the resistance, as shown by the fact that different degrees of U-form give the least resistance. This is also supported by calculations on the wave-making resistance of ships (Weinblum, 1957).

For these reasons good performance in a seaway means, indirectly, a fuller ship. The speed loss, due to increase in resistance, is only of importance up to a certain wind force. Then the movements govern the speed! This might not be reproduced in model tests where the movements are not under full observation. As fishing vessels are relatively small, Mr. Johnsson believed they mostly met sea conditions where the movements are the cause of speed reduction.

In this connection, he issued a warning against model tests in regular waves which, although giving answers to many questions, might also lead to the wrong conclusions, as the basic motion in regular waves differed from that in irregular waves.

Much has been written in the past few years about ship movements. A statistical model of ship behaviour was made by Pierson and St. Denis (1953), who assumed linear relation between ship motions and wave motions. With this assumption, they and many others believed much in model tests in regular waves. Through carrying out tests in regular waves of different frequencies, they thought it possible to produce a response spectrum for the ship in irregular waves.

However, Mr. Johnsson was not sure that the assumption of linear superposition would be valid in that case. If one solves the differential equation for the damped oscillatory motion in waves for a ship with just one degree of freedom (only pitching or rolling or heaving) the solution would consist of two harmonic terms. The first would however be fitted with a factor e^{-ct} where c is a factor depending on the damping characteristic of the ship and t is time. The equation could be written simply as: $\psi = A + e^{-ct}.B$; ψ being the pitch angle and A the motion forced upon the ship by the waves. B would be the ship's own movements, but as time goes *in a state of motion with the same period*, the second term $e^{-ct}.B$ fades, because of the exponential expression. After some waves coming in the train of regular waves, only the first term would be left and the second would be damped out, i.e. $\psi = A$.

But in irregular waves the second term would remain as *the state of motion with unchanged period does not usually continue for more than half a period*. This means that every motion would have a "residual motion" from the nearest preceding motion.

This is a very important statement when one studies the motions of fishing vessels. This second term will show when and why vessels plunge head on in seas, which will not be apparent when using the linear superposition theory.

It is necessary to be very careful when making model tests and statements based upon them. Mr. Johnsson believed most in tests in irregular waves, because motions in regular and irregular waves showed such physical differences.

Tests in regular or irregular waves

PROF. E. V. LEWIS (U.S.A.): Johnsson's remarks are interesting and he was pleased to offer a few comments. Irregular waves can be of great value for determining the comparative behaviour of different hull forms by model tests. When motions are moderate, it seems that linear superposition work very well for pitching and heaving and the transient effects Johnsson describes are properly allowed for in superposition. However, when motions are violent, with bow emergence and wet decks—as is common with fishing vessels—there is no doubt that superposition breaks down. It is then that direct comparative tests of alternative hulls in irregular tank waves are of great value. Such tests have been carried out for some time at the Davidson Laboratory (as described in a paper "The Feasibility of Higher Sea Speeds" presented before the Metropolitan Section, SNAME, and to appear in its 1959 Transactions). The particular need at the present time is for more recorded data on ocean wave spectra in order that the model irregular seas will be realistic for the ships under study. Meanwhile, however, it seems we know enough about the sea to obtain much more meaningful results than can be obtained by regular wave tests alone.

MR. Y. OTSU (Japan): One might easily get the impression from Johnsson's statement that he did not at all accept the results of model tests in regular waves, but Mr. Otsu did not think that he implied this.

It was really an approximation, confirmed by many, including Lewis, that the ship's responses in a few different regular waves was equal to a ship's response in an irregular wave. Accordingly, phenomena which did not occur in regular waves might happen in irregular waves, if details were considered.

It is well known that the model is hardly upset in regular waves even if synchronism of rolling occurs, and furthermore shipping water rarely happens in regular waves. However, in irregular waves the model is often seen to be upset, which might also happen in the case of pitching motion.

The model experiments are to give important data to the designers, and it should not be necessary to introduce all detailed factors of the motions of the real ship into the model. It is however essential to find the trend of each main factor. As mentioned, shipping water does not happen in regular waves, but one can find symptoms of this even in a regular wave test.

It should not be necessary to depart from regular wave tests because of their weak points, but one must naturally be careful when judging the results. If one is too conscious of minor phenomena, one might make great mistakes. Mr. Otsu rather thought that it was enough to test models only in regular waves at present. From the academic point of view, Johnsson's desire for tests in irregular waves is quite correct.

The influence of Johnsson's second item is great in irregular waves, and it is, roughly speaking, caused by the difference of phase between the wave motion and ship motion. When the damping effect is considered one must, correctly speaking, think of all the preceding movements of the model, as it is not enough to think of the motion only at the instant of taking records. The phase difference between the model and wave can be of an infinite number of combinations, depending on when the wave starts, when the wave is stabilised, when the model carriage starts, and also on the amount of acceleration of the model carriage. It is quite impossible even in a very long tank to make waves which include all phenomena of the sea. Therefore, in such a short tank as the Japanese Fishing Boat Laboratory's, irregular wave tests would cause unnecessary confusion.

However, this does not mean that they do not care for irregular wave tests. There are still many opinions in Japan as to the best method for irregular wave tests, and Mr. Otsu did not think it was possible to reach any quick agreement on the method of such tests, as long as there is not yet any definite agreement even for the test methods in regular waves.

Mr. Otsu concluded that the relative trend obtained in regular waves was not opposed to those obtained in irregular wave tests.

MR. G. VOSSERS (Netherlands): Johnsson's view concerning the difference between regular and irregular waves is incorrect, since it can be shown (which is beyond the scope of this discussion) that the summation of the transient solutions, as given by the terms $e^{-ct}.B$ in his equation, is equivalent to the steady state transfer function, which is used for converting wave spectra into motion spectra. However, this applies only as far as the motions are linear with the wave height. Recent measurements indicate that this applies fairly well as long as wave height/length ratios do not exceed values of 1 : 30. From these tests it appears that the characteristic differences between the irregular and regular wave tests can be adequately described by the St. Denis-Pierson technique. For higher waves, some modifications occur, and other techniques have to be used for converting regular wave tests into irregular wave tests, but not a technique based on the criticisms of Johnsson.

GENERAL DESIGN

MR. J. TYRRELL (Ireland): Chapelle's approach to this subject is, he thought, the same as that of all designers and builders of the smaller fishing boats; that is, "from long study of successful design, and upon practical experience, but without the opportunity for measured model tests".

Sound development of design is possible, and is frequently achieved in large measure, when the designer is engaged on the continuous development of a type within a fairly restricted size range. Much can be done—and has been done—to improve hull form, particularly in the 50 to 70 ft. (15.3 to 21.7 m.) range, where the performance of successive boats can be closely studied and assessed. Unfortunately, there is sometimes a tendency, when a reasonably good craft has been produced, to regard this as "good enough", and to relax further investigation. Aiding this view is often the requirement for a number of standard vessels from a given design, which is quite legitimate from the economic standpoint.

As an addition to experience and observation as noted above, he had found the *Fishing Boat Tank Tests*, published by FAO, of much assistance in verifying personal observation, and in pointing out possible new approaches to the problems of hull shape.

Prismatic coefficient: The data available on this is of considerable value, but it must be interpreted in a practical manner. He fully agreed with Chapelle that there may be a considerable variation in resistance on a given prismatic. He was at present getting good results from a relatively high value.

Length-depth ratio: There is no doubt that this has great influence on the resistance as pointed out.

Midship section: In conjunction with a high prismatic value, the mid-section can be relatively easy at the bilges. This helps to reduce the angle of entrance, and helps to produce a more seakindly hull.

Position of propeller: He was not convinced that the propeller should be well under the boat; this position is likely to cause undue snubbing of the hull where approaching the sternpost.

Entrance angle: There should be no need to have pronounced shoulders following a relatively hollow entrance; this matter is closely tied up with the shape of forebody above the waterline.

Balance of fore and after body: This balance is essential to any successful vessel, and the balance must be maintained for almost the full freeboard height. Checks are most desirable for shift of LCB at increasing draughts, both in upright and heeled conditions. The more these shifts of LCB can be minimized, the better is the prospect of having a well-behaved vessel, with good steering qualities. particularly important in a following or quartering sea.

Diagonals: His experience was that a diagonal at 45 degrees, drawn from waterline level, is of the greatest assistance in helping to balance the underwater fore and aft bodies. It shows quickly any undue fulness or snubbing of the approach to sternpost.

Topsides: There does not appear to be any good reason for tumble-home in a fishing vessel. On the contrary, moderate flare provides useful reserve buoyancy, and provides a means by which the architect can minimize changes in trim at increasing draughts.

Shape of stern: There are many practical points in favour of transom sterns on fishing vessels. Such sterns can be designed to preserve balance in no way inferior to that of cruiser types.

MR. J. T. TOTHILL (Canada): Bulbous bows have received a great deal of attention, and rightly so because they reduce the resistance and improve the propulsion, when running free, in the speed range now used in trawlers (Doust, Henschke, Johnsson, and Tothill). It is significant that the finer the form is in the first place, the less is the improvement due to a bulb. The main effect of a bulb is to make the load waterline entrance finer and the bow wave smaller, and it is to be expected that with a sufficiently fine waterline a bulb might be of no advantage at all. However, in the light of Doust's pitching tests, in which a bulb of only 5 per cent. area reduced the maximum angle of pitch by 36 per cent., he thought that bulbous bows have a far more important function than to save a few per cent. on power—and that is to reduce the motions in the forecastle to a most significant degree. Taken with Möckel's measurements of up to 0.9 g in the forecastle, this discovery may be regarded as a major achievement and there is no doubt that a good big bulb will be a normal feature of fishing vessels in the years to come.

Nozzles have been discussed in two papers. Van Manen, Vossers, and Rijken compare a normal propeller and a nozzle propeller in still water and in waves, with results that are mainly unfavourable to the nozzle. Had they adopted a steerable nozzle in place of the rudder and moved the propeller aft, as in his model, he thought they would have found a substantial improvement in the performance of the nozzle propeller. The "hood" extending forward from the top of their nozzle must cause unnecessary resistance, especially when pitching, and he found it hard to see any merit in this feature. When considering whether or not to adopt a nozzle, the choice should evidently lie between a conventional propeller ahead of the rudder, and a steerable nozzle where the propeller is farther aft, higher up, and can be made larger. His work and van Manen's valuable nozzle experiments show that in many practical cases a steerable nozzle can improve the trawling efficiency without loss in free-running efficiency, and he believed that steerable nozzles will become commonplace on trawlers in the future.

Rough water tests and measurements have deservedly been given much attention, and the standard of the papers presented is very high. There are so many different aspects of rough water work that it is necessary to define some objectives before applying any results to the design of an actual boat. To his mind the objectives to be achieved at sea must be considered in the following order:

- Safety of the ship
- Comfort of the crew
- Technical efficiency

For safety of the ship the critical situations include icing, steering in quartering seas, and heavy rolling.

For comfort of the crew the critical situations include synchronous pitching, heavy rolling, and to a minor extent heaving.

For technical efficiency the critical situations appear to be steaming and trawling in head seas with strong winds.

Progress has been made in most of the above categories. Icing danger can be delayed by cleaning up the rig (Lackenby) and could be delayed further by incorporating a tank of fuel or fresh water in the upper superstructure which can be drained when danger threatens. Steering in quartering seas can now be investigated in model tests (Vossers), and heavy rolling is alleviated by bilge keels (Vossers), steadying sails and actuated fins, plus the use of moderate GM values (Möckel).

Synchronous pitching does occur at sea, in his experience, even in a confused sea where it happens irregularly every few minutes whenever a component of the wave system has the right period. Attempts to alleviate the pitching have usually been centred upon the fullness or fineness of the form (Traung) or the choice of section shape and flare forward (Taniguchi). Of these the fineness of the form appears to be the more effective and for a long time the adage that "the best form in still water is the best form in head seas" was generally found to be true, not only as regards resistance and propulsion but also as regards pitching. Now we have strong evidence (Traung) that the best form for propulsion in head seas is finer still, although the least pitching and accelerations occur at a prismatic coefficient which upholds the old adage. These results are far outweighed, however, by the large effect of a bulbous bow (Doust) in the region of synchronous pitching. In a film from Wageningen's oblique sea tank, a model in a confused sea was seen to build up a large pitch angle over several cycles, and it was apparent that a little extra damping at the bow would have ironed this out. What is needed is a bulb or bow planes beneath the water surface rather than reserve buoyancy above.

Technical efficiency is important in good or average weather at sea, but in severe weather it becomes even more important if it can enable a vessel to continue steaming and trawling when others are forced to heave-to. Progress in this direction is related to crew comfort on the one hand, and to the reserve of power available on the other. In Möckel's vessels it was the reserve of torque that was critical, but in his own model (which is relatively higher powered for trawling) a 33 per cent. reserve of power and torque is released as necessary by the governor when steaming against wind and sea.

The pull and speed of nets is of great importance in the total design of a trawler. The results of Dickson and Möckel are most welcome, but a dimensioned description of the nets is also necessary for design purposes. He was under the impression that the hydrodynamic aspects of trawls are beginning to receive more attention in several countries, and would not be surprised to see revolutionary developments.

Bulb rudders for small craft

MR. W. P. MILLER (U.K.) was much concerned with the economic operation of the small wooden fishing boats. In reading the papers presented, he regretted that no reference had been made to the fitting of a bulb type rudder. From his experience, this very cheap form of improvement was very much worthwhile. On a 53 ft. (16.2 m.) 25 ton seine netter fitted with 114 h.p. engine, experiment gave an increase in speed of .12 knots and the turning circle was reduced by 20 per cent. Another experiment on the same boat was the fitting of a fairing piece to the stern post. This gave a speed increase of .45 knots, along with a big decrease in propeller noise. The discusser's yard was an ordinary boatbuilding yard without the facilities for carrying out extensive experiments, but he thought it would be to the general advantage of the small fishermen if such economical fittings could be further investigated.

Transom sterns

CAPT. P. F. EDGE (U.K.): With regard to transom sterns, the experience of *Kelvin*, sistership of several oil-fired vessels of the same size and operating under identical conditions, was that this transom stern vessel gave about .25 knots more speed, with .2 ton less fuel consumption. She was also felt to show better movements when steaming free in a heavy following sea.

DR. R. G. INKSTER (U.K.): From the viewpoint of a yachtsman interested in small cruisers liable to be caught occasionally in what is, for the size of the boat, very rough weather, some of the papers have been of very great interest. The cruising yachtsman and the fisherman have two things in common, the need for reasonable comfort and the necessity of getting there and back in safety. It follows, then, that the boat must be as seakindly as possible and completely seaworthy. These two requirements can scarcely be separated for, though no small boat can be called comfortable in a seaway, it is obvious that, the more seakindly she is, the less tiring will be the work of her crew and risks of accident will be correspondingly reduced.

He would like to refer particularly to two points. First, Chapelle stated, without giving reasons, that "there is no advantage in tumble-home in small craft". If the boat is one that may heel considerably, he could not agree. His own boat has a high freeboard and about 7 in. (178 mm.) of tumble-home on each side in a beam of 7 ft. 9 in. (2.36 m.). When she heels over to bring the sea well above what would be a normal sheer line, a wave will meet the tumble-home as an almost vertical bulwark and is easily reflected. A vertical or flared bulwark, when so heeled, tends to scoop in water. This argument does not, of course, apply in the same way to a flared bow or a vertical transom but, amidships, even the psychological effect of the tumble-home may be worth it.

The second and closely related point is that of freeboard. A low freeboard amidships may be necessary in a working boat designed to do her job well but it can be overdone and is unnecessarily common.

The old Shetland "haaf" boats, the sixareens, had a freeboard of less than 2 ft. (0.6 m.)—dictated by the need for oars—to a 30 ft. (9.14 m.) length. They were light, fast and excellent seaboats but required skill and constant vigilance to get them home in very heavy weather. A big storm such as that of 1881 could be disastrous and any boat which requires specially skilled handling to counteract such a deficiency in freeboard becomes a danger the moment such skill is lacking, whether from lack of concentration, accident or for any other reason. Green water coming over the gunwale of a hard-pressed open boat with insufficient freeboard can be very dangerous.

The consequences of insufficient freeboard (in this case in the after sections) are well shown in Paulling's paper, where he refers to the loss, though not, Dr. Inkster supposed, all from this cause, of 75 vessels in three years.

The greater one's experience of boats, the less is one inclined to be dogmatic but a relatively high freeboard would seem to be sufficiently desirable to warrant emphasis even though many—if not most—modern boats are quite well designed in this respect. Modern yachts can possess a very high freeboard indeed, in conjunction with a reverse sheer, and the trend is such that "Argus" can truly write in *Yachting Monthly* (vol. 106, p. 103) that "the importance of adequate freeboard in the hard-sailed yacht of today has become well known". Perhaps the development of stern trawling will lead to an increase in freeboard in trawlers.

Kent (1958, pp. 166 et seq.) gives a clear account of the effects of the type of bow-wave on the chances of shipping sea water and links this with the need for good freeboard at appropriate places. But, while the shape of the bow and the consequent bow-wave have as much importance as freeboard in obtaining a dry ship, this is something which can hardly be worked out except by the designer to suit each individual case.

For small boats of shallow draught a nearly vertical stem, convex bow lines and V-shaped sections forward would seem to be increasingly acceptable but enlightenment on the question of upright or raked stems would be appreciated. Chapelle refers to "a straight nearly upright stem with a good depth of forefoot and a fine entrance" as producing a dry bow. Fine sea-boats such as the old Shetland sixareens, which could ill afford to take in water, had a very pronounced rake to the stem. Is this upright stem necessary in the combination mentioned by Chapelle or is the rake in the sixareens counteracted by other features? And again, Kent (1958, p. 272) writes "to keep large quantities of spray from wetting the open decks forward . . . for low speed ships this can be done with convex bow load waterlines, V-shaped transverse sections, the stem raked well forward and a quick rise of floor all along the entrance".

Dr. Inkster had, in fact, abandoned two deeply rooted prejudices favouring a raked stem and a pointed stern for small boats. A third, however, still remains in the form of a strong liking for a full displacement forward with a maximum beam situated about one-third of the overall length from the stem. This may have been perpetuated by being, on one occasion, in a boat when she was "sailed under" by an over-enthusiastic racing helmsman. It would be nice to know whether this one longstanding bias can usefully be retained.

MR. E. MCGRUER (U.K.): Chapelle's courageous paper is timely, for it has been proved that the "sheers and beuls" method of getting out the "lines" of a boat is simple and quick. This method is based on the projection of the lips of the strakes of the clinker construction method in elevation and plan.

The Dixon Kemp method, as Chapelle names the "grid" of level lines, buttocks and diagonals, is wasteful of time in the sense that the boatbuilder does not use these planes of reference in setting-up the skeleton frames, though he sometimes uses a horning diagonal. He uses ribbands, and the sheets and beuls method gives him the location of his constructional ribbands.

Chapelle's hypotheses and opinions are based on the appearance or shape of the edges of planes of reference not usually corresponding with the paths of flow of the water at the surface of the hull, though in the case of fast boats the buttock lines may well represent these, as Chapelle points out, for in boats with a flat run the fluid pressure would normally follow the line of a flat buttock parallel with the middle line.

The pressure of water on the hull is normal to the surface, therefore a *sheered* diagonal ought to be a better plane of reference. A straight ribband offered against the midships frames at or below the turn of the bilge and allowed to make its own track without restraint is an ideal fairing device. It is the boatbuilders ribband, and this is to be preferred to level lines and buttocks and bow lines; or even to plane diagonals.

The edge of a parabolic sheer seen in elevation is also the lip or beul (gaelic for lip) when seen in plan, and is seen in end elevation as a *sheered* ribband or *sheered* diagonal. This is a true line of reference controlled directly by the shape of the master section and its inclination and fore and aft position. If then one makes the ribband lines parabolas in the "plane" of a parabolic sheer, one is bound to produce a "fair" hull.

If the parabola is too fine—as, of course, it must be for a fishing boat of considerable displacement—then is decided the deck edge or mouth line required and in direct progression this full mouth line is reduced to a parabola at the keel.

The design of an 80 ft. (24.4 m.) fishing boat, fig. 622, is produced by the sheers and beuls method. This boat will be used for "lining" mainly and will operate from Aberdeen from September 1959.

Economic factors

MR. J. GARDNER (U.S.A.): The biggest barrier to break through in hull-form design of smaller fishing craft is possibly the economic one. Research is retarded more by lack of funds and facilities than by partisan adherence to any limited approach, mathematical or otherwise.

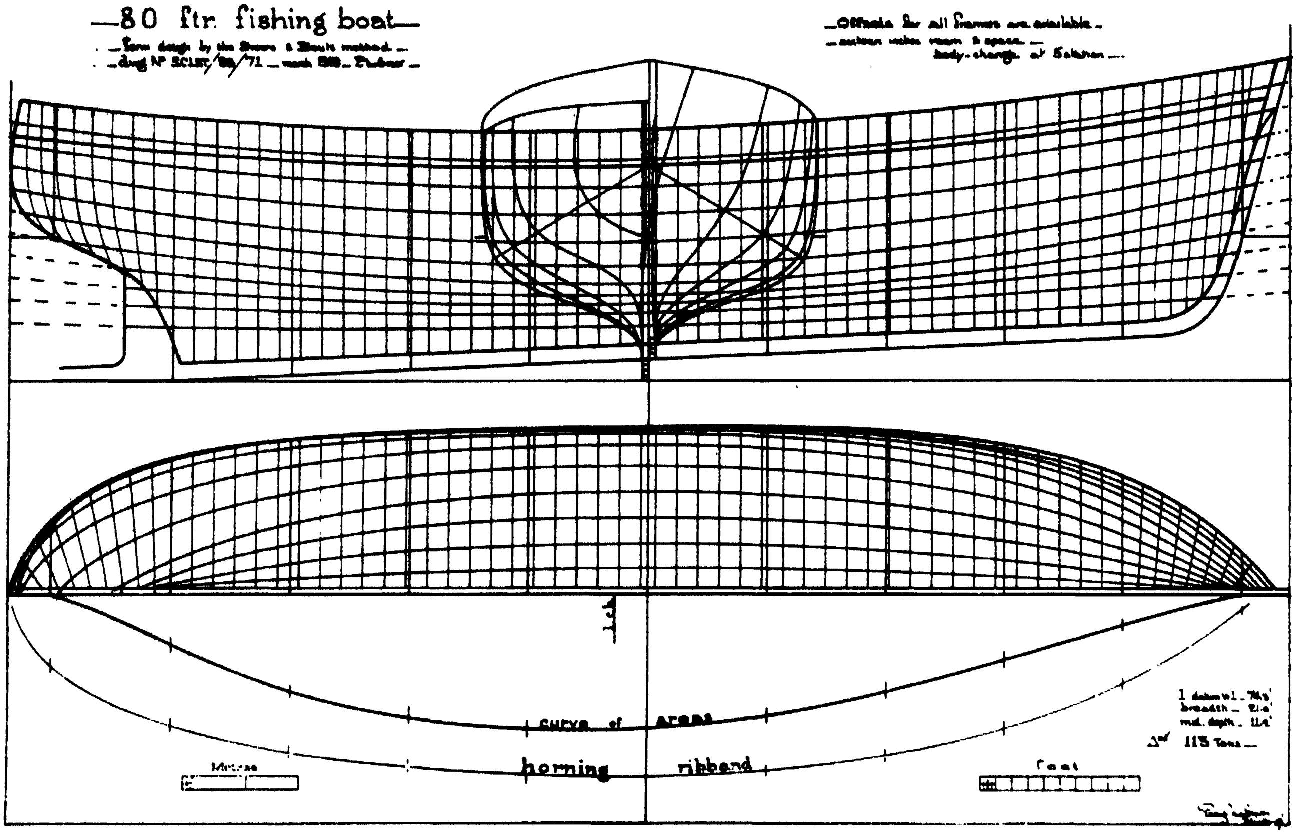


Fig. 622. Lines drawing according to the "sheer and beuls" method

Scientific level in small-craft design should be higher than it is. Chapelle is all too correct in submitting that designers are still proceeding mainly by rule-of-thumb, "art" and personal opinion, without much aid from mathematics or controlled model testing, and apparently without well-formulated theory.

What too often passes for science is vague, highly generalized mathematics from which precise numerical values for a given practical situation are not obtainable. After piously invoking the usual shibboleths, designers frequently fall back on intuition and personal hunches.

As one way out of the impasse, Chapelle suggests what he calls the "drawing board attack", that is to say, "manipulation in lines drawing". This technique is neither new nor unknown but it is not used as much as it deserves to be, and is sometimes disparaged as being unscientific.

The truth is, however, that "analysis of the lines plan" is not merely a methodology of great practical utility, but it is perhaps the most precise, that is to say, scientific, means developed so far for recording and comparing the complex variables of hull form in their organic interrelationships. From the lines plan the trained eye can quickly synthesize a wealth of interrelated detail wholly lost in the generalized formulae of the standard treatises.

A very great deal has been accomplished over the years in small craft design by empirical methods. Not solely the occasional illuminations of genius, but the steady up-hill efforts of generations of workaday builders turning out good boats and bad, but always under economic pressure to build something better.

The great preliminary task of a science of small craft design is to collect and to record the details and characteristics of the small craft heritage. So far, the most fruitful and mostly the only possible method, has been the assemblage of the lines plans of the great diversity of boats already built. This labour has meant innumerable hours in libraries and museums, unending search in far-flung boatshops for sketches, half-models, moulds, and like artifacts, and the exacting process of measuring the boats themselves, wherever found, in the water, on slipways, or rotting quietly among the weeds on the bank of some forgotten backwater.

For upwards of three decades Chapelle has occupied himself indefatigably with this task. The wealth of information and design detail that he has himself assembled is both the inspiration and the despair of those likewise ambitious in this endeavour. Of late a growing amateur interest has come forward in what might be called the historical approach to small craft design. And not a few amateurs are making contributions in this field. Indeed, something of an anomalous situation now obtains with amateurs showing more interest than many professionals.

One great limitation to the historial approach to boat design as it has developed has been lack of performance data. Performance characteristics have had to be taken mostly on hearsay, or inferred upon circumstantial grounds. Of course, it is impossible to test directly boats no longer in the water. For boats still in service, the economic obstacles to reliable performance testing have usually been insuperable, up to now. Simply to obtain the necessary measurement required for an accurate lines plan of a boat in service is often difficult enough to tax the patience and ingenuity to the utmost. To test the boat in use both for factors of resistance and seakindliness would be impossible in many cases. It would cost too much to take the boat out of service for testing and to pay for labour and fuel required during the testing period. And secondly, suitable procedures and standards for testing performance of smaller fishing craft in use still remain to be worked out.

A science of design for fishing boats of the smaller class must concern itself with at least four interrelated categories of data, namely, resistance, seakindliness, construction and suitability for the specific fishing operation. In the background is always economics. Fishing must pay, whether measured by direct cash value, or justifiable expenditure of labour time. Is small-craft fishing of sufficient economic importance to pay for scientific investigation of design?

This is a question to ponder. With small-boat fishing a division of a depressed industry, as in the U.S.A. today, is it wishful thinking to look for much progress in design? Yet the means and methods are at present at hand to bring in overnight, as it were, a full-fledged science of small-craft design. It may be that an eventual absolute need to augment the world food supply will over-ride ordinary economic considerations, forcing an all-out scientific effort in all phases of the fishing industry, regardless of cost.

Chapelle's criticism of the traditional mathematical approach to small-boat design must *not* be taken as rejection of mathematics, *per se*. What Chapelle has done is to question the relative usefulness of certain limited mathematical generalizations drawn largely out of the frame of an obsolete nineteenth-century science, and now hardened into something of a dogma. His objections are not to be confused with the position of a few extreme critics of the mathematical approach, who assert that the interacting variables of hydrodynamics and seakindliness are so complex as permanently to resist useful mathematical formulation.

Complexity defying formulation at the turn of the century and even for some decades after is no longer impregnable today. The development of electronic computers and their rapid advancement during the last two decades, first in nuclear research and now in the missile programme, makes simple the solution of heretofore insoluble problems. Certainly the variables encountered in rocket research are as numerous and as complicated as those clustered about the hydrodynamics of small displacement and semi-planing fishing craft. Surely the hydrodynamics of a 30 ft. (9.15 m.) lobster boat are not in the same order of complexity as those of a modern nuclear submarine. It is not that mathematics will not work for small craft design: it is simply that the fishing industry at present appears unable to pay for the sort of mathematics that will work. Seakindliness is obviously more difficult to investigate with tank models than is hydrodynamics. This is not to exclude model tests for seakindliness nor to deny their utility. But wherever working tests of full-size boats under actual sea conditions can be made, those would seem to be more directly significant. Here, again, the cost factor is the obstacle. It is doubtful if the fishing industry can now afford any extensive testing with full-size craft. Perhaps the most promising expedient, here, is the organization of co-operative testing programmes among groups of fishermen who would test their own boats under suitable professional supervision in slack periods between fishing.

Fishermen, builders, and designers, as individuals, cannot afford testing, nor is it likely that private industry can be persuaded to underwrite extensive test programmes for the advancement of public knowledge, that is to say, science. Research investigations calling for any considerable expenditures, would apparently depend upon organizations supported by public monies or by research endowment funds.

But the financial barrier can be bypassed in some cases by joint voluntary efforts of groups of interested individuals pooling contributions of skill, time, materials, access to testing facilties, and the like. One such co-operative project, the first of its kind in the U.S.A., is the one now in progress under the direction of Gillmer.

In his discussion of lines analysis, Chapelle offers a number of comments on hull-form design components to be considered as hypotheses for exploration in subsequent testing. He has wisely refrained from suggesting numerical values for these components, leaving such to be determined in the future by controlled experimentation. For one of these components, the entrance angle, Gillmer's findings indicate that, hydrodynamically, a half-entrance angle of from 10 to 12 degrees is optimum in light displacement power launches of the kind tested. This with a prismatic of from .65 to .70 resulting from a flat run and evenly distributed displacement from amidships to the transom. As the project continues, it will undoubtedly be possible to adduce additional optimum numerical values for other hull-form components listed by Chapelle.

The project reported by Gillmer may be taken as a concrete example of the method and approach suggested by Chapelle. Actually it was Chapelle's prior work (such as Chapelle, 1955) and his subsequent suggestions and advice that more than anything else inspired this project in the first place. Thus the practical value and workability of hull-form analysis and testing advocated in Chapelle's paper is demonstrated in this present example.

REPLIES BY AUTHORS

MR. J. T. TOTHILL (Canada): Replying to P. Chardome, he expressed thanks for an intelligent discussion of nozzles with which he was in full agreement, and for the information on nozzle performance of two fishing boats. The benefit of a nozzle increases in adverse weather and is especially pronounced when the propeller loading is high due to restricted diameter or high r.p.m. In his own model the propeller loading was light and a large gain in efficiency due to the steerable nozzle was not to be expected when running free. Indeed, the propeller appeared to act as if the nozzle were not there. Increased resistance due to adverse weather or the drag of the trawl brought the advantage of the nozzle into play.

Csupor had raised many questions and he thanked him for the interest displayed. He thought that construction of the bulbous bow would present no particular problem in steel, aluminium, or fibreglass. In a wood boat it was more difficult but, he thought, by no means insurmountable. With regard to slamming, he was optimistic that the large damping which could be expected from the bulb would eliminate most of the situations where slamming occurs in conventional boats. He was preparing the equipment to do wave tests on the model which would throw more light on this question.

In the light condition the bulb was close to the surface in in the static condition. When running the bulb pulled the bow down almost to the medium waterline. This characteristic provided an answer to the question as to whether the flare in the bow sections was too high up to do any good.

The fine bow undoubtedly increased the sensitivity to trim, but the broad stern sections compensated for this and he did not find the model to be abnormal in this respect. The main consequence of the fine bow as an easily-driven vessel in which the engine room could be materially shortened, thus allowing the fish hold to be placed farther aft where the fish load would not affect the trim unduly.

He did not believe that fishing could be done in ice and had not considered ice-breaking when designing the form. Nevertheless, he thought a concave surface should be less liable to buckling under ice pressure than a convex surface, and in the present case it would be reinforced with transverse struts in the region of the waterline to provide panting strength in any case.

The real test of the effectiveness of the contra stern frame would be to measure the rotation of the flow behind the propeller. If this turned out to be zero, the contra stern frame would be achieving its purpose. This test had not yet been made. He did not blame the contra stern frame for the variation in wake over the propeller disc, which was normal for a single-screw vessel. It could be blamed for a certain asymmetry in the wake shown by the tests, but he did not regard this as important.

With regard to Csupor's question concerning vibration from a two-bladed propeller, he agreed that there was always some risk. In the Ottawa tank the torque was measured on a spring and the fluctuations of the needle gave a rough indication of the torque variations. The present model had surprised him in giving exceptionally steady torque readings and he thought that the homogenizing action of the nozzle-propeller combination, referred to by other contributors, might be responsible. His preferred approach was to start with two blades and change to three or more if vibration proved to be troublesome, because a two-blader gave a real gain in efficiency and was easy to make.

Several questions regarding manoeuvrability had been asked by Csupor and an account of the manoeuvring tests on the model might be of interest. When moving ahead, the steering was stable and the turning circle appeared to be normal in relation to rudder angle. When stopped, the stern could be kicked to port and to starboard by applying appropriate rudder angles, when going either ahead or astern. When moving astern, the steering was under control for small rudder angles up to about 5°, and the model could be steered in a slow curve either to port or to starboard. Larger rudder angles appeared to cause a breakdown of flow around the nozzle and steering effect was lost. Steering torques were light at all times. In the light of these results he did not think that the manoeuvrability due to a steerable nozzle need be seriously questioned.

Csupor's reference to fig. 331 of the paper were in error; these were effective power curves, not propulsive power. With regard to the model with a Maierform type bow referred to therein, Mr. Tothill did not agree that a 4.6 per cent. increase in length would be sufficient to increase the saturation speed by 5 per cent. He agreed that the model in question had almost equally low effective power below 9 knots, assisted by a lower beam/draught ratio which would not provide the stability required for model 149A. It would indeed be interesting to see the results for a Maierform hull designed for the same objectives, and tested in the same manner.

Welcoming the discussion by Gutsche, Mr. Tothill agreed that rough water performance was important and thought he had indicated in the paper a number of features which would be conducive to good performance at sea as well as in smooth water. Among these were the fine bow, the bulb, the bow flare, the flat run, and the steerable nozzle. With regard to steering astern, he referred to his reply to Csupor.

As for the margin of power required for seagoing conditions, it was his opinion that small boats, which are always relatively highly powered, do not need a margin of power because they very soon have to reduce power voluntarily in a bad sea. Bigger vessels which are relatively lower powered usually do need some power margin, and in the case of slow cargo vessels and tankers this might run as high as 30 per cent. In the trawler version of his own design with a single-speed gearbox, a power reserve of 33 per cent. was available but he did not think it would be used except when trawling.

He agreed that the optimum speed for a given duty was best determined by economic considerations, where these were known with reasonable precision in advance. However, he stressed that the seventh power law gives a saturation speed and power for heavy vessels which it is illogical to exceed on economic grounds, since an "oversaturated" vessel can always be beaten by a slightly bigger "saturated" vessel which will carry more at the same speed with less power, yet cost the same. He could thus visualize no situation in which the "economic speed" would exceed the "saturation speed" and for the present he was content to use a designed speed 5 per cent. below saturation for small fishing vessels. Both the "economic speed" and the "saturation speed" are defined by a tangent to a curve so that 5 per cent. error makes very little difference.

He could not agree that his proposals regarding pitch distribution for a nozzle propeller were fundamentally the same as those of Dickmann (1955) and van Manen (1957), they were fundamentally different. Recent tests of the pitch distribution by van Manen and Superina (1959) showed a loss of efficiency at all but the lowest loadings compared with the ordinary Troost series. He thought that this might be due to excessive hub vortex losses caused by overloading of the root sections, which is a consequence of the "constant disc pressure" pitch distribution. This convinced him, for the present, in preferring his own pitch distribution.

He thanked Gutsche and Klaasen for their explanations of the homogenizing action of the nozzle on the wake, as being induced by the propeller.

Henschke's interesting results for bulbous bows, when contrasted with Johnsson's, tended to suggest a conclusion that the better the basic hull form was, the less benefit it would derive from a bulb, in smooth water. Doust's results, on the other hand, suggested that the bulb could well be exaggerated to improve the pitching characteristics, and this now seemed to Mr. Tothill to be the main justification for using a bulb.

He could not agree with Hunter that a bulbous bow was of questionable advantage in small vessels. If it helped a 100-tonner it would also help a 10-tonner or a 1,000-tonner in the proper speed range.

Lackenby had asked for a breakdown of the overall improvement due to the separate features of the model, compared with normal arrangements. One had first to decide what was normal and a main consideration on his own particular model would be a loss of perhaps 17 per cent. in propeller diameter and a 50 per cent. increase in revolutions. The breakdown might then look somewhat as follows.

	Resistance	*Propulsion*	*Trawling*	*Synchronous pitch angle*
Bulbous bow	4	5	0	40
Contra stern frame	–1	3	1	0
2-blade propeller	0	2	5	0
Steerable nozzle	–3	4	30	5

In giving these figures he hoped he would be credited for courage rather than being blamed for foolhardiness; they were based entirely on indirect evidence.

Proskie had cited two cases where an increase in power had given better profits in trawlers. He agreed that this might be beneficial in some cases, but not in others. Each case had to be considered on its merits. Very often the demand for more power was a consequence of poor efficiency rather than too little power, and he could cite cases where the adoption of a steerable nozzle was equivalent to fully 50 per cent. increase in engine power when trawling, and would show a far greater return in the economic analysis.

He was not necessarily advocating a 75-ft. (22.9 m.) boat for the Canadian Atlantic provinces; his model could be scaled up to any size without affecting its merits. He had simply used 75 ft., or more properly 100 ton, as a convenient basis for comparison. Finally, he expressed thanks to Roscher and Zwolsman for their reports on fixed and steerable nozzles, which went far to prove their advantage and practicability, and thanked the other contributors for their valued comments.

MR. D. J. DOUST (U.K.) thanked Lewis for his encouraging remarks and hoped to extend the statistical method given in this paper to other classes of merchant vessel.

As far as the choice of form parameters is concerned, the cross-coupling of terms referred to by Lewis is also an essential part of the procedure if the regions of minimum resistance are to be fully explored in the analysis.

The C_R-$V/\sqrt{L}$ presentation has several advantages in an analysis of this type (Doust and O'Brien, 1959) although Mr. Doust agreed that the ©, Ⓚ system is a possible alternative which might give satisfactory results. However, it should be remembered that once the regression equation based on the C_R-$V/\sqrt{L}$ system has been built up, the effect of changes in length can be calculated directly by substituting in the equation. The use of an electronic computer such as "Deuce" is of course invaluable in the assessment of changes in single parameters, since programmes can be prepared which yield the required information very readily. The changes in length from 200 ft. (61 m.) do, of course, entail small frictional corrections in C_R which are calculable.

Mr. Doust was interested to hear of the attempts made at the Davidson Laboratory to statistically analyse model resistance data from various sources. Due to the differences in model sizes, turbulence stimulators, tank boundary interference and other discrepancies between the various tanks he discarded a considerable amount of trawler data to avoid these anomalies. In this way the changes in resistance used in the analysis are more truly representative of the changes in form parameters.

A wider range of parameters could only be used after more data from model tests became available.

Johnsson commented on the effect of proportions in the use of a bulb, and particularly its use in fuller ships. Doust, in his paper, had been careful in laying down the limits of the different parameters within which this analysis was valid. Anyone referring to this paper should, therefore, be sure to keep within the limits of parameters which Doust has defined.

As Hunter pointed out, the performance of the bulbous bow trawlers at sea has fulfilled the expectations of the designers.

MR. W. DICKSON (U.K.): He thanked Tyrrell for his not very reassuring remarks concerning the relative heights of the gallows on big and small trawlers. The question of stability of small 75 ft. (23 m.) fishing boats caught with their trawl at the bottom ought to be thoroughly considered. Crewe had answered his own questions so far as they can be answered at this stage.

Regarding Hunter's query of the tide and the effect of the difference between the speed of the boat and the speed of the net, he would like to measure the speed of the net. But there were at the time no instruments for this, so measuring the speed of the boat and assuming it to be the speed of the net was all that he could do.

Regarding Möckel's paper, he had compared some of his own results on the *Explorer* and found that the drag was less and the speed somewhat higher. He attributed the discrepancy to the gear which was used. Another reason for the difference might be that Möckel's ships might have been working in deeper water with more wire out. On the *Explorer* iron bobbins were not used but heavy rope bosoms of 14 in. (356 mm.) diam. All the same, Möckel's figures on the drag of the gear appeared high.

A calculation of propeller thrust of both vessels should give some cross checks on results. He was interested in Möckel's fig. 429, the diagram of stability and rolling time. He had taken the rolling time of two Scottish 75 ft. (23 m.) MFVs, which appeared to correspond with Möckel's curve, although both were a little on the stiff side of the graph.

MR. G. VOSSERS (Netherlands): Measurements of waves were a necessity in future seakeeping research; as long as it is not known what waves are encountered, one cannot predict the behaviour of a ship. Therefore the work of Oceanographic Institutions such as Woods Hole is absolutely necessary.

Du Cane's remarks are highly appreciated. His observations on seasickness were new to Vossers and the explanation offered for the rare occurrences of seasickness on board high speed planing vessels seems very reasonable.

In reply to Todd, he said that the significant wave height is defined from crest to trough and it can be arrived at with the following procedure: tabulate the observed apparent wave heights from a record with increasing wave height; count the number of apparent wave heights and divide by three. Take the highest waves, the next highest wave, and so on until one-third of the total number of apparent wave heights has been selected. The average of these apparent wave heights is called the significant wave height.

It is true that the theoretical support for the resistance decrease in head seas was found in calculations of an oscillating ship in still water, as is remarked by Weinblum. Eggers' calculations will be studied with much interest as they seem to indicate that this theoretical support is not correct. The experimental evidence of this phenomenon remains, however, present, although not in waves higher than 1/40 of the wavelength.

CAPT. W. MÖCKEL (Germany): Measurements of horsepower, speed and warp pull have been made at the Hamburg Tank during the last few years. Problems relating to the influence of the sea bottom on pull and power requirements have still to be solved. On one occasion during the experiment the speed fell to nought while the engine was still working ahead. No research data is available on these problems.

During the investigations, the length of warp was from 525 to 725 ft. (960 to 1,370 m.). Iron bobbins and ponies were used. Due to the seaway the instruments sometimes were difficult to read. The pull was taken from each warp by two calibrated dynamometers. The results have been confirmed by other observers working with a different kind of dynamometer.

When measuring the speed with a Kempf log a small metal cone was towed 20 ft. (6 m.) off the ship's side behind the vessel at lengths of the logwire, ranging from 330 to 560 ft. (100 to 170 m.). Measurements were taken at each 16.5 ft. (5 m.). The ship's speed was calculated by means of calibration curves as the average of the 15 single measurements. Numerous trials on the measured mile showed a very good agreement of the results of both methods.

The fish load is decisive for the fore and aft accelerations. These also depend on the body shape fore and aft and the radius of gyration.

Natural rolling periods of small ships are not easy to determine due to wave influence. Sometimes 50 to 60 measurements were needed for an average reading. Measurements made by other workers generally corresponded to those described here.

Ships F, G, J were investigated about one month before docking. Examination in dock showed that none of the ships had any fouling, and bottom painting was still in very good condition. The skin roughness of these three ships may be regarded as equal. The skin friction of ship H was somewhat less since the bottom of the vessel had been painted just before the start of the voyage.

As du Cane stated, excessive rolling and shipping of water can be reduced by the increase of freeboard and damping. Fig. 429 is intended to show by simple means how conventional trawlers of different stability behave in waves. These vessels are of the same type and have freeboards that differ only very little.

It is difficult to find means of much greater damping effect than produced by the normal bilge keel. It is to be doubted whether the dynamic lift of activated fins at the low trawling speed of about 3.5 knots will reduce rolling, to say nothing of when the vessel is drifting and making no headway at all.

The shape of a ship is more precisely defined by the prismatic coefficient, and this coefficient was therefore adopted in fig. 412. Because the prismatic coefficients of the cargo ships formerly investigated in the U.K. and Germany were not known, comparison of the loss of speed of these vessels and trawlers was based on the block coefficient.

Captain Möckel, referring to Tsuchiya's contribution, hoped that in Japan, where so many naval architects were employed by the Government Fisheries Agency, many more full-scale observations would be made from different types of fishing boats. This would form a most important contribution to a third Congress. He also felt that other countries should do similar research, which would be of great assistance when designing better fishing boats.

Tsuchiya's results tended to agree with the data obtained on German trawlers. The differences lay mainly in the shape and size of the vessels and the lower efficiency, which was probably due to the comparatively high speed propeller used in the Japanese boat. It was, of course, easier to measure rolling periods on board a large trawler than on a small fishing boat. The real difference existed in the m-values, which were 0.428 respectively for the three given loading stages of the Japanese craft, while they differed slightly on the German trawlers according to the load condition of the individual stages of the voyage, as shown in table 143.

Dr. J. D. van Manen (Netherlands): In answer to Roscher, he would like to state that the trawler with nozzle-propeller was actually tested over a wide range of wave-lengths, speeds, directions and wave-heights. In practically all cases the nozzle had shown a better performance than a propeller without. Under some conditions, in a head sea, for example, with wave-length equal to ship's-length, the nozzle showed bad results, with less thrust, and did not give as much damping as expected. The same tests were done with another nozzle on the same model and the results confirmed the previous tests.

Mr. J-O. Traung (FAO): If one wants to determine whether a fishing boat design can be improved, there are quite a few things to consider, among them being:

- Distance to fishing grounds and weather conditions
- Fish availability and behaviour; fishing methods
- General layout—is the size economical?
- Are the lines the best possible to give most comfort, thus highest fishing efficiency, and economical propulsion?
- Is the safety adequate?

If the type of fish to be caught and fishing method are known, then the general boat type and size are more or less fixed. The task is then to see where improvements could be made. Length is very difficult to change because it is such an important cost factor. It might be possible to reduce the hull weight by choosing a lighter engine, by carrying less permanent ballast, by improved insulation, therefore loading less ice, and by reducing scantlings. But not very much can be done with the displacement, and thus $L/\nabla^{1/3}$. The beam must be selected to ensure the correct GM—and previous discussion has shown that this matters little to the resistance. The draught and also the depth are very much determined by the propeller diameter, so they are difficult to manipulate, therefore the B/T ratio is given. The location of tanks, engine, fish hold, etc., can be used to bring about a certain shift of LCB to give less resistance on the lines. Similarly, one can consider the use of such resistance-decreasing features as a transom stern or a bulbous bow. However, the normal situation is that $L/\nabla^{1/3}$, L/B, B/T and LCB are more or less fixed, and the question then is what is the important parameter to consider in order to see whether any improvements are possible.

Chapelle rightly stressed in his paper the importance of a commonsense approach when designing lines, and issued a warning against the "mathematical attack". Nevitt's (1956) findings that there could be a variation in resistance of as much as 27 per cent. when testing fishing boat models of a fixed prismatic coefficient of .65, had apparently made a deep impression on Chapelle and Tyrrell. It is true that Nevitt created somewhat of a sensation when he published the results of these tests, but Chapelle and Tyrrell seemed to have overlooked the fact that all individual models in the series were not really designed with practical construction in mind. Nevitt wanted his students to find out how much difference could be obtained by making very extreme variations and using rather distorted shapes in some models, and thus great variations in resistance resulted. Had the models been designed with practical construction in view, the variations would not have been so much. Professor Nevitt, who later tested models of .55, .60 and .70 prismatic coefficients, had permitted the preliminary results to be published at this stage—fig. 623.

Four models of .55 prismatic had been tested, and each model was designed with a "commonsense" approach. The difference between the models was not greater than 4 per cent. It was Nevitt's feeling, however, that this spread would have been larger in the .65 series, and it seemed as if the variation between models was reduced if a lower prismatic coefficient was used, and as long as one kept within reasonable shapes. In the .60 and .70 series only one model had been tested.

With parameters like $L/\nabla^{1/3}$, L/B, B/T and LCB fixed, according to the general arrangement, size and type of the vessel, and using a commonsense approach in design, Chapelle would probably agree that the prismatic coefficient was the most important numerical factor to consider in design.

The choice of the magnitude of the prismatic coefficient, from the point of view of resistance in calm water, is much simpler than is generally realized. A hull with a low prismatic coefficient has less wave interference effect, and thus there are fewer humps and hollows in the curve of the calm water resistance coefficient, as evident from fig. 623 and Johnsson's fig. 615. This was nothing new. Taylor had shown these effects many years ago for the lower displacement-length ratios. A low prismatic is always the best below a speed-length ratio of 1.17, according to fig. 615, and 1.13, according to fig. 623, say 1.15. At higher speeds, the larger prismatic gains in importance. However, the difference in resistance between low and high prismatics at a speed-length ratio of, say, 1, is several times greater than at, say, a speed-length ratio of 1.3.

Now, if fishing boats operate at less than, say, 1.15, the choice is simple, but if they should, under very ideal conditions such as absolutely calm water, be able to run at higher speed-length ratios, one must determine whether it would be more economical in that case to choose a slight decrease in resistance at the ideal condition and take the very heavy loss as soon as the speed drops down below the transition speed. Even if calm water operation should constitute 50 per cent. of the total operation, it would always be more profitable to have a low prismatic coefficient because of the saving in fuel at the lower speeds. At a speed-length ratio of 1.25, a .62 prismatic would have a residual resistance coefficient, according to fig. 615, of 7, and a .56 prismatic a coefficient of 8, or about 14 per cent. more, and perhaps only 7 per cent. more in total resistance. By a speed-length ratio of 1, the resistance coefficient for the .62 model would be 4.15, and 2.05 for the .56 model. Thus the high prismatic model would require twice the residual resistance and perhaps 30 per cent. more in total resistance. Johnsson chose a prismatic of .67 to "provide less motions in a seaway", and that would require a residual resistance of about 8.2, or four times that of the model with the lower prismatic.

Doust's diagrams show, according to Fujinami, that the choice of low prismatic and high prismatic depend very much on the angle of entrance, and that a combination of high prismatic and large angle of entrance can sometimes compete with a combination of low prismatic and small angle of entrance. The diagrams, however, also indicate that a large angle of entrance always gives higher resistance speed-length ratios below 0.9. In practice, NPL seem to choose the combination of low prismatic and small angle of entrance for fishing boats.

What speeds do fishing boats normally make? Johnsson met a skipper who wanted to make 12 knots, or a speed-length ratio of 1.32. Mr. Traung had also met skippers claiming both high speeds and the desire to make them, but, when checked,

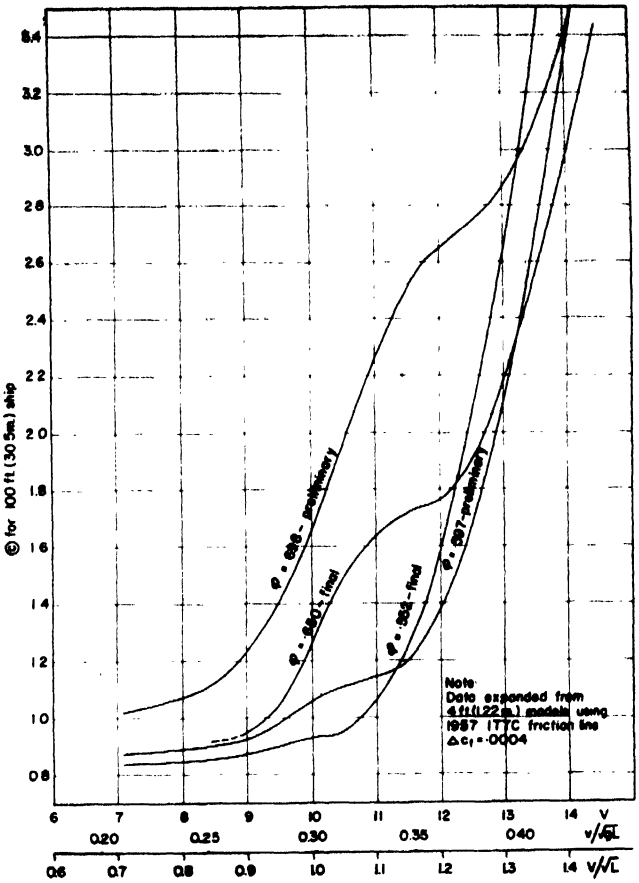


Fig. 623. Resistance curves of the high displacement-length series of trawler hulls being tested by Professor Cedric Ridgley-Nevitt at the Webbs Institute of Naval Architecture, Crescent Beach Road, Glen Cove, New York, U.S.A. The .552 and .65 prismatic series are final but for the .597 and .698 series only one model has been tested of each

on fishing trips with boats from many countries, including Sweden, he had never found that these speeds were attained. There is very little realistic information on operating speeds of fishing vessels, disregarding those given in the Japanese fishing boats register, but some had been published in a diagram (Traung, 1955), now reprinted as fig. 624a. The maximum speeds recorded in Möckel's paper and in Tsuchiya's discussion had been introduced into this figure, as well as results from a fishing trip in 1956 in a newly-built Swedish trawler with a .66 prismatic coefficient. Fig. 624b gives a record of the speed observations of the Swedish trawler, which had the following dimensions:

L	79 ft. (24.05 m.)
B	21.3 ft. (6.5 m.)
T	9 ft. (2.74 m.)
Δ	197.5 tons (199 ton)
LCB	−0.54 per cent.
$L/\nabla^{1/3}$	4.15
δ	.453
φ	.6625
L/B	3.7
B/T	2.38
$\frac{1}{2}\alpha_e$	32°

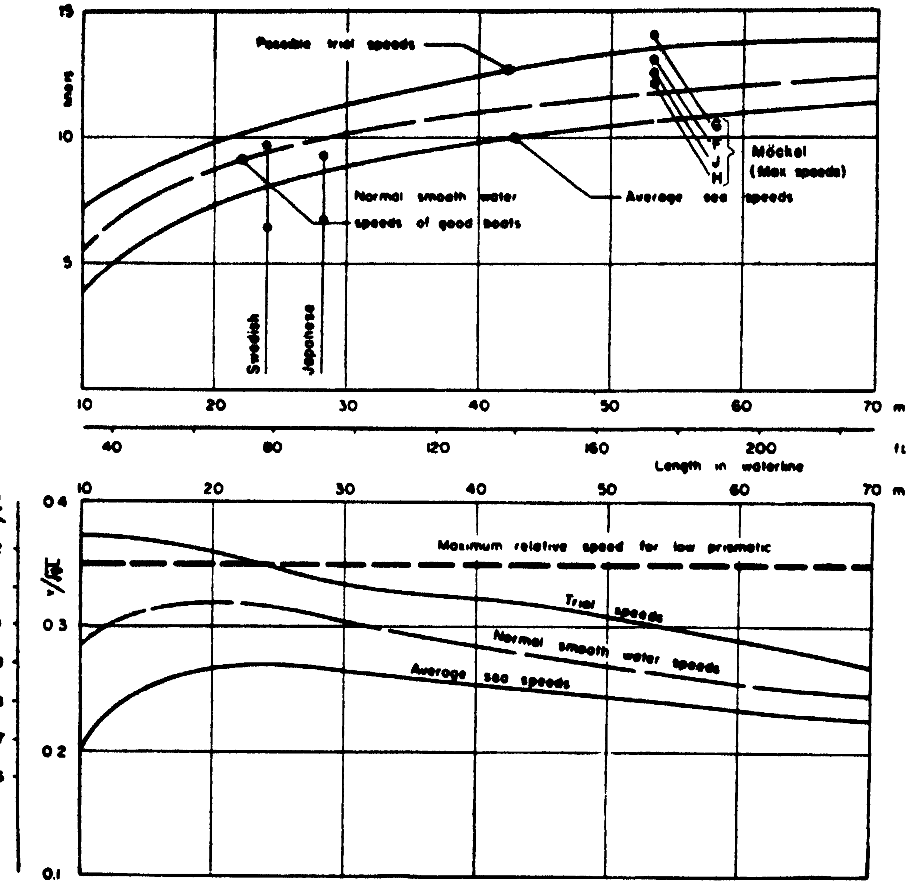


Fig. 624a. The top diagram shows curves with trial speeds of good boats. The medium curve indicates normal speeds obtained in smooth water by modern boats and the lower curve is an estimation of the average sea speed at which fishing boats normally sail. The lower diagram shows the same information expressed in curves for non-dimensional speed-length ratios. The diagram is based on data available at FAO and was originally published by Traung (1955). Now additional plots have been introduced for results given by Möckel, Tsuchiya and Traung in this discussion. The limiting line for speed-length ratio of 1.15 indicates that fishing boats normally sail at speeds where a low prismatic coefficient is profitable

It was unrealistic to believe that fishing vessels normally operate at a higher speed-length ratio than 1.15.

For operation in waves, it is naturally important to consider whether the low prismatic would also give low resistance, high propulsive efficiency and moderate motions. Du Cane stated that this "seems to be a theme running throughout the papers". Hopwood and Mewse, the latter an experienced superintendent of a large trawler fleet, stated in their paper, on page 276, that a fine hull produced a seakindly ship. Tyrrell, although doubtful about a low prismatic coefficient, said that a finer bow gives less resistance and is drier in head seas. Sir Fred Parkes gave a vivid account on pages 357 and 370 of *Fishing Boats of the World* of the behaviour of the low prismatic model-tested British super-trawlers. There seems to be little question that the larger trawlers have less motion if they have a low prismatic coefficient, and everyone who has been "playing about in small boats" will certainly confirm Gardner's statement that excessive wetness in a head sea is due to a full, blunt entrance. The types covered in Mr. Traung's paper were of a size between such small boats and the large super-trawlers. They should also behave in practice as indicated by the reported model tests. It was difficult to understand why Johnsson had to issue a warning against the findings from the model tests reported because they were made in regular waves only.

The model testing technique is still being improved and the user of test results should naturally be aware of the risks which interpretation and extrapolation involve. Laminar flow, for example, has been a rather difficult problem. Similarly, the question of whether to test in regular or irregular waves is important. The essential thing, when judging model tests, is to observe the trend and look upon them more qualitatively than quantitatively, which was emphasized in the paper, and always to apply commonsense to the results. While the warning against model tests in regular waves had partly been modified by the statements of such tank experimenters as Lewis, Otsu and Vossers, it would have been interesting if there had been funds available to test the FAO models in both irregular and oblique waves to get a quantitative comparison. But Mr. Traung did not think that the regular wave tests made the low prismatic models appear more attractive than the high prismatic ones.

Johnsson quoted Weinblum and St. Denis' (1950) paper to answer a request for elaboration of his rather flat statement that a high prismatic "*undoubtedly* gives a more seaworthy ship". Johnsson now limited his statement to: "A fuller waterline gives more damping of the motions than a finer one."

Weinblum and St. Denis stated in their 1950 SNAME paper that "the damping coefficient is now proportional to the square of the moment of inertia of the water plane" and that "under comparable conditions ships with fuller water lines experience lower pitching amplitudes in long waves". They quoted an investigation by Perelmutr, and said that his "experimental results confirm our theoretical deductions that in this region of wave lengths finer waterlines lead to heavier motions." In their summary they stated that "the damping of heave and pitch is increased by:

(a) increase of beam
(b) decrease of draft
(c) decrease of vertical coefficient (increase of V-forms)."

Johnsson had probably not read the discussion which followed Weinblum and St. Denis' paper during which Todd stated:

"In their summary, the authors state that at longer waves vessels with full waterlines are likely to heave and pitch less than vessels with fine waterlines. While this may be so, perhaps it does not follow that the vessel with full waterlines will still be a better design from all points of view. Some years ago an attempt was made to introduce a new design of ship into the trawler fleets in Great Britain. As a result of exhaustive model tests, both in smooth water and in waves, it was found that the design with a fine waterline forward, adequate freeboard at the stem, and a great deal of flare above water, gave the best results from the point of view of minimum horsepower, minimum loss of speed in waves, and dryness of the decks. Some of the trawler captains were extremely sceptical when shown these designs in model form, and still more so when they saw the first ships ready for launching; in particular, they voiced grave objections to the fine waterlines and the probable result on the ship's behaviour. However, in service these vessels proved themselves extremely successful. They were able to maintain a better sea speed than other ships in their fleet of the same general size, thus reaching their markets sooner and obtaining better prices for their cargoes. At the same time they proved more economical on fuel and generally much drier and more seaworthy craft. It was not long before the captains of the older craft were demanding boats of the new type."

Weinblum and St. Denis' answer was:

"The remarks on trawler forms merit serious reflection. When resistance is considered, a finer waterline may well be superior. Although we are unable to judge what other features may have been responsible for the success of the design discussed, we admit that the example indicates how necessary it is to remove some of the restrictions underlying the present work when one attempts to judge the over-all performance of a vessel."

Todd's contribution to this discussion confirmed his 1950 observations. One reason why British trawlers with finer waterlines behave better in a seaway may be that trawlers with a low prismatic coefficient naturally have to be made wider to maintain the same transversal stability as those with

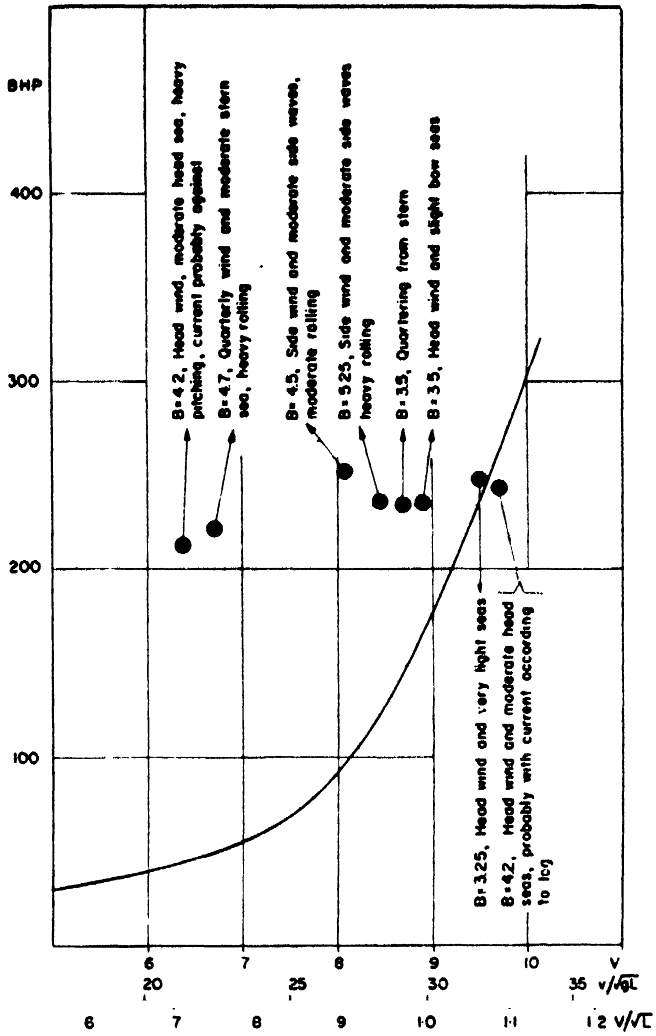


Fig. 624b. Estimated speed-power curve for a 1956 wooden trawler and records of actual steaming speeds and engine outputs at various wind and wave conditions. The boat had a controllable-pitch propeller and an engine of 450/495 h.p. at 375 r.p.m. The engine speed was between 295 and 330 r.p.m. and the output never higher than 250 h.p. during the actual fishing trip at which these records were taken

a high prismatic. Their beam is increased, and this, according to the Weinblum and St. Denis' paper, is a means of decreasing pitching. Similarly, the beams of the low prismatic models in Mr. Traung's paper were larger, so that all ships should have about the same transversal stability. As a result, the differences of the longitudinal moment of inertia of the waterline were reduced, compared with what the case would be if all the models had the same beam.

Todd's 1950 discussion and his confirmation now, as well as the fact that large British trawlers are built according to these principles, were further confirmed by Möckel's paper, which clearly shows that German low prismatic coefficient ships also lose less speed, and fig. 431 shows that the more slender trawlers F and G had less pitching angle than H and J. Chardome in Belgium is on the same line, and Ringhaver's paper states that his shrimp trawlers, of the same size as those under review and with a prismatic coefficient of .54, behaved well in head seas.

It is unfortunate for Zwolsman that he has had such bad experience of low prismatic vessels. His example, fig. 440, is not a very good one. Perhaps the bad behaviour of this vessel was not caused by the shape but by the low metacentric height. It appeared that ballasting improved behaviour. Zwolsman also advocated high prismatic vessels as being more economical because of their larger carrying capacity. This is not the case with the FAO models. They have all the same displacement to the same waterline length and, as the free-board is the same, the carrying capacity should also be the same. Actually, the low prismatic FAO models with larger beam have even a larger carrying capacity.

Mr. Traung thanked Lewis and Otsu for their constructive contributions, and the co-operation he had experienced with their laboratories. The prismatic coefficient as a simple design parameter was also little used in Europe, despite Taylor's work. This was because cargo vessels have an almost maximum midship section coefficient, and thus the block coefficient is in direct relation to the prismatic coefficient. For fishing vessels, however, it was most important to study both. It should be possible to change the midship section area of many Japanese fishing vessel types, and thus the prismatic coefficient, by changing beam, draught, or both. The FAO tests had been appreciated in Japan, although the models had been based on boats from northern Europe and North America, where more attention should be given to the prismatic.

The expression "beamier" was an over-simplification, and Otsu was right in saying that angle of entrance and draught might also play their part. Any systematic variation had its limitations, and one should never think that the optimum prismatic is the same both for a large cargo ship and a small fishing vessel.

With regard to Otsu's suggestion for making a more "honest" comparison of the self-propulsion tests, Mr. Traung found it difficult to understand why the rather abrupt endings of the FAO high prismatic models, caused by the forced design method, should not influence the flow of the water to the propeller. The essential thing was, however, that Otsu's comparison also showed the lower prismatic models to be best.

In order to form an opinion on the behaviour of the four models, he had also plotted the results in various ways, even if he could only present a few diagrams. Lewis' and Otsu's additional plots now gave the reader a better perspective and also indicated that the statements in the paper were not too sweeping.

Otsu's suggestions for further tests were welcome. Additional work on the influence of the period of pitch might also be enlightening. Above all, it would be valuable if one could obtain more observations of the behaviour of fishing boats of the 80 ft. (25 m.) length group in operation, similar to those obtained by Möckel for larger trawlers.

Du Cane had rightly pointed out the sensitivity of low prismatic hulls for trimming. Such hulls require more care in design and in the placing of fish holds, tanks, etc., and too much trim by the bow might arise if fishing conditions are not studied carefully and competent professional advice obtained before construction. A "rule of thumb" boatbuilder, without drawings, but who may be convinced of the advantages of a low prismatic coefficient might easily run into trouble if he changes the shape without taking into account this sensitivity for trimming.

There is another disadvantage. It may be difficult to make good use of the sharp bows of small, low prismatic ships for crew accommodation. Also, because low prismatic ships have to be somewhat beamier to maintain the same stability, the larger beam will increase the scantling number and require heavier scantlings. Simpson showed on page 185 that it did not matter much when the prismatic was varied, but he did not take into account the necessary increase in beam. On the other hand, as low prismatic ships can be driven faster in a seaway, the extra scantlings might not be any harm.

Too little was said about the craze for over-powering of fishing vessels. Proskie's example II was a good one. The ship with the largest engine landed more fish but, as indicated in table 141, the fuel costs were less than those of the lower powered one, so it was evident that the captain had not made full use of his large engine. It had given him only moral backing. If such skippers could be made equally enthusiastic about improved design, transom sterns, bulbous bows and, perhaps, nozzles, and these would give them the same moral backing as the BHP particulars of the name plate on the engine, the owner would at the same time have less investment and less running costs.

Tyrrell stated that a knuckle in the bow at an appreciable distance below deck level gave a very strong top side, and that it provided greater reserve buoyancy. This permitted a greater degree of fineness of the waterline with reduced resistance as a result, and a boat that was drier in a head sea and had easier motions. This confirmed Mr. Traung's experience (*Fishing Boats of the World*, p. 374) and had also lately been confirmed by model tests (Newton, 1960).

Lewis wanted some qualification on the finding of "a prismatic coefficient of .525 to be the best in waves". That meant simply that the power requirement in the operating speed range was lowest when the motions were no worse. The practical limitations were those of trimming and the use made of the end space.

Sea behaviour was not a question of coefficients as such, but of shape and weight distribution, of which coefficients were an expression. More work on the question of supercritical speeds was needed. If investigations should establish that fishing vessels normally work at such speeds in heavy weather in the short waves of shallow water, it would change present ideas about concentrating weights amidships and there would be a better explanation why fishing boats with a low prismatic coefficient, such as the super-trawlers, are so successful.

MR. H. I. CHAPELLE (U.S.A.): The proposal made by McGruer was most interesting. First, however, he wanted to submit that the conventional method (or "grid", as McGruer called it) was almost a world standard and therefore he believed he should approach the matter on that basis or convention. He also stated that it was his considered opinion that no known form of the lines plan, that was useful practically in the mould loft, contained true indications of actual lines of flow or of eddy-formation. The application of McGruer's system, at this late date and some 300 years after the conventional lines plan was first developed, would certainly cause great difficulty in comparative lines analysis. His only personal experience with diagonal, or "normal line" projection produced an unfair hull on the mould-loft floor. Perhaps he was prejudiced, but it did not seem to him that the proposed line system gave sufficient means of form analysis, for the average designer or boatbuilder at least.

In reference to Tyrrell's comments—he did not recommend any amount of flare as a criterion, for the quantity was due to requirements of design established by distribution of weight fore and aft, which he assumed would be determined by design requirements and not wholly free predetermination of the optimum. What he desired to convey was that V-shaped flare was preferable to the usual hollow-V. Rake of the stem, beyond enough for aesthetic purposes, was wasteful of waterline length. He stated that rake was overdone in compliance with a wholly illogical modern fashion. With regard to the "trawler bow" fore section mentioned by Tyrrell, he referred to Gueroult's comments during the first Fishing Boat Congress. This form was not very strong in wood, for the stanchions above the deck or knuckle did not have much depth below the planksheer for strength unless crooks were available. He believed his comment answered Hunter's reference to flare in the fore section.

Any comparison of transom and "cruiser" or "canoe" stern must be guided by the speed-length ratio sought. His contention was merely that the transom, overhung byond the sternpost, was inherently the faster and easiest to design with suitable buttock forms. The requirements for high speed-length ratios on one hand, and of seakindliness on the other, were often incompatible. For the fast boat the transom should be wide at the waterline and flat, or nearly so, in deadrise. The demands for seaworthiness required sharp deadrise in the transom bottom, and high and easy bilges there. In the U.S.A. the stern was more overhung in both transom and cruiser stern, to hood the wheel and in compliance with requirements for high speed-length ratios than seemed to be the general practice in Europe. However, the usual advantage of the transom over the cruiser stern was that the former usually allows flatter buttocks—the exact form of either stern being a matter of decision and compromise—speed to seakindliness.

Chapelle made a plea for more complete lines illustration in model test reports. The average small craft designer had little time for reprojecting sketchy model test illustrations. He strongly suggested that model test reports show ¼ beam buttock form and waterline form as well as profile and body plan. Model test illustrations showing level trim lines but tested with keel drag were most objectionable in lines analysis.

The model test lines illustration should show body-plan with sections perpendicular to load line, the load line in half-breadth, and the quarter-beam buttock profile at least—he saw no good reason why a proper lines plan might not be used to illustrate the hull form—unless information was to be restricted. The usual test report illustration cannot be "refaired" due to lack of longitudinals and the common distortions of reproduction. With regard to conclusions on form drawn from model tests, he suggested that the *number* of models tested was of little account—it was the *variety* of form represented.

Furthermore, he was of the opinion that many models are tested and accepted as worthy of serious discussion, by the present criteria of "hydrodynamic theory", that are very poor designs. This opinion was based upon examination of many tests of fishing boat hulls. If this is possible in model testing, within the criteria of "hydrodynamic theory", it is also possible in actual design using this same guide. The prevalent references to "good" and "poor" design in model report discussions were additional support to Mr. Chapelle's opinion. It seems to follow, then, that "hydrodynamic theory"—as a guide to design and model selection for testing —now requires some additional basis of criteria to insure "good" design being selected in both cases. Unless research reports are in error in the use of "good", and "poor" design there is little practical evidence that the sole answer is given by hydrodynamic theory.

With respect to Inkster's comments Mr. Chapelle believed there is a great difference between the requirements of most motor fishing boats, where relative high speed is usually desired, and those of rowing-sailing craft like the Shetland sixareen and of yachts. Freeboard and flare in the sides of a fishing launch are obviously related and both would obviously be desirable. However, freeboard is commonly limited by use requirements and this is not a matter to be changed by design theory.

Regardless of where the maximum beam is placed at deck, it must be at or abaft mid-length on the loadline to achieve speed and seaworthiness in combination. The fallacy of the full entrance as a prevention of "sailing under" by hard driving in sailing craft was exploded by the middle of the last century. As a matter of fact full-ended heavy displacement sailing yachts tend to "bore" if pushed.

Mr. Chapelle wished to express gratitude to those who commented—particularly as they were all talented, practical and much-experienced designers.

THE CHAIR'S SUMMING UP

PROF. G. P. WEINBLUM, Vice-Chairman (Germany): Problem of resistance (powering) and sea behaviour are closely connected as far as their influence on the development of ship forms is concerned. It is therefore advisable to treat these topics as far as possible simultaneously as done in the present case.

Two aspects of this work can be distinguished: the purely scientific one, which requires that a clearcut problem should be treated in the most general way, and another one reflecting the wisdom of artisanship, which consists to an appreciable extent in appraising or weighing the various requirements involved. To some extent the different attitude of the research and design engineer are described by the two tendencies mentioned. Although problems presented by powering and sea behaviour of fishing craft should be dealt with by general principles used in ship theory, there are mainly two reasons why a separate treatment has been developed: the existance of special practical conditions and the bluntness of forms by which many types of fishing vessels are characterized (large ∇/L^3 or small $L/\nabla^{1/3}$). Fortunately, there was a strong tendency to link up the specialized information with the more general field of knowledge, especially to state as to how far well established general rules can be applied to the fishing vessels. It was his aim to dwell at some length on this topic and he asked for permission to refer to some of his papers perhaps less known amongst the fishing boat experts.

Speaking about ship forms of low resistance, it is necessary to determine the range of speed-length ratios or Froude numbers, $V/\sqrt{L}$ or $v/\sqrt{gL}$, to which our reasoning should apply. The establishment of such ranges for various types of fishing vessels has been emphasized by Traung (1955) as a prerequisite for useful discussions. The present discussions should be restricted to those forms which are operated in the range of the so-called second hump of the wave resistance curve and the adjacent hollow, i.e. below $V/\sqrt{L}=1.1$ or $v/\sqrt{gL}=0.33$. Up to this limit the *sectional area curve* A(x), the curve of the longitudinal displacement distribution, is the most decisive form characteristic of a hull; although this statement applies to displacement vessels in general, at higher Froude numbers hulls with chines become competitive and the design of the latter may become extremely important. In general one tries to avoid operating commercial vessels above $V/\sqrt{L}=1.175$ or $v/\sqrt{gL}=0.35$, i.e., in the speed range corresponding to the rise of the "first hump"; a class of fishing vessel presenting an exception is treated in the paper by Gillmer. Professor Weinblum did not feel competent to suggest eliminating this exception by slight reduction of speed and increase in length. The development of ship forms in this higher range of Froude numbers is a thrilling subject and more problems are still left open than in other domains.

The preceding remarks made use of the fact that because of the high volume coefficient ∇/L^3 and relatively high Froude numbers the wave resistance was a decisive element in shaping hull forms of fishing vessels. The *hydrodynamic* theory of wave resistance presented, therefore, a valuable means of understanding the phenomena involved, notwithstanding the shortcomings of the former, especially when blunt (flat) forms were involved (Weinblum, 1959). In the light of hydrodynamic theory many populer ideas on advantageous hull forms lost their significance as far as wave phenomena are concerned. Conditions were different for the viscous pressure resistance (eddy resistance in Froude's nomenclature). It was suggested that more data should be collected by known methods dealing with the total viscous drag of fishing vessels.

The sectional area curve is a means of describing some of the most important hull properties, and the prismatic coefficient φ is only one though precise parameter determining the sectional area curve. Therefore doubts expressed by various contributors as to the sufficiency of φ in hull description were legitimate. However, theoretical considerations which were well supported by general experimental evidence proved that in the actual speed range for fishing vessels the prismatic coefficient was the most important form parameter when dealing with the resistance of good forms. To avoid a vicious circle, the question must be answered: how can "good forms" be determined? In principle this answer could be given by hydrodynamic theory. The well established concept "hydrodynamic theory" should be substituted for the somewhat nebulous designation "mathematical approach", within the range of its limited validity (Weinblum, 1957). For research and design work empirical methods are frequently but not always used to find "good" lines. When planning systematical model series it was customary to start with a parent form and to keep the shape of sections unchanged, while varying the longitudinal displacement A(x). In developing, for example, the Series 60 sectional area curves, A(x) for various block (prismatic) coefficients were derived from empirical material so that good resistance properties might be expected. The same applied evidently to Taylor's Standard Series. There are well-known geometrical methods by which the A(x) of the parent form can be transformed in such a way that a prescribed new prismatic is obtained. The shortcoming of these methods—of the simplest one, the so-called l-prismatic (l-φ) method, and of another one—was pointed out by Traung. Obviously, curves designed from the point of view of expediency in determining a fixed area can fail completely from the point of view of resistance even if the starting curve was good.

The description of resistance properties of a sectional area curve by Taylor's tangent value t, as a second parameter, was useful but not yet always sufficient, even leaving aside full forms with parallel bodies (Weinblum, 1957). This led to Doust's statistical methods which, in Professor Weinblum's opinion, filled out a large gap in the evaluation of resistance data. This referred especially to form parameters, the influence of which could not at the present be dealt with by hydrodynamic theory, such as the optimum LCB position. Although it was to be expected that semi-empirical "theories" based on systematical experiments would reduce the need for a statistical approach, the stimulating effects of the latter should be highly esteemed. The objective attitude of Doust precluded the necessity to dwell upon the shortcomings of the analysis so far carried out, like the omission of the t-value (in addition to α_e!) and the statement regarding the influence of β which though restricted, could be estimated reasonably well by theory.

In appraising the influence of the LCB position, R. E. Froude's hypothesis on the preponderance of the forebody with respect to wave making was a useful heuristic approach. It explained not only the need for fining the forebody at the expense of the afterbody ($\varphi_f < \varphi_a$) in the speed range considered as long as the actual φ was larger than optimum φ, but helped to solve still more intricate problems, dealing with the shape of the lines involved rather than with prismatic (Weinblum, 1938). Recommendations as to the optimum LCB position had to be given in detail with respect to speed and form parameters.

Possibly in the field of fishing boats a similar erroneous approach had developed as earlier in the design of some liners, i.e. to choose too high prismatic coefficients. The Congress had contributed appreciably to the clarification of the situation.

Two papers and several substantial discussions were devoted to the bulbous bow problem. Those valuable communications indicated that by and large results derived for shapes of ocean vessels could be applied to fishing craft forms, well known experimental data as well as less known theoretical ones (Weinblum, 1934). The latter could be summarized as follows:

- The effect of the bulbous bow could be essentially explained by the change in the *sectional area* curve caused by its application. The pear-shaped forms of the *sections* was accidental (or even detrimental) from the resistance point of view, but essential to avoid spray.
- The speed range considered $V/\sqrt{L}=.84$ to 1.3 ($v/\sqrt{gL}=0.25$ to 0.33)—and considerably beyond—was in principle suitable for a bulb application
- The effectiveness of the bulb depended upon its "strength", measured for example by Taylor's "f" ratio, and the shape of the basic sectional area curve; with increasing φ and decreasing t (increasing hollowness), the effectiveness increase for a given f, respectively higher f values became advantageous. Further, if two "normal" A(x) with equal φ and t were given, there were reasons to expect that by applying the same bulb in both cases stronger improvements would be reached for the inferior normal A(x). Within the speed range considered there existed good "normal" sectional area curves (ship forms) with low φ, suitable t and duct of line, such that no appreciable gain by a bulb was to be expected. These conditions were reached for example by a good form with $\varphi=0.56$ and $t=1$, while for a closely resembling A(x) the use of a bulb led to an improvement (Weinblum, 1938)
- For the sake of curiosity, it was mentioned that the application of an additional *stern* bulb resulted in a further improvement. So far a practical solution for the latter had not yet been developed. Summarizing, the bulb might be a valuable means to improve sectional area curves which for some reasons departed from the optimum, from the resistance point of view, especially because of excessive prismatic coefficients.

The papers and discussions proved that the appraisal of seagoing properties of ships was fortunately losing its mystical character nourished by practical people especially in the field of small craft. At the same time a gratifying modesty in scientific claims forwarded by the authors was acknowledged —a fact which differed so favourably from the earlier habit of immediately presenting "final" solutions. Traung had put forward as an urgent topic the discussion of a fishing vessel's behaviour in an *irregular* seaway. The quantitative treatment of the latter problem (theoretically and experimentally) had decisively contributed to the de-mystification mentioned before and established confidence in the applicability of pertaining studies to practice. However, because of the large number of problem parameters involved and the numerous inherent difficulties, it was Professor Weinblum's contention that simplified investigations in calm water and in regular seaways should be stressed at the present to establish explicit dependencies upon form, mass and wave properties. As long as investigation is restricted to small ranges of main variables, *contradictions* in "conclusive" practical results were almost inevitable, not to mention the lack of accuracy in experimenting as a source of possible errors. As to concrete results the properties of U and V sections and of the bulb were re-established (Kempf, 1935); this meant that the prejudice against the latter was destroyed. The statement regarding a strong influence of a large flare—Taniguchi's paper on motions—disagreed, however, somewhat with earlier findings (Perelmutr, 1946). It was quite natural that the superiority of fuller ends with respect to motions had not yet been established, although considerations on damping and exciting forces (in large waves) favoured this solution.

It was noted with satisfaction that more emphasis was laid again on the investigation of resistance increase. The big surprise was the discovery—by Vossers and his collaborators —of resistance *decrease* when heading into medium length shallow waves. The theoretical support claimed for this effect referred to the discusser's knowledge to forced oscillations in *calm* water; following Eggers (1959), this effect disappeared in *waves* of normal steepness.

STABILITY

Prof. G. P. Weinblum (Germany): In his great memoir presented to the INA 1898, A. N. Krylov promised to solve the problem of transverse stability in a seaway. Neither he nor his followers so far have reached this goal. However, earlier attempts to find approximate solutions now became more successful. Paulling demonstrated firstly that for unusual ship forms the routine stability calculations might fail even for calm water conditions, thus indicating the need for a "three dimensional" treatment. Secondly, he presented a comparison of Reed's diagrams for ships moving normally to wave crests obtained by hydrostatic calculations and model experiments. The heavy reduction in the magnitude of stability levers, as compared with routine calculation results, agreed well with earlier findings and was of primary practical importance.

Wendel had started a rather ambitious programme on stability research based on calculations, model experiments and full size investigations. The dynamic facility mentioned was a promising ingenious contribution to the field of fishing boats, notwithstanding possible minor trouble due to damping effects. Pertinent investigations, as well as corresponding ones on the actual loads experience by a ship, were necessary prerequisites for working out reasonable stability standards on which the safety of ships depended to an appreciable extent.

Mr. D. S. Simpson (U.S.A.): Möckel's paper on the use of the rolling period as a handy safety criterion, and at the same time an indication of most "agreeable" rolling was an excellent one. Unfortunately it was difficult to apply in New England. Since 1930, and after considerable experience with the U.S. East Coast fishing fleet, he had been able to make inclining experiments on only four designs (from which 14 vessels had been built). By the time a vessel reached the stage where an inclining test was possible the owner was too anxious to put her to work. No argument will persuade him to spare time for the test.

Except for trials, it was almost impossible to get a passenger aboard a fishing vessel so that the determination of rolling periods was equally difficult.

Skippers and engineers appeared to be poor observers. Over a period of five months, in an attempt to get data for this discussion, he selected six vessels reputed to be good or bad performers, carefully instructed the skippers and provided them with stopwatches, only to get two useful reports (none of these boats had been inclined). Both were for "good" boats and both plotted nicely between Möckel's two "good" lines.

Of the four boats inclined (no roll periods available), one with a ready for sea GM of 2.22 ft. (.676 m.) and a return to port GM of 1.32 ft. (.402 m.) was treated to an unknown quantity of additional ballast by her captain. Another with GMs respectively 1.65 ft. (.503 m.) and 2.10 ft. (.64 m.) was also given additional ballast after a couple of trips.

The other two, known as "good" boats, had GMs varying between 2.02 ft. (.615 m.) and 2.31 ft. (.705 m.) and also plotted nicely between the Möckel's "good" lines.

Although sparse data, all this appeared to confirm Möckel's conclusions and indicated, at least tentatively, a rule-of-thumb criterion to the effect that no fishing boat, under any condition, should have a GM of less than 2.25 ft. (.685 m.), nor more than 3 ft. (.915 m.).

Based on a short investigation, that figure seemed to leave plenty of room for the winter icing up.

It was encouraging to see several papers concerned with freeboard. Too little attention had, in the past, been given to this most important ingredient of a comfortable and safe ship. Many European trawlers appeared to have very little freeboard. The U.S. pre-war vessels, and many of those built in the late forties, had very little freeboard. This was probably a carry-over from the old dory days when fish had to be lifted over the side, and dories hoisted aboard. Since dories, fish and nets were no longer manhandled there was no reason for the low freeboard, wet vessel of bygone years.

Old vessels, from 110 to 150 ft. (33.5 to 45.7 m.) long, coming in with freeboards of 12 in. (.3 m.) or less had to stop fishing early through the winter months to be safe. Modern 115 ft. (35 m.) vessels came home with a full trip of 350,000 lb. (156 tons) and had still a freeboard of 3 to 3.5 ft. (.9 to 1.07 m.) —and the crews liked them. They had a much greater range of stability. They could fish in rough water when other vessels had to quit. They were much dryer on deck and did not ice up as quickly or as much. The greater freeboard usually carried with it slightly greater beam and probably a bit more in cost, the greater safety and comfort of the crew was well worth the change.

CAPT. S. REMØY (Norway): During the herring season of last winter he had had the opportunity to make eight rolling tests with typical fishing vessels in his home port.

As time, during a very hectic fishing season, is a limiting factor, he never had the opportunity to do many extensive tests. For instance, he would have liked to make rolling tests on each ship in several conditions:

- Empty without ballast
- Empty with ballast
- Loaded with fishing gear on board and all tanks hardened up

The tests were made with empty ships with their purse-seine nets and net-dories on board; some fully bunkered, some not. But all was ready for fishing. The conclusion was that the rolling method was a convenient, informative and proper aid to the skipper as to the stability condition.

The interviews with the skippers about stability and behaviour in a seaway confirmed the results from the rolling tests.

He hoped to incline at least five of the ships investigated in order to find the centre of buoyancy and the GM. When this was done, one could arrive at more dependable conclusions.

The formula used was:

$$GM = \left(\frac{0.4 \times B}{T_r}\right)^2$$

where 0.4 is a constant factor m

B is the beam in ft. midships and it was taken from the tonnage certificate

T_r is the time of the rolling period over-and-back in sec.

All ships had their net-dories in the davits—with or without a purse-seine in them; if not in the net-dories, the purse-seines were placed either on the main deck or on the boat deck, or one purse-seine would be on deck and the other on the boat deck. The net dories weigh approximately 7,200 lb. (3,200 kg.). The "fish-detecting boat" weighs approximately from 2,400 to 3,300 lb. (1,100 to 1,500 kg.). The approximate weight of a purse-seine is 4,400 lb. (2,000 kg.)—the average weight being about 2.5 tons. In a wet condition the purse-seine is said to double its weight, but this was difficult to confirm.

At least two tests were made in order to check the rolling period. Thus, if listing the ship to starboard the trigger of the stop watch was only pressed when she had rolled over to port side. All tests were made in good weather conditions in the harbour and the skippers were all very helpful and showed great interest. All tests were made using the "fish-detecting boat" as listing weight. The results were:

TEST 1

179 GT—58 NT

L=110 ft. (33.5 m.); B=20.5 ft. (6.25 m.); D=10.7 ft. (3.26 m.)

520 h.p. diesel (18 tons)

Oil bunkers: 10 tons (can take 18 tons)

Water ballast: 19 tons below crew quarters forward from bow to two frames aft of crew quarters bulkhead.

Nets: One on deck—dry; one on boat deck—dry; one in the net-dories—wet.

Rolling period: 11.5 sec. GM=0.51 ft. (.155 m.)

The ship could heave one net-dory without difficulties. Master complained about low speed. 520 h.p. should give considerably more than 9.5 knots. Behaved fine when wind and sea abeam but bad with sea on the quarters.

TEST 2

172 GT—84 NT

L=117 ft. (35.7 m.); B=20.7 ft. (6.3 m.); D=12 ft. (3.66 m.)

300 h.p. diesel

Oil bunkers: 8 tons (can take 18 tons)

Fresh water: 1 ton (can take 2 tons)

Ballast in fish hold: 30 tons

Nets: One purse-seine on boat deck—dry

Rolling period: 7.5 sec. GM=1.26 ft. (.384 m.)

The ship could heave one net-dory without difficulties. Skipper said she was too stiff when water tanks and oil bunker tanks were all filled and when the net-dories were *not in the davits.*

TEST 3

154 GT—68.5 NT

L=112 ft. (34.1 m.); B=21.85 ft. (6.66 m.); D=8.5 ft. (2.6 m.)

180 h.p.

Bunkers: 7 tons (can take 15 tons)

Water: 11 tons (can take 14 tons)

Ballast: 2.5 to 3.0 tons in the fish hold, covering the keel only

Nets: Two on boat deck—one dry, one wet

Rolling period: 6.5 sec. GM=1.8 ft. (.55 m.)

She could take one net-dory without difficulties. This ship is an old Dutch trawler with a small draught. Skipper very happy with her.

TEST 4

92.72 GT—27.2 NT

L=81.1 ft. (24.7 m.); B=19.2 ft. (5.85 m.); D=9.6 ft. (2.93 m.)

Bunkers: 2 tons (can take 9 tons)

Water: 2.6 tons (can take 3 tons)

Ballast: 20 tons in the fish hold (from end to end)

Nets: One on the boat deck—wet; one forward on deck—dry

Rolling period: 7.6 sec. GM=0.96 ft. (.292 m.)

Ship could not heave single net-dory, without hooking on other side. Skipper very satisfied: she was easy and gentle. Processing work (in open sea) not delayed by rolling.

TEST 5

179 GT—81 NT

L=119 ft. (33.2 m.); B=22.33 ft. (6.8 m.); D=9.5 ft. (2.9 m.)

240 h.p.

Oil bunkers: 5 tons (can take 9 tons)

Water: 5 tons (can take 5 tons below deck)

Ballast: 15 tons in hold

Nets: One net in the net-dories

Rolling period: 5.8 sec. GM=2.37 ft. (.723 m.)

This ship could take one net-dory without any difficulties. She was rather stiff.

TEST 6*

? GT— ?NT

L=107 ft. (32.6 m.); B=20.33 ft. (6.2 m.); D= ?

Oil bunkers: 15 tons all tanks filled

Ballast: 20 tons in the fish hold

Nets:

Rolling period: 10 sec. GM=0.66 ft. (.209 m.)

This ship could not take one net-dory without capsizing—the ship had to be hooked on the other side before heaving. When doing the test, the net was in the net-dories (wet). Skipper said he had to be very careful with the ship when the net-dories were in the davits in order not to capsize her.

TEST 7*

138 GT – 60 NT
L = 106.33 ft. (32.4 m.); B = 19.5 ft. (5.95 m.); D = 10.1 ft. (3.08 m.)
240 h.p.
Bunkers: 6 tons (can take 12 tons)
Water: 0.5 tons
Ballast: ?
Nets: Two on boat deck—wet
Rolling period: 9.4 sec. GM = 0.69 ft. (.210 m.)

The skipper said he had some ballast in the fish hold. There was no time for a proper interview before ship had to leave, but skipper said he had to be careful while the net-dories were in the davits. Knife and axe were always ready near the davits in case they were needed. She could not take one net-dory without capsizing.

TEST 8

78 GT – 25 NT
L = 75 ft. (22.9 m.); B = 19.5 ft. (5.95 m.); D = 10 ft. (3.05 m.)
180 h.p.
Oil bunkers: 6 tons (can take 8 tons)
Water: 3 tons (filled up)
Ballast: None in fish hold
Nets: One in the dories and one on the boat deck—both dry
Rolling period: 7.7 sec. GM = 1 ft. (.305 m.)

This ship could not take one dory without capsizing. She was very nearly the same form and dimensions as one that capsized in the open sea on her way homeward in ballast. All hands were lost.

The GM value of test 1 is possibly too low because the skipper said he could heave one net-dory (weighing over 4 tons) in the davits without capsizing the ship. The weights on board were:

Engine	18 tons
Oil	10 „
Ballast	19 „
	47 tons

No ballast was placed close to the keel.

Another very similar ship, test 2, which was tested under the same conditions, had 50 tons on board:

Engine	12 tons
Oil	8 „
Ballast	30 „
	50 tons

The ballast was close to the keel, in the fish hold. Here the skipper complained that she was too stiff when the net-dories were not in the davits.

The results indicated that the m-factor 0.4 was too low for a purse seiner with dories. The radius of gyration was at its maximum when the net-dories were in the davits with half the net in each. Takagi reported quite large variations in the m-factor, ranging from 0.32 to 0.49 or even more. It should therefore be of interest to have his opinion as to the masts, rigging, weight of superstructures on board the ship concerned in his paper in order to have a discussion on the variation of the m-factor.

* Formerly old British trawlers re-built for purse-seining and longline fishing. Their hull shape and dimensions are almost identical.

The m-factor was bound to cause errors as it would not be the same for ships with different fishing gear and rigging: this was most obvious in the case of purse-seiners.

However, if the m-factor was clearly determined for a special type of fishing, such as purse-seining, longlining or drifting, then one should have quite good criteria for an easy check of stability when needed.

A large number of Norwegian fishing vessels were operating with very low GM values. Shippers could not use ships with very high values, as those ships were too lively and delayed processing work at sea by as much as 40 per cent.

Hailed as a classic paper

MR. A. HUNTER (U.K.): Yamagata's (1959) INA paper would be a classic on the treatment of stability for years to come. It concerned passenger vessels, and there were some difficulties in applying such stability calculations to fishing vessels because of their lack of space, different loadings, varying weather conditions, etc. Above all, there was the spirit of adventure of the fishermen, who would not study the underlying principles.

In Britain the freeboard used to be low. The naval architect was criticized for giving too stiff a boat if he provided a ship with a high freeboard for stability reasons. The BSRA icing experiments helped enormously: they were actually supervised by an experienced trawler skipper. As a result it was found that bigger ships with greater freeboard and a higher metacentric height performed very well.

Some vessels did not have to face icing conditions. It was not the black frost which started to build up on the mast and rigging that counted, but the getting into conditions of sea and the critical air temperatures, whereby keeping head on into the seas, the spray with the aerodynamic effect of the hull sprayed it high on the superstructure and the weights built up rapidly. With better weather prediction it was hoped that skippers would take early note of icing condition and turn round quickly to get the weather astern. No ship could survive heading into such conditions as with increased list due to weight of ice high up the effect of rudder would become less and less.

The arrangement for fishing on one side only had also helped, as with accommodation on the port side from the stern side almost to amidship, a high shoulder was given to come round against the bad weather. Under a variety of conditions, obviously different ships would require different treatment. The near-water ships would not, perhaps, require the same provision. Without the space to give, perhaps, the safety factors, one would like to build in, say, a tank high up which could be filled in normal conditions and emptied or transferred to a bottom tank when ice started depositing. This, like all shipbuilding, was a matter of compromise. One did not want to saddle the ship with too much weight and thus reduce the speed or increase fuel consumption.

He returned to his plea for more education of the operating personnel as to what stability meant. Many skippers thought that their ship was stiff when in fact it was not so, and the converse applied.

The stability paradox

PROF. DR. J. RAHOLA (Finland): Möckel had collected interesting facts concerning the value of the metacentric heights of trawlers, and the crew's view of stability and behaviour of the ships. In other papers also the importance of metacentric height was discussed at some length. On account of this there was good reason for saying a few words of warning.

Low metacentric height made a ship really tender, but in heavy seas it might also give the crew a feeling of security which did not exist. The known fact was that a tender ship did not always roll even in the high waves as heavily as a stiff ship with a greater GM. This is the well-known paradox of stability which might be dangerous. Therefore one ought to avoid judging stability only on the ground of metacentric height. The other factors of a ship's form, especially the freeboard and the stability arm curve, must be taken into consideration. According to his experience, it had often occurred that the ship's captain had made an error in his judgement of the ship's seaworthiness when he had based his opinion on the the ship's rolling in waves. The misjudgement had even reached such a point that the captain had argued that his ship was very seaworthy although, as a matter of fact, her stability had been so poor that her capsizing had only been a question of time.

Professor Rahola had not had the opportunity to investigate more exactly the Japanese method of judging the stability of fishing boats and other small ships presented by Takagi, but he had reason to suppose that the Japanese method was not as strict as his. Takagi said that "it is very difficult to fulfil a value of statical stability arm greater than .66 ft. (200 mm.) in the condition of 30 or even 40 degrees of inclination" as Professor Rahola had proposed. It should be noticed that in addition to those values the stability of ships could and must also be judged on the basis of the dynamical stability arm at a certain predetermined angle of inclination (at maximum 40 degrees) so that the dynamical arm ought to be at that point at least 3.15 in. (80 mm.). This dynamic judging method afforded greater freedom to determine the other factors of stability—including the metacentric height—than the statical method. That is why the dynamical method, in his opinion, was preferable.

If the Japanese method really was less strict, there was reason to fear that it was too low. He knew, for instance, that his method was less strict than that required by the Russian regulations of 1947. The new Russian regulations of 1956 were somewhat easier to fulfil than the old ones, but they too were stricter than his. In Finland many ships had been constructed according to the Russian regulations and there had been many difficulties in fulfilling them. The demands of his method did not cause any difficulties as to those ships. Therefore he felt that one ought to be very careful about the judging of stability if the regulations were not at least as strict as his dynamical method.

In conclusion, he wanted to support Takagi's proposal that FAO should organize a committee to promote the safety of fishing vessels. He hoped that in the work of that Committee special attention would be paid to the causes of ships capsizing and to their stability.

Russia's stability regulations

MR. A. F. JOUDINSTEV (U.S.S.R.): The U.S.S.R. fishing boat authorities considered that the stability of fishing vessels was a matter of the greatest importance. It was for that reason that, after extensive theoretical and experimental work, the U.S.S.R. introduced at the beginning of 1931 special standard regulations, the need for which had been clearly indicated at the Congress.

MR. F. MINOT (U.S.A.): Takagi had made a valuable contribution to the difficult problem of providing and maintaining adequate stability in fishing vessels. It was to be hoped that the increased freeboard and improved watertight integrity in large trawlers, made possible in stern trawlers, might be attained in some similar manner on small trawlers and other small fishing vessels.

In view of the amount of water which was apt to be present in the fish hold and bilges of small fishing vessels, was a loaded GM of only 2 ft. (.6 m.) likely to care for the occasionally large free surface effect? Takagi's comment on this would be very much appreciated.

The discusser strongly endorsed Takagi's suggestion that FAO should organize a committee on fishing vessel stability.

MR. O. JABLONSKI (Poland): Takagi in his paper proposed a very interesting system of simplified criteria for a combined regulation of stability and freeboard. Those criteria were based on a study of statistics for a number of existing ships. The question arose, however, whether the approximate estimates in those proposals were not far-fetched.

For example, Takagi assumed that in order to take into account individual stability characteristics of different ships it was enough to use an index of the type $GM/BG \times 2f/B$. That approximate estimate was, however, too inaccurate and did not take into account the considerable differences in the shape of the underwater hull as well as of watertight superstructures.

Probably it was not necessary to reckon the forecastle in the buoyancy lever, but all other superstructures had to be included in the calculations, at least as high as the coamings. In addition there was the important matter of whether the cross dimensions and shape of the ship were correctly designed.

Takagi assumed that the approximate influence of external forces (especially wind) might be considered as inversely proportional to the vertical distance between points B and G. For ships of the same type and materials, that approximation might be satisfactory. If, however, the present possibilities of using superstructures of light materials (aluminium or plastic) were considered then the index numbers suggested might prove insufficient.

Generally speaking, the simplification proposed was attained by sacrificing accuracy, so important to the safety of the ship. Takagi's criterion might lead to an increased deadweight for poor stability ships and to a decreased deadweight for good ships. So the question arose as to whether it was necessary to deviate so far from the exact methods.

Although the indexes were very simple in form, making use of them required almost all theoretical ship calculations, e.g. there must be hydrostatic curves, Bonjean scale, load calculations for various conditions of displacement and KG and GM.

The only thing not necessary were the cross-curves of stability (levers of buoyancy forces). In Mr. Jablonski's opinion, the design of ship lines with cross-curves calculation should always be checked, the more so as that could easily be done with the help of calculating machines. It could be assumed that cross-curve calculation would gradually be used for the smallest units. Then the minimum of stability could be determined easily and accurately on the basis of the righting arm curves (GZ).

As to matters relating to methods of combining regulation of stability minimum and freeboard minimum, Mr. Jablonski's proposals furnished a simple way of solving the problem on the basis of KG_s and KG_o curves.

It might be added that owing to an ever increasing practice of measuring rolling periods, a return to the traditional judgement of stability with the help of metacentric height (GM) was noted. But that renascence of the GM was probably a passing one. On principle, however, judgement of stability must be based on righting arm curves which depended less on GM than on cross-curves and KG.

As to the possibility of approximating stability from the measure of rolling periods, special calculations might also be prepared for the master of the ship which would enable him to find not GM but the KG value.

He added that, on the basis of his own paper on the graphical method called "The radial analyser of ship's stability", it was possible to construct a very simple instrument for the mechanical modelling of the righting arm curve, for every load condition. It was only necessary to set this instrument to the proper displacement and KG.

Differences noted

Mr. F. Thiberge (France): With reference to Takagi's paper he noticed that there was a very great difference in the length between the short French and long Japanese boats when considering freeboard.

The French wooden boats are too small to have an international freeboard, yet under French law they are now forced to have freeboard marks when the gross tonnage exceeds 25 ton. The ratio between overall length and moulded depth varies, generally speaking, from 5.5 to 7.5.

Takagi mentioned that the freeboard from the regulations of the Japanese Fisheries Agency, in relation to moulded depth, was 1:15 of the moulded depth + 8 in. (20 cm.). The freeboard allowed to French boats by Bureau Veritas seems to be slightly greater than that envisaged by these regulations. But above all, the difference seems great if the freeboard is related to the length of the boats. This ratio, together with certain sheer requirements, may be the cause of the boats tendency to become submerged and lost stability in rough seas. Then the ratio of the freeboard to the length of many Japanese boats seems very small.

It is to be hoped that research on ship behaviour in rough seas will make rapid progress. For the present, however, it seems extremely complicated to deal simultaneously with the freeboard of very short and very long boats, which really depends on the very different techniques employed.

Mr. J. G. de Wit (Netherlands): Takagi suggested an international stability standard, and Jablonski suggested an international freeboard standard for fishing vessels. Takagi further suggested that FAO should organize a standing committee to promote the safety of fishing vessels and to study the subject. The discusser had been informed that it was not within the scope of the Congress to organize such a committee; the only thing the participants could do was to ask their respective Governments that the Government delegates to the next FAO conference would be entitled to ask FAO to organize such a standing committee. He recommended the participants in the Congress to submit to their Governments the points which Takagi and Jablonski had raised.

He agreed with Jablonski that fishing vessels were little affected by the 1948 International Convention on Safety of Life at Sea; he supposed however, that they would be by the next one. Fishing vessels were not dealt with by that Convention. Every Government was completely free to declare resolutions of that Convention to be enforced for fishing vessels.

In the Netherlands it was usual to allow the man on board the fishing vessels to participate in the benefits of those international treaties regarding safety and related matters. The only exceptions were the freeboard regulations and therefore he wanted to support Jablonski's suggestions on the study of freeboard regulations. He did not agree with Jablonski that no satisfactory solution to safety problems could be expected from national regulations, as was stated.

As Mr. de Wit had said in Paris in 1953, the Dutch started to use the Rahola criterion as a standard and they were still using it. The Rahola criterion fulfilled their expectations completely. In the Netherlands they did not want another stability standard and they would go on with Rahola's for the time being. However, there was the question of stability in waves. It would be desirable to extend Rahola's work from smooth water to waves and to see whether a review of his standards became necessary.

Prof. Ata Nutku (Turkey): The initial stability in calm water cannot be a true criterion for a boat's behaviour and performance at sea. Even when cruising in calm water, the distorted surface at the waterline and the variation of pressure distribution along the hull influence the righting moments. In a seaway, the forces tending to heel and trim the boat have

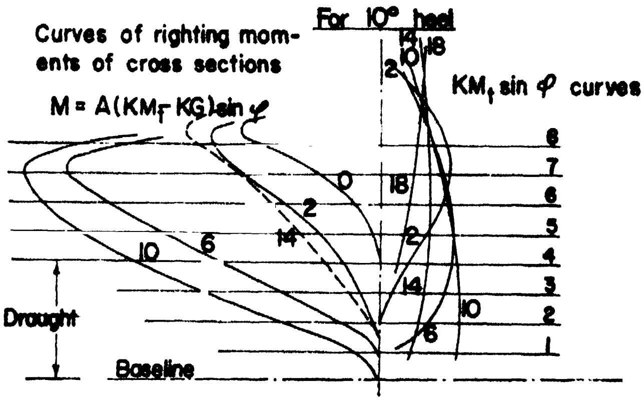


Fig. 625. Calculation of the contribution of each section to the total righting moment

widely varying values. Dynamic pressures created along the bottom and sides of the hull when rolling, pitching and heaving affect the buoyancy and righting moments, according to the position of the boat in the waves. Graff and Heckscher (1941), Stenvaag and Garberg (1953), and Paulling (1959) observed changes in the stability of models at speed.

It has been the practice in the Turkish Tank to investigate form stability by ascertaining the contribution of each section to the total righting moments. This gives an idea of the stability efficiency of each section at different draughts and heel angles. This contribution is restricted to hull-generated waves, as it is impossible to consider at present the influence of pressure distribution in seaways.

For this purpose, $KM_t \sin \varphi$ values of the horizontal projection of distance from keel to metacentre are plotted on respective waterlines and heel angles, a shown in fig. 625. By multiplying these values by the corresponding areas, the righting moments are obtained:

$$M = A\,(KM_t - KG)\sin\varphi$$

M, the righting moment curves, are also drawn in fig. 625 and 626. The contribution of the forebody of $^1/_5$th ship length is negligible in normal waterlines. The righting arm curves at

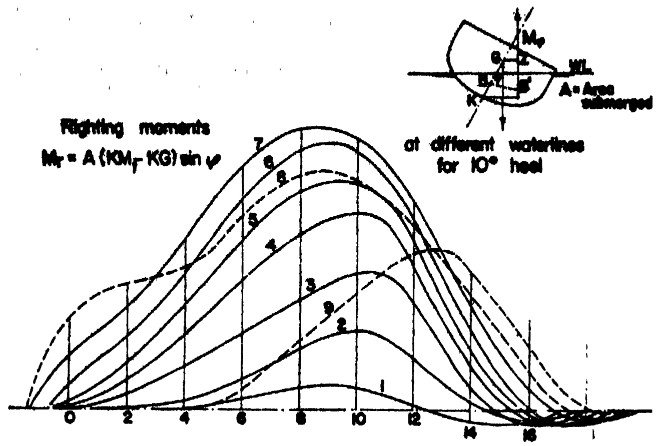


Fig. 626. Righting moments for different water lines at 10° heel

different speeds are shown in fig. 627 as obtained from fig. 626. The loss of stability for hull-generated waves at $V/\sqrt{L}=1.4$, 1.2 and 0.9 is 10.2, 6.4 and 12 per cent. respectively. If the boat is lifted by a stern wave, as shown in fig. 627, the stability loss amounts to about 13 per cent. It appears from fig. 626 that most of the stability is contributed by the middle body in this type of boat, which has a shallow draught and wide beam, and, contrary to the normal type of ship, the wave condition amidships seems to be critical. For comparison, the $KM_t \sin \varphi$ and M curves of rectangular and triangular sections are reproduced in fig. 628.

Prof. J. R. Paulling, Jr. (U.S.A.): The stability curves, fig. 629 and 630 were presented as additional evidence to support the contention that the tuna clipper stability problem differed from that of vessels of more normal form. Those curves consisted of dimensionless righting arms in the form of the ratio of righting arm to beam vs. the heel angle for three tuna clippers and two New England trawlers. The initial GM was taken as B/10 in each case.

In fig. 629 the statical stability curves in calm water were given, the solid curves being computed in the conventional manner by the method of cross-curves and the dashed-curves by the method outlined in his paper. A comparison of the two stability curves for each of the two trawlers showed that the conventional method yielded satisfactory results for this type of vessel. That result might have been expected since the dissimilarity between the fore and after bodies was not excessive in the case of a trawler of normal form and arrangement. For the tuna clippers, in every case, the method permitting trim yielded lower righting arms than were obtained by the conventional method. In addition, the maximum righting arms were considerably less than those of the trawlers in all cases. The reason for the first of those effects was given in the paper. That was the extremely dissimilar fore and after bodies of the tuna clipper resulted in trim as the vessel heeled, and a consequent reduced righting as compared with that obtained by the conventional computation. The deficient maximum righting arms characteristic of tuna clippers resulted from the extremely low freeboard possessed by those vessels over a major portion of the length.

Fig. 630, giving righting arm curves for the same example when on the crest of a wave of length equal to ship-length, further emphasized the deficiency of the tuna clippers as compared to the trawler forms. It should be further noted that the stability reduction in waves was an absolute quantity, not a percentage of the calm water righting arms. Therefore, for lower GM values than those illustrated, the tuna clippers would compare even more unfavourably.

Since a GM of B/10 represented the upper bound on the range of values encountered in service with those vessels, it was seen that fig. 630 gave a conservative comparison of the two types and in practice the tuna clippers might well be worse off than indicated there.

It could be concluded, therefore, that the number of those vessels lost as a result of capsizing was not greater primarily because of the moderate weather and sea conditions characteristic of the areas in which they operated.

Mr. H. C. Hanson (U.S.A.): He felt that some good thinking was required in fishing boat designs. Many boats were often loaded so heavily with fish that the water came on to the deck. The papers of Paulling and Wendel took care of certain parts and left the rest to the human factor. As regards the liquid cargo in the boat, if a loadline was established, many people might go out of business. People fishing in the North Atlantic were not faced with that problem.

Swedish use of ballast

Capt. H. Hansson (Sweden): The goal of the Congress was to get lighter, cheaper, speedier and safer fishing vessels. It had been rather a shock to him to hear about so many accidents in different countries. He knew that accidents to Polish and Icelandic fishing boats had been caused by lack of stability. However, the Swedish trawlers operating in the North Sea and the North Atlantic under very severe weather conditions had not had any capsizings. The Swedish boats were not necessarily better boats, but they had a very low frequency of accidents, possibly because the boatbuilders

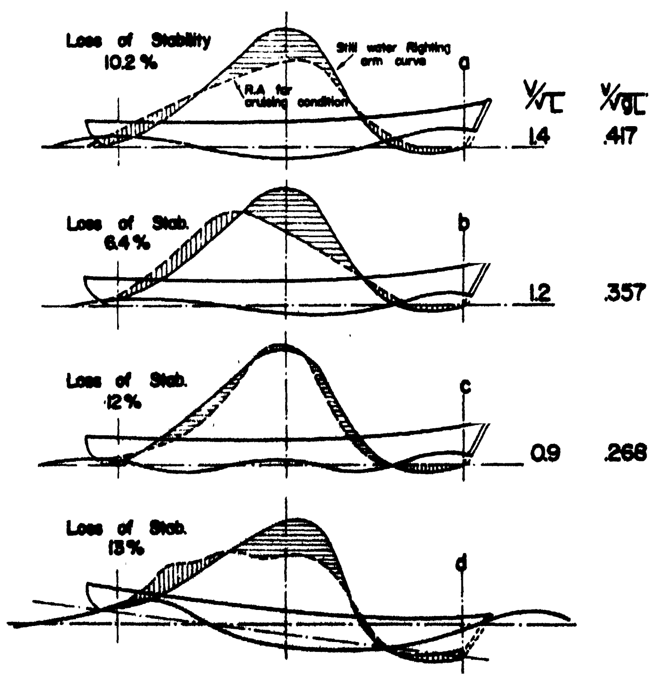


Fig. 627. Righting arm curves at different speeds and (d) when lifted by a stern wave. Full lines corresponds to stationary ship

added a lot of permanent ballast. In the midwater trawl fishing, they got heavy catches of up to 15 tons in one haul. Therefore, it was difficult to find a compromise for a good platform to work on and adequate safety, and at the same time have economical propulsion.

Model tests had been made in Sweden but no authorities' advices or instructions based on the results from these tests had been given to boatbuilders and fishermen to help them to design and build more economical boats. The Swedish boats sailed far, and it was important that they went to the grounds in the lightest condition. On the fishing grounds heavy loads were added and they were also subject to icing: it was then that the ballast was necessary. Hunter's ballast tank suggestion would be one way to solve that problem. Captain Hansson asked if possibly a bottom tank could be a solution but then it is necessary that the crew be educated how to handle it. He did not think that any international rule could

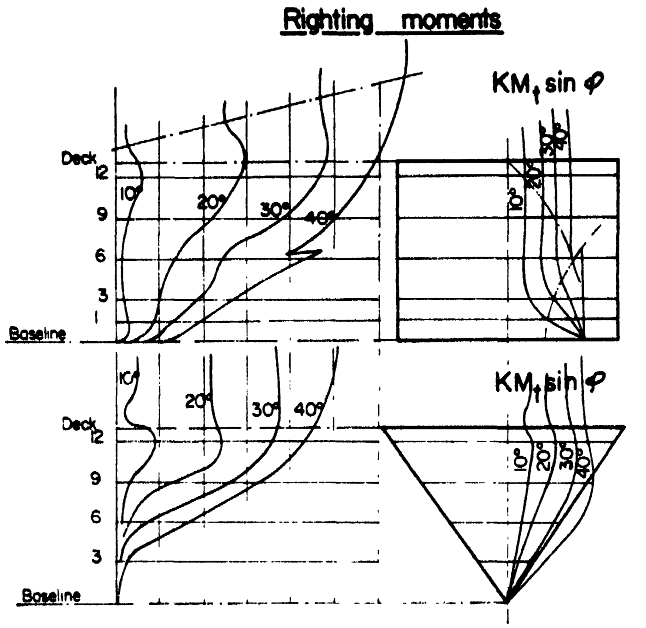


Fig. 628. KMt sin φ and righting moment curves for rectangular and triangular sections

be made applicable for boats in different countries, but believed in a better co-operation between fishermen, boatbuilders and naval architects. He proposed that surveyors and naval architects should make practical tests by loading fishing boats with the same weights as could be met under icing conditions or when a catch is taken on board and make these tests at sea under improved weather conditions in order to give a realistic demonstration of the stability needed for different types of boats and to find a rule for minimum stability.

MR. J-O. TRAUNG (FAO): The extensive model tests made in Sweden had been reviewed in many articles in the Swedish fishing papers, and a full review was also given in the proceedings of the 1947 Scandinavian Fishing Boat Congress (Traung, 1948). FAO has later published the results from all tests as data sheets (Traung, 1955; 1959).

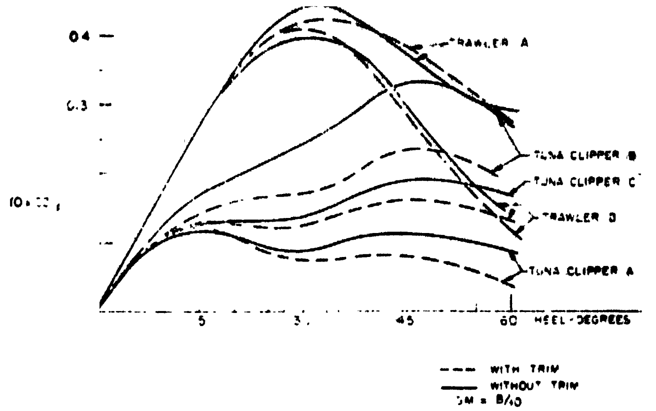


Fig. 629. Statical stability curves for tuna clippers and trawlers in calm water indicating a deficiency in stability of the former

He was glad to note that H. Hansson seemed to realize the paradox that an agreeably rolling ship could lack sufficient stability and vice versa. Unfortunately fishermen were not always equally enlightened on this point, and the reason for the amount of permanent ballast they sometimes added was their belief that they could slow down the rolling motions in that way. Ballast in itself was naturally not the only means to achieve sufficient stability. That could also be had by increasing the beam. Fortunately enough, as the resistance discussion had shown, increased beam did not influence resistance appreciably, not even in head seas.

H. Hansson seemed to believe, together with many non-naval architects, that there should be a similar paradox between adequate safety and economic propulsion. The fuel consumption, i.e., the power to propel the ship ahead, depended especially on length, hull shape and weight. That was in a way the *longitudinal* characteristic. The safety against capsizing, i.e. the stability, depended particularly on the beam, freeboard and the vertical position of the centre of gravity, and that was an *athwartship* characteristic. Both had nothing really in common, and it was possible to design a very economical ship from the propulsive point of view which, at the same time, had such high stability that there should have to be a cowboy riding on her! Now naval architects knew

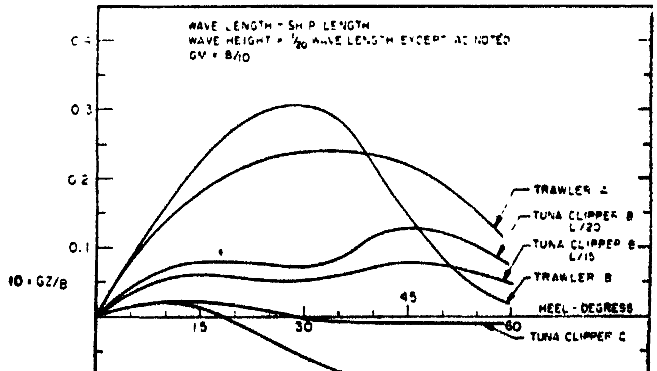


Fig. 630. Stability of tuna clippers and trawlers in waves of length equal to ship's length, with crest amidships

a great deal about the necessary stability. Rahola's (1939) work and Möckel's new curve (fig. 429) were particularly valuable guides for a stability which gave a good compromize between adequate safety and agreeable rolling motions. It should, therefore, not be necessary to add ballast to achieve a still shorter period of roll than recommended by Möckel. Full-scale tests by loading boats with weights resembling icing and a heavy fish catch on deck would certainly be most convincing to non-technical men. Any such test should, however, be combined with a study of the characteristics of the vessels, including participation in fishing trips by experienced observers. Actually technicians could, with general knowledge of naval architecture and the help of the fishing boat experience data presented in this book, do much to produce a seakindlier Swedish fishing vessel without in any way taking any risks so far as safety was concerned.

MR. H. E. STEEL (U.K.): Safety at sea required three basic rules to be observed:

- Complete watertightness of the hull
- Water shipped must be cleared overboard as fast as possible
- Weights on board (cargo, stores, equipment) must not shift under any circumstances

He felt it was not so much the lack of stability that caused many accidents as the fact that the hull was not completely watertight. Stability should be ample and not just enough. Statical stability calculations should be based on two additional conditions:

- The ship having a heavy catch on deck; and
- The fish catch still on deck, with another catch coming on board

PROF. A. TAKAGI (Japan): The tables in his paper were compiled from data selected at random. It would be seen from the tables that the freeboard of Japanese boats was quite small. It was to be remembered, however, that the freeboards shown were the difference between the depth (D) and the draught (T), and that no correction had been made for deck erections, etc.

With regard to icing, practically no Japanese fishing boats operated under icing conditions, and this might be one reason for the small freeboards.

Sometimes the freeboard was sacrificed for other reasons, such as heavy machinery or large holds.

A few boats were once designed in Japan following the Rahola criteria, but the design resulted in too short a rolling period and the crew complained of difficulty in working on deck.

Eventually, the various seas of the world might be divided into zones according to climatic and topographic similarity, when it might be possible to adopt a freeboard standard for each zone.

Danger of broaching

COMDR. P. DU CANE (U.K.): He had studied Wendel's paper with very great interest, more particularly because he was in the process of attempting to study the broaching phenomena analytically. Directly or indirectly he regarded this as one of the greatest menaces to safety at sea, certainly for small ships at the present day.

Here is not only the reduction in stability due to waves as described by Wendel, but also once the "broach" has commenced the effect of the centrifugal forces tending to heel the ship outward.

It is furthermore well established that the effect of rolling is to reduce directional stability. He suspected also that there is an additional force possibly of overriding importance due to an effective shift forward of the CG of the lateral area presented to the oncoming fluid (relative to the ship). This force like the centrifugal heeling effect will be proportional to the square of the velocity through the water.

This force he suspected becomes the most important in considering this "broaching" behaviour and in effect arises from a modification of the "derivatives" found in still water by the rotating arm process.

It can also lead to the result that in practice the worst condition for broaching may not of necessity be frequency of encounter zero. It may well occur when:

$$\frac{V\ \text{ship}}{V\ \text{wave}} > 1$$

In describing the apparatus developed by Roden and Baumann it appears that the moments in which one is interested are proportional to the moment of inertia multiplied by the angular accelerations. Presumably the acceleration here applied to the rolling plane.

Now it would seem that the results for righting moments presented by this apparatus would not be able to allow for any effective reduction in righting lever brought about by the dynamic effects mentioned above. Probably the added inertia due to the added mass of entrained water is small in the rolling plane, but possibly is not so small when the yawing and drifting motions are considered.

He apologized for admittedly departing somewhat from the subject covered by Wendel's paper by introducing dynamic terms in other planes, but hoped nevertheless they may be considered of interest in considering the general subject of seaworthiness, seakindliness and stability, which must, of necessity, be somewhat interlinked in any serious consideration.

MR. S. RODEN (Germany): Du Cane emphasized that when a ship in waves broaches, heeling movements take place which, according to him, are very dangerous for the safety of the ship. No doubt such moments are not as small as to be disregarded. The same goes for either direct or indirect heeling moments created by bad weather and heavy seas, such as moments due to wind pressure, shifting of cargo or flooding. Only a careful summing up of such single moments will give the value of the total forces which must be balanced against the existing moments of stability, so that one may give a judgement on the safety. For such a consideration, only existing stability criteria must be used. Wendel has shown that in a seaway moments of stability will be imposed on the ship under speed which differ from those in calm water.

With the instrument for measuring stability in waves, the product of the mass moment of inertia of the ship, plus the moment of inertia of the entrained water and the angular roll acceleration equal the moment of stability, if the damping is disregarded exactly as du Cane assumes.

Du Cane is now afraid that when turning or drifting the entrained water mass will change considerably and therefore give incorrect stability values. The normal procedure of taking into account hydrodynamic moments by making an addition to the mass, is naturally only possible for hydrodynamic moments which have the same direction, the same frequency and the same phase position as the original moments. That is only so far as rolling is concerned—with turning or drifting this is not the case. In addition, the vector of the total hydrodynamic moments does not lie in the same plane and furthermore is not in the same phase. It can be considerably larger than for a simple roll. It is however not known if the component in the rolling plane and of the same phase is considerably different from the component at the normal rolling movement. It should be possible to look on the rolling stability movements as correct also.

PROF. A. TAKAGI (Japan), answering Thiberge, said that from various data of Japanese fishing boats, one can naturally establish some criteria due to the long Japanese experience. In the ranges of principal dimensions, their ratios, the hull shape and its coefficients shown in his paper, one can reach such a criterion. In the case of smaller boats, they have sufficient sheers to prevent the dangerous condition otherwise caused by the sea water coming up on deck. He was sorry but he could not show their profiles in his paper. He wished to be able to find a common way of establishing criteria based on the actual data in the world.

Professor Takagi thanked Jablonski for his detailed discussion. It seems that the standard of stability to be required should be a dynamical one up to some inclination angle, say 30 to 35 degrees. In calculations, perfect watertight superstructures are assumed which may result in larger GZ and larger angle of stability range, which one has in practice. Perfect watertightness in rough sea is, naturally, desired. As described, external forces are considered as a function of BG plus other factors, but now BG has been used for simplification. For light alloy superstructures, a correction of KG is naturally necessary.

In the initial design stage, one must be able to determine the stability easily. This is also true for the master and crew to ensure safe navigation and fishing. The freeboard and rolling period will be good parameters at any condition and for any persons.

GM as used in his paper was not to be calculated by equation but to be determined in each case. Because the hull shape has a great influence on the location of M and thus the GM, it cannot be said that the hull shape was not taken into account.

PROF. J. R. PAULLING, JR. (U.S.A.): There were no comments directed specifically on his paper, but he concurred with Simpson on his remarks regarding the necessity for adequate freeboard. He was convinced that the only thing that brought many tuna clippers back home was the watertight bait tanks on the after deck.

PROF. K. WENDEL (Germany): Paulling's paper confirmed fully results obtained in Hannover and Hamburg. Furthermore his paper gave a lot of numerical information about the decrease of righting levers for tuna clippers. Calculations and experiments in Russia gave practically the same results. The reason for the investigations in those three countries was capsizing accidents of fishing boats and bigger ships.

In Germany there had been further studies on the subject, with results summarized as follows:

- Longitudinal waves altered the righting lever; transverse waves did not
- If longitudinal waves overtook the vessel directly or obliquely the decrease was considerable. The worst condition occurred when the crest of a high wave of ship's length was situated amidships. The decrease then came up to 6.3 in. (160 mm.) or more in unfavourable circumstances. Evidently this endangered the ship if it had the same or nearly the same speed as the wave
- If the longitudinal waves came from ahead or overtook the vessel fast, the decrease lasted only a short time, and a ship would not have enough time to capsize even if the righting lever was temporarily negative. In this case the mean value in longitudinal waves was important. In most cases it was also lower than the still water value, but the decrease was only a fraction of the value in the wave crest. This was confirmed by model experiments
- These conclusions were only valid if the ship heeled to such a degree that the deck became immersed. This was not the case at small inclinations or a great freeboard amidships, when the ship would on the contrary become stiffer in longitudinal waves. The reason was the centre of buoyancy, B, and the metacentre, M. The centre of gravity would not shift, so a greater metacentric height, GM, must result. This was confirmed by measuring the GM on the research ship *Anton Dohrn* in transverse waves. The apparatus mentioned in his paper was used for measurement in a seaway. In calm water and in transverse waves GM was nearly 2 ft. (0.6 m.), whereas in longitudinal waves 5 in. (0.127 m.) more was measured. The ship had a shelterdeck, it heeled only to 8 degrees, so it was not possible to measure the decrease at great inclinations

Wendel made one historical remark to the effect that a prediction of some of those seaway effects were found in the famous books of Pollard et Dudebout, published some seventy years ago. But only recently naval architects had begun to study those effects more carefully.

He added some remarks on the investigation of Nutku concerning stability in hull-generated waves and supposed that if Nutku would make experiments to check his calculations he would find some alterations of the righting lever. But the cause would be the change of righting levers according to ship waves as well as the lift force, which must come into action if the submerged hull is assymetric. That unfailingly happened if the ship had a list and a speed. Perhaps those two effects would summarize—perhaps they would cancel. Wendel supposed they were of the same order of magnitude.

Many naval architects wanted freeboard regulations for fishing boats and he thought FAO should promote that. But in his opinion it would be absolutely necessary to include stability to reach this aim. Some further investigations and much calculation would be required. Jablonski had made a proposal of this kind and shown a formal way to find a maximum admissible displacement with the help of the cross-curves, and consequently a minimum freeboard. But the difficulty was not the formal side of the subject. It was firstly necessary to gain clearness about the minimum necessary righting lever. This was a matter of physics. Jablonski chose—referring to Rahola—the criterion:

Righting lever GZ 8 in. (200 mm.)
for an inclination of 30 degrees
and a stability range 60 degrees

That was hardly tenable in his opinion; for further particulars Wendel referred to his paper.

He thought, however, that that was a very important matter and proposed that FAO should form a committee which would participate at the International Safety Conference in London in 1960.

The Japanese had carried out much work on the calculation of the heeling moments. They considered the moments, which came into action if the passengers crowded together on one side of the ship, and the moments in a gust.

Watanabe had given a paper on this subject to the Institution of Naval Architects. The experiments concerning size and decrease of the wind-pressure moment executed by Kinoshita and Okada had already been mentioned. For fishing boats a lot of useful information was found in the paper presented by Takagi. The work of the Japanese naval architects would be very useful for the numerical calculation of the heeling moments.

But the chief object of the Japanese work seemed to be to set up new criteria for minimum stability. Such criteria 50 years ago demanded a minimum GM. Later, initiated by the very comprehensive work of Rahola, a minimum righting lever was recommended. Surely, that was progress. In Japan naval architects were trying to improve those criteria and to adapt them to special ships. But he supposed this procedure should be abandoned. Compared with resistance and propulsion, the general stability criterion corresponded with the Admiralty formula or similar summary formulae for estimating the necessary SHP. Those formulae were of practical use only for similar ships. They were by no means of general validity. Further, they put together very different things—friction, wave and eddy making, resistance, propeller efficiency, wake, thrust deduction, etc. The modern achievements in resistance and propulsion had not been possible if naval architects had refused to accept a physically correct conception of predicting SHP.

There were no general valid stability criteria and it was impossible to establish such general criteria. Ships varied not only in shape and principal dimensions but in cargoes, stores, subdivisions and in erections, and they encountered different weather conditions on their voyages. Good progress could only be achieved if further material were collected and worked out, with the aim of making possible the numerical prediction of the single heeling moments in the worst possible condition. Their sum must be less than the righting moment over a sufficient range. That was the only criterion suitable without exceptions and which would give safety in all cases. As soon as the necessary information about the different heeling moments was collected that procedure would not be more tedious than the search for the suitable criterion, the number of which was nearly as great as the number of naval architects engaged in this matter.

A further advantage would be connected with this procedure. It would stimulate the search for methods or devices to reduce the heeling moments: for instance, the heeling moments and the rise of the centre of gravity caused by icing which especially endangered fishing boats. They were small ships and the icing was proportional to the surface, consequently to the second power of linear dimensions, whereas the righting moment was proportional to the displacement, consequently to the third power of linear dimensions.

Recently an incident between Greenland and Iceland was reported to him: the crew of a trawler had to throw their ice-covered lifeboats overboard in order to avoid capsizing. The icing in the worst weather conditions could probably not be overcome by a sufficient righting lever. This was in full agreement with the experiments referred to in Lackenby's paper. It was necessary to search for methods to get rid of the ice or, better, to prevent the gathering of too much ice.

SAFETY AT SEA

DR. L. CRISTIANI (Italy): According to the results of many researches made after 1945, lifesaving means should be such as to:

- Enable the ship to be in service with a list of more than 15 degrees
- Protect the survivors from sea and bad weather
- Be easy to locate

Inflatable liferafts could satisfy those requirements. Rafts were small in volume when stowed, and their weight was limited—392 lb. (178 kg.) for a particular raft for 25 persons. Rafts for merchant vessels ranged in capacity from 4 to 25 persons. They were made of rubber fabrics, having special characteristics as regards resistance and chemical properties. Further, they had an entirely self-supporting arch tube structure; they were provided with accessories like a sea-water operating cell without electrolyte for lighting purposes and a complete emergency outfit. They could also be equipped with a wireless apparatus. To make sure of their good condition on board, periodical inspections could be made through a chain of land stations, as was done in the U.K.

The price of a rubber liferaft and its equipment was favourable in comparison with a conventional lifeboat of the same capacity.

Up to 1959, 107 human lives had been saved by inflatable rafts of one particular make. The record of rescue operations carried out in 1958 and in the first quarter of 1959 were as follows:

1958: The crews of six stranded vessels were saved

1959: On 9 January the Fisheries Protection Vessel, *Freya*, heeled over to 45 degrees in rough sea (60 m.p.h. wind); 17 persons saved
On 9 March the motor-drifter, *Primrose*, grounded off Stornoway; the crew was saved by using a raft
On 10 March the trawler, *Stella Carina*, collided with a cargo vessel while going out from Victoria Dock at Hull; the crew was saved by using a raft

The Government of Iceland had since 1953, the U.K. and France later, made regulations for the use of inflatable liferafts. He felt that it was time to propose regulations regarding the use of inflatable liferafts by all Maritime Countries.

MR. H. R. BARDARSON (Iceland): In Iceland rubber liferafts had been used for many years, and they had been regulation equipment for all vessels for nearly two years. Fishing vessels below 80 GT had no lifeboats, and were relying on the rubber rafts. Inspection by specialists on land was required every year for rubber rafts, and the training of the crews in the use of the rafts was very necessary. This was done mainly in swimming pools, to give the crews an idea what the rafts looked like when inflated. A picture poster was placed on board every Icelandic ship, showing what to do in case of emergency. Every seagoing Iceland fishing vessel was fitted with radio telephone to call for help. Life-saving equipment had to give effective shelter to the crew for relatively short periods, as help would usually come soon with the use of planes and rescue vessels. A reflector for radar and light beams was required and a safe and simple automatic transmitter on board the rafts should send out SOS signals with the biggest possible power on the wavelengths used for distress signals for vessels and aeroplanes. He requested firms producing radio equipment to continue experiments with such transmitters. When suitable equipment became available, he felt sure it would be welcomed by all concerned with safety at sea.

Pocket transmitters

PROF. M. JACOBSSON and CAPT. H. HANSSON (Sweden): When accidents happened at sea, it was of the utmost importance that those in distress had the means of sending out distress signals by radio and with other apparatus. In bigger ships and also in large fishing craft radio telephone was a common instrument. In small fishing craft, however, the owners had not the technical means to install, nor could they afford to buy the rather expensive instrument.

Since the last war, the Swedish Sea Rescue Institution had asked for a small and cheap automatic radio transmitter for use in small fishing craft, lifeboats and rafts and by yachtsmen and aviators. A few years ago a British firm produced such an instrument for the RAF and airlines in the U.K., but this was too expensive for civil use.

The same British firm had made a cheaper version and it is to be used by the Swedish RAF and the Swedish Sea Rescue Service for a safety system. They had decided to introduce those instruments in small craft, aeroplanes, searching planes and rescue cruisers on the Swedish coats. It was also planned that special automatic alarm receivers should be fitted in high light towers and radio masts on the coast.

After a meeting in London in 1958 with NATO, the U.S. Coastguard and the British authorities concerned, the Swedish Sea Rescue Institution proposed to all those international bodies interested that that safety system should be internationally adopted because such a safety system at sea could be effective only when accepted all over the world.

The price of this pocket transmitter, DIANA (in England SARAH), was in 1959 about £27 ($75) but if it is mass-produced the price would drop to less than half.

As the Congress had a special interest in safety at sea, it was proposed that it should accept the following resolution:

"The 2nd World Fishing Boat Congress recommends that all maritime nations and all sea rescue organizations should study with the greatest care the proposal for a safety system with pocket distress radio transmitters, DIANA, which proposal will be presented at the International Lifeboat Conference in Bremen on 23 to 25 June, 1959, and if the proposal is accepted in Bremen, work for its introduction throughout the world."

Reflectorization

MR. M. DUTRUIT (Switzerland): The last 50 years had been characterized by, amongst others, the prodigious strides made by science in all its various forms, and the lives of a great number of people had been greatly altered by a multitude of technical devices. The part of human activity which normally exerted itself on the oceans—fishing, merchant navigation, cable laying, marine research, etc.—had naturally been greatly influenced by scientific conquests and the risk and peril of the sea, fortunately enough, were not any longer as bad as they were half-a-century ago. Modern vessels and airliners were equipped with high-precision devices—radio telephone, radio goniometers, radar and echo sounders—which permitted more precise navigation to increase safety.

In spite of that, there was not a week without a disaster at sea! Recent and, if permitted to use the term, spectacular catastrophes such as the one of the *Stockholm* and the *Andrea Doria*, or the *Pamir*, or the most recent one of the *Hans Hedtoft*, had shown that, under certain circumstances, the best instruments could fail and also that their indications could be misinterpreted by the crew members, because the human factor had remained more or less what it was in the olden days.

The sea still claimed too many victims and, every year on the globe, thousands of human beings, full of hopes and plans for the future, disappeared in the waves. When a sailor was washed overboard, the ship immediately turned round and everything was set in motion to recover the unfortunate man. When two ships ran foul of each other, the less damaged one gave all the possible help to the other one. A ship in distress in a storm or having collided with an iceberg had generally time to send an SOS, an airliner in difficulties could signal her position. Help action was immediately organized and all the possible assistance was generously given, irrespective of race and nationality, by the great brotherhood of the sea and air.

All shipwrecked people, however, were not rescued: some had been caught in their sleep, others had been wounded or killed during a collision or explosion; others were not saved because the ships and planes taking part in the rescue did not see them.

A man in a life vest, a raft, even a larger lifeboat, was really not much in the immenseness of the ocean. By day, they were not easily sighted even when the sea was calm and with powerful glasses. At night, when darkness limits the visibility and cancels the contrast effects, the unfortunate passengers of those precarious rescue appliances were likely not to be seen at all, in spite of the powerful projectors. And they drift, drift more and disappear. . . .

Normally shipwrecked people very often only had makeshift means at their disposal to draw the attention of rescuers. Privileged shipwrecked persons—passengers of a steamer or an airliner, pilots who had to bail out, castaway crews—generally had a radio set, an electric light and one or more flares to signal their position and made themselves recognized. Those devices were no doubt very effective and had certainly saved many lives already. They, however, did not perform for hours and days and people had to be fully conscious to operate them. If they were sick, tired or wounded, or had fainted, they could not indicate their presence to the ships and planes searching for them.

In order to be fully effective under any circumstances, a signalling device must perform without any co-operation from the doomed man.

Modern industry had perfected a material which performed continuously without any operation from the persons in peril, which did not unload or exhaust itself and which was very suitable for the marking of life vests, rafts and buoys—the retro-reflective sheeting. This sheeting could be applied on to the flexible surface of life vests and rubber dinghies as well as on to the rigid surface of rafts and boats of wood, light metal or reinforced plastic.

The flexible sheeting was a retro-reflector (auto-collimating), not a phosphorescent nor a fluorescent material; it was a reflecting product which did not emit any light of its own but which reflected back to their source all the light rays which strike its surface, without any divergence, i.e. without noticeable loss. A retro-reflector must be illuminated so as to be visible, and every observer placed within the luminous cone or close to it would see the full effect. Objects reflecterized with this material get a capacity of visibility in darkness far superior to the capacity of similar objects painted with conventional colours, even very brilliant ones. By day, reflectorized objects looked exactly the same as non-reflectorized ones. At night, when caught in the beam of a light they lit up as if by magic, and when illuminated by a strong projector they were visible in the dark at a longer range than by day. The diffuse "border" light of a beam was sufficient to render the reflective material very brilliant against the dark background, and reflectorization practically increased the range of headlights and projectors, because a reflectorized buoy or dinghy were visible at night even beyond the area illuminated by the projector. Moreover, the reflective sheeting was wide angle and reflected luminous rays under any angle of incidence up to 75 degrees.

A great advantage of reflectorization lay in the fact that any ship or plane fitted out with a projector—today every craft, even the smallest tramp or fishing vessel was equipped with a powerful light—could take an active and effective part in the rescue action. How often does one read in the papers: ". . . Search had to be interrupted at nightfall and will be resumed next morning at early dawn. . . ." Reflectorization, on the other hand, enabled the search action to go on all throughout the night.

The retro-reflective sheeting had a thickness of only 0.008 in. (0.2 mm.) and was composed, amongst other things, of metallic layers performing as a spectacular reflector (mirror reflector), which was also a good reflector of radar waves. A metallic object covered with this reflective material was naturally not more visible on the radar screen than the same object without any reflecting material, but the radar echo of wooden seamarks or rubber boats, was notably increased through reflecting sheeting.

Reflecting materials have been used for over 12 years for road and railway signs, for police equipment and vehicle markings, and has proved their usefulness and suitability under all climates. They were also being used for maritime signalling because they were not affected at all by salt water, sun's rays and ice.

The technique of reflectorization of rafts, dinghies and life vests had already been adopted in many countries and was being used by the following organizations: U.S. Navy and Air Force, Swedish Air Force, German Navy and Air Force, Italian Navy and Air Force, Belgian Navy, French Naval Air Force.

Tests and trials were being conducted in other countries and the British Admiralty was about to make compulsory the reflectorization of certain types of buoys, seamarks and life saving appliances.

The use of this new technique did not entail high expenses, and existing life saving equipment could easily be reflectorized for a relatively small expense compared to the cost of the equipment itself. When it is thought that for a few dollars a human life could often be saved, one wondered why reflectorization was not in general use on board ships.

Why had the technique of reflectorization already been adopted by many military, naval and air force establishments, and not by civilian companies? The answer was to be found in the International Convention of Safety of Life at Sea, signed in London in 1948, which did not contain any recommendation or obligation to reflectorize life saving appliances. That was natural enough since retro-reflective materials were just beginning to be used for road signs at the time when the Convention was under discussion. That was something lacking in the Convention which, it was hoped, would be made good in 1960 when the IMCO Assembly will revise the Convention. Fishermen, merchant sailors, airmen and passengers had a right to profit by the same technical achievements as military personnel, and it was therefore hoped that the new Convention would contain a paragraph making reflectorization of life saving appliances compulsory.

Reflective material could also be used aboard ships for the marking of pumps, fire extinguishers, emergency exits, lifeboat stations, etc. As a matter of fact, in case of a disaster, it very often happened that electric power failed or was cut off and, when that happened at night, the entire ship was plunged into darkness—darkness which generated panic and confusion. A small hand torch was sufficient to make reflectorized panels and signs perfectly visible and legible in the dark, in the same shape and colours as by day. Operations were greatly facilitated and the necessary measures could be taken without loss of time and without confusion.

Net buoys could also be reflectorized for quicker location and identification at great distance in the night with a small projector.

Reflectorization was not a universal medicine but it certainly was an important additional safety factor which should be used aboard all ships.

Over-icing

CAPT. S. REMØY (Norway): He felt that high GM increased the danger of over-icing considerably, due to the violent motions of the vessel. Over-icing of the standard rigging was extremely dangerous and it might happen that an iced-up radio aerial could break. During the winter of 1952, five Norwegian ships were lost in the North Atlantic, three of them having lost connection with sister ships. He advocated the use of a plastic cover for radio aerials and standard rigging.

Many years ago, when sailing, it was comparatively easy to keep a ship against the weather, thus reducing over-icing. Mechanized ships tended to be driven too fast, and he suggested the use of a small sail to be able to reduce engine speed when lying against the weather.

Iron and wood collected ice readily, canvas very much less, and rubber was nearly free from icing. There was now on the market a plastic material which was an effective anti-icing cover for stays, halyards, radio antennae and similar exposed parts of the ship. Heavy icing on radio antennae could cover it to breaking point and in arctic conditions repairs were very difficult: this could lead to loss of contact with shore and other stations. So the plastic material was very valuable. It did not in any way hinder transmission or reception. It should be applied to the antennae halyards, as well as to the antennae itself.

MR. J. HØJSGAARD (Denmark): He pointed out that Remøy had successfully covered the wires of his radio transmitter with a plastic coating which had reduced icing considerably. The U.S. Navy had found that paint made on a silicone base attracted only two per cent. of the ice as compared with a normal paint.

In a hurricane a captain would turn the stern against the waves and steam ahead at low r.p.m. to keep the ship on course. But engines were not built to run at very low speeds and engine trouble might, therefore, very soon arise. That was an added reason, he felt, to adopt the controllable-pitch propeller, with which engines could run at normal r.p.m. and the ship's speed could be controlled simply by manipulating the pitch.

MR. H. KLAASSEN (Netherlands): Højsgaard stated that several losses of fishing vessels in gales must be attributed to the engine stopping after prolonged work at very low output and low r.p.m. Højsgaard claimed that a number of these ships could have been saved if a controllable-pitch propeller had been fitted, and in such particular cases operated at low pitch and high r.p.m. The above point of view might be explained by Mr. Klaassen's previous fig. 262, because at low pitch values (just keeping enough water pressure on the rudder) and maximum r.p.m., the engine output C is in the order of 35 to 45 per cent. of the maximum engine output A.

It is here that another advantage can be added to the already known advantages of twin engine installations driving a controllable-pitch propeller. If one engine is shut down, the remaining engine will be loaded between 70 and 90 per cent. at maximum r.p.m. On top of that the second engine will be most convenient in case of an emergency.

MR. J. G. DE WIT (Netherlands): Miller's paper related to what had been said so many times about automatic steering gear and radar. The advantages of an automatic steering gear was evident, but there were dangers of negligence. In the Netherlands it was not permitted to have less than two men on the bridge for watch-keeping, but that was, unfortunately, not always the case. Automatic steering might have the disadvantage that watch-keeping was left to the automatic steering gear. Radar had the disadvantage that fishermen thought they could operate at full speed in bad weather. New navigation equipment would, of course, be brought into use, but people who were to use it should study carefully *when* the instruments were to be used, *what* their limitations were, etc. The nautical schools should direct their attention to any new developments *before* they came into use, rather than after.

Training of crews

MR. D. S. SIMPSON (U.S.A.): Once again he was delighted to note that Miller agreed with him in a matter that he had been trying to bring home to the fishing industry for many years. Most of the fishing vessel accidents could be avoided if there had been properly trained crews. To paraphrase a recent remark of friend Chapelle—"we can model test a hull no end but we can't model test a crew or a skipper"!

Whatever the New England crews might be, by and large they were not seamen. The majority of them were not even helmsmen. They were careless and inattentive. Obviously Miller felt the same about the West Coast crews, and Takagi brought up the same troubles with Japanese crews. They uncomplainingly go to sea time after time with faulty arrangements of gear, faulty equipment and even in unseaworthy ships. When an accident did occur, the owner took the blame, although generally he was just a business man and could not be expected to make corrections unless the fault was brought to his attention.

They used wrong leads for their winches, either unaware of safer ones or too careless to rig them. Small boats and life preservers were lashed down with twisted wire. The most convenient place to stow a spare propeller or anchor appeared to be on the life raft.

Few of them could steer their vessels properly. Through inattention, a helmsman might find himself 20 degrees off course and in a hasty attempt to correct would immediately find himself 20 degrees off in the other direction. In his own mind he had not changed course and would so testify in court.

Fishermen do not understand whistle signals nor the "rules of the road". Steamship officers had told him that they seldom bothered to signal fishing vessels for this reason.

A few years back a trawler was lost with all hands. The last word heard from her, the skipper and crew were arguing as to whether or not they should be paid overtime for chopping the ice from the rigging. Obviously neither knew enough to realize that their ship was in danger.

A few years ago Mr. Simpson had occasion to investigate the causes of breakdown-at-sea of some 120 fishing vessels towedin to New England ports by the U.S. Coast Guard. Of these 120, 84 cases were due to engine failure, 72 (60 per cent. of the whole) being definitely traced to lack of lubricating oil—in other words, incompetent or inattentive engineers.

U.S. fishing vessels of up to 200 GT (roughly, a \$200,000, or £71,000 investment) required no licensed personnel. A man was a captain or an engineer on his own assertion—until experience proved otherwise. The U.S. Coast Guard had no control over those vessels and he believed he was correct in saying that they did not want it (in his opinion they should not have it) until and unless new regulations for both vessels and crews were devised and made suitable to the service.

A fishing captain did not need to know how to take his ship to Timbuctoo. In these days he did not need to know navigation. He does however need to know how to handle his ship in rough weather; he does need to know how to fight fire, how to launch and handle his lifeboat, and how to interpret his electronic equipment.

An engineer did not need to know how to build an engine: he does however need to know how, when and where to oil it.

Since the Government had not seen fit to furnish funds for the establishment of proper regulations, the next logical sponsor would be the insurance companies—who would benefit by fewer accidents.

While he was in hearty agreement with Miller and Takagi in their desire for training courses for fishermen he doubted if an FAO committee would provide the method of getting at it, or even of working up a set of regulations to propose. That would be a long and arduous task for men of special knowledge and experience and they should not be expected to work at it without compensation.

The regulations and examinations in existence in the U.K. (which were sponsored by the insurance companies) would, he felt, make a splendid starting point.

The influence of an FAO committee should, however, be of great service in stirring up an interest among those who should be the sponsors.

CAPT. S. REMØY (Norway): He found Simpson's remarks most interesting. At the Norwegian School for Fishermen it was possible to get a certificate authorizing the holder to be captain of a ship up to 500 GT. He would like practical and theoretical training combined much more than has been done, and if possible on board a training ship.

COMDR. G. L. SICKLES (U.S.A.): He augmented the conclusions derived by Miller, listing the causes of marine accidents, and made an appeal to owners and skippers, in particular.

When the owner or operator spent thousands of dollars having a vessel designed and built to do his job in the most efficient and profitable way, he left too much to chance in not guaranteeing that those who manned his vessel were aware of the capabilities of all the life saving and fire fighting equipment placed aboard the vessel.

In most countries those vessels were required by regulatory agencies to maintain a minimum standard of amount and size of life saving and fire fighting equipment. Too often, those pieces of expensive equipment were left to deteriorate due to lack of proper care or were disregarded because of ignorance of how to use or maintain them properly.

He referred, in the latter instance, to fire fighting equipment. If all ship's personnel were exposed to an indoctrination period as to the use of such equipment, those items would cease to be a worriesome thing that had to be maintained just to satisfy the inspectors.

He had learned, by experience, that fire on board was no longer a thing to be feared, if one was properly trained in the use of the various pieces of equipment. He did not need to elaborate on the various types of the equipment, as that would be already known, but he raised the question whether it was also known how and when to use it. If this raised a question in the mind, it must be asked—"If I don't know, how am I to be sure that my skipper and crew know!" The answer to this should be—"I'll provide for them being taught properly". That was a very small premium to pay for so much insurance.

In regard to the life saving equipment, a lot of good money was paid to have it placed aboard. One should insist on it being maintained in a seaworthy condition. He referred in that instance to life rafts, boats, buoyancy apparatus and life preservers. Another important piece of life saving equipment was the vessel's radio telephone apparatus. Too often the regulations pertaining to its use were violated. In every instance this was done carelessly and thoughtlessly and to the jeopardy of all concerned.

With the advent of radar, the tendency to rely on this valuable instrument was ever increasing. There was no legal premise in its being used as a substitute for a proper lookout, under International Rules.

The interpretation of data obtained from radar and other electronic navigational aids was a matter of education and training of the individual using the equipment. It was not enough to know how to service the gear; one must know how to use the information put out by the equipment.

So much depended on the human element in maintaining safety of life and property at sea. No ship was any more seaworthy than her crew. No cheaper insurance could be had by the owners than the investment in education of the crews that manned the vessels, in matters pertaining to the proper use of the safety features which have been placed aboard the vessels at such great expense.

Mr. J-O. Traung (FAO): Some countries had training facilities for fishermen and others not, and FAO was therefore trying to provide a bridge between those countries. One staff member was in charge of making a review of the training facilities for fishermen in various countries. He was an experienced trawler skipper and had been teaching at a fishermen's school in Ostend for many years.

Traung agreed with Sickles that training was the cheapest insurance an owner could have for his ship. It was therefore amazing how it was possible that they could select a man to run a quarter million dollar boat without at least testing him. But this was, of course, up to the owner, and FAO could only interchange information between countries.

Mr. J. G. Hutchinson (Canada): In Canada the RCAF were operating a search and rescue organization, which alerted all ships in an area whenever a distress signal was received. Many ships then converged on the danger area. A search master on the scene was appointed to take charge. He would decide if aircraft were necessary. That practice had proved most successful.

PART IV

PRODUCTIVITY

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DEVELOPMENT OF A BOAT FOR INDIA'S SURF COASTS

by

PETER GURTNER

India has a coastline of about 2,900 miles (4,650 km.) which is mainly surf-beaten, with very few shelters for its vast number of indigenous fishing craft that operate all along the coast from numerous scattered villages. These craft, which are mostly catamarans and dugout canoes, are small with very limited range and capacity for fishing, and are not well suited for mechanization. The need of this large fishing community is a suitable beach landing craft which will give them the benefits of mechanization, help them to do better fishing, and increase total output of fish, thereby adding to their own prosperity.

Work on evolving a suitable beach landing craft has been undertaken over the years and from 1953 FAO has been closely collaborating with the Government of India on this project. Since then, five types of boats have been designed. Experiments are now being conducted with the fourth type, built in accordance with experiments gained with the earlier versions. This project, apart from its technical side, has an equally important economic and social aspect. The fund of information gained during the investigations could well benefit communities in other parts of the world who have to contend with similar conditions.

MISE AU POINT D'UN BATEAU POUR LES CÔTES À BRISANTS DE L'INDE

L'Inde a environ 2.900 milles (4.650 km.) de côtes qui sont surtout battues par les brisants, avec très peu d'abris pour les nombreux bateaux de pêche indigènes qui travaillent tout le long de la côte et sont basés sur un grand nombre de villages éparpillés. Ces bateaux, qui sont surtout des catamarans et des pirogues monoxyles, sont petits, avec un rayon d'action et une capacité très limités pour la pêche, et ils ne conviennent pas pour la motorisation. Pour tous ces pêcheurs, il serait nécessaire d'avoir un type de bateau pouvant être échoué sur les plages et bien adapté, qui leur assure les avantages de la motorisation, les aide à mieux pêcher et augmente la production totale de poisson, améliorant ainsi leurs conditions de vie.

Depuis des années, on a entrepris d'élaborer un bateau pouvant être échoué sur la plage, bien adapté, et depuis 1953 la FAO collabore étroitement avec le Gouvernement de l'Inde sur ce projet. Cinq types de bateaux ont déja été dessinés. Actuellement on effectue des expériences avec le quatrième type, qui a été construit d'après l'expérience acquise avec les versions précédentes. Ce projet, en plus de son côté technique, a également un aspect important au point de vue économique et social. La somme des données acquises pendant les recherches pourrait être profitable aux pêcheurs d'autres parties du monde qui doivent affronter des conditions similaires.

CONSTRUCCION DE EMBARCACIONES ESPECIALES PARA LA COSTA DE LA INDIA BATIDA POR LAS OLAS

La India, con una costa de 2.900 millas (4.650 km.) casi toda batida por las olas, tiene muy pocos abrigos para la infinidad de embarcaciones de pesca que operan desde numerosas aldeas desperdigadas por todo el litoral. Estas embarcaciones, casi todas catamaranes y canoas de troncos ahuecados, tienen limitadísimo radio de acción y capacidad de pesca y no se prestan para la mecanización. La enorme communidad de pescadores necesita una embarcación adecuada para atravesar las rompientes y subirla a la playa, que les proporcione las ventajas de la mecanización, les ayude a perfeccionar las actividades pesqueras y a incrementar las capturas, mejorando asi su propio bienestar y prosperidad.

Desde hace años se busca una embarcación adecuada para subirla a la playa y desde 1953 la FAO colabora con el Gobierno de la India en este proyecto. Desde ese año se han proyectado cinco tipos. En la actualidad se hacen experimentos con el cuarto tipo, construído de acuerdo con la experiencia adquirida con los tipos anteriores. Además de su aspecto técnico, este proyecto presenta importantes facetas económicas y sociales. Los datos recogidos y la experiencia adquirida durante las investigaciones pueden ser de la mayor útilidad para comunidades de otras partes del mundo donde se encuentran condiciones análogas.

INDIA has a coastline of about 2,900 miles (4,650 km.) which is, to a large extent, open and surf-beaten. Fig. 631 shows the main areas under consideration. While it is generally recognized that fishing activities will ultimately be concentrated in sheltered places and harbours, the widespread fishing communities on the beaches must as an intermediate step be provided with an efficient mechanized boat until such sheltered places are readily available. This has long been recognized and provision has been made in the development programmes of the maritime states, as well as the Central Government, to support such efforts.

Some 60,000 indigenous craft in these four States are regularly used from the beaches by about 200,000 fishermen.

The bulk of these craft are catamarans, with dugout canoes and simple built-up boats of distinct local characteristics completing the number. Fig. 633 and 634 show fishermen at work with their catamarans on the beach.

Catamarans and dugout canoes are difficult to mechanize. They are of small capacity and radius of action, especially the dugouts, and even if an engine could be installed it would not result in a substantial increase of

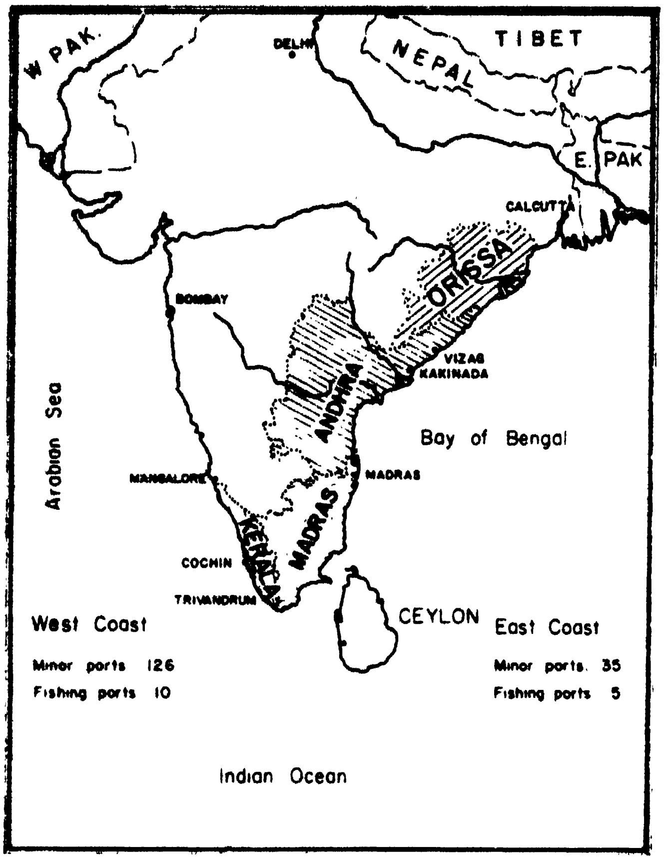


Fig. 631. The open and surfbeaten coastline of India (hatched)

the craft's earning power. The sewn boats and the majority of the planked boats are likewise not suitable for mechanization, with the exception of the vallams in South Madras State.

Hence the imperative need is to develop a small, open or half-decked, mechanized boat for regular beach fishing, capable of operating through moderate surf. This paper endeavours to relate this development up to March, 1959.

SURF CONDITIONS

Wave height and period

It is almost impossible to measure the height of breakers in surf, but by estimating the height of deep-water waves before they break, a sufficiently accurate estimate can be made. A record of mean maximum wave heights has been kept in India and its results are presented graphically in fig. 632, the data being contributed by Mr. P. K. Kulkarni, Chief Research Officer, Central Water and Power Research Station, Poona, Bombay State. The Meteorological Observatory has set up 24 observation posts, 13 on the west and 11 on the east coast, recording twice daily deep-water wave heights, periods, directions and wind speeds. The graph gives the results for the first five-year period of observation in 12 localities. The number of days for which a wave height of 0 to 1 ft. (0 to 0.30 m.) prevailed were grouped together for each post and expressed as a percentage of the whole five-year period. Wave heights of 1 to 2.5 ft. (0.30 to 0.76 m.). 2.5 to 4 ft. (0.76 to 1.22 m.), 4 to 5.75 ft. (1.22 to 1.75 m.). 5.75 to 7.25 ft. (1.75 to 2.18 m.) and 7.25 to 9 ft. (2.18 to 2.74 m.) were similarly grouped. These wave height ranges are shown on the graph as blocks from left to right. Observation indicates that waves up to 2.5 ft. (0.76 m.) would not result in breakers too severe to be regularly negotiated by a specially designed boat. Blocks 1 and 2, summed up, give the percentage of days on which wave heights of 0 to 2.5 ft. (0 to 0.76 m.) prevail in fig. 632. Table 145 gives similar percentage figures for wave heights up to 4 ft. (1.22 m.).

Along the west coast, up to Bombay, sea conditions are relatively calm; only during the monsoon months are wave heights over 2.5 ft. (0.76 m.) registered. The Saurashtra coast (Porbandar) has somewhat rougher conditions. Along the east coast, wave heights, and thus surf, become generally worse going north, and are very unfavourable along the Andhra coast. The Orissa coast is even more surf-beaten than Andhra, although the data available shows diminishing wave heights.

Wave periods were generally between 7 and 10 sec.

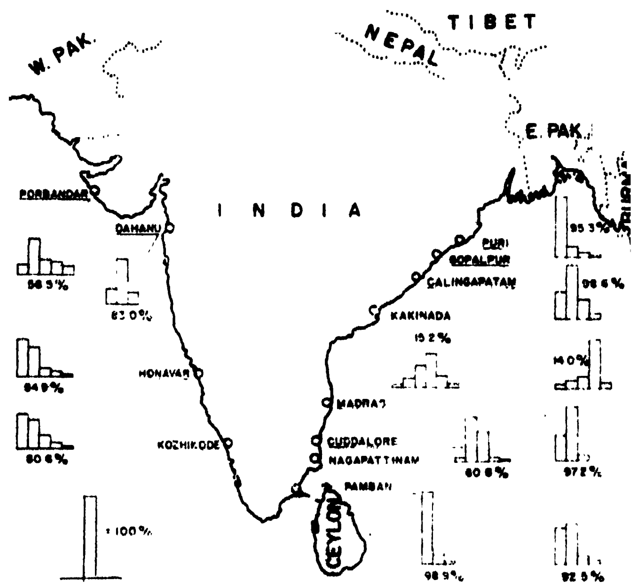


Fig. 632. Mean maximum wave heights 1950–55 along the coast of India. Histogram blocks (from left to right)

(1) 0 –1 ft.
(2) 1 –2½ ft.
(3) 2½–4 ft.
(4) 4 –5¾ ft.
(5) 5¾–7¼ ft.
(6) 7¼–9 ft.

Percentage figures indicate sum of blocks 1 and 2. Locations without higher waves have fewer blocks indicated

Types of wave

Patrick and Wiegel (1955) distinguish between three main types of breakers:

(a) Spilling: In general associated with steep deep-water waves on flat beaches (ratio wave height to wave length, h_w/λ, between 0.06 and 0.03).

(b) Plunging: h_w/λ ratios of 0.03 to 0.009 on all beaches, but mainly steeper ones.

(c) Surging: waves with h_w/λ ratio below 0.009 on steep beaches.

In addition to the h_w/λ ratio and the beach slope, winds, currents and the presence of an offshore bar will also influence the breaker characteristics.

When waves run from deep into shallow water, their period will generally not change, while their length and speed decrease and the height increases. A trochoidal wave would break on the beach when the wave face slope becomes 90° (Patrick, 1955; Kent, 1958). This usually occurs at a depth of water between 1 and 1.5 times the height of the wave. On moderately steep beaches waves tend to break farther out at low tide and near the shore line at high tide. The presence of a bar would be indicated by one line of breakers at high tide, but several diminishing lines at low tide.

Waves usually approach the shore at an angle. They will also break at an angle on the beach, and a current is set up parallel to the beach. This longshore current is a very treacherous phenomenon when landing a boat through surf, and is largely responsible for the tendency to broach.

Many factors tend to influence the shape of a beach, and thus the kind of breakers that will be encountered, such as the geomorphology of the land and the local hydrography, the type of beach material, the quantity of material and the interaction between waves and beach (Patrick, 1955). The last is of particular interest in this connection.

Fig. 633. Indian fishermen at work with their catamarans

Fig. 634. Indian catamaran

Waves of an h_w/λ ratio around 0.03 tend to flatten the beaches and produce an offshore bar. Flatter waves (h_w/λ less than 0.02) tend to steepen the beach face a little and deposit sand; bars tend to disappear and a distinct step is formed in the beach face.

For a given deep-water wave steepness, the breaker height will increase with a bigger bar and with its distance from the beach face. Bars also tend to increase in height with decreasing beach steepness.

Personal observation, and a scrutiny of the scanty material available, indicate that surf in India consists mainly of plunging breakers, sometimes with a tendency to spill.

DEVELOPMENT—FIRST PHASE

Since 1950, when FAO employed its first naval architect, there has been a constant search for a suitable type of boat which could be used under surf conditions such as those in India. In 1952 FAO made a thorough survey of beach fishing boats used in Europe (Zimmer, 1955). At the same time, enquiries were made about similar boats used in North America. Later visits and enquiries were made in Australia, California, Hawaii, Japan and West Africa. Similarly, military landing craft were studied, especially in the U.S.A.

On the whole, existing motorized beach boats are large and expensive at first cost, especially the military ones. Efforts to interest freelance naval architects brought about a number of ideas, but no concrete designs, which could be considered ready to be introduced. It therefore became necessary to develop a new design.

Prototype, 1954

The first prototype was built in Madras in 1954 to the design of Mr. P. B. Ziener, then FAO Naval Architect in India. Fig. 635 gives an idea of this boat, which measured 20 ft. (6.09 m.) overall, 5 ft. 9 in. (1.75 m.) max. beam, and 2 ft. 1 in. (0.63 m.) depth. The boat was equipped with a water-cooled engine, and difficulties were experienced with sand getting into the cooling system. While the boat was successful in negotiating moderate surf, she was found to be a bit heavy for beach handling, in spite of the fact that she was of light construction. Apparently the intention was to lift and carry the boat.

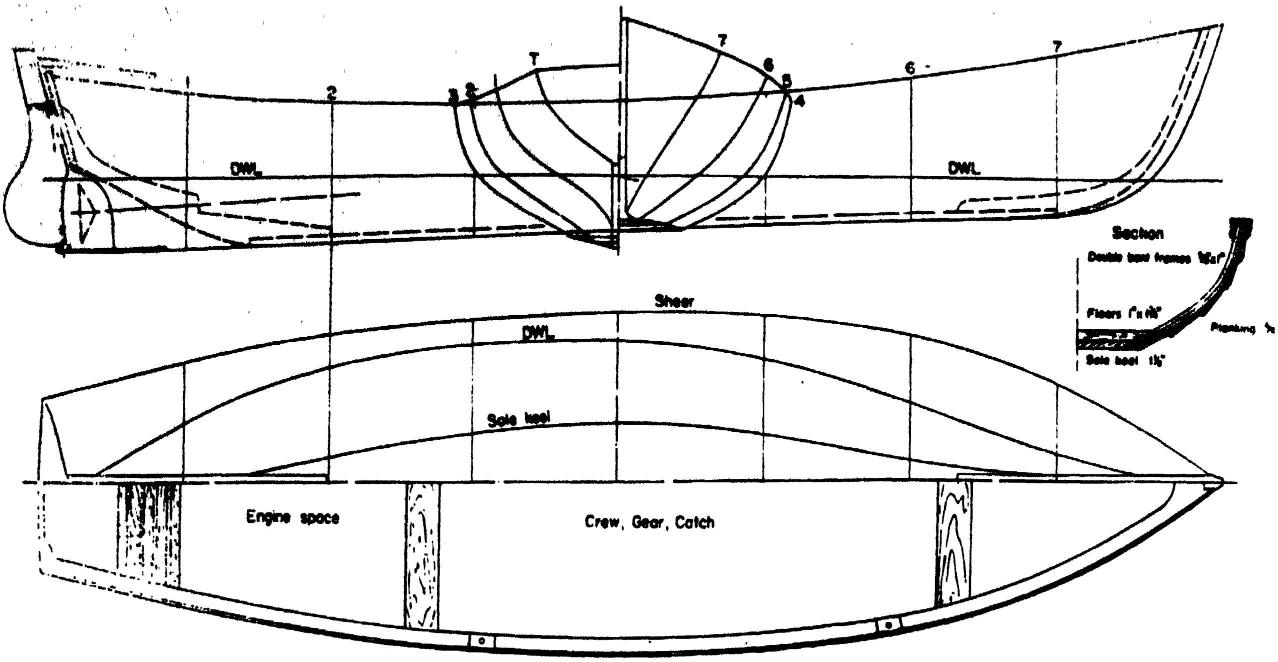


Fig. 635. The first prototypes, surfboats, 18 ft. (5.49 m.) and 20 ft. (6.10 m.), designed by Mr. P. B. Ziener

Prototype, 1955

A second but lighter prototype was designed, essentially of the same shape as shown in fig. 635, but only 18 ft. 3 in. (5.56 m.) overall length, 5 ft. 5 in. (1.65 m.) beam and 2 ft. (0.61 m.) depth. Altogether five boats were built, two by State Fisheries Departments and three by FAO. In late 1955, the first boat, equipped with a 3½ h.p. air-cooled diesel engine, was tried. The 3½ h.p. proved to be only just sufficient for very moderate surf, and the danger of the boat being pushed back by the breaking wave was apparent. Fishing trials showed that a 18 ft. 3 in. (5.56 m.) boat was not an attractive economical proposition to the fishermen, as it could not take sufficient gear on board for a profitable catch.

Extensive trials were held early in 1956 with all three FAO boats, mainly to compare engines of different power, stern gear, and to simplify beach handling. Even if the type was too small for commercial fishing, it was felt that the tests should be made as a kind of model test to gain experience for a larger type. The engine tests indicated that 6 h.p. was adequate for going out through moderate surf; it also became clear that bigger boats could be handled on the beach, provided suitable gear was available. During the trials it became obvious that the boats were of too light construction and would have to be considerably reinforced. They also showed a marked tendency to be rough and wet at sea due to the flat bottom, which had been devised to prevent capsizing in a breaker, taken at an angle. Tests with a deep keel indicated that there was no such danger.

After the trials, local fishermen were encouraged to use the boats from the open beach near Madras. Gudjon Illugason, one of the FAO's Master Fishermen, gave a series of demonstrations. The fishermen, however, would not use the boats from the beach, but preferred to operate them from a sheltered cove. One reason might have been that the fishermen were not sufficiently acquainted with the technique of taking a mechanized boat through surf and were afraid to lose the boat and their catches. Further trials were then discontinued, mainly due to lack of funds and personnel.

CONCLUSIONS FROM FIRST EXPERIMENTS

Sea and surf. Fig. 632, supplemented by table 145, indicates that mean maximum waves, and their resulting breakers, of up to 2.5 ft. (0.76 m.) height must be safely

TABLE 145

Wave heights from 0 to 4 ft. (0 to 1.22 m.)
Percentage of five years

	%		%
Bombay:		Madras:	
Porbandar	73.8	Cuddalore	97.3
Dahanu	99.7	Madras	100.0
Honaver	95.6		
		Andhra:	
Kerala:		Kakinada	42.4
Kozhikode	95.5	Calingapatam	27.4
Madras:		Orissa (questionable):	
Pamban	100.0	Gopalpur	100.0
Nagapatinam	98.8	Puri	99.3

negotiated by the boat. Setting the standard higher, i.e. at 4 ft. (1.2 m.), as required by Andhra and Orissa, would unnecessarily penalize a design for the remaining areas with regard to required strength of construction and safety. It was suggested that Andhra and Orissa should be treated separately, and a special boat developed for these States.

Beaches. Most beaches considered for mechanized boats are only moderately steep and will not prove too difficult for beaching. Narrow, flat beaches, with a marked step near the water, will be the most difficult. A careful study of simple, effective beaching gear is, however, required for all beaches.

The majority of beaches consist of fine sand, forming a soft surface. This will have to be remembered when deciding the bottom shape of the boat, and when designing beaching gear.

Operation. A boat that has to be handled in breakers requires its centre of gravity as far aft as possible. The forebody should have maximum reserve buoyancy. To minimize broaching risks, the boat must have the best possible directional stability. Sensitive steering is of the utmost importance. Draught must be as small as possible to keep the boat afloat near shore. Clean water-flow is essential to make the most of the small propeller that can be fitted in a shallow draught boat. The propeller has to be well protected as frequent grounding will occur; this necessitates a strong stern construction. Due to severe slamming when going out and touching the bar and shore when landing, the forebody must also be extremely strong. Air-cooled engines are preferable as the boat will frequently operate in very silted waters, and the engine has to be kept running on the beach before taking off. Closed circuit fresh-water cooling systems could also be adopted, but they mean added cost and possibilities of failure.

Handling. The weight of the boat must be restricted to allow handling by manpower only. The engine must have a low weight/h.p. ratio. A maximum weight of the complete boat of 2 ton was considered suitable.

Economics. Low initial cost is essential, should the boat be made available to the majority of the coastal fishermen. This means a careful study of all possible methods of mass production, including such modern techniques as fibre glass moulding.

Due to its greater initial cost compared with existing craft, the boat will have to carry a larger quantity of fishing gear to bring home a larger catch. The boat should not be too small, because a bigger boat is safer provided there is sufficient depth of water.

DEVELOPMENT—SECOND PHASE

The first experiments were followed closely by FAO's headquarters, which also endeavoured to interest some of the bilateral technical assistance organizations to take up the task. These bodies had much greater financial resources and did not always require the receiving country to match the expenses from their own funds. There were no immediate responses, but in the meantime the author, who at that time worked at FAO headquarters, was given the task of developing a new design. In this work he received valuable assistance, especially from H. I. Chapelle, who worked as FAO naval architect in Turkey.

Prototype, 1957—BB-57

The outcome was a preliminary design of a boat 24 ft. (7.31 m.) long, 6 ft. 4½ in. (1.94 m.) wide and 2 ft. 7 in. (0.79 m.) deep. She was to be equipped with a 15 h.p. at 1,500 r.p.m. direct-drive air-cooled diesel engine, installed off-centre, giving her sufficient reserve power when going out and even allowing the use of a small trawl. The drawings were sent for comments to a number of FAO field workers and to naval architects in many countries. As a result of the comments received, a new design was prepared in May 1957, called BB-57.

The main dimensions and scantlings were:

The length to remain at 24 ft. (7.31 m.), with 6 ft. 10½ in. (2.09 m.) beam and 2 ft. 10 in. (0.86 m.) depth. The same engine as before.

The backbone to be made up of a 1½×8 in. (38×203 mm.) hog keel, keel plank of ¾×3 in. (19×76 mm.) and a shoe of 1×3 in. (25×76 mm.). The hog continuous fore and aft, the keel plank stopped short about 2 ft. (0.61 m.) aft of midships, where the heavy 3 in. (76 mm.) centre skeg begins. This skeg to be tongue-and-groove joined to a 3 in. (76 mm.) stern post just forward of the transom. The transom to be conventionally built up over a transom frame and joined to the hog with a heavy transom knee. A single piece 3 in. (76 mm.) stem, joined to the hog by a long knee, to complete the backbone assembly.

Planking to be in clinker (lapstrake) fashion, using 11 planks of ⅝ in. (16 mm.) thickness per side. Frames to be steam bent, 1½×½ in. (38×13 mm.), spaced 5 in. (127 mm.) centre to centre. 1½ in. (38 mm.) floors set on every third frame (each frame under engine), reaching up to the bilge stringer and covered by a half frame from stringer to stringer.

Longitudinal strength members to include 1×3 in. (25×76 mm.) gunwale, 1×3 in. (25×76 mm.) covering board, ¾×2 in. (19×51 mm.) rubbing strake, ¾×3 in. (19×76 mm.) short stringer carrying the outside grab rail, ¾×4 in. (19×101 mm.) bilge stringer and very long, 2½ in. (63 mm.) engine bearers. Transverse stiffening to be added by a 2 in. (51 mm.) thwart forward, forming a base for the gurdy, thwarts aft for the helmsman and 1½×3 in. (38×76 mm.) beams at either end of the engine box. A well cambered foredeck of ¼ in. (6 mm.) marine plywood with an oversize, raked splash board to provide protection against spilling waves.

An air-cooled diesel engine of 15 to 18 h.p. was proposed on the port side with shaft parallel to the centre line, and the propeller on the side of the skeg, thus protected by the skeg. There were two main reasons for this unconventional engine disposition:

- A rigid centre line installation, with shaft tube through the skeg, is expensive and would be subject to severe shocks when the skeg hits the bottom. These shocks would create misalignment and might result in damage to the crankshaft bearings and the propeller shaft. The shaft was now only to be supported by a single strut bracket with rubber bearing at the propeller end, being led through the hull planking in a copper tube with flexible stuffing box. The shaft bracket was to be fastened to the hull side and not to the skeg
- With this arrangement it was possible to use a larger diameter screw well tucked away under the stern of the boat. Earlier trials with the 18 ft. (5.48 m.) boats indicated the desirability of having the propeller as far forward as possible, to prevent it from loosing its grip when the stern came out of the water

A further advantage was considered to be that a solid skeg could be built without aperture and consequent weakening at its lower edge. The probable unbalanced steering was foreseen, but it was left to see what could be done about it. The engine was, however, placed so that the turning moment of the propeller would neutralize the turning moment of the off-centre thrust to some extent.

The air cooling of the engine would require a complex system of ducts built into the removable engine cover. The engine box was to be spray tight to protect the engine when crossing the surf. Both gear and throttle controls would be in the helmsman's cockpit. A simple hand bilge pump, arranged on the forward engine bulkhead to discharge directly overboard. The rudder was designed in the centre-line on the stern post, to hang on long pintles and allow it to lift without coming adrift when hitting the bottom. A grab rail to be fitted about 15 in. (380 mm.) below the sheerline, running from station 2 to 8.

When the design was ready, FAO succeeded in interesting the Indo-Norwegian Fisheries Project (INP). to build one boat in Norway, for subsequent testing at their project area in India, and another was ordered by FAO and built at Sekondi, Ghana, West Africa. Fig. 639 shows one of the boats on the beach.

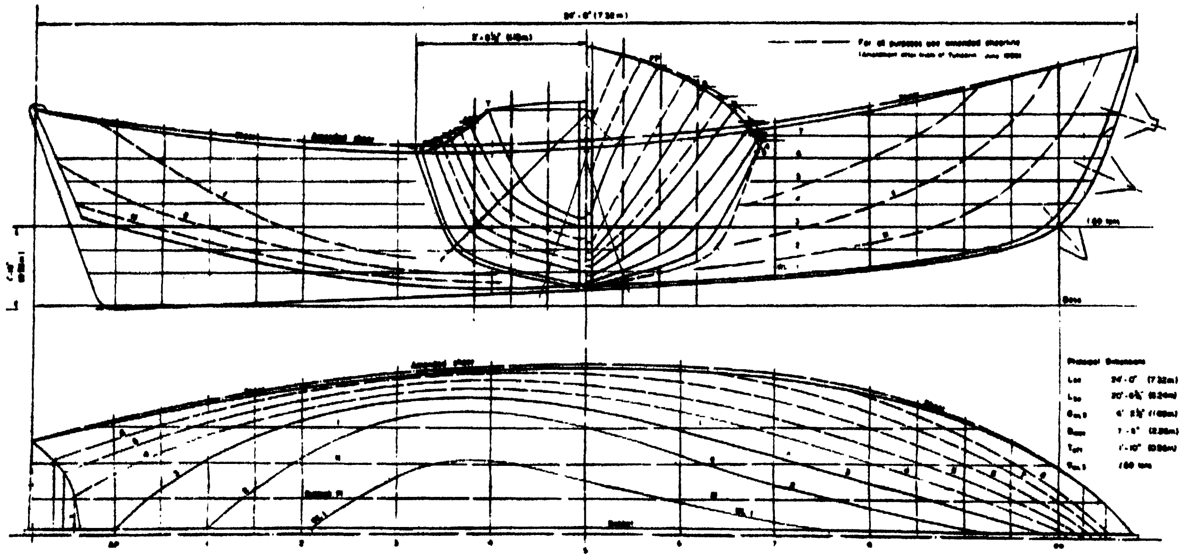


Fig. 636. The fourth surfboat prototype—BB-58

West African tests

Tests were run at Sekondi, Ghana, in January-February, 1958. It was immediately found that the steering arrangement was unsatisfactory, and the rudder was moved to port and hung directly in the propeller wash. Steering then became easier, although it was still an effort to turn the boat in a tight circle to port.

Very good speeds were recorded, 8 knots at 1,400 r.p.m. and about 12 h.p. and 8.1 knots at 1,700 r.p.m. and about 17 h.p. A marked tendency to squat was noticed under speed and the stern wave was great. It was obvious that 15 to 18 h.p. was too much and that 10 to 12 h.p. would be sufficient for normal sailing.

The boat's behaviour in breakers was studied by running her through the breakers in deep water at the harbour entrance. She behaved very well there; no tendency to broach was found and her directional stability was exceptional. She proved to be very dry slamming across the waves, due to her very sharp forebody and the extreme flare of the topsides.

Few beaching trials were made on hard, flat beach, with shallow water extending far out. To move the boat up the beach without great difficulty 16 men were needed, while 10 strong men were required to haul her with rope and tackle. The same number could easily handle her on slide ways and turntable. But all these tests were made with an empty boat; with fishing gear and catch it would have been more difficult.

Landings were made in moderate surf. In the hands of an experienced helmsman the boat came in and out easily, and it was evident that much higher breakers could safely be negotiated. The builders reported successful surf crossings in much higher seas during subsequent trials in the summer of 1958. The following changes to the design were found desirable:

- The freeboard midship to be 3 in. (76 mm.) higher to prevent following waves from spilling in.
- Drain plugs in each compartment to facilitate draining the boat on the beach.
- One additional hand pump and if possible an engine-driven bilge pump to speed bailing after crossing the surf.
- A passageway between aft cockpit and main cockpit. This should be done by lowering the side deck on the off-engine side.

Fig. 637. FAO designed surfboat prototype BB-57 built with Norwegian funds for work at the Indo-Norwegian Fisheries Project

Complete watertightness of the compartments was not felt to be of top importance, provided sufficient pumping capacity could be built in.

Quilon tests

A symposium "The Boat and the Beach", was held in March 1958 at the INP camp in Quilon, Kerala, to discuss general beach boat problems, to compare boats of various designs and to reach conclusions on how to improve these boats. The practical part, trials of the boats, was hampered by the absence of moderate surf, and only general observations could be made.

Various design aspects were discussed, and the FAO team explained the features of its off-centre engine installation, while the INP experts expected better results from a centre-line installation. The outcome was that INP and FAO should co-operate and that both systems should be tried, preferably in the same type of boat.

Three boats were used for practical work during the symposium, a 22 ft. (6.70 m.) INP built boat with canoe stern, a 25 ft. (7.62 m.) INP boat and the FAO designed BB-57, 24 ft. (7.31 m.) long. BB-57 proved to be superior in all respects, the 25 ft. (7.62 m.) INP boat being much heavier and too cumbersome on the beach, while the

Fig. 638. The FAO surfboat BB-57

22 ft. (6.70 m.) INP boat showed similar deficiencies as the FAO 18 and 20 ft. (5.48 and 6.10 m.) boats of earlier years.

Several landings and take-offs were made with BB-57 and she showed definite possibilities. Again, the need for higher freeboard midships and the necessity of providing side keels for easy beach handling was felt. The side keels should run from about station 3 to 7—approximately 18 in. (457 mm.) out from the centre-line—and should be at least 3 in. (76 mm.) deep and 2½ in. (64 mm.) thick at the base. These keels, apart from helping to keep the boat upright on the beach, would also further protect the propeller.

The rudder was moved from the centre line of the boat into the propeller race and was equipped with a balance which was being about one-fifth of the rudder area. This made the steering completely satisfactory; as a matter of fact, the turning circle proved to be the same both starboard and port, which is rarely the case with centre-line installations.

Tuticorin tests

Beaching trials were held in June, 1958, south of Tuticorin, under the guidance of INP's beach landing specialist. The boat was at that time tackling surf conditions nearly approaching those normally encountered. Her behaviour left no doubt that she was

Fig. 639. The FAO surfboat BB-57

capable of coping with much worse conditions in experienced hands. Fig. 637, 638 and 640 give an idea of the ease with which the boat was driven through the breakers. Maximum breaker height during these trials was estimated at about 4 ft. (1.22 m.). As many local fishermen assisted in beaching the boat, the handling was quite easy. It became once more obvious, however, that she could not be managed manually by only ten men. The response of the local fishermen to the boat was very positive and enthusiastic.

Nagapatinam tests

The boat was operated at Nagapatinam for a few weeks on fishing trips. Although the locality is not conspicuous for its surf, it was important to have experienced fishermen use the boat for some time and comment on her suitability for fishing operations. The fishermen complained mainly of the low freeboard midships and the lively motion in heavy seas. The latter will probably be difficult to remedy without sacrificing the good surf-riding characteristics of the boat. Some criticism was heard about the engine, which the fishermen found to be very complicated and requiring detailed maintenance.

The exhaust, taken straight over the side from each of the opposed cylinders, was a source of trouble, as water entered the silencers and even the cylinders.

Beach fishing trials were also to be made at Madras and the boat was moored outside the harbour in shallow water, together with six other fishing boats. A very short, powerful storm ripped her off her moorings early in October and she was thrown on to the boulders outside the harbour breakwater, becoming a total loss. Examination of the wreckage did not indicate that constructional weaknesses played any part in the loss. Three heavily built 25 ft. (7.62 m.) fishing boats were also lost under similar circumstances. The impact on the boulders must have been tremendous, as all boats were shattered to pieces.

EXPERIENCES FROM THE BB-57 TESTS

Reaching the shore

Fig. 641 attempts to give a schematical idea of how to, and how not to, bring a mechanized boat through the breakers when reaching the sea shore. Arrows to the right of the boat outline roughly the direction of the boat's motion in each phase. Correct beaching procedure through plunging breakers is considered to be as follows:

While nearing the beach or inlet, the helmsman will carefully observe the local wave pattern and count the number of small waves and the following single or multiple big wave. He will then try to locate the breaking point of the inrolling waves, a task that can be very difficult from a small boat with practically no height of observation. Approaching this point at low speed, the boat should be kept just off the breaking point until the last big wave of the pattern runs in. As soon as this wave has passed the centre of gravity of the boat, i.e. when the forebody starts to lift, full speed ahead will bring the boat riding in behind the wave like a surf board. Any tendency to overshoot the wave can easily be controlled by the throttle. During the riding in, the helmsman must be very careful to counteract any broaching tendency of the boat in the longshore current. This is not easy, as the boat will make very little speed through the water, with consequent loss of manoeuvrability.

The wrong way of beaching is shown in the right half of fig. 641. It is seen that a boat with its centre of gravity forward of the breaking point of the wave will tip head over, with the breaker very likely swamping her and broaching in the longshore current following.

Beaching a catamaran in surf may be equally, if not more, difficult as the raft has no means of correcting its position relative to the breaking point of the wave. Thus overturning of catamarans occurs quite frequently on the East Coast.

Fig. 640. The FAO surfboat BB-57

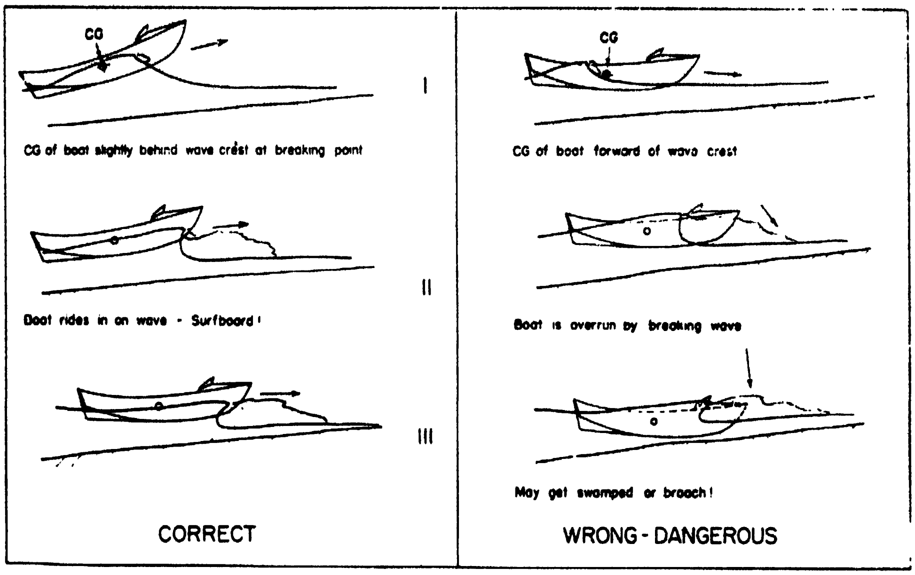


Fig. 641. Schematic idea of the right and the wrong way of handling a mechanized boat through the breakers

The sequence of taking off is shown in fig. 642. If there is sufficient deep water between the shore face and the breaker line for the boat to pick up speed, this operation is not very difficult. There is a critical point again, however, when the boat crosses the second inrunning wave. It must be well over the crest before this wave starts to break, otherwise the released energy will tend to push the boat back and under, swamping it. This is indicated in broken lines in phases III and IV. Crossing the second wave will always be followed by severe slamming of the boat, indicating the need for very strong forebody construction.

With breakers almost on the shore line, and a fairly steep beach, for example, at high tide, launching is somewhat difficult. The boat will have to be steadied against the onrush of the breakers, grounded to a standstill, with engine running and gear in the ahead position. Immediately after the biggest wave in the pattern breaks, the boat must be pushed clear and pick up speed to clear the next wave before it breaks. This is not easy with a wave period of 7 to 10 sec.

Difficulties of beaching

While there are no great difficulties when the boat is hauled by winches or a tractor, beaching is an irksome business when the boat has to be handled by manpower alone. This is the present position in India, and it is doubtful whether even a successful mechanized boat will bring many mechanical beaching aids into use.

The power to drag a boat up the beach depends primarily on the weight of the boat, but to no small extent also on the composition of the beach and the shape of the boat in contact with it. Flat bottom boats proved to be undesirable as a combination of sharp forebody and flat bottom produces a marked plough effect and the boat tends to dig deeply into the sand. Table 146 gives the results of measurements taken with a spring balance hooked into the towing line while different boats were

TABLE 146

Beach-resistance of beach boats

BOAT			PULL		
Type	*LOA* *ft.* (*m.*)	*Weight* (*ton*)	*On sleepers* *lb.* (*kg.*)	*On rollers* *lb.* (*kg.*)	*On sand* *lb.* (*kg.*)
INP—5	22 (6.70)	1.2	772 to 1,587 (350 to 720)	441 to 551 (200 to 250)	1,322 to 1,764 (600 to 800)
FAO BB-57	24 (7.32)	1.5	772 to 1,146 (350 to 550)	—	1,874 to 1,984 (850 to 900)
INP—1	25 (7.62)	2.1	1,433 to 2,204 (650 to 1,000)	1,102 to 1,543 (500 to 700)	2,204 (1,000)

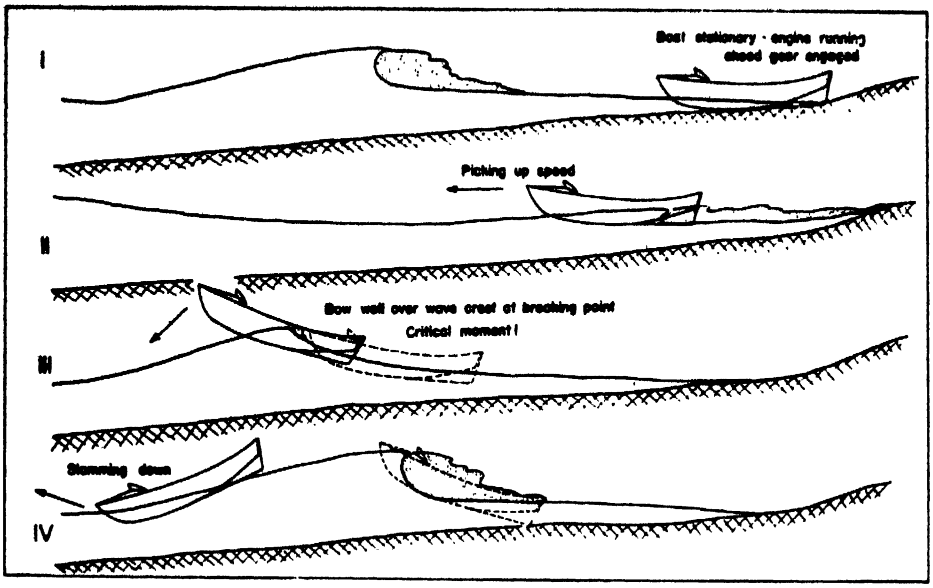


Fig. 642. Taking off from the beach

towed up the beach by a tractor at Quilon. It illustrates the effect of simple beaching aids in minimizing the necessary pull.

Speed of advance was 1 to 1½ ft./sec. (0.30 to 0.46 m./sec.). Rollers had to run on planks or beams as otherwise they dug into the sand. The results were obtained on moderately soft sand.

The earlier observations in West Africa gave the impression that much less pull was needed, but the beach was very hard. The figures in table 146 substantiated by earlier experience in West Africa, would indicate that the boat should not weigh more than 2 ton when being handled by men without any mechanical assistance; if it does, rollers would be necessary. The maximum effort is required as soon as the forefoot of the boat touches the beach. She must then be manually moved as fast as possible up the beach so as to bring her out of reach of any following breakers.

The development of suitable beaching gear must be given priority and keep in step with the development of the boat. It is reasonable to believe that a mass production model of the selected boat will be considerably lighter than the present, conventionally built prototypes. Then, simple wooden rollers, rolling on planks or beams, together with a heavy rope and tackle fixed to a palm tree or anchored a good way up the beach, should be adequate beaching aids for a gang of 8 to 10 men. Another system, as tried in West Africa, would be to have two slide ways, each about 12 ft. (3.66 m.) long, one with a pivot hole in the centre, as well as a simple turntable. With this system the boat is hauled up on the first slide way, the second one, with the turntable under, is placed in front and the boat hauled. Turning the boat with this system is exceedingly easy. The use of ladder-like roller conveyers will also have to be tried.

In many localities the boats could be anchored in deep water during part of the year when there is little or no surf; or existing river inlets with a surf bar offshore should be used, reducing the need for beaching whenever possible.

PROTOTYPE, 1958—BB-58

As a result of the symposium, "The Boat and the Beach", and the trials described above, certain improvements were suggested. It was decided that the boat should have more beam, and more freeboard midships and aft. As 15 h.p. was considered too much power for sailing, and trawling not being likely, it was decided to install only 10 to 12 h.p. in future boats. Furthermore, the fairly marked deadrise in the boat's bottom did indicate that side keels would be a great advantage for beaching. At the same time, it was felt that such keels might help somewhat to dampen the lively motions of the boat in a seaway.

New lines were prepared with these improvements in mind, and fig. 636 shows BB-58. One boat has been built to this design in Madras, but no trials have as yet been made. It is of carvel construction, as no carpenters experienced in clinker building were available in Madras, and it will be interesting to see if this will be strong enough for surf work. A second BB-58 is at present being built in the INP's yard at Quilon and should be commissioned early in April, 1959. Both boats will be equipped with 10 h.p. air-cooled diesel engines, the Madras one with reduction gear and 16 in. (406 mm.) propeller, the INP one with direct-drive and 13 in.

(330 mm.) screw. In addition, INP will test the FAO owned BB-57, built in Ghana, which has been sent to India.

It is hoped that the Madras built BB-58 can be sent to Quilon for trials, thus there will be three boats available for comprehensive testing. The main object of these trials will be to find any possible structural weakness in the design, and the boats will be driven as hard as possible. The tests will also show whether the shape can be improved.

Model tests

At the suggestion of the Central Water and Power Research Station, Poona, it was decided early in 1958 to try to simulate surf conditions in a wave channel and test various designs there. The task proved to be very difficult, and to date there are no conclusive results available.

The tests are run in a long, narrow channel, all waves approach the beaches at 90°, thus not creating any long-shore current. The models are self-propelled, speed and rudder being controlled by overhead cable. It seems that the main difficulty is to simulate "real" operating conditions. Due to the model scale, manoeuvring has to be done very fast and is exceedingly difficult, the helmsman's touch on the tiller is simply missing.

FUTURE WORK—MASS PRODUCTION OF BB-59

On the bases of the BB-57 and BB-58 designs, a new design has recently been made for plywood construction, and a hard chine hull. Fig. 643 gives the lines of BB-59, while fig. 644 gives an idea of its layout. The first boat will be built by bonding together with fibre glass reinforced plastic the ½ in. (12.7 mm.) marine plywood panels. The boat will have longitudinal framing and watertight buoyancy compartments forward and aft. A 10 h.p. diesel engine will be installed off-centre, and it will be possible to move easily from midships to the aft cockpit. One such boat will be built in 1959 to the order of the Indian Ministry of Food and Agriculture, and INP, and the Madras Government have tentatively decided to build one more boat. The INP boat will be built of marine plywood without plastic bonding, and it is

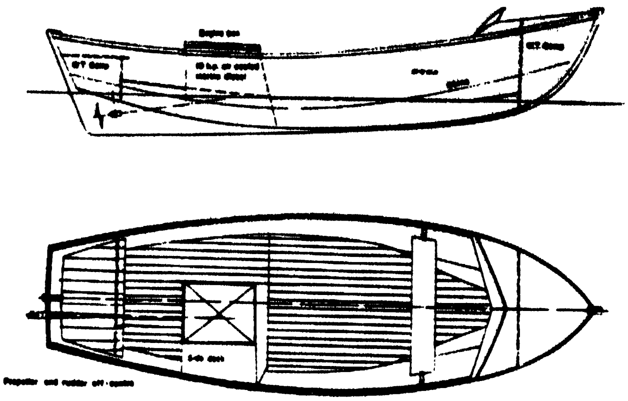


Fig. 644. Arrangement of BB-59

planned to re-design the aft body, giving it a hollow keel line to permit the installation of a bigger propeller in the centre line. To protect the propeller, and still keep the shaft line shock free, it is proposed to use a propeller guard such as those on recent types of LCVP in the U.S. Navy (Moore, 1958). The Madras boat will be conventionally planked, and it is intended that she should have a centre-line installation, too, and the new propeller guard. The plywood boats will be considerably lighter than those built so far, and they should allow reasonable conclusions with regard to beaching gear to be drawn.

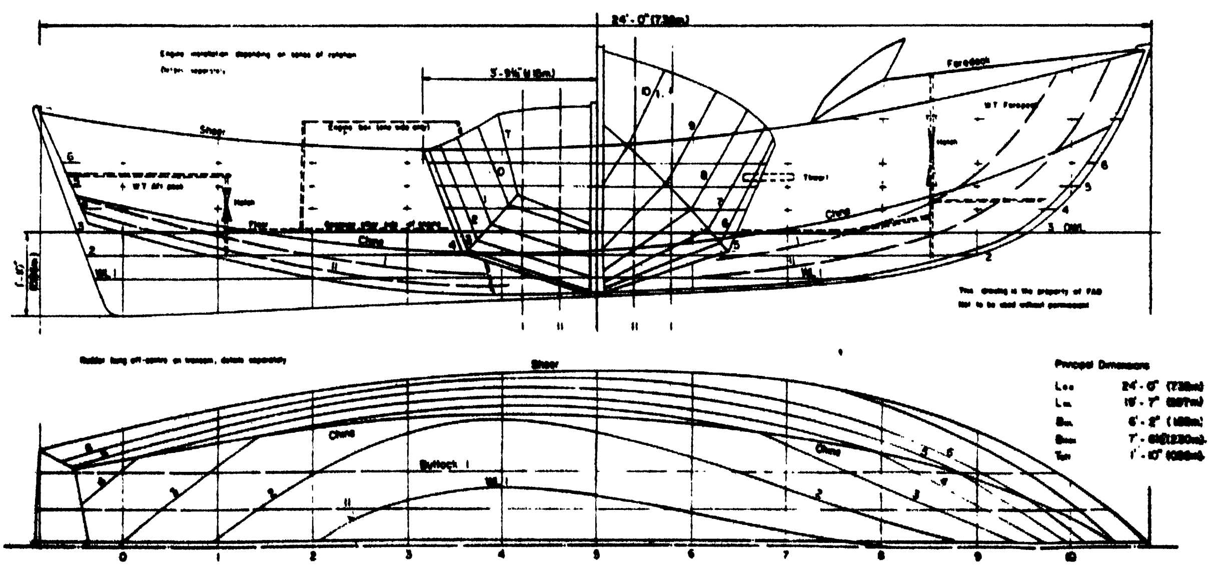


Fig. 643. Lines of the 24 ft. beach boat BB-59—built of plywood bonded with reinforced plastic

Fig. 644A. BB-59 on the beach at Puri, Orissa

TABLE 147

Weights and particulars of the beach boat BB-59

LOA	24 ft. 0 in. (7.32 m.)
B max.	7 ft. 6¼ in. (2.3 m.)
T max.	1 ft. 10 in. (0.56 m.)
Weight unloaded	Conventional construction: approx. 1.8 tons Plywood boat: approx. 1.3 tons
Loading capacity	Conventional construction: approx. 1.0 tons Plywood boat: approx. 1.5 tons
Engine	10 h.p. air-cooled diesel, direct-drive at approx, 1,500 r.p.m.
Propeller	13 in. (330 mm.) diam. 8, 9 and 10 in. (203, 228 and 254 mm.) pitch to be tried

Later in the year, probably during October, it is proposed to move the available BB-59's to Orissa for the North-East monsoon to make a series of tests.

Trials can only be run when surf conditions are right at the testing place. Any improvement or change as a result of trials means building a new boat. Normally about one year lapses before changes can be tried. This will explain the dearth of reliable, exact data, and the belief that it will take at least another two years until a suitable, economical design can be finalized.

With the start of the third Indian Five Year Plan in 1961, it should be possible to start mass production of a thoroughly tested, suitable type of boat. The first production models would only be given to trained fishermen, who in turn would have to train other men in their localities. During the first year about 100 boats may be made available. This fleet would no doubt furnish further specific ideas for improvements to be incorporated in the next production batches.

The main difficulty of getting this ambitious programme through will perhaps not be the boats. The real hurdle is the financing and getting engines in large numbers. The latter will most likely only be possible if good air-cooled marine engines of suitable type can be produced in India, as imports are severely restricted due to the difficult foreign exchange situation.

Table 147 gives the principal dimensions as adopted for boats now being built.

[*Editor's note:* Extensive trials were made along the Indian coast up to 15 February 1960. The main conclusion was that the FAO designed boats have proved to be technically qualified to be operated from beaches under certain limited conditions. Fig. 644A shows the BB-59 on the beach at Puri, Orissa].

COMMERCIAL OUTBOARD FISHING CRAFT

by

DAVID D. BEACH

The mass produced U.S. outboard motor accounts for a very large portion of the internal combustion marine engines manufactured in recent years. These engines, primarily designed for pleasure boating, provide the power for many craft engaged in commercial fishing.

This paper is an attempt to indicate the nature of the craft which have evolved in the U.S.A. in recent years, more particularly since the advent of the larger motors. The several types chosen as illustrations are discussed in some detail, with some attention given to the means of fitting the motors in the boats.

Drawings of the several types are provided which, with the photographs, can be used for building duplicate craft and will stimulate thinking in other parts of the world on installing outboards in local types of fishing boats.

LES BATEAUX DE PÊCHE INDUSTRIELLE A MOTEUR HORS-BORD

Les moteurs hors-bord fabriqués en série aux E.-U. représentent une très grande partie de la puissance en c.v. des moteurs marins à combustion interne produits ces dernières années. Ces moteurs, conçus tout d'abord pour la navigation de plaisance, fournissent la puissance de propulsion de nombreux bateaux pratiquant la pêche industrielle.

La présente communication essaie d'indiquer la nature des bateaux qui ont évolué aux E.-U. ces dernières années, plus particulièrement depuis l'apparition des gros moteurs. L'auteur examine de façon assez détaillée les divers types choisis comme illustrations, et porte son attention sur les moyens de fixation des moteurs sur les bateaux.

Des dessins sont fournis pour les différents types; ils pourront être utilisés avec les photographies pour construire des bateaux semblables et, dans d'autres parties du monde, stimuleront l'idée d'installer des moteurs hors-bord sur les types locaux de bateaux de pêche.

EMBARCACIONES DE PESCA INDUSTRIAL CON MOTORES FUERA DE BORDA

Los motores fuera de borda fabricados en serie en los E.U.A. representan una gran parte de la potencia en c.v. de los motores marinos de combustión interna producidos en los últimos años. Estos motores, proyectados principalmente para las embarcaciones de recreo, suministran la potencia de propulsión de muchas embarcaciones dedicadas a la pesca industrial.

En esta ponencia se trata de indicar la naturaleza de las embarcaciones que se han perfeccionado en los E.U.A. en años recientes, y, en especial, desde la aparición de los motores mayores. El autor examina con bastantes detalles los diversos tipos elegidos como ilustraciones, poniendo de relieve los medios de fijar los motores a las embarcaciones.

Se facilitan planos de los diversos modelos, que, juntamente con las fotografías, pueden emplearse para construir embarcaciones análogas y estimular en otras partes del mundo la idea de instalar los motores fuera de borda en los tipos locales de embarcaciones de pesca.

THE papers and the discussions at the first World Fishing Boat Congress in 1953 mentioned outboard motors only superficially and in a way which suggested that the authors and discussers were not familiar with recent developments, inferring that the two-stroke outboard remained unreliable. But the feats of performance and endurance by these motors have proved their reliability, which is further stressed by the acceptance of them by fishermen.

In general, the craft discussed have been tested in operation. The advent of the 25 h.p. outboard motor, with its separate fuel tank and a neutral and reverse gear, gave considerable impetus to the adaptation of the outboard to fishing boats, which has been particularly rapid since World War II. Hundreds of these craft have been built and used, and the result is an accepted series of models.

No great consideration is given to the adaptations of the standard transom pleasure craft for which the outboard motor was first developed. Such adapted craft are shown, for example, in fig. 645 to 647. These craft, however, are representative of many of the outboard-powered boats which make a living for their operators, especially in fishing for lobsters, shrimp and scallops which command such good prices that even small catches are profitable.

Florida Mullet gillnet skiff

A small boat suitable for gillnetting in placid waters seems to be of first importance. Many areas in the world abound in such waters where large catches may be made close to the fisherman's base of operations. Such a craft is the Florida mullet skiff, fig. 648. These boats abound in the inland waterways in the southern states, from southern Georgia around the Florida peninsula into Texas. They are built with planking of sheet plywood, and, generally, they have an overall length of about 20 ft. (6.1 m.) with beams at the transom approaching 7 ft. (2.13 m.). The depth is usually less than 2 ft. (0.61 m.); because they operate in sheltered waters,

Fig. 645. The conventional application of an outboard motor to the transom of a small lobster pot tender is an example of a planing type working fishing craft. Where pots are set some distance from base, a larger craft must be used

seaworthiness is not a prime requirement. The shallow gillnets are set and hauled over the stern, and so require substantial buoyancy and working room in the stern. The nets are often carried on a self-bailing tray, while the catch is normally carried in a built-in or loose box athwartship. As a clear working space is required aft, the motor should be mounted elsewhere. The mounting well shown in the drawing allows the motor to be both steered and pivoted.

A feature of the construction of this type is the use of the standard large sheets of plywood, which is widely used in the U.S.A., for small boats of all types. The bottom is cut from the standard panel 6 ft. (1.83 m.) by 20 ft. (6.1 m.), while the two sides are cut from a single panel 4 ft. (1.22 m.) by 20 ft. (6.1 m.). The bottom longitudinals are heavy and provide for nail fastenings to the bottom planking. The inner longitudinals are spaced so as to provide a landing for the sides of the motor well. When not in use, the motors are usually tilted up because they are not protected by marine paints and would foul if left in the water. The metallic additives in anti-fouling paint are not completely compatible with the aluminium die-castings from which the motors are made.

Fig. 646. The high thrust of the larger outboard is needed to tow this small shrimp trawl

Some boats are built more heavily than that shown in fig. 648 having ¾ in. (19 mm.) side planking on closer spaced frames and 1 in. (25.4 mm.) cross-planked bottom. The dimensions do not vary appreciably, except for a somewhat increased beam aft. In normal operation, the one- or two-man crew sit forward and the boats run quite well both light and loaded. The sloped after end of the well does not seem to affect the performance and little water splashes into the boat. A transverse wedge is fitted across the inside of the well to suppress any splash in waves.

Fig. 649 provides curves of the speed-load pushing capabilities of a wide range of standard motors. The bare weight of the boat is 660 lb. (300 kg.). With a 10 h.p. motor, fuel containers and a two-man crew, the displacement exceeded 1,100 lb. (500 kg.). At this displacement the speed was 10.3 knots, which decreased to about 4.9 knots, as more than 1,300 lb. (590 kg.) of fishing gear and catch were added. Corresponding performance curves are shown for the 18 h.p. and 35 h.p. motors, which indicate that these craft are not truly responsive to increased horsepower in the loaded

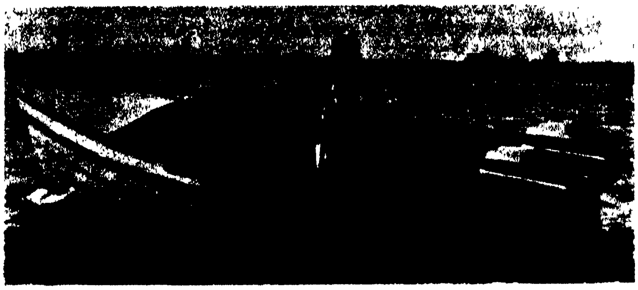


Fig. 647. This twin mounting of large outboards is required to drag a pair of heavy scallop dredges

condition. The power most popular with the fisherman along the west Florida coast is in the 12 to 20 h.p. range, going occasionally up to 25 h.p. The 18 h.p. motor permits speeds of 10.7 knots light and over 4.9 knots with half a ton of catch aboard. These performances, it should be pointed out, are not optimum, as they were run with standard propellers. As the speed decreases due to increased load, the engine speed also decreases because of the excess pitch of the standard propeller and the power falls off considerably. The fishermen are aware of this and equip their engines with lower pitch propellers to attain full engine revolutions and full power development. This increases speed at least 10 to 15 per cent. over that shown in the curves.

Some of these craft, photographed in Naples, Florida, U.S.A. are shown in fig. 650 to 654.

River gillnet tender

There are numerous deep-water rivers along the eastern seaboard of the U.S.A. which lead to the spawning waters of fish such as the shad. Examples are the

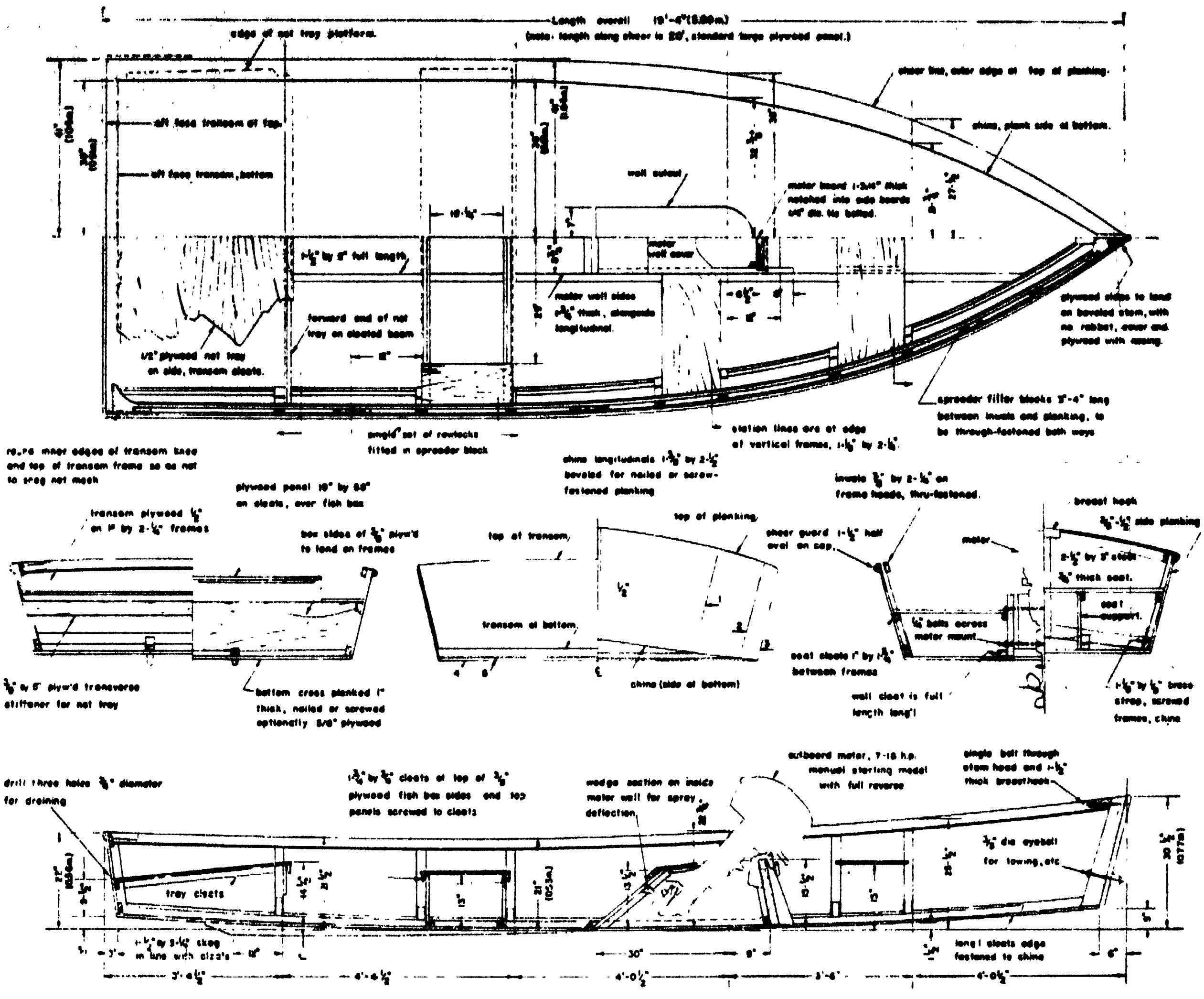


Fig. 648. 20 ft. (6.1 m.) Florida mullet gillnet skiff of usual design

Delaware, Hudson and Connecticut rivers. In these tidal rivers, gillnets are placed on poles driven into the river bed, the nets being below the surface at high tide and often at the surface at low tide. A type of craft something like the Florida mullet gillnet skiff has been evolved to tend these nets which are often set in waters where tidal flows approach 2.5 or 3.3 knots.

When the nets were tended by rowed craft, using two pairs of oars, the normal mode of approach to the net was stern against the tide. The oarsmen would row to hold the boat stern against the net while one or two fishermen would haul the net up and pick out the catch. The fishermen would move the craft along the length of the net with the oarsmen keeping the boat in place.

The boat shown in fig. 655 is of the lapstrake type, built in the Highlands. These boats have a simple motor well about 6 ft. (1.83 m.) from the stem, which is entirely suitable for operation in deep water where there is no need to tilt the outboard. The novel feature of this craft is the use of a cylindrical metallic motor mounting well of heavy gauge pipe. The motor is placed in the well and clamped on. The operator sits on the thwart forward of the motor, and operates the throttle and reverse gear while facing aft so that he can best observe the net handlers. The construction details shown indicate bevelling of both planks at the lapstrake, a method not normally used. Only the top edge of the planks are usually bevelled.

Oyster garvey

The hull form discussed by Chapelle (1955) is also used for outboard craft. Chapelle provided the information for preparing the drawings in fig. 657. This craft, 27 ft. 9 in. (8.45 m.) in length, with a beam of 7 ft. 3 in. (2.21 m.) is a recent development in the oyster fisheries. Chapelle has written that he thinks the future of the

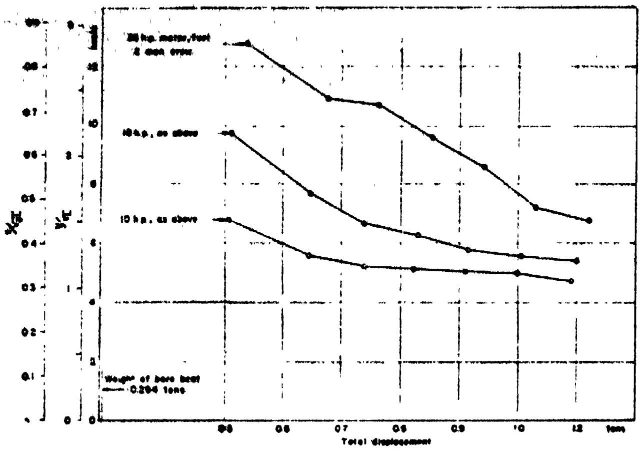
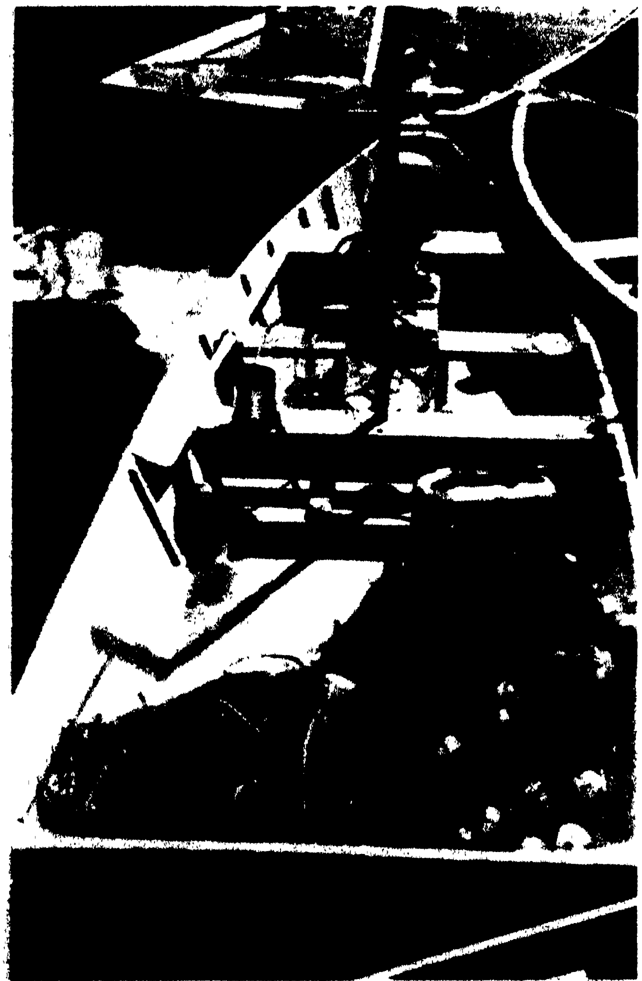
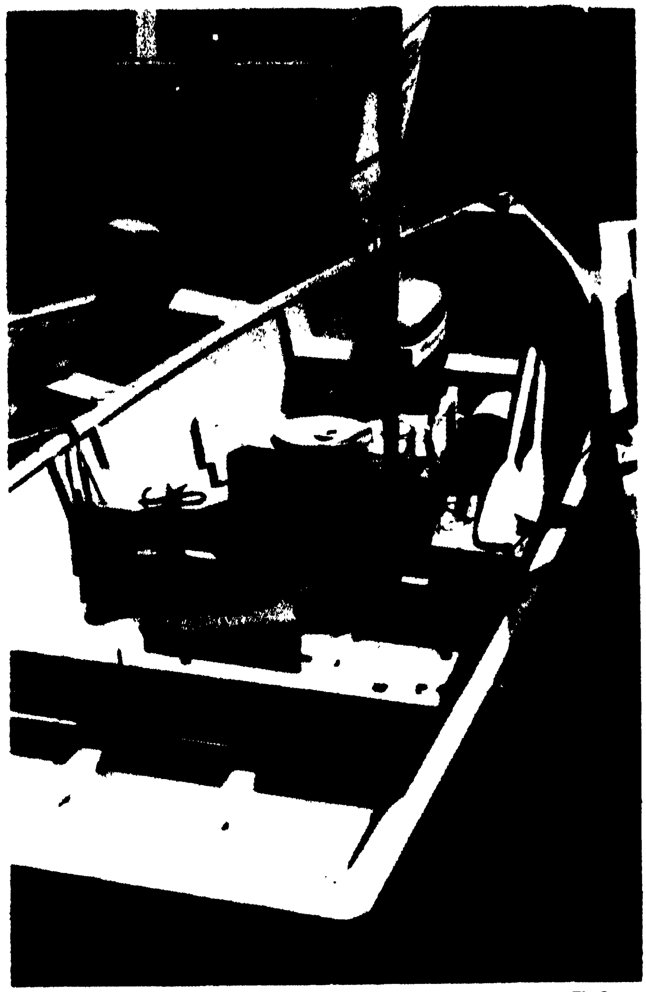


Fig. 649. Performance curves for 20 ft. (6.1 m.) mullet gillnet skiff



Chefneux

Fig. 650. A Florida mullet gillnet skiff is a simple craft, yet often hauls over half a ton of fish.



Chefneux

Fig. 651. Mullet gillnet skiffs are often fitted with an electric light for night fishing.

Chefneux

Fig. 652. A boot of inner tube rubber is often fitted around the motor to reduce the splash into the boat.

outboard in the commercial fisheries lies in the heavy duty motor, not made as yet in the U.S.A., and fitted to larger boats. He feels, with some measure of agreement by the author, that outboard powered *fleets* would be an economic operation if more motors than boats were available and maintenance was provided on a fleet basis.

A feature of this craft is the use of twin skegs which provide protection against grounding, and make it easy to beach and launch the boat. The motor is mounted on a heavy cross-framed bulkhead at Station 12, and projects through the bottom motor cut-out between the skegs. The transom is cut out, as indicated on the body plan, to permit easy after flow of the wake and to permit the escape of exhaust fumes from the by-pass without contaminating the air taken in by the carburettors.

The garvey is popular along much of the New Jersey coast and in Chesapeake Bay. It is generally considered a craft for sheltered waters, but the substantial construction, together with large beam, could allow operations in fairly rough waters, as indicated in their offshore use

Chefneux

Fig. 653. A slightly different well for the outboard motor in a cross-planked 20 ft. (6.01 m.) vessel

Chefneux

Fig. 654. Mullet gillnet skiff from Naples, Florida

through the New Jersey inlets. One of a substantial fleet operating in the Maryland oyster fisheries, with only one man as crew, is shown in fig. 658. A 25 h.p. motor is generally used in a boat of this size and operators report speeds of 12.4 to 14 knots in light condition. The boat is not fitted with the remote controls such as are used in, for example, the New England lobster boat. The arrangement and fitting of the motor well is shown in fig. 659, and the craft under way is shown in fig. 660.

Salmon net

Perhaps the largest commercial use of outboards for fishing is in the salmon fisheries in the Pacific Northeast and the State of Alaska. The craft shown in fig. 661 is representative of the very heavily built type which is widespread in the area. It has proved entirely satisfactory for the rough waters as far north as Cordova Bay on the Alaskan coast. The motor is fitted in a well aft, and the craft is operated from aft, but as noted on the plan view in fig. 661, the motor may be located off the

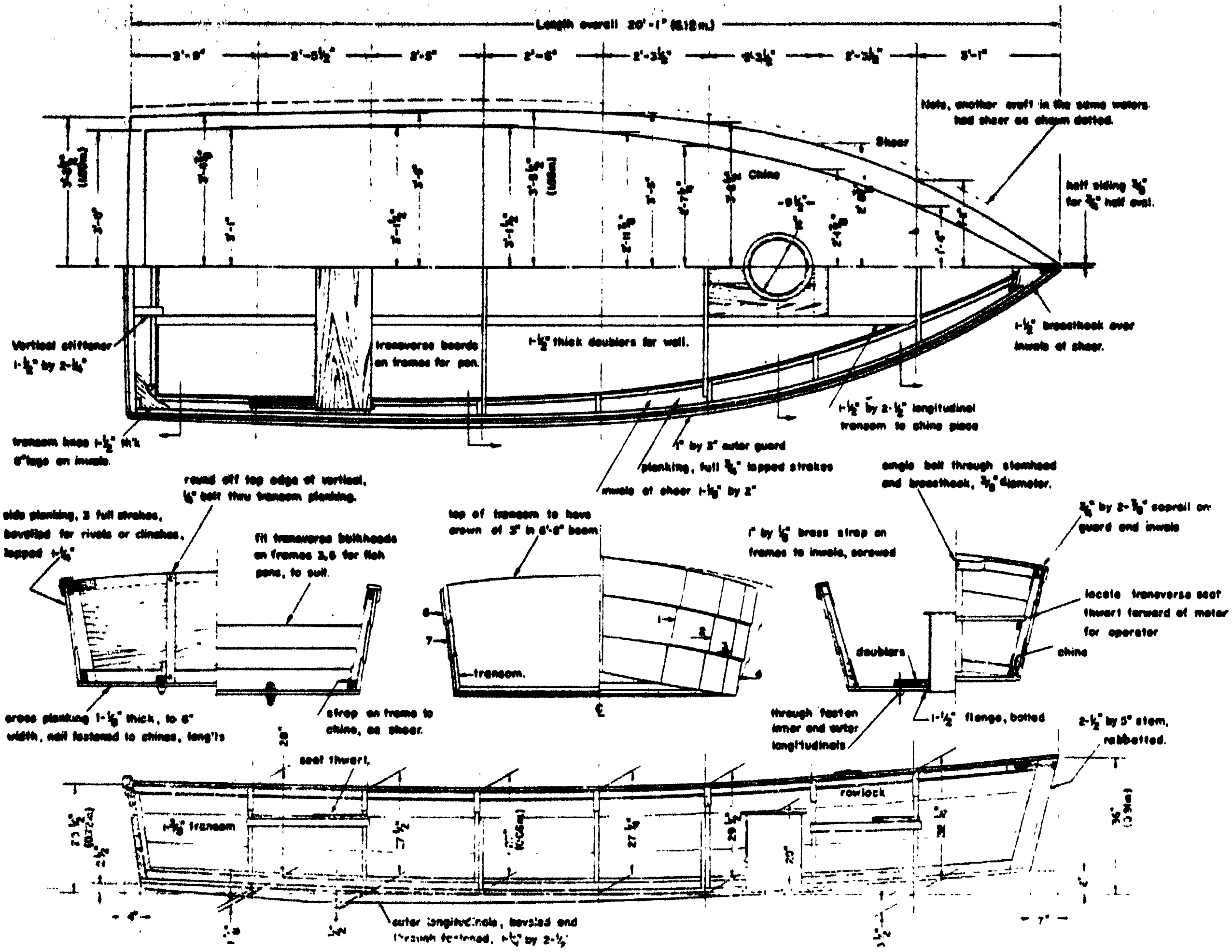
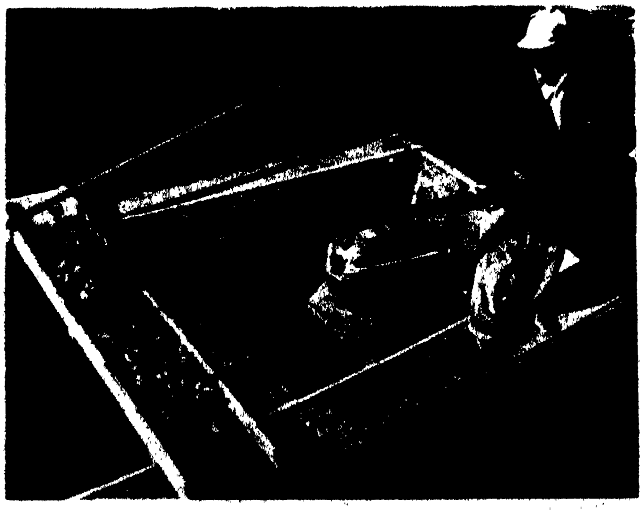


Fig. 655. 20 ft. (6.1 m.) set gillnet fishing boat of the lapstrake type



ABOVE: *Fig. 659. The motor in the stern of this 26 ft. (7.92 m.) oysterman's craft is fitted in a well which permits only slight tilting, which is satisfactory for deep waters over the oyster beds*

LEFT: *Fig. 656. The shad fishermen in the Hudson river, opposite the upper end of Manhattan Island, U.S.A. handling gillnets. The motor is a 10 h.p. model with reverse gear*

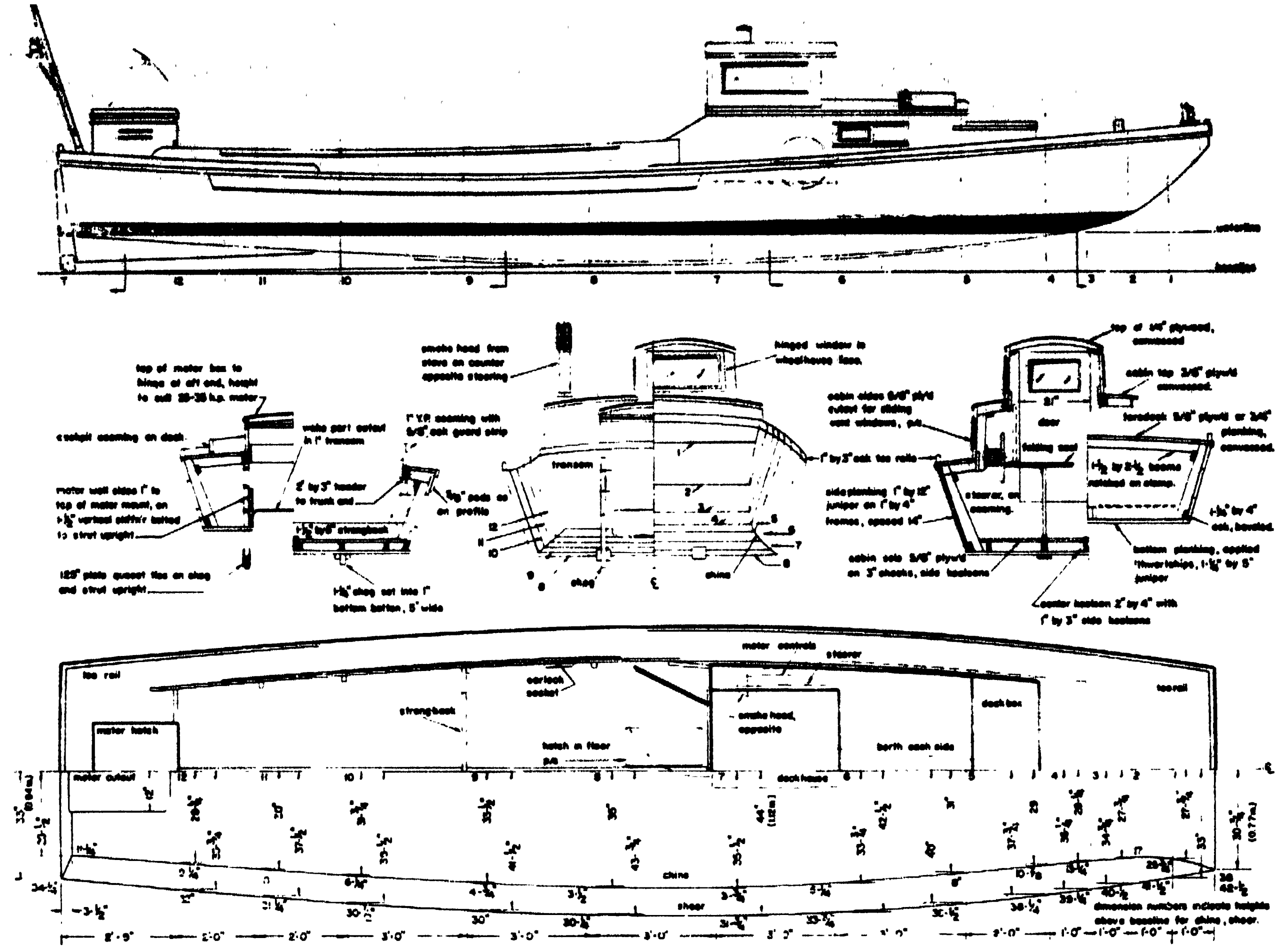


Fig. 657. 27.75 ft. (8.46 m.) Chapelle designed crabbing and oyster garvey

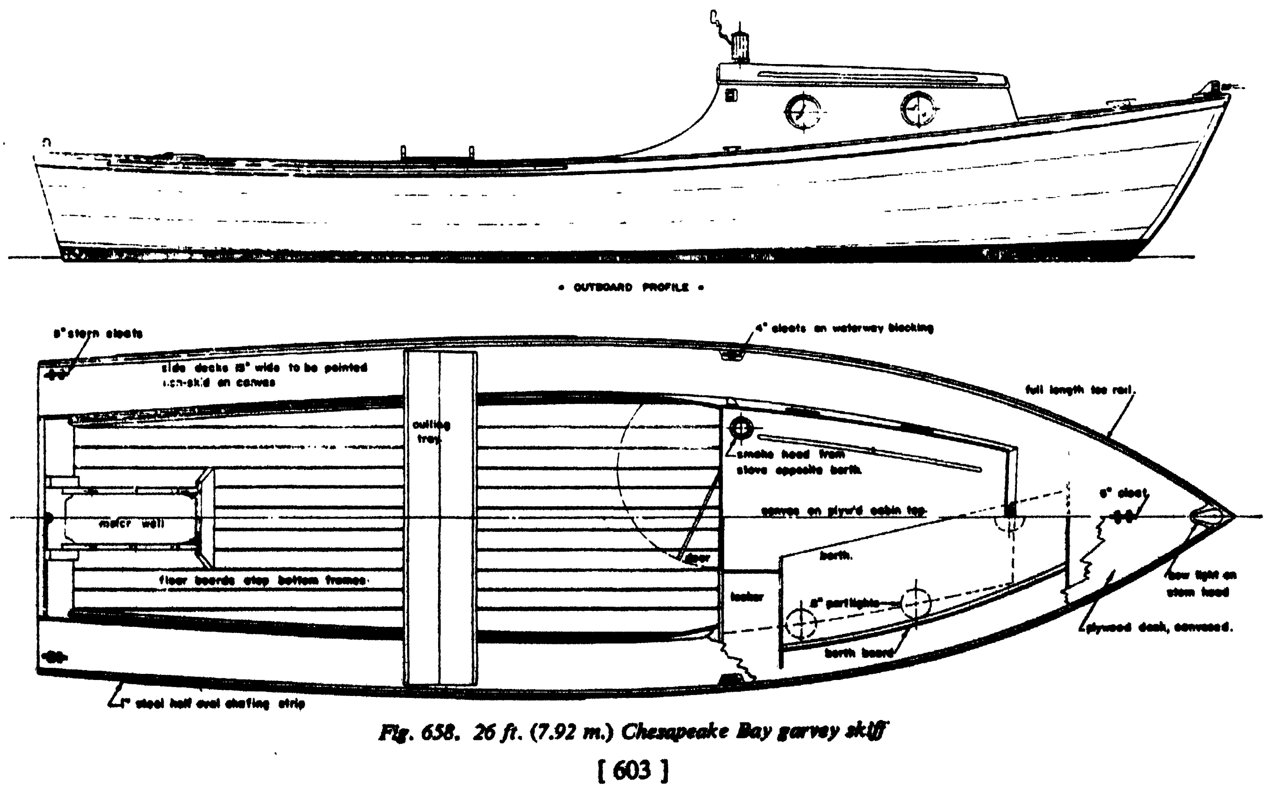


Fig. 658. 26 ft. (7.92 m.) Chesapeake Bay garvey skiff

Macklow

Fig. 660. When light, the Chesapeake Bay garvey boat rides a bit down by the bow, when driven at a speed-length ratio of 3, approximately 12.5 knots.

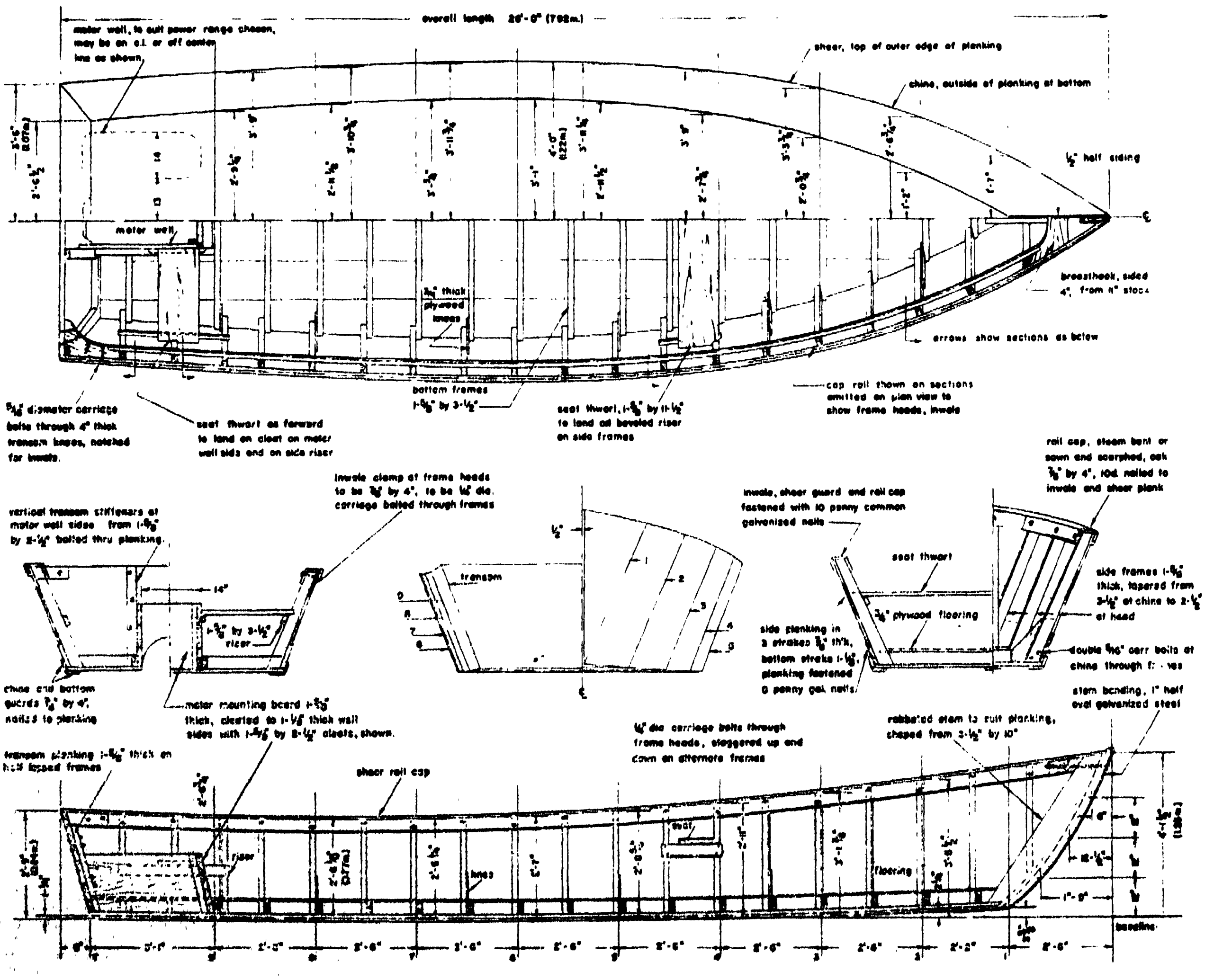


Fig. 661. 26 ft. (7.92 m.) salmon net tender and utility boat

Fig. 662. The off-centre motor installation provides room at the transom for working the nets in this 26 ft. (7.92 m.) Seattle-built boat

Fig. 663. Nearly 500 boats very similar to this Seattle-built 26 ft. (7.92 m.) skiff are engaged in the Alaska salmon fisheries

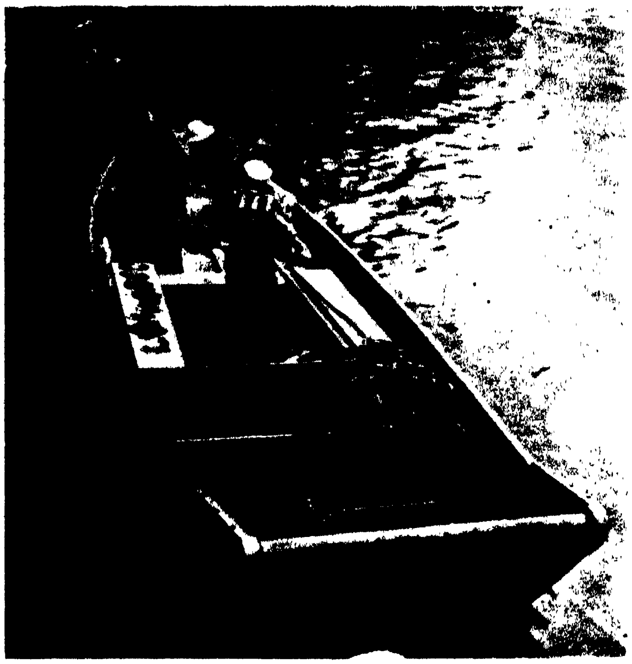


Fig. 664. A 25 ft. (7.62 m.) salmon skiff with bow well installation of a 5 h.p. outboard motor, fitted with full width transom roller for net setting and hauling. This is a typical Cordova Bay (Alaska) salmon skiff

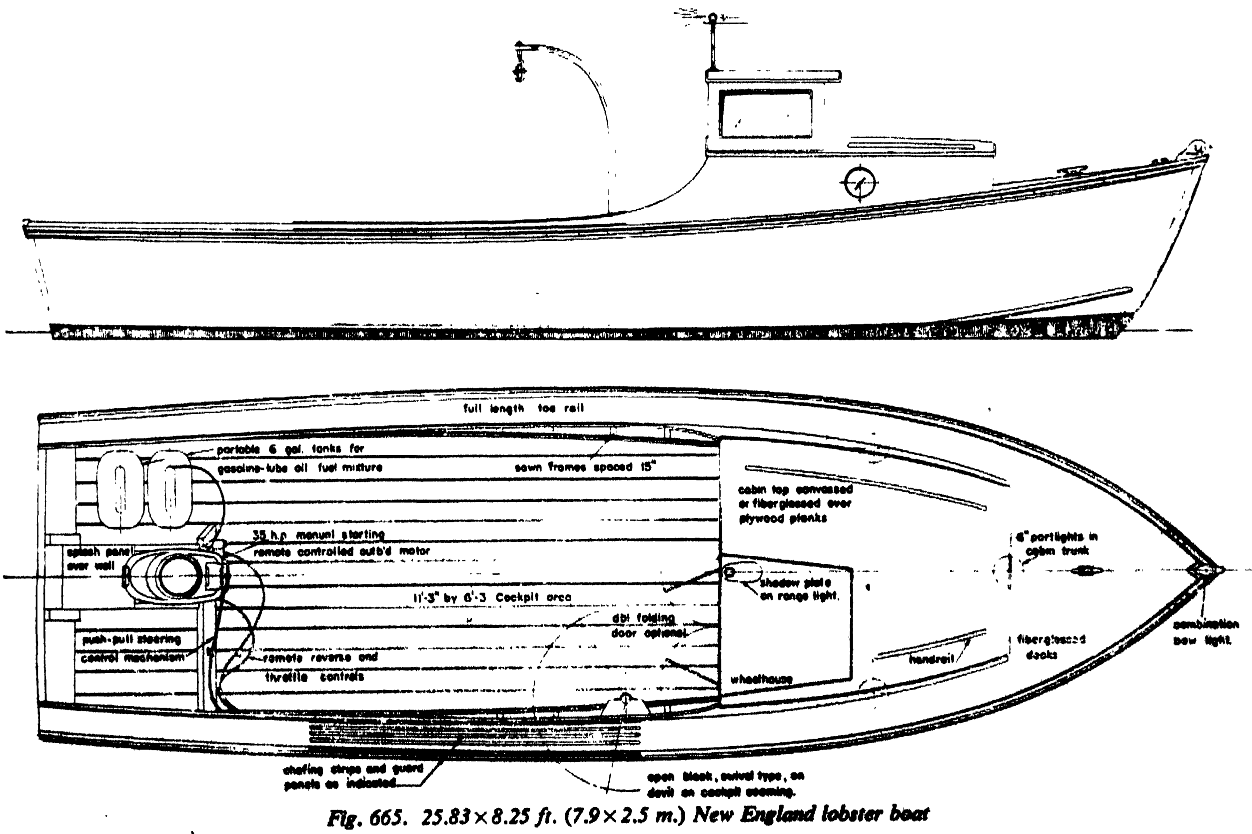


Fig. 665. 25.83 × 8.25 ft. (7.9 × 2.5 m.) New England lobster boat

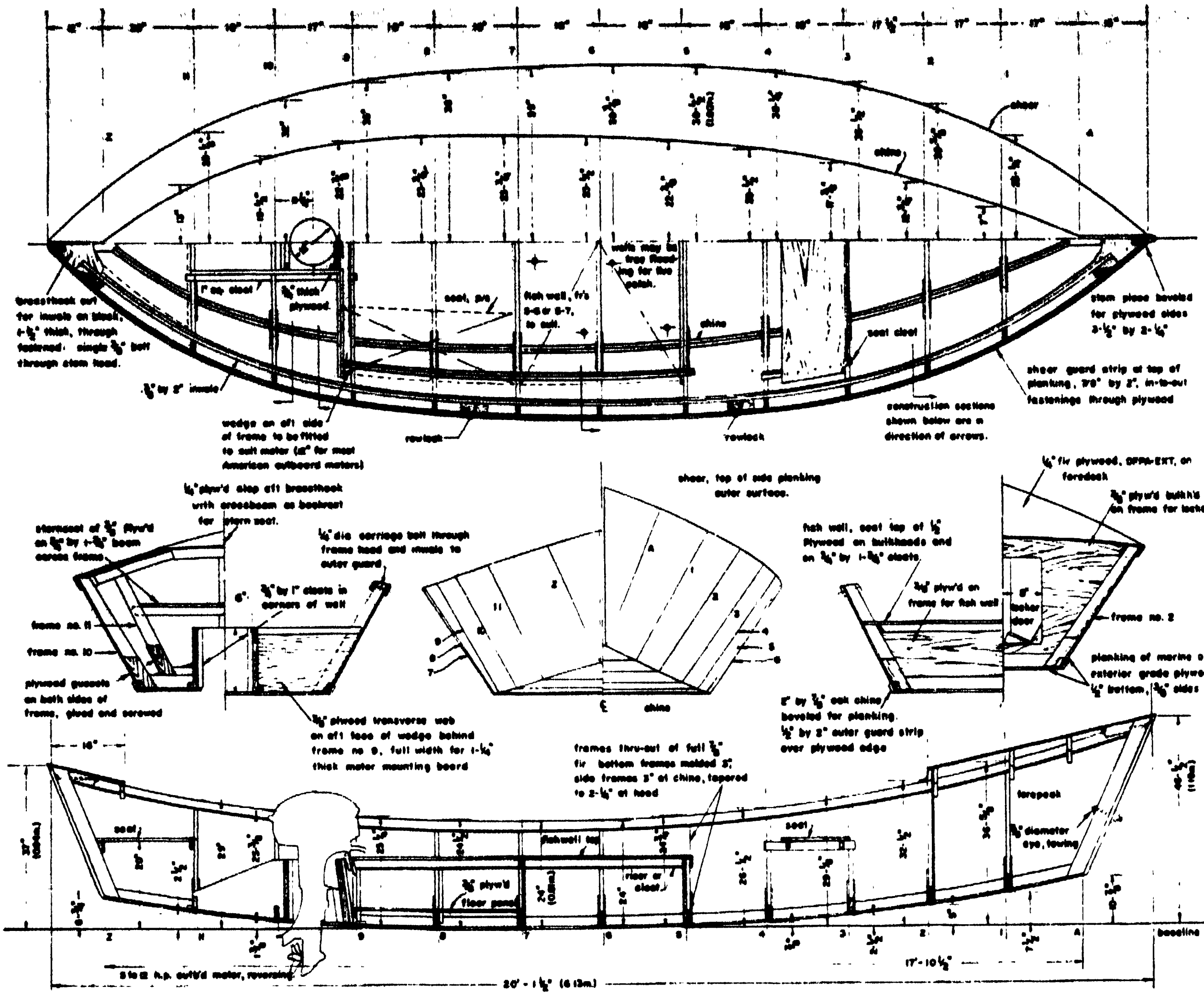
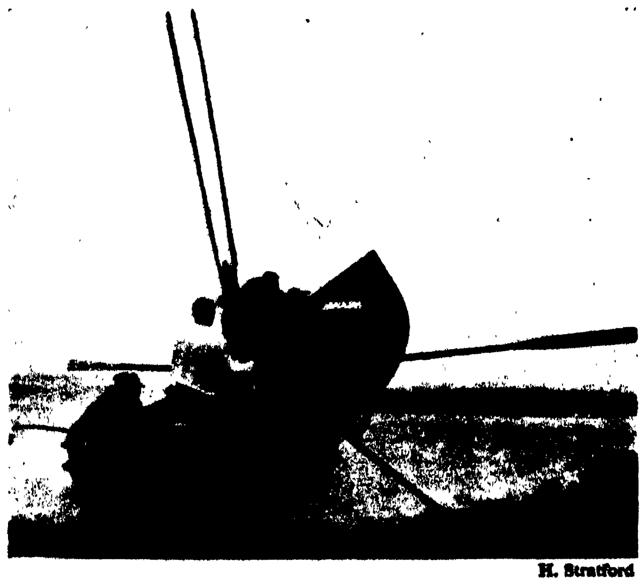


Fig. 666. 20 ft. (6.1 m.) Oregon coast, beach landing outboard salmon troller

H. Stratford

Fig. 667. Employing the universal method of launching surf boats, the salmon dory is pushed from its trailer into the Pacific on the Oregon coast.



H. Stratford

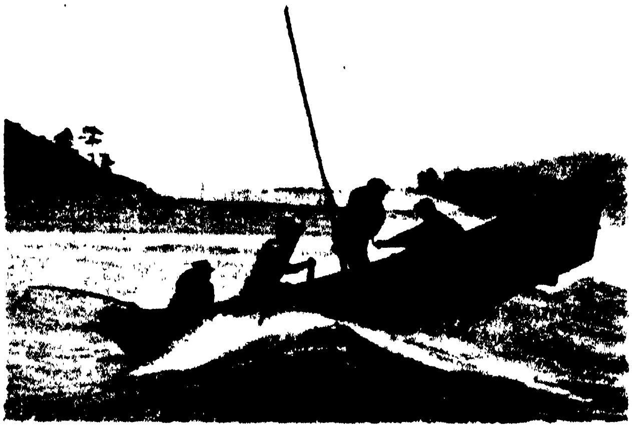
RIGHT
Fig. 668. The salmon dory is rowed through the surf before dropping the motor into place for salmon trolling. The outriggers are inboard while launching through the surf

centre-line to the chine. This installation provides a wide working area at the transom for the handling of nets. The area inside the boat is illustrated in fig. 662. The boat is shown in fig. 663.

This type is also fitted for forward installation of the motor, in a well not unlike that used by the Florida mullet gillnet skiff. The forward installation is very well adapted to the stern handling of nets by one- or two-man crews. The fitting of transverse bulkheads varies with the operators, but generally follows the arrangement in fig. 664, which also shows a net roller fitted across the transom.

New England lobster boat

The lobster fisheries in the North-eastern U.S.A. extend over many hundreds of miles of coastal waters up to Canada, where the fisheries in the Maritime Provinces



H. Stratford

Fig. 669. As soon as the outer bars are passed, the outboard motor is dropped into place and the 20 ft. (6.1 m.) dory can then troll in deep water for the large salmon

are well developed. The 25 ft. 10 in. (7.9 m.) by 8 ft. 3 in. (2.5 m.) craft shown in fig. 665 is representative of the type which is replacing the typical inboard lobster boat.

The New Englander demands a measure of seakindliness and shelter that is not always possible in small, working craft. Also, the craft must be efficient and inexpensive, and capable of one-man operation.

The craft has lines adapted to diagonal planking, and is often so planked. The lines are characterized by a deep forefoot and as long and smooth a run as is possible. This form provides a combination of characteristics which makes it ideal, with the outboard motor, for pot hauling. The lobsterman pilots his craft from the little shelter forward where he has excellent vision as he approaches the lobster pot buoy on his starboard side. As the pot comes alongside, he reduces the throttle, and makes a hard starboard turn as he picks up the buoy with his hook. While he hauls the pot over the block fitted to the davit aft of the shelter, the craft makes a tight circle to starboard, pivoting about the deep forefoot with the motor thrust as far over as possible. Such a

T. Neilson

Fig. 670. Salmon trollers with commercial trolling gear: the stainless steel wires are led to the hand gurdie drums over large sheaves. Four lines are trolled from most 20 ft. (6.1 m.) dories

craft makes a circle with a diameter about equal to its own length. The lobsterman can haul the pot, remove the catch, rebait the pot and throw it overboard in a very short time during which the craft does not lose its position. Of course, in heavily potted waters this is not possible, so the usual weather approach is made and easy handling by the remote throttles permits the rebaited pot to be replaced almost exactly where it was.

These boats have very easy driving characteristics and the 25 to 35 h.p. motors normally used have proved to be adequate.

Salmon trolling dories

In the Pacific Northeast, along the very stern Oregon coast, there has evolved a species of dory which is used through the surf, and is a small beach-landing outboard fishing craft. It is used for both sport fishing and commercial salmon trolling offshore in fairly heavy seas. A typical boat is shown in fig. 666 to 671.

J. Neilson

Fig. 671. The wider transom of the eastern dory is used on the west coast of the U.S.A. in some types. The wider transom with a wider bottom with less rocker therein permits higher speeds

These boats are, for the most part, constructed from Douglas fir plywood. Oversize 22 ft. (6.7 m.) panels are used for sides, and standard 18 ft. (5.5 m.) by 4 ft. (1.2 m.) panels for the bottoms. Fir frames are used, with double plywood gussets at the chine joint of side and bottom frames. The craft are provided, as shown in the photographs, with fish wells that are frequently open to the sea to provide circulating water for the catch. The motor well, as in fig. 666, is often only a bulkheaded opening in the bottom through which the small motor is dropped after the boat has been rowed through the surf. Some boats allow the motor to tilt, but these are rare as a long cut out in the bottom is not practicable in the dory ends.

These dories, true double-enders or with the wider "tombstone" transom shown in fig. 671, are launched from trailers or rollers directly into the surf. They troll under power, at 2.5 to 4 knots with motors that seldom exceed 12 h.p. They row very easily but, because of the extreme rocker of the bottom, they tend to squat at speeds above 5.8 to 6.6 knots. In plywood or conventional dory planking, this is a type of small powered craft which might be used in many parts of the world. The fairly light construction might give some cause for concern, but where the shores shelve gradually and there is no pounding surf, such flat-bottomed craft give admirable service.

Conclusion

The variety of methods whereby outboards can be fitted to small fishing craft should serve to stimulate designers and builders to adopt outboards for other types of boats. It is regretted that so little specific performance data are included. The reason for this seems to be general satisfaction with the boats felt by the fishermen. While they are satisfied with the performance, they do not know exactly what it is, and show little interest in finding out.

TRAP-NET BOATS AND HARPOON BOATS

by

VITO FODERÁ, RAIMONDO SARÁ and ALBERTO CAMBIANO

The first part describes the boats used in Sicily for setting the tuna traps, operating them and recovering them after the fishing season. These boats are a compromise between sometimes opposite requirements, and their features are due to the need for multipurpose craft.

The second part deals with swordfish-catching boats, a fishery that was practised in the Messina Strait and is now developing due to the introduction of a motor boat. The boats used for locating and harpooning the fish, and the new type of motor boat are described. This boat has made an increase of the campaign possible and has extended the fishery from the coasts to the high seas.

DES BATEAUX DE PÊCHE SICILIENS SPÉCIALISÉS

La première partie de la communication décrit les bateaux utilisés en Sicile et servant à la construction des madragues, à la pêche avec les madragues et à la récupération du matériel à la fin de la saison de pêche. Ces bateaux représentent un compromis entre deux exigences parfois opposées, et leurs caractéristiques sont en relation avec le besoin de bateaux à plusieurs usages.

La seconde partie de la communication traite des bateaux utilisés dans la pêche de l'espadon, une pêche qui était pratiquée seulement dans le Détroit de Messine et qui est en voie de développement en raison de l'introduction d'un bateau à moteur. Les auteurs décrivent les bateaux utilisés pour le reperage et le harponnage des poissons, ainsi que le nouveau type de bateau à moteur. Ce bateau a permis d'étendre la durée de la campagne et a transformé une pêche côtière en pêche hauturière.

EMBARCACIONES PESQUERAS ESPECIALIZADAS DE SICILIA

La primera parte de la ponencia describe las embarcaciones empleadas en Sicilia para calar, explotar y levantar, después de la campaña de pesca, las almadrabas atuneras. Estas embarcaciones son un término medio entre necesidades en ocasiones antagónicas y sus características se deben a que es imperativo disponer de embarcaciones de usos múltiples.

La segunda parte de la ponencia trata de las embarcaciones dedicadas a la captura del pez espada, que es una clase de pesca que se practicaba en el estrecho de Mesina y que actualmente se propaga a otros lugares gracias a la introducción de la embarcación con motor. Se describen las embarcaciones empleadas para localizar y arponear el pez espada y el nuevo tipo de embarcación con motor, el que ha permitido ampliar la campaña y propagar esta pesca desde la costa hacia alta mar.

THE Sicilian fisheries are one of the most important in the Mediterranean. Fishing for tuna and swordfish is carried out by small vessels in coastal and offshore waters. The fishing methods used are the trap net or "tonnara" for tuna, and the harpoon for swordfish. This paper describes these two methods and the vessels from which they are operated.

TUNA TRAP-NET BOATS

A very great number of fishermen and boats are needed to set and operate the tuna trap, a highly complicated structure weighing several hundred tons. The season is about three months, of which half is spent in fishing, the rest in setting and removing the trap. Multi-purpose boats are used to reduce either the total number of boats required for operating the trap, or the number of men. Two types: main boats in two sizes, large and medium, and small boats (these can generally be used interchangeably) are designed so as to meet all essential requirements for the setting and removing of the trap, and for fishing. Although these boats are the result of a whole series of compromises and adaptations to different, and sometimes opposite requirements, they work efficiently and well. For the nine months of the year between seasons the boats are beached and kept under shelter.

A tuna trap consists of a framework of ropes and moorings and nets. The frame is built by putting each piece into place separately. For this operation, generally four of the small boats are needed, each carrying about 4 tons, and assisted by two other small boats not used for transport. To put the frame of the largest trap into place takes from four to five days. The number of boats varies sometimes, depending on time in hand and on crews available.

The body of the trap consists of a series of chambers where the fish are gathered and enclosed before passing into the death chamber (an independent part). The body is divided into two symmetrical parts which can each weigh up to about 30 tons for nets with the maximum depth of 200 ft. (60 m.). They are immersed in one single operation. The lead nets are divided into pieces of such length as the capacity of the boat permits and set separately.

As the nets are set, they are ballasted with large stones.

TABLE 148

Boat requirements for tuna trap fishing

Operations	*Boats* *Large*	*Medium*	*Small*
For setting the frame	–	–	6
For setting the nets	2	2	5
For fishing	1	1	6
For retrieving the material	2	1	4

weighing in all about 100 tons for the body and about 90 tons for each mile (50 tons per km.) of the lead net. To transport these stones, at least two large boats are needed, one of which is later used to transport and put into place the death chamber, and to haul it out at the end of the fishing season. It must then be beached together with its load.

During the fishing, one large boat lies at one of the sides of the square where the fish are caught. The netting of traps set in shallow water is short enough so that it can be retrieved at the end of the fishing season, using the same large boats. For fishing, it is necessary to have six small boats to attend to the openings and to keep watch; one large boat to raise the death chamber; one medium-sized boat to hold the other end of the

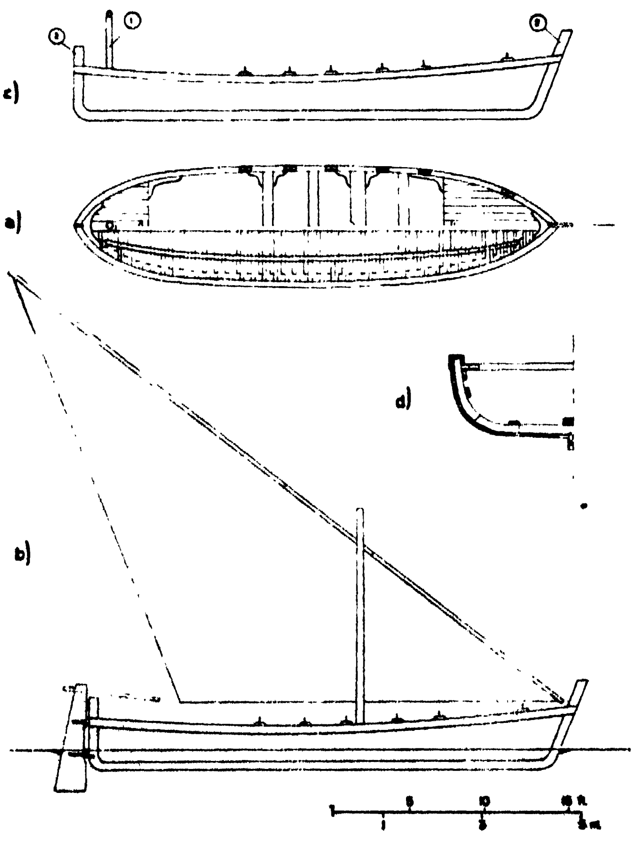


Fig. 672. Small non-mechanized Sicilian trap-net boat

death chamber. To retrieve the ropes and moorings (which are sometimes sunk deep in mud) large boats are needed. Table 148 summarizes boat requirements during the various operations.

Fishing boats

Fig. 672 shows the design of the small boats. The sail, mast and rudder are used only for movements outside the trap; within it and during fishing, the craft is propelled by six oars. Fig. 672 (c) shows the side profile during fishing. The dimensions are shown in table 149.

Two of the small boats which do not transport material during fishing are also used for the night watch, and are provided with a deck aft up to the first bench. Another peculiarity of these boats is that the stern, shown in fig. 672 (c) (2), is not raked on account of a technical necessity connected with the laying of the mooring ropes. The small stern mast, shown in fig. 672

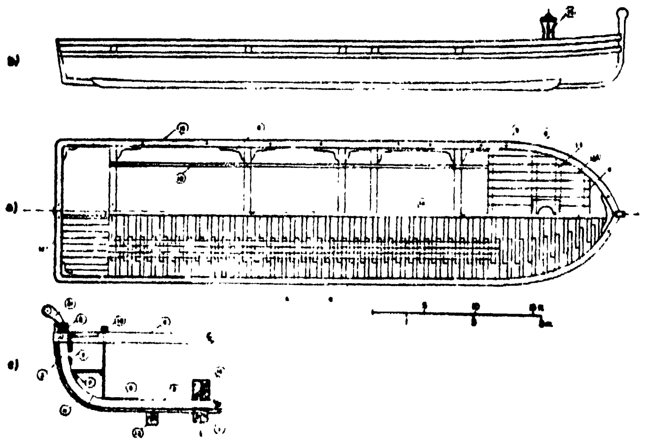


Fig. 673. Large non-mechanized Sicilian trap-net boat

(c), is used for supporting a canopy which also serves as a rain-awning. In the final phase of fishing, when the two sides of the death chamber square are formed by small boats, it serves to hold up the two corners of the net on the medium-sized boat side.

Fig. 673 shows the design of the large boat, the medium-sized boat is built on the same lines. Table 150 shows the dimensions, and table 151, the scantlings. Fig. 674 shows the profile of the boat equipped with all the accessories required for the various operations.

A lengthwise bulkhead, shown in fig. 673 (10), protects

TABLE 149

Dimensions of the small tuna trap boats

	ft.	*m.*
Length overall, LOA	32.2	9.80
Beam, B	8.2	2.50
Depth, D	2.6	0.80
Draught, light, T_0	1.3	0.40
Gross tonnage, GT	4	

the crew during fishing from the blows of the fish, which continue to struggle on the bottom of the boat for some time after they are pulled aboard.

The capstan is worked by six detachable crank-handles; its function, when the nets are being lowered into the water, is to draw on an anchorage so as to stretch and thoroughly tighten the surface cable attached to the first bench aft. The capstan is used again when the moorings are retrieved. During fishing, the capstan is removed in order to lighten the bow; the deck forward is also removed. The capstan is supported on one side by the last bench forward, and on the other by a movable bench.

The first bench is placed very far back so as to make it possible to fix into it the two supports of the swivel crane (19), which is required for raising the moorings. This is a pulley with block extending as a long arm hinged

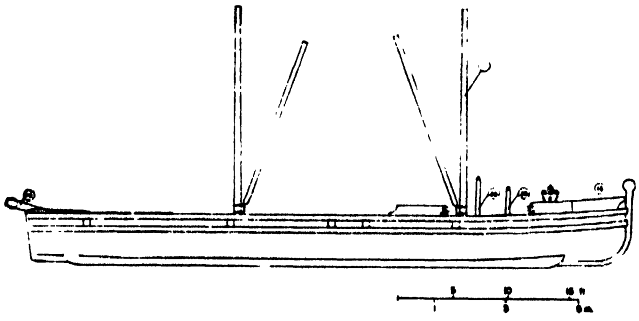


Fig. 674. Profile of vessel in fig. 673

on two brackets lying on the aft bench and on the stern bulkhead. The extended block with the pulley is so capable of tilting lengthwise on the bench aft. The rope is stretched by the capstan and passes through the pulley; when the mooring ring comes under the pulley, the rope can only go further by making the crane swivel; it rises and then falls towards the centre of the boat, drawing the shank of the mooring which can thus be easily pulled aboard. The davits (20), are used only for lowering the nets.

The fixed cranes, shown in fig. 673 (c) (21), eight in number, are set along the port side of the boat; each has a pulley for the rope which serves to raise the door of the death chamber quickly. Once this is raised, the cranes are dismantled so as not to hinder subsequent fishing operations.

TABLE 150

Dimensions of the large tuna trap boat

	ft.	m.
Length overall, LOA	55.4	16.90
Beam, B	14.2	4.35
Depth, D	3.8	1.15
Draught, light, T_o	1.8	0.55
Draught, fully loaded, T_1	3.1	0.95
Gross tonnage, GT	30	

TABLE 151

Construction details of the large tuna trap boat

	in.	cm.
Keel, oak	$7\frac{7}{8} \times 7\frac{7}{8}$	20×20
Floor-timbers, oak	$4\frac{3}{4} \times 5\frac{1}{8}$	12×13
Frame or timber spacing	$13\frac{3}{4}$	35
Knees, oak or mulberry	$4\frac{3}{4} \times 5\frac{1}{8}$	12×13
6 fixed benches, oak	$7\frac{1}{16} \times 7\frac{1}{16}$	18×18
3 movable benches, pine		
Bottom strakes, pine	$2\frac{3}{8} \times 4$	6×10
Spirketings, pine	$1\frac{5}{8} \times 3\frac{1}{8}$	4×8
Gunwale, pine	$7\frac{7}{8} \times 5\frac{15}{16}$	20×15
External planking in pitch-pine thickness	2	5
Bottom frames, holm-oak	$7\frac{7}{8} \times 5\frac{15}{16}$	20×15
Keelson, pine	$9\frac{7}{8} \times 11\frac{7}{8}$	25×30
Capstan, cast iron, height × diam.	$29\frac{1}{2} \times 11\frac{7}{8}$	75×30
Horizontal and vertical gussets, oak; longitudinal bulkhead ("stirato"), pine; flooring, fir; Rails, iron		

When the boat is loaded with nets, the first bench aft must be cleared of any obstruction so that the surface rope which supports the whole of the tuna trap can be fixed there and can be tightened when the nets are lowered.

During fishing, the boat is equipped with two masts as shown in fig. 674, with two spars which are used for transferring the tuna to the boats that will carry them ashore. During bad weather, the freeboard is raised by wash-boards (18), which are detachable as they would hinder the work during fishing or while the nets are being lowered into the water.

The keelson is very thick in cross-section in order to withstand the strain when the nets are loaded, the boat being on land. The side keels ensure a broad basis of support on the ground by distributing the weight of the load and thus ensuring stability at launching time. In the water, such keels also help to dampen rolling.

The medium-sized boat is of the same type, having, however, smaller dimensions (table 152).

TABLE 152

Dimensions of the medium-sized tuna trap boats

	ft.	m.
Length overall, LOA	46	14.00
Beam, B	11.8	3.60
Depth, D.	3.5	1.07
Gross tonnage, GT	18	

The only difference is that the capstan is set on the two central benches and on the deck, on a level with the gunwale, resting on them and on the two other benches at either side. There is no longitudinal bulkhead.

SWORDFISH (XIPHIAS GLADIUS) HARPOON BOATS

Swordfish fishery, as practised for centuries in the vicinity of the Strait of Messina, is far better known for its picturesqueness than from the technological standpoint. Swordfish appear at the beginning of spring, first towards the Lipari Islands and, somewhat later, along the coast of Calabria. During May and June, they enter the Strait of Messina and reach the Ionian Sea. They swim near the surface and their average weight

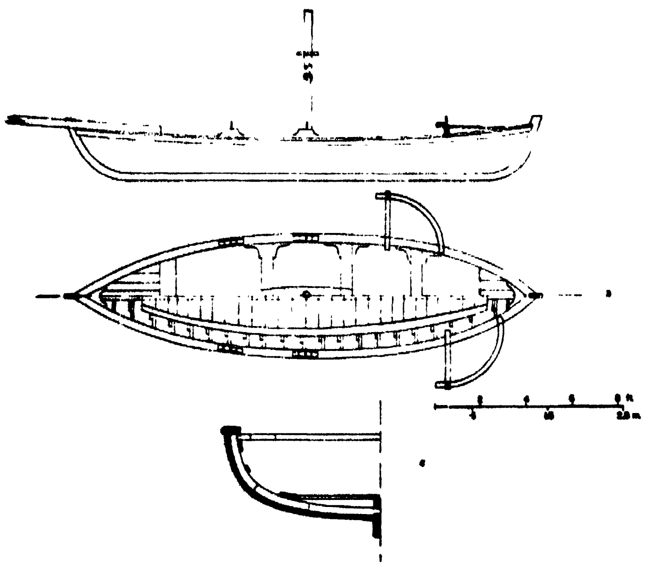


Fig. 675. Catcher boat, having good manoeuvrability and being fast

is between 220 and 240 lb. (100 and 110 kg.). During July and August, swordfish approach the Sicilian shore off the Strait of Messina, coming from the south and going towards the Tyrrhenian Sea. They weigh on an average between 90 and 110 lb. (40 and 50 kg.). Although swordfish are often caught with gill or tangle nets during the fishing of albacore and especially in the tuna traps of the north and east coasts of Sicily, the specialized method is by harpoons.

To detect the fish from afar, it is necessary to have a look-out point fairly high so as to be able, in a calm sea, to see to a depth of 10 to 13 ft. (3 to 4 m.) below the surface within a radius of at least 1,000 ft. (300 m.). In Calabria, where the high coastline offers an advantage, the spotter takes up a position on a cliff. It is from this position that he gives instructions for catching and he must therefore be stationed within earshot. In Sicily, where the shores are low, it is necessary to use a special

TABLE 153

Dimensions and construction details of the old type catcher

	ft.	*m.*
Length overall, LOA	20.4	6.20
Beam, B	5.6	1.70
Depth, D	2.0	0.61
Height of mast	9.9	3.00
Length of bridge	18.7	5.70

Keel, oak; floor-timbers, oak; knees, mulberry; side planking, pine

TABLE 154

Principal characteristics of the new type motorized swordfish boat

LOA (excluding bow platform)	28.7 ft.	8.75 m.
Beam, B	4.9 ft.	1.50 m.
Depth, D	2.8 ft.	0.85 m.
Height of lookout mast	42.6 ft.	13.00 m.
Length of bow platform	39.4 ft.	12.00 m.
Motor	15 h.p. at	600 r.p.m.
Weight of motor	1,200 lb.	550 kg.

boat anchored a few hundred feet off the coast and carrying a mast about 65 ft. (20 m.) high, at the top of which the spotter is stationed.

Types of boats

Two types of boats are used for fishing:

Searcher. This is a boat with a canoe stern. It is from 40 to 46 ft. (12 to 14 m.) long, 13 ft. (4 m.) wide and 6.5 ft. (2 m.) deep. It is decked from stem to stern and has no peculiarity except for the mast amidship, which is 65 ft. (20 m.), and sometimes 82 ft. (25 m.) high, and is held in place by stays. A cross-piece 2.6 ft. (0.8 m.) below the top serves as a foothold for the spotter.

Catcher. The catcher, shown in fig. 675, has a good manoeuvrability and is very fast; it has a canoe stern

Fig. 676. Catcher boat for swordfish

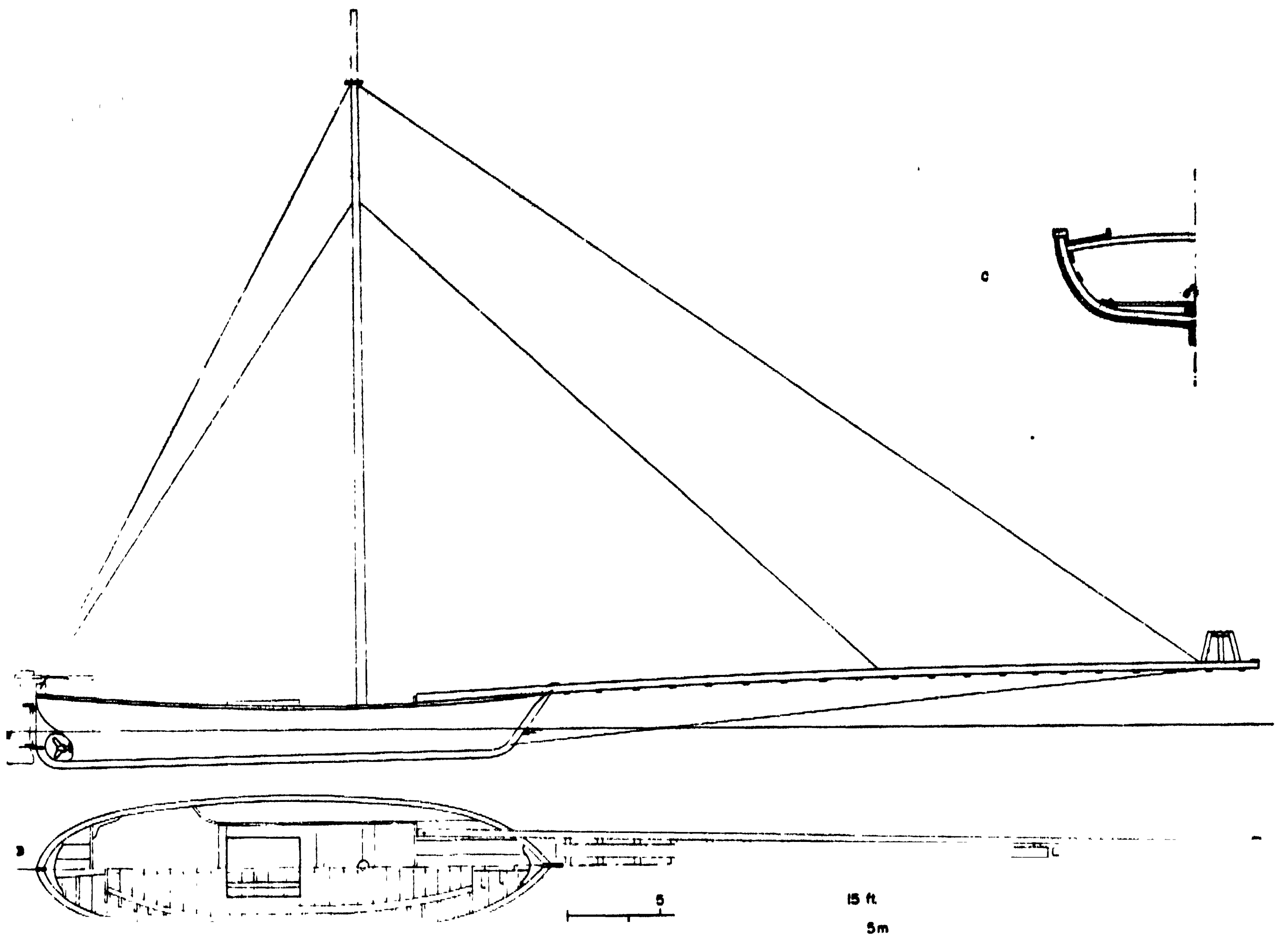


Fig. 677. Combined swordfish catcher and searcher vessel

which differs very little from the bow. The fish are approached from the rear. It carries amidship a mast of 10 ft. (3 m.), on which a spotter is stationed who directs the pursuit, together with the spotter in the searcher. A plank platform which juts out beyond the bow to a length of 20 ft. (6 m.) carries the harpooner. There are two outriggers bearing the rowlocks of the two stern oars. A catcher carries a spotter, a harpooner and four rowers.

The two special characteristics of this fishing are:

- The need to wait for the fish to come within the range of visibility of the spotter watching either on land or on the mast of the searcher.
- The need to guide the catcher almost on to the fish in order that the harpooner can work properly.

The extended bow platform, introduced in recent years, has increased the "size" of the boat by up to 20 ft. (6 m.).

New type of boat

A new boat, introduced quite recently, has made it possible for this fishery to expand into the high seas, and the fishing grounds—formerly limited to the immediate vicinity of the Strait of Messina—now extend as far as the Lipari Islands. Fig. 677 shows the profile, design and cross-section of the new boat, which combines the characteristics of the searcher and the catcher and can, because of its long bow platform, carry the harpooner over the fish when the stern is still from 80 to 100 ft. (25 to 30 m.) away; this boat can therefore be fitted with a motor. In the month of July, this type of boat is authorized to fish in the Strait, but it must keep at a distance of at least 2,600 ft. (800 m.) from the nearest searcher. Table 154 gives the details of this type of boat.

This type of boat is to be improved in the future and it is proposed:

- to make the bow platform retractable (fireman's ladder type) so that it can be drawn in during navigation or in bad weather. This would improve seaworthiness;

- to install a chain drive along the mast to enable the spotter to work the rudder directly without having to give his instructions to the crew on deck; and
- to increase transverse stability by means of outriggers.

It must be pointed out that during the autumn and winter the bow platform and mast are dismantled (fig. 678) and the swordfish fishing boat is converted into a normal boat which is used to fish for tunny by trolling or hand line, or for fishing saury pike (*Scomberesox saurus* W.) with drift nets.

With the adoption of the motorized swordfish fishing boat, the harpooning of swordfish has gone beyond the small-scale fishery phase and has become the most important fishery in the Strait of Messina area.

Note: The part on the tuna boats was prepared by Dr. V. Foderá and Mr. A. Cambiano and the part on the harpoon boats by Dr. R. Sará and Mr. A. Cambiano.

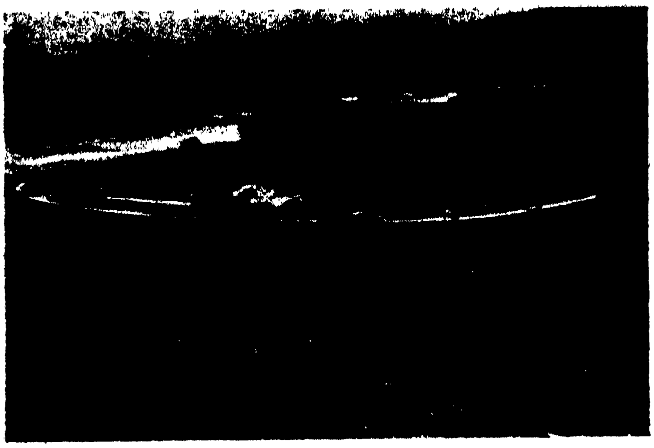


Fig. 678. Swordfish catcher boat converted for common fishing

DESIGN AND MASS PRODUCTION OF SHRIMP TRAWLERS

by

L. C. RINGHAVER

The design of the Florida shrimp trawler is based on a Greek sponge boat.
These boats are now spreading into Central and South America. The typical vessel is 67 ft. (20.4 m.) long with the deckhouse forward, the mast and winch amidships and a wide working space aft.
The main points of the design are the low cost of construction, the simple and safe handling by only a small crew, comfortable accommodation and seakindliness. Standardization of the design is another point in its favour, as American trawler crews frequently change ships.
The scantling materials used are detailed, and a new trawling device, the double-rigged trawl net, is described.
The method of mass producing this type of boat, using a 67 ft. (20.4 m.) trawler as an example is fully explained.

LE DESSIN ET LA PRODUCTION EN SÉRIE DES CHALUTIERS A CREVETTES

Le dessin du chalutier à crevettes de Floride est basé sur un bateau grec pour la pêche des éponges.
Ces bateaux sont en train de se répandre en Amérique centrale et en Amérique du Sud. Le navire type mesure 67 pi. (20,4 m.) de long avec un deckhouse à l'avant, le mât et le treuil au mileu du bateau et un large espace permettant le travail à l'arrière.
Les principaux avantages de ce type de bateau sont le bon marché de la construction, la manoeuvre simple et sûre avec un équipage réduit, des logements confortables et une bonne tenue à la mer. La standardisation des plans est un autre point en sa faveur car les équipages des chalutiers américains changent fréquemment de navire.
L'auteur donne des détails sur les échantillonnages et décrit un nouveau dispositif de chalutage: le chalut à double grément.
La méthode de production en série de ce type de bateau, en prenant comme exemple un chalutier de 67 pi. (20,4 m), est expliquée en détail.

PROYECTOS Y PRODUCCION EN SERIE DE ARRASTREROS PARA LA PESCA DEL CAMARON

La forma del arrastrero de la Florida para la pesca del camarón so basa en la de los barcos griegos para la pesca de la esponja.
Estos arrastreros comienzan a aparecer en América Central y del Sur. El barco tlpico tiene 67 pies (20,4 m.) de eslora, caseta del timón a proa, mástil y maquinilla en la mediania y una amplia cubierta de trabajo a popa.
Sus principales caracteristicas son bajo costo de construcción, sencillez y seguridad de manejo por una tripulación pequeña, alojamientos cómodos y buenas condiciones marineras. La normalización de las formas es otro detalle en su favor, pues a las tripulaciones de los arrastreros de los E.U.A. les gusta cambiar de barco con frecuencia.
Se dan detalles de los materiales empleados en los escantillones y se describe el nuevo arte doble de arrastre.
Se explica con pormenores el método para la producción en serie de este tipo de barco, empleando como ejemplo un arrastrero de 67 pies (20,4 m.) de eslora.

THE origin of the Florida shrimp trawler is regarded as the Greek sponge boat. Many Greek fishermen settled in Florida and brought their own designs and construction methods. Even today many of the smaller boatyards are owned and operated by Greek builders. It was only natural that these builders should enter the trawler field.

Many years ago the typical small shrimp trawler of Greek origin had no winch and the trawl was hauled manually; therefore, the crew wanted a maximum of free working space aft, and any cabin would be built forward. Thus, when many other U.S. trawlers were locating their deckhouse aft, the shrimp trawlers deliberately placed theirs forward, and the design and layout has remained the same to this day.

General arrangement

The Florida shrimp trawler shown in fig. 679 has spread to Texas, hundreds have been built in Mexico and the type is now spreading into Central and South America. Briefly, a typical Florida shrimp trawler is a 50 to 70 ft. (15 to 21 m.) wooden vessel, with a rather fine bow, full lines amidships and aft, and a transom stern. Ample sheer forward and aft ensure a dry vessel. The deckhouse is forward, the mast and winch amidships and the working deck space aft. The engine room is located under the deckhouse and the fish hold is aft.

The most popular size is the 67 ft. (20.4 m.) trawler because of its cruising range, seaworthiness and flexibility. Fig. 680 shows such a trawler, which is able to undertake 50-day fishing trips to the remote areas of the Gulf of Mexico. Smaller vessels, as shown in fig. 681, fish inshore close to the home port, and trawlers under 50 ft. (15 m.) engage in bay and sound fishing.

The builder aims at a large, clear working area aft so that the crew has room to handle the gear safely and to sort and head the catch comfortably. Ample sheer at the stern tends to keep this working area dry even in

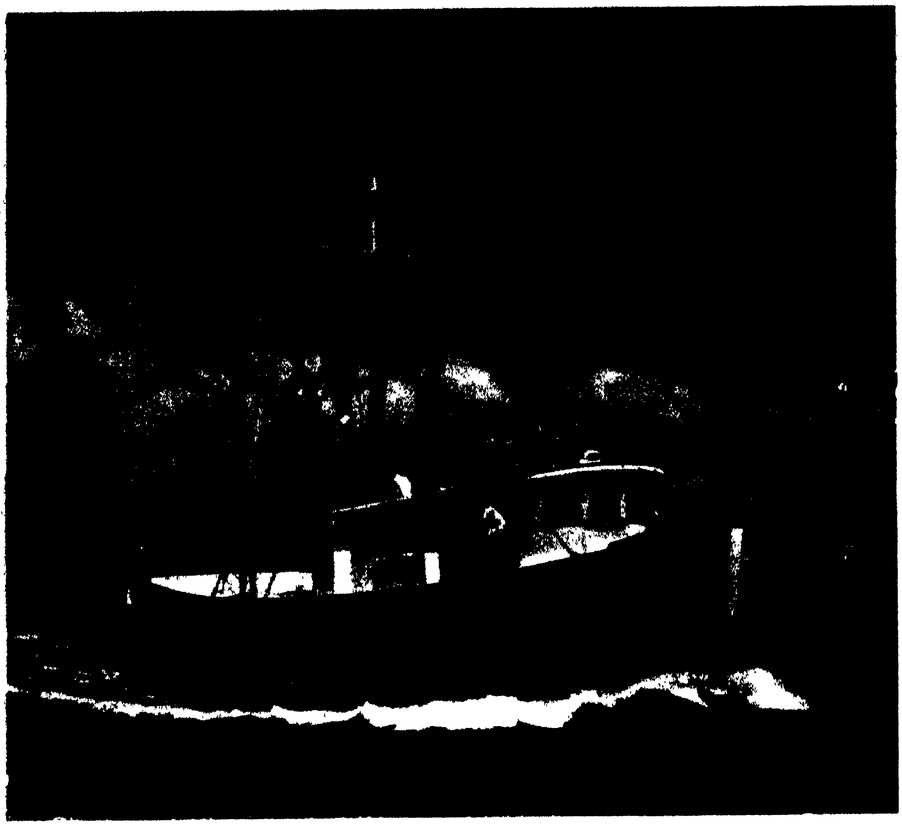


Fig. 679. A typical mass-produced shrimp trawler on trials, rigged for double trawling

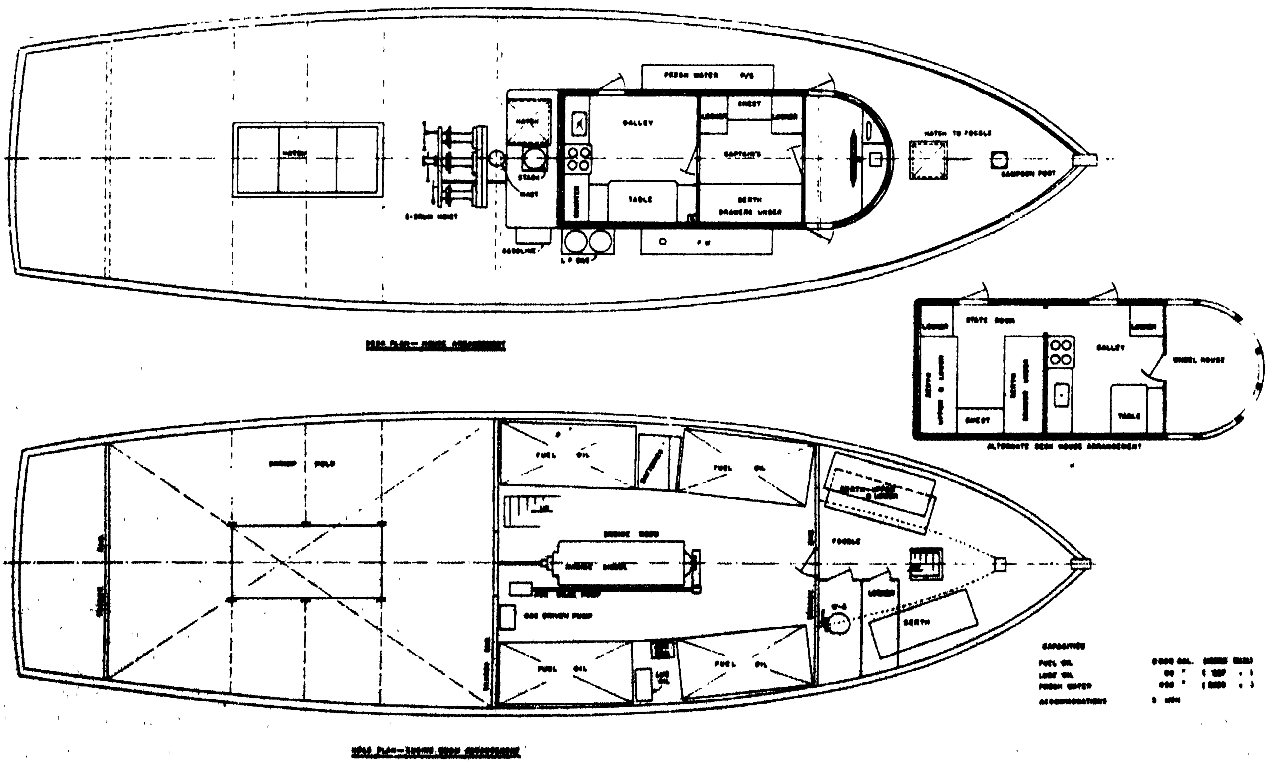


Fig. 680. 67 ft. (20.4 m.) shrimp trawler operating in the Gulf of Mexico

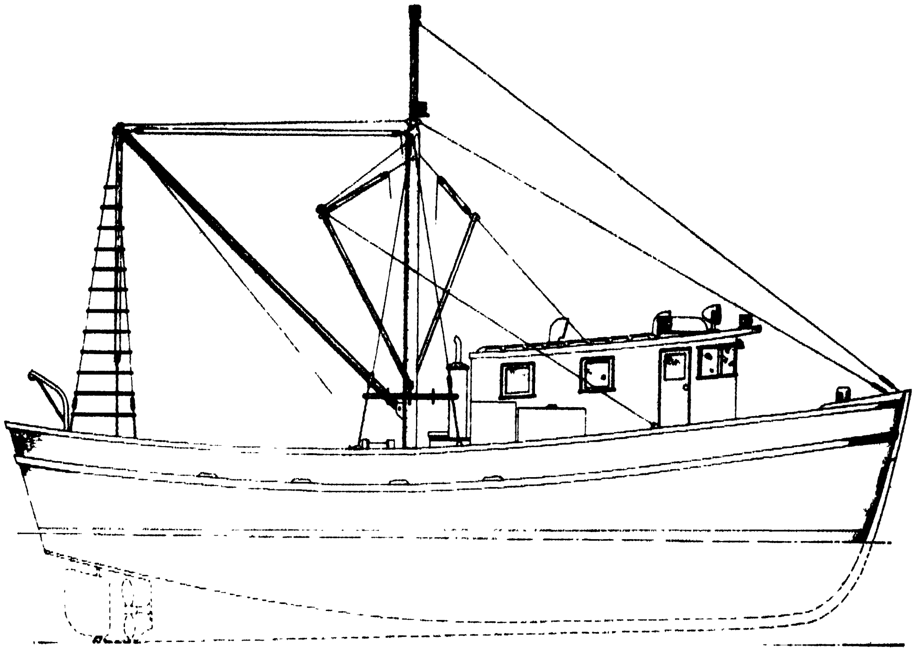


Fig. 681. 53 ft. (15.9 m.) shrimp trawler, rigged for single trawl, and used for inshore fishing

choppy seas. The round-bilge hull form, fig. 682, has a tendency to roll quickly in a seaway but the design is good in a head sea. With ample sheer at the bow, perhaps excessive to some eyes, the vessel is assured of a relatively dry deck.

New trawling gear

The most radical change in recent years is the system employing two smaller trawls in lieu of one large. The most important reasons for this change are the easier handling of gear, the lower gear replacement expense, and the greater production of shrimp. Virtually all new vessels are now being double-rigged, and the majority of the existing fleet has been converted.

Fig. 683 shows a double-rigged shrimp trawler towing two 40 ft. (12.2 m.) trawls. Many theories have been advanced for the superiority of the double rig over the single, the most likely of which is that a smaller trawl

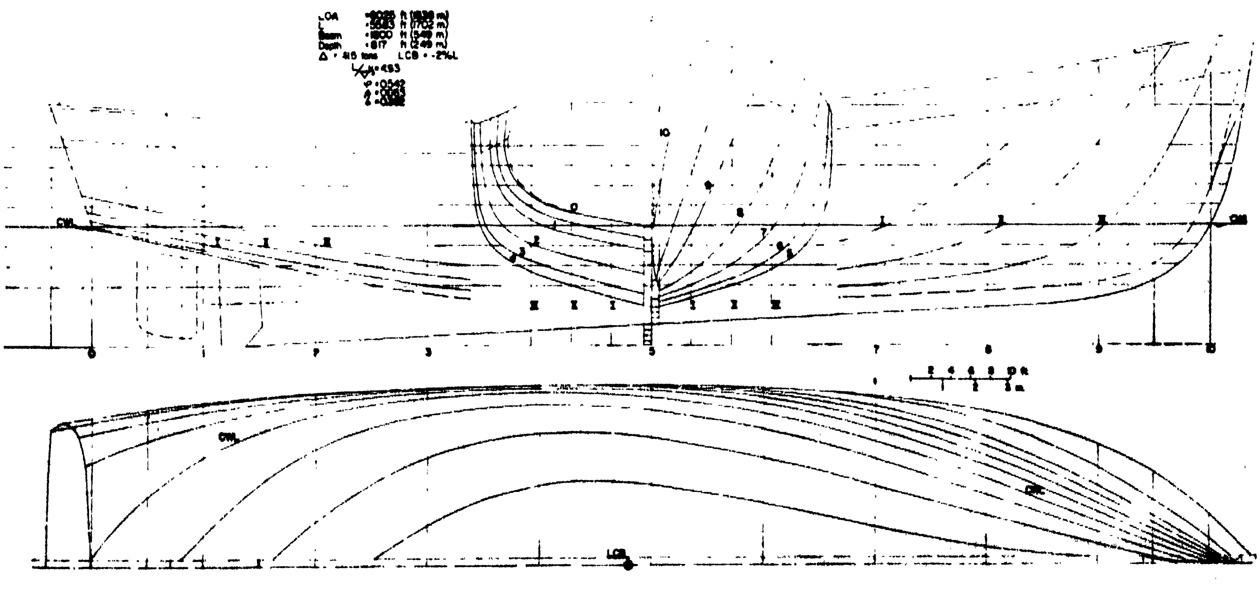


Fig. 682. Florida shrimp trawler

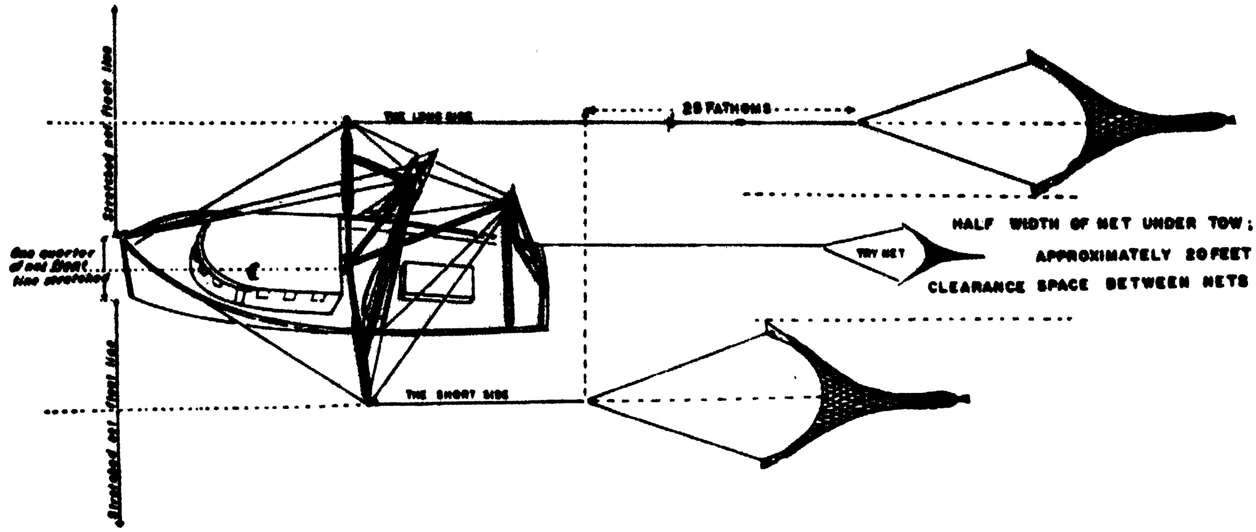


Fig. 683. Double-rigged shrimp trawler with two 40 ft. (12.19 m.) shrimp trawl nets and 24 ft. (7.32 m.) outriggers

inherently fishes better because it adjusts to irregularities in the bottom more easily.

Fig. 684 represents two common outrigger trawling boom designs; there are many variations of these basic designs but most well-designed booms are built around used or discarded oil-field drill-stem pipes. In Texas and nearby States, the oil-well drilling companies use 24 ft. (7.3 m.) heavy-walled pipes, 4 in. (102 mm.) diam. After the walls are worn down to about ½ in. (13 mm.) they are discarded. Such pipes make fine outrigger booms when properly braced and they are quite inexpensive. Fig. 685 presents details of a typical double-rigged trawler.

Production

The catch of shrimp varies greatly with the season and January to June is the poorest season in the Gulf of Mexico. Efforts are being made by the industry and Government experimental units to develop a part-time fishery for industrial and reduction fish during this period, using shrimp trawlers rigged with purse seines or lampara nets.

Some three or four years ago it was considered satisfactory for a Campeche Banks trawler to produce 80,000 lb. (36,300 kg.) of shrimp (heads off) per year, but today a good yearly catch would approximate 50,000 lb. (22,700 kg.). An average price, ex vessel, would be 5s. 0d. (U.S.$0.70). The long-distance trawler stays at sea approximately 45 days and sends the catch home weekly on vessels returning to port.

When used for freighting shrimp from remote grounds, the 67 ft. (20.4 m.) trawler will carry 40,000 lb. (18,000 kg.) of fresh, well-iced shrimp.

Engine output and cruising range

Fuel cost is an important factor and the vessels are usually powered with 150 to 200 h.p. diesels; with such

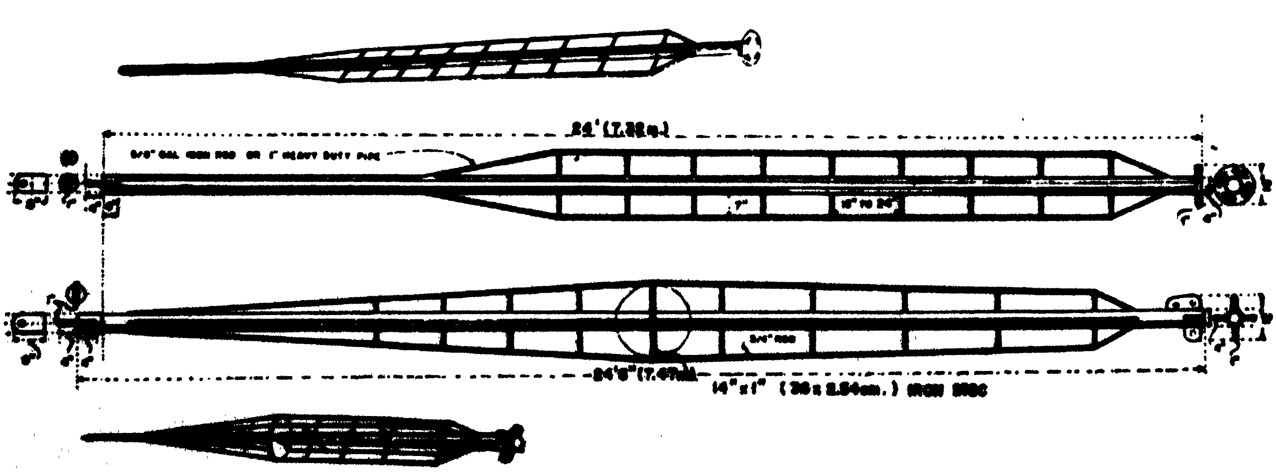


Fig. 684. Two common outrigger boom designs

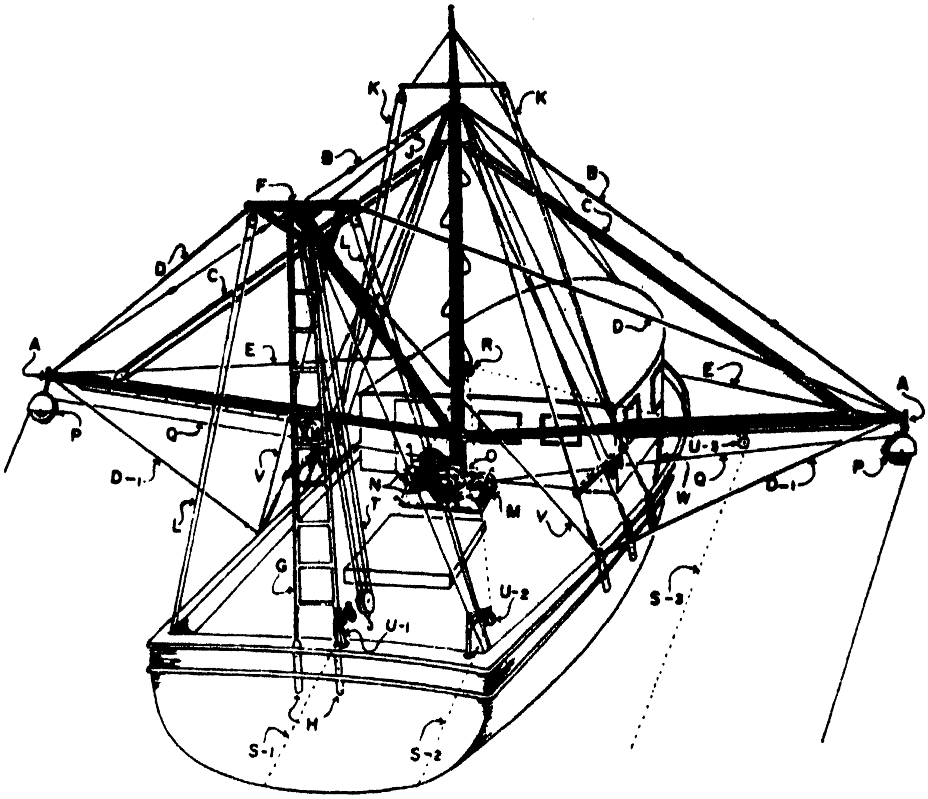


Fig. 685. Rigging arrangements required for double rig shrimp trawling: A—towing boom or outrigger; B—towing boom topping stay; topping lift preventer; C—topping lift tackle; D or D-1—towing boom outrigger back stay; either one may be rigged, but not both; E—towing boom outrigger bow stay; F—modified boom superstructure; G—boom back stays—ratline structure; H—boom back stay plate on transom; J—boom topping lift stay; K—single block tackle; L—single block tackle; M—modified trawl winch; N—gypsy heads two on trawl winch; O—centre drum for try net wire; Q—towing wire; R—leading block for try net; S-1, S-2, S-3—try net lead block; any one may be used; T—main fish tackle tail block; U-1, U-2, U-3—try net lead block; any one may be used to accord with selection of S-1, S-2 or S-3; V—boom shrouds; W—chain stoppers for outriggers

power they will average 8 knots sailing speed and will properly tow a pair of 45 ft. (13.7 m.) trawls.

Data on trawling speed is not really available but is considered to average 3 knots. Recently, where radar bearings were used to plot the speed, a typical 67 ft. (20.4 m.) trawler towed a disabled vessel, at normal trawling engine r.p.m., at 3.4 knots in the open sea during fairly calm weather.

Experiments with a Scandinavian controllable-pitch propeller connected to a 150 h.p. diesel are now being carried out to determine both speed and trawling pull.

The typical 67 ft. (20.4 m.) shrimp trawler is equipped to fish anywhere in the Gulf of Mexico or Caribbean Sea and has a fuel capacity of at least 5,000 Imp. gal. (6,000 U.S. gal. or 22,712 l.), and a crushed ice capacity of 45 tons.

Since they stay at sea 45 or more days, ice-holding ability is as important as ice capacity. Normally, the vessels have 6 in. (152 mm.) foam insulation with concrete plaster cover.

Construction materials

It is important to use the best domestic materials obtainable, properly seasoned, and resistant to rot. It is necessary to soak important members thoroughly in copper naphthenate solution as a rot preventive. Stems are of choice Apalachian white oak to provide resistance to shock; keels are one piece of Douglas fir or pine, and planking is of cypress from keel to waterline and Douglas fir from waterline to deck. Frames are steam-bent white oak. The structural members in the average 67 ft. (20.4 m.) type are shown in table 155.

Fastenings are $\frac{7}{8}$ in. (22 mm.) galvanized steel bolts for the stem, keel and shaft-log and other heavy components, and 3 in. (76 mm.) galvanized boat nails for planking. Galvanized nails are used for decking.

The average 67 ft. (20.4 m.) trawler will require approximately 25,000 board feet (2,080 cu. ft. or 59 cu. m.) of timber, broken down as follows:

3,000 board feet (250 cu. ft. or 7.1 cu. m.) of white oak
7,000 board feet (580 cu. ft. or 16.5 cu. m.) of cypress and fir, air dried

15,000 board feet (1,250 cu. ft. or 35.4 cu. m.) of long-leaf yellow pine, air dried

Crew's comfort

It is essential that the vessel should be easy to operate; it must be comfortable, and it must be designed for a small crew, i.e., the captain and one man. Normally, a 67 ft. (20.4 m.) vessel will carry three men, but in difficult times or poor fishing it must be capable of operating with two. In times of rich fishing, such as on the new shrimp beds in Honduras, an additional three or four men may be carried to handle the catch, but the design goal is a two- to three-man crew.

By and large, crews find the vessels comfortable to work, even on the long voyages to the Gulf of Mexico Campeche Banks. There is a trend towards building all sleeping accommodation above deck, for coolness, and the galley is roomy and well-appointed. The interior is finished in cypress, and, while not luxurious, does contribute to the morale of the crew.

One further consideration—from the crew standpoint, a vital one—is that U.S. trawler crews often change vessels. Since the master of this type of vessel is also the engineer, radio operator, and occasionally winch man as well, part of the success with some designs may be due to standardization. If all gears and machinery are in the same places on different vessels and a fleet owner wishes to switch captains or crews he can be assured that the crew is familiar with the vessel after an hour or two on board; the master can quickly locate all light switches and other working gear, because their location and operation have been standardized.

Mass production

The trawlers from the author's shipyard are built on an assembly line serviced by 12 different departments. Each of the 11 construction departments is headed by an experienced foreman.

Proper purchasing is important to any assembly line operation and the parts and supply inventory must be constantly watched. Every item bought is entered in a card file which shows the cost, the name of an alternate supplier, and the number of items in stock.

Scheduling of sub-assemblies is also important. One full-time machinist and a helper do all the turning work. Four welders fabricate all engine mufflers, masts, outrigger booms, intermediate propeller shafts and other miscellaneous items. By careful attention to scheduling, the sub-assemblies are ready when needed and the mechanics, for example, will find the 3 in. (76 mm.) bronze tail-shaft ready for installation when they want it. Nearby they will find the propeller, bored and keyed for the shaft, ready to install. Any engine can be fitted, as the purchaser requests, usually in the 100 to 200 h.p. class. The average engine is medium or high-speed, and has to be on hand at least a week before installation.

To facilitate operation, a 60-page handbook is provided for each vessel. This handbook is written as a guide to proper—in particular, preventive—maintenance. In addition, it provides specifications covering all major machinery parts in the vessel. If a part breaks down, the captain can radio for it to be sent to him. Normally, two copies of the handbook are supplied: one for the vessel and the other for the owner's office.

The assembly line

At the water's edge there is a trawler hull ready for launching, next to her, or "up" the production line, is a trawler planked but in the process of receiving the keel-cooling system, rudder, shaft and propeller; next there is another receiving the finishing touches to the planking, above is a vessel just being framed, and the first vessel on the line is merely a keel and stem: the mould crew is setting the moulds in place. As soon as the finished hull is launched, all the hulls move one step down, and a new keel and stem assembly is set in place at the beginning of the line.

In operating this assembly line, efficiency and speed are the watchwords: no workman must fumble and search for tools. Therefore, there are many electric hand tools, saws, drills, planers and other portable tools, as shown in fig. 686. These are assigned to each man and he does not

TABLE 155

and dimensions of shrimp trawlers

Member	*Material*	*Nominal size*	*Remarks*
	White oak	9×12 in. (229×305 mm.)	
Keel .	Douglas fir or yellow pine	9×12 in. (229×305 mm.)	One piece
Transom .	Yellow pine	2 in. (51 mm.) thick, doubled	—
Floor timbers	Yellow pine	3×10 in., 3×12 in., and 3×14 in. (76×254 mm., 76×305 mm., and 76×356 mm.)	—
Deck be[illegible]	Yellow pine	4×4 in. (102×102 mm.) on 12 in. (305 mm.) centres	—
Decking	Yellow pine	2×4 in. (51×102 mm.)	—
	Cypress and Douglas fir	1½ in. (38 mm.) thick	
	Yellow pine	3×4 in. (76×102 mm.)	—
	Yellow pine	Four clamps, each composed of four 2×8 in. (51×203 mm.) members	—
	Cypress	1½×4 in. (38×102 mm.)	—
	Yellow pine	1½ in. (38 mm.), doubled	Three bulkheads, non-watertight
Framing . . .	White oak	2¼×4¼ in. (57×108 mm.) on 12 in. (305 mm.)	

have to make time-wasting trips to a store to draw what he needs, nor does he have to carry awkward or heavy pieces of timber. Men are specialized to learn their jobs thoroughly: the planking crew work exclusively on planking, the stem and forefoot crew work exclusively on stems.

Where timber must be handled, as in the stem department, overhead tracks support small electric hoists which enable one man to do the work of several without risk of injury. The operation has a fine safety record because safe practices are emphasized to the men. Further, the electrical system is earthed so that electrical injuries from the portable tools are very rare.

Stem and keel crews cut out the stem from heavy pieces of oak, fit it to the forefoot, and scarf-joint both into the 50 ft. (15.24 m.) keel, a single piece of Douglas fir or longleaf yellow pine. The keel crew will consist of four men and they will spend two and a half days setting up the keel, stem, shaft log assembly and transom. Once this assembly is set up on the line, the mould crew, consisting of six men, will set up the moulds and battens.

The framing crew then take over. Two men bend the oak ribs after steaming them for 1½ hr. at 10 lb./sq. in. (0.7 kg./sq. cm.), and four men put them in place and nail them to the battens. The oak ribs vary in length from 14 to 18 ft. (4.3 to 5.5 m.) and are spaced on 12 in. (305 mm.) centres. Once the frames are in place the moulds are removed. The whole framing normally takes one day.

The 14-man structural group then moves in and spends three and a half days installing longitudinal stringers, clamps, deck beams, engine beds, floor timbers and decking. This group insures that all longitudinal clamps and stringers are bolted to each frame with ⅜ in. (9.5 mm.) galvanized carriage bolts.

Top planking, from the deckline to the waterline, is 4 in. (102 mm.) wide Douglas fir, while the planking from the waterline to the keel is of cypress and may be as wide as 12 in. (305 mm.). The four-man planking crew spends a day and a half installing 15 strakes down from the deck, and then another day and a half installing a further 17 strakes just to pass the turn of the bilge. Wide planking is used here and three men are employed on each side of the hull. They will require another two days to finish the planking; two helpers counter-sink all nails. In addition to the usual galvanized boat nails, each plank has at least two screw-nails, sometimes called "hold-fast" nails. Planking is installed with fitted seams and no caulking is required except at the garboards and butts. When first launched, the hull will leak slightly for several hours but as soon as the planking expands slightly the leakage ceases and the hull is not only tight but virtually free from expensive re-caulking.

The two-man sanding crew equipped with electric sanders will take three days to prepare the hull for its priming coat of paint. Four painters putty all nail holes and prime the hull with first and second coats of oil paints, taking three and a half days to complete the job.

During the planking operation, the pilot-house crew

Fig. 686. Portable electric power tools assigned to each man, kept ready at his working station, contribute greatly to efficiency. Here a carpenter uses an electric planer in fabricating a stem component

of nine men start work on the deckhouse, which is approximately 21 ft. (6.4 m.) long × 9 ft. (2.7 m.) wide × 6½ ft. (2 m.) high, and contains the wheelhouse, galley and crew quarters. It is constructed of well-seasoned cypress. The interior finish is important and good joinery work on lockers and cabinets is essential. It takes three and a half days to complete the deckhouse.

As soon as the painters have finished the hull, a mechanic and helper will install the propeller shaft, propeller, stern bearing, stuffing box, engine keel-cooler, sea-cocks and other underwater fittings and prepare the boat for launching. The crew of mechanics will require three days.

After launching, last-minute carpentry is carried out and the fuel tanks are installed. This stage requires seven men, working for two and a half days, and then the 12-man rigging crew fixes all the wiring, piping installation and alignment of the engine and auxiliaries, installation of mast, booms and winch, etc., in about three days. The vessel is then taken on a shake-down trip to check the machinery in operation.

The final five-man painting crew paint the vessel inside and out in two days. By this time the vessel has been equipped with fire extinguishers, life jackets, galley stove, and is ready for the installation of insulation in the fish hold and electronics in the wheelhouse. The

TABLE 156

cost of producing shrimp by items of expense of typical shrimp vessel operation, 1952, 1953 and 1954
(U.S. cents per pound, heads-off)

Item	*Region I* (*11 vessels*) 1953	1954	*Region II* (*2 vessels*) 1952	1953	1954	*Region III* (*12 vessels*) 1952	1953	1954	*Region IV* (*13 vessels*) 1952	1953	1954
Trip expenses:											
Crew wages	18.14	13.55	19.00	20.10	17.04	12.34	15.95	10.01	15.08	17.94	13.87
Ice	1.96	2.26	1.24	1.54	2.49	2.24	2.95	2.61	3.08	3.05	3.26
Fuel	5.59	7.30	2.87	4.08	5.98	3.90	5.02	4.78	3.92	4.57	4.44
Packing and unloading	3.29	3.47	3.79	4.18	4.88	0.03	0.02	.02	0.55	0.29	0.30
Groceries	0.47	0.48	—	—	—	2.48	2.83	2.76	1.09	1.14	1.24
Miscellaneous	0.01	0.03	—	—	—	0.02	0.06	0.03	0.11	0.08	0.03
Total trip expenses	29.46	27.09	26.90	29.90	30.39	21.01	26.83	20.21	23.83	27.07	23.14
Boat [illegible]											
[illegible] and maintenance	8.16	6.62	3.05	4.46	3.34	4.42	4.14	3.00	5.56	7.39	5.89
Boat supplies	1.45	1.39	2.32	4.21	5.06	1.13	2.63	1.49	2.47	2.64	2.32
Fishing gear	2.03	1.86	1.41	1.95	2.01	2.45	2.53	1.57	2.89	3.14	2.51
[illegible]	1.93	1.89	0.98	2.36	3.21	0.87	0.90	0.87	1.95	1.86	2.14
Depreciatio[illegible]	3.41	4.57	3.39	3.09	3.84	2.68	2.55	2.61	3.13	3.22	3.98
[illegible]	0.33	0.09	0.60	0.52	0.69	0.09	0.19	—	0.35	0.40	0.39
License and tax	0.39	0.33	0.37	0.43	0.76	0.01	*	0.01	0.01	0.01	0.02
Miscellaneous	0.91	0.92	1.58	1.12	1.69	0.39	0.44	0.59	0.86	1.27	0.86
Total boat expenses	18.61	17.67	13.70	18.14	20.60	12.04	13.38	10.14	17.22	19.93	18.11
Total expenses	48.07	44.76	40.60	48.04	50.99	33.05	40.21	30.35	41.05	47.00	41.25

*Less than 0.01; 1 U.S. cent = 0.86 penny (English)

owners have a wide choice of insulating and electronics and they often get these from outside contractors. The vessel is now ready to fish; in fact, some customers actually put their fishing gear aboard when they take delivery and "fish their way home".

This saving of time in construction has been brought about by paying careful attention to the suggestions of owners, captains, marine surveyors and others.

Cost and finance

The 67 ft. (20.4 m.) Campeche Banks trawler will cost approximately £17,000 (U.S. $47,500) when fully equipped with 6 in. (127 mm.) of foam plastic insulation in the fish hold and completed with the usual echo-sounder, radio telephone and automatic pilot.

The builder strives to offer a sound, profitable vessel of minimum cost. It is possible to build a more expensive

TABLE 157

Production and gross receipts of typical shrimp trawlers

Region	*Year*	*Number of vessels*	*Total production* (pounds)	*Gross receipts* (U.S. dollars)	*Weighted average* (U.S. cents)
Region I					
South Atlantic	1953	11	353,197	220,048.	62.30
	1954	11	325,162	153,719.	47.27
Region II					
Florida West Coast	1952	2	166,602	104,629.	62.80
	1953	2	183,547	114,476.	62.37
	1954	2	101,907	47,036.	46.16
Region III					
Alabama	1952	12	517,391	214,559	41.47
Mississippi	1953	12	468,673	237,160.	50.60
Louisiana	1954	12	470,915	173,269.	36.79
[illegible] IV					
	1952	13	861,597	431,348.	50.06
	1953	13	906,826	550,303.	60.68
	1954	13	843,015	351,040.	41.64

Production is expressed as U.S. pounds, heads-off. 1 U.S. cent = 0.86 penny (English). £1 = U.S. $2.78

boat but it is more important to build one which the shrimp industry wants and can operate and maintain economically thereby getting a good return on their investment, which has been proven by the large number of boats that have been constructed.

Financing the purchase of a new shrimp trawler is not difficult as the post-war profit-history of these vessels, plus the standard designs, have encouraged financial institutions to readily lend funds for their purchase. No other fishing vessel in the U.S.A. is as readily financed as a shrimp trawler.

Since the purchaser will usually borrow 75 per cent., he is required to make a down-payment of 25 per cent. of the cost, and the balance, with added payments of 5 to 6 per cent. interest, is divided into 48 equal monthly payments. Lending institutions demand that the vessel be fully insured and also that the mortgagee be named in the insurance policy. The money lent by the bank is protected by a preferred maritime mortgage on the vessel.

TABLE 158

Operating profit and loss of typical shrimp trawlers (U.S. cents per pound, heads-off)

Item	*Region I* 9 vessels		*Region II* 2 vessels			*Region III* 12 vessels			*Region IV* 13 vessels		
	1953	1954	1952	1953	1954	1952	1953	1954	1952	1953	1954
Gross receipts	62.30	47.27	62.80	62.37	46.16	41.47	50.60	36.79	50.06	60.68	41.64
Costs of production	48.07	44.76	40.60	48.04	50.99	33.05	40.21	30.35	41.05	47.00	41.25
Profit or loss	14.23	2.51	22.20	14.33	−4.83	8.42	10.39	6.44	9.01	13.68	0.39

1 U.S. cent = 0.86 penny (English)

Economics

The success or failure of a vessel will depend upon her production. Due to the reluctance of fleet operators and owners to disclose their records, it is difficult to obtain precise figures on trawler earnings. However, it can be stated that an average new trawler will earn its monthly payments without difficulty and that it will pay for itself in four years.

Various organizations under contract to the U.S. Fish and Wildlife Service have studied the cost of operation and earnings of shrimp trawlers in the U.S.A. For convenience, the shrimping grounds have been divided into four regions: Region I, the south Atlantic coast from North Carolina to Key West, Florida; Region II, Florida west coast where most of vessels fish the Campeche Banks off Mexico; Region III, the states of Alabama, Louisiana and Mississippi; and Region IV, the state of Texas.

Great variety exists in the character of the fishery, the vessels and the economics of these four areas: Region III, for example, has many in-shore vessels and a high production of smaller shrimp boats. Region II is composed almost entirely of larger vessels which cross the Gulf of Mexico and remain at sea 40 to 50 days. The Texas area, Region IV, depends almost entirely on the off-shore grounds for the fishing.

While wages or shares will vary, as will production itself, an examination of table 156 will show that despite the variables involved, the ratio between trip expenses and vessel expenses is relatively constant in all areas: trip expenses account for roughly three-fifths of total production expenses and vessel expenses account for the other two-fifths.

Table 157 compares production and gross receipts over the period studied, 1952 to 1954. In 1953 prices for shrimp increased significantly and the shrimp industry experienced a major expansion; in 1954 shrimp prices slumped and the industry experienced a major recession.

Table 158 summarizes operating profit and loss for typical shrimp vessels and emphasizes that the shrimp industry, while speculative in many ways, can be made to yield a fair return if market prices are reasonable and good business management practices are followed.

DEVELOPMENT OF A TRAWLER OF UNORTHODOX DESIGN

by

E. C. B. CORLETT and J. VENUS

The recent practice in trawler design is to use fine entrance angles and small water plane coefficients. This, however, results in lack of stability and expensive work for the fore body. A new type of hull with double chines has been developed, and it has a good performance.

The trial results of a 115 ft. (35 m.) vessel of the new type tallied closely with the predicted resistance obtained by model tests and the vessel was about 1 knot faster than an ordinary type of the same size and engine output. There is also a big advantage in the simple method of construction and subsequent low cost of building. The main merits can be summarised:

- Cheaper, due to lower hull costs.
- More economical to operate due to the lower power required for equivalent service.
- Cheaper because of smaller and lighter machinery, if required only for a given speed.
- As efficient as the best normal ships in respect of fish caught, which are brought back without delay even in the worst weather.

The paper describes a practical way to introduce the type into under-developed areas, and mentions prospects for development, especially a smaller size under 100 ft. (30 m.) with twin screws.

DÉVELOPPEMENT D'UN CHALUTIER D'UN TYPE NON-ORTHODOXE

La pratique récente dans le dessin des chalutiers est d'utiliser un angle d'acuité aigu et un faible coefficient de remplissage à la flottaison. Il en résulte cependant un manque de stabilité et un travail coûteux pour l'avant du navire. On a mis au point un nouveau type de coque avec double bouchain, et il a donné de bons résultats.

Les résultats des essais d'un navire du nouveau type de 115 pi. (35 m.) concordaient étroitement avec la résistance prévue, obtenue à l'essai de modèle, et il était plus rapide d'un noeud environ qu'un navire du type courant de mêmes dimensions et ayant un moteur de même puissance. La méthode de construction est simple, ce qui présente un gros avantage, et le coût de la construction est, en conséquence, peu élevé. Les avantages principaux pourraient être résumés comme suit:

- Meilleur marché, par suite du coût plus faible de la coque.
- Fonctionnement plus économique par suite de la plus faible puissance nécessaire pour un service équivalent.
- Meilleur marché parce que la machinerie est plus petite et plus légère, s'il est demandé seulement une vitesse donnée.
- Aussi bon rendement que les meilleurs navires normaux en ce qui concerne les poissons pêchés, qui sont amenés au port sans retard, même par les plus mauvais temps.

La communication décrit aussi un moyen pratique d'introduire ce type dans les régions sous-développées et mentionne des perspectives pour le développement, spécialement d'un navire plus petit de moins de 100 pi. (30 m.) avec deux hélices.

PERFECCIONAMIENTO DE UN ARRASTRERO DE MODELO HETERODOXO

Ultimamente, al proyectar arrastreros se tiende a emplear ángulos de entrada agudos y coeficientes de la flotación pequeños, lo que da por resultado una falta de estabilidad y un trabajo costoso para el cuerpo de proa. Se ha perfeccionado un tipo nuevo de casco con doble arista que ha dado buenos resultados.

Los resultados de los ensayos de un barco de 115 pies (35 m.) concuerdan muy de cerca con la resistencia prevista, obtenida en el ensayo de un modelo, y era, aproximadamente, un nudo más rápido que un barco de tipo corriente de las mismas dimensiones y con motor de igual potencia. Tiene la gran ventaja de que el método de construcción es sencillo y, por tanto, los costos menores. Las principales ventajas pueden resumirse como sigue:

- Más barato por costar menos los cascos.
- Funcionamiento más ecómico por necesitar menos potencia para un servicio equivalente.
- Más barato porque la maquinaria es más pequeña y más ligera si se pide solamente una velocidad dada.
- De igual rendimiento que los mejores barcos normales en lo relativo al pescado capturado, que se lleva a puertos sin retrasos incluso en mal tiempo.

Se describe una manera práctica de introducir este tipo en las regiones insuficientemente desarrolladas y se mencionan las posibilidades de construir otros barcos, en particular uno más pequeño de menos de 100 pies (30 m.) con dos hélices.

FOR the past two years trawlers of a new hull form have been fishing out of Aberdeen and Grimsby with success on the Faroes grounds. In design they embody several features which run counter to generally held design tenets in the U.K. and yet it is these very features that give them what is regarded as outstanding performance.

In the U.K. trawlers are built in four or five distinct size groups as a result of operating experience and the Government support system. Generally, these groups are as follows:

Group 1. Deep-sea or distant-water: 160 to 220 ft. (49 to 67 m.) registered length.

Group 2. Middle-water: 130 to 160 ft. (40 to 49 m.) with some 115 ft. (35 m.) ships fishing in the group.

Group 3. Near-water: 100 to 115 ft. (30 to 35 m.).

Group 4. Inshore: 50 to 100 ft. (15 to 30 m.).

The initial approach to the new design was in Groups 2 and 3 at 115 ft. (35 m.) registered length. Dimensions here are virtually standard, the registered length representing a subsidy step while the breadth is usual at 25 ft. (7.6 m.), the depth at 12½ ft. (3.8 m.) and δ around the 0.58 mark. It is common practice to fit 650 to 750 h.p. provided by a direct-drive diesel engine running at about 250 r.p.m. These dimensions have been found well suited to the Faroes grounds and generally result in a ship capable of about 10¾ to 11 knots in the two-thirds fish load condition leaving the grounds, with a fish hold in the region of 6,500 to 7,000 cu. ft. (185 to 200 cu. m.). The trawl winch is generally electric with about a 100 kW direct-drive diesel generator situated at the forward end of the engine room in line with the main engine.

DESIGN

There is a marked tendency to adopt exceptionally fine angles of entrance in modern trawlers and this has become extreme recently with the adoption of bulbous bows. Low resistance forms have been produced but the resulting low waterplane coefficient has required a substantial increase in breadth to maintain adequate stability and this has offset some of the original resistance advantage. Also the very fine angle of entrance makes the fore body difficult and expensive to construct, while, although model tests show small pitch and heave responses in heavy regular seas, many question whether this hull form represents the best fishing platform obtainable in practice. Certainly this widespread trend represents an acceptable type of vessel, but it was felt it could not be the only one and accordingly the development of a new design was started.

Hulls with a fine angle of entrance are of substantially waterline flow type forward and, as such, resistance is relatively susceptible to increase of breadth. At the same time, the main flow of the screw has strong horizontal characteristics and, as a result, quite moderate pitching may effect the screw unduly, due to air drawing and general loss of homogenity in the flow. It was decided, therefore, that a stern of basically buttock flow type should be adopted with the buttocks so arranged that any pitch up of the stern was minimized due to immediate and appreciable loss of buoyancy aft. The buttocks were kept straight or slightly hooked aft to minimize squatting at the higher speed-length ratios and the lines were designed to give a breakaway to the flow such as is obtained in a carefully designed transom stern. This is, of course, only possible with buttocks which do not have any convexity downwards immediately forward of the breakaway point.

In association with this stern, it was clearly necessary to design a bow that would give a flow over the midship body consistent with that the stern was intended to accept. For instance, a bulb bow would be inconsistent as clearly the waterline flow forward would have to change to buttock flow aft with a long resultant flow path incorporating large local velocity variations. A bow giving a diagonal flow, having markedly V-sections and feeding water into a mainly buttock flow stern, was designed with a much greater half angle of entrance than the normal type.

The entire surface of the hull was made developable, using the surfaces of various irregular conical and cylindrical bodies. This was not only possible but advantageous and added the advantage of simplified methods of construction and prefabrication. The exact methods of doing this are the subject of patents.

The dimensions and coefficients of form resulting are given under ship B in table 159. A direct-drive four-

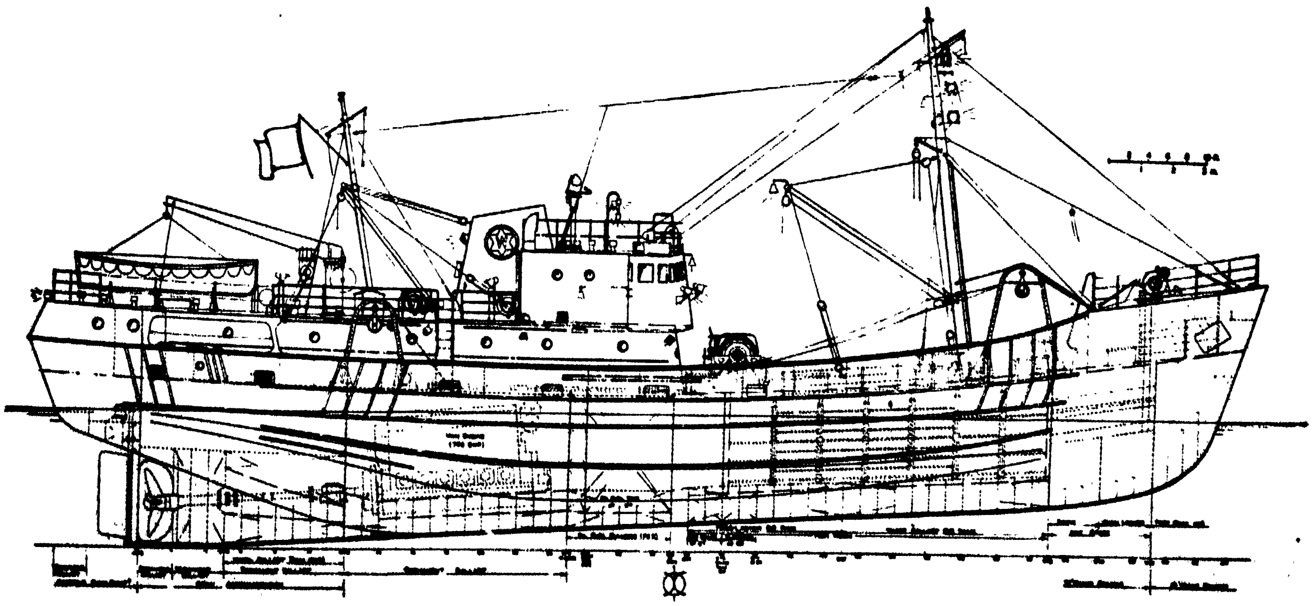


Fig. 687. Star of Aberdeen, *a 115 ft. (35 m.) near-water trawler of double-chine*

stroke diesel engine with an output of 760 h.p. at 250 r.p.m. was fitted.

The general arrangement is shown in fig. 687.

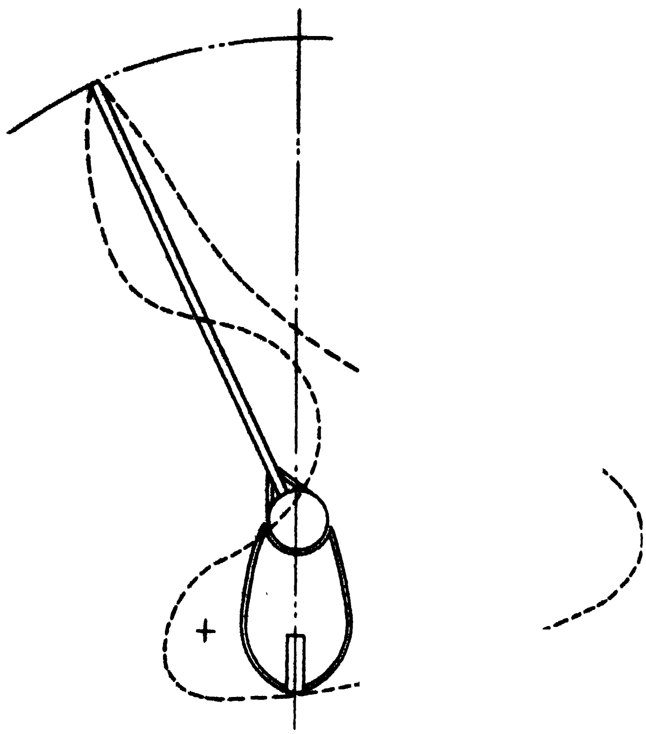


Fig. 688. Bulb post rudder (patented), originally developed for tugs, fitted to Star of Aberdeen

A patent bulb post rudder, fig. 688 and 689, originally developed for tugs with the same type of hull, was fitted and is to some extent responsible for the propulsive efficiency achieved. It is simple and robust and has a large turning moment at comparatively small angles, with constant steady torque values at varying angles but constant speed. More important, however, due to its marked contra-rudder characteristics at varying angles of inflow, it exerts a beneficial effect upon the propulsive efficiency both when trawling and sailing.

All-welded construction was used, with very robust scantlings, and a double bottom was fitted in way of the fish hold—an innovation in this class of trawler which has well proved its worth and is only possible in an all-welded hull.

Model tests and trials

The form was tested at NPL and proved to have very good resistance and propulsive characteristics for the type and size. The influence of the bulb rudder was, as expected, not markedly apparent due to scale effect, but, nevertheless, the propulsive efficiency predicted was comparatively good.

Table 159 compares the predicted performance with those for a trawler of normal type and form and of good average quality. Fig. 690 gives the ship prediction on the measured mile corrected to the two-thirds fish condition, compared with the same conventional ship.

The vessel of the new design is a knot faster in service than the normal 115 ft. ships, and this is so in all weathers. An interesting point is that the actual vessel is appreciably better at high speeds than the model test predictions, largely due to the effect of the rudder, which may not be properly accounted for in a model test due to scale effects. The trials were run on the Newbiggin deep sea mile, using a calibrated torsion meter, and extreme care was taken to obtain reliable results.

Stability and weights

Because of the unusual double bottom under the fish hold it was possible to place all the solid ballast in the

Fig. 689.

TABLE 159

Principal particulars and performance of normal and new form

	Ship A—Normal	Ship B—New type
Length registered	115 ft. (35.1 m.)	115 ft. (35.1 m.)
LBP	111 ft. (33.9 m.)	110 ft. (33.5 m.)
Breadth, B	25 ft. (7.62 m.)	25 ft. (7.62 m.)
Depth, D	12.5 ft. (3.81 m.)	12.5 ft. (3.81 m.)
Displacement, Δ_s	488 tons	490 tons
Draught, mean, T	10.64 ft. (3.24 m.) moulded	10.90 ft. (3.33 m.)
Drag of keel	5.5 ft. (1.68 m.)	6.0 ft. (1.83 m.)
δ	0.578	0.580
φ	0.67	0.68
LCB aft of ⊠	3 ft. (0.91 m.)	4.6 ft. (1.40 m.)
$\frac{1}{2}\alpha_e$	28.0°	32.3°
Propeller diameter, D	6.75 ft. (2.05 m.)	7.02 ft. (2.14 m.)
Mean effective pitch, P_e	5.7 ft. (1.74 m.)	5.7 ft. (1.74 m.)
Disc area ratio, DAR	0.43	0.55

	Ship	10 knots	QPC	11 knots	QPC	12 knots	QPC	12.4 knots	QPC
Predicted BHP	A	366	0.58	715	0.56	1,065	0.54	—	—
	B	244	0.63	478	0.62	812	0.61	—	—
Trial BHP at 430 tons displacement	B	280	—	465	—	620	—	760	0.696
Corrected trial BHP 490 tons displacement		310	—	518	—	760	—	835	—
Predicted trawling pull at 4 knots and 500 SHP	A	5.30 tons							
	B	6.10 tons							

Note:—1½% allowed for shaft losses

most advantageous position, namely, aft of amidships. It was a requirement that the metacentric height should not be less than 2.5 ft. (0.76 m.) in any condition. Later this requirement was reduced, due to owner's modifications, to 2.4 ft. (0.73 m.).

Particulars of vessel:

Weight of steel including belting, etc.	156 tons
Wood and outfit	88 „
Machinery	69 „
Ballast	48 „
Lightship	361 „

The make-up of the normal load condition, i.e., the two-thirds capacity fish condition, is given below:

Lightship	361 tons
Fish and ice	70 „
Fresh water (50% capacity)	11 „
Oil fuel (60% capacity)	22 tons
Nets and gear	20 tons
Stores, crew, etc.	6 „
Total	490 „

GM (corrected for free surface)	2.41 ft. (0.73 m.)
Draught forward	7.73 ft. (2.35 m.)
„ aft	14.23 ft. (4.34 m.)

In all other standard conditions, such as ready for sea, full load departure from grounds and arrival at port, the metacentric height is between 2.40 and 2.50 ft. (0.73 and 0.76 m.), corrected for free surface, and the trim between ±0.5 ft. (±0.15 m.) from the basic rake of keel.

Bilge keels

Effective bilge keels are an important feature of these vessels. Originally, keels as shown left in fig. 691 were fitted but this proved inadequate and those shown right in fig. 691 were substituted. These are most successful and may set a fashion. It is necessary to construct them as shown because flat plate construction suffers unduly from trawling warp damage and from buckling due to water pressure when rolling, for it is not unknown for these ships to continue fishing in Beaufort 10.

COST OF CONSTRUCTION AND OPERATION

A trawler fishing in northern waters is very complicated and expensive. In some part, this is due to the comprehensive navigating equipment, but the hull of a normal steel trawler forms a considerable percentage of the total cost. There is considerable curvature and bevel in all frames and many of the shell plates have intricate double curvature. If it is possible to eliminate this expensive shaping, a considerable saving in building cost and building time would result. Straightline framing and single curvature plating has often been used in the past, but usually with the result that the performance, as regards speed and sometimes also seakeeping, has been adversely affected.

The advantages of this special hull type are that, whilst preserving the simplicity of construction of the hard chine hull, it gives improved performance in speed and seakeeping compared with most traditional types.

In addition, the capital equipment required in a shipyard designed to build such ships is not nearly so great as that necessary for the production of round bottom vessels. Plate and frame furnaces are not necessary and, although the vessel is of all-welded construction, heavy prefabricated units, requiring large and expensive cranage, have been dispensed with. A simplified form of construc-

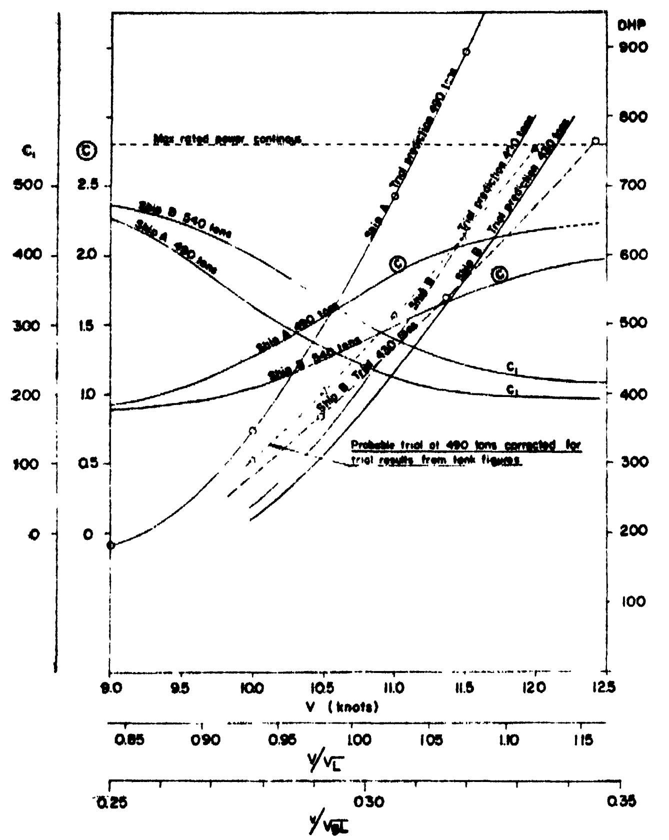


Fig. 690. Performance curves from measured mile trials compared with the predictions from model tests

tion coupled with a relatively inexpensive shipyard layout, must become attractive in parts of the world where a large reserve of skilled labour is not available and where money for capital investment is scarce.

Although each owner has his own particular preference in the matter of deck arrangement and accommodation, it has been possible to standardize to a considerable degree the shape of the hull, and the drawing work has thus been lightened considerably.

Methods of construction

After the whole steelwork is lofted, all plates and bars are cut exactly to size. So-called frame rings are fabricated to give transverse stiffness during erection. They consist of floors, side frames, brackets and deck beams, and where an opening is required in the hull in the way of a frame ring, this is carried right across and the opening cut after erection. The shell and deck plates are welded into panels up to about 3 tons in weight and all the steelwork, as it is made, is carefully arranged on the ground alongside the building berth in the sequence that will be required during building. Then erection starts and the time taken to erect the greater part of the hull and decks is only 10 to 15 working days. This, of course, is before fairing has taken place and before any large-scale welding has commenced. The fairing of the steelwork runs concurrently with the gradual increase in the number of welders and, after about 5 to 6 weeks from the commencement of construction, the maximum number of welders can be employed economically. As the overhanging stern would present a certain amount of difficulty if erected entirely in plates, the framework of this structure is usually built on the ground and the plating welded on after erection.

During fitting out it is of considerable importance that an economical number of men should be kept employed. Trawlers are complicated and the interior very crowded, particularly in the engine room and living accommodation. It is, therefore, necessary to see that the maximum amount of access throughout the vessel is created by providing temporary openings through bulkheads, etc., during the fitting out process.

These particular vessels are comparable with any of the size afloat today and this seems to dispose of the contention that decades of experience are necessary to design and construct deep-sea trawlers satisfactorily. It is essential that there should be continuous consultation with the owners and the men who are to fish. It is necessary for the owners to state clearly and unambiguously all their requirements of performance. The design is then a matter of sound naval architecture and the arrangement of the trawler and the detailed layout of fishing gear, accommodation, etc., can best be laid down by an owner in consultation with a builder rather than by any builder, however experienced.

Comparison of the new and normal type

A comparison of the new trawlers in service with normal ships shows that the former are:

- Cheaper due to lower hull costs
- More economical to operate due to the lower power required for equivalent service
- Cheaper because of smaller and lighter machinery if required only for a given speed
- As efficient as the best normal ships in the quantity of fish that can be caught and brought back to port even in the worst weather

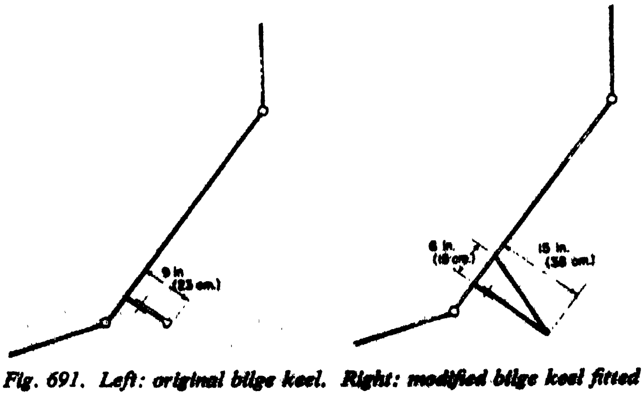


Fig. 691. Left: original bilge keel. Right: modified bilge keel fitted

To illustrate these points, it is worth considering specimen records for voyages for two ships; one the *Star of Aberdeen*, the other a normal vessel of similar dimensions and power belonging to the same owner. These records relate to trips made at about the same time.

At approximately 650 h.p. the new type vessel made an average speed of 11½ knots and for a trip of eleven days the fuel consumption averaged 1.5 tons per day. The fish landed amounted to 700 Aberdeen boxes, being an average of 64 boxes per day for the trip. The normal vessel averaged 10½ knots on a fuel consumption of 1.75 tons per day, the catch for a twelve-day trip was 742 boxes, averaging 62 boxes per day. As the new type requires a smaller investment, it can be seen that the advantages claimed are maintained in service.

LICENSED BUILDING

A further advantage of this system of design and construction is that it is very suitable for countries in which

Fig. 692. Star of Aberdeen

this size of vessel has not hitherto been constructed. The cost of the necessary shipyard is generally less than the cost of a single vessel and the design lends itself more readily to construction with a minimum of skilled men. The procedure adopted in setting up a yard abroad for building the new type of trawler is that, first, the principal requirements are investigated in conjunction with the persons who, ultimately, will run the yard. A prototype is then constructed in an experienced shipyard, while the key personnel who eventually will manage the new yard are present to study the entire construction. They are given access to all building costs, including a detailed breakdown of man-hours and detailed costing of all the material supplied. Meanwhile, the new yard is being built and when the first vessel is finished, the material for the second vessel is despatched to it, together with a representative from the parent yard to give all assistance during assembly. The third vessel is constructed entirely by the new yard with the assistance of the parent yard. Whenever necessary, materials for this and subsequent vessels can, if desired, be ordered and progressed for correct delivery by the parent organization. This scheme is working satisfactorily at the present moment.

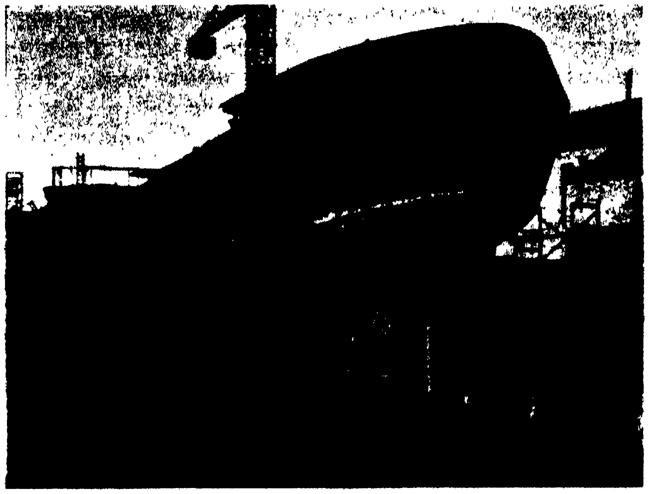


Fig. 693. Star of Aberdeen. *Notice the double chines*

FUTURE DEVELOPMENTS

Development of the new trawlers of chine and round bilge types is being carried out in both the distant- and near-water classes. A very successful 100 ft. (30.5 m.) form has been produced for the Scratcher class and work is almost complete on a 180 ft. (55 m.) distant-water design.

At the same timew, hile all these types offer the eco-

Fig. 694. Fairing of double chines into stem

nomic possibility of high service speeds for a given power/ length, it is considered that a drastic revision of fishing methods is long overdue in the smaller ships. Stern trawling is not uncommon now in the 180 to 220 ft. (55 to 67 m.) size group and, indeed, might become standard practice in some countries. Much thought has been given to the design of a ship of less than 100 ft. (30.5 m.) registered length, capable of both near- and middle-water fishing, because small ships suffer badly when side trawling, as freeboard and rolling are deficient by comparison with large trawlers, while power and ability to punch through bad weather suffer likewise.

The solution may be twin screws for sustained sea power in a hull so designed that the screws do not tend to race whatever the weather, a forecastle carried aft to about amidships and, of course, a stern trawling layout. This layout is akin to that developed by combination boats on the Pacific Coast of the U.S.A. The North European conditions for this size of ship, however, are much more severe, especially on the Faroes grounds, and the reasons for adopting the basic layout are fundamentally different.

The ratio between non-resonant pitching and rolling angles is of the order of 6 or 8 to one and this alone is a fact of tremendous advantage to these small ships if stern trawling is adopted. Twin screws are highly desirable for seakeeping and manoeuvring reasons, but it is essential that the vessel shall be capable of steaming on one screw with a maximum of, say, five degrees of helm only. This, combined with direct bridge control, using oil-operated reverse reduction with clutches, and a clear view of the working deck from the wheelhouse, ensures simple and effective control by the skipper. The key to the fishing gear is at the extreme stern itself and an original arrangement has been produced. This new trawler type, in different sizes, may offer the possibility of covering much single ship trawling with one multi-purpose type.

THE NETHERLANDS POST-WAR FISHING FLEET

by

P. BOOGAARD

The Netherlands fishing fleet can be divided into large sea-going boats and small coastal fishing craft. The former consist of cutters, trawler-drifters and trawlers. The total number of boats in the sea-going fleet has not changed since 1938, but its composition has altered considerably, and the individual boats have also been greatly improved in size, output and fittings. Four examples are given to show typical small sea-going shrimp trawlers, cutters, trawler-drifters and trawlers.

LA FLOTTE DE PÊCHE DES PAYS-BAS APRÈS-GUERRE

La flotte de pêche des Pays-Bas peut être divisée en grands navires de haute-mer et en petits bateaux pour la pêche côtière. Les premiers comprennent des cotres, des chalutiers-drifters et des chalutiers. Le nombre total de navires de la flotte de pêche en mer n'a pas varié depuis 1938, mais sa composition a beaucoup changé, et les navires ont aussi été améliorés en ce qui concerne les dimensions, la puissance et l'équipement. L'auteur donne quatre exemples pour montrer des types de petits chalutiers à crevettes, de cotres, de chalutiers-drifters et de chalutiers.

LA FLOTA PESQUERA DE LOS PAÍSES BAJOS EN LA POSTGUERRA

La flota pesquera de los Países Bajos puede dividirse en embarcaciones grandes para la pesca de altura y pequeñas para la pesca de bajura. Las primeras consisten en cúteres, arrastreros y barcos mixtos para la pesca al arrastre y a la deriva. Desde 1938 permanece inalterado el número de barcos de la flota de altura, pero su composición ha variado mucho e individualmente los barcos han experimentado grandes majoras en cuanto a tamaño, rendimiento y armamento. Se dan cuatro ejemplos típicos de embarcaciones pequeñas para la pesca del camarón al arrastre, cúteres, arrastreros y mixtas para la pesca al arrastre y a la deriva.

THE Netherlands fishing fleet can be divided into large boats, operating mainly in the North Sea, and small coastal fishing craft. The sea-going fleet consists chiefly of cutters, drifters and trawlers, some for combined trawling and driftnet fishing. The coastal fleet contains a great variety of types, some obsolete and usually built of wood.

The sea-going fishing fleet at present numbers about 600 vessels, which was its strength in 1938, but its composition has changed considerably. After World War II reconstruction started in such an energetic way that the Netherlands had an effective fishing fleet within a few years. This post-war recovery, stimulated by profitable catches, has led to further modernization and renewal. The three main types are: (a) small sea-going craft and cutters; (b) trawler-drifters; and (c) trawlers.

In 1938 the proportion of the types was about 7:6:2, and it is now 9:4:2, that is, an increase in the cutters, a decrease in drifters, while the trawlers have more or less kept their position. The so-called "small sea-going craft" are built primarily for shrimp trawling. To increase its productivity, this type is also used in coastal waters for flat-fish, by increasing the power of the engine from 80 h.p. to 120 h.p. It has good navigation qualities and shows profitable returns.

In the cutter class, the trend is to increase the dimensions and the output of the motors to be able to go beyond the over-fished areas; in 1938 the length of the cutter was about 49 to 65 ft. (15 to 20 m.), with an engine between 80 and 150 h.p. The new cutters have a length of 65 to 88 ft. (20 to 27 m.) and the engine has increased to about 150 to 300 h.p.

No more drifters are being built, thus they are decreasing in number. Drift-netting is still important, even though it cannot be carried on throughout the year. The older drifters, with a length of 79 to 92 ft. (24 to 28 m.) and with diesel engines of 80 to 150 h.p., or from 92 to 108 ft. (28 to 33 m.) and powered by steam engines of about 180 to 250 h.p., do not have sufficient power for trawling, which decreases their production. Almost all steam vessels are out of service but some have been rebuilt and fitted with diesels. A number of motor drifters, fitted with more powerful engines, continue in service, and these and the rebuilt vessels now trawl and do drift-netting as well. In addition, new combined trawler-drifters were built after 1948 with a length of 105 to 115 ft. (32 to 35 m.) and with 250 to 400 h.p. motors. Generally, favourable results have been obtained because fishing is carried on throughout the year.

Important changes have also taken place in the trawler

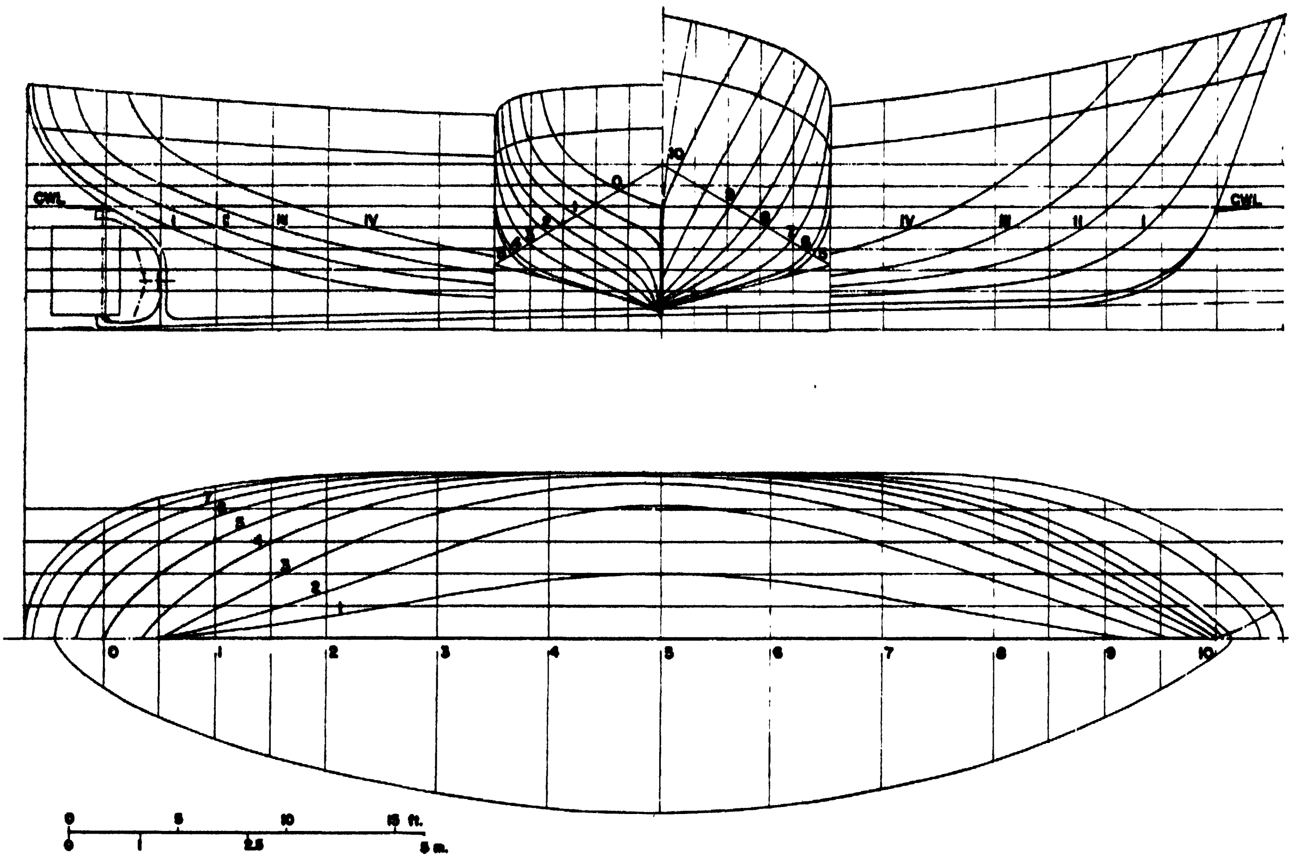


Fig. 695. Small motor cutter—Lines

fleet. In 1938 the length of the trawlers averaged 98 to 125 ft. (30 to 38 m.), with steam engines of 300 to 600 h.p. They are being replaced by motor trawlers, a few of which were already in service before the war. The new trawlers have a length of 115 to 138 ft. (35 to 42 m.), with engines of about 500 to 1,000 h.p., and most fish in the northern waters of the North Sea and in higher latitudes.

From the following examples of recently-built vessels the characteristics of the modern Dutch sea-going fishing vessels can be observed. The plans and descriptions were kindly submitted by:

1. Shrimp trawler:
   Shipping Department of the Netherlands Ministry of the Building Industry.
2. Motor cutter:
   N.V. Scheepsbouwwerf "De Industrie" D. en Boot, Alphen a/d Rijn.
3. Trawler-drifter:
   N.V. Scheepsbouwwerf "De Dageraad" v/h Wed. J. Boot, Woubrugge.
4. Trawler:
   N.V. Scheepsbouwwerf "De Hoop" v/h Gebr. Boot, Leiden.

Shrimp trawler (fig. 695 and 696)

Trawling for shrimps takes place both to port and starboard, and the net is lifted by steel derricks on the foremast, to which the fishing tackle is fastened. Hoisting and lowering is done by the drums of the winch, which extend on each side of the wheelhouse. The winch, operated from the wheelhouse, is driven from the main engine by a belt with a tension roller. The winch has two drums each containing 1,000 ft. (300 m.) of $\frac{7}{16}$ in. (11 mm.) wire. The hauling-in speed is 330 ft. (100 m.) per min. with a pull of 4,400 lb. (2,000 kg.). The shrimps are kept alive in the fish well before processing.

The vessel is divided, as shown in fig. 696. The forepeak can also be used as a ballast tank. There are four bunks in the crew's quarters, with lockers, table and benches, dresser with sink and pump, and space for a gas range and a coal stove. Electricity for lighting is provided by a 24 V dynamo and battery. The vessel has steel masts. The wheelhouse is of teak.

The steel weight is 24 ton. The hull is partly or totally welded. The fuel oil tanks, with a total capacity of 4 ton, are on both sides of the fish well. The diesel engine is normally 80 h.p., but 120 h.p. is necessary when trawling flat-fish. For this type of ship, a medium speed diesel is preferred, the speed of the propeller being reduced to 300 r.p.m. Particulars of the propeller are: three blades, 39⅜ in. (1,000 mm.) diam., 34 in. (860 mm.) pitch, and 52 per cent. blade surface. The diameter of the propeller shaft is 3.5 to 4.0 in. (90 to 100 mm.). Speed: 8 knots, trawling depth: 1 to 6 fm. (2 to 11 m.), speed during fishing: 3 knots. The ship has a liferaft.

Motor cutter (fig. 697 and 698)
These ships fish in the North Sea in winter, about latitude 53°30′ N. and between longitude 4°0′ and 5°0′ E., at a depth of 20 to 35 fm. (37 to 64 m.), with a trawling speed of about 3 knots. In summer they fish between latitude 56° and 58° N. and longitude 3° and 4°30′ E., at a depth of 30 to 50 fm. (55 to 90 m.), with a trawling speed of about 4 knots. One fishing trip takes about 10 to 11 days, the distance from Ijmuiden being 300 to 360 miles. The fuel oil consumption is about 1 ton per day. With the bunker capacity of 25 ton, a trip of about three weeks is possible.

The principal dimensions are:

LOA	88 ft. 7 in. (27 m.)
LBP	77 ft. 9 in. (23.7 m.)
B	21 ft. 4 in. (6.5 m.)
D	10 ft. 6 in. (3.2 m.)
T	8 ft. 2⅛ in. (2.5 m.)
Δ	180 ton
Fuel oil	917 cu. ft. (26 cu. m.)
Fresh water	275 cu. ft. (7.8 cu. m.)
Fish hold	650 boxes
Speed	10 knots
δ	0.50
β	0.80
φ	0.63

The hull is mainly welded, only the frames and seams being riveted. The hull is of strong construction, protected on the gallows sides by 3×1½ in. (76×38 mm.) half-round bars. The total steel weight is about 75 ton.

The fish hold has a capacity of about 38 ton. The insulation consists of cork layers, 5 in. (127 mm.) thick

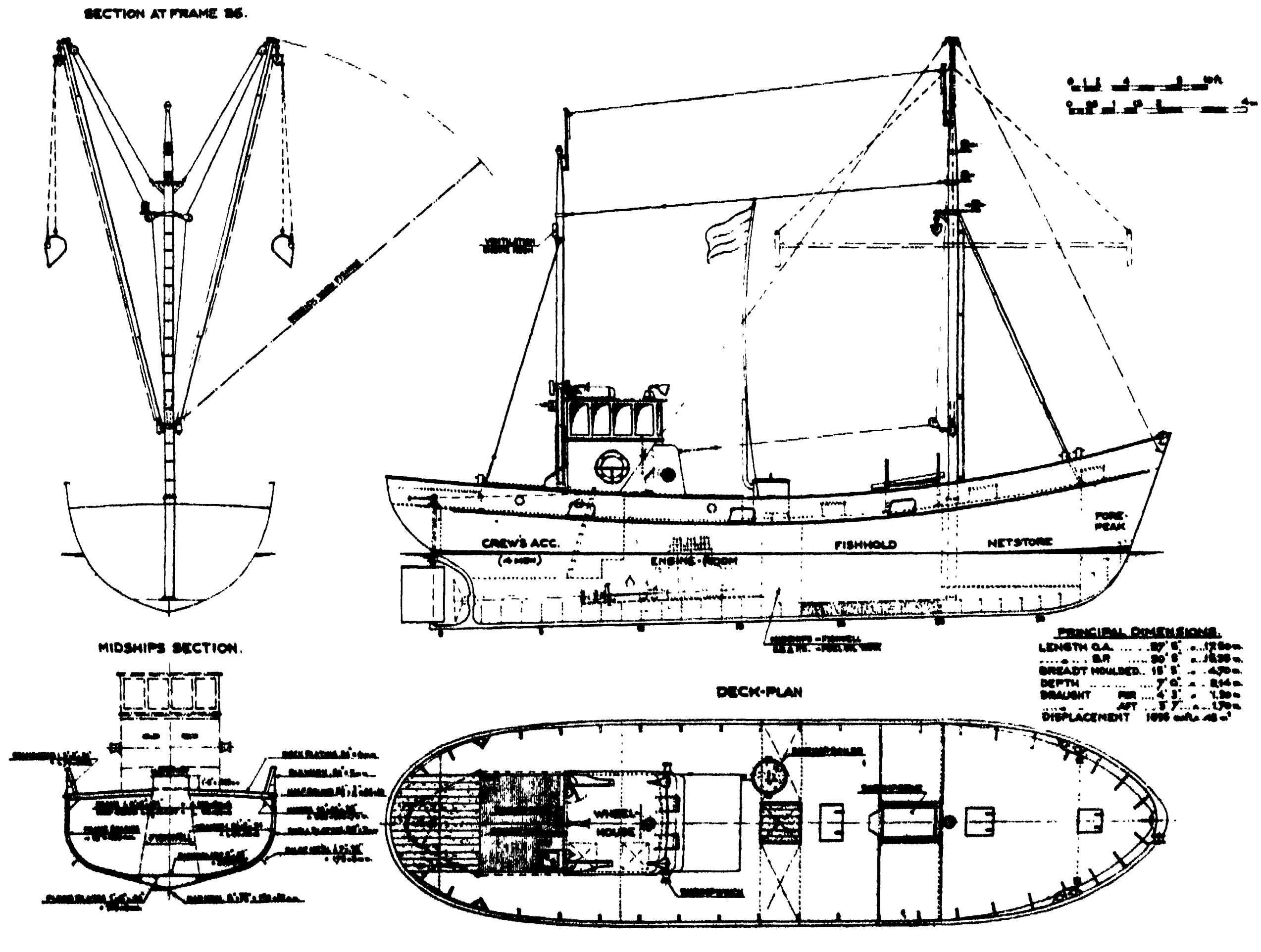


Fig. 696. Small motor cutter—General arrangement

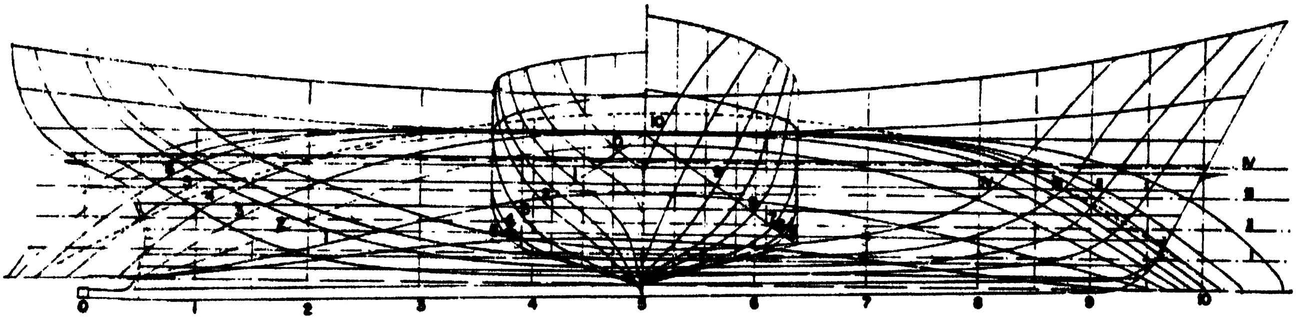


Fig. 697. Dutch motor cutter—Lines

under deck, 4 in. (102 mm.) on the hull and 3 in. (76 mm.) on the bulkheads, covered with a layer of cement. The fish hold is divided by wooden bulkheads fixed in galvanized iron stanchions, and the shelves are of pine.

There is accommodation for six men aft; the skipper has his berth in the chart room. The main engine is a 6-cylinder diesel, developing 300 h.p. at 460 r.p.m., with a reduction gear of 2:1. The propeller has a diameter of 6 ft. 5 in. (1,950 mm.), four blades, 4 ft. 2 in. (1,280 mm.) pitch, 40 per cent. of blade surface. An auxiliary engine developing 20 h.p. at 1,000 r.p.m. and two generators of 7.1 kW, 110 V DC are fitted in the engine room. The trawl winch has 420 fm. (768 m.) of 2½ in. (63.5 mm.) steel wire, and a capacity of 7,700 lb. (3,500 kg.) at medium barrel diameter. Each ship is equipped with a lifeboat or dinghy. The gross tonnage amounts to 119 and the net tonnage is 42.

Trawler-drifter (fig. 699 and 700)

The speed is 9½ knots, and 3½ knots when trawling at a depth of 22 to 27 fm. (40 to 50 m.), and the ship can remain at sea for 21 days. The fuel consumption is about 3,900 lb. (1,775 kg.) in 24 hours. Gross tonnage: about 118. Net tonnage: about 42. Other main particulars are:

LOA	118.38 ft. (36.05 m.)
LBP	104.75 ft. (31.95 m.)
B	22.92 ft. (7.00 m.)
D	12.46 ft. (3.80 m.)

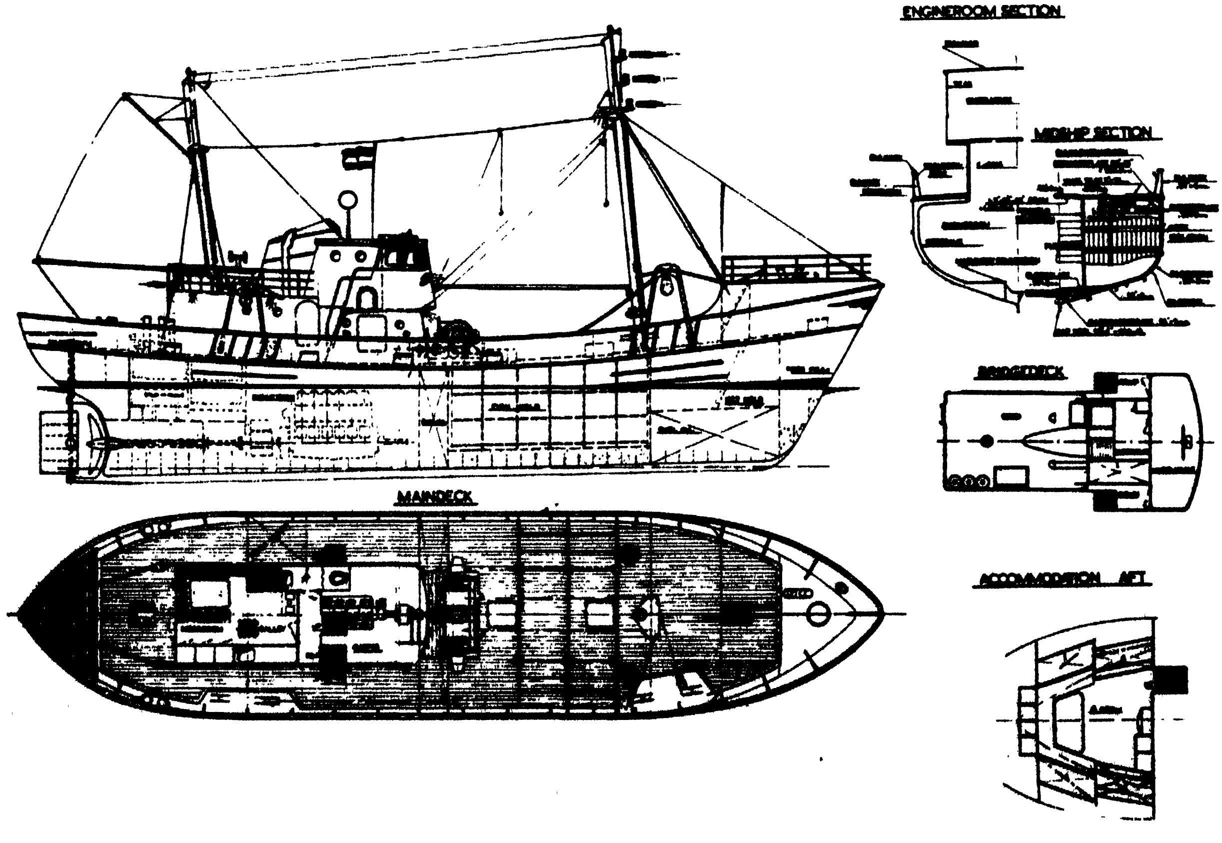


Fig. 698. Dutch motor cutter—General arran

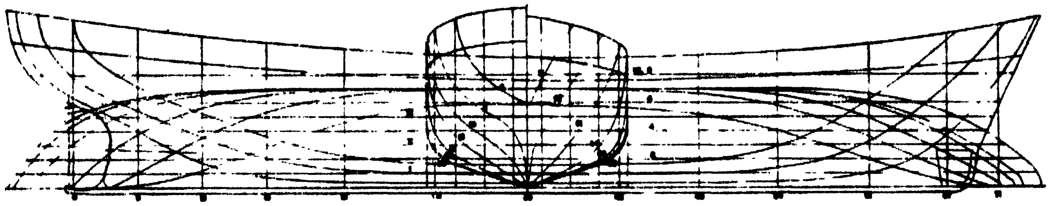


Fig. 699. Dutch trawler-drifter—Lines

T fwd.	7.58 ft. (2.31 m.)
aft	12.29 ft. (3.75 m.)
Δ	329 ton
GM	3 ft. (920 mm.)
Frame spacing fr. 28–57	1.51 ft. (460 mm.)
elsewhere	1.48 ft. (450 mm.)
Fuel oil capacity	1,554 cu. ft. (44 cu. m.)
Freshwater capacity	283 cu. ft. (8 cu. m.)
Fish hold capacity	4,415 cu. ft. (125 cu. m.)
Barrel capacity	650
Accommodation	18 men
δ	0.459
β	0.835
φ	0.593

The ship is divided by five watertight bulkheads. The forepeak is used as a chain locker. The insulated fish hold has eight partitions with four rows of galvanized iron pillars and three barrel stores. The insulation is 4 in. (102 mm.) thick expanded cork at the sides, fore and aft bulkheads 2 in. (51 mm.) cork plates, and the deck has 5 in. (127 mm.) cork plates. The whole fish hold is sheeted with pine, has a wooden floor and is divided by a wooden bulkhead. The rope store is only on the starboard side and there is a double barrel store on the port side.

Both the fore and the aft cabins have eight bunks. In the deckhouse there is a messroom, a shower and toilet washing place, entrance to engine room and aft cabin.

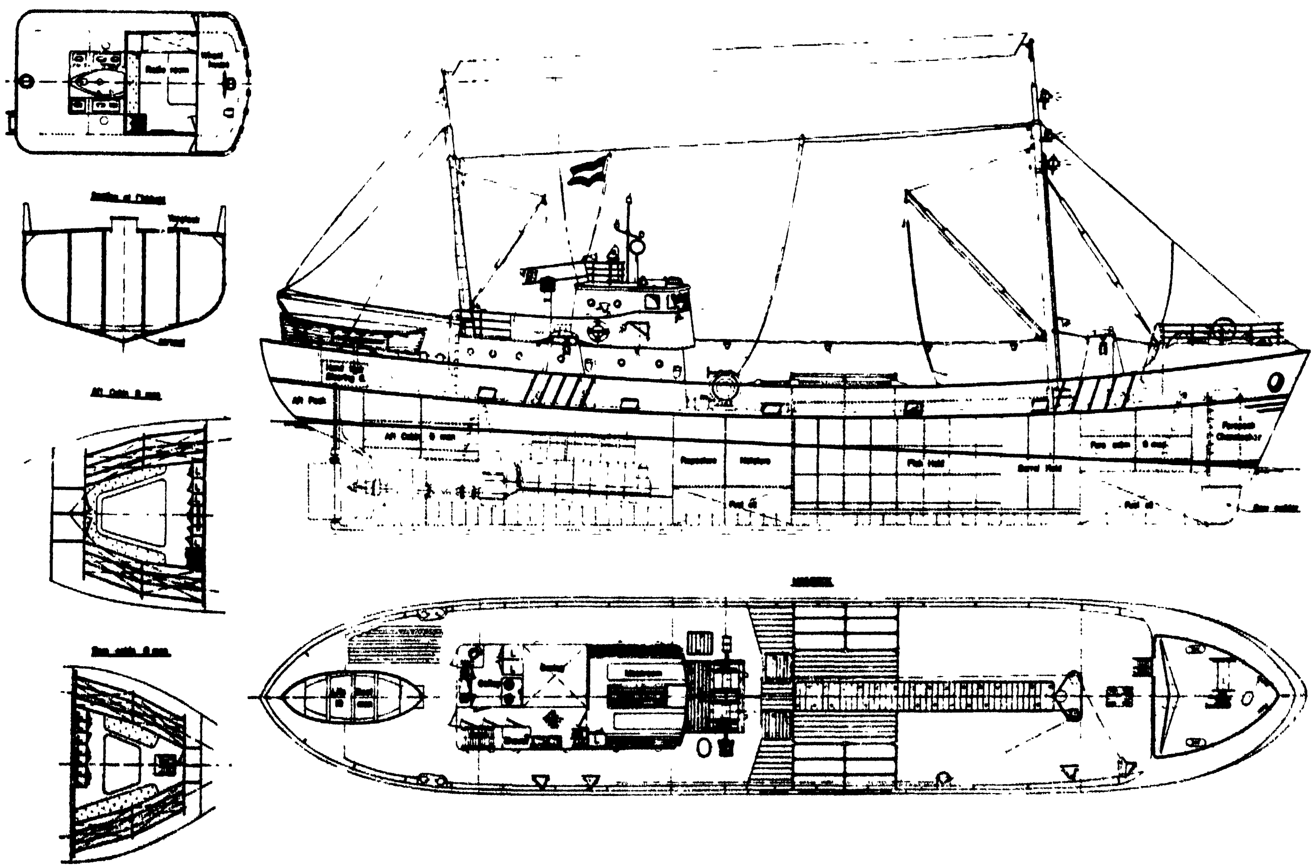


Fig. 700. Dutch trawler-drifter—General arrangement

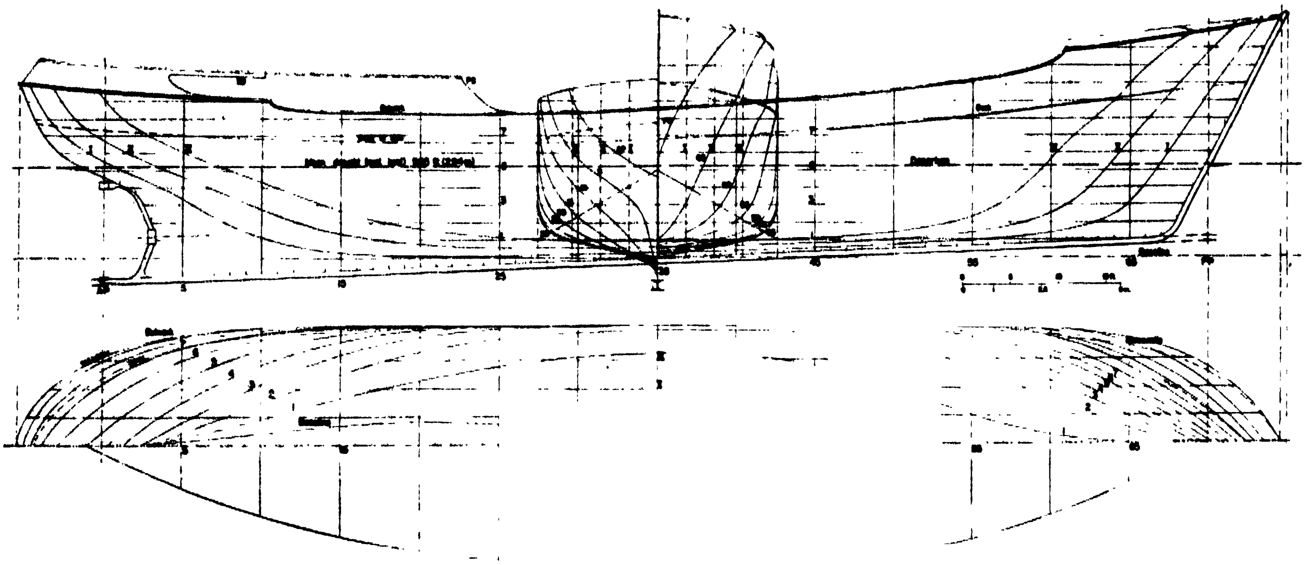


Fig. 701. Dutch trawler—Lines

The captain's cabin is also the radio room with the Decca navigator and direction finder. The echo sounder is in the wheelhouse. On the aft deck, under a steel watertight casing, is the hand-hydraulic steering gear.

The ship is constructed of steel with riveted seams and frames and welded butts, welded bulkheads, bottom tanks and decks. The bar keel is welded to the keel plates. Two built-in freshwater tanks are arranged on both sides of the engine.

The scantlings of the midship sections are:

Barkeel	8×2 in. (200×50 mm.)
Keelstrake	0.44 in. (11 mm.)
Garboard strakes	0.32 in. (8 mm.)
Bilge strake	0.38 in. (9.5 mm.)
Sheer strake	0.44 in. (11 mm.)
Strake below	0.38 in. (9.5 mm.)
Bulwark	0.28 in. (7 mm.)
Floor plates	16×0.32 in. (400×8 mm.)
Center line keelson	5.5×5.5×0.32×0.48 in. I (140×140×8×12 mm.)
Frames	4×2.5×0.32 in. L (100×65×8 mm.)
Deck beams	5×2.5×0.32 in. L (130×65×8 mm.)
Deck stringerplate	20×0.32 in. (500×8 mm.)
Deck tie plates	2×24×0.32 in. (2×600×8 mm.)

The main engine develops 400 h.p. at 350 r.p.m. and has a reduction gear of 2:1 with a built-in clutch. This special clutch absorbs sharp pulls on the rope when trawling. A diesel of 100 h.p. at 1,000 r.p.m. on the port side, drives the winch through a shaft and V-pulley. The winch has 710 fm. (1,300 m.) of ⅞ in. (22 mm.) steel wire.

A 25 h.p. at 1,250 r.p.m. auxiliary diesel drives an intermediate shaft by means of a flat belt from which two generators of 7½ kW, 110V DC are driven by V-belts, as well as one general service pump of 810 cu. ft. (23 cu. m.) per hr. capacity, one stand-by compressor of 1,060 cu. ft. (30 cu. m.) per hr. capacity, and one stand-by lubricating pump. In addition to the main 110V DC supply, there is an emergency plant of 24V DC with a lead-acid 190 A hr. battery. The main switchboard is in the engine room, and the distributing boards are on the bridge. There is also an electric fuel transfer pump of 210 cu. ft. (6 cu. m.) per hr. capacity for trimming the fuel from the fore bottom tank to each of the side bottom tanks.

Trawler (fig. 701 and 702)

With this ship, trawling is possible at a depth of 55 fm. (100 m.) at 4 to 5 knots. Radius of action: about 1,250 miles. Fuel oil consumption: 2.55 ton (3 cu. m.) in 24 hr. Gross tonnage: 275. Net tonnage: 126. The trawler's principal dimensions are:

LOA	132.11 ft. (40.25 m.)
LBP	114.83 ft. (35.00 m.)
B	24.94 ft. (7.60 m.)
D	12.47 ft. (3.80 m.)
δ	0.599
β	0.863
φ	0.694
Frame spacing	19.40 in. (500 mm.)
Fuel capacity	16,500 Imp. gal. (74.9 cu. m.)
Fish hold capacity	9,540 cu. ft. (270 cu. m.) 2,700 boxes
Sailing speed	10.75 knots
Trawling speed	4.91 knots
Departure:	
Mean draught (excl. keel)	9.65 ft. (2.94 m.)
Displacement moulded	16.550 cu. ft. (468 cu. m.)

The deck gear consists of: (a) a hydraulic-driven trawl winch, each barrel having 1,000 fm. (1,830 m.) 3 in. (76 mm.) wire rope; (b) a windlass, driven by the trawl winch (with one of the trawl wires); (c) steering gear (hand-hydraulic).

The tripod mainmast is of steel. The fish hold is cork insulated, with cement ceilings.

The metacentric heights (GM) under the various conditions are:

Leaving port	2.13 ft. (646 mm.)
Arriving fishing grounds . .	2.08 ft. (636 mm.)
Leaving fishing grounds . .	2.25 ft. (686 mm.)
Arriving port	2.11 ft. (644 mm.)

The crew quarters aft, under the maindeck, accommodates ten men.

The superstructure extends to the port side, and here there is located the galley with gas stove, a provision storeroom with refrigerator, mess-room, three cabins, washing place with shower bath, two toilets, engine casing and stairs to the crew quarters and the wheelhouse. Aft of the wheelhouse is the combined wireless chartroom and captain's cabin. The crew quarters, cabins and engine room are heated by means of an oil-fired central heating system, the boiler of which is in the engine room.

The main engine develops 750 h.p. at 380 r.p.m., with a reduction gear of 2:1. The main engine has a freshwater cooling pump with a capacity of 10 ton per hr. The auxiliary engines consist of a winch motor of 230 h.p. at 600 r.p.m., an air-cooled auxiliary diesel of 40 h.p. at 1,200 r.p.m., a harbour set of 8 h.p. at 2,000 r.p.m., with a 4 kW generator and 600 cu. ft. (17 cu. m.) per hour compressor, and two generators, each of 22 kW, 220V. All engines have freshwater cooling. Other equipment in the engine room is: one electric pump for deck washing, capacity 23 ton per hour; one electric fuel transfer pump, capacity 4 ton per hour; one bilge pump, capacity 19 ton per hour; one electric spare lubricating oil pump, capacity 3 ton per hour; one compressor, capacity 1,300 cu. ft. (36.8 cu. m.) per hour; one salt-water automatic water pressure system, capacity 33 Imp. gal. (150 l.); one freshwater automatic water pressure system, capacity 33 Imp. gal. (150 l.); one electric separator with heater, for both fuel and lubricating oil.

The hull is welded and the total steel weight is 182 ton.

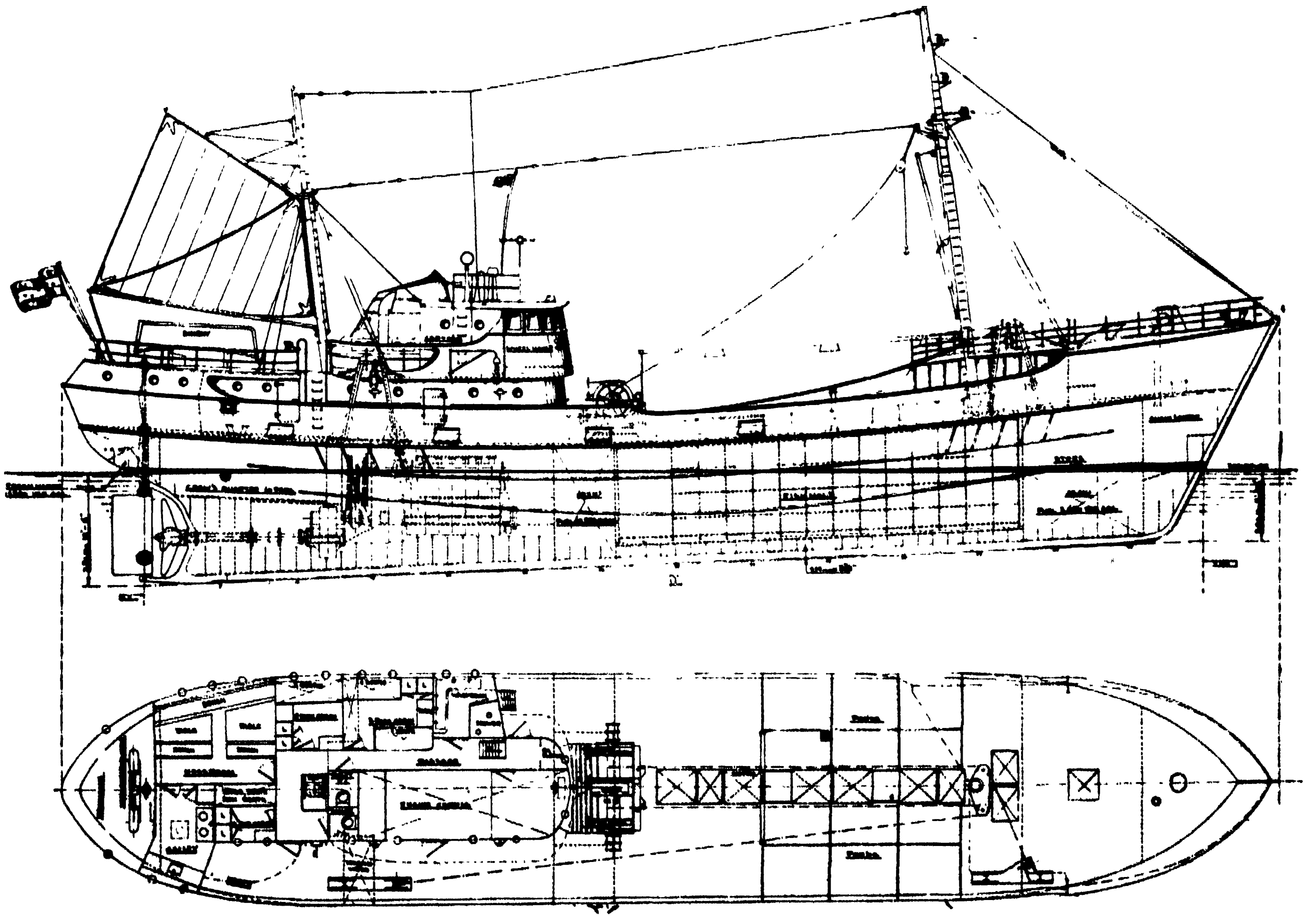


Fig. 702. Dutch trawler—General arrangement

DESIGN STUDIES FOR STERN TRAWLERS

by

HEINZ HEINSOHN

The underlying ideas and design problems concerned in building the stern motor trawlers *Heinrich Meins*, *Carl Kämpf* and *Sagitta* are discussed. These vessels, the first of their size and type, operate with the same gear as was used by conventional trawlers under the same conditions and on the same fishing grounds. Although designed and built by the same yard, they differ, reflecting the opinion of their owners and the uncertainties arising from trying out new ideas which have not been proved in practice.

ÉTUDE DES PLANS DE CHALUTIERS PÊCHANT PAR L'ARRIÈRE

L'auteur examine les idées fondamentales et les problèmes d'établissement des plans, considérés dans la construction des chalutiers à moteur pêchant par l'arrière: *Heinrich Meins*, *Carl Kämpf* et *Sagitta*. Ces navires, les premiers de cette taille et de ce type, travaillent avec le même engin que celui qui est utilisé dans les mêmes conditions et sur les mêmes lieux de pêche par les chalutiers courants. Bien que dessinés et construits par le même chantier, ils diffèrent entre eux, réfléchissant l'opinion de leurs armateurs et les incertitudes provenant de l'essai d'idées nouvelles qui n'ont pas été prouvées pratiquement.

ESTUDIOS DE LOS PROYECTOS DE LOS ARRASTREROS QUE PESCAN POR LA POPA

Se estudian las ideas que han inspirado los motoarrastreros *Heinrich Meins*, *Carl Kämpf* y *Sagitta* y los problemas que se encontraron cuando se proyectaban. Estos barcos, los primeros de su tamaño y tipo, emplean el mismo equipo que los arrastreros corrientes, trabajan en las mismas condiciones y explotan los mismos caladeros. Aunque proyectados y construidos por el mismo astillero, son distintos, reflejando las opiniones de sus armadores y las incertidumbres que presenta el ensayo de ideas nuevas que no se han probado en la práctica.

THE productive time of a trawler, when the trawl is on the bottom, is comparatively short. The steaming time to and from the fishing grounds can only be reduced by higher speed, and it is very expensive. Much time is required for handling the net and if this could be reduced, valuable fishing time would be gained. Hauling is mainly a question of winch power, and shooting depends mainly on the weight of the gear and the ship's speed.

The time and work of bringing gear and catch on to the ship, emptying the net, making repairs, and paying the gear back into the water is reduced by fishing over the stern. Trawl warps are less liable to wear and tear and are led over the stern in a simpler and more symmetrical way. For example, only one gallows roller is used per warp. Heavy manual work is reduced and conditions are made safer for the crew.

The crew are protected against cold and stormy weather by working on the high upper deck while handling the trawl, and are under cover on the 'tween-deck while gutting the fish. There is also less danger of capsizing because of a substantial freeboard and a much larger range of positive stability levers.

The final solution for fishing on distant grounds is thought, in Germany, to be the factory ship. But the first costs and risks involved in factory trawlers of the *Fairtry* and the *Poushkin* size were beyond the financial resources of German trawler owners. They had to restrict themselves in their first venture to ships of a size comparable to the present distant-water trawlers fishing over the side.

Influence of length of gear

It was decided that normal gear should be used, perhaps with small adaptations. When the ships were in operation, improvements or new ideas could be tried and, in fact, nylon for the codend and lengthening pieces have already been introduced with success.

The trawl, when hauled through the narrow stern chute, as shown in fig. 703, is about 183 ft. (56 m.) long. Ideally, it should be brought to the deck in one pull. The length makes this impossible, but it is imperative that the number of pulls be kept to a minimum to save time and labour and to reduce stresses which may occur when strops, beckets, etc., are applied.

Three points are clearly indicated where to apply the pulls: the danlenos or small doors, which are mostly used on German trawlers, the ground tackle and bobbins, and the codend and lengthening piece.

The distance between the upper end of the stern ramp, which is the first safe position where a strop can be applied, and the centre of the drums of the trawl winch should be at least 70 ft. (21.4 m.). This is the length b, 64 ft. (19.6 m.) plus an allowance of 6 ft. (1.8 m.) for the distance of point B to the drums (fig. 703). This is the bare minimum, and it is one of the fundamental measures of the design, although it varies with the size of the trawl. For example, these distances are 97.3 ft. (29.7 m.) for the *Heinrich Meins*, 84.5 ft. (25.8 m.) for the *Carl Kämpf*, and 71 ft. (21.6 m.) for the *Sagitta*.

Manoeuvring of ship during hauling and shooting

Two main decisions were taken:

- The ship's speed must be controlled from the bridge by the skipper himself
- One bridge must be sufficient, the stern being easily observed from it. (This saved costs and avoided handing over command from one bridge to the other, which would have involved more crew)

Fish holds and fish landing

All three trawlers were intended mainly to land iced fish, so the fish holds could be of conventional type with pounds and shelves. A refrigerated hold (−18°F or −28°C) for frozen products was also arranged on the *Heinrich Meins* and the *Sagitta*.

As the main catch would be iced fish, unloading had to be done in one night by normal methods. Although the common small hatches used on side trawlers were sufficient, it was necessary, for quick unloading, to have only a small distance from the aftermost pound to the aftermost hatch; therefore, most of the main deck over the hold had to be free from superstructures. When quick unloading is not necessary, as with frozen cargo, obstructions over the hold can be accepted.

A shaft alley in the fish hold was eliminated because it would interfere with loading and unloading and take up valuable space.

Transport of fish from stern to hold

On all three ships the catch is fed from the codend direct to the working deck. At first it was intended to work with a double codend, so two hatches were provided aft, leaving enough space between them for the net. The full codends were to be lifted vertically over the two hatches to release the fish directly to the working deck. The passage from the shelter deck to the main deck was rounded, started nearly vertical at the shelter deck and then sloped forward into the main deck, an arrangement influenced by the location of the fish-meal plant.

Later, a new method was adopted with a flap just forward of the upper radius of the stern ramp. After untying the codend knot with the full net still lying on the deck just forward of the hatch, many fish flow out, thus relieving the pressure when the net is lifted between the samson posts. This arrangement is very efficient and only redfish are difficult to get out of the codend.

Many different flaps with different drives were designed until a strong, inexpensive one was developed. This flap swings on three bearings aft and is counterbalanced, and is operated by a double-acting cylinder working with compressed air which is drawn from a compressor in the engine room, no extra compressor being necessary. The joint with the deck can be steam-heated to prevent freezing. Conveyor belts carry both fish and offal, and they should preferably work in both directions.

Fish-meal plant

A fish-meal plant, with a maximum capacity of 20 ton of raw material per day, was installed for processing offal and surplus fish. If bad weather holds up fishing, the catch already made is put through the plant, so that a fresh start can be made, because iced fish should be landed within 16 days of being caught. The plant consists of steriliser, press, steam-heated dryers, and accessories. The various items can be arranged in different ways to suit the available space.

In addition to the complement of about 26 men for fresh fish trips, space had to be provided for salters on salting trips and for factory workers. As there were no figures available for the number of factory workers required,

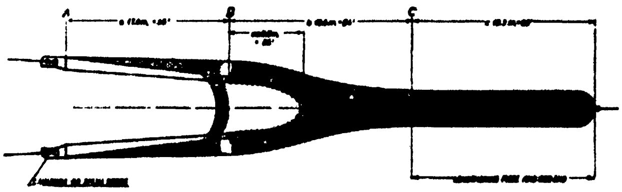


Fig. 703. Shape of trawl when hauling

the available space was used to accommodate as many as possible. The *Carl Kämpf*, with no processing plant, has the smallest complement (38 men); the *Heinrich Meins*, with the biggest plant, has 46 men. The *Sagitta* has accommodation for 43.

Because drainage could not be provided above the fish holds, the galley and sanitary rooms were kept clear of them. Officers and crews have separate quarters away from the working spaces and both have easy access to the upper and working decks.

Lifesaving appliances

Inflatable liferafts and a rubber boat were installed instead of lifeboats, by special permission of the authorities. Since then experience has demonstrated the superiority of this lifesaving equipment over the conventional lifeboat. It is now compulsory for German trawlers to carry a small liferaft for four persons, which is very useful, handy and quickly available.

Classification and freeboard

Classification society regulations for trawlers do not apply to those fishing over the stern, so the rules for shelter deck vessels were mainly used. Reasonable amendments were agreed with the Germanischer Lloyd. The shell plating of the transom stern is strengthened (0.55 in. or 14 mm.) and the stern ramp was increased in thickness (0.47 in. or 12 mm.). This has been found sufficient. The upper rounding of the stern ramp to the deck level was provided with doublings which can be easily replaced when chafed by the trawl warps. Strengthening for navigation in ice was done to the normal requirements of the classification society.

The minimum freeboard regulations for shelter deck vessels were adhered to, the height of coamings and sills of doors being increased considerably where possible. Sills to entrance doors on the upper deck, as well as from the working space to cabins on the main deck, are 2 ft. (610 mm.); hatch coamings for the fish hold on the main deck are 9 in. (230 mm.) and 2 ft. (610 mm.) on the upper deck. Scuppers from the working space on the main deck are of the non-return type, with a second independent watertight cover in case the flap should become choked by offal. Because of the low freeboard in loaded condition, scuppers are provided draining into special tanks which can be pumped out. Therefore the scuppers to outboard can be completely closed in heavy storms. The fish-meal plant also drains into this tank.

Choice of main engines

As the ships were mainly for iced fish, the sailing speeds had to be high and the trawling qualities had to be good for fishing in deep water and rough sea. Some convenient and not too expensive form of emergency drive was also wanted, in case of a breakdown of the main engine, as well as a shaft generator for the electric system.

The trawl winch drive also had to be considered. This should not, if costs allowed, be operated by only one prime mover. For better efficiency and lower maintenance costs all power, including auxiliaries, should be provided by the main engine, the auxiliary diesels acting as booster engines and a reserve.

Steam machinery was out of the question because of its high fuel consumption, weight and space requirements. Three possibilities existed for diesel propulsion: direct drive, geared drive, and diesel-electric, the former two only in conjunction with controllable-pitch propellers.

From the purely technical point of view, the diesel-electric system appears to be ideal and its flexibility is unchallenged, although the operation is not as simple as is sometimes believed.

Electric current for propulsion and the ship's mains must be taken from different generators which, of course, can be driven by one prime mover. The trawl winch drive, whether of the Ward Leonard system or similar or the constant current system, adds to the complications. For real flexibility, a substantial switchboard with many interlocked circuit-breaker safety devices, etc., is necessary, and this requires space. The heat generated has to be removed by big fans without bringing too much moisture into the engine room. Highly qualified engineers should run the plant. With these conditions fulfilled the system is very safe, and requires little or no maintenance. Real troubles with diesel-electric plants usually originate, to the author's knowledge, in the diesel engines. Diesel-electric propulsion is very expensive if used with prime movers of moderate load and r.p.m., although costs can be reduced to some extent by the use of modern supercharged high-speed diesels of advanced design.

Savings in space and weight are gained only with high-speed diesels, but such engines raise the centre of gravity, which means either ballast (loss of the weight saved) or more beam, which leads to other problems.

An arrangement providing a main compartment for the prime movers and generators, auxiliaries, etc., and a propeller motor compartment, makes diesel-electric drive very attractive in special cases. But it is a common error to believe that the propeller motor can be near the propeller. Unfortunately, the electric motor, even if geared to reduced size and first costs, has to be placed at a considerable distance from the propeller because of the fine lines of the afterbody.

"Father and E son" propulsion

The "father and E son" propulsion was developed for owners who want one slow-running main engine moderately supercharged and substantially constructed. It is a development of the well-known "father and son" system, the main characteristic of which is that the main diesel engine ("father") and the auxiliary diesel ("son") driving the winch generator, work together through a common gear with couplings on the single shaft. The power of the diesel winch generator can therefore also be used for propulsion. The drawback is that the gearbox requires much space, especially in breadth, and consequently cannot be placed so far aft as a single motor. With the "father and E son" system, the winch generator set does not work directly on the gear but through a separate electric motor, the "E (electric) son"; so it is possible to place the winch generator in any convenient position and the "father" engine works directly without any gear on the shaft. The gear of the "E son", the size of which is governed only by the output of the "E son" and not by that of the "father" engine, is of moderate size and very narrow. Therefore the main engine can be placed further aft.

Of course, there are merits only as long as a direct working "father" engine is used, which was the case in the *Carl Kämpf*. Here also, the gearing of the "E son" could be dispensed with by having a big motor-generator directly on the shaft line, which works either as the trawl winch generator when fishing, as the booster motor when steaming, or as reserve drive if the main engine breaks down after uncoupling the "father" engine.

There are two auxiliary diesel generator sets, a big one for the trawl winch, or the booster motor in the shaft-line or the ship's mains, and a small set for the ship's mains.

This system combines some of the flexibility of the diesel-electric system with the robustness of the slow-running main engine. In first costs, it comes between the diesel-electric system and the simple reversible diesel with an independent winch generator set.

Gas turbine propulsion

A gas turbine, with Pescara free piston gasifiers, a type now becoming increasingly popular, was installed in the *Sagitta*. Although its specific fuel consumption is higher than that of diesels, a cheaper oil of lower quality (a somewhat improved Bunker C oil) is used. This results in considerable savings in the fuel bill. And as there are few moving parts to wear away, and these are comparatively cheap and easy to renew, it is hoped that maintenance costs will be very low. The two gasifiers are of standard design with a maximum of 1,000 h.p. each at the turbine coupling, giving ample reserve of power for bad weather. The whole plant normally has an output of about 1,500 h.p., which is sufficient for a speed of about 14 knots. The plant can also run with one gasifier only, thus giving the necessary reserve. The turbine itself is very safe, and has a controllable-pitch, non-reversible propeller. A generator for the ship's mains, as well as for the pumps for the hydraulic winch drive, is driven from the intermediate shaft of the articulated double reduction gear. For harbour duties these pumps are driven from the generator which works as a motor, the power coming from two diesel generator harbour sets.

Compared with "father and E son" propulsion of the same output, this system results in a saving in headroom but not in space. There is some saving in weight and the centre of gravity is low.

Voith-Schneider propulsion

For the *Heinrich Meins*, which was first planned for diesel-electric drive, the Voith-Schneider system seemed to be ideal for these reasons:

- Only one engine room, which reduced watch keeping and maintenance
- No propellers at the stern, therefore no risk of them fouling the net
- Superior steering qualities

Against these advantages was the fact that there was no real experience with Voith-Schneider propellers in the bow of ships of the size of the *Heinrich Meins*, although there was experience with smaller craft, especially tugs, which applied to trawlers. The first costs were favourable compared with diesel-electric and, after extensive model tests (also in an artificial seaway), it was decided to take the risk.

Propeller arrangements and diameters

Although fishing over the stern seems likely to foul the propeller, this is more apt to occur in fishing over the side, because a stern trawler is always moving forward during hauling. The only danger is that the motor stalls when going dead slow, and does not re-start before the vessel drifts backwards over the trawl warps. It is overcome by a controllable-pitch propeller or diesel-electric drive. Also a large distance between the propeller and ramp reduces the risk. The maximum draught aft could not exceed about 17 ft. (5.2 m.) as the vessels had to pass through the lock at Bremerhaven at low tide. This limited the maximum diameter of the propeller to about 9.5 ft. (2.9 m.), a satisfactory figure, as controllable-pitch propellers of large diameters are becoming quite expensive. Furthermore, on the *Carl Kämpf*, gearing for the main diesel, which ran at 250 r.p.m., was not necessary when the propeller diameter was reduced to 8.5 ft. (2.6 m.). Model tests with a rudder nozzle showed that, in smooth water, it had no measurable effect on the trial speed. This meant that, apart from trawling where a considerable improvement in pull was to be gained, especially in rough water, the nozzle would be a paying proposition by saving oil fuel or by improving the speed. The nozzle replaces the rudder and provides very good steering power even when turned only a few degrees. Furthermore, the propeller is better protected against the trawl warps, although this was believed to be of minor importance. The *Carl Kämpf* was, therefore, fitted with a nozzle rudder. The *Sagitta*, with its 9.17 ft. (2.8 m.) propeller, did not need a nozzle. The Voith-Schneider propellers in the forebody were made as large as possible for the *Heinrich Meins*. Larger diameters would have meant bringing them further aft with corresponding changes of the forebody. This would have spoiled the general arrangement and brought the fish hold too far aft.

Diesel-electric propulsion has an electric efficiency of about 84 per cent., but about 5 per cent. could be gained by using a fixed-bladed propeller, compared with a controllable-pitch propeller of 8.5 ft. (2.6 m.) diameter and 250 r.p.m. It could be further improved by more than 10 per cent. by the use of a large slow running propeller, but this was impossible. Such possible improvements should always be kept in mind when comparing electric propulsion systems with smaller propellers of high r.p.m. The Voith-Schneider propeller in the forebody, besides having a high specific load, could not make use of the wake as does the ordinary aft propeller, and it also had friction drag. However, compared with the diesel-electric drive, the disadvantages were more than offset because the system avoided electrical losses.

The total efficiency of the four propulsion systems does not differ very much, but slightly favours the "father and E son" as long as only the "father" engine is working. Therefore, the choice of the systems was based on their other merits.

Lines and stability

Experience shows that the stability of a trawler should not be too high, otherwise it will be "stiff". A long range of positive stability levers is more important for safety than a great initial stability, and this is typical of a shelter deck ship which has ample freeboard, compared with that of a single deck trawler. The most dangerous condition, apart from icing up, would be in harbour after landing the catch, when the ship is empty and there is some ice on the upper deck, with many pound boards put there for cleaning. The transom stern, which is necessary for a stern trawler, improves stability for a ship which trims

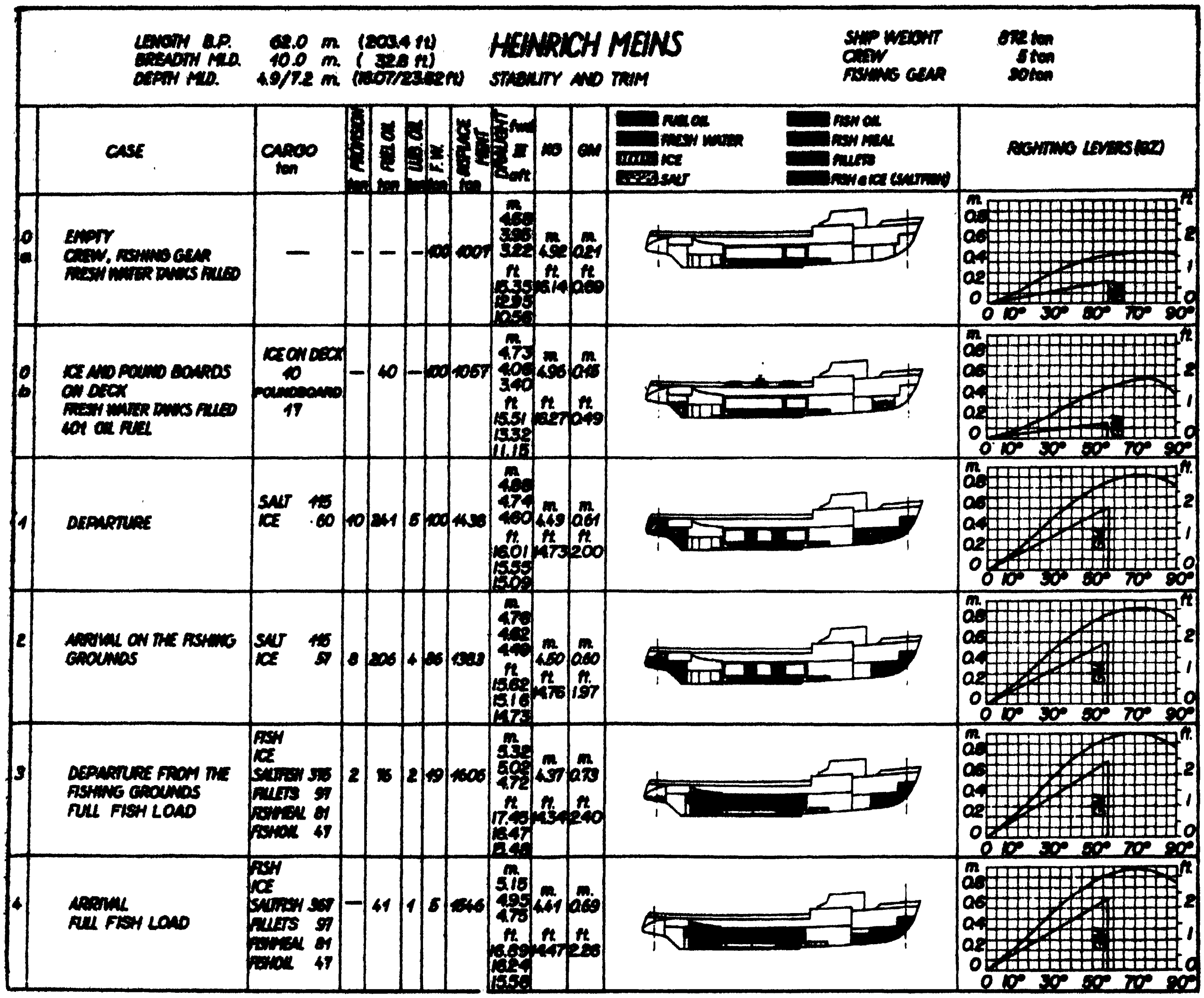


Fig. 704. Heinrich Meins, *stability and trim*

considerably aft in light condition. It also improves stability when the boat is loaded.

Therefore the lines of a successful type of side trawler could be used for the *Carl Kämpf*. Only a new afterbody had to be designed, the main dimensions (LBP, beam and draught) being the same. Stern trawlers also have comparatively small superstructures, and the centre of gravity was raised only about 1.4 ft. (0.43 m.).

The type with engine forward, and, consequently, head trim in light condition, is far more of a problem. It benefits from the transom stern in loaded condition but not much in light condition. This type, therefore, must have more beam. In the case of the *Heinrich Meins*, because of the special form of the forebody for the Voith-Schneider propellers and the transom stern, the metacentre was exceptionally high, compared with a normal form, and her beam of only 32.8 ft. (10 m.) is sufficient.

All three ships roll gently and ship little water. For further stability information, see fig. 704, 705 and 706.

Model tests showed that, for the indicated range of speed, the transom stern is at a slight disadvantage compared with the cruiser stern, as shown in fig. 707, but there seems to be some room for improvement. Only the EHP can be compared. The SHP's include the higher propeller efficiency of a slow running large diameter fixed-blade propeller, the lower efficiency of a controllable-pitch propeller with smaller diameter and higher r.p.m. The lines of the *Heinrich Meins* were consideraby improved after additional model testing. The EHP is exceptionally good but the SHP is not, due to the propeller efficiency.

Trawl winches

The trawl winches are basically the same as on ordinary trawlers. It was thought to be practical to have another two small drums for net hauling. This would avoid having too many wires on the warping heads. It was also thought to be useful to have some net-hauling reserve in the event of a method being developed for the use of three or four warps for pelagic fishing. However, these small barrels are not necessary and, for economy's sake, were not fitted on the *Sagitta*. Instead, a second shaft with two further warping heads was installed, as in most side trawlers.

In the *Carl Kämpf* and *Sagitta*, the trawlers with engines aft, there were difficulties with the winch drive. The winch drive had to be arranged as far forward as possible and then interfered with the engine casing.

The hydraulic drive is ideal for saving space at the trawl winch. Hydraulic motors are so small that it is possible to arrange them on the winch bedplate at very little cost in space. The drawbacks are that hydraulic pumps in the engine room may require more space than electric generators (depending on the system employed) and that the hydraulic system cannot serve, except at extra cost and complications, the different purposes met by the "father and E son" system. Furthermore, the hydraulic system can be noisy and the ratio between maximum and slowest speed for full power is smaller than that of an electric motor, so the gear ratio between pump and trawl winch shaft has to be carefully chosen.

SAGITTA
STABILITY AND TRIM

LENGTH B.P. 189.0 ft. (57.60 m.)
BREADTH MLD. 31.5 ft. (9.60 m.)
DEPTH MLD. 16.1/23.5 ft. (4.90/7.15 m.)

SHIP WEIGHT 805 ton
CREW 3 ton
FISHING GEAR 30 ton

	CASE	PROVISIONS ton	FRESH W. ton	LUB. OIL ton	ICE ton	FISH OIL ton	FILLET ton	FISH & ICE ton	FISHMEAL ton	DISPLACEMENT ton	DRAUGHT fwd / aft	KG	GM
0 a	EMPTY CREW FISHING GEAR	—	—	—	—	—	—	—	—	838	m. 1.83 / 3.90; ft. 5.97 / 12.80	m. 4.50; ft. 14.76	m. 0.41; ft. 1.35
0 b	AS ABOVE ICE AND POUND BOARDS ON DECK	—	—	7	ON DECK 10	—	—	—	—	855	m. 1.92 / 3.90; ft. 6.30 / 12.80	m. 4.63; ft. 15.19	m. 0.26; ft. 0.85
0 c	AS ABOVE FRESHWATER TANKS FILLED BUNKERS NEARLY EMPTY	1	85	71	ON DECK 10	—	—	—	—	1005	m. 2.45 / 4.11; ft. 8.37 / 13.48	m. 4.14; ft. 13.58	m. 0.64; ft. 2.10
1	DEPARTURE	5	85	266	175	—	—	—	—	1369	m. 4.08 / 4.33; ft. 13.39 / 14.21	m. 3.85; ft. 12.63	m. 0.84; ft. 2.76
2	ARRIVAL ON THE FISHING GROUNDS	4	75	223	155	—	—	—	—	1295	m. 3.98 / 4.14; ft. 13.06 / 13.58	m. 3.86; ft. 12.66	m. 0.80; ft. 2.62
3 a	DEPARTURE FROM THE FISHING GROUNDS FULL FISH LOAD	2	35	113	—	33	35	355	35	1446	m. 4.14 / 4.56; ft. 13.58 / 14.96	m. 3.98; ft. 13.06	m. 0.75; ft. 2.46
4 a	ARRIVAL FULL FISH LOAD	1	15	71	—	33	35	330	35	1358	m. 4.06 / 4.31; ft. 13.32 / 14.14	m. 3.98; ft. 13.06	m. 0.71; ft. 2.33

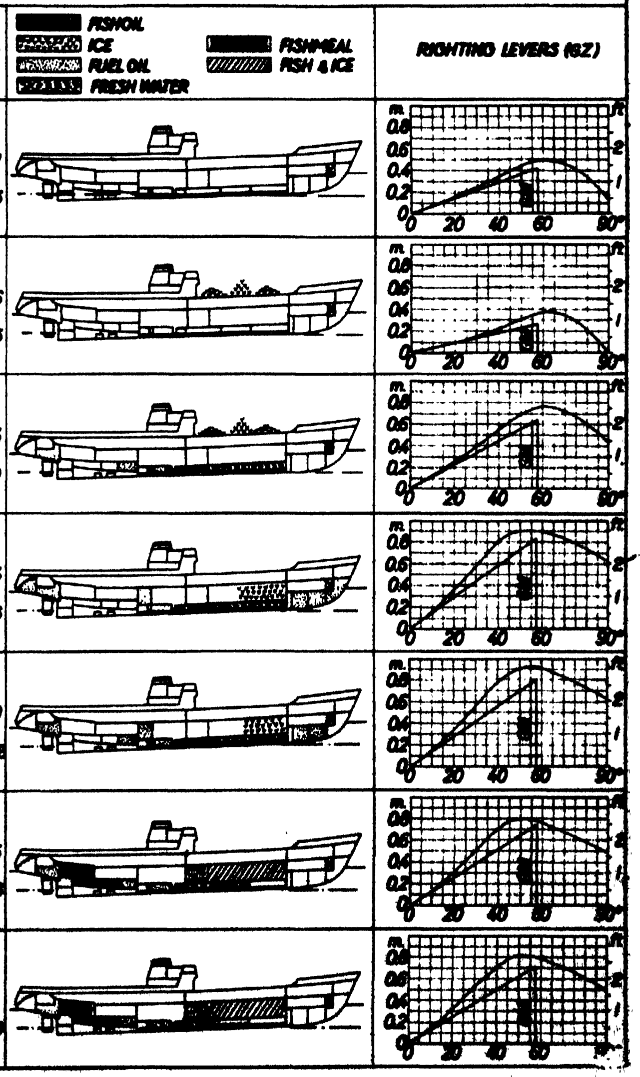
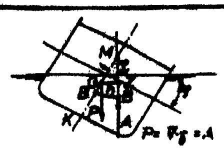


Fig. 705. **Sagitta,** *stability and trim*

LENGTH B.P. 55.20 m. 181.1 ft.
BREADTH MLD. 9.60 m. 31.5 ft.
DEPTH UPPER DECK MLD. 7.16 m. 23.5 ft.
DEPTH 2nd DECK MLD. 4.90 m. 16.1 ft.

CARL KÄMPF
STABILITY AND TRIM



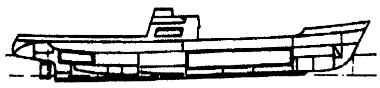
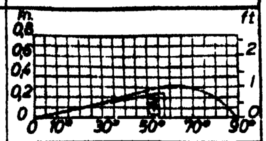
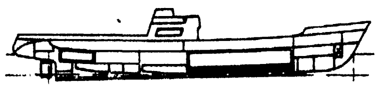
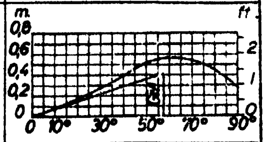
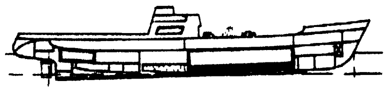
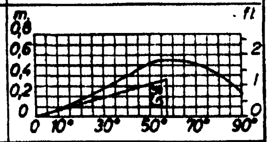
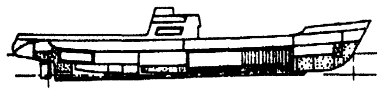
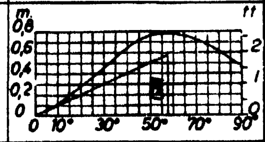
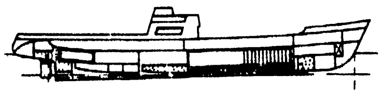
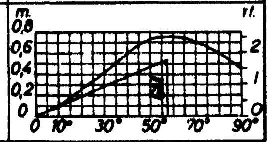
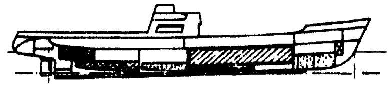
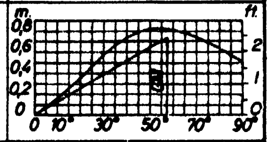
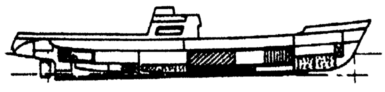
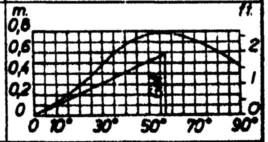
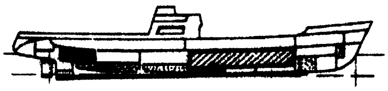
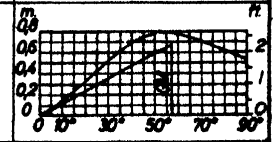
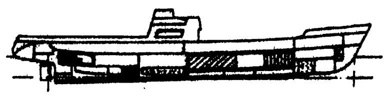
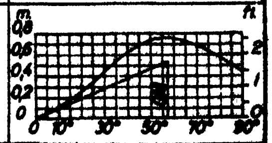
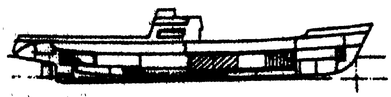
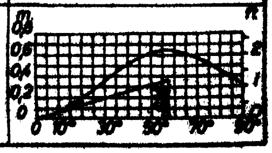
	CASE	CARGO ton	CREW PROV ton	FUEL OIL ton	LUB.OIL ton	F.W. ton		DISPLACEMENT ton	DRAUGHT	KG	GM	FISH & ICE / ICE / FUEL OIL / FISHMEAL / FISHOIL / FRESHWATER	RIGHTING LEVERS (GZ)
0a	EMPTY (CREW, FISHING GEAR)		5					810	m. 3.14 ft. 10.30	m. 4.732 ft. 15.52	m. 0.256 ft. 0.84		
0b	AS ABOVE FRESH WATER TANKS FILLED		5			70		880	m. 3.32 ft. 10.89	m. 4.408 ft. 14.46	m. 0.407 ft. 1.34		
0c	AS ABOVE ICE AND POUND BOARDS ON UPPER DECK 43 ton FUEL OIL	ICE ON DECK: 10	5	43		70		933	m. 3.45 ft. 11.32	m. 4.421 ft. 14.50	m. 0.371 ft. 1.22		
1	DEPARTURE	ICE: 140	10	145	6	70		1176	m. 4.02 ft. 13.19	m. 4.088 ft. 13.41	m. 0.582 ft. 1.91		
2	ARRIVAL AT THE FISHING GROUNDS	ICE: 128	9	115	5	60		1122	m. 3.90 ft. 12.80	m 4.140 ft. 13.58	m. 0.54 ft. 1.77		
3a	DEPARTURE FROM THE FISHING GROUNDS	ICE: 104 FISH: 325 FISHMEAL: 43 FISHOIL: 30	7	70	3	40		1427	m. 4.57 ft. 14.99	m. 3.984 ft 13.07	m. 0.742 ft 2.43		
3b	DEPARTURE FROM THE FISHING GROUNDS ONLY HALF FISH LOAD BUNKERS AS 3a	ICE: 104 FISH: 162 FISHMEAL: 22 FISHOIL: 15	7	70	3	40		1228	m. 4.14 ft. 13.58	m. 4.075 ft. 13.37	m. 0.595 ft. 1.95		
4a	ARRIVAL FULL FISH LOAD	ICE: 92 FISH: 320 FISHMEAL: 43 FISHOIL 30	6	45	2	30		1373	m. 4.45 ft. 14.60	m. 4.043 ft. 13.26	m. 0.687 ft. 2.25		
4b	ARRIVAL HALF FISH LOAD BUNKERS AS 4a	ICE: 104 FISH: 160 FISHMEAL: 22 FISHOIL: 15	6	45	2	30		1189	m. 4.05 ft. 13.29	m. 4.132 ft. 13.55	m 0.540 ft. 1.77		
4c	ARRIVAL HALF FISH LOAD BUNKERS NEARLY EMPTY	ICE: 80 FISH: 160 FISHMEAL: 22 FISHOIL: 15	5	15	1	10		1083	m. 3.83 ft. 12.57	m. 4.286 ft. 14.06	m. 0.392 ft. 1.29		

Fig. 706. **Carl Kämpf,** *stability and trim*

The performance depends in part on the way skippers handle their ships during hauling. Most of them believe that the ship should go "full speed ahead" at the start of a haul so as to lift the net quickly from the bottom. With the high engine powers of modern trawlers, this practice requires a very high winch torque. If the hydraulic motor is adequately geared for this, then, in the second half of the haul, the necessary high speed at less torque of the winch will be too low.

The electromotor is more flexible and errors in selection of gear ratio are, to a certain extent, simple to correct.

Heinrich Meins

This design is the oldest of those under discussion. First, a suitable way for handling the gear was worked out with models. A conclusion was that the trawl winch had to be placed as far forward as possible. Therefore it was decided to place the engine room forward, the fish hold midships and the fish-meal plant aft. Because the engine room was forward, a diesel-electric drive was chosen. The first general arrangement plans indicated considerable loss of space aft where the propeller motor room was sited. However, as the fish-meal plant, which had to be above this room, could be moved one deck higher up, this was not of great importance. In case more fish were caught than could be immediately gutted, ample storage space was provided in the 'tween deck next to the fish-meal plant. This general arrangement gave a clear and simple division between the crew's accommodation forward with the engine room below, working space midships with the fish hold below, and gutting space aft with the fish-meal plant below.

It was thought that this arrangement would ensure very easy movement of the fish into the holds. However, after it was decided to install a processing plant when the vessel was already on the stocks, it was discovered that the transport problem was not so simple, the gutted fish had to be sorted and then moved forward either into the processing plant or through the hatches into the hold. This became difficult when the aftermost pounds had been filled and the foremost hatches had to be used. Both sides of the working deck were blocked by the processing plant and manual transport in baskets, as on ordinary trawlers, was impossible. The difficulties were eventually overcome by using conveyor belts which had, in any case, to be installed for the processing plant. As a result, the work of the crew is easier and quicker, thus improving productivity, and the conveyor has proved to be a real asset.

The processing plant was arranged in two sections, one on the starboard side to deal with ungutted redfish, consisting of a filleting machine with two de-skinning machines, and the other on the port side to deal with gutted whitefish, consisting of a beheading machine, filleting machine and two de-skinning machines. The fillets drop from the de-skinning machine into trays which are part of the tables where the fillets are packed before they are frozen by a horizontal plate freezer at the rate of 8 ton per day working with Freon 22 and direct evaporation. For further details see fig. 708 and 709.

Carl Kämpf

Studies were made to develop a design which would cost little more than an ordinary trawler. Diesel-electric propulsion was too expensive and the position of the engine right aft was impossible because a central engine casing would interfere with the trawl winch. The vessel had too little beam for casings on each side to give enough space for pulling the net through. On bigger trawlers (for example, the large trawlers fishing off Newfoundland for cod) this arrangement would be possible, and would be similar to the arrangement in a whale factory ship.

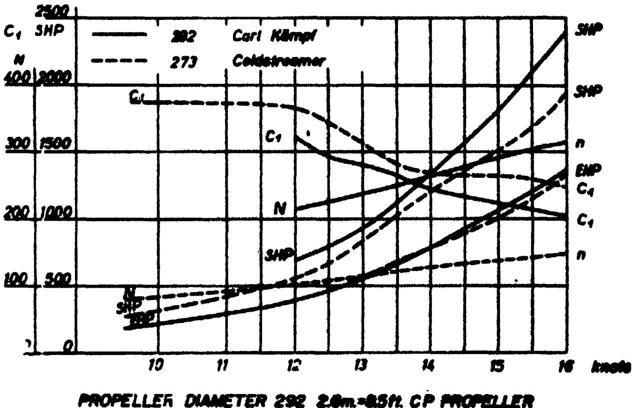


Fig. 707. Comparison of resistance curves of stern trawler (Carl Kämpf) *and side trawler* (Coldstreamer). *Lines of* Coldstreamer *(ordinary trawler with cruiser stern) amended only by a transom stern for* Carl Kämpf. *Same dimensions and nearly same displacement*

By having the fish-meal plant and hold aft of the engine room, it seemed possible to move the trawl winch far enough forward to allow sufficient space for pulling the net onto the deck. Length was gained by making the ramp steeper and by developing the flap for emptying the codend. The narrow but high fish-meal plant of previous trawlers, including the *Heinrich Meins*, had to be modified.

The bridge front was moved as far forward as possible, the skipper's accommodation and the wireless room were placed on the shelter deck, and a very narrow chart room was made a part of the funnel casing. Ordinary lifeboats in luffing type davits were provided, but the space between them and the funnel casing was just sufficient to allow a view aft from the wheelhouse. Unfortunately, the electric motor of the trawl winch had to be moved about 3 ft. (0.9 m.) to starboard from midships and be equipped with small drums on the port side.

The arrangement in the 'tweendeck was very satisfactory, as the fish are carried to the hold by conveyors in a straight flow, which saves labour. A rotary drum type of fish washing machine, about 2 ft. (0.6 m.) internal diameter and 20 ft. (6.1 m.) long, was installed in the

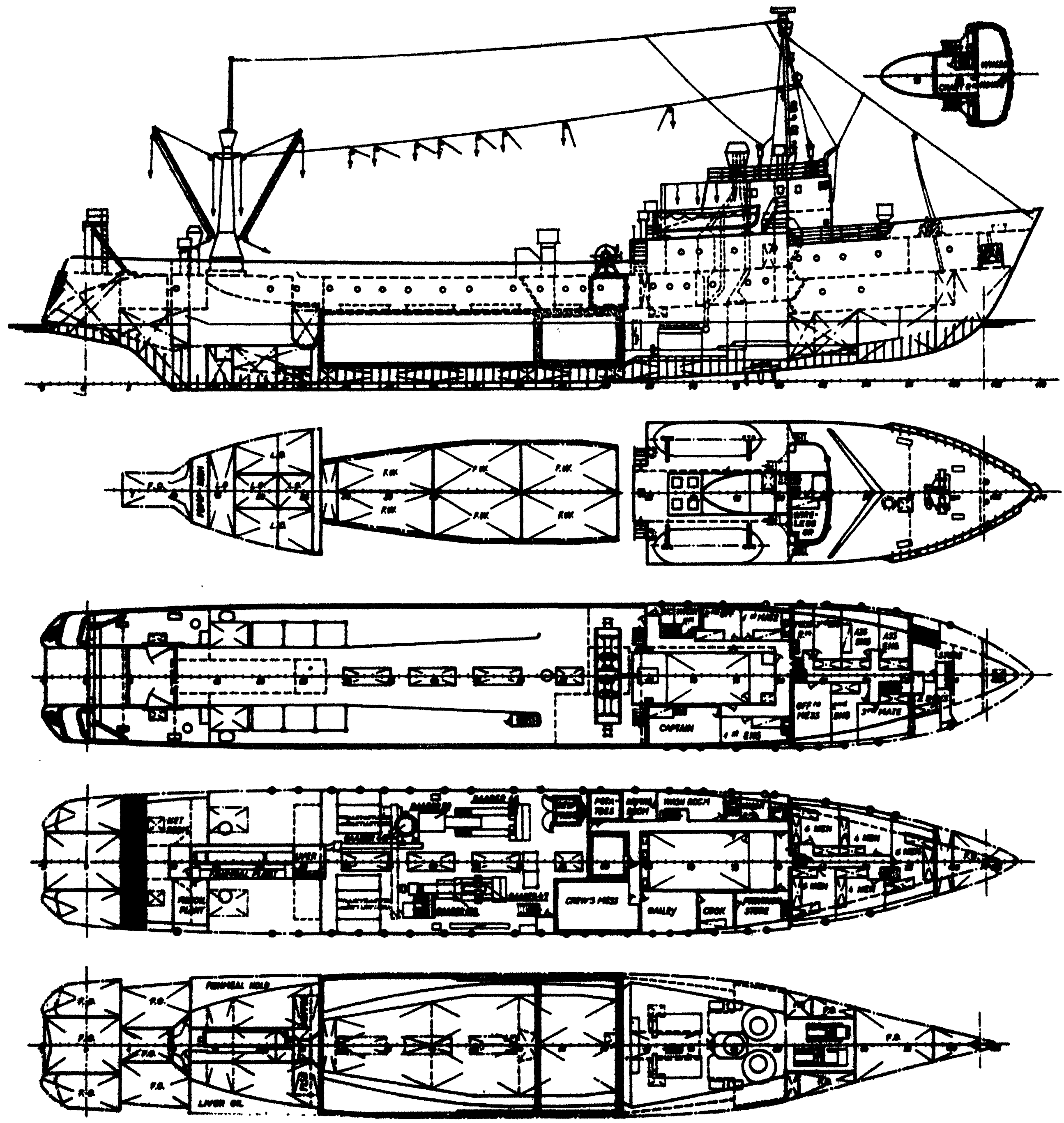


Fig. 708. Heinrich Meins

conveyor flow. A pipe in the upper part of the drum sprays the fish as they are moved forward by a small worm fastened to the drum. Gutted fish are carried by conveyor into the fish hold, being drawn off at the hatches through removable slides. There are funnels with adjustable chutes at the hatches to feed the fish into the pounds.

It was felt, however, that a length of 59 ft. (18 m.) from the stern chute to the trawl winch was too short, so the winch was placed forward of the engine casing, behind the aftermost hatch, with the electric motor aft. This was possible because the warp drums were distant from one another to allow an unobstructed run to the gallow rollers aft. Sheaves had to be provided for the small drum. The engine casing is no hindrance because the net bosom leaves enough free space midships. Indeed, the casing prevents the bosom and the heavy bobbin gear from swinging from side to side when the vessel is rolling. But the view from the winch to the stern is not very good, only just sufficient—a disadvantage which had to be accepted.

The captain's quarters and the wireless room had to be placed behind the wheelhouse above the trawl winch, which is under cover and protected from the sea. Small trolleys, fitted to strong webs welded to the underside of the bridge deck, are used to lift heavy parts of the winch when repairs have to be done. One drawback is that a small fishing bridge at the rear end of the deckhouse had to be provided. It was equipped with levers for manoeuvring the controllable-pitch propeller. A voice pipe leads to the helmsman on the front bridge. The lifeboats had to be replaced by a rubber boat and inflatable liferafts. For further details, see the general and engine room arrangements plan in fig. 711, 712 and 713.

Sagitta

This vessel is basically an improved *Carl Kämpf* and a small processing plant was included in the design from the beginning. The required space for this plant, as well as for the more powerful propulsion machinery, made it necessary to lengthen the hull midships by four frames.

The greater length of the engine room and the decision to unload the refrigerated hold through a side port, made it possible to place the trawl winch behind the engine casing, the length from the trawl winch to the stern chute of 71 ft. (21.6 m.) long being just sufficient. However, an hydraulic winch drive had to be used for the first time in Germany for trawl winches of this power. The experience with smaller winches of 125 h.p. on combined drifter-trawlers had been good, and by doubling up the hydraulic system the necessary power was obtained. At the same time, ample reserve was provided as each system was independent.

The refrigerating machinery and processing plant were located on the starboard side midships and on top of the fish hold on the 'tweendeck. The plant consisted of a beheading machine on the working deck aft, besides a

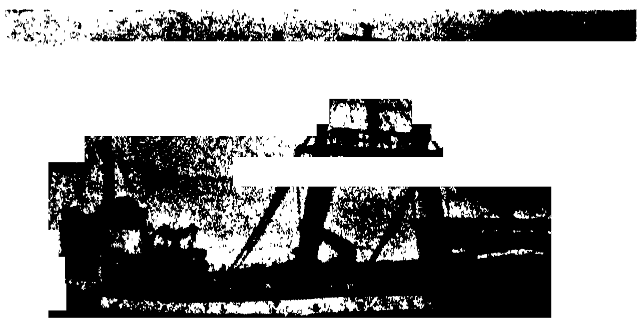


Fig. 709. **Heinrich Meins**

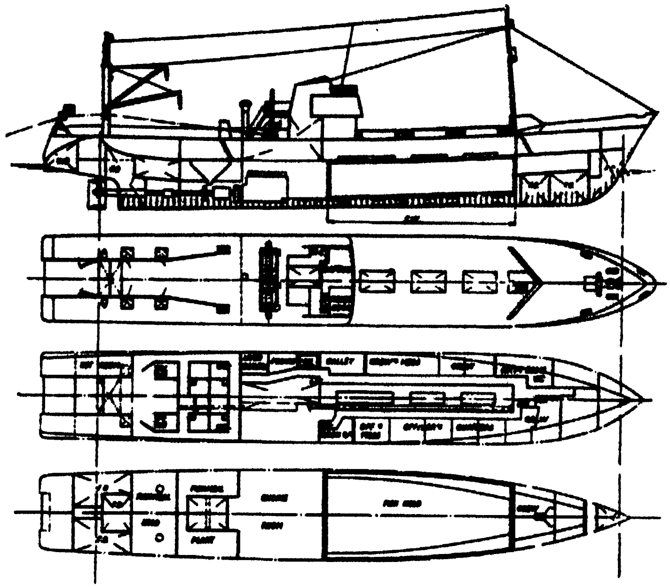


Fig. 710. Carl Kämpf, *first design*

funnel to the offal hopper, a filleting machine, a deskinning machine and a small freezer of the same type as in *Heinrich Meins*. The filleting machine was placed forward to process fish already stowed in the fish hold because the capacity of the plant was too small to process a normal catch immediately. It was planned to stow the catch first and always to fillet the oldest fish so as to lengthen the trip.

There were no difficulties in providing accommodation for the crew. The position of the trawl winch behind the engine casing made it possible to have a good view to the stern from the bridge. Fig. 714 and 715 show the general and engine room arrangements. Fig. 716 shows the vessel ready for fishing.

Performance

The main particulars of the stern trawlers are given in table 160. Shooting and hauling the trawls worked far better than had been anticipated, as both skippers and crew quickly gained experience in the new technique. A main improvement, developed independently on the first two trawlers, was to apply a "third" and, if necessary, more pulls from a tackle suspended more or less in line with the slope of the stern chute. This considerably eased the pressure on the codend and lengthening piece when they were hauled over the upper radius of the stern chute. On the *Heinrich Meins*, with a longer distance from the stern chute to the trawl winch and, consequently, a shorter "third pull", the forward derrick on the samson post aft was used. On the *Carl Kämpf* and, later, the *Sagitta*, short pole masts, stayed to the ship's side and the funnel, were erected as far forward as possible, i.e. directly behind the rubber boat platforms, the distances to the stern flap being just sufficient to avoid a "fourth pull". This improvement prevented the net from bursting open with a big catch when being pulled through the

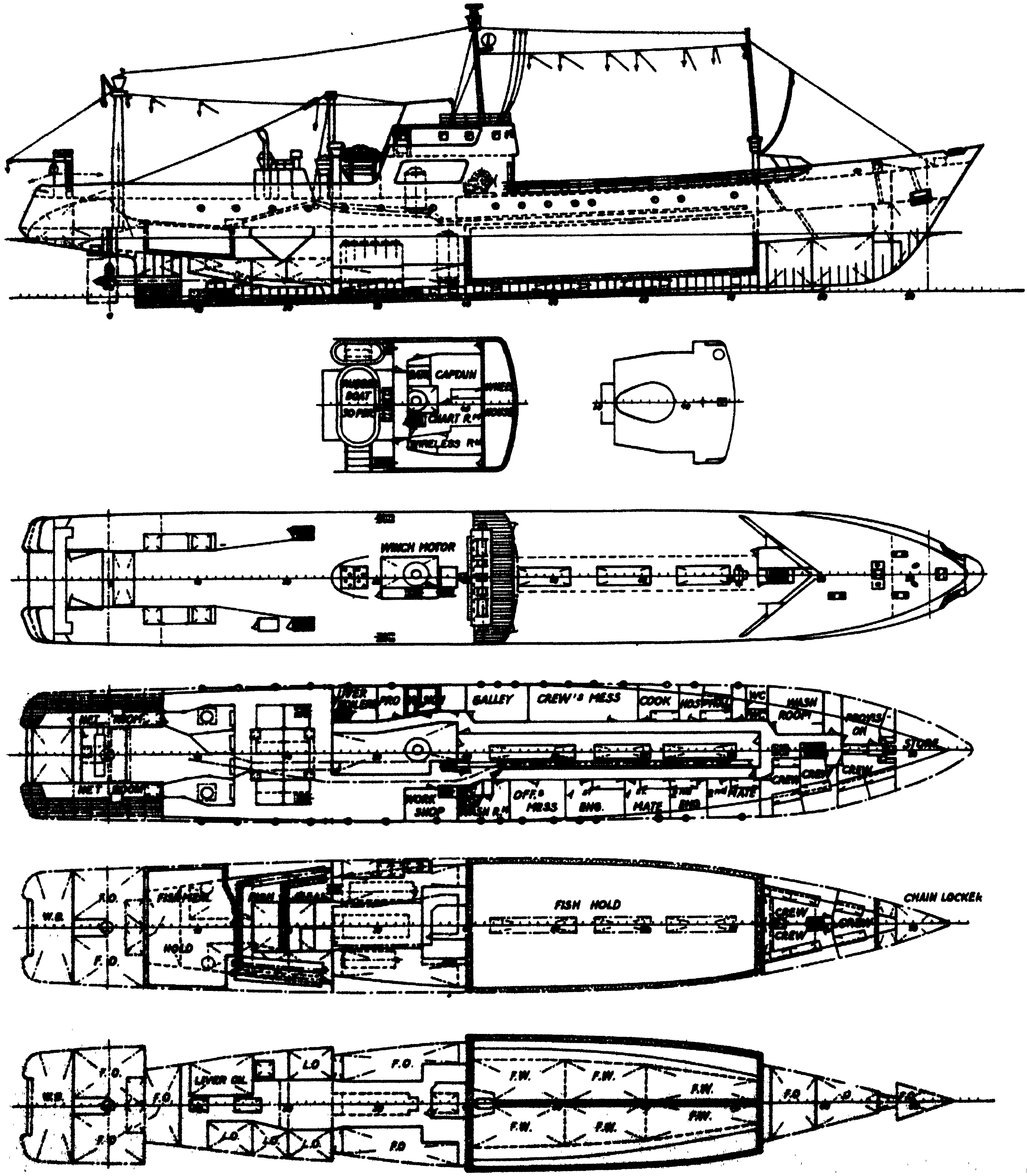


Fig. 711. Carl Kämpf, *as built*

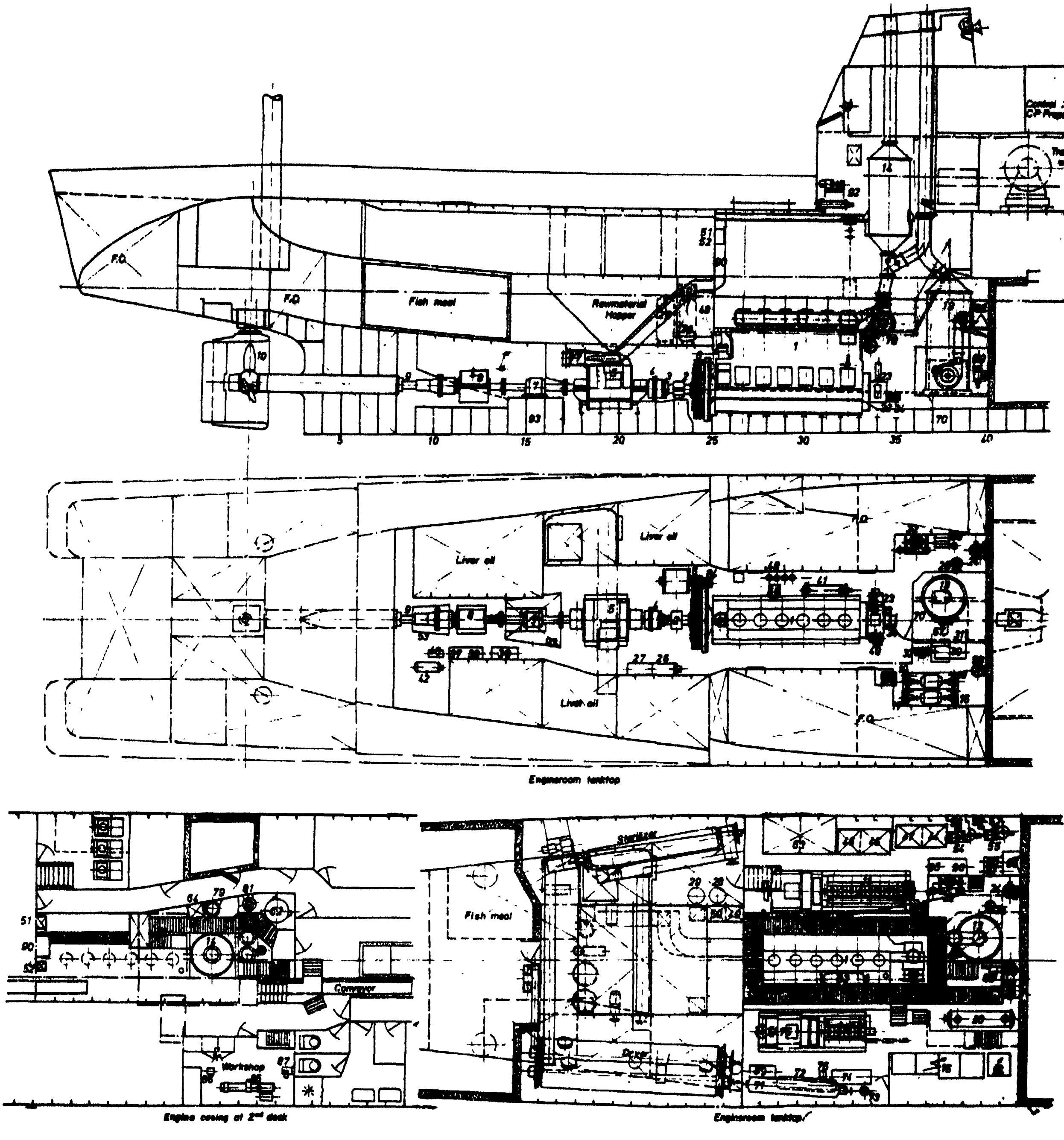


Fig. 712. Carl Kämpf, *engine room arrangement*

stern chute, because before sufficient experience was gained, this happened occasionally, especially when the ships were pitching heavily in bad weather.

The best and safest course in shooting and hauling in heavy seas is not against the sea, as first was believed, but with the sea. This also applies when sailing at full speed. Several times, when sailing under full power against the sea, the very robust steel doors closing the stern chute on the upper deck level, were severely damaged. They had eventually to be replaced by open guard rails. The explanation for this is that, when quick and heavy pitching occurs, the transom stern throws the water with such force aft that a momentary "cave" is formed in the wake. The crest of the wave at the end of this "cave" breaks forward and, with the support of the drag behind the transom stern, rushes up the stern chute with very great force. There is little pitching at the stern when sailing with the sea because the waves pass slowly and the upsetting forces are small.

The biggest catches brought safely to deck by the three

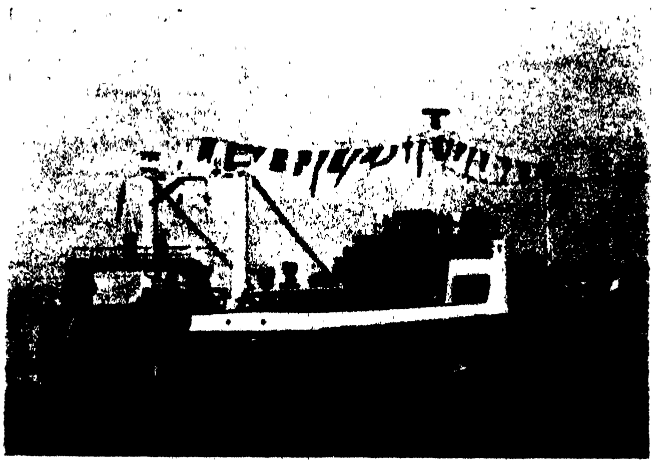


Fig. 713. Carl Kämpf

vessels have been more than 500 Korb (German measurement, about 25 ton or about 400 kit), and nylon codends with special strengthening were developed to make it possible. With further improvements and strengthening, still bigger hauls can be made.

The saving in time by stern trawling is considerable, especially with bigger hauls. A record taken during one trip of the *Sagitta* showed that the mean time for the doors to be out of the water was 24 min. Of this, 10 min. were used for repairing the trawl and 4 min. for collecting fish from the fore part of the net. Therefore, only 10 min. were used for clipping and unclipping the doors, hauling the trawl on deck, emptying the codend and shooting again.

At the time of writing this paper (November 1958) the performance of the *Carl Kämpf* has been good. There has been no engine trouble, and the vessel's behaviour has been very good.

The crew of the *Heinrich Meins* had to accustom themselves to the Voith-Schneider propellers in the bow, a device never before tried on a ship of this size. During the first year of operation it was found that the propellers were too small, hydraulically as well as mechanically. The speed dropped too much in rough seas because too much power was consumed for steering, and wear and tear of some highly loaded parts was high.

Both troubles could be overcome by using propellers of larger size and with slightly increased output of the main engines. However, new propellers with a larger diameter could not be fitted to the existing hull and the vessel was, therefore, converted to diesel-electric drive. This was comparatively simple because the design was first made for diesel-electric drive. The electric generators were fitted in the space the Voith-Schneider propellers had occupied, and two cod-liver oil tanks aft and the last pound of the fish hold had to be sacrificed to provide space for the electric propeller motors and gears. Double propellers were chosen because of the lines of the aft body.

It is only fair to mention, however, that, although the Voith-Schneider installation had to be removed, the principle is basically sound and can be used with advantage in special circumstances. The system would have worked with propellers of larger size, but they were not chosen because of lack of experience. The crew, once they became adapted to the completely different way of steering and handling the ship, were impressed by the superior manoeuvring qualities and would have preferred to retain the system with, of course, larger propellers. After replacement by conventional propellers, it was also found by comparison that the Voith-Schneider propellers had worked to some extent as stabilisers, the vessel rolling more without them.

The *Sagitta* also had teething troubles with the gas

TABLE 160

Main particulars of the stern trawlers *Heinrich Meins*, *Carl Kämpf* and *Sagitta*

		Heinrich Meins	*Carl Kämpf*	*Sagitta*
Length over all, LOA	ft. (m.)	227.0 (69.20)	212.8 (64.87)	220.7 (67.27)
Length in the waterline L		212.6 (64.80)	199.4 (60.77)	207.3 (63.17)
LBP		—	181.1 (55.20)	189.0 (57.60)
Breadth mld., B		32.8 (10.00)	31.5 (9.60)	31.5 (9.60)
Depth mld., D		23.6/16.1 (7.2/4.9)	23.4/16.1 (7.15/4.9)	23.4/16.1 (7.15/4.9)
Draught, amidships without keel, T		13.6 (4.15)	14.1 (4.30)	14.1 (4.30)
Draught, aft with keel, Ta		14.9 (4.55)	15.7 (4.80)	15.8 (4.82)
C[illegible]				
[illegible] fishhold (inside of linings)	cu. ft. (cu. m.)	5,224 (148)	—	3,177 ([illegible]
Fishhold (inside of linings)	" "	16,061 (455)	20,121 (570)	15,885 ([illegible]
Fish-meal hold (inside of linings)	" "	4,765 (135)	2,541 (72)	2,330 ([illegible]
Fish and liver oil tanks	" "	1,800 (51)	1,130 (32)	1,341 ([illegible]
Fuel oil tanks	" "	9,990 (283)	7,201 (204)	8,931 [illegible]
Freshwater tanks	" "	3,177 (90)	2,471 (70)	3,000 [illegible]
Tonnage				
GT		825.74	681.13	720.21
NT		347.08	277.59	257.17
Engine output normal	h.p.	1,200	1,250	1,500
max.	h.p.	1,500	1,490	2,000
Speed on trials	knots	13	14	15

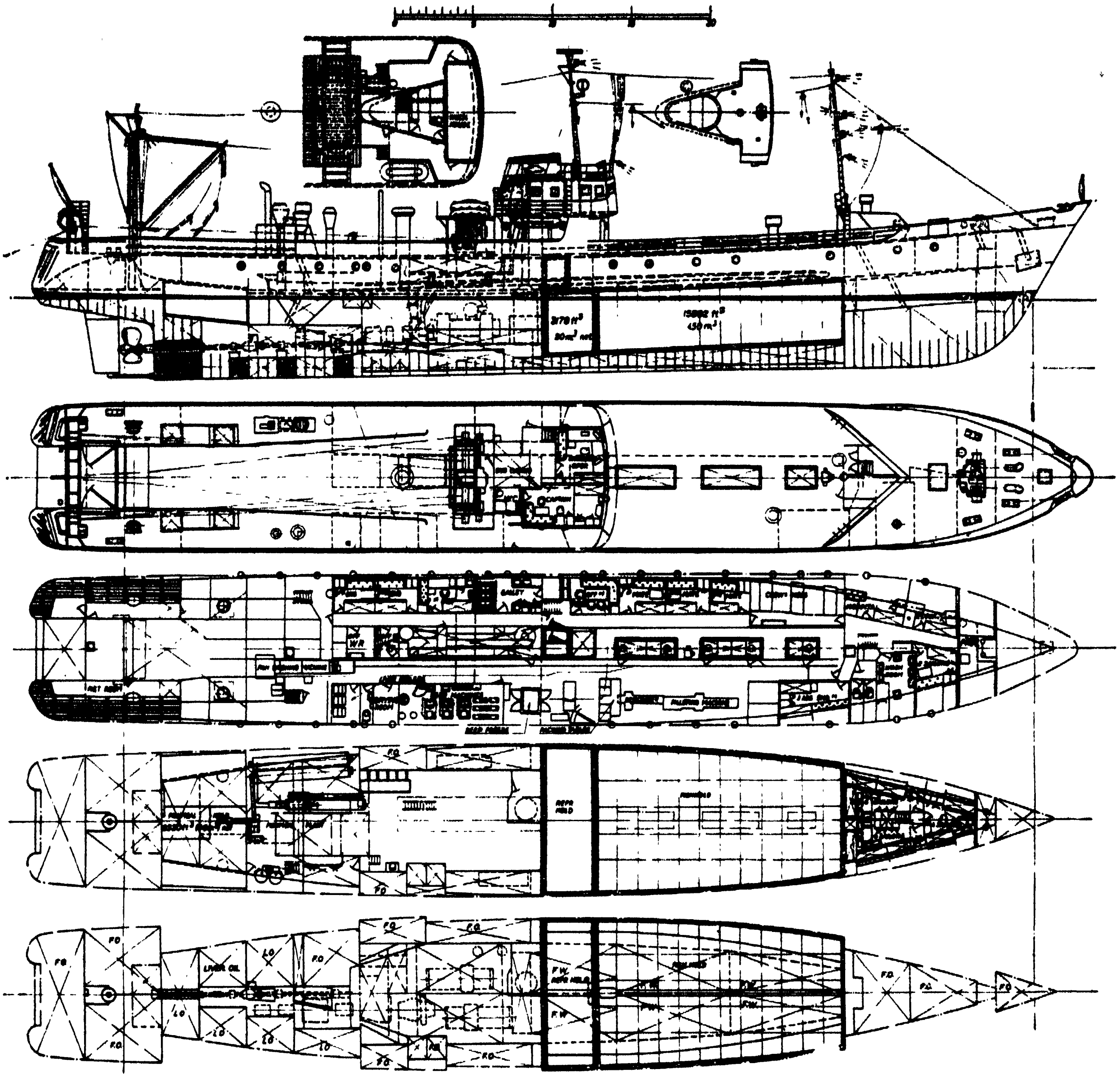


Fig. 714. Sagitta, *general arrangement*

turbine and the hydraulic winch drive. The gas turbine troubles were of a minor nature and these have been more or less overcome.

As mentioned, the hydraulic components of the winch drive were the double-up version of a successful unit used on drifter-trawlers, but one plus one did not turn out to be two, as so often happens in practice. The main failure was a too low gear ratio between motor and winch, so that the system always worked with the maximum pressure and minimum oil flow, opposite to what was required. There was also governor trouble in operating the clutches, the revolutions could not be reduced enough and the winch started too quickly; and a broken ball bearing, which was only bad luck and could have happened to any drive. But it was possible to carry on work with the other unit. After putting in two gear wheels of a more suitable gear ratio, the oil pressure went down and the winch worked more quickly and smoothly. During this repair, some slack in the connection between the control wheel on the winch and the governor was detected and corrected. Since that time no other trouble of importance has occurred.

Other minor improvements in handling the gear have been made for quicker and safer hauling of big "bags"

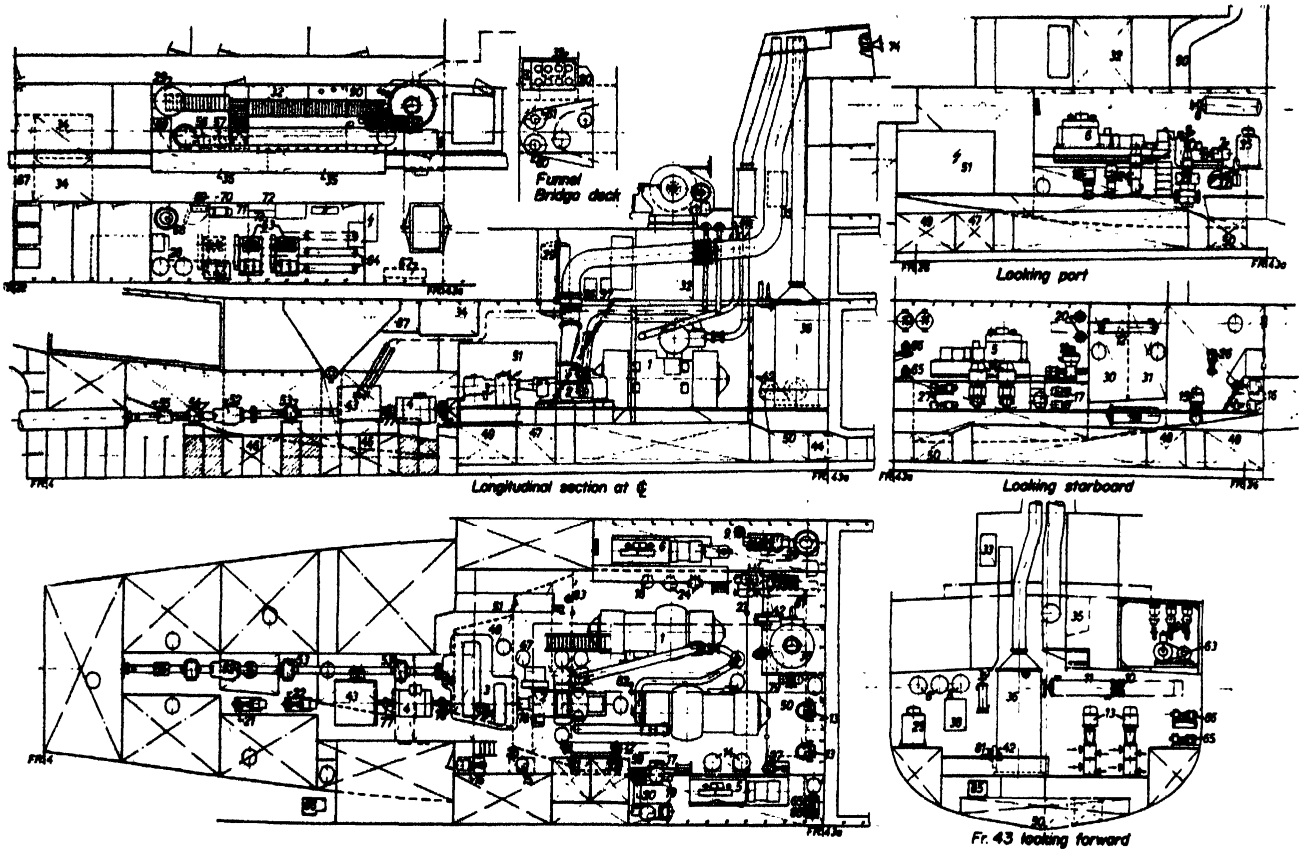


Fig. 715. Sagitta, *engine room*

aboard. Where there are strong currents and fishing can only be done in one direction, as off the Norwegian coast of Andenes, etc., considerable time is saved because the stern trawler can start the return trip the moment the net is out of the water. The ordinary trawler must first bring the catch aboard and then haul in the gear. On the other leg of the round trip, the stern trawler shoots immediately after the turn, but the ordinary trawler has to stop, bring the gear out and turn round before paying out.

The stern trawlers can shorten or lengthen the warps during trawling as desired, but the ordinary trawler would very quickly ruin her warps in the towing block if she tried to do the same. This may also be of some

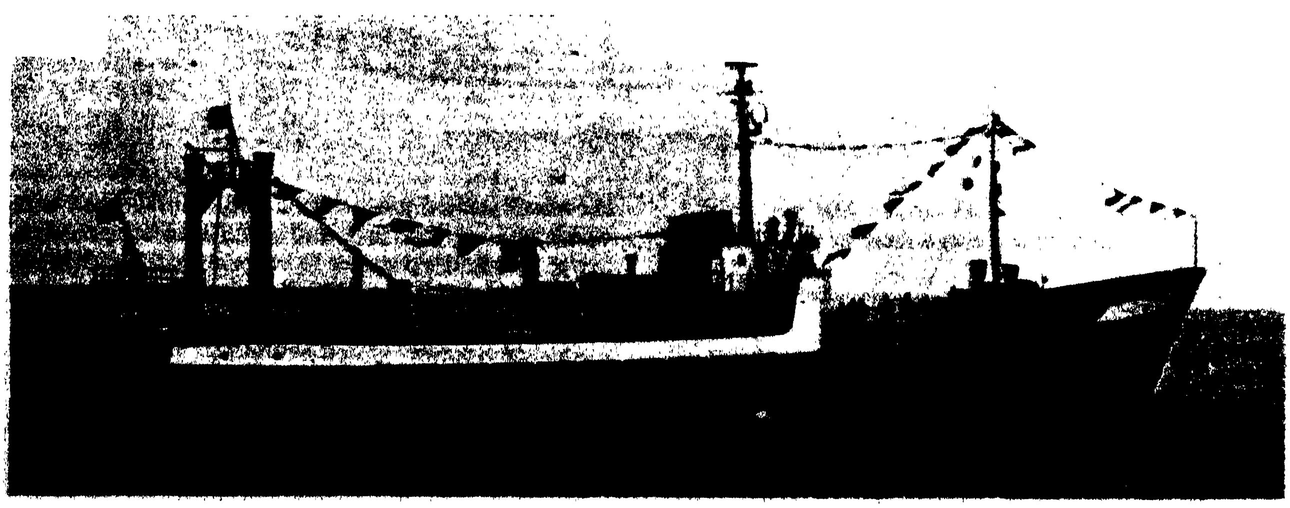


Fig. 716. **Sagitta**

importance on difficult fishing grounds off the Norwegian coast and elsewhere, where the depth of water changes rapidly.

The stern trawlers can fish in heavy weather up to Beaufort number 9, with the crew remaining dry. In cold weather, with temperatures below 32°F (0°C), very little icing occurs because of the large freeboard, which means that less spray is shipped. Decks and freeing ports of ordinary trawlers are sometimes iced up, which does not happen so frequently on stern trawlers. The quality of the fish appears to be better because the death struggles of the fish are shortened and they are protected from the sun by the shelter deck before being gutted.

A fourth stern trawler is on order for one of the owners of the first three. All the experience gained so far has been used in the design. The vessel will be of the *Sagitta* size, with improved machinery of the *Carl Kämpf* type, while the general arrangement will embody the most favourable details of all three ships. The new ship, therefore, will be a synthesis of its three forerunners.

FRENCH DEEP-SEA SALT COD TRAWLERS

by

E. R. GUEROULT

The author discusses the development of the French trawlers fishing cod for salting aboard. The special requirements for that fishery—great range, long duration of the trips, adoption of the diesel engine, the ratio between power for trawling and power for sailing—have brought along changes of the hull and propulsion systems. A brief description of five recent trawlers gives a picture of the actual trends in the construction of French trawlers engaged in that fishery.

NAVIRES FRANÇAIS DE GRANDE PÊCHE SALÉE

L'auteur examine le développement des types de chalutiers de pêche salée en France. Les exigences spéciales de ce genre de pêche —grand rayon d'action, durée de chaque voyage, adoption du Diesel, rapport puissance en pêche/puissance en route—ont entraîné d'importantes modifications de la coque et des systèmes de propulsion. La brève description de cinq chalutiers récents donne une image des tendances actuelles de la construction des chalutiers français engagés dans cette pêche.

LOS BACALADEROS FRANCESES

El autor reseña la evolución de los bacalderos franceses. Las necesidades especiales de la pesca a que se dedican: gran radio de acción, viajes de larga duración, adopción del motor Diesel, relación de la potenica en pesca—potencia en ruta, han culminado en importantes modificaciones en el casco y en los sistemas de propulsión. La breve descripición de cinco arrastreros de construcción reciente da una idea clara de las tendencias actuales en la construcción de los barcos bacaladeros franceses.

AT the beginning of the century, when cod fishing off the Newfoundland banks was carried on exclusively by non-powered, sailing boats, using longlines from dories, several steam ships tried trawling with the equipment known at the time. The results were encouraging and trawling eventually replaced line fishing in the French distance fishery and spread to the Spanish, Portuguese and Italian. It is now also practised by the British and the Germans with large trawlers.

The first boats in 1905 had 700 h.p. steam engines and were 148 ft. (45 m.) long, they crossed the Atlantic in fifteen days and had to stop fishing to refuel in Newfoundland or Canada. Despite the large tonnage of some of the steam trawlers and their large bunkers, refuelling difficulties made them obsolete as they were unable to compete with diesel trawlers. Even modern steam trawlers have also to carry fresh water for their boilers.

Starting from the 148 ft. (45 m.) long trawler, shipbuilders adapted it to the needs of the "Banks" fisheries. Fuel economy on long-range cruises influenced the choice of engines. The weight of the fuel, water, salt and provisions for two trips a year very soon convinced owners of the need to increase the tonnage, which was doubled in twenty years from 1905 to 1925, while the length was increased from 148 to 213 ft. (45 to 65 m.).

Such a length results in a low speed-length ratio and gives sufficient speed for crossing the Atlantic without undue power requirements. The sailing power can therefore be taken as 1.25 of the trawling power. High speed *a priori* would require, in the case of the loaded cod-fishing boats, a power requirement and fuel consumption which would upset the financial balance sheet of the fisheries.

As the displacement rose from 1,000 to 2,000 ton, the power increased first from 700 to 900 h.p. and for a long time it did not exceed 1,000 h.p.

Introduction of diesel propulsion

After the *Islande*, a 210 ft. (64 m.) steam trawler, was put into service in 1926, it was followed by the *Victoria*, the first diesel trawler, which was 190 ft. (57 m.) long. This was a compromise vessel with a diesel motor for propulsion and steam-driven auxiliaries and winches, thus only part of the machinery saved fuel.

The *Victoria* proved that the diesel engine had sufficient endurance for a nine-months fishing period in the year, covering two or three trips, so from 1929/30 onwards, confidence was established in the slow, direct-drive diesel engine, running at from 135 to 175 r.p.m. During the decade 1930/1940, the deep-sea cod trawler became standardized as regards dimensions, power, crew and quarters, equipment and fishing gear, and

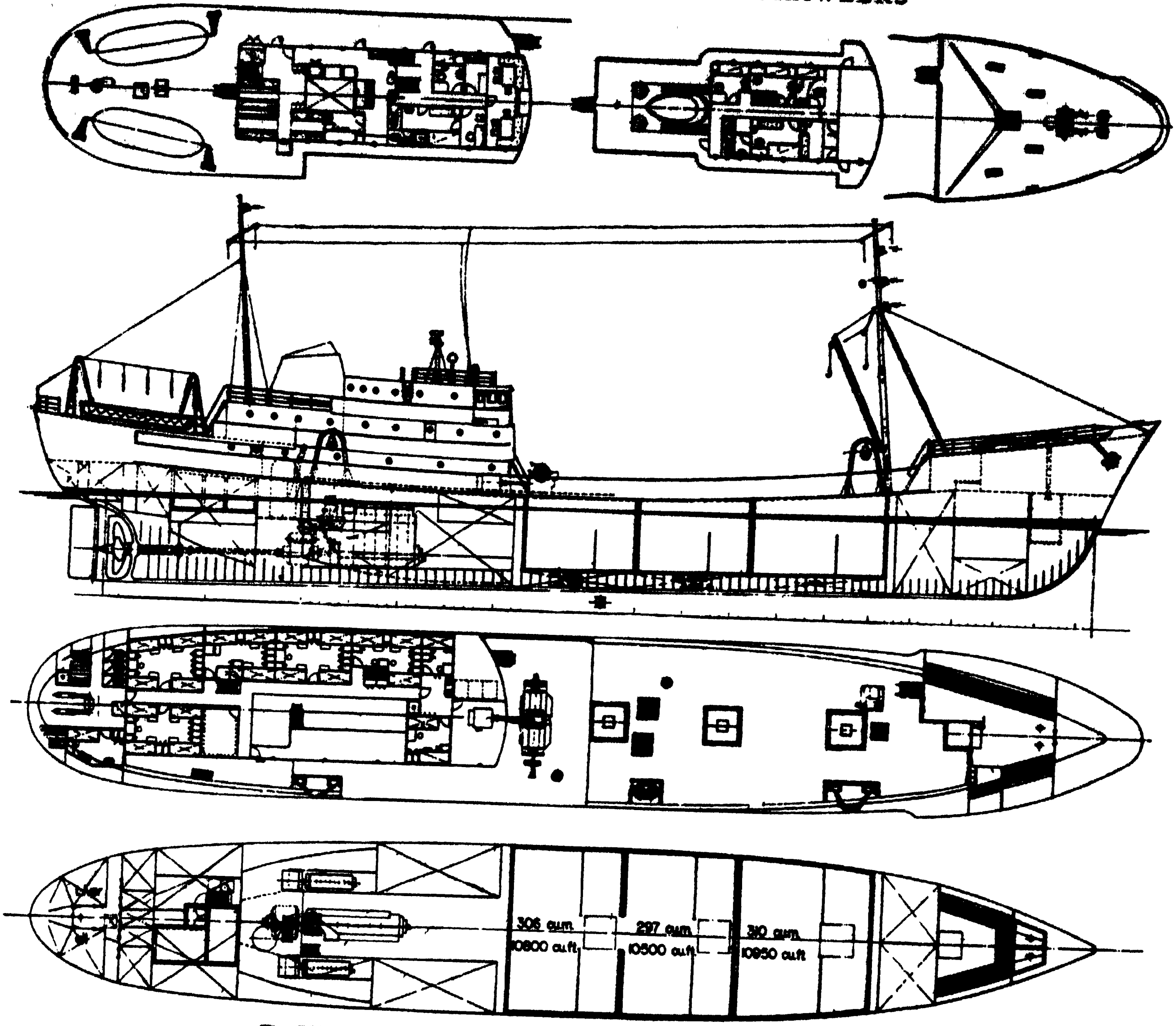


Fig. 717. Boat A with geared diesel (1,500 h.p.) and multi-speed gearbox

subsequent evolution took place slowly until the present type was developed.

Modern trawlers

The trawlers recently put into service do not differ very much from those which replaced the fleet lost during World War II. The length between perpendiculars is still 223 to 230 ft. (68 to 70 m.) with some exceptions, described further on. On the other hand, the power has been raised since the 1947 design (Gueroult, 1955).

The power increase is the result of the demand for higher speeds from the shipowners, despite the fact that the power required for trawling has remained substantially the same. The power for trawling, measured at sea, ranges between 500 and 900 h.p., depending on the fishing gear, the speed of the trawl, the depth of the fishing grounds and the state of the sea. The ratio between power for trawling and sailing, which was 0.80 to 0.85, has come close to, or dropped below, 0.45 to 0.50. If the owner demands a speed corresponding to 1,800 to 2,000 h.p., the ratio between the average powers is:

$$\frac{\text{fishing } 700}{\text{cruising } 1{,}900} = 0.37$$

One engine cannot satisfactorily work continuously when trawling at half power, at full torque, or even sometimes with higher than normal torque. The engine stalls and two-stroke engines are particularly apt to do this. There must therefore be a division of the total power and the installation of three engines. This change has led to modifications in the types of propulsion engine and to abandoning the slow, direct-drive diesel. In the present French fleet, 85 per cent. of the engines are four-stroke and supercharged.

The power required for paying out, which is definitely higher (approximately 1,200 h.p.) than that for trawling, must also be taken into consideration. It excludes, with the present powers, solutions involving two engines only.

The higher sailing speeds required from 11 to 14 knots have led to finer hulls. The prismatic coefficient, which was 0.68, has been brought down to around 0.60 to 0.61, the midship section coefficient remaining at 0.96. The LCB is moved aft. In fact, these boats have the same relative speed and shape as fast, small cargo boats. As with cargo boats, fuel consumption per ton-mile is an operational item which must not be overlooked so as not to upset the balance of weights which is difficult to achieve for a 120-day range.

Cargo capacity and stability

The loads, on departure and on arrival, for the boats A and B are given in table 161. The fishing gear and the provisions for 65 men for three months are important items.

The increasing demand for hot and cold potable fresh water raises a problem of storage capacity in the double-bottoms. The production of fresh water by distillation consumes too much fuel. The rationing of fresh water is inevitable, despite the 200 ton or so that are stored in the double-bottoms.

Salt is carried on board at the rate of 550 to 600 kg. per ton of salted cod, or 650 to 700 ton in the case of 223 ft. (68 m.) boats. On the return journey the load of

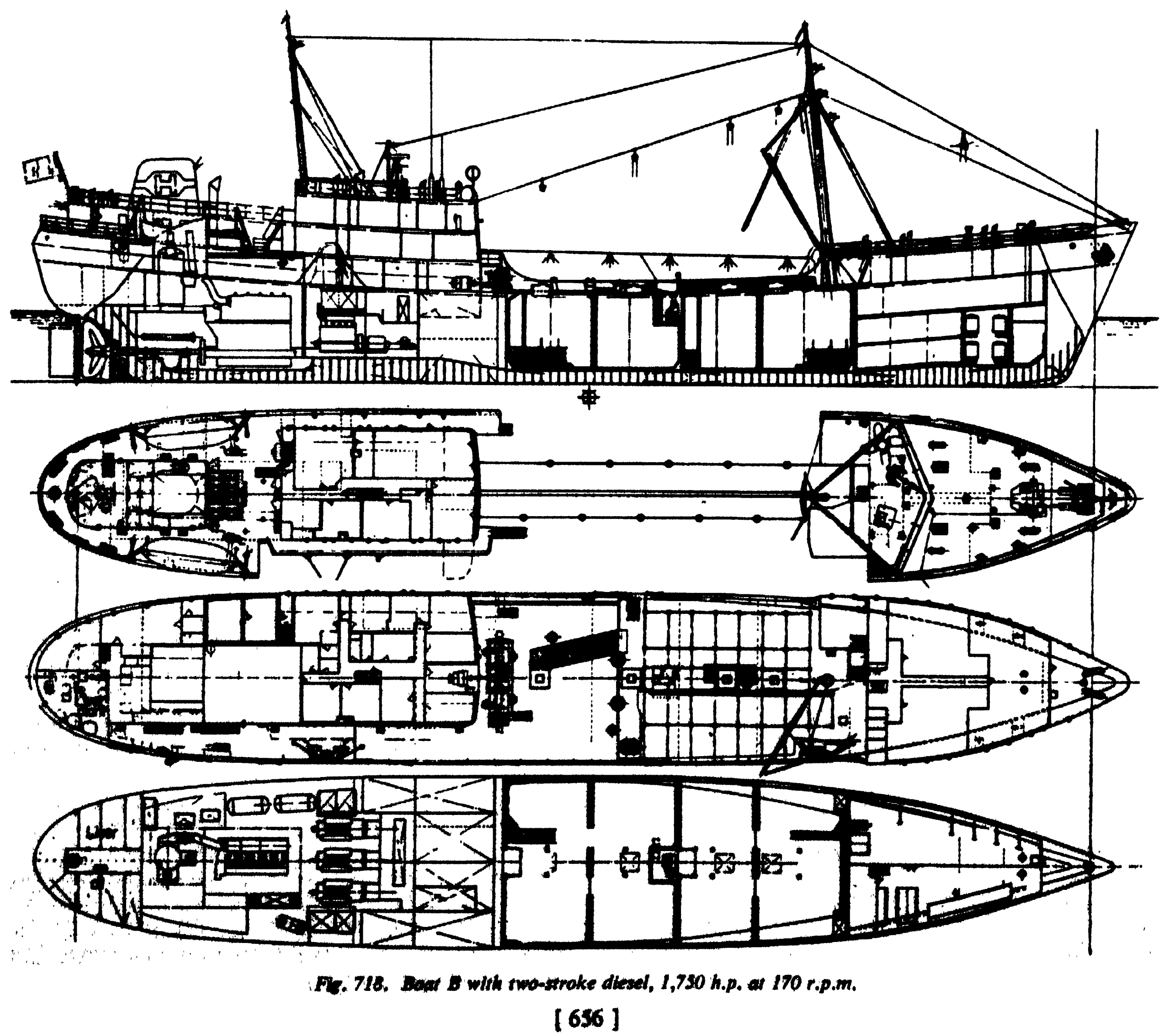


Fig. 718. Boat B with two-stroke diesel, 1,730 h.p. at 170 r.p.m.

salted cod varies in density depending on the duration of the voyage and the stacking of the fish in piles of from 3.6 to 4.25 ft. (1.10 to 1.30 m.) in bad weather, often being higher in certain units. It is, however, advisable to allow for a density of 0.85 for the main hold and between-deck storage holds. The cod-liver oil storage capacity varies from 50 to 120 tons.

The trim varies very little during a voyage. The salt is shifted from one place to another during salting, etc., and the distribution of the load is regulated by the captain so as to balance decreases in fuel and water supplies.

Deep-sea trawlers have a freeboard ranging from 2.62 to 2.95 ft. (0.80 to 0.90 m.), as authorized by the Bureau Veritas. Despite their large superstructures and their marked sheer, the freeboard is much more generous than on cargo boats of the same size. It is advisable to provide for additional freeboard because of a possible extra load of 200 ton at the start of fishing if the haul is large and before the corresponding fuel stocks and water supplies are reduced. Fig. 722 shows the stability curves and metacentric heights (GM) of the boat C, under the following five typical conditions:

(1) Empty ship	0.56 ft. (0.17 m.)
(2) Departure for fishing grounds .	3.24 ft. (0.99 m.)
(3) Start of fishing	3.11 ft. (0.95 m.)
(4) Leaving fishing grounds . .	2.29 ft. (0.70 m.)
(5) Return to port	1.64 ft. (0.50 m.)

With their large crew, although part of it is engaged in handling and preparing the fish, the catching rate is rapid when fish are abundant. Loading 900 ton of salted fish in the hold in 30 days, works out at 60 to 90 ton ungutted fish hauled in on deck per day.

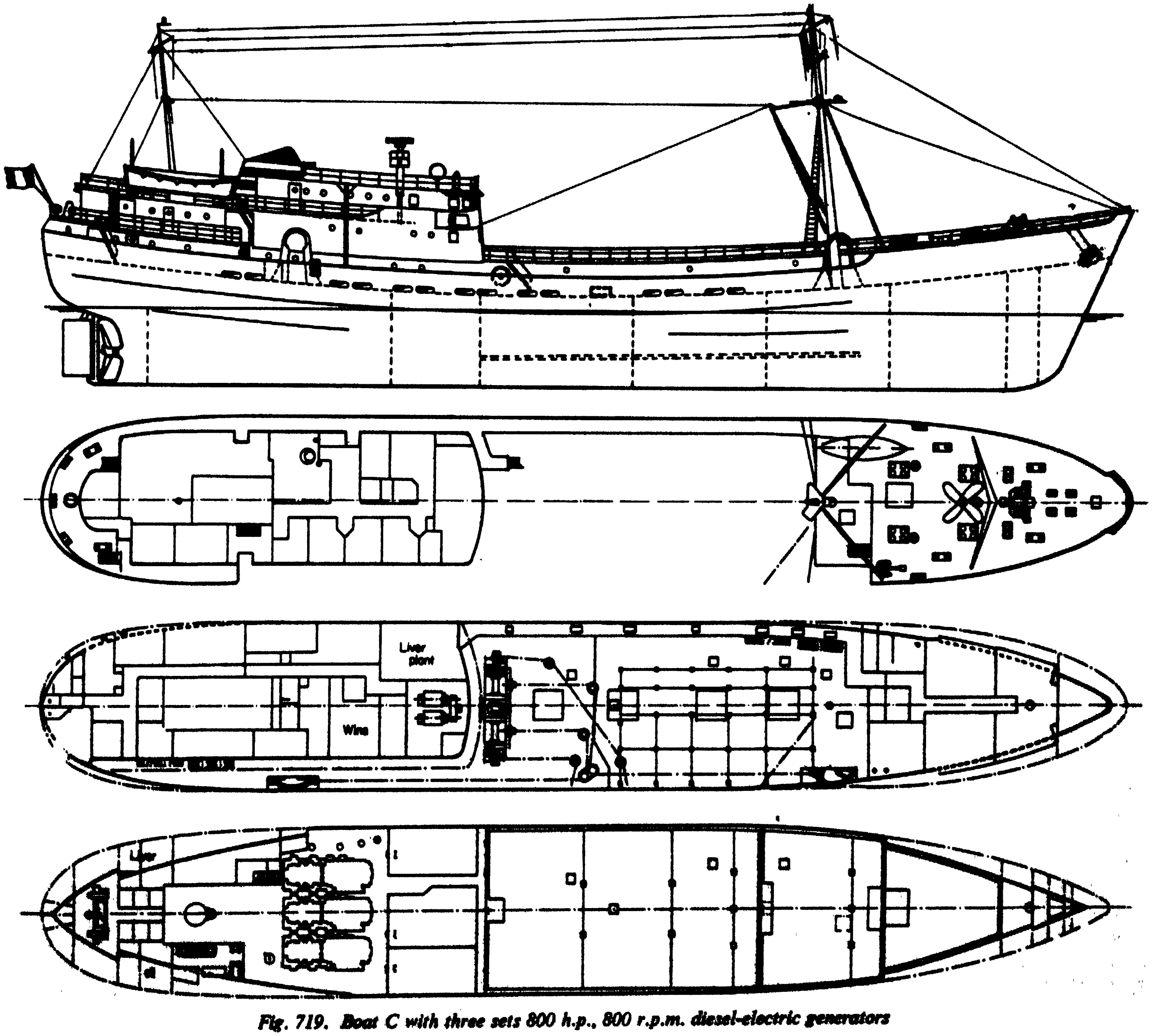


Fig. 719. Boat C with three sets 800 h.p., 800 r.p.m. diesel-electric generators

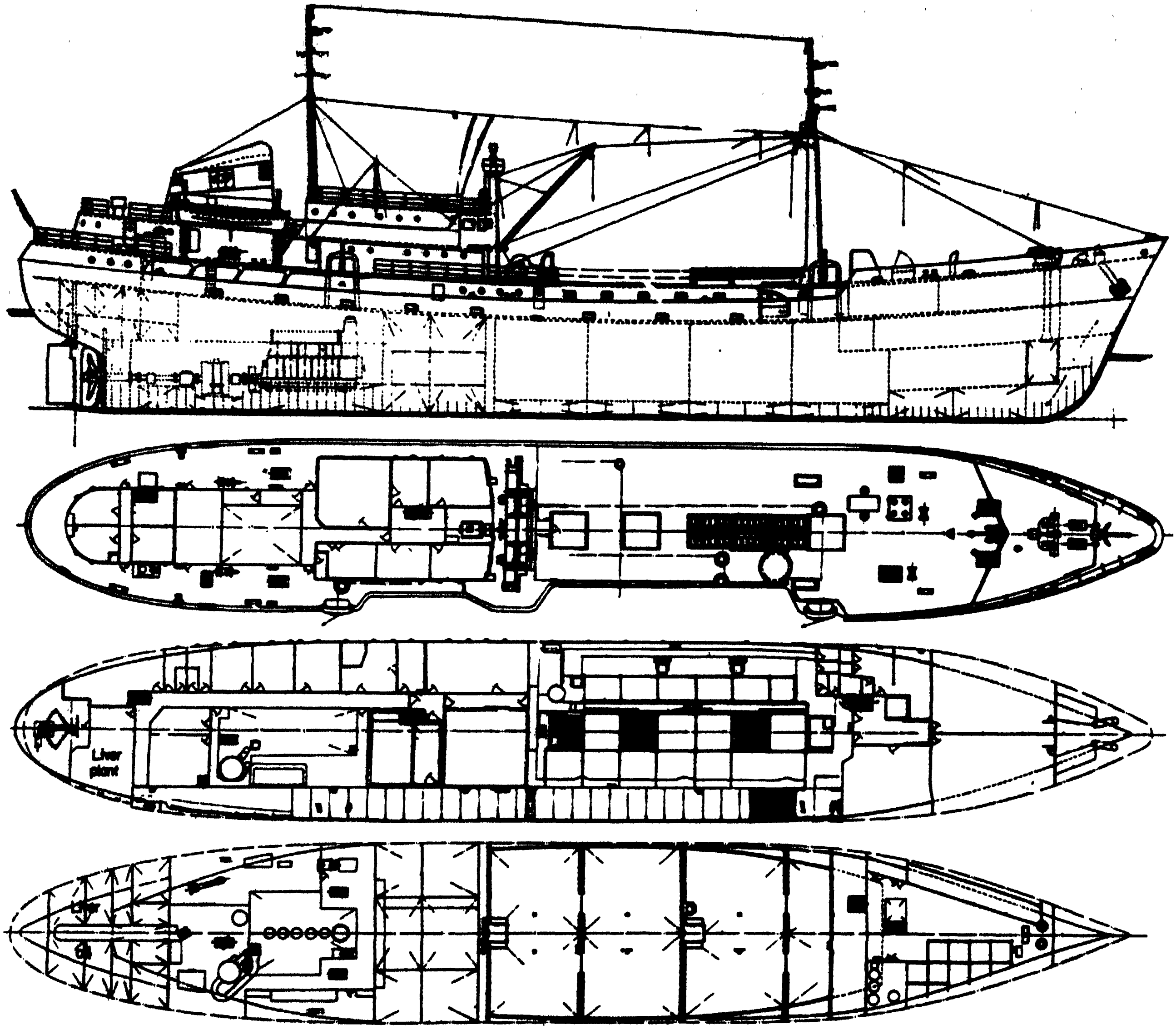


Fig. 720. Boat D with 1,680 h.p., 200 r.p.m. two-stroke engine

Short descriptions of typical vessels

Table 162 gives the specifications for five recent trawlers. A brief description of each of them is:

A. 205 ft. (62.50 m.) trawler (fig. 717) intended for three voyages a year. While having the same fishing capacity as the biggest boats, it has a limited hold capacity and range. The owners aimed at an average production combined with minimum operating costs. The machinery is a geared diesel with a multi-speed gearbox, 1,500 h.p. at 275 r.p.m. Daily fuel consumption is low, owing to high propulsion efficiency. Consumption per ton-mile is however higher than that of the standard 223 ft. (68 m.) boats and less than that of the most recent fast boats.

B. Whereas type A is the smallest deep-sea trawler of the fleet, type B (fig. 718) is the biggest. In principle, the trawler was designed to make two voyages per annum to fill the very large 60,000 cu. ft. (1,700 cu. m.) hold each time. With good fishing, it can of course make three voyages. It is equipped with a two-stroke engine developing 1,750 h.p. at 170 r.p.m.

C. This is the standard 223 ft. (68 m.) type (fig. 719) with diesel-electric propulsion. It is equipped with three diesels developing 800 h.p. at 800 r.p.m. The diesel-electric propulsion has been a success. The port side of the deck is enclosed with a gangway which serves as a passage from fore to aft and protects the men while at work.

D. The special feature of this boat (fig. 720) is its work deck which is three-quarters covered leaving a gangway on the deck level for taking in the trawl. The sorting, handling and preparation of the fish is done entirely under cover. Space between decks allows for the installation of processing machinery and filleting machines. The boat is propelled by a two-stroke engine developing 1,680 h.p. at 200 r.p.m.

E. This deep-sea trawler (fig. 721) for landing salted fish has, since being put into service in 1951, had equipment for freezing at −22° to −31°F (−30° to −35°C) installed. In the insulated forward hold, with a capacity of 9,000 cu. ft. (255 cu. m.), 140 ton of frozen fillets in 44 lb. (20 kg.) cardboard boxes ready for sale can be stored at a temperature of −4°F (−20° C). The propulsion motor is a four-stroke engine developing 1,150 h.p.

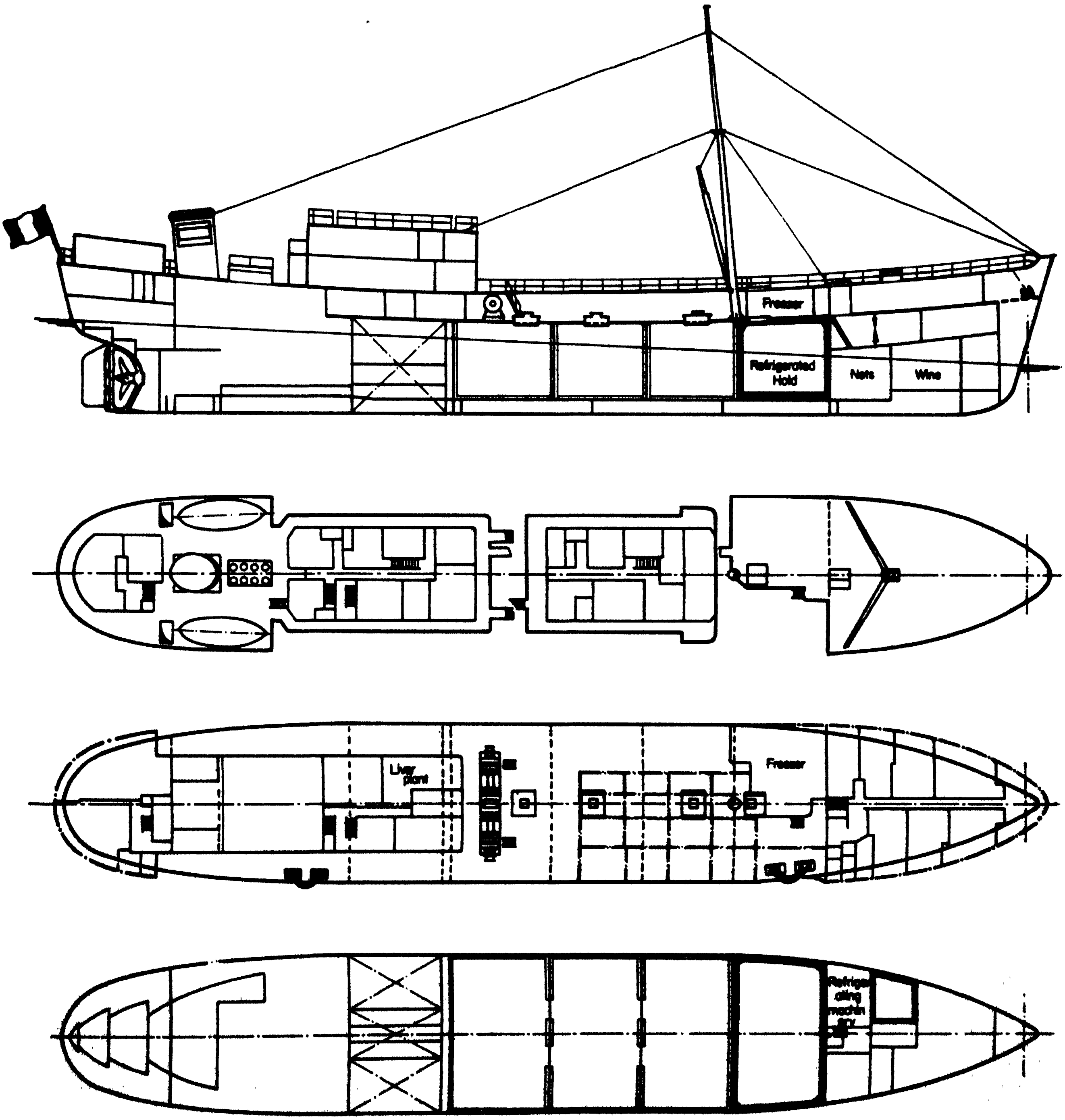


Fig. 721. Boat E with 1,150 h.p., 165 r.p.m. four-stroke diesel engine

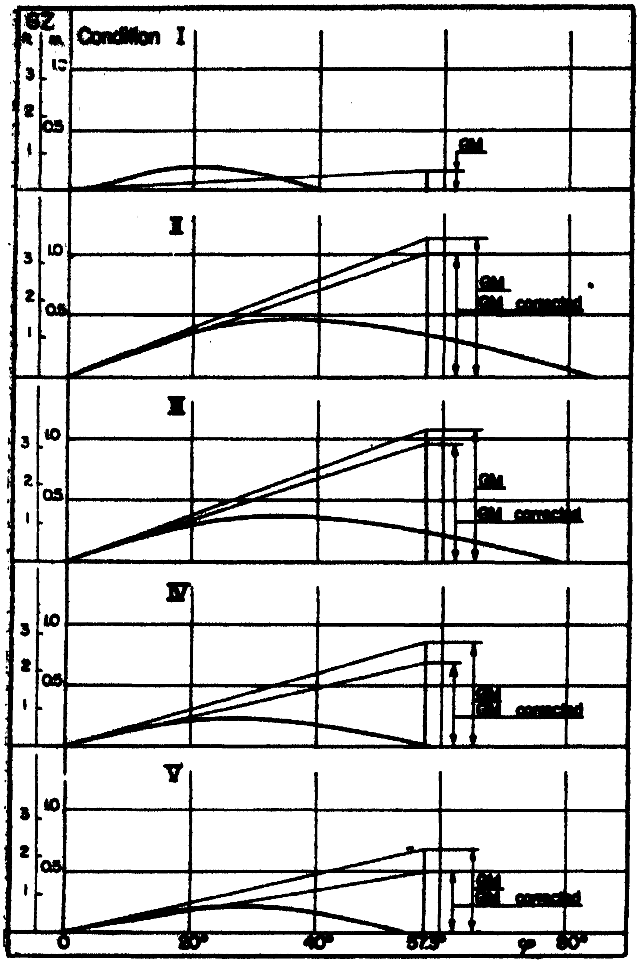


Fig. 722. Stability curves for boat C at five typical conditions given in text

TABLE 161

Loads when departing from and returning to port

	Type A	Type B
	ton	ton
Conditions on departure for fishing		
Salt	430	645
Fuel	350	535
Oil	10	15
Fresh water	104	167
Provisions	20	40
Crew	5	7
Fishing gear	25	35
	944	1,444
Conditions on returning to port		
Fish and salt	720	1225
Cod-liver oil	50	100
Fuel	50	90
Fresh water	10	50
Crew	5	7
Provisions	2	5
Fishing gear	25	35
	862	1,512

at 165 r.p.m. Two trawlers of this type have been in service in the same company since 1952.

Conclusions

The salt cod trawler has been used for testing a number of improvements and innovations: the diesel engine in 1927, electric trawl winch in 1929, asymmetric deck arrangement, diesel-electric propulsion in France, and freezing about 1934.

At present, as in all specialized fisheries, after fifty years of continuous improvements, deep-sea trawling for salt cod is threatened by new developments. The very heavy investments and high operational costs are too burdensome for a cheap product, the consumption of which is on the decline.

TABLE 162

Principal particulars of various types of salt cod trawlers

		Type A	Type B	Type C	Type D	Type E
LOA	ft.	233	274	244	254	240
	m.	71.0	83.7	74.5	77.5	73.0
LBP	ft.	205	252	223	230	223
	m.	62.5	77.0	68.0	70.0	68.0
Beam, B	ft.	34.4	42.6	37.7	39.4	38.6
	m.	10.5	13.0	11.5	12.0	11.75
Depth, D	ft.	18.0	21.6	19.7	20.7	20.7
	m.	5.5	6.6	6.0	6.3	6.3
Average draught, T	ft.	15.6	17.4	17.05	17.7	17.4
	m.	4.75	5.3	5.2	5.4	5.3
Power	h.p.	1,500	1,750	2,400	1,680	1,150
Speed, V	knots	13	13.5	13.75	13.5	11.5
Daily fuel consumption	ton	2.7	4.5	4.65	4.2	3.5
Hold capacity	cu. ft.	32,200	60,000	45,800	50,400	53,300
	cu. m.	913	1,700	1,300	1,430	1,514
Bunker capacity (Gas oil)	ton	400	645	575	500	460
Capacity of fresh water ballast	ton	100	350	158	275	236
Capacity of cod-liver oil tanks	ton	50	120	110	—	105

With crews accustomed to long fishing seasons, partial but satisfactory experiments with fish processing, and the new methods and organization of the shipbuilding business and the fisheries, they are in a good position to change over from the existing type boats, to the shelter deck boat, fishing over the stern and processing the whole of the catch on board ship.

Acknowledgments

The following shipowners and shipbuilders provided information and their help is acknowledged: Type A, Armement A. Ledin—Fécamp, Chantiers Béliard et Crighton, Ostend; Type B, Pêcheries Bordeaux, Bassens—Bordeaux, Chantiers Loire Normandie—Grand Quevilly ; Type C, Les Pêcheries de Fécamp—Fécamp, Ateliers et Chantiers de la Seine Maritime—Le Trait (S.M.); Type D, Armement V. Pleven—St. Malo, Chantiers Van Duyvendyk; Type E, Compagnie Générale de Grande Pêche, Chantiers Loire Normandie—Grand Quevilly.

DIESEL WHALE CATCHERS

by

SEISUKE TAKAHASHI

An experiment was made in Japan in 1936 to determine the influence of diesel engine noise on whales. Since the results were successful, diesel catchers have gradually been developed, and thus cruising range has been extended. Good manoeuvrability is maintained by the use of an "air brake" system.

At first only small boats were used because it was thought that only they would have the necessary manoeuvrability, but this was disproved, so since 1941, and especially after 1950, the size has been increased.

Several new devices have been introduced from time to time, such as the electrically-driven whale winch, replacement of the bar keel by the flat keel, use of bilge keels, echo sounders, and friction clutches and metal brakes on steam-powered catchers. A controllable-pitch propeller was also tried but did not prove successful. In the field of fishing gear, the flat-headed harpoon, radio buoy and nylon rope have also been introduced.

Modern catchers of between 600 and 700 GT have been built recently, an example of the newest vessel of this size being the *Seki Maru No. 18*, built in 1957.

CHASSEURS BALEINIERS A DIESEL

En 1936, une expérience a été faite au Japon pour déterminer l'influence du bruit du moteur diesel sur les baleines. Les résultats ayant été favorables, les chasseurs baleiniers à diesel se developpent graduellement et le rayon d'action a ainsi été augmenté. L'utilisation d'un système de freinage par arrêt de l'injection de carburant maintient une bonne manœuvrabilité.

Au début, on utilisait seulement de petits navires parce qu'on pensait qu'ils étaient les seuls à avoir la manœuvrabilité requise, mais cela n'a pas été prouvé; aussi, la dimension des navires a augmenté depuis 1941, et surtout depuis 1950.

A diverses reprises, de nouveaux dispositifs ont été introduits, tels que le treuil baleinier électrique, le remplacement de la quille massive par la quille plate, l'emploi de quilles de roulis, les sondeurs à écho, et les embrayages à friction et les freins à mâchoires métalliques à bord des chasseurs baleiniers à vapeur. On a aussi essayé l'hélice à ailes orientables, mais les résultats n'ont pas été satisfaisants. Dans le domaine des engins de chasse, le harpon à tête plate, la bouée-radio et la corde de nylon ont aussi été introduits.

On a construit récemment des chasseurs baleiniers dont la jauge brute varie entre 600 et 700 GT; le *Seki Maru No. 18*, construit en 1957, est un exemple du plus récent navire de cette taille.

BALLENEROS CON MOTOR DIESEL

En 1936 se efectuó un experimento en el Japón para determinar el efecto que tiene en las ballenas el ruido del motor Diesel. Como los resultados fueron satisfactorios, los balleneros Diesel se han ido perfeccionando y con ello ha aumentado su radio de acción. Se mantiene una buena maniobrabilidad empleando un sistema de "frenos de aire".

Al principio sólo se empleaban balleneros pequeños porque se creyó que serían los únicos que tendrían la maniobrabilidad suficiente, pero como esto resultó ser falso, su tamaño ha ido en aumento desde 1941, y especialmente desde 1950.

De vez en cuando se han introducido nuevos dispositivos, inclusive la maquinilla ballenera accionada eléctricamente, la quilla plana en vez de la quilla de barra, el empleo de contraquillas, ecosondas, embragues de fricción y frenos metálicos en los balleneros de vapor. También se ensayó, aunque no tuvo éxito, una hélice de paso variable. En lo referente al equipo de pesca se han introducido el arpón de punta plana, la radio-baliza y los cabos de nylón.

Recientemente se han construído balleneros modernos de 600 a 700 tons brutas, siendo ejemplo de los barcos más modernos de este tamaño el *Seki Maru No. 18*, construído en 1957.

JAPAN first started Antarctic whaling in 1934 with vessels powered by steam reciprocating engines. In those days the adoption of the diesel engine was advocated because its speed and manoeuvrability were superior to that of the steam boats used for coastal whaling. In addition, the diesel was considered to be more economical in fuel consumption and re-fuelling was quicker and less troublesome. All these factors resulted in increased operating efficiency of the mother ship and catchers. Owners, however, hesitated to adopt diesel vessels because they believed that the noise of the engine would frighten whales, and also that the steam engine had greater manoeuvrability in chasing, was stronger in towing power and caused less vibration of the hull.

Takagi (1955) reported a 1936 experiment with a diesel-driven submarine chaser which had determined the maximum speed of whales to be about 14 knots. The experiment also disclosed that the noise of the diesel did not matter if the speed was high enough. Nevertheless, every effort was made to produce a noiseless diesel to meet the demands of whale catchers.

The first diesel Antarctic whale catcher, *Seki Maru*, was built in Japan in 1937 and since then diesel has gradually replaced steam. The *Seki Maru* was 298 GT, 900 h.p. was developed at 200 r.p.m., by the airless injection, single-acting, two-stroke, trunk-type piston, self-reversing diesel engine. In this vessel an engine brake was considered essential because if the propeller

TABLE 163

Main specifications of representative types of Japanese whale catchers since 1950

<table>
<tr><th>Year</th><th>Hayashikane
Shipbuilding & Engineering Co. Ltd.</th><th>Hitachi
Shipbuilding & Engineering Co. Ltd.</th><th>Osaka
Shipbuilding Co. Ltd.</th></tr>
<tr><td>1950</td><td>L×B×D
149.24×26.34×14.76 ft.
(45.50×8.00×4.50 m.)
451 GT
2,000 BHP
16.0 to 16.3 knots</td><td rowspan="2">L×B×D
147.60×26.90×14.43 ft.
(45.00×8.20×4.40 m.)
417 to 434 GT
1,800 BHP
15.4 to 15.8 knots</td><td rowspan="2"></td></tr>
<tr><td>1951</td><td rowspan="2">L×B×D
157.44×27.55×14.76 ft.
(48.00×8.40×4.50 m.)
473 GT
2,000 to 2,300 BHP
16.2 to 16.3 knots</td></tr>
<tr><td>1952</td><td>L×B×D
157.44×27.88×14.76 ft.
(48.00×8.50×4.50 m.)
471 GT, 2,200 BHP
16.4 to 16.5 knots</td><td>L×B×D
157.44×27.55×14.92 ft.
(48.00×8.40×4.55 m.)
399 GT, 2,300 BHP
16.5 knots</td></tr>
<tr><td>1953</td><td rowspan="2">L×B×D
173.84×30.18×16.07 ft.
(53.00×9.20×4.90 m.)
599 GT
3,000 BHP
17.1 to 17.2 knots</td><td></td><td rowspan="3"></td></tr>
<tr><td>1954</td><td rowspan="4">L×B×D
186.96×31.82×16.66 ft.
(57.00×9.70×5.08 m.)
744 GT
3,280 BHP
17.6 to 17.9 knots</td></tr>
<tr><td>1955</td><td rowspan="3">L×B×D
180.40×30.83×16.40 ft.
(55.00×9.40×5.00 m.)
648 GT
3,000 BHP
17.5 to 17.8 knots</td></tr>
<tr><td>1956</td><td>L×B×D
186.96×31.16×16.73 ft.
(57.00×9.50×5.10 m.)
696 GT, 3,500 BHP
18.0 to 18.2 knots</td></tr>
<tr><td>1957</td><td></td></tr>
</table>

continues to revolve after a harpoon hits a whale and the engine is stopped, the harpoon rope often gets severed by becoming entangled with the propeller. For this, an "air brake" was devised, in which the main engine cylinders worked as a compressor when the fuel supply was shut down. The torque caused by the sway of the ship was absorbed by the cylinders and the propeller stopped in a few seconds.

No harmful hull vibration was felt in the *Seki Maru*. Although she was not quite noiseless, even at slow speed, she made good catches in the Antarctic, and fuel consumption was only one-third of that of steam vessels of similar size. She proved that the various anxieties about diesel had been quite groundless.

The owner had two further diesel catchers built the following year. The opinion then was that catchers should have a gross tonnage of not more than about 350, to ensure good manoeuvrability, and that the maximum speed should be approximately 15 knots. These two boats had a maximum speed of more than 14.5 knots, were about 360 GT, 139.40×25.26×14.10 ft. (42.50×7.70×4.30 m.), and the engines developed 1,200 h.p. at 210 r.p.m. One of them made a larger catch than any other boat during the 1938 whaling season, in spite of the fact that her gunner did not know the Antarctic.

Increase of boat size and speed

A larger catcher of 456 GT was built in 1941, having a 1,600 h.p. diesel with a maximum speed of about 16 knots.

After World War II, the Japanese whaling fleet was equipped in a short time with 1,600 h.p., medium-speed, four-stroke diesel catchers of smaller size. Almost all of them were of 300 to 370 GT and their maximum speed about 15 knots. These boats obtained fairly good results, but the success of the larger foreign catchers stimulated Japanese owners to order larger vessels, so after 1950, 430, 450 and 470 GT types were built. It was then found that a larger and faster boat made a better catch, and in 1953, catchers of 600 GT and 3,000 h.p., with a top speed above 17 knots, were built.

The main specifications of representative types of Japanese catchers built in recent years are shown in table 163.

At present it is believed that a catcher with a speed of 17 knots in a calm sea will not miss any whale in the Antarctic. But speed is not the only consideration. Finding a rich whaling ground also is important, and this has become more difficult, and mobility and team work of the fleet are of greater importance. While these large high-speed catchers were expensive, they fully satisfied the owners' expectations.

Fig. 723. Seki Maru No. 18 *diesel whale catcher*

New devices on catchers

Parallel to the increased size and speed of the boats, several new devices have been introduced in recent years.

Nearly all Japanese whaling companies now install two diesel-driven generators in place of the steam auxiliaries, and use electric power for the whale winch, steering engine and capstan. The first all-electric system was applied to the *Fumi Maru*, built in 1950 as the first boat of the 450 GT class. This increased the cost by about 20 per cent. but reduced the consumption of both fuel and fresh water; thus the vessel's efficiency was increased by decreasing her dead weight. The most difficult problem was how to use electric power for the whale winch, but an electric winch was designed and constructed which was easy and safe to operate by remote control from the bridge.

In 1951 several improvements were made in the 475 GT class catcher. The flat plate keel replaced the traditional bar keel without impairing the vessel's course-keeping ability. In order to reduce the rolling and improve seaworthiness, and also to increase the percentage of hits with the harpoon, bilge keels were fitted. Some owners feared that the bilge keels would be crushed by the whales, but experience showed this fear to be groundless. The bilge keels were of a double-plated, built-up type: their ends were streamlined so as not to interfere with the harpoon rope. These changes proved successful in the Antarctic and were adopted by all Japanese owners.

The next improvement was the whale echo sounder. The transmitter and receiver were installed in a dome placed at the bottom of the hull. Compressed air was used for setting and retracting the dome, and electric

TABLE 164

Principal dimensions and particulars of the whale catcher ***Seki Maru No. 18***

LOA		ft. (m.)	203.20 (61.95)
LBP		,,	180.40 (55.00)
Breadth moulded		,,	30.83 (9.40)
Depth moulded		,,	16.40 (5.00)
Designed trim		,,	4.92 (1.50)
Sheer, FP		,,	9.51 (2.90)
AP		,,	2.89 (0.88)
Rise of floor		,,	3.94 (1.20)
Radius of bilge circle		,,	7.22 (2.20)
Gross tonnage, GT			647.31
Net tonnage, NT			195.62
Capacities:	Fuel tanks	cu. ft. (cu. m.)	9,959 (282)
	Fresh water tanks	,,	2,401 (68)
Maximum continuous BHP			3,000
Corresponding engine r.p.m.			200
Propeller:	Diameter, D	ft. (m)	11.15 (3.40)
	Pitch, P	,,	8.66 (2.64)
	Disc area ratio, DAR		0.46
	Number of blades		4
Maximum trial speed, knots			17.69

TABLE 165

Draughts and stability of the *Seki Maru No. 18*

		Light load	*Whaling load*	*Full load*
Draught, fore T_f	ft. (m.)	7.51 (2.29)	9.28 (2.83)	10.56 (3.22)
aft T_a	,,	13.64 (4.16)	14.56 (4.44)	16.76 (5.11)
mean T	,,	10.58 (3.23)	11.92 (3.64)	13.66 (4.17)
Trim, excluding designed trim	,,	1.21 (0.37)	0.36 (0.11)	1.28 (0.39)
Displacement	$\Delta_s(\Delta)$	759 (771)	907 (922)	1,125 (1,143)
δ		0.446	0.476	0.512
φ		0.573	0.593	0.618
β		0.779	0.803	0.828
α		0.694	0.738	0.787
KM	ft. (m.)	15.02 (4.58)	15.02 (4.58)	15.19 (4.63)
KB	,,	6.46 (1.97)	7.25 (2.21)	8.33 (2.54)
KG	,,	13.15 (4.01)	12.56 (3.83)	12.27 (3.74)
GM	,,	1.87 (0.57)	2.46 (0.75)	2.92 (0.89)
LCG aft of ⊠	,,	6.66 (2.03)	5.81 (1.77)	7.51 (2.29)
Freeboard, *f*	,,	—	4.79 (1.46)	3.05 (0.93)
GZ max	,,	0.97 (0.297)	1.17 (0.358)	1.06 (0.322)
GZ max. at		32.0°	31.2°	28.8°
Stability range		59.3°	63.4°	64.8°

TABLE 166

Trial results of the *Seki Maru No. 18*

CONDITION

Date	August 27, 1957	Δ	812 tons (825 ton)
Sea condition	Slight swell	L	186 ft. (56.7 m.)
Wind	Light air	S	5,877 sq. ft. (546 sq. m.)
T_f	7.87 ft. (2.40 m.)	δ	0.457
T_a	14.24 ft. (4.34 m.)	φ	0.580
T	11.05 ft. (3.37 m.)	β	0.789
Trim	6.36 ft. (1.94 m.)	α	0.711

SPEED

Engine load	*Speed, knots*	*r.p.m.*	*Slip %*	*BHP*
6/5	17.69	216.1	4.27	3,540
4/4	17.13	199.9	− 0.02	2,730
3/4	16.30	180.1	− 5.88	1,840
1/2	15.10	158.6	− 11.35	1,150
1/4	12.63	127.8	− 15.56	535

TURNING

Initial speed 17.13 knots Helm angle 35°

Turning angle, deg.	15°	30°	60°	90°	180°	270°	360°
Time, sec.: Port	8	12	18	13	43.5	67	90
Starboard	7.5	12	19	24	41.5	67.5	93

		Advance	*Transfer*
Turning circle, diam.:	Port	436 ft. (133 m.)	471 ft. (144 m.)
	Starboard	480 ft. (146 m.)	499 ft. (152 m.)

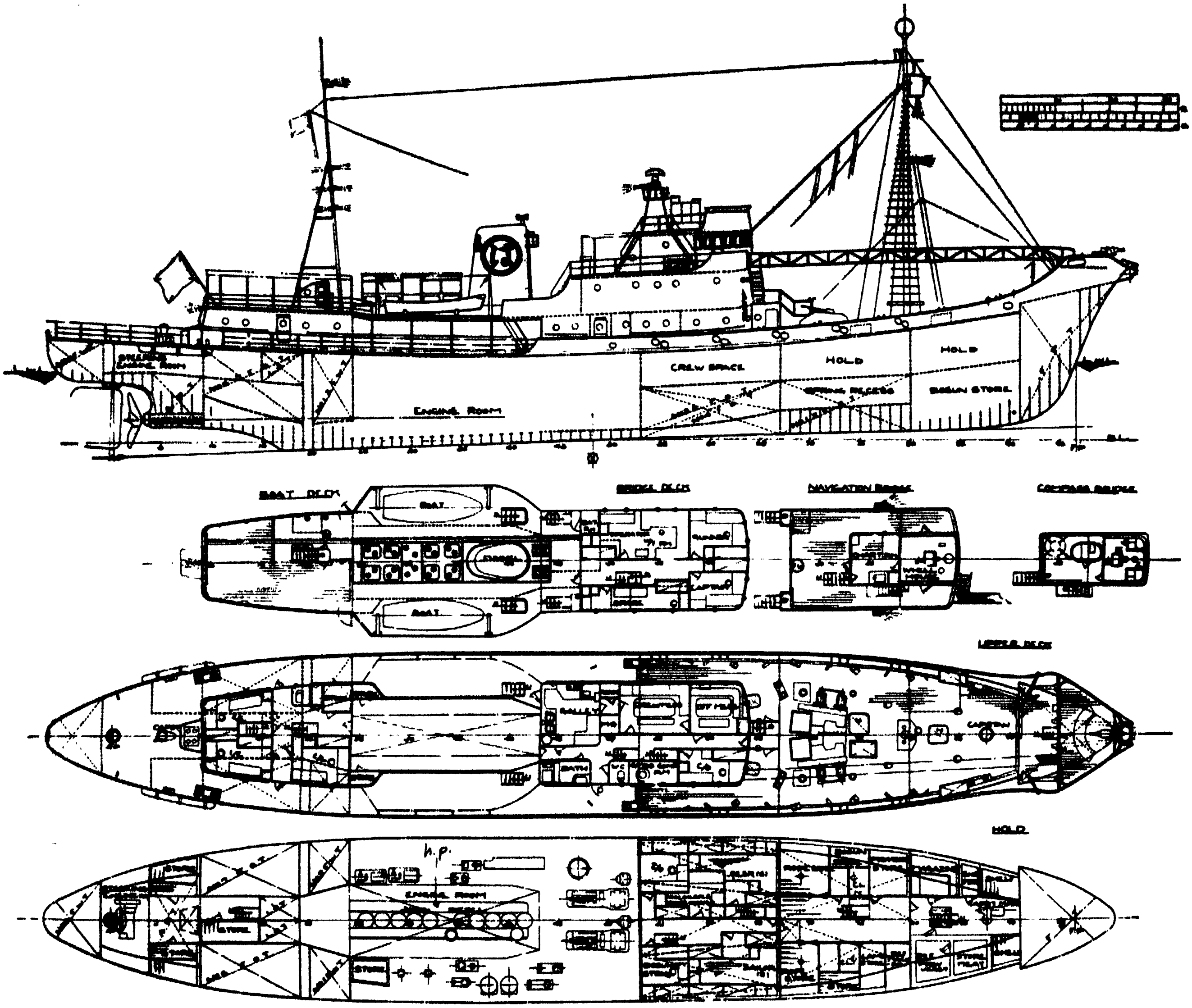


Fig. 724. Seki Maru No. 18. *General arrangement*

motors for turning it. The apparatus was controlled from the bridge, and the operator was able to detect the presence of whales by any of three methods: earphone, cathode-ray tube and recording paper. As the dome could be retracted in a few seconds, it was entirely safe from damage by the harpoon rope. Some British catchers were similarly equipped in 1956. The diesel catcher seemed to be somewhat handicapped in the use of the echo sounder because of engine noise and vibration but this was overcome by suitably training the operator. Once he became familiar with the peculiar tone of the whale the apparatus proved to be very useful.

A friction clutch and a metal brake were added to the steam winch, which was still used in some vessels even after the introduction of the electric whale winch. Some harpooned whales try desperately to escape while being drawn to the catcher, so it is necessary to release the clutch in order to free the warping drums. If this is not done, the excessive tension on the harpoon rope may cause an accident. The conventional gear clutch of the steam winch was unsatisfactory, but the friction clutch and metal brake solved the problem.

A few years ago a controllable-pitch propeller was tried but it reduced the maximum speed, probably because of its comparatively large boss. While controllable-pitch propellers have certain advantages, such as greater towing capacity, they do not justify the high cost involved.

A modern Japanese diesel catcher

The *Seki Maru No. 18* was built in 1957. The main specifications of the vessel are given in table 164, and a photograph in fig. 723.

The vessel has a flush deck, a high raked and rounded stem, a long-stretched cruiser stern and a large overhung rudder, as shown in fig. 724. The bow is designed with due consideration for the harpoon gun, seakindliness in a rough sea, and convenience in handling the whale. The step at the collision bulkhead is so arranged as to reduce the height of the gunner's platform above the deck, the gradient of the fore deck and the distance of mooring holes from the water. Although the bow is well flared, her bulwarks are vertical as far as possible, and accordingly there are knuckle lines at the deck.

The rudder has an ample area of 1/26.8 of the underwater profile of the ship in full load condition. It took the vessel, at full speed, about 20 sec. to turn 90° and about 90 sec. to turn 360°.

Fuel and freshwater tanks are arranged to prevent negative trim in any condition of loading, and to give her positive trim when whaling. The midships fuel tank has three compartments to reduce the free surface effect. Valves are fitted on the partition bulkheads for refuelling at sea.

The living quarters and engine room are ventilated by two reversible axial flow blowers, and there are electric heaters in the cabins, crow's nest and the top of the bridge. A small boiler in the engine room is installed for tank heating and miscellaneous deck uses.

TABLE 167

Principal particulars of the whale catchers

Plot No.	*Gross tonnage*	L × B × D	*Main engine*		*Boiler*			*Main generator*
1 2	451	149.24 × 26.24 × 14.76 ft. (45.50 × 8.00 × 4.50 m.)	Diesel	2,000 BHP 180 r.p.m.	Entirely electrified auxiliaries			DC 180 BHP × 110 kW × 2
3 4	599	173.84 × 30.18 × 16.07 ft. (53.00 × 9.20 × 4.90 m.)	Diesel	3,000 BHP 200 r.p.m.	Entirely electrified auxiliaries			DC 180 BHP × 110 kW × 2
5	648	180.40 × 30.83 × 16.40 ft. (55.00 × 9.40 × 5.00m.)	Diesel	3,000 BHP 200 r.p.m.	Entirely electrified auxiliaries			DC 190 BHP × 120 kW × 2
6	473	157.44 × 27.55 × 14.76 ft. (48.00 × 8.40 × 4.50 m.)	Diesel	2,000 BHP 180 r.p.m.	Scotch	One donkey boiler	8.5 × 8.7 ft. (2.59 × 2.65 m.) 199 lb./sq. in. (1.39 kg./sq. cm.)	AC 75 BHP × 50 kVA × 2
7 8	473	157.44 × 27.55 × 14.76 ft. (48.00 × 8.40 × 4.50 m.)	Diesel	2,350 BHP 190 r.p.m.	Scotch	One donkey boiler	8.5 × 8.7 ft. (2.59 × 2.65 m.) 199 lb./sq. in. (1.39 kg./sq. cm.)	DC 75 BHP × 50 kW × 2
9 10	750	190.00 × 33.00 × 17.50 ft. (57.91 × 10.06 × 5.33 m.)	Diesel	3,500 BHP 180 r.p.m.	Scotch	One donkey boiler	16.5 × 12.5 ft. (5.02 × 3.81 m.) 225 lb./sq. in. (1.58 kg./sq. cm.)	DC 110 BHP × 70 kW × 2
11	720	165.00 × 32.00 × 18.50 ft. (50.29 × 9.75 × 5.64 m.)	Diesel	3,500 BHP 180 r.p.m.	Scotch	One donkey boiler	16.75 × 12.5 ft. (5.12 × 3.81 m.) 225 lb./sq. in. (1.58 kg./sq. cm.)	DC 110 BHP × 70 kW × 2
12	720	165.00 × 32.00 × 18.50 ft. (50.29 × 9.75 × 5.64 m.)	Reciprocating quadruple expansion	2,750 IHP 182 r.p.m.	Scotch	Two main boilers	16.75 × 12.5 ft. (5.12 × 3.81 m.) 225 lb./sq. in. (1.58 kg./sq. cm.)	DC Reciprocating × 20 kW, 10 kW
13	609	160.00 × 31.00 × 17.50 ft. (48.77 × 9.45 × 5.33 m.)	Reciprocating quadruple expansion	2,750 IHP 182 r.p.m.	Scotch	Two main boilers	16.5 × 12.5 ft. (5.02 × 3.81 m.) 225 lb./sq. in. (1.58 kg./sq. cm.)	DC Reciprocating × 15 kW × 2
14	609	160.00 × 31.00 × 17.50 ft. (48.77 × 9.45 × 5.33 m.)	Reciprocating quadruple expansion	2,750 IHP 182 r.p.m.	Water tube	Two main boilers	41.75 in. × 12.5 ft. 29.5 in. × 12.5 ft. (1.06 × 3.81 m.) (0.75 × 3.81 m.) 225 lb./sq. in. (1.58 kg./sq. cm.)	DC Reciprocating × 15 kW × 2
15	544	— × 28.50 × 17.00 ft. (— × 8.69 × 5.19 m.)	Reciprocating quadruple expansion	1,750 IHP 148 r.p.m.	Scotch	Two main boilers	13.5 × 12.25 ft. (4.12 × 3.70 m.) 16.5 × 12.5 ft. (5.02 × 3.81 m.) 225 lb./sq. in. (1.58 kg./sq. cm.)	DC Reciprocating × 10 kW × 2

For anchoring, detachable gypsy-wheels are provided at the outer ends of the twin winch drum. The gypsy-wheel is parallel to the anchor chain line, and the warping drum is nearly parallel to the harpoon rope line; therefore, the winch warps the chain or rope very smoothly. A ladder is fitted on the front of the deckhouse to facilitate communication between the bridge and the winch. As it is convenient for the winch-operator to be able to measure the tensile force of the harpoon rope, a dynamometer is fitted on the back of the foremast. To lessen the wear and tear of the rope, the bow-roller housings, made of built-up steel plate, are covered with brass mouldings. All the roller sheaves on rope lines are of brass, with ball-bearings wherever practicable.

New devices relating to the harpoon gun are the rope-basket and spray-screen. The rope-basket, made of steel bars, is superior to the traditional plate-table, when nylon rope is used, and is fitted just in front of the gun. A detachable folding screen in front of the gunner's platform, protects the gunner from spray. A guide plate at the aft edge of the platform, also one of the new devices, enables the harpoons to be lifted up to the platform from the deck with ease and safety.

The hull is mostly electrically welded. Rivetting is applied only to the lower seam of the bilge strake and the stringer angle. The hull is strengthened for navigation in ice. The stem and stern frames are streamlined and made of cast steel. The thickness of shell plating is increased and fitted with a large number of intermediate frames in front of the collision bulkhead, along the engine room and the bilge keel. The stringer angle is attached under the deck so that seas coming on deck can flow out quickly.

TABLE 168

Comparative table of actual results of diesel-catcher and similar steam-catcher

Classification	Diesel catcher	Steam catcher
Name	*Toshi Maru No. 3*	*Toshi Maru No. 5*
GT	720	
L × B × D	165.00 × 32.00 × 18.50 ft. (50.29 × 9.75 × 5.64 m.)	
Main engine	Diesel 2 stroke 3,500 BHP 180 r.p.m.	Steam reciprocating Quadruple expansion 2,750 IHP 182 r.p.m.
Main boiler		Scotch 16.75 × 12.5 ft. (5.12 × 3.81 m.) 225 lb./sq. in. (1.58 kg./sq. cm.) 2 sets
Donkey boiler	Scotch 16.75 × 12.5 ft. (5.12 × 3.81 m.) 225 lb./sq. in. (1.58 kg./sq. cm.) 1 set	
Main generator	Diesel × 70 kW × 2 110 BHP DC	Reciprocating × 20 kW × 1 Reciprocating × 10 kW × 1 DC
Trial speed, V max.	16.5	15.4
Average consumption taken throughout the whaling season, 1957/8:		
Fuel oil	1,710 gal./day (7,800 l./day)	3,500 gal./day (15,900 l./day)
Fresh water	1.05 ton/day	1.98 ton/day

The vessel has a single-acting, two-stroke, airless injection, 10-cyl., cross-scavenging trunk type piston, self-reversible diesel engine. With a cylinder diameter of 19$\frac{5}{16}$ in. (490 mm.) and a stroke of 28$\frac{3}{8}$ in. (720 mm.), the engine develops 3,000 h.p. at 200 r.p.m.

The engine was designed mainly for the catcher, with emphasis on reliability, simple mechanism and easy handling, and uses the "air-brake" system. This is easily operated by setting the starting handle to its starting position when the fuel supply is shut down. It takes only about 7 sec. to stop the revolving propeller even when the vessel is running at full speed. Each fuel cam, 10 in all, is devised for going ahead and astern, so reversing can be done in a comparatively short time, as it is unnecessary to shift the camshaft.

All the auxiliary machines, including those on the deck, are powered by electricity from either of two generators. These generators are of 120 kW, 250 V, DC, attached to a 7.5 kW, 115 V, AC generator, and are driven directly by a 190 h.p. diesel. The peak consumption corresponds approximately to the full output of one unit, so the dynamos are generally driven alternatively.

Each unit of the twin whale winches is driven independently by a 50 h.p. motor, and its warping speed is variable to suit the load—up to 262 ft./min. (80 m./min.) when there is no load. The maximum load is limited to 20 tons.

The steering engine is of a Rapson-slide type and is driven by a 20 h.p. motor. It takes only about 10 sec. to turn the rudder from hard-over to hard-over at maximum speed.

Table 165 gives particulars of draughts and stability, and table 166 the results from trials.

Comparison of diesel and steam propulsion

It would be theoretically possible to make a very precise comparison of the advantages and disadvantages of these propulsion systems. However, in practice it is difficult because the catch is influenced by various conditions which can neither be calculated nor foreseen, such as the fishing grounds, weather, etc. Also, the cost of operation and maintenance varies a great deal, according to how the fleet is managed by different companies and countries.

The fuel consumption record of Antarctic whaling during 1957 and 1958 did, however, throw some light on the subject. The catchers taken as examples were from the three whaling fleets of the Taiyo Fisheries Co. Ltd., and their principal particulars are shown in table 167. As no steam catchers are built in Japan, the imported ships *Toshi Maru No. 5* to *11* were used as examples of steamers. The *Toshi Maru No. 1* to *3* are also imported steamers, but their engines have been replaced by diesel engines.

Fig. 725 shows the average daily fuel consumption of the main engine of the individual catcher boat. Roughly speaking, the fuel consumption of a diesel catcher equipped with a donkey boiler is only a little more than one-third of that of a steam catcher. Fig. 725 also shows that the fuel consumption of a diesel catcher with electric auxiliaries is approximately one-third of that of the steamers. The fuel for steam engines, however, is of lower quality compared to the fuel required for diesel engines, and thus the difference in fuel costs is not as great as the difference in the amount of fuel used shown in the diagram. However, it must be taken into consideration that with lower fuel consumption less time and labour is needed for replenishment, and thus the total efficiency of the work is increased. Table 168 gives a comparison between the *Toshi Maru No. 3* and the *Toshi Maru No. 5*, the former being a diesel boat and the latter a steamer. The maximum trial speed of the *Toshi Maru No. 3* was 16.5 knots, the *Toshi Maru No. 5* was one knot slower, although using double the amount of fuel.

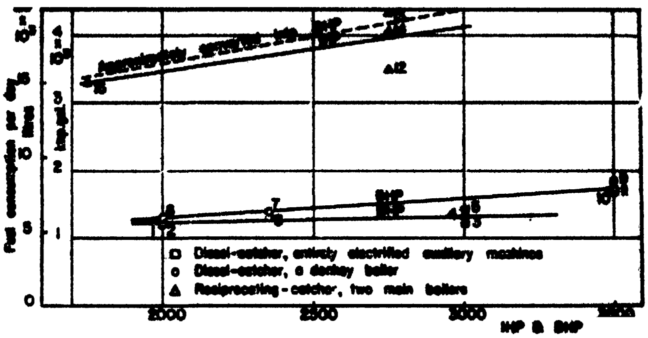


Fig. 725. Average daily fuel consumption of different types of engines taken throughout the whaling season 1957–8

BOAT TYPES — DISCUSSION

SURF BOATS

MR. PAUL B. ZIENER (Norway): He had worked with small surf-landing fishing boats for 15 years in Peru and Chile, and 5 years in India, and had made occasional observations of surf operations in Brazil, Portugal and Norway.

Problems of "surf-landing" should be distinguished from those of beach-landing.

The type of surf depends mainly on the contour of the bottom where the energy of the wave will be dissipated. Three basic surf patterns, i.e. spilling, upwelling and plunging, are shown in fig. 726.

Spilling surf occurs when ocean waves approach shore with unchanged basic wave pattern, dissipating the wave energy gradually over a long distance. The typical spilling surf will calm down to a gentle surge on the beach. It is the least difficult and will normally allow the use of conventional boats.

Upwelling surf is formed when long ocean waves approach a beach rising steeply from great depth. The waves will maintain their characteristics of calm swells right into shore and cause an upwelling of water on the beach, followed by recess of the water masses deep down the beach slope. The problem is that of launching and landing. Any type of boat can be used, provided it can be lifted over the surf; for example by a crane.

Plunging surf is caused by ocean waves gradually building up higher and steeper as they approach shore. The top of the wave, encountering less resistance, will move faster and finally plunge down. A plunging wave will normally break in a water depth equal to its height.

For discussion of surf-landing, plunging surf must be divided into two types: A, breaking at a distance from the shore; and B, breaking on the beach. Plunging surf A is common with a slack and uniform slope of the bottom. As shown in fig. 726, waves will break at a certain distance from the shore, leaving a calm launching zone between the breakers and the shore. As waves will break in a depth approximately equal to their height, the breadth of this launching zone will vary with the height of the waves. The danger zone is from the breakers through a few waves near the breaking point, and the problem here is that of designing a boat that can pass the breaking zone. Plunging surf B has the danger zone close to the beach. The problem here is mainly that of launching and landing.

Combination of surf patterns must also be considered, even if fairly distinct surf patterns prevail. Mr. Ziener had frequently observed a combined plunging/upwelling surf. On beaches with great variation of tides, surf patterns can change with the tides. Local winds can also influence surf conditions considerably.

Varied types of boats

Boat types are naturally influenced by the surf patterns, but not necessarily so. For spilling and upwelling surf patterns, the main problem will be the beaching devices. Where heavy plunging surf occurs, the nature of breakers is important. The craft must be able to pass the breakers during a sufficiently long period of the year to make the fishing a paying proposition. The big breakers are occasionally but suddenly formed when one wave overtakes another. Such "bottom" breakers can become very high in shallow water and have tremendous force, and there is no way of predicting their formation. Their occurrence and intensity vary widely from place to place. They seem to be present to some degree wherever heavy plunging surf occurs and they are the decisive factor for the boat design. Careful planning is therefore needed, including continuous observation over a long period. Records of wave heights, taken once or twice a day, are of no value in this connection.

Mechanized and unmechanized boats of the same type often work side by side, indicating that motorization is not a difficult problem. Small boats for manpower hauling on the beach are generally preferred. Where displacement type boats, not catamarans, have developed, a sheltered harbour is usually within reach.

Boats for upwelling surf

Upwelling surf is mainly associated with hard beaches, such as rocks, pebbles, or hard sand. In this case, the construction of boats is influenced mostly by the kind of fishery, less by landing method, and not by surf conditions. All boats now used have a keel. If they are landed on the beach, but not hoisted, the keel must be strong. The size of the boat varies considerably. The North Norwegian boats and the Peruvian "falucho" are good examples.

Fig. 727 shows a North Norwegian boat type, of which several thousands have been used for commercial and subsistence fishing on surf-beaten shores. The way of diminishing the force of the upwelling surf by making a narrow landing canal from the main shore is shown on the sketch at the right. A few hundred boats are still in use, some motorized.

Fig. 728 shows a Peruvian tuna fishing boat. Many such boats fish from a shore so severely surf-beaten by upwelling that they must be hoisted over the beach. They are conventional boats, mechanized. Smaller boats of the same type, unmechanized, are launched on the same principle as the North Norwegian boats, from narrow landing canals or natural coves between cliffs.

Boats for plunging surf A

Plunging surf A is mainly associated with soft beaches such as sand. The typical boat is long and narrow, with flat midship without keel, and very long and sharp bow and stern. All boats are small and their shape is influenced by surf navigation and landing, not by fishing method. The Malabar monsoon canoe, Andhra nava, Tirunevelli boat catamaran, Chilean bongo, and the two-hull catamaran of Polynesia, are all examples of this type. The problem is to pass the breakers with a safety factor to boat and crew equal to that of conventional fisheries.

The log-catamaran shown in fig. 729 solves the problem by passing *through* a breaker with low resistance and great directional stability, and, generally speaking, has a decided

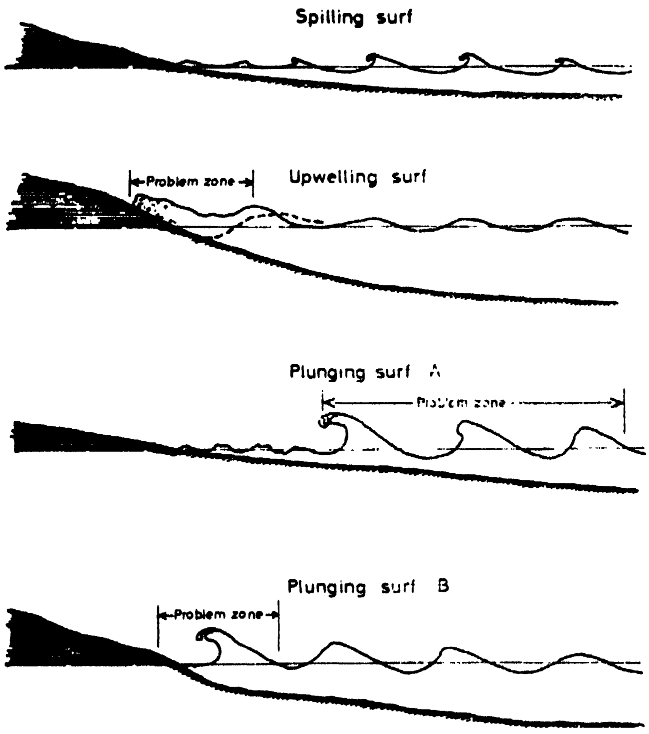


Fig. 726. Each principal type of surf requires a surf boat of a different design

advantage over any displacement boat which must climb the breaker. In a sense, the catamaran is at present the safest craft for heavy plunging surf A. If a log-catamaran is caught in a breaker, as sometimes happens, the logs will hit the bottom with great impact and the ropes will be burst. The crew will through experience jump free of the separating logs and all will be washed ashore. With new rope the catamaran is again ready for use. This is still a minor accident, compared with what could happen to a displacement boat in the same situation, and if the size and shape of the craft were incompatible with the breaker it might be destroyed.

There is a critical size and shape of a displacement boat for a given depth of water and corresponding height of breaker. The preference for relatively small boats with sharp foreship for plunging surf A may be ascribed to this fact.

A displacement boat for plunging surf A designed by Mr. Ziener for India, was shown in fig. 635. The idea behind the design is a very rigid flat keel of teak, on which is rigidly

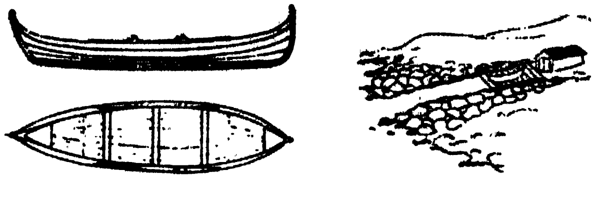


Fig. 727. Surf-landing boat as used in Northern Norway where there is upwelling surf. Boat is 20×5×2 ft. (6.1×1.52×0.6 m.)

mounted stem and stern and engine. Around this rigid structure is swept a very thin clinker skin of springy wood, ½ in. (13 mm.) thick, which can sway and adjust itself to the impacts of waves and when grounding. Construction is simple and cheap. Engine specification 5 h.p. Trials were made with several such boats, with different engines: 3½ h.p. air-cooled diesels were installed in two boats which were tried over a long period. The boats proved entirely satisfactory for plunging surf A within reasonable limits although the 3½ h.p. diesels were rather weak.

Boats for plunging surf B

Plunging surf B on any kind of beach seems to have little attraction for surf-landing, due to its violence. Where attempted only on sandy beaches, the characteristic boat is broad and buoyant, with flat bottom and without keel; it has a broad raking bow and stern and strongly flared sides. The Indian Masula boat and some barges are of this type.

The boat shown in fig. 730 differs greatly from the foregoing types. One outstanding difference is that while the centre of gravity of surf A boats should be placed as far aft as possible, it must in this type be amidships. This is because of the unpredictable directions of surf impacts. Obviously, any kind of outside keel, skeg, rudder or propeller, should not be used.

Plunging surf B is severe and its tendency to dig out and steepen the beach makes things more difficult. Boats must be launched and landed high up on the beach, which means that they must float in the least possible depth of water. Lightness and flexibility of the hull are more important than strength. Launching must be done by manpower, and experience has shown that this is possible with boats up to 2 tons. Retractable propeller and rudder are necessary. It seems practical to use a built-together propulsion and steering unit, hinged on the engine bearers so that, when not in use, it can be tipped up sufficiently to bring the propeller and rudder inside the hull.

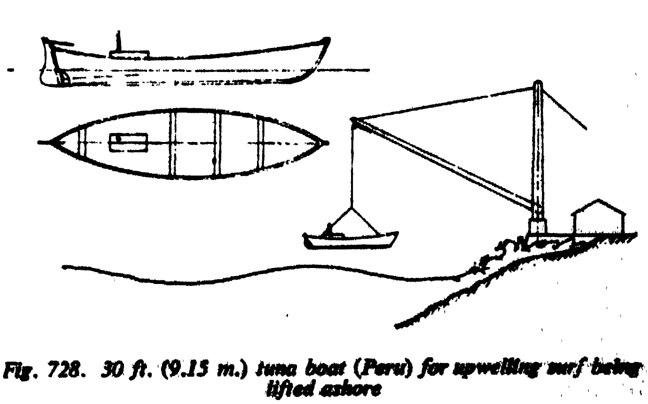


Fig. 728. 30 ft. (9.15 m.) tuna boat (Peru) for upwelling surf being lifted ashore

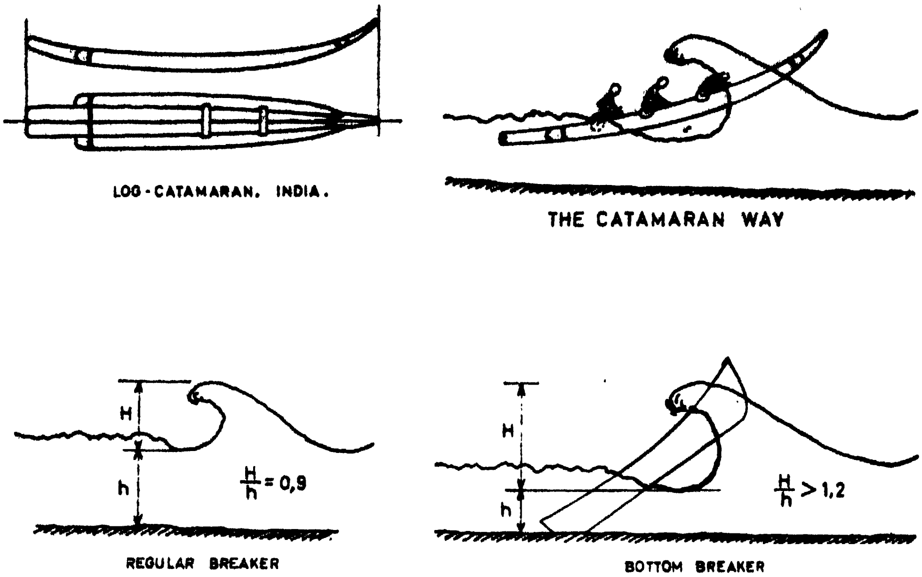


Fig. 729. Comparison of surf passing with raft craft and motorized boats

A boat for the combination of plunging A and upwelling surf is shown in fig. 731, i.e. a Chilean bongo. More than 600 bongos fish on the heavily surf-beaten coast of Central Chile: nearly 300 are motorized with outboards, and a few with inboard engines. They have the characteristic long and narrow shape. The flat bottom ensures safe upright landing. The construction is light and simple as, if a surf boat is of suitable size and form, it does not need to be particularly strong.

Beaching tactics

Beaching tactics are important for safe operation of the boats.

Northern Norwegian boats. These very light boats of 660 to 1,100 lb. (300 to 500 kg.) shown in fig. 727 are launched and landed by their crew only on outgoing and inrushing swell. The wave period is about 10 sec. For landing on wooden slippers, an iron band is used underneath the keel: for landing on pebbles, a wooden keel. The hauling force increases about 40 per cent. if an iron keelband is used on pebbles or rock.

Surfboats, Madras beach, India. The weight of the boat shown in fig. 635 is 1,000 lb. (450 kg.) with engine, and the wave period is 15 sec. Surf pattern is plunging A. The boat is placed low on the beach, bow to seaward, with engine running, and is pushed out on an outgoing swell. It will then navigate under its own power in the calm zone between beach and breakers, awaiting the right moment for going out. When a suitable wave breaks, the boat will give full speed through the calm water that follows and will cross the next wave before it breaks. The principle is thus to avoid the breaker. After crossing a few waves more, the boat is out in calm sea. Landing was found to be easier than launching, as the boat could ride close behind a wave and thus avoid the breaking part of it.

The Chilean bongos shown in fig. 731 are launched by their crew on the receding swell and paddled through the breaker, after which the outboard is swung down and started. Landing is done riding on the breaker with upswung engine. A landing team of six men stands ready in the water, three on each side, and immediately hauls the boat with catch high up on the dry beach, before the next wave breaks. The wave period is 14 to 15 sec. A team can land one boat per minute. Payment is some fish from each boat. Two or three teams are sufficient. Mechanical hauling has been tried, but it was found that no winch could offer the split-second precision required for receiving, steadying and rapid hauling. Manpower was found to be cheaper, faster and more reliable.

Mechanized surf boat operation must necessarily be expensive. Boats must be relatively small for ease of handling, and loading capacity will also be smaller than for similar boats operating from sheltered harbours. There is also a risk of damage or loss that, for plunging surf, rises sharply with increase of height of the breakers. While 3 ft. (0.9 m.) breakers can be considered harmless, a 5 ft. (1.5 m.) surf will

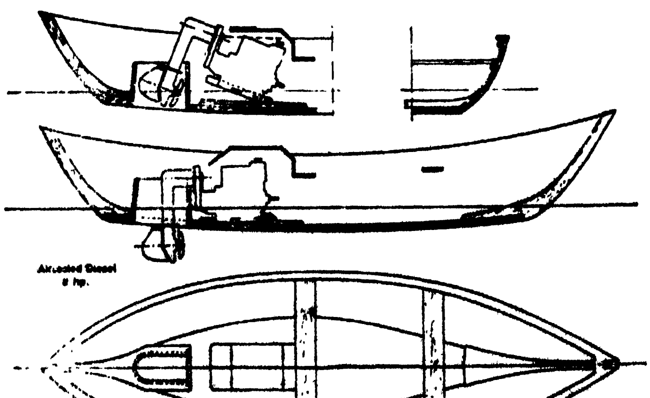


Fig. 730. Indian East Coast Masula beach seine boat with suggested installation of liftable engine. Original boats are used for upwelling surf, type B and a typical size is 24 × 8 × 3 ft. (7.39 × 2.44 × 0.91 m.)

demand substantial investment in high quality craft, and 9 ft. (2.74 m.) breakers cannot be negotiated with any mechanized surf boat in use today.

It is found that hulls are more liable to total losses in case of accidents than the engines. This should be considered when calculating the economic risk. Surf boats must be cheap if they are to be accepted by the poor fishermen of underdeveloped areas. As engine cost is fixed, effort to make cheap boats must be directed to the design of the cheapest possible hulls. The cost of the surf boat in fig. 635 in 1955 was £107 (US$300) for the hull, and £225 (US$630) for the engine, or 32 per cent. on the hull and 68 per cent. on the engine. The same relation applies to other surf boats. To keep the engine cost to a minimum, a reasonably low h.p. should be aimed at. Over-powering should not be necessary if well-designed hulls are developed. If over-powering has to be resorted to in a specific area for forcing the waves, this is in itself a sign that the operation is not safe.

The design of surf boats is a complicated problem which in no case can be looked at as unrelated to a great many operational and local conditions. The interpretation of such conditions is necessary for arriving at the most efficient surf boat designs for a specific surf and fishery.

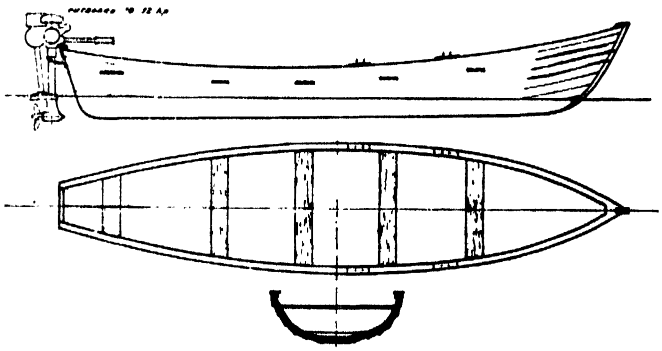


Fig. 731. The Chilean Bongo is a typical boat for a combination of plunging and upwelling surf. This has the dimensions 23 ft. × 4 ft. 8 in. × 2 ft. (7 × 1.4 × 0.6 m.)

Fishing factors come first

MR. HOWARD I. CHAPELLE (U.S.A.): Ziener's classification of surf conditions is, of necessity, an over simplification as he admits. On most beaches there are a variety of surf conditions, depending upon wind, locally or in vicinity, as to force and direction.

In discussions of surf boat design, for fishing purposes, it is important we be reminded that fishing operations come first in requirements of design. Without compliance with this first consideration, the best surf boat is useless for the purposes under discussion. In getting off the beach, with gear aboard for fishing, it seems obvious that weather-and-surf conditions will and do limit operations. As the long history of beach working craft show, it is usually easier to land in heavy surf with a well-loaded boat than it is to get off the beach. Hence getting off is of first importance, to achieve maximum usefulness.

Ziener's examples of surf boats are all small and, except for the Peruvian 30 ft. (9.15 m.) tuna boat, are apparently to be operated without any beach gear, in the most primitive manner. In Mr. Chapelle's opinion, this is not the direction in which mechanized surf-working fishing craft can be developed. There can be no question, of course, that in the early stages of development in a given area, where only the most primitive craft are used, the small motor surf-working boat has a place. Then it can be determined whether the fishery has sufficient economic possibilities to permit further development locally. It may be that, in some areas, the limitations of the small, mechanized surf-working fishing boat must be accepted—but this is not an automatic conclusion in all cases where beach work must be done.

It is obvious that the mechanized beach-fishing boat will cost a great deal more than the local and primitive types in use. This is an inherent difficulty in introducing mechanized boats in this field. It would appear logical, therefore, that the design and construction problems should not alone be factors for study. Beach working equipment becomes a *must* in the development of mechanized beach-fishing boats to overcome their economic handicap in the first stages of development. The weight of the motorized beach-fishing boat alone is sufficient to handicap its usefulness with primitive launching and hauling means, compared to primitive rowing, paddling and sailing craft. If a motorized boat can't get off the beach, and haul, as often as its primitive competitor, it seems apparent that the greater part of the economic advantages of the motorized boat in fishing are lost.

If this reasoning is acceptable it follows that the whole approach to the mechanized beach-fishing boat design must be predicted upon improved launching and hauling means, as well as sound hull and mechanical design. Ziener's discussion is, therefore, of limited value in establishing motorized beach-fishing craft.

MR. E. MCGRUER (U.K.): Regarding Gurtner's surf boat, he mentioned that similar boats used to fish about 40 miles off the Shetland Islands on the 100 fm. (183 m.) shelf edge. These boats were manned by six men at oars, and they could be beached easily. The boats are rather full forward and fine aft. One such boat will be mechanized and the after part will be made somewhat fuller. The idea of the fine stern is that a following sea will not lift it too much. When taking these boats off the surf the propellers should be put to seaward. The propeller should run at sufficiently high revolutions in reverse gear to ensure its grip on the waves of translation. This launching technique followed the principle of the Yorkshire Coble.

DR. K. GOPINATHA PILLAI (India): The development of a surf boat in India became necessary because of the thousands of miles of open coastline and the absence of well developed harbours. It was also necessary because of the population distribution along the whole coastline. He suggested the use of a lifting propeller arrangement as outlined in Inamura and Ninomiya's paper, p.295. Regarding outboards for surf boats, attention should be drawn to the fact that fuel is tremendously costly in India and beyond the means of the ordinary fisherman. The outboard is also too delicate an instrument to be handled roughly by uneducated fishermen.

The power unit

MR. J. M. TITO (U.K.): Little attention had so far been given to the power unit to be put into Gurtner's boat. There are many problems as regards engines, engine weight, cooling, manoeuvrability, but the modern outboard engine should be able to solve the majority of these problems. In order to illustrate the outboard theory, two similar boats were built in the U.S.A., one with a 25 h.p. inboard engine and the other with a 25 h.p. outboard engine. The tests were rather impressive as the outboard powered vessel gave a speed of 7 knots in the loaded condition and 14.7 knots light, as opposed to 5.2 knots loaded and 7 knots light with the inboard engine. There was also more cargo space—322 against 250 cu. ft. (9.1 against 7.1 cu. m.). The cost was £550 ($1,540) against £840 ($2,345) and the manoeuvrability of the outboard powered boat was better, having a turning radius of 30 ft. (9.15 m.) against 100 ft. (30 m.) for the inboard boat. Outboards might also be installed in a well inside the hull if special conditions so warrant.

He said that in many parts of the world the natives' traditional boats are being used with outboard engines.

He could not agree with Gopinatha Pillai's statement that modern outboards were too delicate for illiterate fishermen to handle, since the Authorities in Jamaica, for example, are helping in the financing of outboard engines for the fishermen.

Mr. S. OMeallain (Ireland): He thought there was quite a field for the use of modern outboard engines. Inshore lobster boats in Ireland have for some years used outboard motors fitted on the starboard quarter. They were now trying to develop a boat for use in isolated places, to be fitted with an outboard. This boat had to be light to be beached, as it would be used in very exposed areas. The boat would also have to be very seaworthy.

Experience in India

Mr. D. A. S. Gnanadoss (India): The problem of evolving a suitable surf boat has been a challenge to all those concerned with the development of mechanized fishing industry in India. Several attempts have been made to solve this problem and the FAO has played a notable part in this work. The results obtained so far have been promising and indicate possibilities.

He added a few supplementary comments to Gurtner's paper.

The catamarans, dugouts and other indigenous craft operating from the beaches of India are so built that they will sink or sustain much damage if they capsized. Experience in working the mechanized boats in the surf has shown that any capsizing resulted in considerable damage to the boat and engine. Such mishaps will naturally dishearten the fishermen and put off the progress achieved. Hence this aspect should be taken into consideration which calls for lighter engine and increased buoyancy, without sacrificing working space.

For a surf boat, the air-cooled engine has been favoured for reasons given in Gurtner's paper. The water-tight engine casing necessitated provision of air-ducts which are not always satisfactory.

There is also the risk of the engine getting flooded while crossing the surf. As engine failure at such a critical moment would be disastrous, it is most important to keep the engine working under such extreme conditions without any damage.

It is also of utmost importance that the fishermen who have to work these boats are given necessary training in handling the boats in the surf.

The BB-57, BB-58 and BB-59 mark the progress made and the stage reached in one series of experiment. As Gurtner agreed, these boats are not the final word in the matter.

The surf boat problem is a paradox in many ways. The conditions call for a boat big enough to operate sufficient number of nets to make it economical. The boat has to be light to be handled by a few men on the shore. It also has to be strong enough to withstand natures fury in the surf and all these requirements have to be incorporated in a boat which should not be expensive.

India ranks 8th in the total catch of fish in the world with an annual output of 1.1 million tons of fish and a major percentage of this output is from the thousands of indigenous fishing craft that operate all along the coast of India. The importance of the surf boat problem is thus self-evident.

Gurtner in reply

Mr. P. Gurtner (FAO): In answer to McGruer's remarks he said that he did not believe in launching beach boats stern first. It seemed an illogical thing to do. It would also create new difficulties, should a propeller have to be designed and made that had a better efficiency running at high revolutions astern than ahead. Furthermore, launching stern first through even moderate surf would create serious difficulties with regard to steering. The Shetland "Sixareen" boat looked interesting, and he promised McGruer that he would study the lines carefully. It was said to have finer lines aft than forward; that was probably the reason why stern launching with oars was easier.

He assured Tito that the question of using outboard motors for these beach boats had been considered before. However, he felt that outboards would probably have to be built into a well in these boats. He doubted very much whether a well could be made watertight in a boat which was subject to severe shocks when landing.

Gopinatha Pillai's suggestion regarding retractable propeller gear was felt to complicate the issue, however the technique will be further studied. It might interest him that this propeller gear was treated at some length in FAO report No. 945 to the Government of India on Fishing Boats (FAO, 1958).

He wanted to remind Gnanadoss that extra buoyancy was indeed foreseen for the BB-59 boats in the form of watertight compartments forward and aft.

Ziener's definitions of surf patterns were in close agreement with his own. He would disagree with Ziener regarding the indigenous craft he claims were influenced by the need to pass through surf zones. He suspected that these craft (Malabar canoe, Andhra nava, Tirunevelli boat catamaran and possibly the bongo and two-hull catamaran) are less a development for surfing than rather a first and logical development from the most primitive types, the dugout and the raft.

While it is a fact that with certain craft, mechanization does not offer many difficulties, he would regard Ziener's statement to this effect with some reserve.

He did not agree with the idea that surf-landing boats have to be designed to cope with the outside limit conditions of bottom breakers. It is economically not feasible to design boats for these conditions; surf boats should be designed for moderate surf conditions only, and it is furthermore very unlikely that they would ever encounter such freak bottom breakers if skippered by an experienced man.

It seemed doubtful that a flat bottomed catamaran with very little draught will have superior directional stability when passing surf. Practical trials at the tiller of different boats had taught him the necessity for giving surf boats a good lateral plane for exactly this reason.

While he agreed with Ziener, that surf-going boats should be in a certain size relation to the breakers they have to pass, he felt it would have been a most desirable addition to Ziener's statement if he had included figures for what he considered to be the optimum relation between size and shape of craft and breaker contour. Similarily it would have been interesting to know the limits Ziener's 18 ft 3 in. (5.6 m.) surf boat was intended to operate within.

When discussing beaching arrangements in Chile, the important question is: Two or three beach gangs are sufficient for how many boats?

In his notes on economy, Ziener mentioned clearly the need for planning boats for moderate conditions. It is however doubtful whether anybody would ever attempt to go out fishing with even catamarans when an effective breaker height of 9 ft. (2.74 m.) is apparent. Such attempts would rather be "sporty", as the mentioned over-powering of displacement hulls for forcing the breakers at all cost.

He would like to emphasize once more the need for developing a suitable beach-landing craft, conceived in such a way as to make it possible for the boat to negotiate moderate surf.

SHORT DISTANCE FISHING

MR. J.-O. TRAUNG (FAO, Rapporteur): He said that there were comparatively few papers on small craft at this Congress. As small craft were seldom designed by naval architects there had not been many good papers of this sort offered. On the other hand, many of the papers in the other sections had an important bearing on small boat design, and he drew special attention to the paper by Gillmer. This was a model testing paper, where four small typical craft were shown, and he was sure that many small craft designers would make much use of that paper. Colvin's paper, and naturally the scantling papers, were also important.

Heavy-duty needs raised

MR. JOHN GARDNER (U.S.A.): The enormous recent expansion of pleasure outboarding in the U.S.A. has spilled over into the fisheries. Not a few enterprising U.S. fishermen since World War II have taken up outboard power. While such are often small marginal operators existing on the fringes of the industry, their number is considerable and growing. Just how considerable, and just what the rate of increase is, no one really knows.

Little attention has been paid to the outboard fisherman, that is to his special needs and requirements. The U.S. outboard motor industry, up to now, has ignored the commercial fisherman, concentrating exclusively on the booming and lucrative pleasure boat market.

This is a good start, however, in opening up this *terra incognita* that Beach has made in his paper. His approach, by way of the boats on which outboards are now used for commercial fishing, is well conceived. The building details that he provides will be highly useful in spreading tested designs for a wider trial of working outboards.

It is unfortunate that there is so little reliable performance data as yet available for working outboards. How explain Beach's finding that fishermen seem generally satisfied with outboard performance, appearing to be not interested in the precise details of such performance? This seeming lack of interest may well be at the bottom, lack of awareness of reasonable performance potentials for well-designed heavy-duty work outboards as contrasted to the light, highly-specialized pleasure motors, the only kind available, and the only kind most U.S. fishermen have ever seen or even heard of.

For some types of modern small-boat fishing there is no economic and practicable substitute for outboard power, once it has been used. Any outboard is preferable to no outboard. And the new specialized pleasure outboard is undoubtedly a superior product mechanically. Indeed it is something of an engineering triumph in its narrow, specialized field, limited to the requirements of light, fast pleasure craft. That it is not equally suited to fishing needs might not occur for sometime to enthusiastic newcomers to the dimension of outboard power, whose only alternatives are going back to oars, sail, or to more expensive and cumbersome inboard engines.

Nevertheless there are indications from both coasts of U.S.A., that reveal critical thinking not to say some disillusionment. The most frequent complaint is high fuel consumption. Another is high maintenance costs when motors are operated steadily under hard working conditions, and likewise, comparatively rapid obsolescence. The standard pleasure outboard is a high-speed motor utilizing a small propeller with large pitch driven at high r.p.m. to achieve its rated h.p. As Beach explains in his section on the Florida mullet gillnet skiff, the standard motor equipped with the regular large-pitch propeller cannot deliver the thrust at reduced speeds to push heavy loads.

Besides, responsible spokesmen for the U.S. outboard industry do not deny a genuine need presently existing for a heavy-duty work outboard utilizing a larger propeller of less pitch turning at lower r.p.m., probably under 1,500, and quite likely utilizing reduction gearing. At the same time they contend that the potential demand is too limited to make it profitable for them to produce and to market such a heavy-duty outboard.

With nothing in sight on the domestic market in the way of a work motor, some have begun to investigate the products of European manufacturers. Several heavy-duty European outboards have made good service records in the fishing industry in various parts of the world, but none seems likely to achieve wide distribution in the U.S.A.

In brief, the world fishing industry awaits the development of a new work outboard, that is to say a rugged, economical, heavy-duty engine in several power ranges, one of which must be large enough to meet the requirements of heavy work boats up to 30 ft. (9.15 m.) long. There are reports which indicate that European motor builders are becoming aware of world fishing needs, and that they may soon produce new models aimed for the world market.

One promising suggestion has been made for a heavy-duty outboard powered with an air-cooled diesel. This could be the solution to the economy problem. Previously, when high fuel costs have been thrown up to the outboard people. they have always countered with the truism that fuel must be burned to get power, and that gasoline is expensive.

It is highly significant to note that all the work-boats shown by Beach utilize some type of outboard motor well, except the Garvey, which has a semi-well transom cut-out for mounting the motor. Efficient motor wells are critical for the successful application of outboard power in commercial fishing. The engineering of motor wells is not as simple as might appear, and numerous technical and hydrodynamic problems in this connection remain to be worked out. Up to now, motor wells have frequently been haphazard, makeshift contraptions; nor is it strange that they have frequently worked badly. As a result, motors have been blamed for motor well failures, and further, the choice of boat types for outboard power has been restricted, for without suitable wells some of the best of the time-tested double-end displacement types could not be adapted for outboard use.

Motor well research is badly needed, and some of the

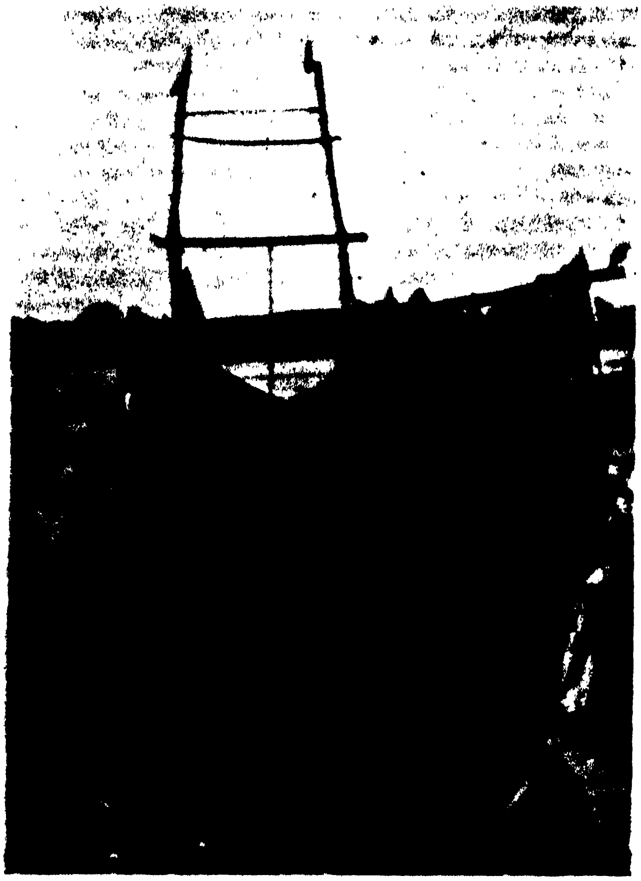


Fig. 732. East Pakistan fishing boats are often painted on the stem showing an " eye " and the picture of a goddess

funds expended on advertising could be more profitably spent by the manufacturers on the engineering of motor wells. As already pointed out elsewhere, motor well units of metal and plastic fitted to the motor, if not integral with it, and designed for easy installation in displacement craft of conventional construction, should have been developed and put on the market by the industry years ago.

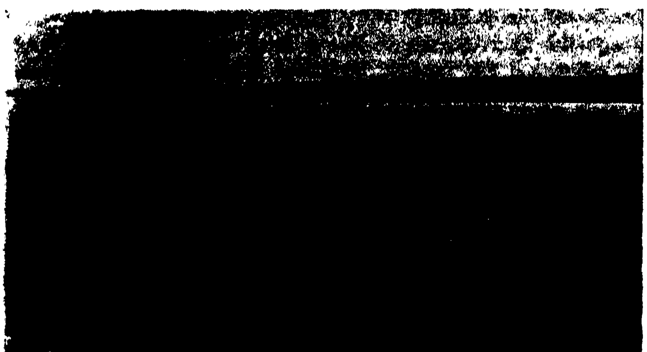


Fig. 733. East Pakistan Modhyam Balam, a typical medium-sized fishing boat on the beach

Dr. M. Rahimullah Qureshi (Pakistan): Only one type of fishing boat, locally called Balam, is operated in East Pakistan. The largest boats, the Bara Balam, are used for long distance transport along the coast, with fishing as a side-line. The Modhyam Balam or medium-sized boats are used for fishing, and the smallest boats called Chota Balam are used for carrying water to the fishing settlements.

Bara Balam is usually 50 ft. (15 m.) in length with a 14 ft. (4.3 m.) beam and 6 to 8 ft. (1.8 to 2.4 m.) depth. The bow and stem are raised, and are painted, sometimes with an "eye" or the picture of a goddess, fig. 732. The bottom is a dug-out from a tree called Gurgeon (*Dipterocarpus spp.*) and above this the wooden planks made from Jarul (*Lagerstroemia flos reginae*) are tied with thongs or "rattan". The mast, also made of this wood, carries a square sail, the top of which is supported by a long bamboo. The deck is partially covered by planks fore and aft, the fore part being

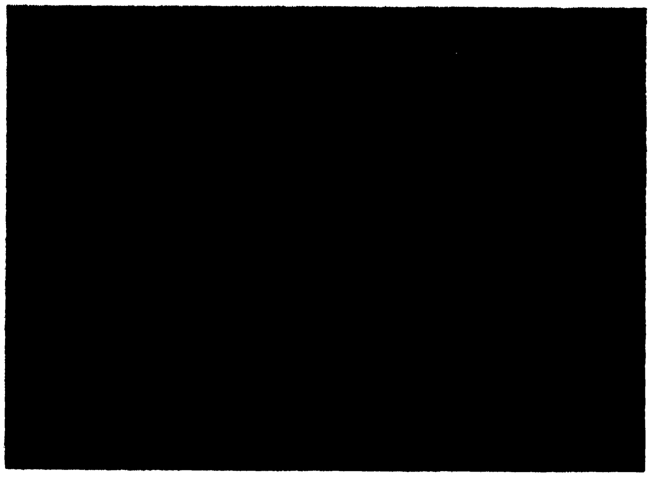


Fig. 734. Two East Pakistan fishing boats sailing

used for storing fish, and the aft for utensils and cooking and for storage of the nets when ashore. A detachable gunwale is fixed when the boat is in operation.

The Bara Balam is manned by 14 fishermen who use oars when the wind or current is unfavourable. This kind of boat usually operates the Behundi Jal or fixed bagnet, which is used in shallow water along the coast, and also the larger stake nets known as Char Patta and Khal Patta operated on the sand banks near the mouths of the rivers. The nets are made of "sunn hemp" (*Crotolaria juncea*) and the stakes are of wood or bamboo. Usually the fish is carried by larger boats which have raised decks and greater depth.

Modhyam Balam are the typical fishing boats, varying from 30 to 40 ft. (9 to 12 m.) in length. See fig. 733.

Construction: The bottom is made up of a dug-out and is planked over. The planks are either tied with thongs or "rattan" or nailed to a height of 4½ ft. (1.4 m.). The boat is strengthened by ribs of Telsur (*Hopea odorata*). A foot behind the bow the boat is decked over by planks of Telsur, a little space being left behind the planking for putting in fish, and a strong wooden beam with a hole being provided to support the mast. Also here the deck is partially covered with planks, and used for storage and cooking and for storing nets when ashore. This portion is covered with woven bamboo for shelter from sun and rain.

The measurements of a boat are:

Length overall, LOA		40 ft.	(12.19 m.)
	LBP	26½ ft.	(8.08 m.)
Beam, B		8 ft.	(2.44 m.)
Depth, D		6 ft.	(1.83 m.)
Mast		18 ft.	(5.5 m.)
Width of the sail		16 ft.	(4.88 m.)
Length of the sail		17 ft.	(5.18 m.)

Some boats of recent construction are built only of planks and have no dug-out bottom. The wood used for the construction is Gurgeon (*Diptocarpus turbinatus*). The cost of such boats varies from Rs. 400 to Rs. 450 (£30 to £34, $85 to $95).

Gear Used: These boats operate gillnets, mostly off the coasts of Chittagong and Cox's Bazaar. The net is made up of sunn hemp twine, each piece being 10 fm. (18.3 m.) long and 18 ft. (5.5 m.) deep, with floats of light wood which is called locally Kura maragas. There are no sinkers. Forty pieces

Fig. 735. East Pakistan fishing boat—construction and internal arrangement

of net are joined together during operations for catching Pomfret (*Stromateus sp.*), less when fishing for Hilsa (*Hilsa ilisha*). The meshes vary according to the size of the fish. The cost of the complete net of 40 pieces is Rs. 1,000 (£75, $210). The nets are tanned with the extract of Goran bark.

The number of fishermen varies between 4 and 6 and the proceeds of the catch are shared amongst them. The fishing season lasts from November till about the second week of March, after which monsoon conditions set in and it is not possible for these flat-bottom, small boats to go out to the sea. See also fig. 734 to 736.

The need for introduction of mechanized fishing boats has been under consideration, in order to extend the fishing period and also to facilitate transport of fish from the catching centres to the ports. Two mechanized boats of 62 ft. (18.9 m.) overall length with 18 ft. (5.49 m.) beam, insulated fish holds and other features as recommended by FAO, are under construction on the beach at Chittagong in order to demonstrate to the boat builders the design of the West Pakistan boats, fig. 737. These boats are expected to be in operation from the November 1959 fishing season. Construction of eight smaller mechanized fishing boats is also being undertaken. If the trials prove successful, it is planned to construct more boats to be handed over to the fishermen on easy terms of payment.

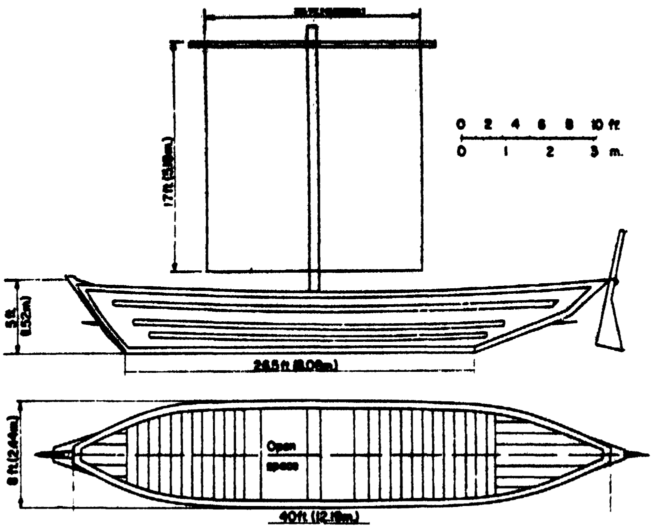


Fig. 736. 40 ft. (12.19 m.) typical East Pakistan boat

Turkish experience

PROFESSOR ATA NUTKU (Turkey): Various kinds of fish pass through the straits of the Dardanelles-Bosphorus and the Sea of Marmara in different seasons. Therefore, the problem is not one of going out to open seas and travelling great distances, since the fish themselves come to the coastal waters.

As trawling is prohibited in Turkey, most of the fishing is by purse seining. Freezing and processing plants are few and of inadequate capacity. Frozen fish is not consumed by the people of the country. Export and exchange difficulties hamper the fishing industry, and the annual catch is therefore limited.

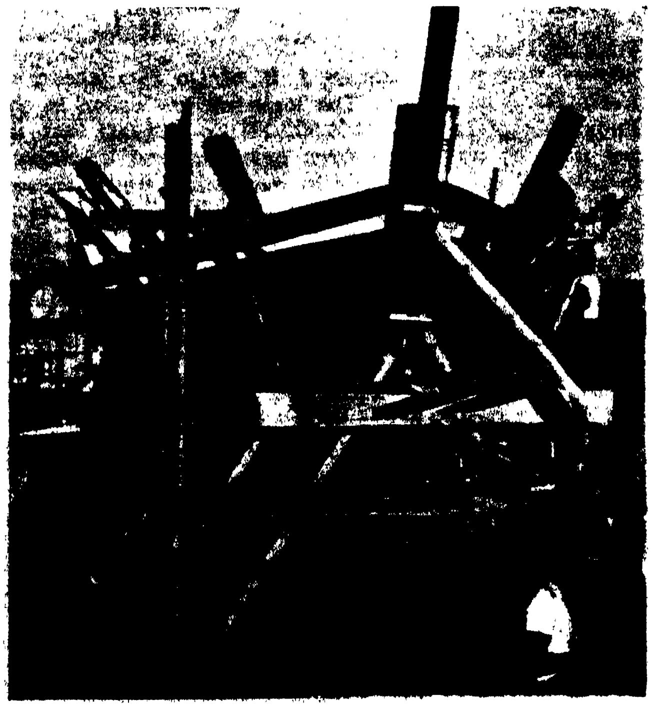


Fig. 737. One of the two mechanized West Pakistan type fishing boats under construction at Chittagong, East Pakistan

Fig. 738. In Turkish purse-seining operations, a large powered boat is used, towing a smaller boat. The boats divide the net between them

Turkish fishing is mostly carried out by private enterprise. The boats are therefore small (40 to 50 ft. or 12 to 15 m.), to be within the reach of individual fishermen. Another reason is that the distances and cruising times at sea are short. Seaworthiness, with respect to wave-length, must, however, be high.

Another important requirement is towing. The large purse seine is partly carried in a long, narrow rowing boat, towed by the power boat. This use of an auxiliary boat is supposed to be economical and more practical than just a single power boat, and with it the handling can be varied considerably. The main boat acts as the searcher, and also serves as a carrier, any surplus catch being carried by a towed boat. This method is adopted generally in sheltered waters, such as the Sea of Marmara and coastal waters. See fig. 738 and 739.

Speed is considered to be important to reach the fishing grounds early and to get the catch to the market before the slower boats. In spite of the higher fuel cost, high speed is considered justifiable by the fishermen, but it results in abnormal powering.

In the Black Sea, where the weather can be extremely unfavourable, beaching is sometimes necessary. The lack of sheltered harbours is another factor demanding easy beaching. This imposes restricted draught, demanding small diameter propellers having low efficiency and resulting in high power. The steep, rugged shores break up the waves, and thus the boats need to be very seaworthy.

What the Philippines do

MESSRS. SANTOS B. RASALAN, J. B. MALIG AND ILDEFONSO LACHENAL (Philippines): The total fish production in the Philippines in 1957 was 855,000,000 lb. (388,000 ton), 65 per cent. of which was from municipal and subsistence fisheries, 27 per cent. caught by commericial fishing vessels, and 8 per cent. from fish-ponds. The landings from municipal and subsistence fisheries were made by dugouts of three gross tons or less, while the commercial catch came from big dugouts, of more than three gross tons, and motor launches. The former are under the control of the municipalities which administer the waters where they operate, while the commercial boats are under the control of the national government through the Bureau of Fisheries and can fish anywhere around the Philippines.

Dugout fishing craft

Non-powered dugouts are propelled by paddles, oars, sails or a combination of these. Some dugouts are power-propelled, the engines being converted World War II surplus power units. Bigger dugouts are equipped with gasoline high-speed engines up to 225 h.p.

The dugouts are constructed from whole trunks of trees, the main species being mayapis (*Shorea palosapis*), tanguile

Fig. 739. In Turkish purse-seining, two boats work together, the larger powered one as searcher and tow boat, the smaller to carry part of the net

(*Shorea polisperma*), red lauan (*Shorea negrosensis*) and white lauan (*Pentacne contorta*) which are light and do not easily crack when exposed to the sun. A log is cut to the desired length and then hollowed out as shown in fig. 740. Outriggers are fitted to make the craft stable in the water. Such types of dugouts are used in rivers, lakes, bays, and in coastal waters for fish corrals, traps, and other subsistence fishing methods. They are also used as auxiliary boats to some commercial fishing vessels.

Handline dugout

Handlining in both shallow and deep waters is one of the most common methods of subsistence fishing in the Philippines.

Fig. 740. Handline dugout from the Philippines

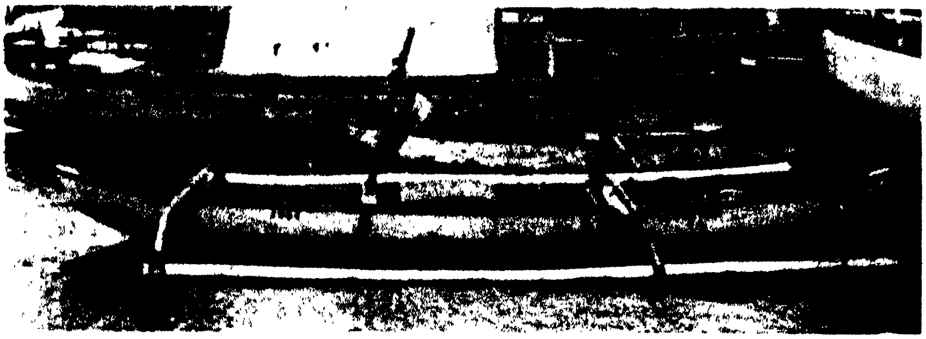


Fig. 741. Baby trawler dugout with outrigger from the Philippines

Sometimes the size of the boat is increased with topside planking. This is done by adding ribs to which the planks are nailed. Alternate ribs are reinforced with crossbars. These dugouts are either powered or propelled by paddle or sail, and one or two men can operate the boat.

Baby trawler dugouts

These are from one-half to one gross ton, generally without a keel, rib frames or side plankings. The depth is increased by the additional wooden planking shown in fig. 741. They have bamboo outriggers on each side of the boat. Although usually deckless, some have a removable deck of wood or bamboo slats. Single-cylinder engines of from 6 to 9 h.p. are fitted, the engine being located about 3 ft. 3 in. (1 m.) abaft the midship section and protected with a wooden cover. Both engine and rudder controls are such that one man can manage the boat.

Basnigan

The stick-held dipnet or bagnet, locally called basnig, is one of the most important commercial pelagic fishing devices in the Philippines. The nets are operated not only by dugout basnigans ranging from 2 to 20 gross tons but also by launches of 30 to 150 gross tons. The basnigan shown in fig. 742 is cut from one log, with the bow more pointed and higher than the stern section. The size and draught are increased with planking, and a bamboo or wooden outrigger is fitted on each side of the boat. There is a bamboo platform on its main section, for stowing and shooting the net. Lamp holders or lighting frames are installed on bow, stern and on the side for kerosene lamps or electric bulbs of 1,000 watts each.

Small basnigans are usually driven by 2 to 25 h.p. gasoline engines and the larger boats by one or two diesel engines of 225 h.p. Generators are installed for electric lighting.

Motor launches

Of the more than 900 motor launches of over 3 gross tons, 60 per cent. are U.S. war surplus P-T (Patrol torpedo) boats, submarine chasers and tugs which were repaired, modified or converted, usually for trawl and bagnet fishing. Locally constructed trawlers, patterned on the West Coast trawlers of the U.S.A., comprise 20 per cent. of the fishing fleet. The remaining 20 per cent. are boats similar in design to the widely used Japanese small carrier, the sampan, which was introduced at the beginning of the 19th century.

Trawler type boat

A typical example of a locally built trawler is the *Southern Lady*, built in 1955, as shown in fig. 743. Its particulars are as follows:

Overall length	80 ft. (24.38 m.)
Length between perpendiculars	70 ft. (21.34 m.)
Breadth moulded	18 ft. 6 in. (5.64 m.)
Depth moulded	8 ft. 8 in. (2.64 m.)
Gross tonnage	70 tons
Fish hold capacity	2,744 cu. ft. (77.7 cu. m.)
Fuel oil capacity	3,798 gal. (3,163 Imp. gal., 14,377 l.)
Main engine	310 h.p., 8-cyl.

The hull is made of best quality timber, 2 in. (51 mm.) thick and 8 in. (203 mm.) wide. The lines were drawn by a local naval architect and were based on the U.S. West Coast trawler.

The deckhouse is located slightly forward from midship and is divided into several compartments, namely the wheel-

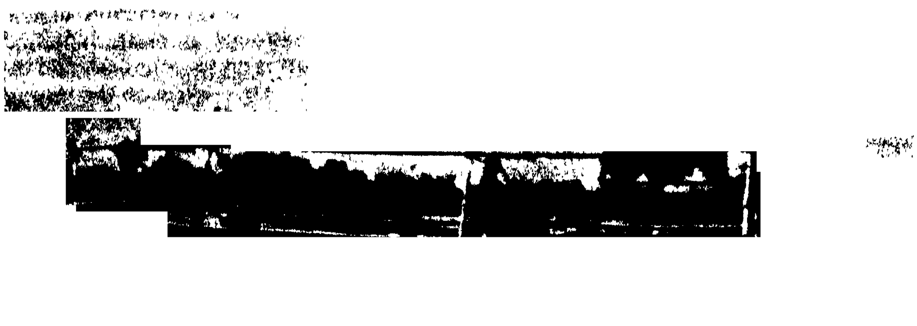


Fig. 742. Dugout for operating the stick-held dipnet or bagnet called basnig

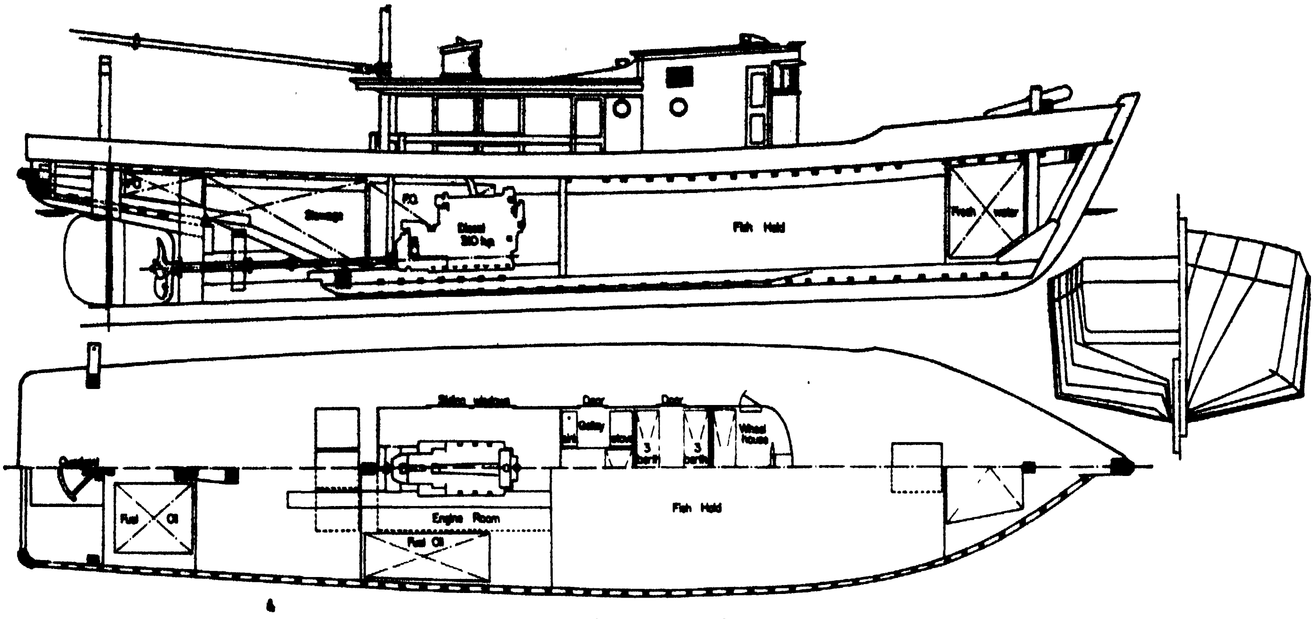


Fig. 743. Filipino trawler based on the U.S. West Coast type

house, officers' berths, crew's quarters, galley, sink and kitchen. The aft is left clear for fishing operations, sorting and cleaning the catch before it is stowed in the fish hold. The foredeck provides a place for the trawl warps when fishing. About 5 ft. (1.5 m.) from the stem are a pair of rollers, one on the port and one on the starboard side, supported by a very thick wooden block fastened and joined to the mooring bitt at the centre and bolted on both ends of the bulwark. About midway from midship to aft is the mainmast fitted with a hauling boom, just above the roof of the deckhouse, which can be swung from port to starboard. Behind the mainmast on both sides of the deckhouse are a pair of drum winches with a common shaft driven by a belt from the main engine. A pair of towing bitts are on the port and starboard. About 6.5 ft. (2 m.) from the stern are stanchions or inserted L-posts, one on the port and another on the starboard side, which are closely built to the gunwale. 2 ft. (0.61 m.) below the stanchions are the cleats, on both sides, to keep the trawl warps free from the propeller shaft.

P-T type boat

A typical P-T type fishing craft, shown in fig. 744 is the *Basnig* which is now under construction with the following principal dimensions and characteristics:

Overall length	99 ft. (30.18 m.)
Length between perpendiculars	90 ft. (27.43 m.)
Breadth moulded	20 ft. (6.10 m.)
Depth moulded	9 ft. 10 in. (3.00 m.)
Average draught	6 ft. (1.83 m.)
Gross tonnage	100 tons
Fish hold capacity	3,950 cu. ft. (111.85 cu. m.)
Fuel oil tank capacity	5,050 gal. (4,205 Imp. gal., 19,116 l.)
Main engine	twin diesels of 225 h.p. each
Auxiliary engine	driving an electric generator, 110 V. DC, 50 kW

The V-shaped hull and high freeboard make the boat suitable for Philippine climatic conditions. Local operators who have tried and tested this type of fishing boat have appreciated its performance, stability and seaworthiness, so new ones are being built locally on similar lines but with a slightly modified deck arrangement. An added feature is the bridge deck. It has been noted that the building cost of this type is about 10 to 20 per cent. lower than the round-bottom boat of the same size and materials.

The hull is made from 2 in. (51 mm.) thick planking and and 3 in. (76 mm.) thick frames of first-class timber throughout. The lines and general plans were drawn by a Filipino naval architect.

The deckhouse shown in fig. 744 is built low and slightly aft of the main deck. The coaming is extended almost three-quarters of the ship's length forward but leaves enough working space, and the afterdeck is left clear for fishing operations. The deckhouse is composed of: locker, officers' room, bunks, crew space and living quarters, hatch and galley. Midway between amidship and stern are a pair of drum winches, one on each side of the cabin and driven by an engine, through a shaft, mounted on the deckhouse. The mainmast is on the afterdeck and there is another mast on the foredeck. Two rollers on the bow are used to operate the anchors. Below the mooring bitt there are three hatches giving access to the fish hold. Two towing bitts, to port and starboard, are fitted close to the gunwale on the afterdeck. The net platform is at the stern. The wheelhouse, chart and radio room and four bunks are on the bridge deck. This type of fishing craft can be operated as an otter trawler as well as a basnigan.

Combination trawler-basnigan

A typical example of a trawler-basnigan is *Marcel VII* as shown in fig. 745. This is a converted submarine chaser and has the following principal dimensions:

Overall length . . .	99 ft. 2 in. (30.23 m.)
Length between perpendiculars	87 ft. 6 in. (26.67 m.)
Breadth moulded . .	. 21 ft. 2 in. (6.45 m.)
Depth moulded . . .	. 12 ft. 8 in. (3.86 m.)
Gross tonnage	. 100 tons
Main engine . .	225 h.p. marine twin diesel

The peculiar features of the boat in fig. 745 are a comparatively low deckhouse which almost fully occupies the main deck from amidship to the bow, a clear foredeck and a clear space aft. The wheelhouse is on the bridge deck, and below it are the living quarters, followed by a galley located to starboard, and a winch engine room at the port side. Immediately behind the base of the mainmast is a winch or net hauler, and the space aft is the fish sorting stall. This stall has a strong roof which serves as a net storage platform.

The boat when used as a trawler has stern towing bitts on the starboard and port quarters. A pair of T-frame davits on the stern and a collapsible rectangular brailing frame, installed well abaft the afterdeck, are used for securing the trawl boards, hauling the main towing warps and for brailing the catch.

When used as a basnigan, the boat is rigged with a special framework of masts and booms for lowering and hoisting the bagnet. This is made of poles, arranged along the wall of the deckhouse, and with suitable tackle for handling the bagnet.

Sampan

The *Galadgad II* is a typical sampan type of fishing boat as shown in fig. 746 with a low freeboard and round bottom hull. It has the following principal dimensions and characteristics:

Overall length	75 ft. (22.86 m.)
Length between perpendiculars	63 ft. 4 in. (19.30 m.)
Breadth moulded . .	15 ft. 6 in. (4.72 m.)
Depth moulded	. 7 ft. 7 in. (2.31 m.)
Average draught	. 6 ft. (1.83 m.)
Main engine	. 2-cyl. 80 h.p.
Auxiliary engine	. 7 h.p.
Electric generator	3 kW
Fuel oil capacity .	1,540 gal. (1,282 Imp. gal., 5,829 l.)
Fish hold volume. .	1,458 cu. ft. (41.28 cu. m.)

Constructed from first-class Philippine wood, sampans vary in length from 60 to 85 ft. (18.29 to 25.91 m.). The

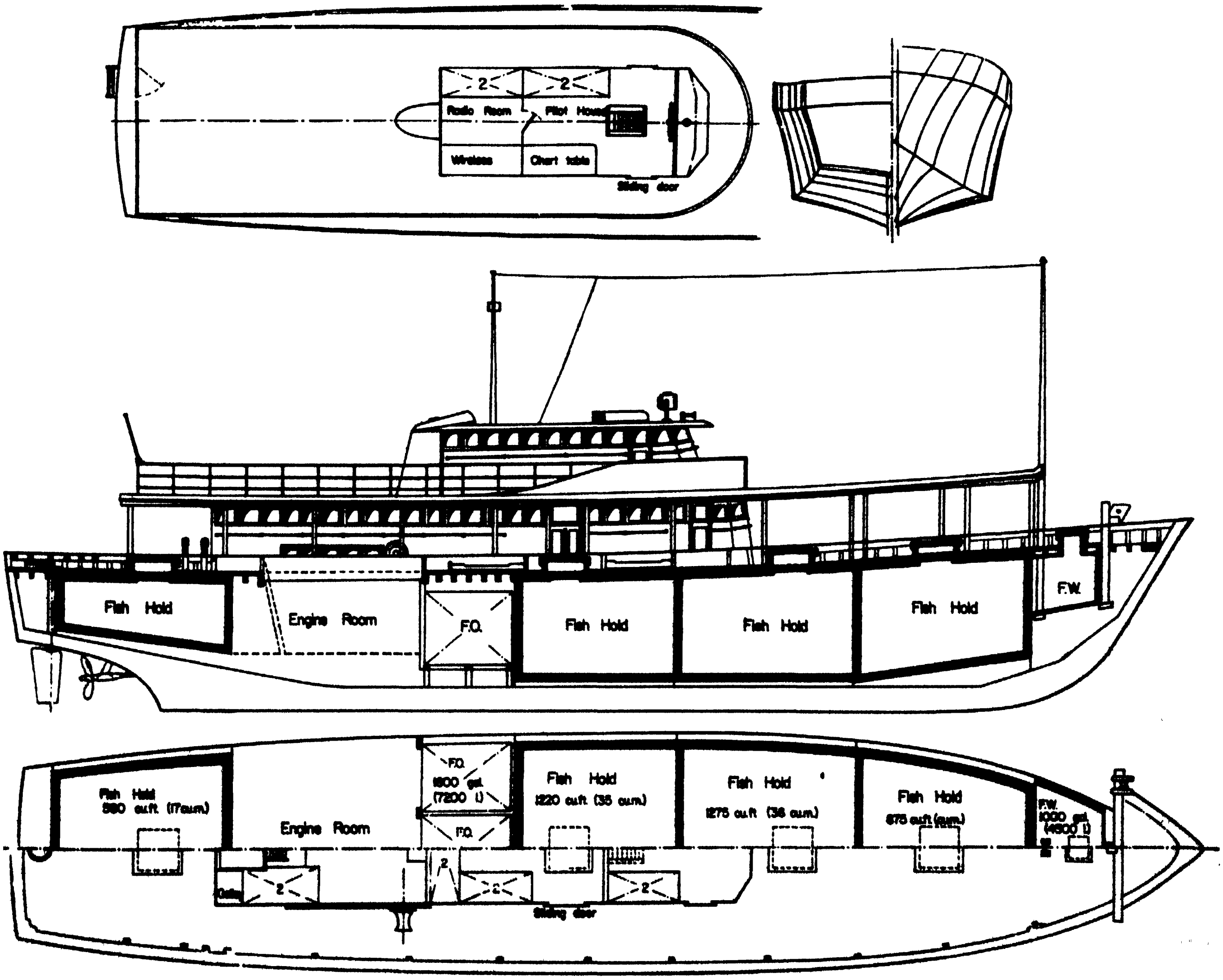


Fig. 744. Filipino fishing boat for operation of the basnig, a stick-held dipnet, and trawls. The hull is based on wartime patrol torpedo-type hulls

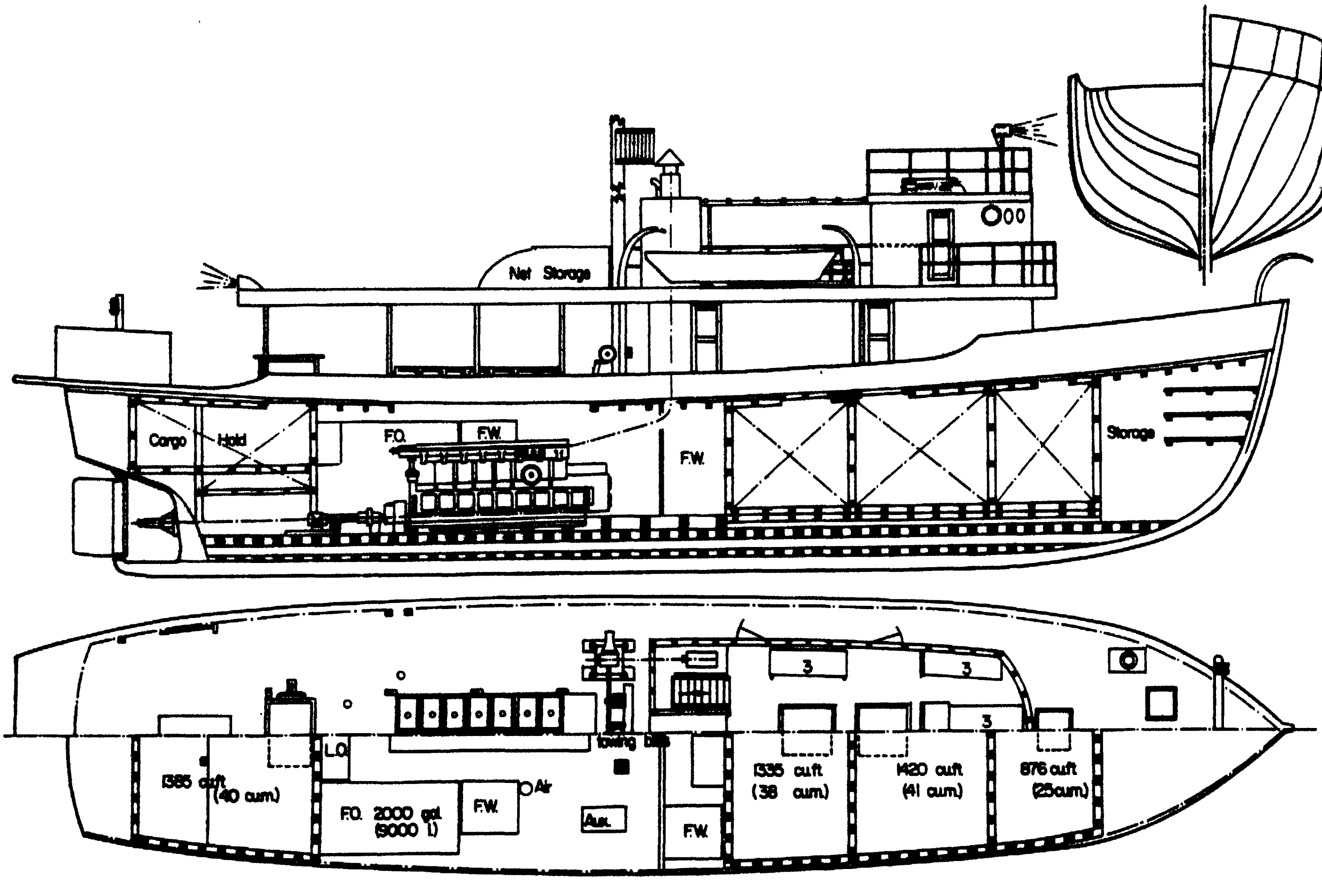


Fig. 745. Filipino converted submarine chasers for basnig and trawl fishing

deckhouse is on the afterdeck which takes the pilot's room, crew's quarters, and the pantry. Below the deckhouse is the main engine. The auxiliary engines used are of the 2 to 3-cyl. hot bulb types.

The boat is so rigged and arranged that it can easily be converted to basnigan, trawler, and other fishing methods, depending upon which fishing is most profitable at the time. There are one or two insulated fish holds and a pair of collapsible masts, one aft and the other on the forward deck. Two drum winches behind the wheelhouse, driven from the main engine with a belt and gears, are used for hauling the trawl, towing warps and the anchor. Wooden stanchions aft hold the otter boards.

Conclusions

The lack of qualified naval architects, technically trained boatbuilders, and marine engineers may be one of the factors which retard the development of deep-sea fishing in the Philippines. Boatbuilding and repairing are mostly done by boat carpenters who have limited training in naval architecture and marine engineering, hence their products are not always seaworthy and are below the standards of other fishing nations. These boats can only be operated successfully in coastal waters and between islands not far from the shore. In the open sea, especially where it is rough, they do not possess the required stability and seaworthiness. Too powerful engines are sometimes fitted in inadequate hulls in the desire to get to and from the fishing grounds speedily, but this adds considerably to maintenance costs.

To improve deep-sea fishing in the Philippines, the services of qualified naval architects are urgently needed to assist the country's fishing boatbuilders.

Canoes in Papua and New Guinea

Dr. A. M. Rapson* (Australia): A variety of vessels is used in New Guinea. Information on the purpose, method of construction etc. of the larger types is as follows:

Single-hulled vessels

(1) Simple log dugout. This is used for river work—best developed in the Sepik—and is a quite seaworthy craft. A variety of designs is used although some are simply hollowed logs. Others have a sound basic structure in both stem and stern, and hull design. Some are large and are not used unless a minimum crew of over 30 is available as paddlers.

(2) Simple outrigger with one or more planks built above the hollowed log. This is probably the most common type of vessel used. Such vessels are used for transport in villages

* Prepared jointly by officers of the Division of Fisheries of the Department of Agriculture, Stock and Fisheries of the Papua and New Guinea Administration, Port Moresby, Papua, Australia, under the direction of Dr. Rapson.

built over the water, as fishing canoes and for transport over considerable distances along the coast. The smallest canoes may be 6 to 10 ft. (1.8 to 3 m.) long for children and one-man canoes, up to the largest of over 60 ft. (18.3 m.) long. These vessels are often decked so that they are seaworthy to a high degree and there is a platform, sometimes more than 2 ft. (0.6 m.) above the water level, permitting people to sit comfortably and to carry articles which would become wet if put into the hull of the vessel. Some canoes are dry sailers and in this respect many are superior to some European vessels of comparable size.

(3) Built-up log. A great part of the construction of the hull is built up from a keel-type structure which is basically a hollowed log. These are deep-sea canoes and are found at Manus, D'Entrecasteaux, Ali Islands and Ninigoes. They can make extensive trading journeys comparable to those made by European-type vessels built for trading.

(4) The Mona. This is a built vessel used at Buka Island, Bougainville. It is very light and will hold 25 men, although it can be carried by four men. The vessel is never sailed but is always paddled. It is essential for fishing in calm seas and is used particularly in pole fishing for tuna.

Multi-hulled vessels

The structure is basically similar to (2) except that the second or third hull replaces the outrigger. Greater stability is achieved and the vessel is completely decked over, which makes it extremely seaworthy.

The Lakatoi is simply a treble-hulled canoe. The name implies transport by three hulls. It is built up from the basic log with sometimes several planks and the decking is sometimes a considerable height above the water. For river work, however, Lakatois are built low and the platform gives extensive—long and wide—living space. Four hulls are also used in Lakatois.

A 48 ft. (14.7 m.) double-hulled canoe has been known to carry, in recent times, 13 tons of cargo. Motor trucks and comparable cargoes are carried by these vessels for considerable distances along the coast.

General use of vessels

The big Sepik single-hulled canoes without outriggers have been known to carry 50 men and the biggest seen recently are about 62 ft. (18.9 m.) long, requiring 35 men as a crew. In recent times, the biggest canoe of which there is a record, travelled from Rabaul to Madang with 138 men. This was an outrigger canoe about 60 ft. (18.3 m.) long. The vessel was over 6 ft. (1.8 m.) high from the floor of the hull to the gunwale. It is recognised that this was a considerable feat and the information about the vessel was carefully recorded. The hull was so big that a man standing in the bottom could not see over the canoe. On a voyage from Rabaul to Madang

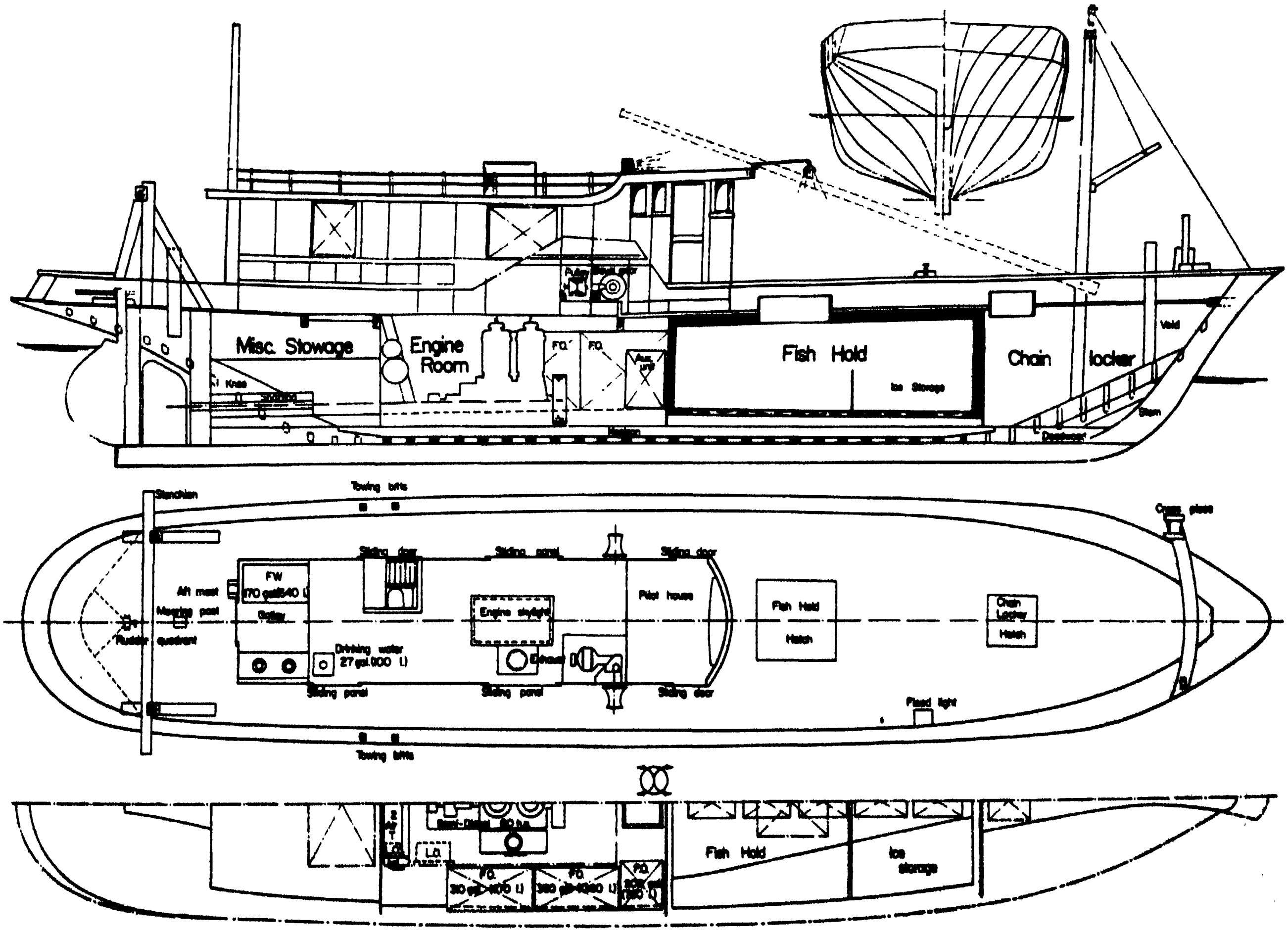


Fig. 746. Sampan type fishing boat for basnig, trawl and other fishing methods

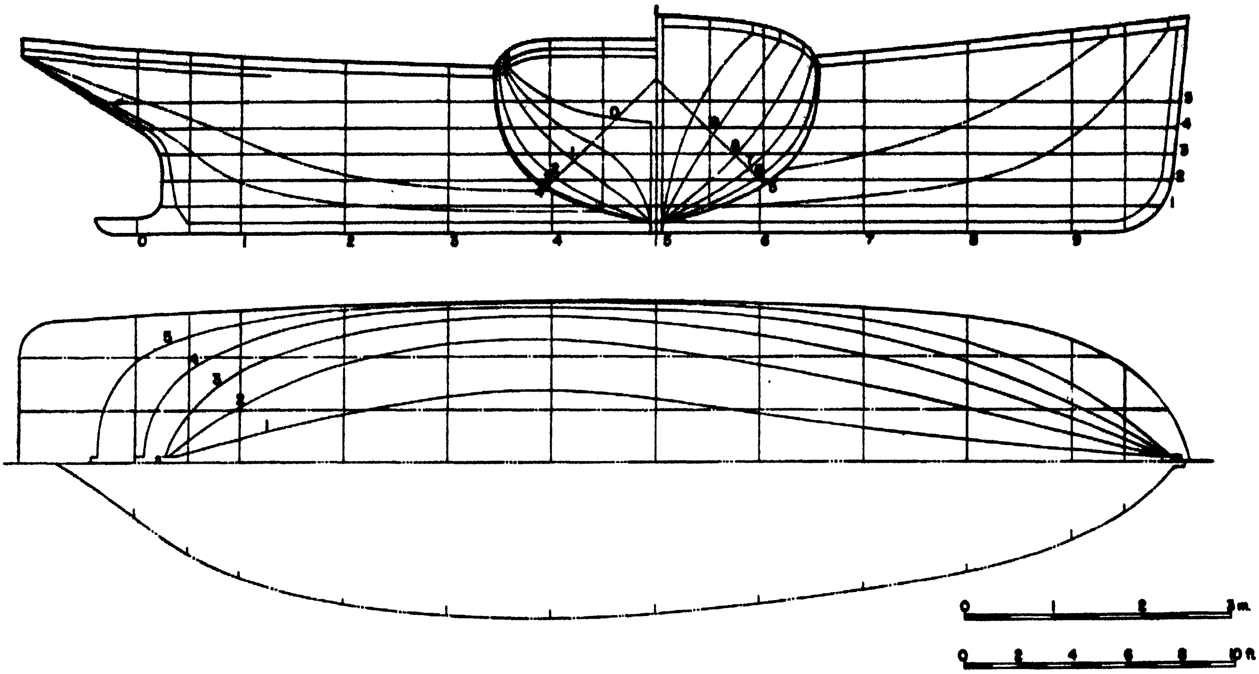


Fig. 747. Lines of a typical small Argentine fishing smack

via Manus, the canoe was attacked by a number of smaller canoes. The attackers were repulsed with bows and arrows and several of the attacking canoes were actually run down. There was difficulty in navigating because the crew were not experienced and in bad wather were not able to handle the vessel satisfactorily.

Motive power

(1) By poling—efficient in shallow water.
(2) Paddles—for light canoes, satisfactory for short distances.
(3) Sails—crab-claw type of sail of Pandanus matting, or of coconut fibres made from the sheath at the base of the fronds, sown together—now rarely seen.
(4) Sawn leaves—inefficient and difficult to change course —the sail was "nursed" along and not the boat—rarely used.
(5) Canvas as used today—efficient, and changing course is quite a pretty operation. Vessels sail well into the wind and are able to sail before the wind up to 21 knots.
(6) The outboards—still in their infancy and not wholly recommended. Satisfactory for some river fishing in simple dugout types of vessels—difficult to install in multi-hulled vessels. Not suitable on south coast of Papua, except for short periods in doldrums.

Caulking

Natural resins are often used, and sometimes quite complicated manufacturing processes are employed. Seeds which produce a fibrous putty-like substance with oiliness and setting quality of putty are used. In the Gulf it is interesting that canoes are built in such a way that the buttocks of a man fit the shape of the stern and this acts as the stern of the vessel when packed with a special type of mud. Such vessels are often easily bailed by a sudden movement of the ship forward, which permits water to flow through the low stern.

Materials used

Timber commonly used for canoes is a softwood, Ulimo, of Papua, which is called Erima in New Guinea. Preparation of material for cordage is often complicated; special vines are used and these are treated with preservatives which keep the cordage in good order for many months. This is necessary when voyages are of long duration. There is a traditional trade in logs for other produce in Bogeia Island, Manu Manu and many other places; and Moresby to the Gulf of Papua was once a recognised trading route, trading earthenware for sago and logs. Such trading routes are common throughout Papua and New Guinea.

Of all the canoes constructed, the most complex is the Mona. It is probably more complicated than an ordinary European planked ship. Pieces of the keel and frames are made of special timbers and even special parts of certain trees. Frame materials are from the buttress parts of the tree trunks and are cut to make a fretwork frame extremely light and very strong. Each piece is known by a name for each particular size of canoe.

Well-boats

Mr. H. I. Chapelle (U.S.A.): Small fishing boat design is of far more importance in the fisheries than is generally realised. This is particularly the case with regard to the Fisheries Division of FAO. FAO is engaged in giving technical advice on fishing craft in many areas, and small craft represent the most common problems. In the various steps necessary in developing a fishery, the use of certain features, too often overlooked, in boat design may be indicated. One is the well-boat or smack, to be used for bait or for handling live fish in lieu of icing. This type is still in use in some parts of the West Indies and, with proper design, is reasonably effective in producing usable cargoes. Some 70 years ago, rather extensive study of wells was made in the U.S.A. by Captain Collins of the then U.S. Fish Commission, or Bureau of Fisheries. The reason was that the then rapid expansion of the U.S. fisheries was occurring in areas where icing facilities did not exist, though climatic conditions were unfavourable to the then usual preservation of fish cargoes—wet salting.

Wells consisted of two classes, the truncate-pyramid form, with sloping walls, small at the deck and large at the bottom. Sometimes the walls were brought up to just below the waterline and then suddenly contracted by a step inward, to produce a small trunk upward to the deck hatch. This latter form was used, Mr. Chapelle believed, during the 18th and 19th centuries in Europe. The usual well in North America was of the first description, the rake of the sides being designed to reduce the movement of water in the well and the resulting damage to fish in the well. Circulation in the well was obtained by boring closely spaced holes in the bottom planking between the frames; there was no ceiling plank in the well area. It was considered important that the bottom of the well cover as large an area of the hull bottom as the hull-form permitted. The favoured hull-form was one having strong deadrise and rather deep draught. The holes in the bottom were 1 to 1½ in. (25 to 38 mm.) in diameter in boats under 50 ft. (15 m.) length, 1½ to 2 in. (38 to 51 mm.) in large schooners. The well was protected from sea-borers by zinc paint—copper paint was found harmful to the fish of course. This problem would now be less troublesome for there are now many coatings that would be preferable to zinc paint which gave protection for a very limited time. Mr. Chapelle offered to aid anyone interested in collecting data on the smack type of hull.

In small boat design the V-bottom has become increasingly popular. Though the V-bottom has been long in use—as have the various simplified hull forms (the earliest "modern" simplified hull form of which he had seen a plan in Europe is a British Navy design of 1745–49), records of performance are far from complete. The exploratory experiments of Gillmer are therefore very useful. There are, however, many inefficient V-bottom designs in use—as is illustrated by the large V-bottom gillnet boats shown in Colvin's paper and in the illustrations of Philippine craft. The use of the high chine forward, with full entrance, and with the chine crossing the waterline near amidships must produce an angular shoulder there, which with the full entrance will certainly result in unfavourable resistance characteristics and waste of power. He had found that such designs produce a heavy wave at the angular shoulder, and in rough water, much

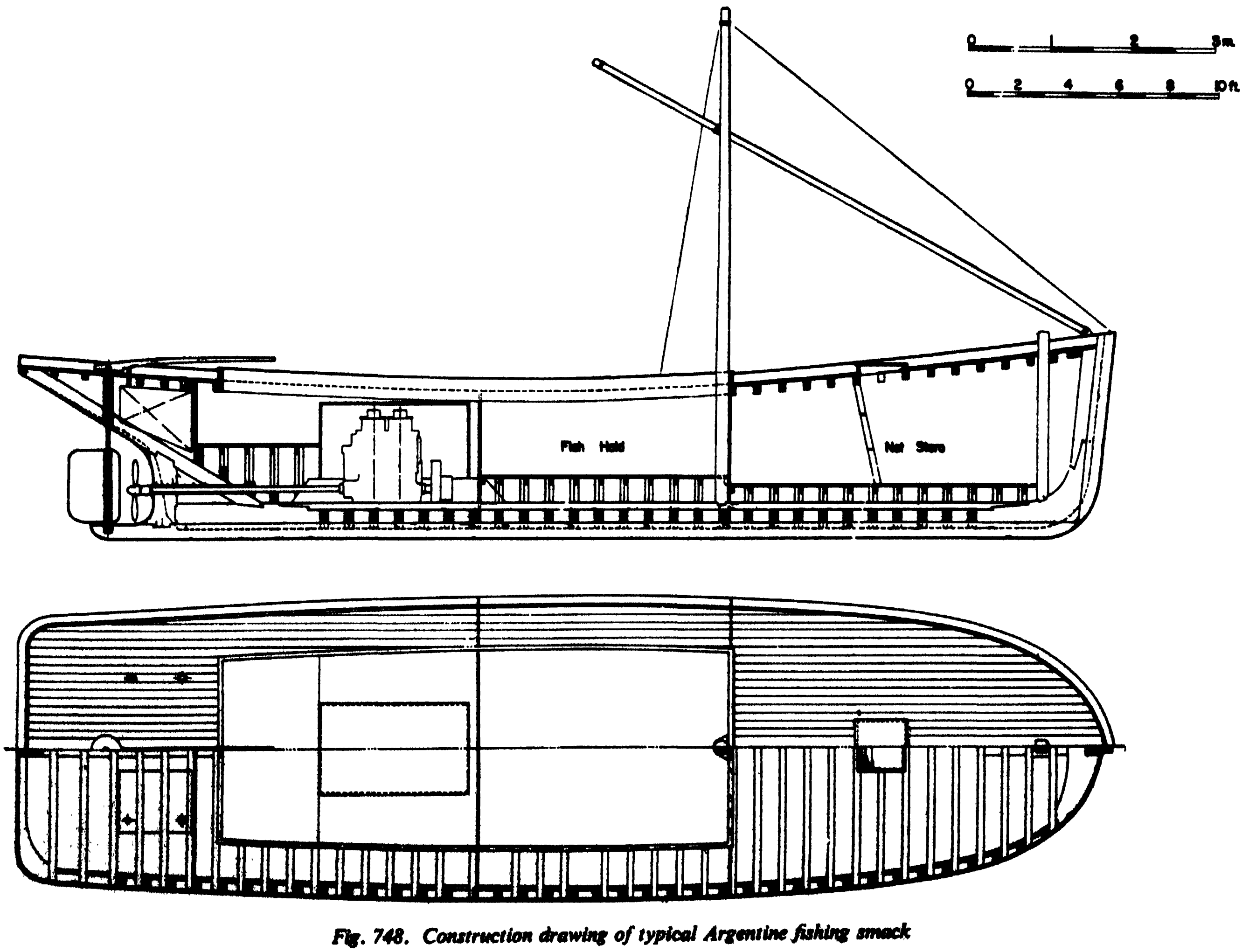


Fig. 748. Construction drawing of typical Argentine fishing smack

Fig. 749. Small Argentine fishing boats for lampara fishing in Mar del Plata

flying spray at the speed lengths common in fishing craft. In freezing weather the spray produces icing—it occurs in most small V-bottoms at the position of the steering shelter or pilot house and the result is icing of the pilot house windows and the complete loss of utility in the designed steering position. More study of the chine models is indicated.

He felt that not enough attention had been given to small fishing boats. However, this is due to the insufficient number of papers in this field that have been submitted. He hoped there should be a more active participation by small craft designers in the next Congress and he promised to bring this to the attention of naval architects in the U.S.A.

In closing, he wished to comment on the preference of V-bottom over round-bottom economically. He did not think this was wholly a logical conclusion. Experience has shown, for example, that it is cheaper to build a round-bottom fishing launch in New England or Eastern Canada than a V-bottom, while the exact reverse is true in Maryland and to the southward. This explains some of the remarks on the cost of simplified hull forms that have been made, for it is a matter of experience—prejudice if one likes—rather than a matter of careful estimate. This was thoroughly examined in the last Fishing Boat Congress and needs no further discussion now.

TABLE 169

Main specifications of Argentine fishing smack

Length overall, LOA	ft. (m.)	43.00 (13.10)
Length in waterline, L	„ „	38.00 (11.60)
Breadth	„ „	11.86 (3.62)
Breadth at waterline, B	„ „	10.85 (3.30)
Depth, D	„ „	5.24 (1.60)
Mean draught loaded, T_l	„ „	3.44 (1.05)
Displacement, volumetric, ∇	cu. ft. (cu. m.)	630 (17.8)
Displacement, Δ	tons (ton)	17.95 (18.25)
Block coefficient, δ		0.442
Prismatic coeficient, φ		0.662
Midship area coefficient, β		0.668
Length-displacement ratio, $L/\nabla^{1/3}$		4.43
Half angle of entrance, $\frac{1}{2}\alpha_e$		26°
Longitudinal centre of buoyancy, LCB	ft. (m.)	1.86 (0.569)
Hold capacity	cu. ft. (cu. m.)	283 (8)
Hold capacity/∇		0.45
Fuel tank capacity	Imp. gal. (l)	20 (90)
Engine power,	BHP	80
Estimated speed, V	knots	7

Argentine craft

MR. MARIO SANTARELLI (Argentina): Argentina's long coast has a continental shelf of almost 386,000 sq. miles (1,000,000 sq. km.), equivalent to approximately 35 per cent. of the land area. The shelf has excellent fisheries resources, but they have not been properly exploited. The average catch of fish *per capita* was only 8.8 lb. (4 kg.) in 1957. Approximately 90 per cent. of the catch comes from the maritime fisheries, the rest from rivers, lakes and ponds. Maritime fishing is carried out mainly by trawlers fishing from Mar del Plata and Buenos Aires and coastal fishing boats based in the ports on Atlantic coast mainly in Mar del Plata. Mar del Plata and Buenos Aires receive, respectively, 60 to 70 per cent. and 20 per cent. of total landings. On the Patagonian coast, excluding Rawson, there are no large consumption centres and practically no fishing, and even near such centres as Comodoro Rivadavia fishing is only on a small scale, enough to satisfy local market demand.

Two types of boat are used for maritime fishing—coastal fishing boats and deep-sea fishing boats.

The coastal fishing boats are based at Mar del Plata, Necochea, Bahía Blanca and, temporarily, at Rawson. They number about 350, of which about 220 are based at Mar del Plata. The nets used are trawls, surface seines with lights (lampara), gillnets, longlines, pole and line, and traps.

Overall length ranges from 30 to 60 ft. (9 to 18 m.), the majority of the boats being between 39 and 43 ft. (12 and 13 m.). These boats have wooden hulls, of 6 to 40 GT, and are powered by diesel or semi-diesel engines of 30 to 150 h.p. The high powered ships have high-speed diesel engines of 1,500 to 2,000 r.p.m. with a reduction gear of 2:1 to 3:1. The boats are built at Mar del Plata, Bahía Blanca, and at

Fig. 750. Argentine fishing smack

Tigre and Avellanada near Buenos Aires, in primitive shipyards and almost always without a plan, although there are some builders who design their boats on the basis of small wooden models which they make themselves. There is no legislation governing design.

These boats have been developed from the sail boats used for anchovy fishing at Mar del Plata early in the century by fishermen from Sicily and Naples. They fished within sight of shore, but as they began to catch other species further offshore, it became necessary to motorize the boats and make them more comfortable and safer.

Coastal fishing boats can be divided into two types—fishing smacks, which comprise about 80 per cent. of the total, and small craft.

Fishing smacks are from 30 to 50 ft. (9 to 15 m.) LOA. The profiles and details of construction of a typical smack are shown in fig. 747 and 748, and the general specifications are given in table 169. Photographs are given in fig. 749 and 750.

The weight of the hull may be estimated at 0.23 ton/ft. (0.75 ton/m.). The hold capacity is between 40 and 150 fish boxes, or 90 to 350 cu. ft. (3 to 10 cu. m.). A box is $2.12 \cdot 1.47 \times 0.76$ ft. ($0.65 \times 0.45 \times 0.23$ m.) in size, is usually made of pine (pino paraná), and has a capacity of 100 lb. (45 kg.) of fish. In some ships, the fish is transported in bulk without boxes, in which case the hold capacity is greater. The volume of the hold is estimated at 45 per cent. of the ship's volume. The holds are not insulated and no refrigeration facilities are installed. The fish is thrown into the hold while the fishing gear is hauled by hand. During the home voyage, the fish is usually packed in boxes which are placed on deck, ready for unloading at the wharf.

The power is 30 to 120 h.p., the trend being towards high-powered engines, which results in smaller hold capacity.

Small craft are now being designed to extend activities into deeper waters where operation is more profitable and trips take from two to three days. The design and structural features do not differ greatly from those of the original smacks. Fig. 751 and 752, and table 170, show one of the latest types of these boats.

The overall length ranges between 46 and 59 ft. (14 and 18 m.). The weight of the hull can be estimated at 0.33 ton/ft. (1.1 ton/m.). These boats differ mainly from the smacks because they have:

- a watertight deck of cedar (lapacho);
- in some cases, a watertight bulkhead;
- accommodation for a crew of four in the bow section;
- a closed pilot house with a small galley and mess;
- radio-telephone; and
- a winch driven by the main engine by means of a belt or chain and two small booms for mechanical hauling of the net.

TABLE 170

Main specifications of small Argentine craft

Length overall, LOA	ft. (m.)	52.40 (16.00)
Length in waterline, L	„ „	47.60 (14.50)
Breadth	„ „	14.60 (4.55)
Breadth at waterline, B	„ „	13.95 (4.26)
Depth, D	„ „	5.24 (1.60)
Mean draught loaded, T_1	„ „	4.53 (1.38)
Displacement, volumetric, ∇	cu. ft. (cu. m.)	1,125 (31.8)
Displacement, ∇	tons (ton)	32.1 (32.6)
Block coefficient, δ		0.379
Prismatic coefficient, φ		0.683
Midship area coefficient, β		0.555
Length-displacement ratio, $L/\nabla^{1/3}$		4.53
Half angle of entrance, $\frac{1}{2}\alpha_e$		31°
Longitudinal centre of buoyancy, LCB	ft. (m.)	0.554 (0.169)
Hold capacity	cu. ft. (cu. m.)	495 (14)
Hold capacity/∇		0.44
Fuel tank capacity	Imp. gal. (l)	110 (500)
Engine power,	BHP	150
Estimated speed, V	knots	8.5

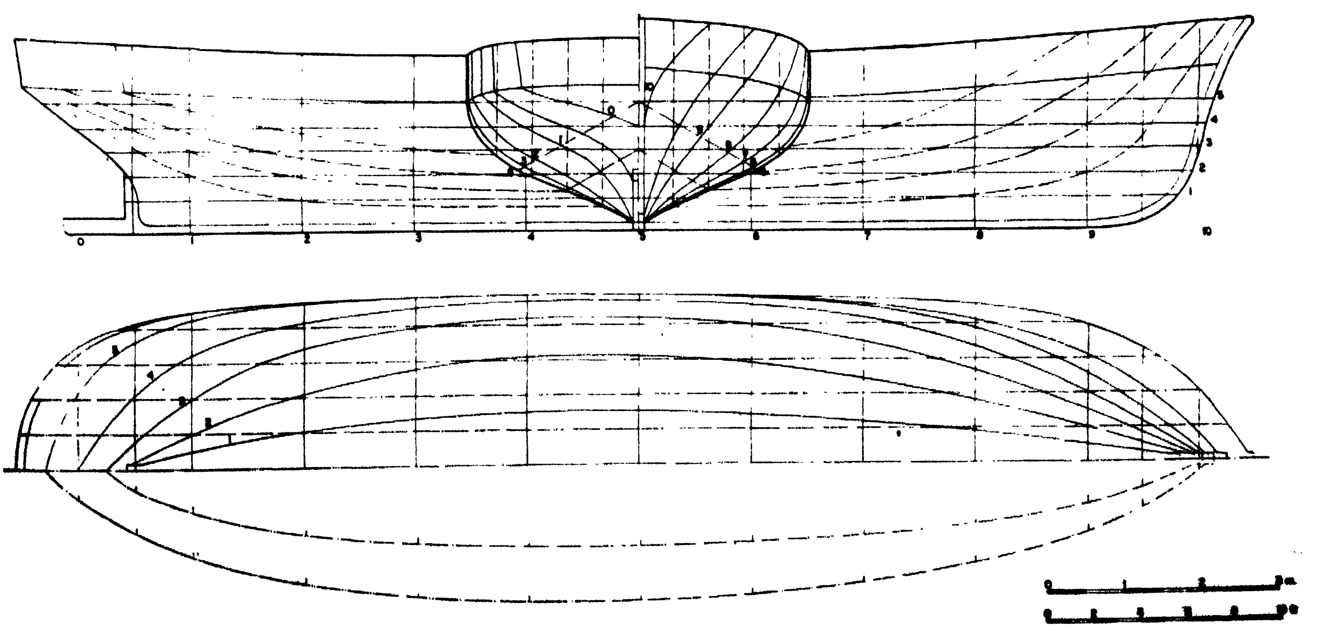


Fig. 751. Lines of modernized Argentine fishing boat for extended operations

TABLE 171

Main specifications of deep-sea fishing boats operating in Argentina

Name of boat	*L* *ft.* *m.*	*B* *ft.* *m.*	*D* *ft.* *m.*	*GT*	*Hull* *Wood or steel*	*Engine power h.p.*	*Hold capacity in boxes 1 box=2.4 cu. ft. (0.067 cu. m.)*	*No. of crew*	*Year of construction*
Jean Pierre	100.30 30.60	21.95 6.70	10.35 3.16	95	Wood	220 BHP	680	10	1948
Nicole	100.30 30.60	21.95 6.70	10.35 3.16	95	„	220 „	680	10	1947
Christiane II	79.90 24.37	21.10 6.44	9.03 2.76	75	„	152 „	580	10	1949
Auguste Nathalie	79.90 24.37	21.10 6.44	9.23 2.76	75	„	167 „	580	10	1950
Gabriel	79.90 24.37	21.10 6.44	9.23 2.76	75	„	167 „	580	10	1950
Luc	79.90 24.37	21.10 6.44	9.23 2.76	75	„	120 „	580	10	1949
Marie Louise	79.90 24.37	21.10 6.44	9.23 2.76	75	„	120 „	580	10	1949
Supremacia I	67.50 20.61	17.00 5.19	6.82 2.08	44	„	125 „	220	6	1949
Abadejo	68.20 20.80	18.45 5.62	7.38 2.25	53	„	150 „	430	7	1947
Cristo de Limpias	98.20 29.95	20.66 6.30	11.30 3.45	130	Steel	160 „	900	12	1885
San Juan Bosco	88.80 27.05	21.80 6.66	10.35 3.15	100	Wood	240 „	580	10	1946
Flandria	140.50 42.80	26.00 7.93	15.65 4.77	270	„	500 „	1,200	14	1947
Luis Alberto	118.60 36.20	23.30 7.11	10.75 3.28	190	„	425 „	1,200	—	1941
Costa Atlantica	112.20 34.23	20.30 6.19	11.45 3.50	170	„	90 IHP	850	12	1940
Capitan Piedrabuena	120.50 36.71	22.60 6.90	11.30 3.45	190	„	350 BHP	920	13	1941
Dalia	67.20 20.47	18.35 5.62	8.00 2.44	56	„	160 „	400	7	1947
Presidente Mitre	179.50 54.80	25.50 7.77	14.32 4.37	372	Steel	600 „	1,800	21	1933
El Plata	137.00 41.74	23.00 7.02	13.12 4.01	235	„	500 „	1,200	18	1906
Corvina	153.50 46.78	22.30 6.80	13.45 4.10	261	„	430 „	1,800	21	1906
Lenguado	130.80 39.90	24.60 7.50	11.80 3.60	215	„	400 „	1,200	20	1916
Besugo	130.80 39.90	24.60 7.50	11.80 3.60	215	„	400 „	1,200	20	1928
Maneco	147.60 45.15	24.00 7.32	14.25 4.35	288	„	650 IHP	1,200	20	1911
Centolla	131.50 40.10	24.25 7.40	12.80 3.90	231	„	450 „	1,020	20	1917
Taiyo Maru 22	150.05 45.75	23.60 7.20	13.30 4.05	304	„	550 „	1,300	24	1946
Taiyo Maru	166.50 50.51	26.90 8.20	14.25 4.35	360	„	850 BHP	2,700	—	1956
Cristo Rey	140.00 42.71	28.10 8.58	14.32 4.37	272	Wood	590 „	1,200	—	1941

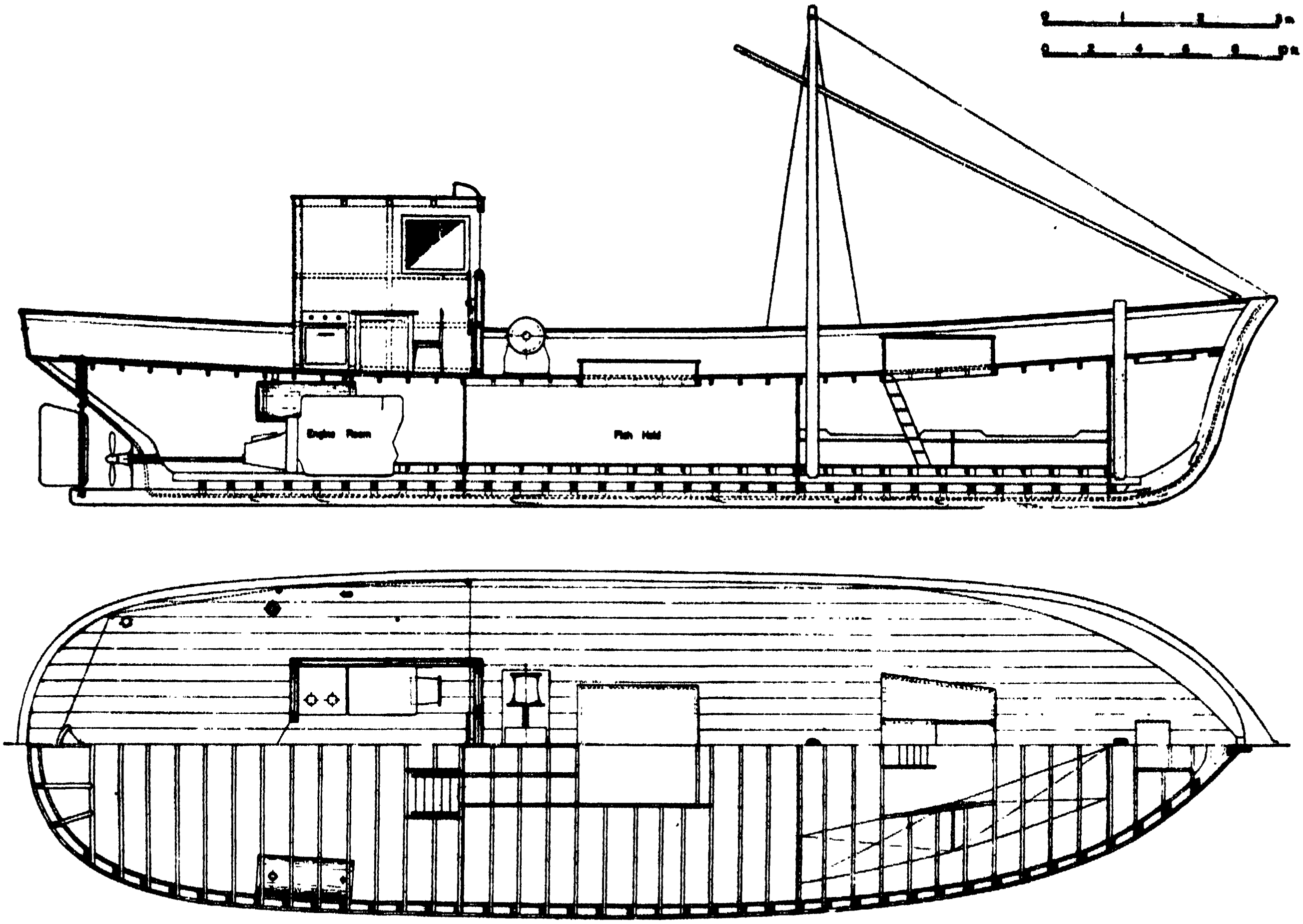


Fig. 752. Construction of a modernized 52.4 ft. (16 m.) Argentine fishing boat

The capacity ranges between 150 and 400 boxes, the volume of the hold being from 350 to 890 cu. ft. (10 to 25 cu. m.). The engines are generally high-speed diesels of 100 to 150 h.p. and are operated from the pilot house. In spite of these improvements, the new boats have some drawbacks from the design standpoint, i.e. excess power as compared with the general features of the boat, poor construction, small hold capacity, little safety, and lack of facilities for proper preservation of the catch.

They are built of timber grown in Argentina or imported from neighbouring countries. The time required for building a boat may be four to eight months. The price of a hull of the smack and of the net type of boat (1959) may be estimated at £260 (U.S. $720) and £360 (U.S. $1,000), respectively, per metre of the length. The price of the completed boat is approximately £460 (U.S. $1,300) and £670 (U.S. $1,880) per metre of the length. Shipbuilding is usually financed by private persons or by private loans. The Government can provide a credit up to 50 per cent. of the total cost of building or converting boats, but few fishermen take advantage of this system.

Deep-sea fishing is carried out by steel or wooden trawlers based at Mar del Plata and Buenos Aires. There are at present (1959) 26 boats in service, their overall lengths ranging from 67 to 180 ft. (20 to 55 m.). Table 171 gives the main specifications of these boats.

Some boats were originally built abroad for other purposes and later converted for fishing. Most of the boats now in use are very old, with the exception of the *Taiyo Maru* and *Taiyo Maru 22*, built in Japan. Consequently, earnings are, generally speaking, very low, because of the frequent repairs necessary, especially to the main and auxiliary engines, and the poor refrigeration facilities, which limit the cruising range.

Future prospects

Future maritime fishing must meet both the demand of the canning industries and of the fresh fish markets, in quantity as well as quality. Great improvements are therefore necessary in the present fleet. The new ship designs must be tested in the light of technological progress, as regards cheap running cost, safety of crew, good manoeuvrability, and proper preservation of fish, and adapted to the special needs of local fisheries. Two types of boat must be developed, one for coastal and the other for deep-sea fishing.

The coastal fishing boats must be multi-purpose boats for either inshore or deep-sea fishing, depending on the season and the various types of gear. A small trawler would be the most suitable, in view of the habits of the fishermen, and the main specifications are given in table 172. The stability under various loads should be particularly studied. The first estimates indicate that the height of the metacentre should be approximately 1.77 ft. (0.54 m.) at full draught. They should have a strong sheer, especially at bow. Wooden construction would be preferable to lower initial cost. The boats should have five sections or compartments, divided by four water-tight bulkheads, i.e. fore storeroom for the anchors and chains, crew space, fish hold, engine room and cabin. The deckhouse, located at the stern, should have a wheelhouse, galley, mess room, small washroom, and an entrance to the engine room. The deckhouse could be made of steel and constructed separately from the hull and then installed on board in one piece. The fish hold should be properly insulated and, if possible, have refrigeration equipment. In order to prevent spoilage of fish when transported in bulk, the fish hold should be divided horizontally with three or four removable shelves.

The ship should have a winch and booms to haul in the catch. A radio-telephone, and possibly an echo sounder, should also be installed. The price of such a ship is estimated (1959) at approximately £18,500 (U.S. $52,000), excluding nets, refrigeration equipment and echo sounder. This price might be lowered if a series of boats were built to the same design. As the present coastal fishing boats have fairly new propulsion engines, these engines could be transferred to the new hulls.

The deep-sea fishing boats should have adequate hold capacity, so that their operation will be economical when they follow migratory shoals of fish and make long trips. A trawler is preferable, the specifications of which would be similar to those used in other parts of the world. The proposed main dimensions are shown in table 173. Other features would be: steel hull, refrigeration facilities for 40,000 to 50,000 kcal./hr., accommodation for a crew of 20, radio-telephone, and echo sounder. The stability and longitudinal weight distribution should be particularly studied in order to avoid considerable shifting of weight during trips. The cost of the boat (1959) is estimated at £141,000 (U.S. $400,000), excluding nets and radio direction finder.

MEDIUM DISTANCE FISHING

MR. JOE D. SMITH (U.S.A.): A standard design of an all-aluminium trawler has been developed by his firm of consulting engineers. It features, in addition to the aluminium hull, a hold of flush-welded aluminium. The smooth ceiling, deck and bulkheads facilitates cleaning, thus making it easy to maintain a sanitary condition.

Aluminium appears to be an excellent boat building material for trawlers because it has both the resilience of wood and almost the strength of steel. Recently aluminium has been used extensively on large sea-going vessels for superstructures, primarily to save top weight. Furthermore, maintenance costs are considerably reduced, since no paint is required on aluminium surfaces. A vessel built of aluminium weighs about one-half as much as one of steel, and the aluminium trawlers can carry much greater cargos at the same draught as that required by a steel vessel.

Since an extensive survey of existing trawlers indicated that the vast majority are about 65 ft. (19.8 m.) long, this size was selected as standard. Such a trawler, because of its rugged construction, can be used in inshore waters as well as offshore. A 65 ft. (19.8 m.) trawler has approximately the following characteristics:

Length	65 ft. (19.8 m.)
Beam	18½ ft. (5.65 m.)
Depth	9 ft. (2.75 m.)
Draught, aft, loaded	6½ ft. (1.98 m.)
Draught, aft, light	5 ft. (1.52 m.)
Crew accommodation	7 men

	Steel	*Aluminium*
Hull weight	50 tons	28 tons
Capacity	20 tons	35 tons

Fig. 753 shows the profile. The engine is located forward. The hold has full headroom, assuring comfortable working conditions as well as maximum storage space. This drawing illustrates a stepped arrangement of the wheelhouse, cabin, and galley: whereby adequate headroom is obtained in the engine room, and greater visibility—of prime importance to the pilot—is afforded the wheelhouse. The mast and booms are of aluminium, while the blocks and rigging are steel. To further minimise maintenance, stainless steel wire rope and blocks could be used.

Fig. 754 gives the layout and arrangement of the main deck. The entire aft deck is clear, facilitating the handling and storage of nets. The cargo hatch coaming is 24 in. (0.6 m.) high in the interest of safety. Also shown is the three-drum trawling winch. Forward are found the galley, mess, quarter, and raised pilot house. This serves as access to the quarters and engine room in the hold below, as well as giving better ventilation during fair weather.

Fig. 755, in addition to showing the lower quarters, engine room and steering gear, gives the layout and arrangement of the cargo hold. This hold is divided by partitions composed of portable aluminium battens. The battens are of box construction, thus facilitating the maintenance of the cargo hold in a sanitary condition.

Fig. 756 shows sections through the boat, and gives the scantlings for the construction. While these sections show a single chine, the design could be modified for a double chine

TABLE 172

Main specifications of proposed future coastal fishing boat for Argentina

Length, L	ft. (m.)	52.5 (16.00)
Breadth, B	„ „	16.7 (5.10)
Depth of hold	„ „	5.9 (1.80)
Mean draught, with maximum load, T_1	„ „	4.4 (1.35)
Block coefficient, δ		0.400
Prismatic coefficient, φ		0.600
Midship area coefficient, β		0.666
Displacement, Δ	tons (ton)	44.3 (45)
Hold capacity	cu. ft. (cu. m.)	1,000 (28)
Engine power	BHP	120
Estimated speed, V	knots	8.5

TABLE 173

Main specifications of the future Argentine deep-sea fishing boat

Length, L	ft. (m.)	115 (35.00)
Breadth, B	„ „	22.6 (6.90)
Displacement, Δ	tons (ton)	344 (350)
Hold capacity	cu. ft. (cu. m.)	7,080 (200)
Engine power	BHP	600
Estimated speed, V	knots	10.5 to 11
Cruising range	miles	1,400 miles

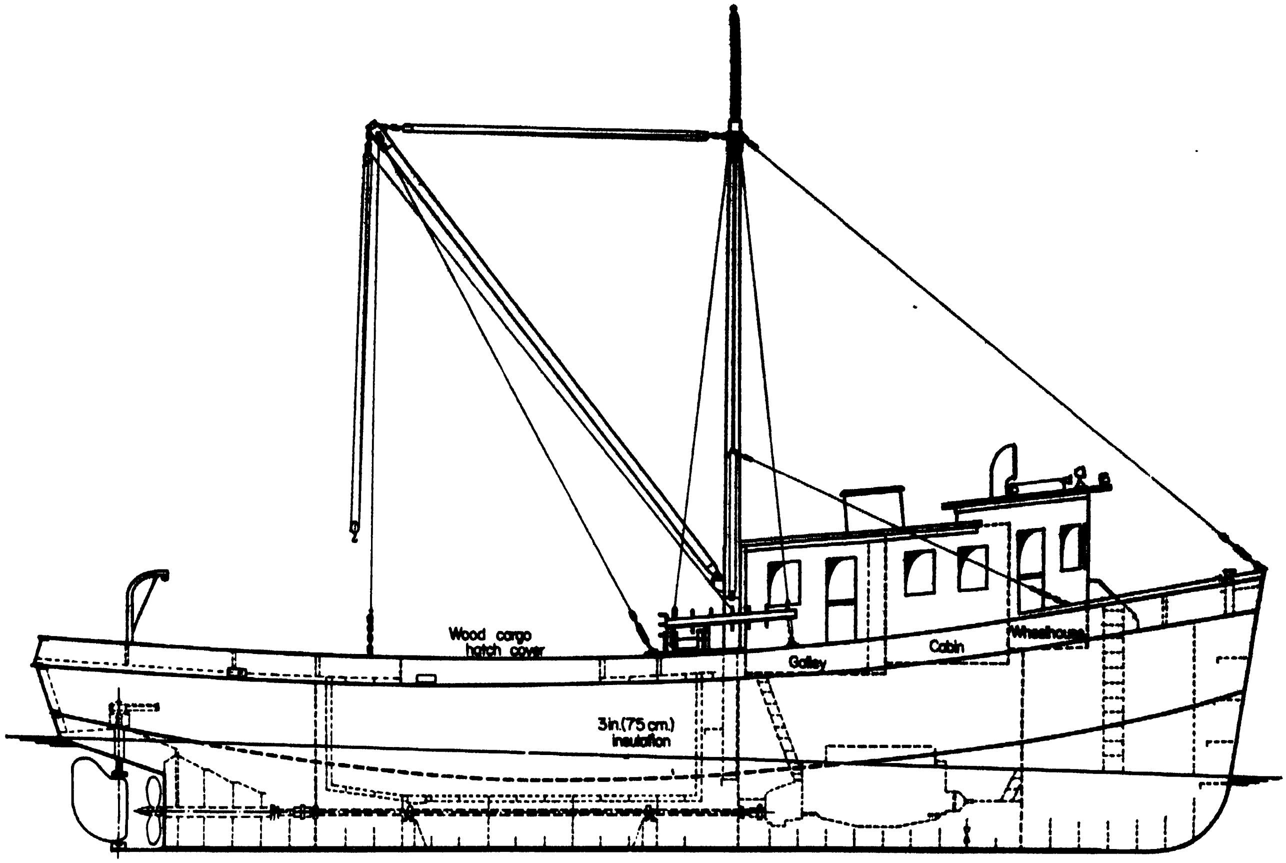


Fig. 753. Profile of proposed 65 ft. (19.8 m.) shrimp trawler built of aluminium

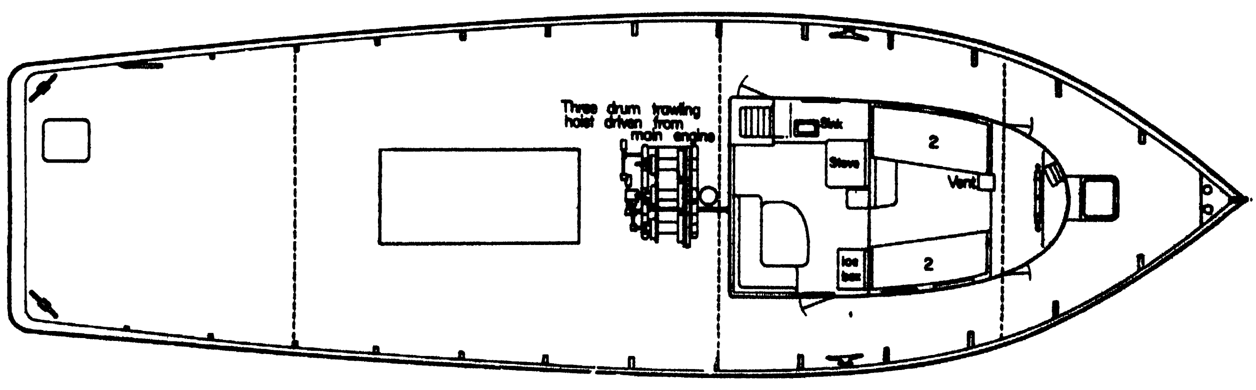


Fig. 754. Layout and main deck of shrimp trawler built of aluminium

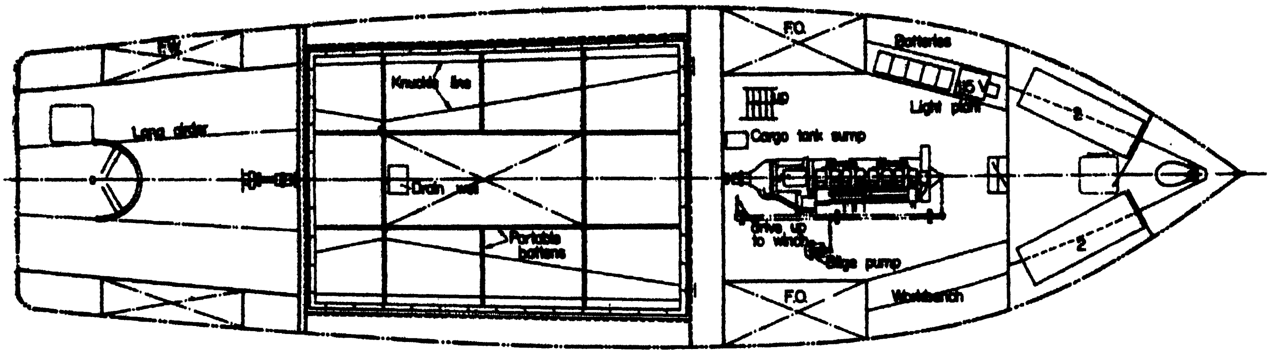


Fig. 755. Below deck arrangement of 65 ft. (19.8 m.) trawler built of aluminium

or moulded construction. The deck is sloped to a channel at the centre-line and then to a sump for adequate drainage. The sump is insulated with a removable insulated plug in order to maintain integrity of the insulation envelope. Special attention is invited to the fact that the cargo hold is lined with aluminium, thus giving a smooth, easily cleaned compartment. Fish holds are insulated with 6 in. (152 mm.) of styrofoam or spun glass on the transverse bulkheads, shell, deckheads, and floors.

Reasons for success

MR. J-O. TRAUNG (FAO): He had tried to find out why Ringhaver had been such a successful builder, because he did not think that the success was only due to good management, good accounting and financing, etc.

This is the first time the lines of one of Ringhaver's trawlers have been published and this made it possible to study the design as such. The boat is extremely light, thus has a big length-displacement ratio. According to Lewis (1955) and Vossers, p. 393, the lighter boat on a given waterline length has a better sea behaviour and less stresses in a seaway. That might be the reason why fishermen seem to prefer

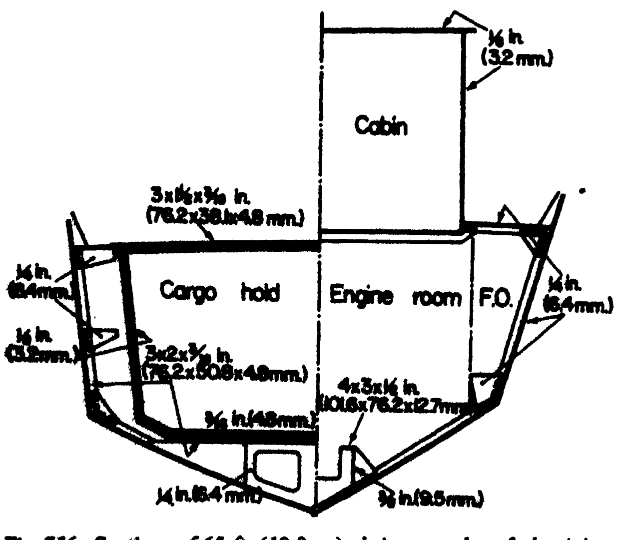


Fig. 756. Sections of 65 ft. (19.8 m.) shrimp trawler of aluminium

Ringhaver's wooden hulls to the many steel hulls which are being built down in Texas, but never came up into a big production. In small sizes these steel hulls will turn out considerably heavier than a light wooden hull like Ringhaver's.

The transom stern of Ringhaver's boat should give good damping and that is probably why the head sea performance is said to be excellent. Recent Coast Guard tests in the U.S.A. have just shown that a transom stern provides less bow accelerations. This may sound peculiar, but if one considers a boat as a kind of a scale it might be understandable. The prismatic coefficient of Ringhaver's boat is very low, which must be another reason for the good head sea performance.

As far as rolling is concerned, Ringhaver said that due to the round bilges, the boat has a tendency to roll quickly. Traung suggested that Ringhaver should look into this matter and obtain the period of roll, to compare it with Möckel's diagram, fig. 429. If his boat is far off from the line in this diagram it might be rather simple to correct it by changing the beam. A few inches might do the trick.

Otherwise, he thought that the boat was a good piece of nice wooden ship construction; the scantlings are very light, thus producing a light ship, and because of this fact the stresses appearing will be small. This is why the scantlings are sufficient. One could criticize, for instance, the fact that the deck is spiked with normal spikes instead of deck spikes, but that is just a small matter.

MR. L. C. RINGHAVER (U.S.A.): Regarding Traung's proposal that a change in beam might be investigated to get an easier motion, his firm has had proposals to increase the beam to 20 ft. (6.05 m.) rather than decrease it. They always attempt to please the customer first.

He considered it necessary to have training facilities for fishermen.

Icelandic types

MR. H. R. BARDARSON (Iceland) said that Icelandic fishing vessels are used for many different methods of fishing and for different fishing grounds, this resulting in a wide variety of types. A common type is that used during the winter for cod fishing, with longline or nets, mostly off the South and South-West coast of Iceland, to supply the freezing plants, and in summer for herring off the North and North-East coast. In order to produce best quality frozen fillets, the freezing plants need a regular supply of freshly caught fish.

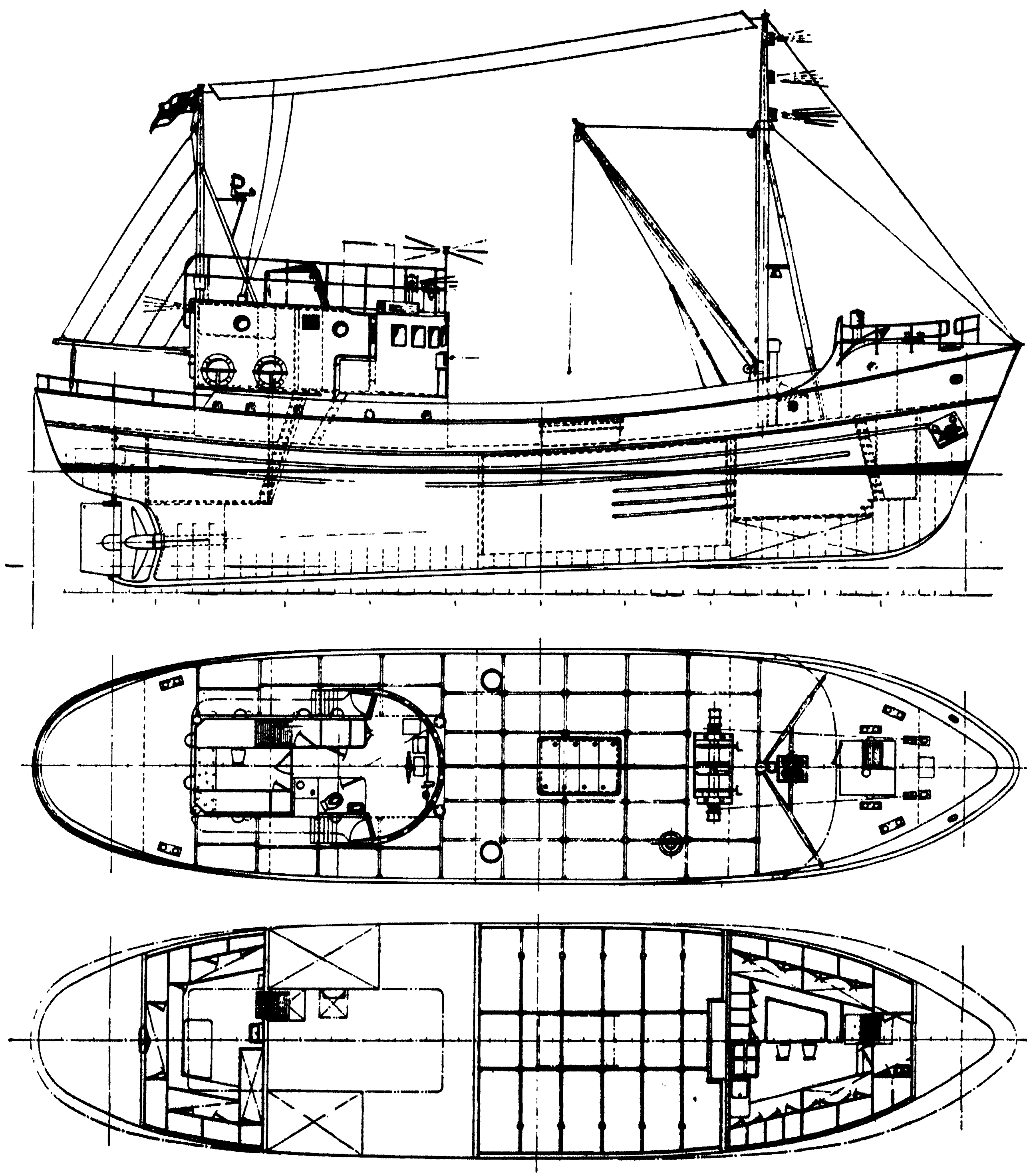


Fig. 757. 82 ft. (25 m.) LOA modern Icelandic multi-purpose fishing boat

These vessels are therefore rather fast running, have high engine power, and must altogether be very seaworthy. Trips usually last for no more than 24 hours, and the fish is processed immediately on landing.

Mr. Bardarson then described a steel vessel which he had designed and was now under construction (fig. 757). Fishing vessels of the same design have been running for some years, and this design is therefore planned on the basis of numerous tests carried out during actual operation and also under very bad weather conditions.

The main dimensions of the new vessel design are:

LOA	82.02 ft. (25.00 m.)
LBP	70.86 ft. (21.60 m.)
B	19.68 ft. (6.00 m.)
D	9.85 ft. (3.00 m.)
T to CWL	8.15 ft. (2.50 m.)
Tonnage (approx.)	90 GT
Main engine	400 BHP

Below the main deck there is a steering gear compartment for hydraulic steering gear, accommodation for four to five men aft, engine room, a fish hold, accommodation for six men forward, entrance to accommodation and fore-peak tank.

In the deckhouse there is the captain's accommodation, entrances to accommodation aft and to the engine room and wheelhouse.

The ship is fitted with a 4-ton hydraulic trawl-winch and a 1.2-ton hydraulic line hauler, both driven by a hydraulic pump connected to the main engine. It has a 25 BHP auxiliary engine with an electrical generator and an electrical generator on the main engine, an electrical stove in forward accommodation, running hot and cold water, radar, two echo sounders, wireless station and direction finder, clear-view screen, etc. A rubber liferaft for 12 men is fitted on top of the wheelhouse. Fuel oil tanks in side bunkers in the engine room are for approximately 11.5 tons of oil, and fresh water tanks below accommodation forward are for about 5.5 tons.

Displacement is about 148 tons at the designed draught of 8.15 ft. (2.5 m.). The GM is from 1.65 to 2.3 ft. (0.50 to 0.70 m.), depending on the loading condition. The lowest GZ curve is for the condition 50 per cent. fish in the hold (approx. 26 tons), deck full of fish (approx. 44 tons), about 5 tons over-icing and 50 per cent. fuel, etc. In this condition the GM is about 1.65 ft. (0.5 m.), the maximum of the GZ curve is about 3.14 in. (8 cm.) at about 22° list, and GZ is zero at 40° list.

Many Icelandic fishing vessels have a lower GM with correspondingly lower curve. A GM of about 1.31 ft. (40 cm.) for this type and size of vessel is considered to be reasonable and sufficient for full efficiency.

The unconventional design

MR. G. S. MILNE (U.K.): He commented upon Corlett and Venus's paper. Too little information was given about the maintenance cost of this type of ship. First it was claimed that a straight frame, hard chine form of construction was cheaper due to the lower hull cost. On similar specifications, standards of workmanship and similar rates of wages, etc., the reduction was said to be due to the reduction in frame setting and shell plate rolling cost. The saving is no more than £500 ($1,400), including overhead charges which are less than ½ per cent. of the cost of the ship. This agreed with Zwolsman's calculation given on p. 418. Secondly, it was claimed that this form of trawler was good because of the lower power required. This claim is not substantiated. Thirdly, it was claimed that these trawlers were as efficient as the best normal trawler, considering the fish catch. Comparison with two trawlers of this type and ten normal trawlers in 1958 has shown that the normal trawlers on the average caught 12 per cent. more fish. The normal trawler has been considered difficult and expensive to construct because of fine entrance angles. But the waterlines are never so fine that access to any parts of the ship is difficult.

The scantlings being robust is hardly borne out because the weight of the steel is only 156 tons. The fitting of a double-bottom tank under the fish hold is not new, as this had been normal practice during the inter-war period.

The information in table 159 was not correct in his opinion. One of his firm's five-year-old motor trawlers gives equal performance to the one mentioned in this paper. The predicted trawling pull of one of his trawlers was 8 tons at 610 h.p. In another trawler the pull was 9.25 tons at 660 h.p. Towing power is equally important as free running speed.

The unorthodox trawler required 48 tons of ballast to give a metacentric height of 2.40 ft. (0.73 m.), considered necessary for sufficient stability. This ballast seems excessive. The freeboard is not sufficient to give good working facilities.

In 1958 it was found that a straight frame trawler landed an average annual catch of fish of 770 tons, as opposed to the average of 860 tons on ten orthodox trawlers. The best orthodox trawler landed 38 per cent. more fish of 20 per cent. higher value than the best hard chine trawler. Hard chine trawlers have been built for 40 years and the method found useful when there is a lack of skilled labour.

MR. A. HUNTER (U.K.): Corlett and Venus in their paper reiterated a sentiment that naval architects had neglected fishing boats, where they suggested that a fresh mind coming to the problem could substitute revolution for evolution and point the only true way ahead. The high standard of papers presented at this Congress surely belied any criticism of neglect on the part of the naval architect in this class of ship. None is so small-minded as to acknowledge and adapt designs which offer advantages but in fact, had their claims been proven? To begin with, chine forms were not new and it was not thought there was particular virtue in the patent. Estimates based on extensive model tests of orthodox trawlers showed that at a speed of 12 knots the Corlett and Venus figures were 30 per cent. more than that for a good normal form. In fairness however, the authors should look at their figures again because they do not appear to reconcile with those of the trial performances. This form, like all forms with a bias on buttock flow was more suitable for small ships with extreme dimensional characteristics. In the larger distant water trawlers it was not felt that there could be any advantage.

Such a form would be more acceptable for harbour craft, but in ships which had to go to sea he could not possibly recommend it to any owner. The motion of a ship in a seaway is a most important consideration and an abrupt change in form can affect this considerably.

From the layman's point of view it was pertinent to say that so many people could not have been wrong for such a long time in adhering to normal form ship and in the light of their experience be prepared to go on building ships of normal form.

Reference had been made to the bulbous bow form, but this would not be recommended for a ship of the size under discussion.

On the question of cost, the steelwork for a normal form is no more than about 8 per cent. of the contract price, and

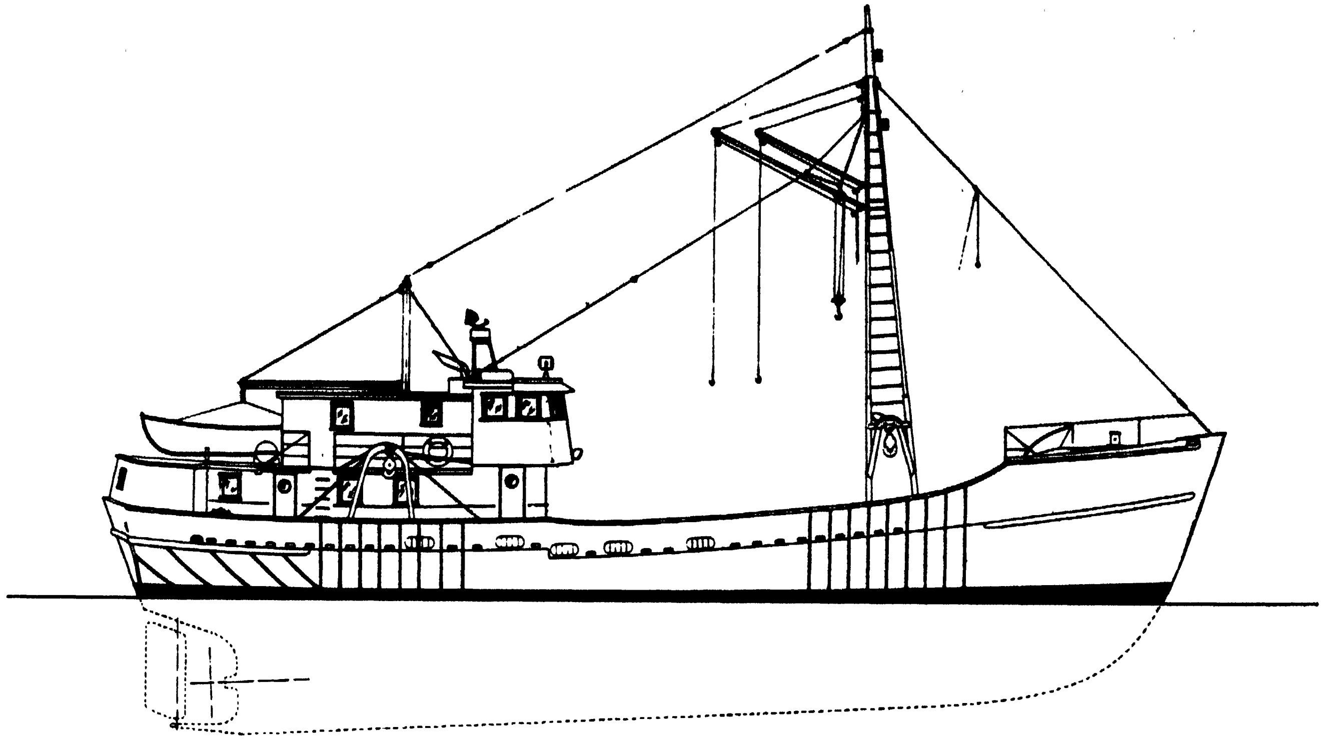


Fig.758. In the U.S.A., V-bottom and double-chine construction of steel fishing boats has been very popular for a long time. This shows a 100 ft. (30.5 m.) trawler of recent design, of which 10 will be built

about a quarter of this amount involved in shell plating and framing, i.e. 2 per cent. of the contract price. At the very best, it could not be seen how the simplified unorthodox form could affect more than ½ per cent. saving on the contract price. Most practical shipbuilders would agree on the difficulty of presenting a large plane area in immaculate fair form and this would be more difficult for a small yard starting up with poor facilities. Owners therefore should not assume that an unorthodox trawler construction as proposed was just as simple as it appeared on paper.

MR. D. A. PAUL (U.K.): Transom stern vessels of normal form can be constructed, having better resistance properties than the unorthodox trawler. This has been proved by model tests.

These ships have as good sea-keeping qualities as cruiser stern ones. What then is to be gained by the adoption of a double chine straight line form with its inherent greater rolling problems, indicated by the need for fitting large bilge keels? Corlett and Venus claim that their form is subject to patent rights, but what is patent about a pure geometrical body, an oblique cone, first accomplished by the early Greek geometricians?

In ship B, the LCB positions is 1.46 per cent. of the length abaft the position in ship A, its draft 3 in. (75 mm.) deeper, giving added length to the load line, and reducing the breadth-draught ratio. Likewise, had the same propeller been fitted in each case, the predicted trawling pull at 4 knots and 500 SHP would have been the same. This can be checked by the Troost charts.

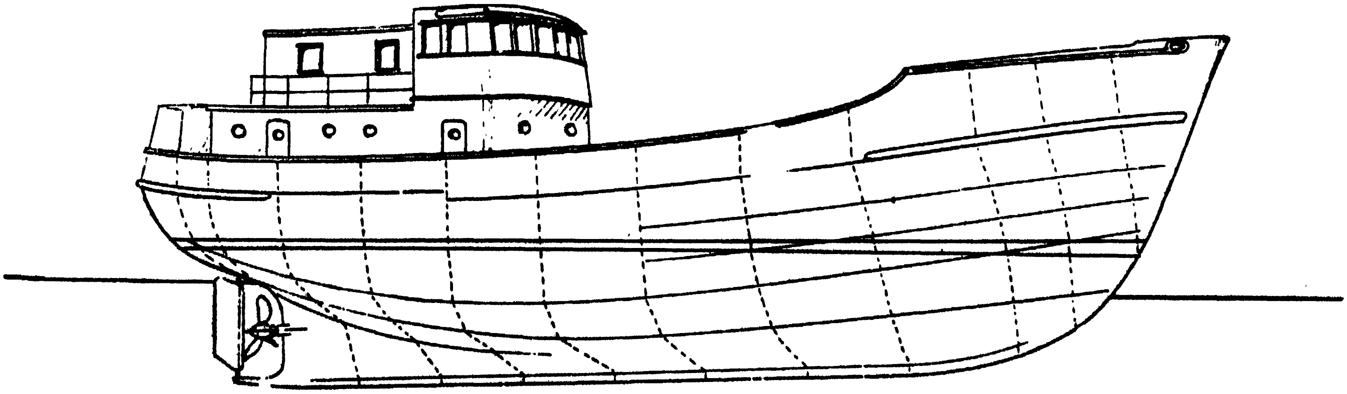


Fig. 759. The lines of U.S. double-chine trawlers can be developed completely, and are more similar in shape to round-bottom boats than the type designed by Corlett and Venus

In a paper read to the Institution of Naval Architects and Marine Engineers in Scotland in 1946, it was proved that there was a slight increase in resistance for a straight line double chine form as compared with the normal form.

Could the authors state how much the speed was decreased by the adoption of larger bilge keels, and would this reduction in speed not nullify the slight increase in speed claimed by bulb rudders?

Information about maintenance costs as compared with a normal form trawler would be welcome.

U.S.A. experience on costs

MR. D. S. SIMPSON (U.S.A.): Multi-chine vessels have been built in the U.S.A. for 35 years, during which time much experience as to cost has been gained. In recognizing the claim for lesser cost, exactly the same answers are obtained from the old time builders of the orthodox vessels in U.K. as in the U.S.A. They have the equipment and are accustomed to building the normal moulded form. In 1944 the double chine form was tried as a substitute for the normal form, thinking that there would be a financial saving. The estimated savings from shipyards of 2 per cent. roughly agreed with those mentioned during this discussion.

On the other side of the picture it has not been recognized that this type of boat may be built in small yards with little equipment where overhead costs may be as low as 45 to 50 per cent. instead of in the normal well equipped yards, where the overheads in some cases in the U.S.A. run to 105 per cent. This saving in the hull cost by building in a small yard is carried through in all the work which is done. It amounts to a differential of 10 to 15 per cent. in cost between building the double chine form in a small yard and building the normal form in a yard which is accustomed to building it.

He was thoroughly in agreement with Corlett and Venus in their statement that these forms could be at least the equal in every way of the moulded hull.

In Boston, one of the best tugs is the 95×21.58×11.08 ft. (28.96×6.55×3.38 m.) *Athena*, a war-built double chine.

Mr. Simpson's first double chine was a 110×32×9.75 ft. (33.5×9.75×2.98 m.) auto and passenger vessel, built in 1939. She has given excellent service on the Great Lakes and the Atlantic Seaboard and is still very active.

He could not agree with the idea of trying to push the water under the hull. Carried to absurdity there would be a scow—notoriously hard to drive; unless, of course, it is light enough to plane.

His office is presently completing the design of a double chine trawler from which it is expected to build ten vessels. The characteristics of this hull differ considerably from those given by Corlett and Venus, being more like those of the normal form, fig. 758 and 759. This hull is completely developable.

LOA	99.75 ft. (30.4 m.)
LBP	87.66 ft. (26.75 m.)
L	91 ft. (27.75 m.)
Beam, extreme	24.5 ft. (7.46 m.)
Draught, mean	9.83 ft. (3.00 m.)
Displacement	275 tons
Block coefficient	.421
Prismatic coefficient	.588
Keel drag	5 in./ft. (42 mm./m.)
LCB, aft	3.1%

It was always nice to have one's pet design turn out to be a high liner, but he questioned the validity of the amount of fish brought in as a sound base for appraisal of efficiency. So much depended on the skipper—and luck. Two vessels trawling only a mile apart are "using the same grounds" but may find very different bags of fish. In the thirties, he had nine vessels, all of the same design, all fishing the same grounds. Over a period of years the annual catches varied as much as 20 per cent. As an immaterial, but interesting correlation, the skippers with the greatest catch usually tore up or lost the most gear.

In connection with the question of simplified hulls, it would be worth while to look at Hanson's remarks concerning the V-bottom vessels p. 332, a still simpler and cheaper design.

Propulsion factors

MR. H. LACKENBY (U.K.): He wanted to comment on one aspect of Corlett's and Venus's paper, namely, the comparison of the resistance and propulsive performance between ship A, which is referred to as a "normal" trawler, and ship B, the unorthodox type.

He was struck by what appeared to him to be the rather poor performance of the normal form and he has compared it with the methodical series data given in his own paper, p. 364. As it happened the normal form was very close to one of the BSRA methodical series forms as far as proportions, fullness and LCB were concerned. He was referring here to the stumpiest form, the © of which is given in fig. 346 at a length-displacement ratio $L/\nabla^{1/3}$ of 4.35.

In the first place, he referred to the resistance comparison in terms of © in way of the service speed at about 11 knots. For the BSRA form at the corresponding speed, the © value would be about 1.50 whereas the "normal" form given in Corlett's and Venus's paper appears to have a © value of about 1.85. There appears to be a difference here of the order of 20 per cent. the BSRA form being the better.

On the propulsive side, a QPC for the "normal" form is quoted as low as 0.56 and for the unorthodox form 0.62 again at a service speed of about 11 knots. The figure of 0.56 seemed rather low to him, and Mr. Lackenby had compared it with propulsion results which had recently become available for the BSRA methodical series forms given in his paper. BSRA carried out comprehensive tests here with two propeller diameters and the results were roughly as follows:

- with the smaller propeller, 8 ft. 3 in. (2.5 m.) diameter designed for 220 r.p.m., the QPC was about 0.66;
- with the larger propeller, 10 ft. 6 in. (3.2 m.) diameter designed for 127 r.p.m., the QPC was about 0.70.

The lesser of these figures is a little better than those quoted in Corlett's and Venus's paper for the unorthodox form and considerably better than the normal form which has a QPC value of 0.56. Of course, one must bear in mind that in the paper the r.p.m. are quoted as being 250 which are somewhat higher than the 220 r.p.m. for the BSRA forms. Nevertheless, Mr. Lackenby should not think that the difference in r.p.m. between 220 and 250 would make all that much difference. The propeller diameters quoted above refer to a ship length of 150 ft. (45.7 m.).

There appears to be every indication, therefore, that the "normal" form A is not a good one and Mr. Lackenby was inclined to have doubts about the statement on page 628 of the paper, namely, that the unorthodox form is more economical to operate due to the lower power required for equivalent service.

analysed

MR. D. J. DOUST (U.K.): Corlett's and Venus's paper gave an interesting comparison of resistance and propulsion data for two 115 ft. (35 m.) LBP trawler forms, one being of conventional type and the other a new proposed design. By comparing the form parameters given in table 159, it will be seen that the major differences occur in the values of LCB and $\frac{1}{2}\alpha_e$. A model of ship B was tested at the Ship Division of the NPL, although not at the same displacement and draught as that at which this comparison has been made, and it is understood that a model of ship A was tested at another tank. One must, therefore, keep in mind the possibility that differences due to experiment technique, different sizes of the models tested and tank boundary interference are included in this comparison. However, using the statistical analysis method described in Mr. Doust's own paper, p. 370, it is possible to demonstrate that most of the difference in resistance between forms A and B is due to the different values of LCB and $\frac{1}{2}\alpha_e$, so that if these values were restricted in any way by other design considerations it would account for the apparent penalty in resistance of form A relative to form B. Furthermore, it can be seen that if ship A, of conventional design, was modified to have the same LCB position as ship B, little or no difference in resistance would be obtained between the two forms.

TABLE 174

Comparison of ship © values for Corlett's and Venus' Form B and three forms designed at the NPL with the same overall dimensions and displacement, but finer angles of entrance

Model	*Form B*	*Model 3885A*	*Model 3885B*	*Model 3886C*
$\frac{1}{2}\alpha_e°$	32.3	18.0	18.5	20.0
LCB % aft	4.21	5.09	4.72	4.10
Ship speed (knots)	*© values for 115 ft. (35 m.) LBP ship*			
9.0	0.889	0.745	0.763	0.756
9.5	0.964	0.785	0.832	0.818
10.0	1.092	0.951	0.976	0.938
10.5	1.306	1.217	1.211	1.207
11.0	1.572	1.494	1.474	1.484
11.5	1.773	1.640	1.659	1.661
12.0	1.896	1.654	1.733	1.747

To establish the least resistful type of fore-body to be used in conjunction with a buttock flow type of stern, three forms were designed at the NPL having fine angles of entrance, the LCB being varied systematically from 4.10 per cent. to 5.09 per cent. aft of amidships. The overall dimensions and displacement are the same as those for ship B and the comparison of © values is given in table 174. It will be seen that each of these three forms having relatively fine angles of entrance for near-water trawlers has better resistance qualities compared with the form of Ship B. The least improvement of © is 5 per cent. and the greatest improvement is 20 per cent. over the speed range 9 to 12 knots for the ship. These results are in general agreement with results for other ship types which indicate that a conventional ship-shape form is less resistful than the equivalent double chine form having the same overall dimensions and displacement.

It is pleasing to note that Tothill's paper which gave results obtained with bulbous bow forms having fine angles of entrance combined with buttock flow sterns, adds further evidence in support of this thesis. The large reductions in resistance which have been reported in Tothill's paper are typical of those which have been obtained at the NPL in recent years, compared with more conventional forms having bigger angles of entrance.

Coming now to the question of sustained sea speed for trawlers, there is little doubt that increased fullness and high angles of entrance are deleterious to the maintenance of high ship speed in waves. Mr. Doust's own paper, in addition to other unpublished work conducted at the NPL indicates that fine angles of entrance are required for good service performance.

It has been suggested that the fine angles of entrance adopted in recent new designs necessitate additional beam to provide the equivalent inertia of the load waterplane and that the increased beam incurs some penalty in resistance. The results of a statistical analysis of all trawler forms tested at the Ship Division, NPL, over a period of some 30 years indicate, however, that an increase in beam is often beneficial from the resistance standpoint. It may well be that undue emphasis on stability may lead in some cases to excessive righting moment, particularly for the smaller trawler, and result in too violent a motion in roll, to the detriment of the design as regards its fishing capacities. In these circumstances an additional benefit in ship motion would be expected for the smaller trawlers having fine angles of entrance, due to the desirable decrease in inertia of the load waterplane.

Testimony of practical skippers

DR. E. C. B. CORLETT and MR. J. VENUS (U.K.): It was most interesting to note the divergence of opinion shown on certain points in their paper between those who have experience of the type of construction described and those who have not. The extensive and successful experience with the so-called Enterprise class trawlers is the best comment on the ships themselves. In its particular category this class of ship has sold well, particularly in Aberdeen, and the ultimate proof of quality in any ship is in its acceptance by shipowners.

Later are given the comments of a senior captain experienced in fishing with both conventional and Enterprise trawlers of the 115 ft. (35 m.) type. These speak for themselves.

Incidentally, the form of ship B was referred to by several speakers as straightline but this is quite incorrect. The form embodies a normal amount of curvature in the body sections where this is desirable and in this feature is quite distinct from other simplified forms.

Hunter and Milne misled when they spoke of the merits and demerits of certain simplified forms. Their comments on resistance and propulsion refer to their own and others' efforts in this field but not to the ship type forming the subject of the paper, which is distinct and has no connection with such efforts. The model test data and service experience with these vessels show them in a favourable light compared with the majority of normal ships of this size and type operating in competition; the data given is factual.

Any comparison must be strict, i.e. must be in the class itself, with fixed length, breadth, draught, block and propulsion characteristics. In addition it must be remembered that considerations such as the size of fish hold needed and seakeeping requirements may effect the values of certain parameters. Also it is pointless to compare ships with differing propeller sizes and revolutions. Nearly all the ships of this type use machinery with about 250 r.p.m. and, contrary to Lackenby's opinion, the difference in propulsive coefficient between 220 and 250 r.p.m. for optimum screws is considerable and invalidates direct comparison. The actual propulsive coefficients obtained on carefully conducted trials were higher than predicted by the NPL model tests. Paul's suggestion that towing results for the two ships quoted would be the same with identical propellers is, of course, impractical due to the differences between the two hulls. The optimum screws for the two ships are quite different.

The doubt cast by Lackenby upon the quality of the normal form A is contradicted by the opinion of the testing tank and by the fact that the actual ships in service are regarded as being above normal in performance.

It would be interesting to know why Milne should regard the information in table 159 as inaccurate. There is no basis whatsoever for this statement which is contradicted flatly. The trial figures quoted were for a Grimsby trawler of the class, fitted with the final type of bilge keels and run, with a torsion-meter fitted on the Newbiggin mile, under standardised conditions.

Dr. Corlett and Mr. Venus were not aware of the five year old trawler mentioned by Milne as built by his firm and it would be most instructive if he would make available for this discussion model test figures for one of his latest 115 ft. (35 m.) vessels. The towing figures quoted by Milne mean nothing unless related to the size of vessel. The larger screw allowed by a larger hull and slower running machinery will, of course, produce larger pulls per horsepower. As in this case the size of hull is standard and the machinery type common, the comparison in the paper is the only valid one.

Table 175

Comparative catch of comparable trawlers

Ship	*Number of days at sea*	*Weight of fish landed (tons)*	*Weight of fish per day (tons)*
Enterprise 1	296	685.80	2.30
Enterprise 2	328	762.85	2.30
Enterprise 3	332	800.29	2.40
			Average: 2.35
Ship 4	292	652.35	2.20
Ship 5	336	786	2.30
Ship 6	342	829.70	2.40
			Average: 2.30

Doust's contribution was of considerable length. He is not correct in supposing that this is a "proposed new design". The Enterprise type was evolved some four years ago and seven ships have been built to date.

It is difficult to follow Doust's arguments in the first part of his contribution, as he states that ship A would be improved by moving the LCB further aft in order to fine the angle of entrance. In fact ship B has both the fuller entrance and the further aft position of LCB, and the suggestion does not appear, therefore, to have much relevance.

Doust's description of the model tests on three different forms at the NPL, subsequent to the tests on ship B, is interesting. In point of fact, the interest of the NPL in the buttock flow type of stern for trawlers arose directly out of the test carried out on ship B. Doust stated this at the time and that up to then no buttock flow trawler form had been tested. Clearly, using ship B as a basis it is possible for anyone, including the NPL, to derive improved forms. Dr. Corlett and Mr. Venus had done this also, but at the time the form of ship B was superior to others tested in the particular category.

The tests on three forms derived from ship B but with finer angles of entrance are interesting but not very relevant to a comparison as it is questionable whether a fish room of over 7,000 cu. ft. (200 cu. m.) and the required stability could be obtained with 18° half angle of entrance. Doust's statement at the end of his third paragraph is not correct on the evidence of a number of vessels of varying types produced by Dr. Corlett's and Mr. Venus' firm and tested by the NPL. The results obtained have been generally equal to, or superior to, good conventional practice.

For example, a coaster form was produced in a certain case, based upon the NPL standard series which gave resistance values 7 per cent. better than the optimum relevant form in the series.

Further examples could be quoted, covering Canadian canallers, coasters, tugs, and other types, all of which showed equally satisfactory results and indeed after the tests carried out at the NPL no suggestion was made by the tank that the form should or could be improved. Therefore the statement in question must be refuted with a considerable amount of evidence, much of which could be made available to Doust.

It is surprising that Milne should consider the freeboard of ship B insufficient. It is the same for both ships A and B and both are exactly as specified by the owner and derived from standard Aberdeen practice. More freeboard could be provided but the owner, who was not lacking in experience, required precisely what he was given. It is relevant to quote from the report by the captain mentioned.

> "In comparison to the ordinary type of trawler the . . . type has a decided advantage. First they are better sea craft, they seem to have one knot more speed, steering is 100 per cent. and the manoeuvring ability is comparable to any other diesel craft. The working performance can be judged in that we have never been stopped from fishing (that is through twelve months of the year at the Faroe Islands), at times fishing in gale force ten winds, while the carrying capacity is such that we have had 1,500 cwt. (75 tons) on board from an Iceland trip and the ship has behaved splendidly on the passage.
>
> . . . the advantage given by the seaworthiness means that a ship can make a passage in any weather and be able to fish when normal ships are stopped."

This verbatim extract speaks for itself and is similar to the expressed views of owners of these ships. Doust's remarks upon seaworthiness may be true in some contexts but not in this particular one as is clear from much available information. He is welcome to examine the facts covering this type.

Much depends, as Simpson said, upon the captain, but owners of these vessels consider that the fishing ability is fully comparable with the best normal vessels while the capital and running costs are appreciably lower.

Milne quoted statistics that are difficult to understand. It is possible that he is confusing differing types and sizes of trawler but the factual comparison for a years' fishing from the Port of Aberdeen is given in table 175. These returns are restricted to ships of the 115 ft. (35 m.) type and it is understood that the skippers are all of comparable ability. Ships 1, 2 and 3 are the first three of the unorthodox type described in the paper, while ship 4 was constructed by Milne's firm, and ships 5 and 6 were constructed by another Aberdeen builder.

As all these ships are the same size, power and age, further comment is unnecessary, although the returns for the best Enterprise class ship in the port are not quoted.

The scantlings are robust and the steelweight is considerable in spite of the comments of Milne who seemed to forget

Lloyds' Requirements and normal owners' extras on top of them. Milne was possibly confusing riveted with welded construction. Dr. Corlett and Mr. Venus are not aware of any other trawlers of this size with double-bottoms but stand open to correction. True, larger ships have been constructed with double-bottoms for a long time but current 115 ft. (35 m.) ships, at any rate as built in and for Aberdeen, do not embody this feature. The trimming flexibility of this Enterprise class is unusual and worthwhile. The ballast is so disposed to permit the postion of LCB, and due to its height much of it does not contribute to the stability, nor was it intended that it should.

While maintenance costs on these ships are not yet available, such costs as have arisen being intitial development costs arising out of a new type of design, there is ample evidence from dozens of vessels using this construction over a number of years. Comparison with conventional construction has been good and in not a few cases has shown improvement. Regarding the gear, it is the same for both types of ship.

The type of vessel described, is here to stay although this fact may not be popular with competitive builders. Whether the middle water trawler as a concept will last is another matter and present developments leave this open to doubt.

MR. G. S. MILNE (U.K.): Regarding the statement that the information given in table 159 is inaccurate, what was said was to the effect that the figures quoted as referring to a trawler of normal type and form of good average quality cannot be accepted as being representative of normal type trawlers of good average form. The figures given for Ship B were not commented upon.

The towing figures given in his discussion did refer to trawlers of 115 ft. (35 m.) LBP, the free running speeds of the propellers being 250 r.p.m. in both cases.

A freeboard of 1.85 ft. (0.565 m.) is not considered to be sufficient to give good working conditions on deck.

The figures given in his discussion as regards weight of fish landed are for the calendar year 1958. The ten orthodox trawlers referred to range in length from 108.5 to 120 ft. (33.1 to 36.6 m.), having an average length of 117 ft. (35.7 m.) and an average continuous rated BHP of 684. This compares with a length of 115 ft. (35 m.) LBP and BHP of 760 for the unorthodox trawlers. The comparison is considered to be a fair one.

No antagonistic attitude

MR. A. HUNTER (U.K.) would like to dispel any impression of a "dog in the manger" attitude to the unorthodox form design. He has always been ready to adopt developments which may make for improvement. He is aware of the general principles of the form for which Corlett and Venus have sought patent protection and the fact that there is a certain fore and aft curvature in the bilge plane.

The authors would concede that although Mr. Hunter's firm have not built 115 ft. (35 m.) trawlers for several years they have nevertheless pursued a very vigorous policy of research and development. Also that with the results before them of a considerable number of model tests of trawler forms ranging from 70 to 190 ft. (21.3 to 58 m.) in length they should be well qualified to evaluate the resistance and propulsive capabilities of a ship of the discussed dimensions and power.

On the basis of the figures given by Corlett and Venus in their paper there is no question but that the unorthodox form design is considerably more resistful than a normal form design.

He would support Milne that if the comparison had been made with some up-to-date trawler the advantages, if any, in the unorthodox form would disappear.

Aberdeen as a fishing port has lagged to a certain extent behind other British fishing ports in modernizing its fleet. The Enterprise class trawlers of unorthodox design may well therefore have represented something very much better than some of the obsolete steam vessels and have merited the Captain's report quoted. The unorthodox form may also have sold well in Aberdeen, but a decision for this type of vessel can depend upon delivery. It is true to say that several normal form trawlers have been subsequently delivered or are in course of construction for services in Aberdeen.

The correlation between model testing and trial results even where torsion-meters are used and with calibrated shafting is not a simple process. The accuracy of the torsion-meter with comparatively low powers and stiff shafting is liable to considerable error and analysis from such trials has to be carefully made before full reliability can be placed on the results.

Considerations of buttock flow forms have always had to be given in the case of vessels of extremely disproportionate dimensional characteristics. In this the trawler is no different from other classes of vessels, although the introduction of transom or cut off cruiser sterns may seem to have indicated the contrary.

Table 175 appears to be rather slender evidence over one year, as to justify a claim for all-out superiority. The average for the unorthodox form vessels is only one cwt. (50 kg.) per day above that of the normal form ships. Probably the newer ships had the better skippers, and Mr. Hunter knew no method yet of differentiating between the skill of the skipper and the intrinsic quality of the ship.

Traditional trawler builders have always had to face competition and have recognized that this begets progress. Where everything else is equal the deciding factor in the owner's mind will be initial cost. Corlett and Venus in their contribution do not appear to comment very much on the statements from Netherlands as well as from Britain that in the same basis of costing, the overall saving for the unorthodox form design must be very small indeed.

MR. H. LACKENBY (U.K.) referred to the following points made by Corlett and Venus in reply to his contribution, viz:

- that it was pointless to compare ships (propulsive coefficients) with differing propeller sizes and revolutions;
- the difference in propulsive coefficient between 220 and 250 r.p.m. for optimum screws is considerable and invalidates a direct comparison.

In response, Mr. Lackenby stated that he would agree with the first point if it were made without qualification, but he had not, in fact, done this. What he had said was that he did not think the difference in r.p.m. between the "normal" form A and the BSRA form would make all that much difference, that is, between a QPC of 0.56 and 0.66 respectively. In other words, in spite of the r.p.m. difference, the QPC for the normal form A did not appear to be nearly as good as that for the corresponding BSRA form.

In view of the second statement, Mr. Lackenby said that he had now looked into the matter more closely. In this connection he pointed out that the BSRA figures referred to a somewhat larger ship than the author's, namely, 134.5 ft. (41 m.) LBP as against 111 ft. (33.9 m.) LBP. To make a rigorous comparison, therefore, the BSRA figures should be scaled down to the same ship size as the author's, namely, 111 ft. (33.9 m.) LBP. When one did this, the original 220 r.p.m. at 134.5 ft. (41 m.) became 237 for the 111 ft. (33.9 m.) ship according to the law of comparison. This meant that the difference between the r.p.m. of the BSRA form and that of the normal form A was less than they probably anticipated. The QPC at 111 ft. and 237 r.p.m. was 0.66 and the corresponding propeller diameter and pitch 7.57 ft. (2.31 m.) and 5.78 ft. (1.76 m.) respectively. The corresponding particulars of the propeller for the normal form were 6.75 ft. (2.05 m.) diameter and 5.7 ft. (1.74 m.) pitch, and if the BSRA propeller was adjusted to these dimensions and the r.p.m. increased to 250, it was estimated that the QPC would not be expected to fall below 0.64. This compares directly with the figures quoted by Corlett and Venus of 0.56 and 0.62 for the normal and unorthodox forms respectively. Mr. Lackenby contended, therefore, that his original expression of opinion was substantially correct, namely, that the difference in r.p.m. between the normal form A and the BSRA model would not account for the difference in QPC between 0.56 and 0.66.

As regards the EHP comparison, Corlett and Venus stated that the doubt cast on the quality of the normal form A was contradicted by the opinion of the testing tank and by the fact that the actual ships in service were regarded as being above normal in performance. Responding to this, Mr. Lackenby said that he could only speak on the tank EHP comparison and reiterated that at 11 knots the BSRA form was about 20 per cent. better than ship A, which was referred to as the normal form.

DR. E. C. B. CORLETT* and MR. J. VENUS (U.K.): They commented on the new replies, which they felt generally did not take the argument much further, as follows under subject rather than author headings:

Freeboard. The freeboard of this size of trawler is standard as required by the owners and is the same whether built by the builders of ship A, ship B, or if built by Milne. They did not understand Milne's comment and in view of the notable dryness of the vessels, did not agree with it.

Fishing results. They felt that in the last resort, fishing results mattered more than any others. The results given in the first reply to the discussion showed clearly that, contrary to the statement by Milne, of six modern diesel trawlers, all built within a few months of each other and of the same size and power, operating out of Aberdeen, the unorthodox vessels, as described in the paper, caught slightly more than the orthodox. It is a red herring to introduce other sizes of trawler. However, they felt that if Milne insisted on doing so, it must be pointed out that the *Aberdeen Fisher*, an orthodox trawler of the type described, has, on a number of occasions, been top vessel for landings both in quantity and value, irrespective of the size of trawler considered.

As stated by Captain Elder in the British Press, his ship, indeed, averaged for the first half of 1959 an average rate of 3.02 tons of fish caught per day at sea, the catch for the six months period earning £33,861, i.e. an average of £3,078 per trip for 11 trips. Further comment on either the earning ability of these trawlers or upon Milne's comments was felt to be quite unnecessary.

The further point was made, however, that the unorthodox ships are compared throughout with modern diesel vessels of the same size, power and type, of the same age, in one case built by Milne's firm and have had no advantage regarding skippers.

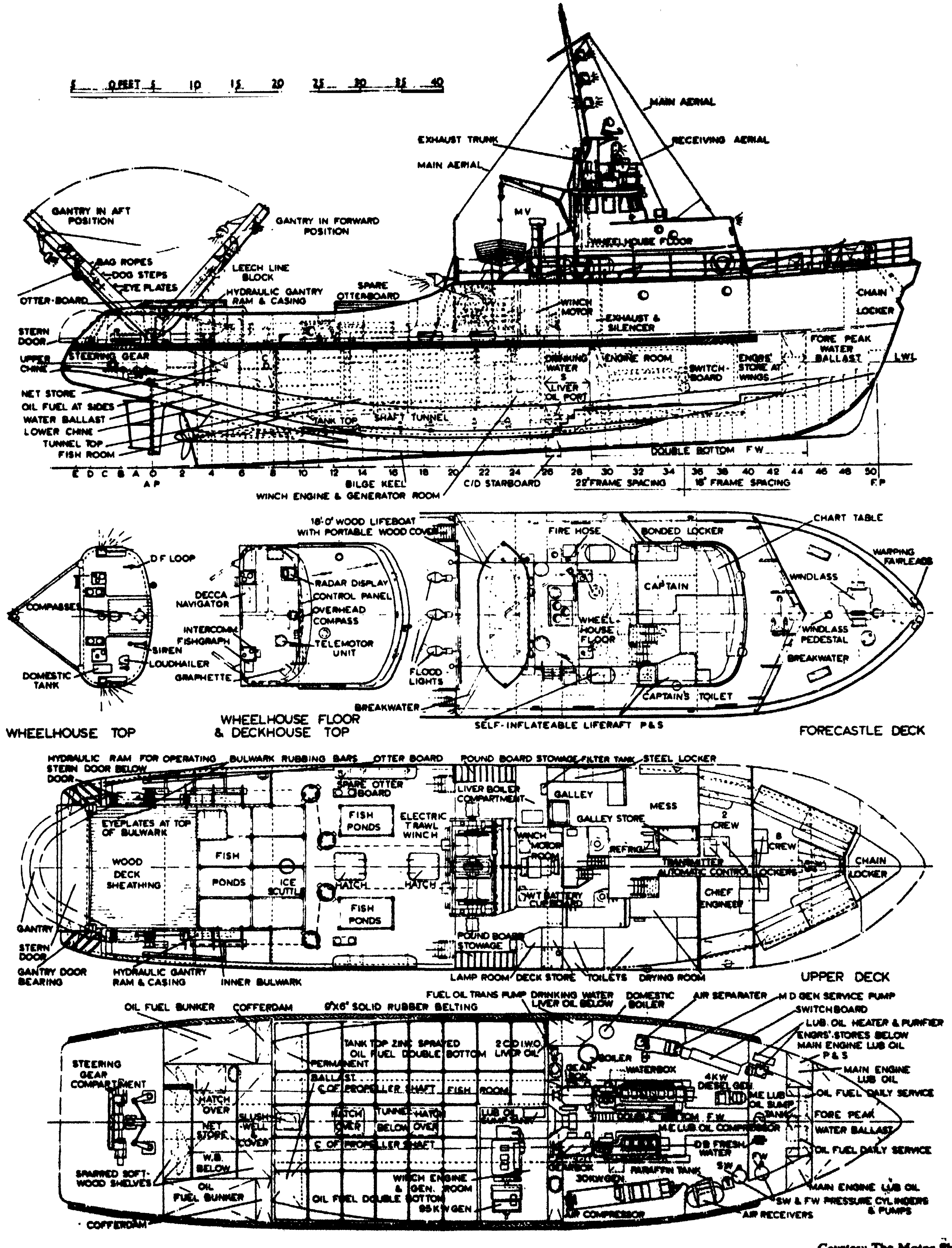
Man-hour saving. Whatever may be said by those who do not have experience of building this type of construction, those who do reiterate the facts. Exact figures are available, not only for trawlers, but for a number of different types of ship, so that systematic quantitative data is available. If competitive builders disregard these facts, it can only be to the advantage of those who do not.

Hull form. The contributors appeared to be confused here by the type of trawler. Hunter reiterated the quite unsupported statement that he did not consider the model test results for the unorthodox form to be good. At the same time, he stated that his firm has not built any of this size of trawler for some years. By reason of its configuration and high power for the size, the 115 ft. (35.1 m.) trawler has per force a high block coefficient and a correspondingly high prismatic coefficient. Non-dimensional plots show that, in fact, the resistance of the "unorthodox" form with a prismatic coefficient of 0.70 compared with the best available comparative normal form with a prismatic coefficient of 0.65 which was a very good result and contradicted Hunter. Incidentally these forms had both longitudinal and transverse curvature contrary to Hunter's statement.

Lackenby supplied details of the ship mentioned in his first contribution but changed the length from 150 to 134 ft. (45.7 to 40.8 m.) which somewhat confused the issue. However, accepting the latter length, Dr. Corlett and Mr. Venus had analysed the figures and found it difficult to correlate them. Lackenby did not give the pitch of the propeller on the 134-ft. trawler, neither did he give any EHP figures to enable proper analysis, but such analysis as was possible indicated that his QPC for the 134-ft. ship was possible. Scaling, however, to 111 ft. (33.8 m.) with a 7.57-ft. (2.31 m.) diameter screw, they did not obtain any correlation, the maximum efficiency possible on this screw on the revolutions quoted being about 0.635 and it is unlikely that the hull efficiency of the vessel would be in excess of 1.0 and anyway did not agree with that of the 134-ft. ship. The further alterations to the 111-ft. ship giving a 6.75 ft. (2.05 m.) diameter screw produced a screw efficiency which would appear to allow the propulsive coefficient, all other things being equal. However, Lackenby clearly overlooked the most important point in this comparison and correlation, namely, that it is impossible simply to scale a 134-ft. trawler to 111 ft. The normal block coefficient for 111-ft. LBP trawlers was of the order of 20 per cent. greater than that of the size he considered and the thrust loadings on the screws for these vessels were correspondingly higher. Starting from the 134-ft. ship and increasing the block coefficient and altering the wake fraction, thrust deduction, etc. to suit, produced a much lower propulsive coefficient. It was reiterated that the paper dealt with a class of trawler that has specialized features and that superficial comparisons with ships that are both larger and of finer form were invalid unless due allowances are made for the differences. To conclude, Dr. Corlett and Mr. Venus felt that they might further quote the skipper of the *Aberdeen Fisher* as follows:

"The first point is that the . . . hull . . . does make an extraordinarily good fishing platform . . . and all skippers give the highest praise to this most important point. The second point is that the . . . hull not only provides a good high speed, but enables progress to be maintained much

*In view of the interest in the discussion, the first reply by Dr. Corlett and Mr. Venus was submitted to the original discussers, [illegible] of whom made further comments.



Courtesy The Motor Ship

Fig. 760. General arrangement drawing of the Universal Star, *showing the gantry aft for hauling trawl wires, otter boards and the trawl and for lifting the gear inside the vessel*

Fig. 761. The Universal Star *on a shakedown cruise*

above average in all weathers, whereas the average normal trip from Aberdeen to Iceland waters takes about 68 hours, these ships have no difficulty in doing the same passage in 62 hours."

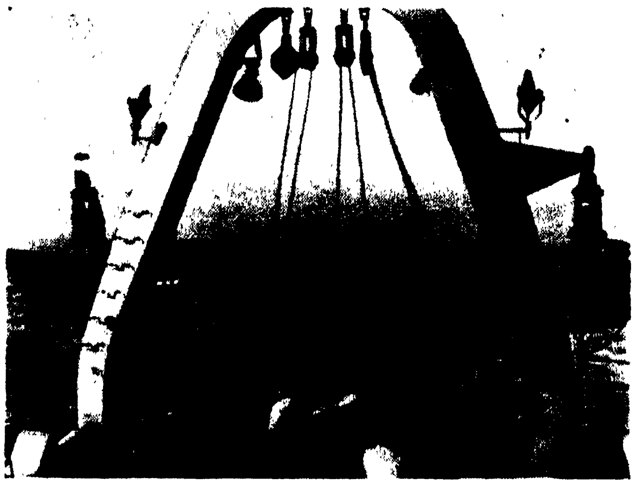
Stern fishing trawler. Since the paper was written and the discussion took place, the stern trawler *Universal Star* has been completed, and the first fishing trials have been held. Dr. Corlett and Mr. Venus felt that it might be of interest for the readers of the proceedings to have at hand fig. 760, showing the general arrangement plans of the new stern trawler *Universal Star*.

First of all, it was considered that the stern ramp arrangement which had been so successful in the larger trawlers might be difficult to incorporate in a smaller vessel owing to the fact that the freeboard to the working deck was so small. Therefore it was considered that there would have to be an after bulwark, but that this would have to hinge down flat to facilitate "shooting the gear". But since the stern could remain open only for the minimum of time, the hauling of the gear would have to be over this bulwark and accordingly it was decided

Fig. 762. The trawl is being hauled in and the trawl wires can be seen in the blocks outside the gantry which is in its stern position

to incorporate a hydraulically-operated gantry for hoisting aboard the trawl doors and the nets. To give maximum safeguard against possible fouling of the propeller by the trawl it was desirable to have the greatest possible distance between the propeller and the stern, and this was one of the reasons for incorporating a twin-screw design which enabled the propellers to be tucked well forward. Also it was felt that owing to the weight of the fishing gear at the stern when trawling, it would be necessary to have exceptional steering power, which is provided by the twin-rudder arrangement. Although at first it was intended that the trawl winch generator should be driven from the forward end of the starboard engine, preliminary trials made it apparent that full power was required on the starboard propeller when hauling the gear and accordingly an independent trawl winch generator was subsequently fitted.

A large-scale mock-up of the after deck was made, complete with gantry, on a scale of one-quarter full size. The Torry Research Station, Department of Scientific and Industrial Research, kindly sent one of their experts and provided also



763. When the otter boards are hauled up in the blocks, the gantry is moved forward for stowing the otter boards

miniature trawling gear to the same scale, and it soon became apparent that with a few slight amendments, the gantry arrangement held good possibilities.

Extensive tests were made on the model to simulate the worst conditions in actual fishing, i.e., recovering the gear with a broken warp, recovering the gear with crossed trawl doors, etc. The results of these tests were satisfactory in so far as the model was concerned and were considered of sufficient promise to warrant proceeding with the construction of an actual prototype.

Fig. 760 and 761 show that the layout is very different from that of the orthodox trawler, the crew are housed in a long forecastle, the machinery is forward and the shafting passes through a tunnel under the fishroom the centre of gravity of which is aft of amidships. A good feature is that the fish hold is almost rectangular with consequent good stowage. The wheelhouse position gives the skipper a good view forward, also aft under the working deck. The winchmen are well protected under the overhanging forecastle.

The main characteristics of the *Universal Star* are as follows:

LOA	104 ft. 0 in. (31.8 m.)
LBP	87 ft. 9 in. (26.8 m.)
Registered length	92 ft. 6 in. (28.2 m.)
Moulded breadth	25 ft. 3 in. (7.7 m.)
Moulded depth	13 ft. 9 in. (4.2 m.)
Mean draft	11 ft. 0 in. (3.4 m.)
Service speed	11½ knots
Fishroom capacity	5,445 cu. ft. (154 cu.m.)
Number of personnel	14

The main propulsion engine is a six-cylinder 460 SHP diesel running at 750 r.p.m. while the starboard engine has only four cylinders and an output of 308 SHP. These transmit through reverse-reduction gearboxes and are remotely controlled from the bridge.

A three-cylinder 190 h.p. engine is installed to drive the winch generator, the trawl winch having Ward-Leonard electric drive.

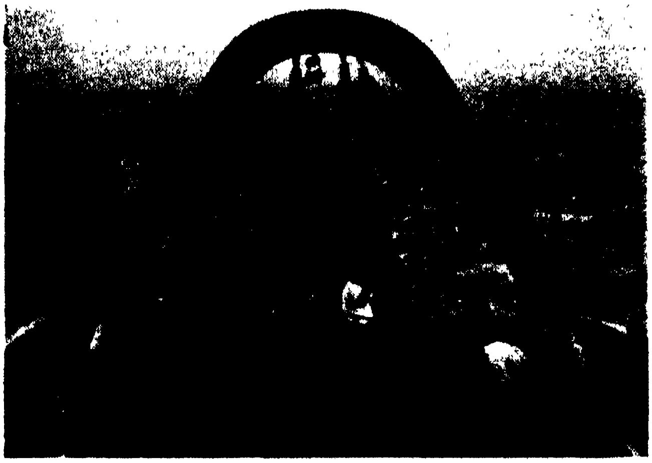


Fig. 765. The gantry is again in its stern position and the ground rope of the trawl is being hauled

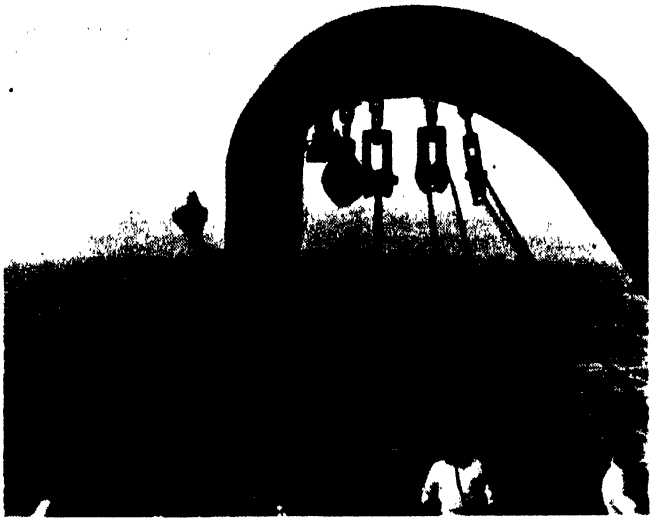


Fig. 764. With the gantry in forward position the otter boards are being lowered into specific places inside the rail

It is intended that the *Universal Star* shall fish for a trial period of about six months and the results compared with the 115 ft. (35.1 m.) size of trawler fishing on the same grounds, probably the Faroes, and that data will be carefully collected over this period so that an exact comparison can be made.

In two days fishing out of North Shields on trials from the shipyard, a catch of approximately 120 boxes was obtained and time for hauling and shooting the gear, an 80 ft. (24.4 m.) Granton trawl, has proved to be approximately half that with normal side trawling. Fig. 762 to 766 show the fishing operation.

LONG DISTANCE FISHING

Commander M. B. F. Ranken (U.K.): In the discussion of stern trawlers it was surprising that no one had mentioned the special stern which had been developed and model-tested by Lochridge and Messrs. Alexander Stephen & Sons to clear water from the ramp which might otherwise be carried inboard particularly when hauling nets in a following rough sea (fig. 767). This stern was incorporated in the design of a projected Portuguese Research stern trawler (Cardosa and Saraiva, 1959). It would be interesting to have comments on the need for such a stern construction.

Mr. A. Hunter, (U.K.): Heinsohn stated that experience shows the stability of a trawler should not be too high

Fig. 766. With the gantry in an upright position the cod end is eventually brought aboard

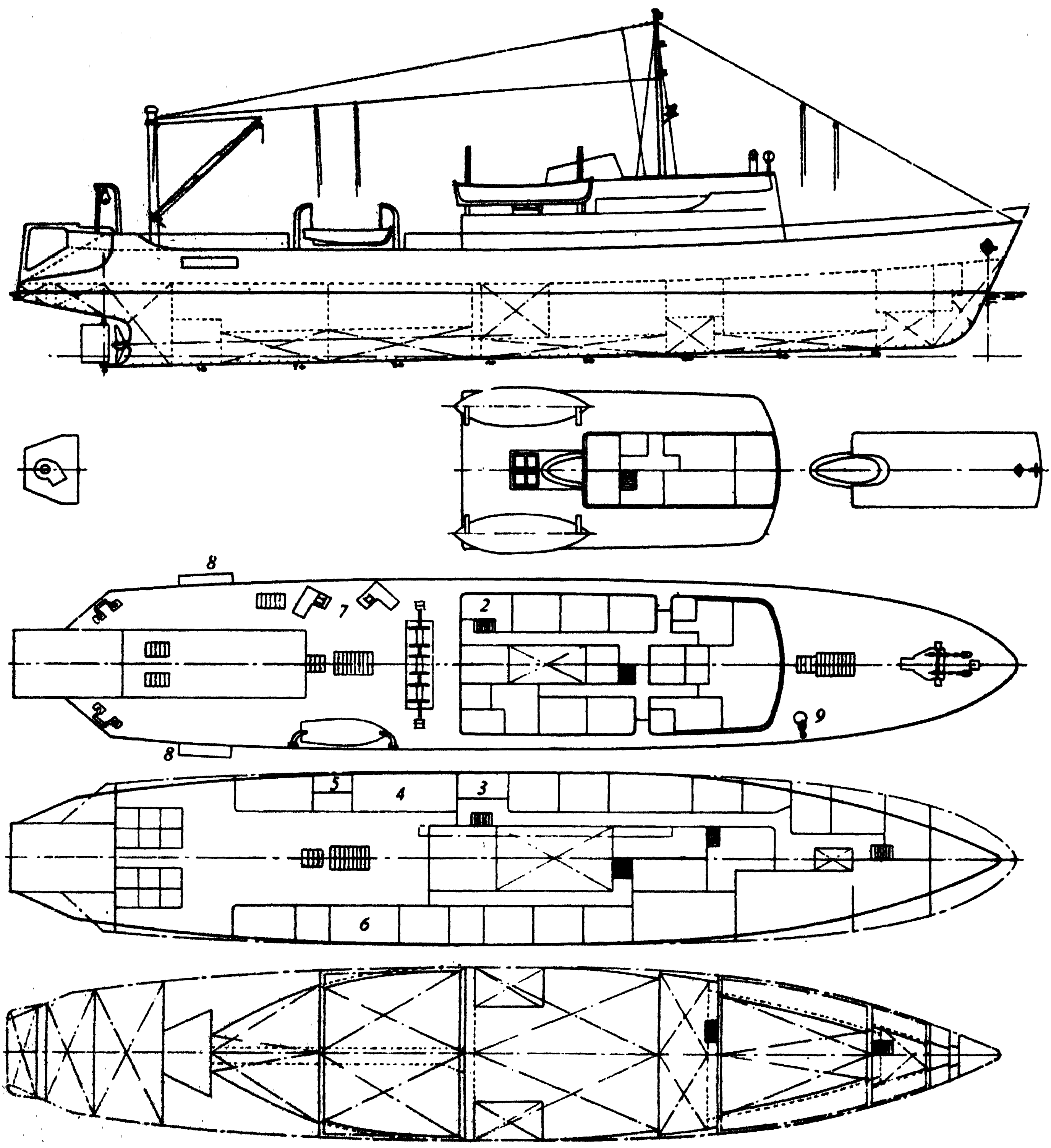


Fig. 767. Research stern fishing trawler

2. Deck laboratory
3. Dark room
4. Main laboratory
5. Main laboratory store
6. Factory laboratory
7. Oceanographic winches
8. Tuna-fishing platforms
9. Long[illegible]

otherwise it will be stiff. While this is accepted, the characteristics have to be such that good safety is provided over the whole range of the trawler's voyage, and depending upon the disposition of fuel and water tanks the stability can in the arrival condition, particularly when discharged, be considerably less than in the loaded departure condition. Further, where icing conditions are met the larger amount of exposed hull above the waterline in a stern trawler with 'tween decks could offer a greater target for the build-up of ice. With too small a metacentric height a list could develop, in which condition helm action would be less effective and the safety of the ship jeopardized.

The main deck had of necessity to be reasonably near the designed waterline. Special consideration would therefore be required for the means of getting rid of any water which came on the lower deck. He would like to ask if the drainage pumps were specially enlarged to deal with this contingency.

Stern trawlers are the future

MR. H. HEINSOHN (Germany) agreed with Hunter that the stability of the empty ship after discharging the cargo was considerably less than over the whole voyage. This was a feature of medium sized stern trawlers which could not be avoided, because the distance between the centres of gravity of the empty ship and that of the load (fish cargo, bunkers, fuel, etc.) was greater than on single deck trawlers, with consequently more change in stability. This is clearly shown by the stability data of the *Carl Kämpf*, fig. 706. The conclusion to be drawn in respect of handling the vessel is also shown by comparing cases Oa (empty), and Ob (empty+ freshwater) and Oc (empty+freshwater+10 ton deck cargo). It is a usual and simple procedure to fill the fresh-water tanks as soon as the vessel is moored. If possible, oil fuel is also taken, although this is done more to ease landing by reducing the height of the upper deck over the jetty. However, cases Oa (empty) and 4a (arrival with half cargo without bunkers or water) showed that the vessel was still safe and had a much better range of stability than a side trawler.

As regards icing up, as a naval architect, Mr. Heinsohn agreed with Hunter that, due to the higher and more exposed hull, the stern trawler should be worse off than the side trawler. However, the reports of the three trawlers showed that under icing conditions they actually performed better and their skippers now have great confidence in them. Mr. Heinsohn then offered two possibilities regarding icing up which he felt were, however, open to question:

- Where the air is very cold and wind is blowing up to force 8 or 9. Mainly spray originating from the ship's motions and occasional seas are shipped. In this case the stern trawler is much better off than the side trawler due to the higher freeboard. This advantage has probably resulted in the favourable reports regarding the three stern trawlers.
- Where gale force 10 to 12 prevails and spray is all over in the air, or where there are lower forces of wind and at the same time snow in the air which sticks very fast and is very difficult to remove. According to crews' reports this is due to the soft nature of the snow, compared with ice which is brittle and can be removed by axes. In this case the stern trawler is worse off than the side trawler because of the higher structure. Apparently this situation has not yet been met by the three trawlers. However, one skipper reported that he could free his foredeck from ice by taking high seas over it without danger due to the absence of bulwarks, guard rails for quick drainage only being provided. Mr. Heinsohn, however, felt somewhat doubtful about this and believed that more experience was needed.

In respect of drainage of the 'tween deck by pumps, reports showed that the necessity for this only very occasionally arose. Nevertheless all pumps in question (bilge pumps, fire pump and fish washing pump) could suck from the drain tank or tanks. On one ship a special pump of 40 ton capacity per hour was additionally fitted in the 'tween deck for this purpose.

To the question regarding the arrangement of crew quarters in the fore body, Mr. Heinsohn then said that the German trawlers over five years old, which were in the majority, had crew quarters forward, and there had been few complaints, the sailors being accustomed to this arrangement. Only crew members, which, like the cook and the greasers, has usually stayed aft, were in heavy weather not too happy. On the other hand, the engineers on the *Sagitta*, who were berthed in the part of the vessel with the least motion more aft, complained about the noise of the bobbins over their head during the net manoeuvre.

With regard to costs, careful calculations had shown that the difference in costs of stern trawlers compared with side trawlers of the same hold capacity and performance varied with the size of the vessels. For small trawlers (i.e. about 150 ft. or 46 m.) the difference was mainly due to the higher hull and the upper deck. With increasing size of the vessels it disappeared and was for vessels of about 190 ft. (58 m.) between 4 to 6 per cent. depending how much money was spent for mechanization of transport, fish washing, etc. When comparing costs it should always be kept in mind that the stern trawler offers more in every respect than a side trawler of the same performance.

As amplification of his statement on page 123, Mr. Heinsohn presented table 176, which gives detail data of every trawl haul during a Labrador trip in November 1959 with *Carl Kämpf*. The exact time when each operation took place was noted, and the actual time spent is set out in detail in the table.

The catch, according to the table, was about 3,474 boxes, or about 180 ton. The real weight landed is somewhat more, because the minimum weight of a box is 132.5 lb. (60 kg.) and the maximum weight 138 lb. (62.5 kg.). However, the boxes are always counted as weighing 132½ lb. Furthermore it is estimated that the fish lost about 5 to 10 per cent. of weight during the trip. The actual weight of the fish caught is therefore estimated to be about 200 ton.

From table 176 it can be seen that the average time from the start of hauling until the trawl was back on the bottom again was 34.4 min. The average length of the trawl warps was 526 fm. (965 m.). The average time spent in hauling the warps was about 9.9 min. Thus the average hauling speed of the winch would be 319 ft./min. (97.36 m./min. or 1.62 m./sec.). The average time spent actually fishing with the trawl on the bottom was 1 hr. 49 min. The average time spent in shooting the trawl with bobbins, lowering the bridles and shakling on the main trawl boards was 2.2 min. and the average time spent from the time the trawl boards were in the gallows until the codend was on deck was 4.3 min.

The fourth stern trawler mentioned in the paper had now been delivered. Fig. 768 shows the general arrangement drawing of *Carl Wiederkehr* which has the following main particulars:

TABLE 176

Data from trawling trip to Labrador with *Carl Kämpf* in November 1959
(engine r.p.m. while trawling=250)

Haul No.	Date	Weather	State of sea	Depth		Length of warps fm.	Trawling		Time spent for							Catch baskets
				ft.	m.		Speed knots	Direction	Shooting trawl min.	Shooting warps min.	Actual fishing hr.	min.	Hauling warps min.	Taking in trawl min.	Emptying ready for next shooting min.	
1st Fishing ground																
1	7/11	SW.5	SW.3	980	300	500	4.6	WNW	2	13	2	0	9	4	5	50
2	..	.. 2	.. 2	..	..	..	4.5	E	3	12	2	5	9	3	6	100
3	..	..	..	885	270	..	4.6	W	2	14	2	8	10	4	5	70
4	..	.. 1	.. 1	980	300	..	4.4	E	2	14	2	9	10	5	5	50
5	6/11	.. 3	.. 2	..	..	..	4.5	W	2	12	2	4	10	4	3	10
6	..	..	..	..	..	..	4.4	E	3	12	2	35	10	5	4	43
7	..	W.	W.	950	290	..	4.6	W	2	17	2	6	9	3	11	48
8	..	..	..	980	300	..	4.3	E	2	15	1	45	10	4	Steaming	95
Position: Lat. North 50 27', Long. W. 50 52'																
9	9/11	S.1	S.1	1,020	310	525	4.4	SW	3	15	1	21	10	4	5	25
10	..	..	..	1,030	315	..	4.5	NE	2	15	1	36	10	4	4	87
11	..	..	..	1,050	320	..	4.5	E	2	13	1	33	11	4	11	30
12	..	..	..	1,020	310	..	4.6	W	2	11	1	29	11	4	6	114
13	..	S.2	S.1	1,080	330	550	4.6	SW	2	10	1	34	11	4	5	83
14	..	..	..	..	..	..	4.4	ENE	2	14	1	52	10	5	14	160
15	..	..	..	1,065	325	..	4.5	E	3	12	1	51	10	4	10	130
16	..	..	..	..	..	..	4.6	WSW	2	13	1	44	9	4	4	50
17	..	..	..	1,080	330	550	4.4	E	3	14	2	0	10	4	8	35
18	10/11	S.3	S.1	1.055	325	..	4.4	W	2	13	2	5	11	4	7	40
19	..	..	..	..	..	..	4.5	ESE	2	12	2	11	11	4	16	40
20	..	..	..	1,040	318	..	4.6	WNW	2	15	2	7	9	4	25	54
21	..	..	..	1.050	320	..	4.4	E	2	13	1	40	11	4	3	30
22	..	S.1	..	..	..	..	4.5	N	2	15	1	34	9	5	7	100
23	..	..	..	..	..	..	4.5	SW	1.5	14.5	1	36	9	4	5	110
24	..	..	..	..	..	..	4.6	NE	2	14	1	31	10	4	7	70
25	..	..	..	..	..	..	4.4	S	2	13	1	56	10	4	9	50
26	..	..	..	..	..	..	4.5	N	3	14	2	10	12	4	4	40
27	11/11	NE.1	E	1,065	325	550	4.6	SW	2	12	2	3	10	4	5	60
28	..	..	..	1,050	320	..	4.6	N	2	14	2	10	10	4	10	40
29	..	..	..	..	..	..	4.6	S	3	12	2	20	10	4	3	30
30	..	..	..	..	..	..	4.5	NE	2	13	2	27	12	4	7	40
31	..	N.4	N.1	..	..	..	4.4	ENE	2	13	2	5	11	4	16	86
32	..	N.6	N.3	1,030	315	..	4.6	SW	3	16	2	3	10	4	6	74
33	..	..	..	1.035	325	..	4.5	E	2	16	2	15	11	8	Steaming	50
Bank of Newfoundland. Position: Lat. North. 47° 57', Long. W. 48° 20'																
34	12/11	N.3	N.5	1,020	310	525	4.5	ESE	3	13	2	1	10	5	5	40
35	..	..	..	1,030	315	..	4.6	W	2	14	1	34	8	7	Steaming	40
36	..	N.2	N.4	..	..	500	4.4	NE	3	13	1	57	10	5	3	30
37	..	..	..	1.050	320	..	4.4	SW	2	12	1	58	9	4	Steaming	20
Sailed distance 175 nautical miles. Position: Lat. North. 45 10', Long. W. 48° 40'																
38	13/11	N.1	N.1	980	300	500	4.6	S	3	13		33	9	5	Steaming	10
39	..	..	..	1,080	330	550	4.4	S	2	13		45	11	4	Steaming	Black
40	..	..	..	1,065	325	..	4.5	S	2	12	1	1	10	4	9	10
41	..	..	..	..	..	..	4.5	SW	2	10		57	9	6	6	65
42	..	..	..	1,115	340	..	4.6	NE	2	12		41	8	4	12	50
43	..	..	..	..	..	..	4.5	S	2	12		54	10	5	Steaming	50
44	..	..	..	..	..	..	4.5	ESE	2	11		44	10	3	5	10
45	..	..	..	..	..	..	4.6	W	2	12	1	6	9	4	5	85
46	..	..	..	1,065	325	525	4.5	E	2	12		42	10	4	4	5
47	..	..	..	..	..	..	4.5	W	2	13	1	30	10	5	Steaming	20

Table 176 (*continued*)

Haul No.	Date	Weather	State of sea	Depth ft.	Depth m.	Length of warps fm.	Trawling Speed knots	Trawling Direction	Time spent for: Shooting trawl min.	Shooting warps min.	Actual fishing hr. min.	Hauling warps min.	Taking in trawl min.	Emptying ready for next shooting min.	Catch baskets
Sailed distance 175 nautical miles. Position: Lat. North. 45° 10′, Long. W. 48° 40′															
48	14/11	N.1	NE.1	1,080	330	550	4.6	N	2	13	2 0	10	4	7	20
49	,,	,,	,,	1,050	320	525	4.6	N	2	14	1 15	10	4	Steaming	40
50	,,	,,	,,	1,030	315	,,	4.5	NE	2	13	1 16	9	4	57	30
5th fishing ground															
51	15/11	Calm	E	980	300	500	4.6	SW	2	13	2 4	9	4	7	50
52	,,	,,	,,	,,	,,	,,	4.6	N	2	12	2 18	10	4	6	40
53	,,	,,	,,	1,020	310	500	4.6	SW	2	12	2 1	10	6	4	50
54	,,	,,	,,	,,	,,	,,	4.6	SE	2	13	0	10	4	9	50
55	,,	,,	,,	,,	,,	,,	4.6	S	2	11	2 23	9	4	3	60
56	,,	,,	,,	1,030	315	500	4.5	NW	2	11	2 9	11	4	3	60
57	,,	S.1	,,	,,	,,	,,	4.6	E	2	12	2 2	11	4	5	30
58	,,	S.2	S.1	,,	,,	,,	4.6	W	2	14	2 0	10	5	5	70
59	,,	,,	,,	980	300	525	4.5	E	2	13	2 40	9	4	12	60
60	16/11	SW.1	S.1	980	300	525	4.5	W	2	13	2 7	10	5	5	25
61	,,	,,	,,	1,020	310	,,	4.6	W	2	12	2 26	10	5	5	60
62	,,	,,	,,	,,	,,	,,	4.6	WSW	2	11	2 40	9	5	5	80
63	,,	SW.2	SW.2	,,	,,	,,	4.5	ESE	2	13	2 1	9	4	6	40
64	,,	SW.5	,,	1,065	325	,,	4.6	WNW	2	13	2 3	10	5	5	80
65	,,	,,	,,	,,	,,	,,	4.6	ESE	2	13	2 7	10	4	Steaming	100
															3,475 (180 tons)
									hr. min.	hr. min.	hr. min.	hr. min.	hr. min.	hr. min.	
Total time spent on the different operations in connection with fishing									2 21	14 23	118 9	10 43	4 40	5 25	
Percentage of grand total (about)									1.5	9.2	76	6.9	3	3.4	
									min.	min.	hr. min.	min.	min.	min.	
Average time for each operation									2.2	13.3	1 49	9.9	4.3	5	

Notes for

Haul No. 2. At 21.10: 4 min. repair work (of trawl).

Haul No. 3. Between 00.10 and 00.60 two hauls were made, total catch 100 baskets. Steaming between 09.15 and 09.36. Repair of trawl between 14.52 and 15.03. Skipper decided to shift to a fishing ground further south—about 150 nautical miles to the south of Hamilton Bank.

Haul No. 11. Repair of trawl between 11.24 and 11.35.

Haul No. 13. Repair of trawl between 18.20 and 18.30

Haul No. 19. Between 10.15 and 10.35 time was spent in exchanging bridles and parts of footrope.

Haul No. 27. Trawling bottom particularly even, no fungi and slightly stony.

Haul No. 29. Repair of trawl, 15 min.

Haul No. 30. Trawl taken in and course set for fishing grounds further south.

Haul No. 34. At 10.00 hours on the fishing ground, sailed distance 175 nautical miles. Steaming between 14.55 and 15.11 hours. At 20.07 hours course set for a fishing ground further south.

Haul No 38. Steaming.

Haul No. 39. Steaming.

Haul No. 40. Chiefly scrap fish.

Haul No 41. Steaming between 18.15 and 18.23 hours.

Haul No. 50. At 00.30 hours the trawl was taken in and course set for Flemish Cap. At 15.18 hours off Flemish Cap 7–8 Russian factory trawlers were fishing here.

Haul No. 51. Between 21.42 and 22.39 hours boards were exchanged as well as part of warps and warps spliced. The entire operation took less than one hour.

Haul No. 56. Repair work, 7 min.

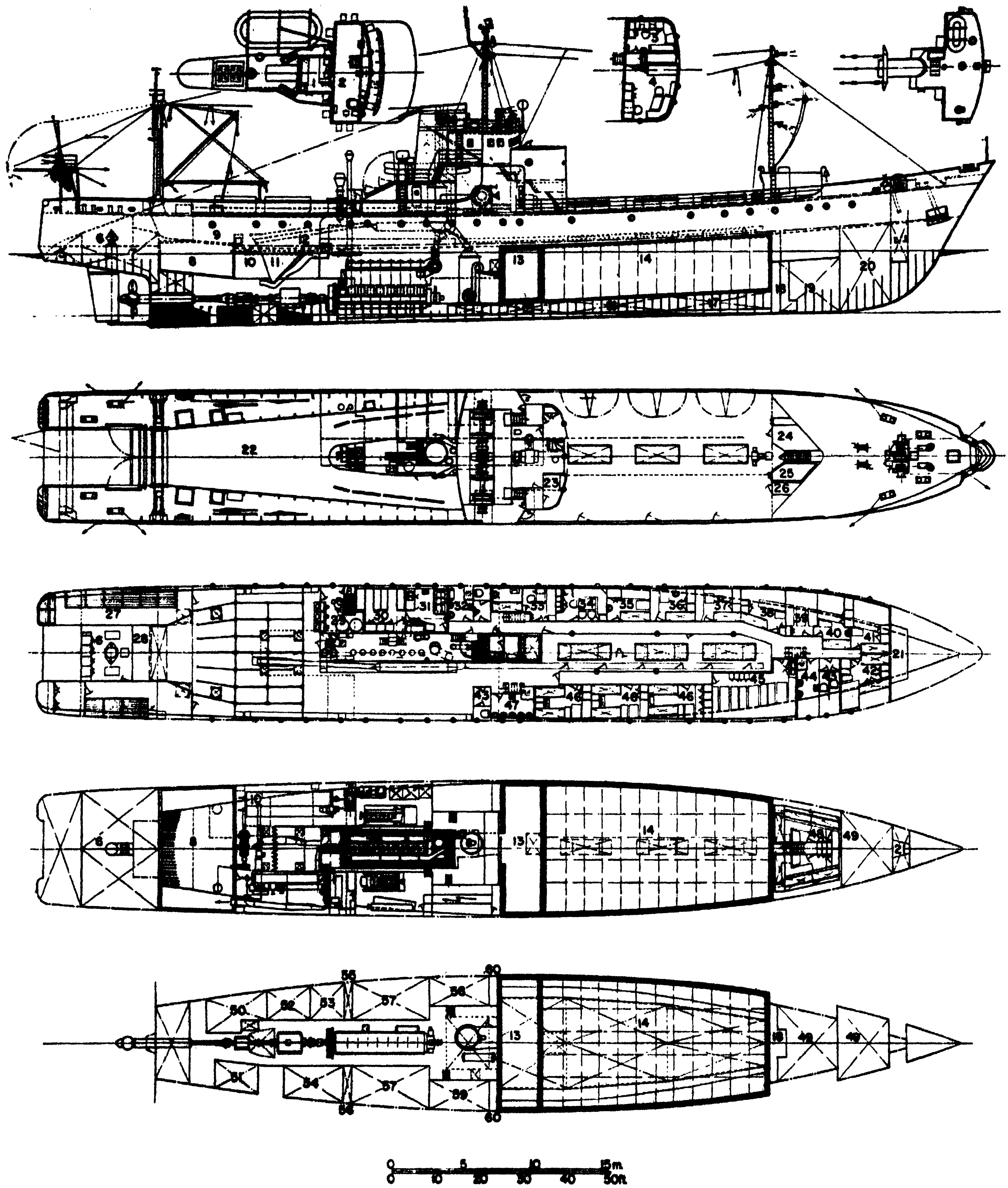


Fig. 768. General arrangement of Carl Wiederkehr, *fourth German medium-sized stern trawler. LOA = 220 ft. (67.25 m.); LBP = 189 ft. (57.60 m); B = 31.5 ft. (9.60 m.); D to upper deck = 23.5 ft. (7.15 m.); D to 'tween deck = 16.1 ft. (4.90 m.)*

Fig. 769. Carl Wiederkehr *during trials*

LOA	220 ft. (67.25 m.)
LBP	189 ft. (57.60 m.)
B	31.5 ft. (9.60 m.)
D to upper deck	23.5 ft. (7.15 m.)
D to 'tween deck	16.1 ft. (4.90 m.)
Fresh fish hold	About 16,500 cu. ft. (468 cu. m.)
Refrigerated fish hold	2,260 cu. ft. (64 cu. m.)
Fuel oil	171 ton (204 cu. m.)
Fresh water	82 ton (82 cu. m.)
Liver and fish oil	30 ton (33 cu. m.)
Fish meal storage	3,140 cu. ft. (89 cu. m.)

Carl Wiederkehr has proved to be highly successful. Fig. 769 shows a photo. The bulk of German orders placed early in 1960 was for stern trawlers, and it is also being discussed to change some of the contracts for side trawlers to stern trawlers. Enquiries to-day are nearly all for stern trawlers. Mr. Heinsohn's shipyard was to deliver 5 stern trawlers during 1960. Side trawlers are now out of the question for German owners and considered only for special cases.

1. Chart room
2. Radar
3. Radio
4. Captain
5. Ballast-water, 4,625 Imp. gal. (21.0 cu. m.)
6. Rudder machinery
7. Fuel, 2 × 7,450 Imp. gal (2 × 33.8 cu. m.)
8. Fish meal
9. Fish pond
10. Fish meal plant
11. Waste pond
12. Sorting
13. Refrigerated hold
14. Fish hold
15. Water, 3,880 Imp. gal. (17.6 cu. m.)
16. ,, 7,430 Imp. gal. (33.8 cu. m.)
17. ,, 6,030 Imp. gal. (27.7 cu. m.)
18. Pump room
19. Fuel oil, 8,100 Imp. gal. (36.7 cu. m.)
20. ,, ,, 9,700 Imp. gal. (44.0 cu. m.)
21. Chains
22. Slip deck
23. Drying room
24. Air heating
25. Potato store
26. Rubber raft
27. Net room
28. Space for fish chute
29. Liver boiler
30. Provisions
31. Galley
32. Wash room for officers
33. Chief Engineer
34. Officers mess
35. First Officer
36. Second Engineer and spare
37. Second Officer and spare
38. Two boys
39. Mess
40. Cook and spare
41. Two men
42. Three men
43. W.C.
44. Wash room
45. Crew's mess
46. Four crew
47. Wash for crew
48. Six salters
49. Fuel oil
50. Liver oil, 1,150 Imp gal. (5.2 cu. m.)
51. ,, ,, 595 Imp. gal. (2.7 cu. m.)
52. Fish oil, 1,340 Imp. gal. (6.1 cu. m.)
53. Liver oil, 1,650 Imp. gal. (7.5 cu. m.)
54. ,, ,, 2,550 Imp. gal. (11.6 cu. m.)
55. Overflow fuel oil
56. Bilge water
57. Fuel oil, 3,900 Imp. gal. (17.7 cu. m.)
58. ,, ,, 2,710 Imp. gal. (12.3 cu. m.)
59. ,, ,, 1,830 Imp. gal. (8.3 cu. m.)
60. Coffer Dam

CHOICE OF BOAT TYPE AND SIZE FOR POLISH DEEP-SEA FISHERIES

by

JERZY SWIECICKI

The investigations were made in three stages:

- Trends of development in the world sea fisheries were analysed, the principal guiding lines were formulated, and the criteria of choice of the optimum type of fishing vessel for specific production conditions, were formulated.
- Preliminary approximations and statistical methods were adopted in choosing the main parameters for fishing vessels: capacity of hold, processing and freezing capacity, type and power of main engine, number of crew. Comparisons of the expected financial results of the various types of vessels were made.
- Simplified methods of choosing the main parameters for the optimum ship were investigated. Graphical analysis was used to find the correlations between some of the vessel's parameters, distance to fishing grounds, amount of daily catches, range of processing operations on board, etc.

LE CHOIX DU TYPE ET DES DIMENSIONS DE NAVIRES POUR LES PÊCHES HAUTURIÈRES POLONAISES

Les recherches ont été faites en trois étapes:

- Les tendances du développement des pêches maritimes mondiales ont été analysées, les grandes lignes ont été formulées ainsi que les critères du choix du type optimum de navire de pêche pour des conditions de production spécifiques.
- Des approximations préliminaires et des méthodes statistiques ont été adoptées pour choisir les paramètres principaux pour les navires de pêche: capacité de la cale, capacité de traitement et de congélation, type et puissance du moteur principal, nombre d'hommes d'équipage. On a fait des comparaisons entre les résultats financiers prévus des divers types de navires.
- Des méthodes simplifiées pour choisir les paramètres principaux pour le navire optimum ont fait l'objet de recherches. On a utilisé l'analyse graphique pour trouver les corrélations entre quelques-uns des paramètres du navire, la distance des lieux de pêche, les quantités pêchées journellement, l'étendue des opérations de traitement à bord, etc.

SELECCION DE FORMA Y TAMAÑO DE LOS BARCOS PARA LA PESCA DE ALTURA EN POLONIA

Las investigaciones se hicieron en tres partes:

- Se analizaron las tendencias de las innovaciones en las pesquerías marinas del mundo, se formularon las principales líneas de orientación y los criterios de selección del tipo óptimo de barco de pesca para condiciones específicas de producción.
- En la selección de los principales parámetros para barcos de pesca se adoptaron aproximaciones preliminares y métodos estadísticos: capacidad de la bodega, capacidad de elaboración y congelación, clase y potencia del motor principal, número de tripulantes. Se hicieron comparaciones de los resultados financieros esperados de las diversas clases de barcos.
- Se investigaron métodos simplificados de selección de los parámetros principales para el barco óptimo. Se empleó el análisis gráfico para encontrar las relacions entre algunos de los parámetros del barco, la distancia a los caladeros, la cuantía de las capturas diarias, la amplitud de la elaboración a bordo, etc.

AFTER World War II, Poland regained access to the sea, which made possible the development of a maritime economy.

A deficit in animal protein, taken together with the slow and comparatively expensive development of meat production, enhanced the economic importance of the sea fisheries. As the resources of the nearby Baltic fishing grounds were limited, it was necessary to develop the long-distance fisheries. Since 1952, owing to the rapid development of the shipbuilding industry, many deep-sea fishing vessels have been built. Table 177 and fig. 770 show the catch of the Polish sea fisheries from 1946 to 1957.

In 1958 the catch per head of population amounted to about 10 lb. (4.4 kg.). This corresponds to a real consumption of some 6.6 lb. (3 kg.).

The deficit in animal protein cannot be covered by meat consumption, which is only 68.4 lb. (31 kg.) per head yearly, and the joint yearly consumption of fish and meat 75 lb. (34 kg.) per head, is much below the level in other European countries. The supply of adequate amounts of animal protein up to recognized biological standards sets a very serious task for Polish agriculture and fisheries. The part to be played by fisheries is particularly important, as protein could be supplied by the fishing industry in a shorter time and at a lower cost (Laszczynski, 1958).

According to the Sea Fisheries Institute in Gdynia, the total yearly catch of the Polish sea fisheries must reach 500,000 ton by 1975 (table 178) to meet the demands of Poland's growing population, which, by then, might reach 37.7 million.

Factors which have had a bearing on Poland's sea fisheries and which have produced special working conditions, are:

- Deep-sea fishing vessels are operated by State-owned enterprises
- The State allots non-repayable investment funds to individual enterprises, and exercises a decisive influence on the character and technical features of the investments

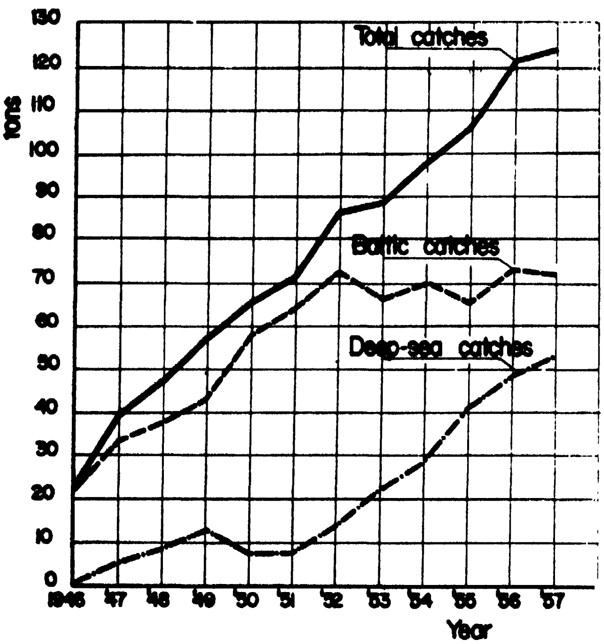


Fig. 770. Polish sea fisheries results

- The limited opportunities for fishing in the Baltic made it necessary to extend activities to remote regions of the North Sea, a distance of 750 to 1,000 sea miles, and to the North Atlantic, i.e. 1,200 to 3,400 sea miles

AIM OF STUDY

As Poland had little experience in building and operating deep-sea fishing vessels, the Ministry of Shipping and Internal Waterways commenced studies in 1954 on the development of Poland's fishing fleet, including an investment policy. The Ministry requested information as to:

- Types and numbers of fishing vessels needed to fulfil the tasks planned
- Approximate extent of the investment
- The economic results to be expected

The aim of the study was, therefore, primarily to establish optimum vessels for Poland's sea fisheries, both from the technical and economic point of view.

TABLE 177

Polish sea fisheries catch—1946 to 1957

Year	*Total*	*Catches* *Baltic*	*Deep-sea*
1946	23.4	22.2	1.2
1947	39.5	33.5	6.0
1948	47.1	38.3	8.8
1949	57.2	43.7	13.5
1950	65.8	58.1	7.7
1951	71.7	64.1	7.6
1952	86.8	72.8	14.0
1953	89.4	66.7	22.7
1954	99.4	70.4	29.0
1955	107.3	65.6	41.7
1956	122.5	73.5	49.0
1957	125.7	72.2	53.5

(1,000 ton)

SUBJECT OF STUDY

The Polish fishing fleet is comprised of
- The Baltic cod and herring fleet:
  - Off-shore fishing boats
  - Short-distance cutters
  - Long-distance cutters
- Deep-sea fleet:
  - Herring fleet
  - White-fish fleet
- Auxiliary fleet:
  - Base ships
  - Research ships, hospital and workshop vessels
  - Other auxiliary vessels

Primary attention was given to deep-sea vessels, as the increase in catches by 1975 was expected mainly from the distant North Sea and Atlantic fishing grounds.

Economic analyses were made of the following vessel types:
- Drifters
- Drifter-trawlers
- Base ships
- Freezing trawlers
- Catchers and motherships

RANGE OF STUDY

Making new investments in Poland is rather complicated, as such investments are subject to special regulations and requirements. A study is first made, which enables the shipowner to give the designer data on basic requirements and to conclude the building contract with the shipyard.

TABLE 178

Presumed distribution of the total amount of fish among various fishing areas and species of fish in 1975

Species	*Total*	*Area* *Baltic*	*North Sea*	*Atlantic*
Total	500	90	120	290
White-fish	275	60	15	200
Herring	200	20	100	80
Other	25	10	5	10

(1,000 ton)

Studies of this character are carried out only for large-scale investments or with regard to a new type of ship. The range of these studies therefore depends greatly on the shipowner's needs. The range and pattern of such studies in fisheries have been established as follows:

Basic elements for operation:

- Character of service performed
- Area and time of fishing activities
- Weather conditions
- Fishing methods and gear
- Processing operations on board
- Programme of production, suggested time-table of trips
- Capacity of hold
- Range of operation
- Number and composition of crew

Engines and gear:

- General remarks
- Engine room characteristics
- Speed and hauling power
- Processing plant and equipment
- Freezing plant and equipment
- Inner transport equipment
- Choice of propulsion and power required

Size of vessel:

- Approximate size of the vessel
- Capacities of hold and store rooms
- Capacity of processing space
- Quantity of provisions and storage capacity
- Crew accommodation
- Approximate loads and the ship's stability
- Comparison of sizes of similar vessels
- Conclusion and scheme of functional arrangement

Economic analysis

- Aim, subject and method of analysis
- Comparative calculation of costs and financial results
- Comparison of various ships

METHOD OF CHOOSING THE OPTIMUM FISHING BOAT

When, in 1954, the Ministry considered making the studies, neither the Sea Fisheries Institute at Gdynia nor the Maritime Institute at Gdansk had an appropriate method of investigation to offer, nor were any suitable foreign examples available. It was necessary, therefore, to device a method.

Studies on the optimum fishing vessels were carried out in three stages:

1. Determination of the guiding theses concerning the type of vessel
2. Preliminary assumptions concerning the type of vessel, based on the guiding theses
3. Precise determination of basic parameters

Determination of guiding theses

Importance of industry in national economy. A broad approach to the subject, taking into account its place in the national economy, was the fundamental principle in the investigations. The future development in a field of production can be determined only by previous detailed investigations of this production and against the developmental background of the whole national economy. Trends of Poland's deep-sea fishing fleet should thus be found in the general programme of fisheries development—the fleet being one of its elements —which in turn can be established from the leading trends in the development of national economy.

By applying this principle and by carrying out an analysis of market demand, consumers' preferences and increase in population, it was possible to determine the quantities and kinds of main fish products for the target year 1975.

The choice of fishing grounds, fishing gear and fishing methods must be made from both the technical and economic viewpoint. Thus, the broad approach entails the services of many experts from various fields of science.

World trend of sea fisheries development. A study of trends in world sea fisheries was undertaken as an auxiliary means of determining the various types of vessels and fishing methods to be employed. Particular attention was given to modern developments in fishing gear and methods, fish preservation, types of vessels, etc.

The trends revealed were then investigated from the viewpoint of the future needs of the Polish sea fisheries. The conclusions reached supplied supplementary material to the main project.

Survey of existing fishing vessels. Survey work was carried out simultaneously on types of vessels, fishing methods, fishing gear, etc., in operation in the Polish sea fisheries. This enabled the investigating staff to become better acquainted with problems of a professional and social character.

Conclusion. The conclusions have been verified by comparing the opinions of the research teams and of the operators, including skippers. The opposite opinions of the two parties often induced valuable discussion and were an instrument of control.

Guiding principles

The guiding theses thus obtained served as a framework for further investigation. The conception of "the optimum fleet" was explained in the guiding theses. Three criteria were taken as a basis:

1. Quality of product as a basis for the development of fish consumption
2. Profit as a basis for providing the necessary investment funds
3. Welfare and safety of crews

The principles involved have been developed into the following seven points:

- The general programme of operation of the new deep-sea fishing fleet should be adjusted in the best possible way to geophysical, geographical, biological, meteorological and other conditions prevailing on the selected fishing grounds, and in Poland

- The deep-sea fishing fleet has been operated in collaboration with base ships. Vessels of the new fleet should be so designed as to be operated without base ships, directly from home ports
- The technical equipment of the vessels and the methods of operation should assure fish supplies of the best quality, satisfying consumers' preferences as well as the needs of the processing industry
- The minimum operation cost for a given type of vessel should at the same time ensure the maximum rate of capital gain
- Realization of these requirements can be assured by the application of the principles of large-scale industrial production and organization of work. This usually results in specialization of the ultimate product, in mechanization of processes and of inner transport, and, finally, in making the best use of technical equipment, facilities and labour
- Welfare and safety conditions for crews require radical changes so as to achieve standards usually met with in the merchant marine
- The development of the fishing fleet should proceed gradually, following the growing need of consumers and the demand by the processing industry

Preliminary assumption based on the guiding theses

The basic parameters of the optimum fishing vessel of a specific type were determined by several methods. A rough estimate was first made and then checked by statistical analysis.

Rough approximation. The method of approximation was primarily to study several common designs, each of which was subject to a thorough technical and economic analysis. This enabled the optimum design to be determined.

Owing to rapid technical progress in the boat-building industry, and to changing operational conditions, etc., it is necessary to analyse these basic designs from time to time. New designs can then be worked out, in line with modified conditions. A general concept of the optimum fishing vessel will be kept up-to-date and in line with current operative conditions.

The greater the number of variants compared, the more realistic will be the general concept of the optimum fishing vessel. Investigations are continued after construction of the prototype vessel, and actual operational and financial results are later compared with those assumed in the general concept.

Statistical analysis of assumed items. Statistical methods have been used as an auxiliary instrument in determining basic parameters of the optimum vessel and in the economic analysis of individual variants, mainly in determining the size of the vessel, namely:

Capacity of hold:

The optimum capacity of the hold was determined from the "Time-table of Trips". An example for a factory trawler is given in table 179. The number of trips was set down in conformity with the yearly number of days at sea, as achieved by similar vessels, based on data drawn from Polish and foreign sea fisheries. Also taken into account were the operative gains derived from a decreased number of trips per year, the daily output remaining unchanged, according to statistics, for the last five years. Opposed to this "propitious" factor, were others of a restrictive character, as, for instance, the limited size of the vessels fishing with drift-nets, the time spent by the crew at sea, the resistance of fish products to deterioration, etc. From a consideration of the opposing factors mentioned above, and of approximations, data for the "Time-table of Trips" were prepared. The catch of a single trip and knowledge of the stowing coefficient for various kinds of fish products, provided a base for computing the required capacities of holds.

Processing capacity:

The area needed for processing was determined by ascertaining the processing capacity of the plant, type of mechanization and transport, and, finally, by considering a given set of processing machinery and facilities. The processing capacity of the plant was determined by analysing daily output at specific fishing grounds and in individual months. As a rule, the processing capacity of the plant was determined on the average catches, and certain buffer storage space was provided to keep surpluses of fish.

Main engine horsepower:

The choice of the main engine was made after a special study of engines and propellers for various types of vessels. It was necessary first to fix the service speed of a vessel to determine the engine horsepower. The choice of an economic service speed was made by the aid of a comparative table (table 180). Cost and value of production columns were compiled from statistical and book-keeping data of fishing enterprises, or by approximate calculations.

Number of crew:

The number of crew was determined by taking into account the work needed, the condition of mechanization of the processing operations and transport, and, finally, the organization of work and the efficiency of labour, the latter being determined for individual processing operations on board by statistical data. If the appropriate data were not available, figures for land processing plants were used, allowing for a decrease of 30 to 50 per cent. The number of crew was fixed for deck, engine room, fishing and processing.

Economic appreciation:

The financial results were analysed. The comparative

TABLE 179

Time-table of trips for a factory trawler

No.	*Time of trip*	*Fishing ground*	*In port* days	*At sea* days	*Under-way* days	*Stormy weather* days	*Fishing time* days	*Daily catches* ton	*Catches during trip* ton	*Frozen products* *Fillets* ton	*Frozen products* *Gutted and de-headed* ton	*Fish meal* ton	*Fish oils* *Liver oil* ton	*Fish oils* *Offal oil* ton
I	1.II–22.IV	Greenland	5	81	16	10	55	28	1,540	403	220	140	28	7
II	27.IV–16.VII	Greenland–Labrador	5	80	19	8	53	30	1,590	417	230	150	29	7
III	21.VII–9.X	Greenland–Newfoundland	5	80	24	6	50	32	1,600	420	240	155	30	8
IV	14.X–30.XII	Greenland–Newfoundland	5	77	22	8	47	34	1,600	420	240	155	10	25
		Total . .	20	318	81	32	205	30.9 mean	6,330	1,660	930	600	97	47
		Percentage of time at sea .		100	25.6	10	64.4							

Hold's capacity for:		cu. ft.	(cu. m.)
Fillets	cu. ft. (cu. m.)	28,957	(820)
Frozen deheaded fish .	,, ,,	18,363	(520)
Total . .	,, ,,	47,320	(1,340)
Fish meal . . .	,, ,,	9,172	(260)
Oil and liver oil tanks .	,, ,,	1,766	(50)

tables contain presumed financial results based on general concepts of the vessels in question (table 181). The main value of these tables consists in providing a means of comparing costs and financial results for several vessels. The comparability of the data can only be achieved if the same method is used in computing successive items. The calculations are based on the statistics and accounts of fisheries enterprises, in conformity with the principles of calculation which are obligatory in Poland (Noetzel, 1958).

These calculations are of relative value only as regards the various vessels discussed although, in a certain sense, they contain a synthesis of the consequences of the assumed general concept of operation and of the technical solution.

By comparing the rate of capital gain, conclusions may be reached as to the most suitable choice of vessel.

TABLE 180

Arrangement of table for determining the optimum service speed of a fishing vessel for — nautical miles distance from fishing grounds

No.	*Elements of comparison*	*Measures*	*Speeds in knots* 11.5	12.6	13.5	14.5
1	Engine power	h.p.	—	—	—	—
2	Fishing time	days	—	—	—	—
3	Yearly catches	ton	—	—	—	—
4	Fuel consumption	ton	—	—	—	—
5	Value of products	million zlotys	—	—	—	—
6	Cost of production	million zlotys	—	—	—	—
7	Profit or loss	million zlotys	—	—	—	—

Precise determination of basic parameters

Analysis to establish an exact method for determining the basic parameters of the optimum fishing vessel is based on the following correlations:

Correlation between yearly catches and distance to fishing ground, for various daily outputs and hold capacities. Fig. 771 gives information on the operation of four suggested drifter-trawlers, carrying salted herring from the North Sea grounds. The diagrams also show the yearly production of round-fish against the distance

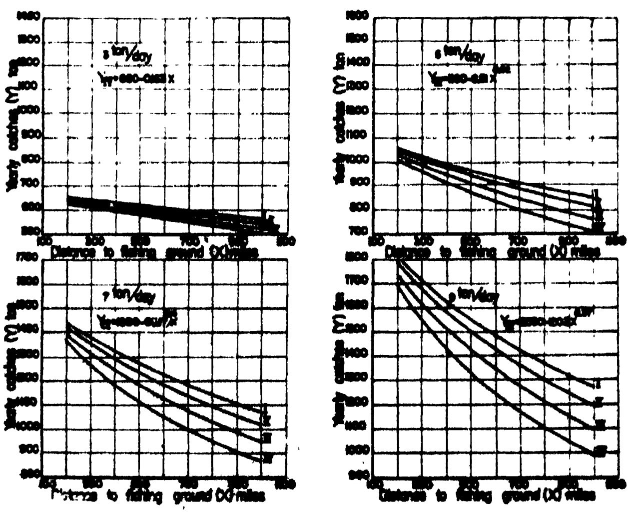


Fig. 771. Correlations between yearly catches Y and distance to fishing grounds X in nautical miles for various daily outputs, (3, 5, 7, 9 ton), and hold capacity 7,100 (IV), 8,800 (III), 10,600 (II), 12,400 (I) cu. ft. (200, 250, 300, 350 cu.m.)

from fishing grounds (200, 400, 600 and 800 nautical miles), the average daily catches (3, 5, 7 and 9 ton) for the different hold capacities (7,100, 8,800, 10,600 and 12,400 cu. ft.—200, 250, 300 and 350 cu. m.) A uniform service speed of 10 knots was assumed and 270 as the yearly number of days at sea. Stormy weather was assumed for 20 per cent. of the time spent on the fishing ground.

An analysis of the diagrams proves the well-known principle of increased gains derived from a bigger hold capacity—assuming the fish to have good resistance to deterioration. It also indicates the critical distance at which a vessel can operate from a base ship with economic success.

Correlation between the range of processing on board and of hold capacity. The correlation between the range of processing operations on board and hold capacity is shown in fig. 772. It was assumed that the processing of the catch into frozen fillets varied from 0 to 80 per cent., the rest being frozen, gutted and deheaded, and the offal made into fish meal. The capacities of the hold for fish and fish meal are given jointly in the diagram.

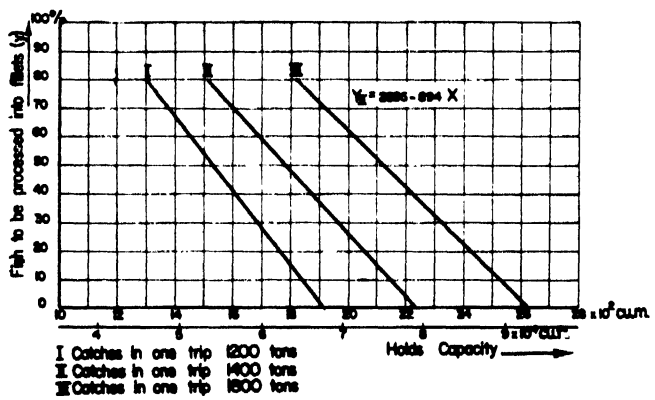


Fig. 772. Correlation between the range of processing operations on board and hold capacity for a factory trawler of Fairtry-Pushkin type

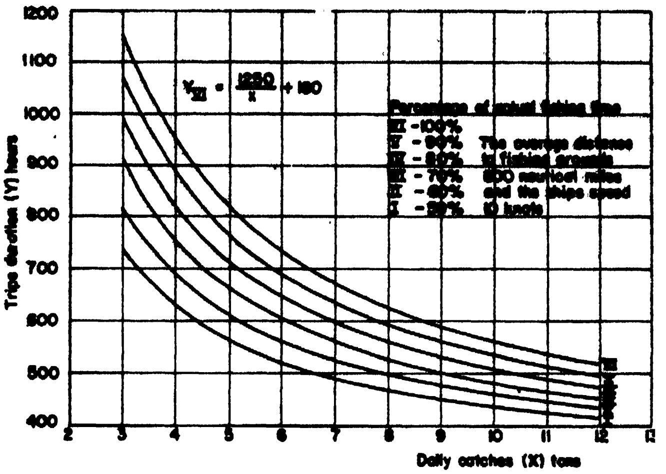


Fig. 773. Correlation between trips' duration and the daily catches for a drifter trawler with 12,400 cu. ft. (350 cu.m.) hold capacity

An analysis of the diagram shows that the biggest gains are from fish processed into fillets, which suggests the possibility of extending the time spent on the fishing grounds, thus achieving additional operative gains.

Correlation between the trip duration and the daily catches (for a drifter-trawler with 12,400 cu. ft. (350 cu. m.) hold capacity). An example of variations in the time taken to fill the hold in relation to actual daily catches is given in fig. 773. The suggested vessel is a drifter-trawler fishing herring in the North Sea. She has a hold capacity of 12,400 cu. ft. (350 cu. m.).

In drift-net fishing, 50 to 70 per cent. of the time spent on the ground is assumed to be actual time. In trawl fishing, the corresponding figures are 70 to 90 per cent. The diagram serves as an auxiliary means for determining the most suitable range of operation for a given vessel.

TABLE 181

Arrangement of table for calculation of costs and financial results for three variants of factory trawler in Polish deep-sea fisheries

No.	*Elements of cost*	*Variant I* Method of computation	*Variant I* 1,000 zlotys	*Variant II* Method of computation	*Variant II* 1,000 zlotys	*Variant III* Method of computation	*Variant III* 1,000 zlotys
1	Capital depreciation						
2	Insurance . .						
3	Fishing and auxiliary equipment including repairs						
4	Packing						
5	Repairs, maintenance and spare parts						
6	Fuel and water						
7	Wages, contributions, foreign currency supplement, food and other provisions						
8	General expenditure of company .						
9	Other costs .						
A	Total . .						
B	Value of products .						
C	Profit . .						
D	Rate of capital gain						
E	Production value in dollars ($1,000)						
F	Cost of gaining ($1) . . .						

GENERAL RESULTS

Studies of the problem of providing a new deep-sea fishing fleet for Poland have resulted in finding a working method to determine the three most suitable types of vessels for specific conditions, and their basic parameters. The working methods thus far developed, though in many ways satisfactory, still require to be perfected and simplified.

Frequent changes in general fishing conditions—biological, political, economical, etc.—as well as rapid technical progress, require continued studies and regular checking on the general concepts assumed.

The studies have pointed out the need to start investigations along new lines, covering various fields of science, as, for instance, biology and fisheries technique, economics, etc. They have also proved that it is essential to prepare a training programme and to build up crews who are thoroughly trained in each specialized job on board ship.

PROPULSION AND PROCESSING MACHINERY FOR DEEP-SEA TRAWLERS

by

G. C. EDDIE

The paper discusses modern developments in propulsion machinery for British distant-water trawlers and new methods of preserving the catch. The difficulty of determining the economic optimum power is discussed briefly. The paper then attempts to show that the improved methods of preservation now available will alter the choice of machinery for optimum economic performance.

LA MACHINERIE DE PROPULSION ET DE TRAITEMENT POUR LES CHALUTIERS DE HAUTE MER

La communication examine les développements modernes de la machinerie de propulsion des chalutiers britanniques pêchant dans des eaux éloignées et les nouvelles méthodes de préservation des poissons pêchés. La difficulté de déterminer la puissance optimum économique est examinée brièvement. Ensuite l'auteur essaie de montrer que les méthodes perfectionnées de préservation disponibles actuellement modifieront le choix de la machinerie pour un rendement économique optimum.

MAQUINARIA PROPULSORA Y DE TRATAMIENTO DEL PESCADO EN LOS ARRASTREROS DE ALTURA

Commenta el autor los últimos adelantos en cuestión de maquinaria propulsora para los arrastreros británicos de altura y los nuevos métodos para conservar la captura. Discute brevemente la dificultad de determinar la potencia óptima económica. El autor demuestra a continuación que los métodos de conservación de que se dispone actualmente influirán en la selección de maquinaria para obtener el rendimiento económico óptimo.

OF ALL the fish landed in the U.K. almost half is caught by the large trawlers fishing the distant waters; in other words, these vessels produce nearly two-thirds of all the fish caught by trawl. There are about 250 distant-water trawlers ranging in length from 160 to 190 ft. (49 to 58 m.) LBP and having 900 to 1,800 SHP. Until six years ago the propulsive equipment invariably consisted of a single Scotch boiler and triple-expansion reciprocating steam engine supplemented, in a few cases, by an exhaust turbine on the Bauer-Wach system. Such machinery has a high degree of freedom from total breakdown and has the manoeuvrability desirable for trawling, while the characteristics of a steam winch are almost ideal for the duty of hauling the gear. Until 1946 the furnaces were all coal fired but the majority of the fleet now burns oil.

Trawlers are called upon to face the worst weather of the North Atlantic. In the distant waters it is rarely possible to run for shelter and the storm may be ridden out, steerage way and position being maintained by the use of the engines. Air temperatures of 0°F (−18°C) and seawater temperatures of 28°F (−2°C) are experienced. Seawater spray can freeze on the superstructure and rigging until over 100 ton of ice have accumulated. Bottom trawling at 3 to 5 knots continues in winds at least up to Beaufort Force 7, or just short of a full gale; this goes on sometimes in a strong tide or a few miles from a lee shore. Motion is considerable, accelerations of about 1.0 g have been experienced at the forward end of a 180 ft. (54.9 m.) trawler. Heavy slamming causing severe vibration sometimes occurs in head seas. A failure in the prime mover supplying power to the winch might lead to loss of the gear, and a failure in propulsion might have a more serious outcome. Therefore the tendency of the distant-water trawler owners to use steam machinery arose from understandable caution, to get complete freedom from total breakdown.

The diesel engine offers economies in space, weight and fuel consumption, an improvement in endurance and a reduction in standby losses; it also eases some of the problems of the naval architect. For these reasons most of the trawlers built since 1951 under the White Fish Authority's Grants and Loans Scheme, as part of a plan to modernize the fleet of 500 trawlers fishing the near and middle waters, as far as the Faeroes, have been motor ships.

The last six years or more have seen the adoption of the internal combustion engine also in the British distant-water trawler fleet for both propulsion and winch duties, at first in only one or two ships, but for the last two years on such a scale that very few, if any, steam trawlers are now being ordered. It may be interesting to examine the various ways of adapting the diesel engine to the requirements of Arctic trawling as carried out by the British and to compare different designers' approaches to broadly similar schemes.

TYPES OF MACHINERY

Direct-drive

The standard layout for the small, near and middle-water trawler at present is a single direct-coupled or geared propulsion engine and a separate winch engine (Hunter and Eddie, 1959). With this layout, it is argued, the failure of a pump or a valve spring might hazard the ship. However, one or two owners with considerable experience of the near-water vessel began building distant-water trawlers of similar design about 1953 and experience seems to show that the machinery chosen is sufficiently reliable. It may be remarked that the engines of British motor trawlers are always heavily derated except when one of the well-known slow-speed marine types is used.

Other distant-water trawler owners, with no experience of diesels, have preferred to ensure reliability by the use of multiple engines. All multiple engined trawlers so far built for British owners have electrical transmissions. Proposals have been made for other types of drive: for example, two reversible engines geared to a single shaft through hydraulic clutches. It would also be possible to devise a constant-torque scheme where the speed and the number of engines in use were varied by a transmission consisting of inverted differential gears on the lines employed in the experimental Fell railway locomotive.

Diesel-electric drive

Reliability is not the only attractive feature of multiple-engined electric propulsion. The trawl winch in British deep-sea vessels is almost always electrically driven since hydraulic machinery of sufficient power is not available. The winch in a distant-water trawler may absorb 300 h.p. and in a trawler where the main propulsion unit is a single large diesel the winch motor will be supplied by a separate 400 h.p. generating set. This set will be in use for less than ten per cent. of the life of the ship; it occupies a great deal of space, adds several tons to the displacement, and requires maintenance.

Since maximum power should never be required simultaneously on propeller and winch, there is no need for a separate winch generator in a diesel-electric trawler, the winch deriving its power from the propulsion generators.

Even so, the first cost of diesel-electric is higher than direct-drive because owners restrict the diesel generators to 750 r.p.m. in spite of the fact that V-type diesels designed to run continuously at 1,500 r.p.m. and delivering over 1,000 h.p. are now available in the United Kingdom.

It might be expected also that the running costs of diesel-electric would be higher than for direct-drive, owing to the electrical losses. This is not true for two reasons: first, the propeller r.p.m. of the electrical ships is 175, whereas a direct-drive diesel acceptable on the score of space and cost will be running at 215 to 250 r.p.m. The electrical efficiency of the latest ships is so high that the difference in propulsive efficiency almost counterbalances the electrical losses. Second, recent research (Eddie, 1957; Dickson, 1959) has shown that the power required for trawling is only 450 to 600 h.p., depending upon weather and depth of water, so the multiple engined ship can shut down some engines when fishing and run the remainder at high efficiency, thus saving fuel and maintenance costs. In ships with single large engines there is a temptation to trawl at much higher powers and the increased fuel consumption can be shown to have very little effect in the case of Arctic cod fishing with the Granton trawl (Eddie, 1957).

The direct-drive scheme has fewer units to service but the individual parts are much larger.

Because the separate prime mover for the winch is eliminated, diesel-electric schemes can result in shorter engine rooms. So long as crushed ice is used to preserve the catch, there is more space than can be used on a 185 ft. (56.4 m.) trawler, but if better means of preservation were used, a shorter engine room would have an economic advantage.

"Father and son" system

It is possible to eliminate the separate winch prime mover even when the propulsion unit is a single large engine. One solution, which goes part of the way towards this, is the "father and son" scheme favoured by the Germans, where the power of the winch engine can be used to augment the power of the main engine when on passage. Since this requires electrical transmission, the cost of the machinery can approach that of a full diesel-electric scheme with higher-speed engines. The main engine of a trawler has sufficient power to drive both propeller and winch, as already explained, and the problem really is to provide independent speed control of ship and winch.

Controllable-pitch propeller

A number of trawlers built some years ago for Icelandic owners incorporated scoop-controlled hydraulic couplings between main engine and propeller, and the winch generator was coupled to the forward end of the main engine. This gave a very short engine room. When the winch was in use the main engine was governed to run at constant speed and the propeller controlled by the hydraulic coupling.

A similar scheme with some advantages is to have a controllable-pitch propeller instead of a variable-speed coupling. In the opinion of some people, a clutch would be necessary to ensure that both propeller and ship were stationary when the trawl is alongside. One British distant-water trawler, the *Kingston Beryl*, is fitted with a controllable-pitch propeller but has a separate winch engine.

It is worth noting that in the near and middle-water trawlers, with shaft horsepower of up to 900 plus, the heaviest engine loading occurs when fishing. These vessels tow much the same type of gear as the distant-water ships and when trawling are therefore called upon to develop about the same power, that is, up to 600 h.p., while the speed is only 3 to 4 knots. This they can do only at maximum torque, that is, maximum mean effective pressure, and exhaust temperatures are usually high. There seems to be a good case for the use of the controllable-pitch propeller in this class of vessel in order to allow them to trawl at higher revolutions and lower exhaust temperatures and indeed to allow the fitting of smaller engines. The distant-water motor ships on the other hand have maximum shaft horsepowers of 1,400 to 1,800 and the problem is rather that an engine of this size may run too cool at 450 h.p. This seems to indicate multiple engines for the bigger vessels. Controllable-pitch propellers would, however, improve the performance of some of the older distant-water steam vessels with shaft horsepowers of well under 1,000

As just indicated, the controllable-pitch propeller allows constant horsepower to be developed regardless of speed of advance, that is, the best possible use can be made of the power whether trawling, running free in bad weather or running free in a calm. This characteristic is shared by certain types of electric propulsion and the economic value of this feature is discussed later.

The difficulty in applying the controllable-pitch propeller to trawlers is that of ensuring that it will be operated properly, i.e. near the point of maximum efficiency at all times. The cheapest solution is a propeller with two positions, one for fishing and one for running; the most elegant is an automatic control of pitch according to r.p.m. and fuel rack position, the man on the bridge being given control of power level. Both controllable-pitch propellers and electrical transmissions lend themselves more readily to bridge control than does direct drive and the advantages of this for a trawler hardly need stressing.

DESIGN OF DIESEL-ELECTRIC EQUIPMENT

In the trawlers with straight diesel propulsion the engine rooms are much as would be expected in a modern ship built for Arctic service. The designers of the diesel-electric equipment had a number of extra problems to solve and a few of these will now be touched upon.

The first British diesel-electric trawler for commercial fishing was *Portia* (Blackburn, 1957), which came into service late in 1956. There are three main generating sets arranged for 3-point mounting, running at 750 r.p.m. The auxiliary generators for ship's supply and excitation are also driven from the main engines, a chain drive being adopted to save length. The *Cape Trafalgar* (Eddie, 1957) has four main engines running at 600 r.p.m. with tandem-mounted auxiliaries. The *Cape Trafalgar* and some other vessels have a double armature propulsion motor which, incidentally, because of its smaller diameter, allows installation further aft than would otherwise be possible.

The diesel-electric *Sir William Hardy* (Eddie, 1957), equipped for research in fish preservation, has four main propulsion generators and two separate auxiliary sets all driven by identical high-speed engines. These are exhaust-turbo-charged four-stroke six-cylinder engines each delivering 200 h.p. at 1,400 r.p.m. The machinery weighs the same as that of a direct-drive trawler of the same shaft power and propeller r.p.m. and with much less auxiliary power. A seventh engine is kept ashore to allow of servicing by replacement; an engine could be replaced in less than 24 hours. After some teething troubles with a new design of engine the machinery has settled down well. The engine room is noisier than the other diesel-electric ships, which are remarkably quiet, but no noisier than many trawler engine rooms when harbour duty diesels are running.

The *Falstaff* of 1,800 h.p. (*World Fishing*, 1959), generally similar to *Portia*, and the *Saint Dominic* (*Shipbuilder and Engine Builder*, 1958), a three-engined vessel of 1,600 h.p., both recently delivered, bring the number of British diesel-electric trawlers to five.

Notable features

Features common to all these ships are very fine bridge control of speed down to about 10 r.p.m., and fast response. The propellers of *Sir William Hardy* and *Cape Trafalgar* can be reversed when the ships are going full ahead at top speed in three seconds, and while there is little practical point in that spectacular manoeuvre, it shows that diesel-electric propulsion incorporating feed-back amplifier exciters has the fast response wanted by trawl skippers. All ships have comprehensive alarm systems, coupled in some cases with automatic shut-down, for such parameters as lubricating oil temperature and pressure, engine underspeeding, overspeeding, cooling water failure, earth faults and so on. All ships also incorporate heaters in the main electrical machines to prevent condensation.

The *Sir William Hardy* has a separate coal-fired boiler in the forecastle for liver oil extraction and de-icing and, as in *Saint Dominic*, the accommodation is electrically heated; she can therefore be ready for sea in half an hour after complete shut-down. The other vessels have steam heated accommodation. The *Portia* generates some of her steam by an exhaust gas boiler but, owing to the fluctuation in power requirements when fishing, only one engine is so equipped.

One of the problems in the design of these ships was to arrange for the cooling of the electrical machines. In a 1,500 h.p. trawler well over 200 kW has to be dissipated. The air inlets and outlets are not far above water level and must be so arranged as to avoid intake of water and spray as well as avoiding re-circulation of warm air or diesel exhaust.

The *Sir William Hardy's* system had to be modified to increase the air flow but has since proved adequate in 100 miles per hour (50 m./sec.) gales. In this ship and in *Cape Trafalgar* the air is delivered near but not into the machines. In *Portia* the air was delivered into the machines, a system which experience has shown needs very adequate water traps. The popular place for the main intake is at the base of the funnel on the aft side, which is probably a region of low pressure. A possible alternative is the wheelhouse overhang with an outlet through the derrick post.

The atmosphere in an engine room always contains some oil, salt and carbon dust and this can cause trouble if it accumulates behind the commutator risers of the electrical machines. This is one reason why fresh air was ducted straight to the machines in *Portia*. In *Sir William Hardy* the commutator risers were embedded in plastic to avoid trouble, the penalty being larger machines owing to the reduced cooling of the armatures. The broad alternative to direct air cooling is closed-circuit cooling with sea-water-to-air heat exchangers. This avoids the difficulties but at the expense of weight, space and possibly corrosion troubles.

In the Arctic, the air entering the engine room may be at too low a temperature for easy starting and operation of the engines. Also, the seawater may be at a low enough temperature to freeze the freshwater in a heat exchanger when an engine is idle. It is necessary to take precautions against these things happening while at the same time keeping the idle engines warm, both for quick starts in emergencies, and to improve general conditions of running. In *Portia* these objects are achieved by having a freshwater cooling system common to all engines, cooling water being continually circulated under thermostatic control. The seawater is maintained at not less than 65°F (18°C) by re-circulation, thermostatically controlled. It passes first to the oil coolers, then to the after coolers fitted beyond the superchargers and then to the freshwater heat exchangers. The system in *Sir William Hardy* is a complete contrast, each engine having its own mechanically-driven seawater and freshwater pumps, with freshwater thermostats. Again seawater at below 32°F (0°C) cannot circulate when an engine is stopped. In this vessel and in *Cape Trafalgar* the engines are kept warm by immersion heaters in the sumps; no special effort is made to preheat combustion air but this, as already noted, is delivered near and not into the engine intakes.

Experience has shown that in *Portia* all temperatures stay constant within a few degrees regardless of fluctuations in load. The engines are not entirely independent because of the common cooling system and success does depend upon a fairly expensive saltwater thermostatic valve. In *Sir William Hardy*, on the other hand, with independent engines, there are more small units to go wrong.

Towle (1958) has pointed out that the torque necessary to drive the generators in diesel-electric installations of the type under discussion does not decrease as speed decreases and in that sense the application is a severe one for the diesel engine. The engine is so arranged that if load temporarily increases the governor supplies more fuel to the working cylinders; if an injector or pump unit is defective or if the supercharger is fouled, or if the intake air temperature is too high, so that output is reduced, the governor again supplies more fuel and overheating can result. This is especially difficult to detect in the small high-speed engines of *Sir William Hardy* where there is only one exhaust thermometer to every three cylinders. In *Portia* there is an arrangement for reducing the generator field, and hence the torque required, when such a situation arises. The electrical systems do, of course, prevent deliberate overloading of engines and electrical machines. Some have features which provide for the propeller coming out of the water and in some cases the winch motor can remain stalled on overload for thirty minutes.

There remains the question of the electrical system employed. All are variable-voltage DC systems, the *Portia*, *Cape Trafalgar* and *Falstaff* being Ward-Leonard; the *Sir William Hardy* and *Saint Dominic*, constant-current. The latter is said by various authorities to be from one or two to five or seven per cent. dearer than Ward-Leonard but it seems to have some advantages. In the Ward-Leonard system each motor must be coupled to a separate generator or group of generators, so that to have stand-by on both propulsion and winch, four engines are necessary, or three if one stand-by is shared between winch and propulsion. In the constant-current system one generator can serve several motors so there is complete stand-by with only two engines.

The Ward-Leonard system gives a characteristic of rising torque with falling r.p.m., but not to the extent achieved in *Sir William Hardy* and *Saint Dominic* where truly constant power is available over a wide range of propeller r.p.m. As pointed out earlier in connection with controllable-pitch propellers, a constant-power characteristic is ideal for a trawler.

ECONOMICS OF SPEED

Difficulty in determining mean annual service speed

In all distant-water motor trawlers so far built for British owners, advantage has been taken of the reduced weight of machinery and fuel bunkers to increase speed. Material published on the design of *Portia* (Blackburn, 1957) suggests that if capital cost is taken into account there will be little or no direct saving as compared with a 1,250 IHP steam trawler (without exhaust turbine), but the advantage in mean annual service speed will be between one and two knots. Compared with a Bauer-Wach ship of the same total costs the advantage in service speed would be about halved.

An attempt has been made to determine more closely the relationship between mean annual service speed and nominal maximum power in British distant-water trawlers. For this purpose the engineers' logs of the ships in a large company were examined for a two-year period. One great difficulty was to fix the geographical points where fishing began and ended. This could be partly overcome by confining the study to Bear Island trips on the assumption that the distance run would, on average, be that to the island itself. Variations in course-setting and in course-keeping could not be allowed for, nor could the effect of variations in displacement arising as a result of the varying total catches of different ships over the period. Again, there were probably differences in the condition of the machinery and in the manner and skill of its operation so that the actual maximum power developed may have differed from the nominal maximum power. Furthermore, it is possible that some ships encountered a higher number of bad-weather trips than others; and an attempt was made to eliminate this by studying trips made during certain months only, as well as over the whole two years. If the effects of all these factors could be eliminated, there would remain those due to the design and condition of the hull as regards speed, seakeeping, steering and state of fouling.

A wide scatter in the points was inevitable. Accurate information could come through better knowledge of the operation of the ships, say by automatic recording of powers and courses. Alternatively, an approach through statistical analysis would be possible, but would probably require collection of data on a basis of the entire fleet. Without knowledge of mean annual service speeds and fuel consumptions, the determination of the optimum economic speed, and decisions as to the way of applying such improvements as bulbous bows to give optimum economy of operation, cannot be on a very sound basis.

Relation between service speed and maximum power

Although no exact relationship between service speed and maximum installed power can be stated, nor even upper and lower limiting lines, the band of points did indicate a trend or shape of curve. Mean service speed seemed to increase with maximum power according to a straight-line law from the region of about 10 knots at 900 IHP on the average to about 13½ knots at 1,400 IHP. A similar result has been obtained in the past in studies of the service performance of a cargo fleet. The explanation of the departure from the shape of a power-speed curve taken during trials is two-fold; first, the higher-powered ships are newer and therefore have better hull forms and better sea-keeping qualities; second, the higher-powered ships enjoy the advantage, when running into the wind, of higher torques than the older ships at the same propeller r.p.m.

The straight-line type of relationship may possibly have had some influence upon owners' ideas about the ease of obtaining higher speeds. However, all the data obtainable about ships of over 1,400 IHP or equivalent suggest that above that power the line is no longer straight but follows closely the typical calm-water speed-horsepower graph. The 1,400 IHP vessel has a mean service speed only about half a knot below its maximum trial speed and maintains a mean power level very near maximum power, whereas a ship of 12 knots trial speed might have a service speed of only 10 knots. In older vessels the mean power level is well below the maximum, for the reasons given earlier. An attempt to determine the ratio of mean power to maximum power, by a study of fuel consumption, failed. The scatter in consumptions was due not only to skill and to the condition of machinery but also to varying degrees of superheat and to the habit of some skippers of fishing at far higher powers than others, thus defeating any attempt to make a straightforward allowance for fuel consumed when fishing.

Some typical total fuel consumptions averaged over the trip have been given (Hunter and Eddie, 1959).

The motor trawlers built in the last two years achieve speeds which are hardly practicable in steam trawlers so long as LBP is restricted by docks' facilities to about 190 ft. (57.9 m.); this is because the steam vessel must displace, in the departure condition, some 300 tons more than the motor ship. It is this fact which has forced acceptance of the motor trawler for distant-water fishing, since the demand for speed could no longer be satisfied by a reasonable design of steam vessel.

Likewise, improvements in hull form, such as the bulbous bow, are used to give two per cent. extra speed at the same power rather than, say, ten per cent. reduction in fuel consumptions at the same speed.

Advantage of high speed

There are several reasons for high speed. Much could be said on the subject of prestige. It is also said that the fastest ships get the best places on the market. Analysis of the records of a large company shows that over a sufficiently long period of time—two years, say—every ship from the fastest to the slowest is berthed on average half way up the market; it is hardly reasonable to expect otherwise since the ships come from fishing grounds thousands of miles apart, and the skippers cannot predict the weather. There is also a good deal of doubt as to which is the best place on the market. Sometimes, perhaps once a year, a ship of moderate speed just misses a market, but such an event can be regarded as a loss of several hours' fishing time rather than as a reason for higher speed.

Sometimes it is said that faster ships mean fresher fish. This is not necessarily true. The faster ship gets to the fishing grounds sooner as well as leaving later and so faster ships can mean staler fish. This can be avoided if the voyage is shortened by at least half of the time saved. The latest ships can save well over a day on the average trip, as compared with the average vessel, and so can make an extra trip in the year, but of each day saved in this way only some ten hours will eventually be spent on the fishing grounds. If the freshness of the catch could be disregarded, each day saved would represent 24 hours extra fishing and no extra costs in running to and from the grounds for an additional trip in each year.

The latest trawlers operate on a very steep part of the speed-horsepower curve. In a motor trawler of 1,500 h.p., raising the power level from three-quarters to full power gives an increase in speed of four per cent. If allowance is made for the extra displacement represented by the larger engine and extra fuel, the real advantage is not more than three per cent. On the average British distant-water trip in 1956 this would have saved five hours. If all this time saved had been devoted to fishing, the average skipper would have caught an extra £135 ($380) worth of fish. The cost of the extra fuel burnt would in itself have been £135 ($380), to which must be added the extra capital, maintenance and fishing costs.

Torque for trawling

The foregoing applies to calm water conditions. The modern high-powered ships do have one real advantage over the ships built earlier and that is their ability to tow the trawl in worse weather and in deeper water, and to maintain speed when running free in bad weather. The abilities, however, are not, strictly speaking, due to high power but to high torque. In the conditions just mentioned the ships are never operating near maximum r.p.m. Even when shooting the gear the power absorbed rarely exceeds 1,000 h.p. There is therefore a strong case for machinery which will give high torque when required but which will not allow fuel to be wasted at high r.p.m. in fine weather—that is, there is a strong case for machinery with a characteristic approaching constant-power rather than constant-torque. Machinery with a constant-power characteristic, either diesel-electric or diesel with controllable-pitch propeller, would save money in spite of its extra complexity, since the maximum power installed could be less. There would be no difference in fishing power and the small difference in mean service speed averaged over the year would have little or no adverse effect on the economics of operation.

ECONOMICS OF PRESERVATION

Advantages of preservation

The demand for speed arises partly from the limitations of crushed ice as a preservative for fish. The trawlers almost always have to turn for home before the holds are full because of the fear that the earlier-caught fish will be condemned. So long as this is the case, the economics of distant-water trawling can be improved in only two ways: by increasing the speed of passage or by increasing the rate of catch. As indicated above, speeds already seem to have passed the economic limit, at least in relation to the abilities of the average skipper. Research directed at improving the effectiveness of the trawl is going on, but with the closing of some grounds and the increasing number of European trawlers on the others. the chances of the rate of catch being increased more than temporarily are not high.

There remains the solution of extending the trawler's stay on the fishing grounds in another way, namely, by improved means of preservation. This has a double advantage: it increases the number of days per annum on the fishing grounds and it reduces the necessity for high speeds and high fuel consumptions. When a trawler makes voyages of three months' duration, as do the Grand Bankers salting their catch and the freezing factory trawlers, each day saved on passage is of very much less economic importance than when the vessel makes a voyage every three weeks.

Use of antibiotics

One way of improving the keeping quality of fish in ice is to use antibiotics. Unfortunately, the fresher fish is not improved, so the average quality of the catch would tend to remain the same (Food Investigation Board, 1956). Also this method would tend to aggravate the problem of seasonal surpluses. At present, in some months, the proportion of edible fish surplus to market requirements is as high as 15 per cent. of the landings.

It is not desirable to save the surpluses by freezing and cold storage on land, because in order to produce an article equal to good fresh iced fish it is necessary to freeze within three days of catching. The two problems of staying longer on the fishing grounds and saving the seasonal surpluses can both be solved by freezing at sea. Moreover, the average quality of the landings would thereby be much improved.

Factory trawling operation

Two solutions of the problems involved have been developed in U.K. The first is the factory trawler fishing over the stern and processing the entire catch in the form of catering packs of frozen fillets (Lochridge, 1956). The *Fairtry*, the first commercial factory trawler in the world, is now joined by the diesel-electric *Fairtry II*

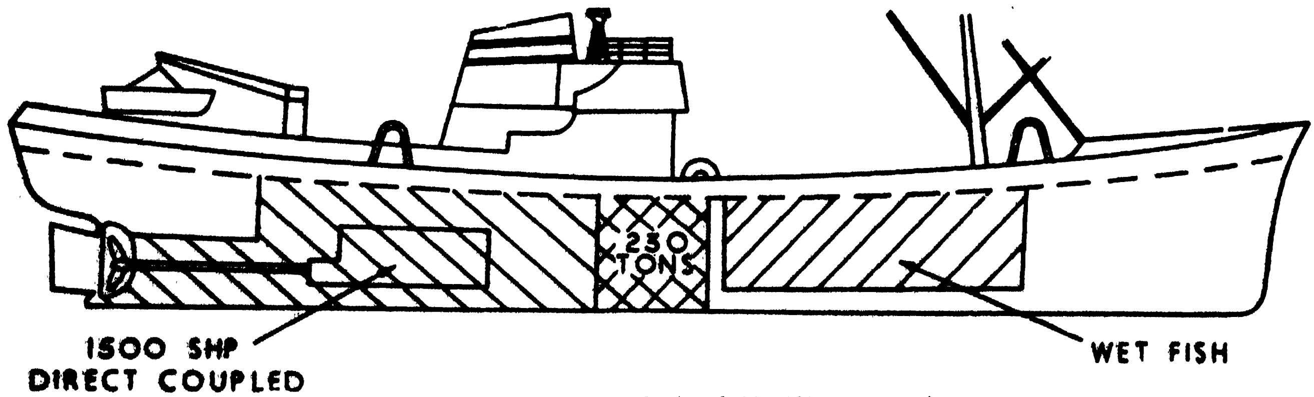


Fig. 774. 15 knot icing trawler (catch 110–150 ton average)

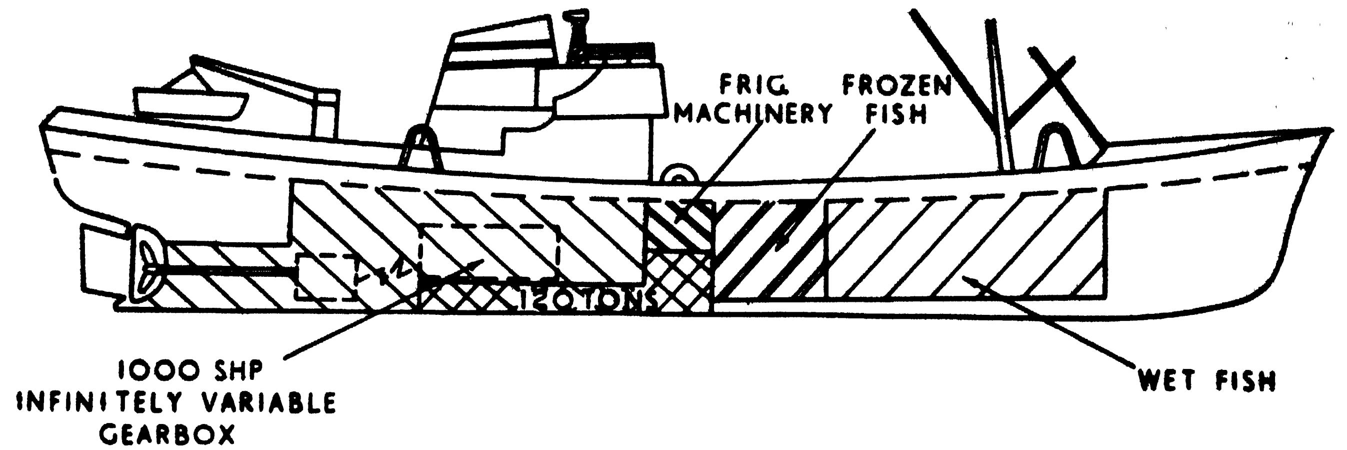


Fig. 775. 13 knot semi-freezer trawler (catch 180–220 ton average)

and *Fairtry III*. In these ships the generating machinery and the propulsion motors are in separate compartments to achieve optimum weight distribution as well as operating convenience for the factory. The Russians have a large number of vessels similar to *Fairtry*. The production of one of these ships in a year is equivalent to that of two ordinary trawlers. The main problems are the first cost, the size and the long voyages necessary for economic operation. All these factors put extra strain on the skippers. The handling and processing of the fish are similar to what is done in shore-based factories. These processes are not entirely suitable for ships of the size and type of orthodox trawlers.

Freezing of headless fish

The second solution aims at freezing part of the catch of an orthodox trawler. Whole headless fish are frozen in vertical plate freezers (Eddie and Yule, 1953). The advantages are the ease of operation in a small ship in a seaway, the low demand on labour and the very important one that the fish when thawed can be used for all purposes including smoke curing. No sudden changes in the structure of the industry are necessary. The suitability of this type of plant for trawlers was proved in the *Northern Wave* experiment of 1956 (White Fish Authority, 1957) and the acceptability of the products to the consumer was also demonstrated.

Obviously, if the economics of distant-water fishing are to be improved, the costs of freezing, cold storage and thawing must be more than offset by the saving of fish temporarily surplus to market requirements and by the extension of fishing time per voyage. The *Northern Wave* experiment provided information about costs but was not designed to demonstrate the savings. Since then, however, design studies and comparisons of costs have indicated what size and type of vessel would be necessary to show an improvement in economics of operation as compared with the vessel using crushed ice alone.

The capacities of the fish holds of post-war distant-water steam trawlers range from 13,000 to 16,000 cu. ft. (368 to 453 cu. m.). The latest motor vessels have holds of 18,000 cu. ft. (510 cu. m.) and a study of their general arrangements indicates that holds of over 20,000 cu. ft. (570 cu. m.) would be possible in the existing size of ship, if desired. The average British distant-water catch in 1956 occupied only 10,500 cu. ft. (300 cu. m.) and 14,000 cu. ft. (400 cu. m.) was exceeded on less than eight per cent. of all occasions. In the opinion of many, a fish hold of 13,000 to 14,000 cu. ft. (370 to 400 cu. m.) is adequate for a catch consisting predominantly of Arctic cod if preserved by ice alone.

In the motor trawlers, therefore, there is room to fit a freezing plant. Economic analysis seems to indicate that this would have been worthwhile even in the existing high-powered vessels. However, much larger quantities of frozen fish and much greater extensions of voyage would be possible in vessels especially designed so that the space available for the stowage of fish is increased at the expense of machinery and fuel bunkers. As indicated earlier, the size of machinery and bunkers can be reduced without affecting fishing performance and without affecting service speed by more than a fraction of a knot if machinery with constant-power characteristics is adopted.

Proposed freezer-trawler

In order to get as much fish as possible into a ship of a given length, the engine room must be kept as short as possible. Thus, when freezing is considered, certain types of machinery have an economic advantage. These include diesel-electric with high speed engines of V-construction and a single large diesel driving both winch and a controllable-pitch propeller.

Fig. 774 and 775 show two motor trawlers each of 185 ft. LBP (56.4 m.). Fig. 774 represents the very fast motor trawler popular in the U.K. at present. The average vessel of the Birtish distant-water fleet spends about 140 days on the fishing grounds in a year and on this basis the fast vessel will spend about 160 days on the grounds in a year, none of its fish being staler when landed. Fig. 775 is a part-freezing trawler with constant-power machinery and of the same overall dimensions and about the same capital cost. It would spend 180 days in a year on the fishing grounds and in running to and from the grounds would burn little more than half as much fuel in a year as the faster ship. In the hands of an average skipper it would produce in a year an amount of edible fish not far short of the most successful vessels at present, and of higher average quality. Preliminary calculations indicate that for the reasons just given this type of vessel will compare favourably in economics of operation with the average orthodox trawler. Proper design studies and estimates are being undertaken. These already indicate that the speed of the design has been underestimated; it may be possible to achieve 13½ knots.

There is no reason why this type of vessel should not develop gradually in size, in which case a higher proportion of the catch would be frozen. This line of development could in time merge with the large factory trawler.

The recent developments in propulsion machinery and in refrigerating equipment offers a means of escape from the limitations hitherto imposed by steam machinery and by the use of crushed ice as a means of preservation.

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MODERN FACTORY SHIPS IN JAPAN

by

SHIGERU SATO

Salmon and trout fishing in the Northern Pacific Ocean and whale catching in the Antarctic Ocean are especially important to Japan, not only as sources of animal protein but also as a means of securing foreign currencies.

The refrigerated factory ship plays a central role in these types of fishing. Many modern factory ships, fitted with the latest equipment and machinery, have been built in Japan since World War II.

For a short while after the war, because of scarcity of materials and lack of capital, the factory ships used were converted war-time vessels. Since then, however, one or two newly-built refrigerated factory ships have been delivered every year, starting with the *Miyazima Maru* in 1953. The main particulars are given of fourteen of these new ships. Three recent types are the midship engine type, the centre bridge type with engine aft, and the fore bridge type with engine aft; their operating performances are compared. The preliminary design of a factory ship is described.

The following installations and characteristics are explained: Conveyors; Refrigerating machinery; Freezing equipment; Cooling equipment for refrigeration of cargo holds; Canning systems, and Insulation.

LES NAVIRES-USINES MODERNES AU JAPON

Pour le Japon, la pêche de la truite et du saumon dans le Pacifique nord et la chasse à la baleine dans l'Antarctique sont particulièrement importantes, non seulement en tant que sources de protéines animales mais aussi comme moyens de se procurer des devises étrangères.

Les navires-usines frigorifiques jouent un rôle important dans ces types de pêche. Depuis la seconde guerre mondiale, on a construit au Japon plusieurs navires-usines frigorifiques munis de l'équipement et de la machinerie les plus modernes.

Après la guerre, par suite de la rareté des matériaux et du manque de capitaux, les navires-usines utilisés pendant une courte période étaient des bateaux standard du temps de guerre transformés. Cependant, depuis lors un ou deux navires-usines frigorifiques neufs ont été livrés chaque année, en commençant par le *Miyazima Maru* en 1953. L'auteur donne les particularités principales de quatorze de ces nouveaux navires. Trois types récents comprennent: le type à machine au milieu du navire, le type à passerelle centrale et machine à l'arrière, et le type à passerelle à l'avant avec machine à l'arrière; leurs rendements sont comparés. L'auteur décrit en détail le projet préliminaire d'un navire-usine, c'est-à-dire les dimensions principales, la stabilité, la vitesse, l'autonomie, etc.

Des explications sont données sur les installations et caractéristiques suivantes: Convoyeurs; Machines frigorifiques; Equipement pour la congélation rapide; Equipement pour la réfrigération des cales; Système de mise en conserves hermétiques; Isolation.

LOS BUQUES FABRICA MODERNOS DEL JAPON

Para el Japón la pesca del salmón y de la trucha en el norte del Océano Pacífico y la captura de la ballena en el Antártico revisten especial importancia, no sólo como fuentes de proteínas animales sino también como medios de obtener divisas extranjeras.

Los barcos fábrica frigoríficos desempeñan un papel central en estas clases de pesca. Después de la segunda guerra mundial se han construido en Japón muchos barcos fábrica frigoríficos dotados del equipo y maquinaria más modernos.

Después de la guerra, debido a la escasez de materiales y falta de capital, los barcos fábrica empleados durante un corto período eran los barcos corrientes de la guerra transformados. Desde entonces, uno o dos barcos fábrica frigoríficos se han entregado cada año comenzando con el *Miyazima Maru* en 1953. Se dan las características principales de 14 de estos nuevos barcos. 3 modelos recientes comprenden: el tipo con la maquinaria en la medianía, el tipo con el puente en la medianía y la máquina a popa, y el tipo con el puente a proa y la máquina a popa. Se comparan sus rendimientos. El autor describe el proyecto preliminar del buque fábrica, es decir, dimensiones, principales, establidad, velocidad, autonomía, etc.

Se explican las instalaciones y características siguientes: transportadores; máquinas frigoríficas; equipo para la congelación rápida: equipo para la refrigeración de las bodegas; sistemas de preparar conservas en latas; aislamiento.

SALMON and trout fishing in the Northern Pacific Ocean and whale catching in the Antarctic Ocean are especially important to Japan, not only as sources of animal protein but also as a means of securing foreign currencies.

Refrigerated factory ships, for salmon and trout fishing, play a central role in the fishing fleets and, co-operate extensively with the whale factory ships, which may be said to be the hub of the whale catching activities. The performance of these ships may, therefore, decide the success or failure of the fishing.

Most of the refrigerated factory ships of Japan are engaged in whaling in the Antarctic Ocean in winter, and from spring to summer for salmon and trout fishing in the Northern Pacific Ocean. In the off seasons they fish for turbot or tuna, and sometimes are used solely as refrigerated cargo carriers.

In pre-war days, in the whaling industry, the main effort was directed to whale oil production, and little attention was given to whale meat. After the war, however, the whale came to be considered as a source of animal protein supply for the Japanese nation.

TABLE 182

fish factory ships

Name	*Tenyo Maru No. 2*	*Tadotu Maru*	*Settu Maru*	*Tenyo Maru No. 3*	*Kaiko Maru*	*Miyazima Maru*	*Elzin Maru*
Builder	Kawasaki	Hitachi Mukaizima	Mitubisi Nagasaki	Kawasaki	Hitachi Innoshima	Hitachi Innoshima	Kawasaki
Owner	Taiyo F.C.	Nippon Suisan	Nippon S.	Taiyo F.C.	Nippon S.	Nippon S.	Taiyo F.C.
Date	1947	1948	1948	1948	1950	1953	1954
LBP ft.	501.35	501.84	465.76	327.34	305.04	459.20	425.42
LBP m.	152.85	153.00	142.00	99.80	93.00	140.00	129.97
Breadth, mld. ft.	65.60	65.60	64.21	49.20	45.26	62.32	59.70
Breadth, mld. m.	20.00	20.00	19.58	15.00	13.80	19.00	18.20
Depth, mld. to workdeck ft.	37.72	37.72	39.36	26.24	24.93	44.28	36.41
Depth, mld. to workdeck m.	11.50	11.50	12.00	8.00	7.60	13.50	11.10
Draught, mld. ft.	28.21	29.75	28.67	20.93	20.14	27.22	26.44
Draught, mld. m.	8.60	9.07	8.74	6.38	6.14	8.30	8.06
Displacement ton	19,360	20,535	15,284	7,235	6,186	15,980	14,280
Gross tonnage	10,595	10,544	9,329	3,689	2,941	8,964	7,456
Net tonnage	7,092	7,220	5,545	2,868	1,849	4,898	5,612
Deadweight ton	12,303	13,143	7,800	4,076	3,112	9,003	8,654
Capacity in bales: Ref. cargo hold cu. ft.	197,890	167,180	250,380	91,530	76,950	267,400	175,790
Ref. cargo hold cu. m.	5,606	4,736	7,093	2,593	2,180	7,575	4,980
Salt-fish hold cu. ft.	76,740	104,100	30,220	24,460	—	30,780	33,182
Salt-fish hold cu. m.	2,174	2,949	856	693		872	940
Tank capacity: Fuel oil cu. ft.	104,810	60,750	102,440	47,480	38,940	77,700	85,530
Fuel oil cu. m.	2,969	1,721	2,902	1,345	1,103	2,201	2,423
Freshwater cu. ft.	77,590	97,320	69,510	33,430	18,360	89,630	54,430
Freshwater cu. m.	2,198	2,757	1,969	947	520	2,539	1,542
Speed . knots	14	11	10	11	9	14	11½
Main engine h.p.	Diesel 5,400	Turbine 3,500	Diesel (2) 2,600	Diesel 2,250	Diesel 1,200	Diesel 5,525	Turbine 2,200
H.p. of motors for NH_3 refrigerators	750	400	520	510	500	750	600
Freezing capacity ton/day	86	75	81.6	38	50	150	150
Complement: Officer and crew	80	99	73	66	64	85	75
Management and workers	212	221	220	84	45	253	212
Total	292	320	293	150	109	338	287
New built or converted	C	C	C	New	C	New	C

Name	*Itukusima Maru*	*Koyo Maru*	*Kasima Maru*	*Kyokko Maru*	*Chiyo Maru*	*Zinyo Maru*	*Nozima Maru*
Builder	Hitachi Innoshima	Mitubisi Hiroshima	Hitachi Innoshima	Osaka	Saseho	Saseho	Hitachi Innoshima
Owner	Nippon S.	Taiyo F.C.	Nippon S.	Kyokuyo H.C.	Taiyo F.C.	Taiyo F.C.	Nippon S.
Date	1955	1955	1956	1956	1957	1958	1958
LBP ft.	344.40	427.38	393.60	419.84	429.84	429.84	446.08
LBP m.	105.00	130.30	120.00	128.00	131.05	131.05	136.00
Breadth, mld. ft.	56.42	59.70	57.73	59.04	61.99	61.99	64.94
Breadth, mld. m.	17.20	18.20	17.60	18.00	18.90	18.90	19.80
Depth, mld. to workdeck ft.	38.38	32.80	38.70	38.05	39.69	39.69	41.00
Depth, mld. to workdeck m.	11.70	10.00	11.80	11.60	12.10	12.10	12.50
Draught, mld. ft.	26.14	26.24	25.58	26.73	26.27	26.34	25.75
Draught, mld. m.	77.9	8.00	7.80	8.15	8.01	8.03	7.85
Displacement ton	11,560	14,291	12,790	14,290	15,040	15,070	16,470
Gross tonnage	5,889	7,659	7,163	8,601	7,195	7,207	9,100
Net tonnage	3,372	4,325	4,360	5,984	4,024	4,319	—
Deadweight ton	7,322	8,310	7,667	8,111	9,252	9,218	9,400
Capacity in bales: Ref. cargo hold cu. ft.	204,210	230,860	226,660	272,020	274,810	277,950	296,520
Ref. cargo hold cu. m.	5,785	6,540	6,421	7,706	7,785	7,874	8,400
Salt-fish hold cu. ft.	—	15,210	—	41,940	16,520	16,520	—
Salt-fish hold cu. m.		431		1,188	468	468	
Tank capacity: Fuel oil cu. ft.	59,230	70,740	71,620	79,210	73,280	72,930	98,840
Fuel oil cu. m.	1,678	2,004	2,029	2,244	2,076	2,066	2,800
Freshwater cu. ft.	25,950	34,100	9,280	33,080	37,590	37,590	69,360
Freshwater cu. m.	735	966	263	937	1,065	1,065	1,965
Speed . knots	12	14	13½	14	14	13	14
Main engine h.p.	Diesel 3,280	Diesel 5,000	Diesel 4,600	Diesel 5,500	Diesel 5,600	Diesel 5,000	Diesel 6,250
H.p. of motors for NH_3 refrigerators	660	800	880	800	880	880	910
Freezing capacity ton/day	120	150	150	150	162	162	198
Complement: Officer and crew	62	77	70	70	80	81	71
Management and workers	218	251	258	237	267	250	273
Total	280	328	328	307	347	331	344
New built or converted	New	New	New	New	New	New	New

When the whale catching industry was resumed in the Antarctic Ocean in 1946, salted whale meat was of primary importance, the frozen meat being secondary. An improvement in living standards led to a demand for frozen rather than salted whale meat.

Before World War II, the main salmon and trout fishing grounds were in the Kamchatka Peninsula, where the fish gathered to spawn. The catch was sent to the factories on the mainland or to the motherships (small in number) in which the catch was canned.

The same practice was resumed in 1952, but the fishing moved to grounds around the Aleutian Islands and was governed by an international fishing agreement. Conditions at this new location were very different from those at the Kamchatka Peninsula, and, accordingly, a striking change has taken place in the operating system. Part of the catch is canned, but most of it is refrigerated, a practice not seen in pre-war days.

It was in these circumstances that the refrigerated factory ships were developed in Japan, and it can be reasonably claimed that their method of operation is peculiar to Japan.

In table 182 are listed the main refrigerated factory ships built after the war. Fig. 776 shows the general arrangement of the *Miyazima Maru*, as typical of these vessels. For a short while after the war, because of the scarcity of materials and lack of capital, most of the factory ships were converted war-time standard ships, but, starting in 1953 with the *Miyazima Maru*, one or two new refrigerated factory ships have been delivered every year.

This developement has taken place rapidly, not only because the Japanese are quick to adapt themselves to changes in the fishing industry, which is of primary importance to them, but also because the refrigerated factory ship can be used for various types of fishing operations. The abundant supply of labour and low wages in Japan are further factors conducive to this rapid development.

Basic design

In designing cargo ships, oil tankers and passenger ships, the transporting capacity of the ship is the basic requirement. In the case of the refrigerated factory ship, however, the processing capacity is regarded as the basis for design; therefore, refrigeration, canning and salting should be given first consideration. The accommodation of the process workers as well as the crew, must be taken into consideration, and also such basic performance characteristics as the ship's speed, radius of action, stability, the amount of fuel, fresh water, etc. By stability, in this instance, is meant the righting moment, which involves many difficulties and makes the designing different from that of a single-purpose vessel.

As shown in table 182, more than ten factory ships have already been built since 1953 and, although they may appear similar, each has its own features which reflect the difference of operation or the management system of the owners. Indeed, the requirements of various ships built for the same company may differ, depending on the circumstances existing at the time of construction.

The fishery companies take into consideration the market demand and are constantly investigating operations in an endeavour to improve the quality of their products. In building new ships, therefore, the fishery companies plan to be able to handle the products in greatest demand with the highest efficiency.

The designers should always investigate past data and examine and align the various planning requirements. These are complicated and often not integrated, being made by different shipowners. The designers must, therefore, analyse such data and information before starting the design and construction of the most efficient factory ships.

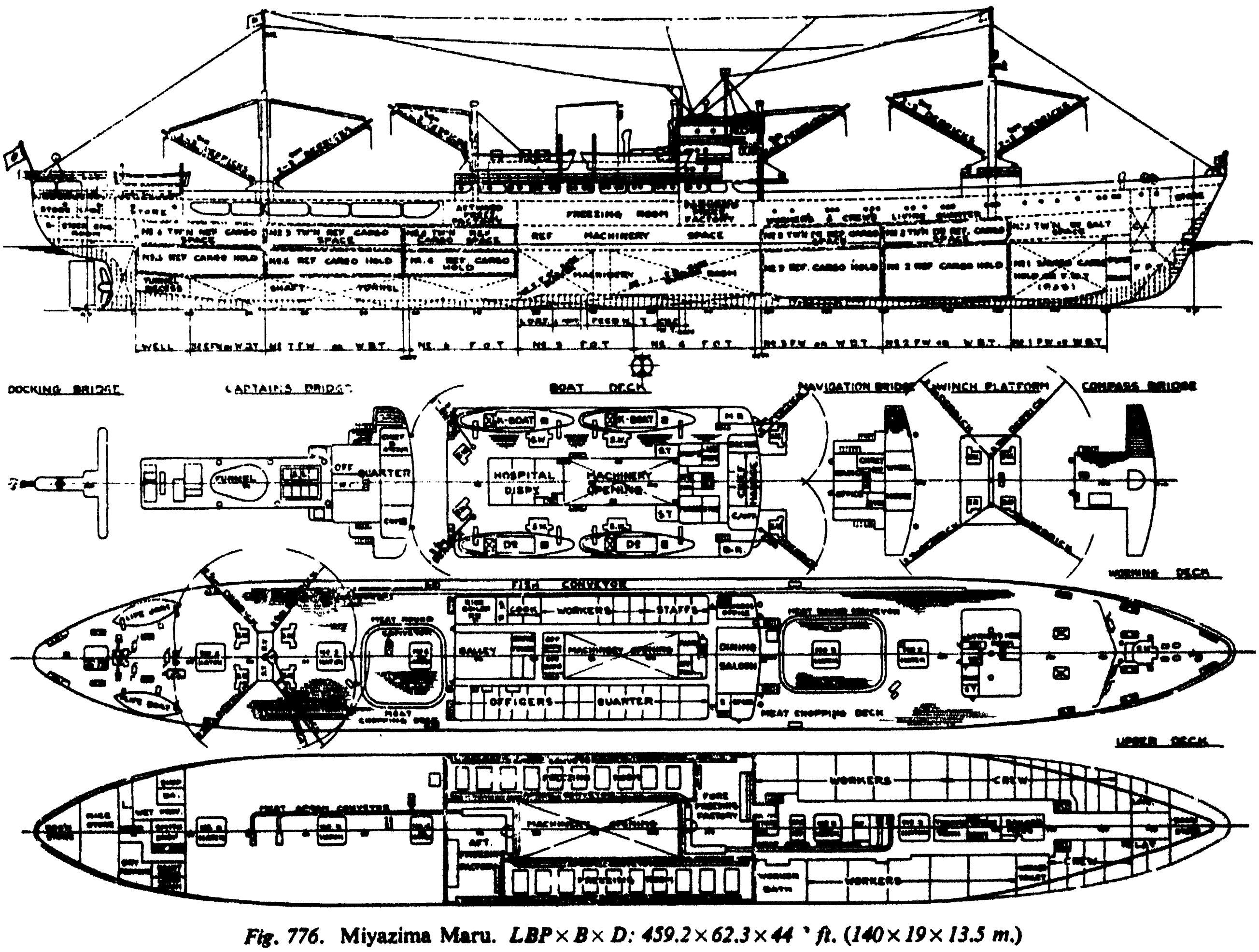

Fig. 776. Miyazima Maru. *LBP × B × D: 459.2 × 62.3 × 44 ' ft. (140 × 19 × 13.5 m.)*

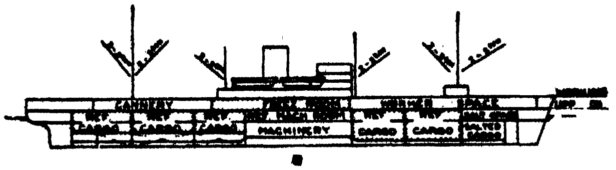

Fig. 777. Miyazima Maru. *LBP × B × D: 459.2 × 62.3 × 44.3 ft. (140 × 19 × 13.5 m.)*

Fishing operations

Two refrigerated factory ships are usually assigned to one whale mother ship working in the Antarctic Ocean. The whales are loaded on the whale mother ships, where they are dissected, the bones and skins are processed into the whale oil; the meat is cut into pieces about 1 sq. ft. (0.09 sq. m.) and 3 ft. (0.9 m.) long and is passed through the meat discharge openings by a chute into the K-boats, which lay alongside the ship directly below the openings. K-boats are meat-carrying motor boats of 10 to 15 ton displacement: four boats are used by a refrigerated factory ship. When a K-boat is fully loaded (about 5 ton) it goes to the refrigerated factory ship where derricks lift the meat aboard. The meat is then cut into pieces about 5 in. (12.7 cm.) in thickness, and classified, according to quality, for refrigerating or salting. Deck hoses are used in cleaning the meat on deck and to cool it to about 60° F (15° C) before despatch to the refrigerating factory or the salting section. After processing, it is stored in the holds. Conveyors and chutes are used for handling the meat on board.

In the northern Pacific Ocean salmon and trout fishing, about thirty catcher boats (50 to 80 GT) are used by a refrigerated factory ship. The loaded catcher boats usually approach the factory ship on the starboard side, two at a time. As the factory ship is always drifting, the leeside is used for convenient positioning of the catcher boats. Immediately after getting alongside the "mokkoes" (woven straw trays) loaded with pre-sorted fish are taken aboard at the tally place. After being counted the fish are pushed out to pre-determined fish ponds from where, by means of conveyors and chutes, they are passed to the cannery, the refrigerating factory or the salting section.

The factory ship is responsible for supplying fuel, provisions and gear required by the fishing vessels.

Selection of types

Three representative types of recent refrigerated factory ships are shown in fig. 777, 778, and 779. A comparison of the particulars of the three ships is made in table 183.

Rough classification of the types are:

- Fig. 777. Shelter deck or three island
- Fig. 778. Midship engine or aft engine
- Fig. 779. Forepart or midship used as the bridge house

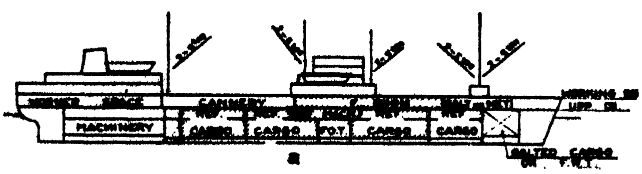

Fig. 778. Nozima Maru. *LBP × B × D: 446.1 × 64.9 × 41.0 ft. (136 × 19.8 × 12.5 m.)*

Among the converted factory ships there are three island types, but most of those built recently are the shelter deck types. A serious shortcoming of the former is that the working decks are separated by the midships bridge. In the latter type, the flush shelter deck is used as the working deck. The upper deck is used as the freeboard deck, on which the freezing room, the cannery workers' accommodation, and the net or salt store, etc. are arranged. Many openings are required for the installation of the conveyors and for the movement of the workers; there can be many such openings on the shelter deck type. Another advantage of this type is the protection given to the refrigerating hold, thus effectively decreasing the load on the refrigerating machinery.

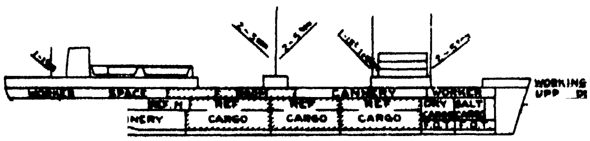

Fig. 779. Chiyo Maru. *LBP × B × D: 429.8 × 62.0 × 39.7 ft. (131.05 × 18.9 × 12.1 m.)*

Advantages and disadvantages. The advantages of having the engine midships are:

- The long bridge deck amidships accommodates the four K-boats, and the equipment for raising and lowering them in rough seas, especially in whaling
- Shorter wiring and piping from the engine room to the refrigerating room, the freezing room, the cannery, etc.
- The refrigerated cargo holds and deep tanks can be easily arranged to obtain good trim

The disadvantages are:

- As the sharper sections of the fore and aft parts of the ship are used for mooring catcher boats or transport ships, loading meat is often hampered by waves, wind, and the shape of the vessel
- The capacity of the refrigerated cargo hold is decreased because of the shaft tunnel
- Having the engine casing in the freezing room is undesirable from the insulation point of view
- Because of the engine casing, only the sides can be used as a passage between the work decks

Some special features. The special features of the aft engine type are:

- Loading, unloading and mooring can be done easily because the parallel midships section can be used for the catchers or transport ships
- Ample hold capacity, as there is no shaft tunnel
- The layout of the refrigerating machine room and the freezing room is very efficient

There are, however, the following weak points:

- The K-boats must be accommodated separately both at the bridge and at the poop, and it is not convenient to lift or lower them in rough seas
- The engine room, the refrigerating machinery room, and the freezing room are separated; therefore, the wiring and piping are longer
- The operation of the ship in rough seas is rather difficult

Deck design. Placing the bridge in the fore part of the ship allows for a wide area midships which can be used both for fish storing and sorting. From here the fish is transferred to the aft freezing room or to the cannery forward.

If the bridge is placed amidships, the work deck is divided into fore and aft sections. Fish loaded at the fore work deck, if it is for the cannery, must be transferred to the aft deck by means of the fore-and-aft conveyor; and if fish to be refrigerated is loaded on the aft deck, it must be transferred to the fore deck. The capacity of the fore and aft conveyor should be large enough to deal with peak loads.

The catcher boats and K-boats can be tied along the fore or aft part of the bridge, which is most convenient for the transmission of orders from the bridge. The tunnel under the bridge is used effectively as a communication passage between the fore-and-aft work decks and also as a night working place.

As both fore and midship bridges have their strong and weak points it is difficult to decide which is the better position.

Size of ships

Deadweight and speed are the basic elements considered in designing ordinary cargo vessels and oil tankers, but in refrigerated factory ships the size is determined by the

TABLE 183

Comparison of particulars of three types of refrigerated factory ships

		Miyazima Maru	*Nozima Maru*	*Chiyo Maru*
		LBP × B × D	LBP × B × D	LBP × B × D
Principal dimensions	ft.	459.2 × 62.3 × 44.3	446.1 × 64.9 × 41.0	429.8 × 62.0 × 39.7
	m.	140 × 19 × 13.5	136 × 19.8 × 12.5	131.05 × 18.9 × 12.1
Cubic number (LBP × B × D)	cu. ft.	1,268,000	1,190,000	1,060,000
	cu. m.	35,900	33,700	30,000
Main engine	h.p.	5,525	6,250	5,600
Hold capacity				
Refrigerated	cu. ft.	267,400	296,520	274,810
	cu. m.	7,575	8,400	7,785
Salt	cu. ft.	30,780	—	16,520
	cu. m.	872	—	468
Total	cu. ft.	298,180	296,520	291,330
	cu. m.	8,447	8,400	8,253
Ratio of hold capacity to cubic number				
Refrigerated hold		0.211	0.249	0.259
Total		0.235	0.249	0.275
Tank capacity				
Fuel oil	Imp. gal.	485,000	615,000	455,000
	cu. m.	2,201	2,800	2,076
Fresh water	Imp. gal.	557,000	432,000	234,000
	cu. m.	2,539	1,965	1,065
Total	Imp. gal.	1,042,000	1,047,000	689,000
	cu. m.	4,740	4,765	3,141
Ratio of tank capacity to cubic number		0.133	0.141	0.104
Area of quick freezing room	sq. ft.	6,424	8,339	6,908
	sq. m.	597	775	642
Number of freezers		40	40	40
Cannery				
Length	ft.	106.6	115.5	111.5
	m.	32.5	35.2	34.0
Number of lines		2	2	2
Total length of working deck				
Fore	ft. (m.)	83.3 (25.4)	90.2 (27.5)	—
Aft	,,	108.2 (33.0)	93.5 (28.5)	—
Total	,,	191.6 (58.4)	183.7 (56.0)	162.4 (49.5)

TABLE 184

Trim and GM of *Miyazima Maru* in whaling

		Departure from port	*Beginning of fishing*	*While fishing*	*End of fishing*	*Returning to port*
Light weight	ton	6,867	6,867	6,867	6,867	6,867
Fresh water		2,538	2,095	925	364	—
Fuel oil		276	1,774	797	537	—
Salt		—	1,526	112	—	—
Whale meat on deck		—	—	295		
Salted meat	,,	—	—	571	787	787
Frozen meat	,,	—	—	2,608	4,953	4,953
Ballast water	,,	—	—	—	291	1,041
Miscellaneous	,,	796	761	438	298	273
Displacement	,,	10,477	13,023	12,613	14,097	13,921
KG	ft.	23.20	21.13	22.84	23.49	23.85
	m.	7.07	6.44	6.96	7 16	7.27
GM	ft.	3.18	4.79	3.08	2.43	2.07
	m.	0.97	1.46	0.94	0.74	0.63
Trim	ft.	6.14	5.74	1.41	0.13	2.85
	m.	1.87	1.75	0.43	0.04	0.87
Mean draught	ft.	19.19	23.16	22.57	24.87	24.57
	m.	5.85	7.06	6.88	7.58	7.49

requirements arising from the work or operation, and the capacity of the refrigerated cargo holds. In general, as full loading is never made up to the minimum freeboard the designed draught is often less than the maximum draught permissible. In short, the effective area or the volume of the ship is said to be the primary concern in designing ships.

Length. In salmon and trout fishing two catcher boats lay alongside the ship on its lee (ordinarily the starboard) side and drift in a seaway, pushed by the factory ship. These boats are believed to have difficulty in getting away from the factory ship unless there is sufficient clearance between the two catcher boats, namely 1.5 times the length of the catcher boat. In addition, it is desirable to moor the catcher boats at the parallel midship section which should, ideally, be about 3.5 times as long as that of the catcher boats. However, in practice it is very difficult to make the parallel midship section so long e.g. if the length of a catcher is 82 ft. (25 m.), the required distance becomes 287 ft. (87.5 m.), so, if the length of the parallel midship section is 60 per cent. of the ship length, the required ship length would be 480 ft. (146 m.)

The longest refrigerated factory ship, the *Miyazima Maru*, is 460 ft. (140 m.). Judging from the loading and mooring of the transport ships and the work of taking in the K-boats, the size of the present vessel appears satisfactory, but the catchers are tending to become bigger so that longer refrigerated factory ships are likely to appear in the future.

Breadth and stability. The stability of factory ships is a problem of heel. As speed is not so important, the beam does not have to be restricted too much. The beam should be decided in relation to work space and the heeling of the ship.

As refrigerated factory ships continue working in strong winds and heavy swells their stability is very important.

- When the GM is small and the heel is too big:
  - Lifting and lowering the K-boats is dangerous
  - The working efficiency is decreased, as the hatches of the factory ships are designed to be small in order to widen the working space; and heavy rolling makes it difficult for the workers to maintain their positions
  - Considerable additional free water is produced on the work deck which decreases the GM; thus a hazardous situation is created
  - The flow of the brine in pipes and flat tanks is not uniform; thus their refrigerating capacity will be decreased
- When the GM is too big and the rolling is violent:
  - The loading and unloading efficiency, such as from the K-boats or from the catcher boats, is decreased
  - The fish brought on deck are spoiled
  - The efficiency of the workers is decreased

Two typical examples of the trim and GM are shown in tables 184 and 185.

According to experience, a GM value of 2.6 to 3.3 ft. (0.8 to 1.0 m.), without taking the free water into consideration, can be considered adequate.

Speed. Refrigerated factory ships receive the meat carried by the K-boats from the whale motherships and take the K-boats aboard and follow the motherships which often sail two or three miles apart. It is desirable that the factory ships catch up with the motherships before they reach the next operating site, usually more than 20 miles away, so that all ships can start work immediately.

In view of this, the speed of the factory ships should be one or two knots faster than that of the whale motherships. The speed of recent factory ships is 13 to 14 knots, which is about the same as that of the whale motherships, and should be increased in the future.

In salmon and trout fishing, the speed of the catcher boats is around 7 to 8 knots and there seems to be no speed problem as there is no additional mothership as in whale fishing.

Fuel and freshwater

In southern whaling, the fuel consumption of the *Miyazima Maru* for 60 days' sailing and 60 days' operation is 22.5 ton per day and 16.5 ton per day, respectively, totalling 2,340 ton for 120 days, which is equivalent to the total fuel capacity of this ship. In salmon and trout fishing, the fuel consumption of ships for 10 days' sailing and 100 days' operation is 22.5 ton per day and 17.5 ton per day, respectively, totalling 1,975 ton for 110 days, which leaves approximately 200 ton for supply to the catcher boats.

As large quantities of freshwater are required in both the whaling and the salmon and trout fishery, many ships are fully equipped with evaporating plants.

As more distant fishing grounds have been worked in recent years, more fuel is required: factory ships are, therefore, tending to become larger.

Arrangement of factories

The arrangement of the factories can be roughly classified into the three types shown in fig. 777, 778 and 779. The merits and disadvantages of each are:

- As a considerable amount of electric wiring, steam and air pipes to the cannery must run from the engine room, it is desirable to install the cannery as near as possible to the engine room, not only from the point of saving material, but also for power efficiency. From this aspect, the types in fig. 777 and 778 are good, but that in fig. 779 has disadvantages.
- From the point of view of saving wire for the refrigerating machinery room, fig. 777 and fig. 778 are preferable.
- In fig. 777, in arranginging the refrigerating machinery room and the freezing room as indicated, the dead space for loading and unloading can be utilized. However, the engine casing penetrates through the middle of the freezing room and requires better insulation, while the piping and wiring systems are too complex and may prove to be a source of trouble
- For material flow, fig. 777 and 778 are preferable, and fig. 779 is inferior. In fig. 777 and fig. 778, the raw materials flow in from the fore and aft part of the ship, and the products flow out from two discharge openings fore and aft, and into the hold. The transport efficiency is excellent, the flow of the product and the raw material being co-ordinated. However, at the peak period, fig. 779 has the advantage because the inflow passage is one way only and the peak load can be easily managed.

Conveyors

Work in a refrigerated factory ship is a flow process but is still far from being completely automatic, and a certain amount of hand work is involved. This fact, combined with the peculiarities of each section necessitates a different type of conveyor from those used in other industries.

These peculiar circumstances are:

- Depending on the nature of the fishing, the amount and speed of material supply varies considerably.

TABLE 185

Trim and GM of *Kasima Maru* in salmon and trout fishing

		Departure from port	*Beginning of fishing*	*On 40th day after fishing starts*	*After shifting of products*	*End of fishing*
Light weight	ton	5,041	5,041	5,041	5,041	5,041
Fuel oil	,,	1,791	1,669	1,110	1,110	386
Fresh water	,,	508	409	316	316	316
Empty cans	,,	481	481	170	367	—
Salt	,,	344	344	241	276	—
Fish on deck	,,	—	177	177	177	177
Fish below deck	,,	—	—	44	44	44
Products:						
Salted	,,	—	—	89	—	497
Frozen	,,	—	—	295	—	959
Canning	,,	—	—	650	—	1,807
Ballast water	,,	—	—	—	—	509
Miscellaneous	,,	788	779	601	613	306
Displacement	,,	8,953	8,900	8,734	7,944	10,042
KG	ft.	20.51	20.83	20.80	21.69	20.37
	m.	6.25	6.35	6.34	6.61	6.21
GM	ft.	3.61	3.38	3.45	3.08	3.48
	m.	1.10	1.03	1.05	0.94	1.06
Trim	ft.	9.02	7.81	1.90	4.46	0.20
	m.	2.75	2.38	0.58	1.36	0.06
Mean draught	ft.	18.96	18.90	18.47	17.00	20.93
	m.	5.78	5.76	5.63	5.18	6.38

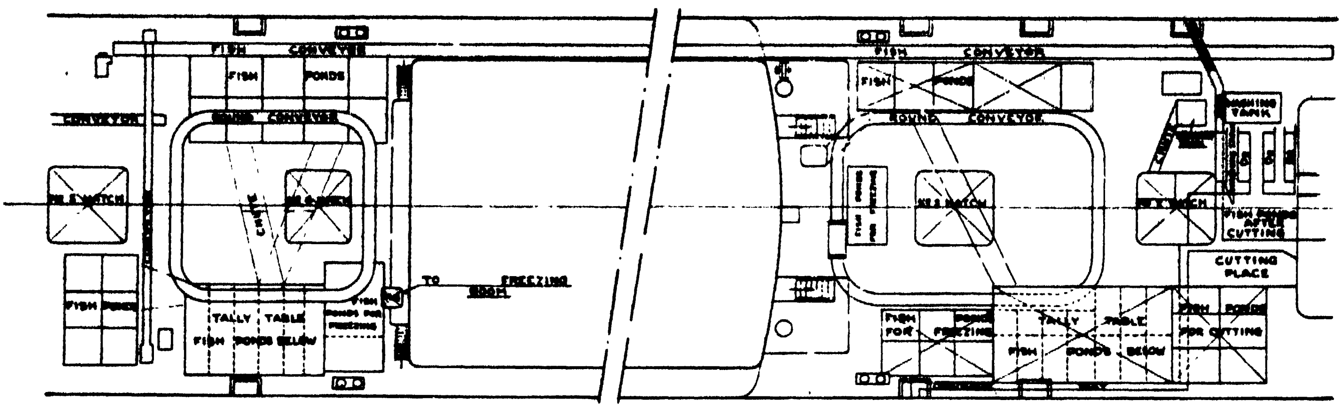

Fig. 780. Miyazima Maru *working deck arrangement in salmon and trout fishery*

● The quality of the material is not consistent. For example in whale fishing, there are meats for salting and for freezing and in salmon and trout fishing there are meats for salting, for freezing and for canning, which have to be sorted by hand and put on the same conveyors.

● As the factory ships themselves are multi-purpose vessels, the conveyor system must be designed to meet all requirements.

● Operating conditions are very hazardous and difficult, considerably influenced by rolling, pitching, vibration, low temperature, moisture, and seawater.

● The place of installation is narrow and is restricted by the existence of other machinery or structures.

● Repair and maintenance are very difficult, due not only to the hazardous operating conditions, but also, to a certain extent, to irrational operational requirements.

Important points. Consideration should be given to the following points:

● Transport capacity should be determined so that the conveyor is able to meet the peak load.

● As the hand work is the determining factor, the transport speed should be determined on this basis. The standard has been found to be about 1 ft. (0.3 m.) per sec., but it is necessary to make the speed variable, taking into consideration the peak load.

● For the purpose of adjusting the carrying amount and the handwork, the timing space must be adequately arranged.

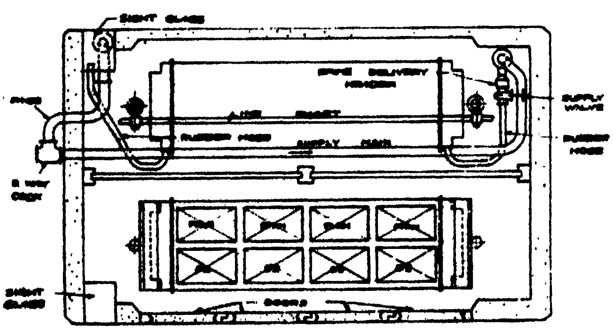

Fig. 781. Typical arrangement of shelf-freezer (plan view)

● Detachable conveyors should be used as it is easy to transfer them to meet multi-purpose work requirements.

● Independent motors for each machine have been found superior to line shafting. There were many troubles with shafts and bearings in earlier vessels.

● Machinery must be robust and simple in design.

● Adequate measures should be taken to deal with low temperatures.

● Parts which come into contact with the products should be galvanized or be made of rubber or stainless steel.

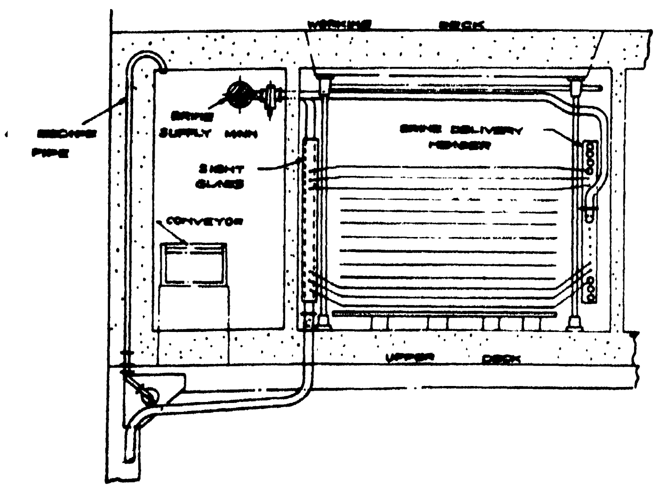

Fig. 782. Typical brine piping for shelf freezer (side view)

Conveyor machinery. Data on the conveyor of the *Miyazima Maru* are as follows:

Fore and aft conveyor: 262 ft. (80 m.), 15 h.p.—1 set

Round conveyors:

138 ft. × 17.7 in. (42 m. × 450 mm.)—1 set

120 ft. × 17.7 in. (36.5 m. × 450 mm.)—1 set

Apron conveyors:

For raw meat:

113 ft. × 13.2 in. (34.5 m. × 350 mm.)—2 sets

For products:
92 ft. × 13.2 in. (28 m. × 350 mm.)—2 sets
59 ft. × 13.2 in. (18 m. × 350 mm.)—2 sets
84 ft. × 13.2 in. (25.5 m. × 350 mm.)—2 sets
Tray conveyors for each hold:
36 ft. × 13.2 in. (11 m. × 350 mm.)—5 sets

Fig. 780 shows the conveyor arrangement on the working deck of the *Miyazima Maru*. The conveyor arrangement for freezing can be seen in fig. 784.

Refrigerating machinery

Ammonia refrigeration is used in all the refrigerating machines and indirect brine for the cooling system. Details of the refrigerating machinery in the *Miyazima Maru* are given in table 186. The capacities are shown in tables 187 and 188.

Freezing equipment

There are many methods for freezing, and almost all the Japanese refrigerated factory ships use the shelf-freezer system, in which brine is circulated. The material to be frozen is pressed between the "shelves" shown in fig. 781 and 782, ⅜ in. (9.5 mm.) thick, and measuring 6.1 × 2.1 ft. (2,000 × 700 mm.). This seemingly primitive apparatus has proved reliable in service. Its special features are:

- The framework of the "shelves" is made of steel plate, 1/16 in. (1.6 mm.) thick, through which the cool brine is transmitted. One batch of salmon and trout can be frozen in 4 to 5 hr., and one batch of whale meat in 5 to 6 hr.
- No fan is required.
- Even if the thickness of the whale meat changes as it is pressed and cooled from the upper and under sides, the freezing efficiency is constant. Discharge is comparatively easy.
- In an air-blast freezer, efficiency can be increased only if the temperature of the air is lowered, but with a shelf-freezer lowering the temperature of the brine alone increases efficiency. The temperatures of operation are:

  Brine temperature −13°F (−25°C)
  Meat temperature (in centre) 17.6 to 14°F (−8° to −10°C)
- The system is simple for cleaning, and repairs can be carried out with ease.
- When the shelves are lifted, the brine in the tank is run off and is received by a surge tank of large capacity.

In the early vessels, a manual gear system was used for lifting and lowering the shelves. Later this was motor-driven, in which case a line shaft drove the countershafts through switching clutches, but many drawbacks were encountered. In the latest system, the lifting and lowering is done by oil pressure pumps and the performance is excellent. About 1 min. is required for lifting and about 15 sec. for lowering. An outline diagram is shown

TABLE 186

Particulars of refrigerating machinery plant of *Miyazima Maru*

	For freezer use		For refrigerated cargo use
Compressors			
Name and number of sets	Sabroe NH_3 type II × 35 − 18 (2 sets)	Sabroe NH_3 type II × S − 20 (2 sets)	Sabroe NH_3 type S × 20 (2 sets)
Type	Vertical 3 cyl. single acting	Vertical 2 cyl. single acting	Vertical 2 cyl. single acting
r.p.m.	368	420	420
Capacity per set	1,016,000 BTU/hr. (256,000 kcal./hr.)	1,008,000 BTU/hr. (254,000 kcal./hr.)	504,000 BTU/hr. (127,000 kcal./hr.)
DC motor	150 h.p. × 1,200 r.p.m. (2 sets)	150 h.p. × 1,200 r.p.m. (2 sets)	75 h.p. × 1,800 r.p.m. (2 sets)
Total capacities	750 h.p. standard capacity 5,054,000 BTU/hr. (1,274,000 kcal./hr.)		
Condensers			
Type	Horizontal shell and tube type	Horizontal shell and tube type	Horizontal shell and tube type
No. of sets	2	2	1
Ammonia receivers			
Type	Horizontal	Horizontal	Horizontal
Number of sets	2	2	2
Brine coolers			
Type	Horizontal shell and tube type	Horizontal shell and tube type	Horizontal shell and tube type
Number of sets	2	2	1
Brine pumps			
Type, number of sets	Horizontal centrifugal (3 sets)	Horizontal centrifugal (3 sets)	Horizontal centrifugal (1 set)
Capacity	200 ton/hr. × 82 ft. (25 m.)	200 ton/hr. × 82 ft. (25 m.)	100 ton/hr. × 82 ft. (25 m.)
DC motor	40 h.p. × 1,750 r.p.m. (3 sets)	40 h.p. × 1,750 r.p.m. (3 sets)	25 h.p. × 1,750 r.p.m. (1 set)
Cooling pumps			
Type, number of sets	Horizontal centrifugal (2 sets)	Horizontal centrifugal (2 sets)	Horizontal centrifugal (1 set)
Capacities	130 ton/hr. × 52.5 ft. (16 m.)	130 ton/hr. × 52.5 ft. (16 m.)	60 ton/hr. × 52.5 ft. (16 m.)
DC motor	20 h.p. × 1,800 r.p.m. (2 sets)	20 h.p. × 1,800 r.p.m. (2 sets)	10 h.p. × 1,750 r.p.m. (1 set)

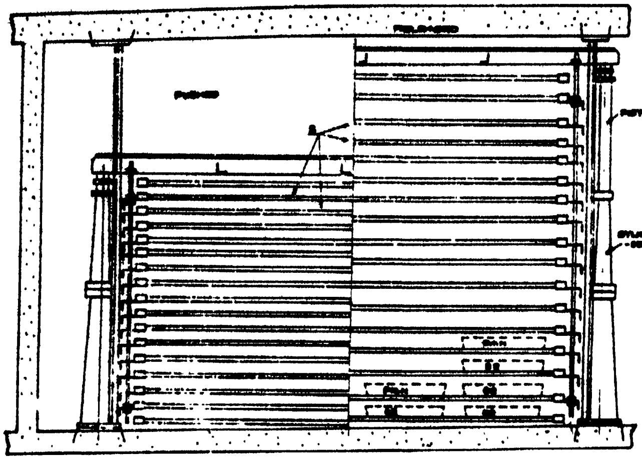

Fig. 783. Lifting arrangement, shelf-freezer

in fig. 783. Fig. 784 shows the arrangement of the freezing room. The meat discharged from the shelf-freezers is carried by conveyor to a tank where it is glazed. The water-bath type of glazing tank has several advantages: the surface of the meat is cleaned, the glaze is not easily peeled off and the amount of water required is negligible.

TABLE 187

Refrigeration load of the freezer of *Miyazima Maru*

	Antarctic Area		*North Ocean Area*	
Compressors to be used	3S–18	S–20	3S–18	S–20
Temperature				
Atmosphere	32°F (0°C)		53.6°F (12°C)	
Seawater	35.6°F (2°C)		50°F (10°C)	
Expansion	–22°F (–30°C)		–22°F (–30°C)	
Cooling capacity				
BTU/hr.	642,700	633,100	547,400	537,500
kcal./hr.	162,000	159,600	138,000	135,500
Cooling ability for meat	Whales 150 tons/day		Salmons and trouts 120 tons/day	
Refrigeration load				
BTU/hr.	2,400,000		1,920,000	
kcal./hr.	605,000		484,000	
Number of machine sets to be used	2	2	2	2
Cooling capacity				
BTU/hr.	1,285,400	1,266,200	1,094,800	1,075,000
kcal./hr.	324,000	319,200	276,000	271,000
Total cooling capacity				
BTU/hr.	2,551,600		2,169,800	
kcal./hr.	643,200		547,000	
Margin of cooling capacity	6.3%		13%	

Cooling equipment for refrigeration of cargo holds

The hold interior is kept at 0 to —4°F (—18 to —20°C) by means of a brine circulating system. Steel cooling tubes of 1½ in. (38 mm.) diam. are used, the outside only being galvanized. From five to ten tubes per space are arranged, according to the capacity of the hold. Each tube should be separated to ensure that the inside of the hold is cooled evenly, although some of them may be out of action due to maintenance problems. The cooling water should be circulated as uniformly as possible in each tube.

An example of the ratio of the cooling area inside the hold is shown in table 189.

Compared with that in the *Miyazima Maru*, the cooling area of the other two ships is considerably smaller. This is the result of experiments, and it is believed that further decreases of area may be possible.

It is also believed that a coefficient of heat transmission

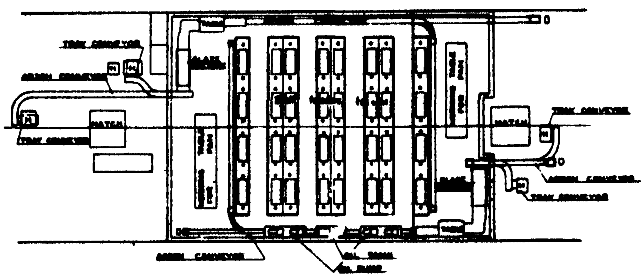

Fig. 784. Typical plan of freezing room

'K' of about 3.0 BTU/sq. ft./hr./°F (15 kcal./sq. m./hr./°C) may be satisfactory for the cooling pipes.

Insulation

The temperature of the refrigerated hold has been gradually reduced in recent years. The temperature of the meat in its centre is first reduced to 17.6 to 14°F (—8 to —10°C) by freezing and then further cooled in the hold. It is advisable that the temperature should be lower than 1.4°F (—17°C).

For perfect heat insulation it is most important to select the best materials and apply the best workmanship to ensure watertightness. For insulating, material of low heat conductivity (having abundant fine pores), low specific gravity and specific heat should be chosen, otherwise considerable refrigeration capacity may be lost in cooling the heat insulating materials themselves.

Formerly cork was used, but this has gradually been displaced by glass wool which is lighter in weight and cheaper. Of late, synthetic resin products have come into use, but these synthetic materials have a disadvantage in that their pores are bigger than those of glass wool, so conductivity is increased at high temperatures. Nevertheless these water and moisture-repelling properties are better, and this eventually results in a lower conductivity and longer useful life, so they are considered at present

TABLE 188

Refrigeration load of refrigerated cargo hold of *Miyazima Maru*

Position		*Area*		*Antarctic Area* — *Atmosphere 32°F (0°C) Seawater 35.6°F (2°C)*				*North Ocean area* — *Atmosphere 53.6°F (12°C) Seawater 50°F (10°C)*			
				Difference of temperature		*Heat to be penetrated*		*Difference of temperature*		*Heat to be penetrated*	
		sq. ft.	*sq. m.*	*°F*	*°C*	*BTU/hr.*	*kcal./hr.*	*°F*	*°C*	*BTU/hr.*	*kcal./hr.*
Cargo hold −0.4 F (−18 C)	Deck	13,041 1,399	1,212 130	37.8 32.4	21 18	39,670 3,170	10,000 800	54.0 32.4	30 18	56,730 3,170	14,300 800
	Shell	12,363	1,149	37.8	21	30,700	7,740	54.0	30	43,880	11,060
	Floor	11,814	1,098	36.0	20	30,940	7,800	50.4	28	43,320	10,920
	Eng. room bulkhead	2,712	252	50.4	28	10,310	2,600	59.4	33	12,140	3,060
	End bulkhead	2,130	198	36.0	20	6,150	1,550	50.4	28	8,610	2,170
	Total	43,459	4,039			120,940	30,490			167,850	42,310
Freezing Room	Deck	2,087	194	5.4	3	950	240	21.6	12	3,810	960
	Shell	301	28	5.4	3	160	40	21.6	12	630	160
	Floor	2,087	194	—	—	—	—	—	—	—	—
	Eng. room bulkhead	334	31	18	10	630	160	27	15	950	240
	Freezing factory	301	28	—	—	—	—	—	—	—	—
	Accommodation bulkhead	1,098	102	18	10	2,940	749	27	15	4,400	1,110
	Total	6,208	577			4,680	1,180			9,790	2,470
Grand Total						125,620	31,670			177,640	44,780
Balance	Refrigerating machine to be used			S−20 (1 set)				S−20 (1 set)			
	Cooling capacity					241,990	61,000			206,280	52,000
	Capacity margin					92.5%				16%	

to be the best in performance. Glass wool, or synthetics have never been used for floors, but their application for this purpose seems promising.

Comparisons are made of these heat insulating materials in table 190.

The thicknesses of the heat insulating materials are:

Refrigerated cargo holds:

Outside shell and bulkheads 10 in. (254 mm.)

Ceiling, 8 in. (202 mm.)

Ceiling at bottom of freezing room, 4 in. (101 mm.)

Floor—with 2½ in. (63 mm.) concrete, 6 to 8 in. (152 to 202 mm.)

Freezing rooms:

Outside shell and bulkheads, 9 in. (228 mm.)

Ceiling, 9 in. (228 mm.)

Floor—with 1 in. (25 mm.) cement or asphalt, 2 in. (51 mm.).

The second deck is wooden and of the tie-plate type, and the heat insulation is usually applied about 2 ft. 8 in. (800 mm.) from the shell side.

An air space is often provided in heat insulation, but in spite of the theoretical effectiveness of this method, it is

TABLE 189

Ratio of area of cooling pipes

	Capacity of hold		*Temperature*		*Surface area of cooling pipes / Hold capacity*	
	cu. ft.	cu. m.	°F	°C	sq.ft./cu.ft.	sq.m./cu.m.
Miyazima Maru	312,229	8,845	0	−18	0.166	0.545
Itukusima Maru	228,038	6,460	0	−18	0.131	0.430
Kasima Maru	257,478	7,294	−4	−20	0.128	0.420

TABLE 190

Comparison of insulating materials

	Cork board	*Glass wool*	*Rock wool*	*Mineral wool*	*Isoflex*	*Alflex*
Coefficient of heat conductivity, λ						
BTU/ft.hr. °F	0.027 to 0.030	0.015 to 0.024	0.027 to 0.030	0.021 to 0.047	0.032	0.024 to 0.027
kcal./m. hr. °C	0.040 to 0.045	0.022 to 0.035	0.040 to 0.045	0.031 to 0.070	0.048	0.035 to 0.040
Value of λ in design						
BTU/ ft. hr. °F	0.081	0.040 to 0.054	0.067	0.067	0.054	0.054
kcal./m. hr. °C	0.120	0.06 to 0.080	0.100	0.100	0.080	0.080
Specific gravity	0.23 to 0.25	0.065 to 0.075	0.18 to 0.25	0.350	0.010	0.010

not acceptable, the reason being that, with falling temperatures moisture in the air condenses and penetrates the insulating material resulting in higher heat conductivity. The waterproof paper used in insulating should, therefore, be thick enough to prevent moisture penetration. The sweat should drain into the bilge well.

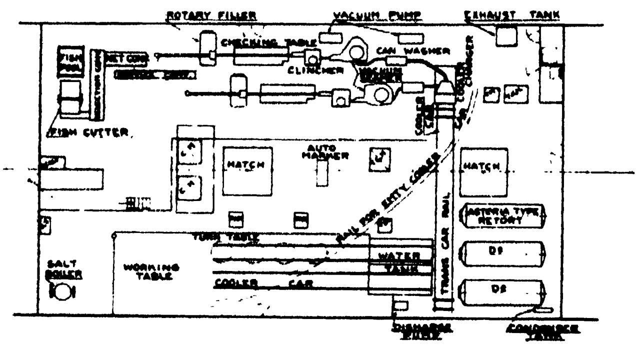

Fig. 785. Typical canning arrangement on upper deck

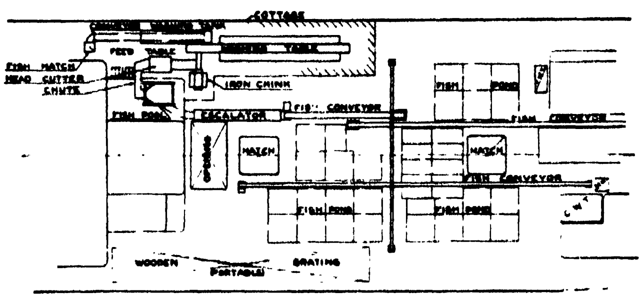

Fig. 786. Typical canning arrangement on working deck

Canning systems

The canning systems in the ships are almost identical. Generally the "iron chink", "head cutter", "washing pool", etc., must be arranged on the working deck as the waste from these must be easily disposed of, while the meat is carried to the canning machines on the lower deck. The minimum length of a canning plant is 100 ft. (30 m.) and the minimum deck height is 8 ft. 3 in. (2.5 m.). The canning plant of the *Itukusima Maru* is shown in fig. 785 and 786.

PRODUCTIVITY — DISCUSSION

CHOICE OF SIZE AND TYPE

Ship owners' view points

MR. L. SOUBLIN (France): It might be asked what a ship-owner could have to say to naval architects. But, although he usually has to listen to their advice, he can also suggest objectives. And here, quite simply, are some of them.

The fisheries industry throughout the world is one of the best examples of the partnership of labour and capital, even in countries where the government contributes this capital. Its efficiency, therefore, depends on the requirements of these two factors being met. To satisfy labour, it is necessary to:

- Improve safety
- Increase comfort
- Lessen human exertion
- Pay better wages

To meet capital requirements, it is necessary to:

- Improve its profit-earning capacity

The first three conditions have long been, and will continue to be, studied. It is on the last two conditions that his observations are submitted here, because they are not necessarily met by increasing the possible catch of fishing boats. The improvement of profit-earning capacity depends, first, on the economic situation of the home market, and, secondly on the more or less proper balance achieved between return on capital and remuneration of labour.

When the home market for fish is not saturated, the aim should be to increase production as much as possible. Everyone will benefit thereby, and the naval architect can deliberately orient his studies to achieve maximum production.

When, besides such an economic situation, there is a state system of planning, the naval architect can further extend his research in the direction of optimum-maximum production.

When, on the contrary, the home market is more or less saturated, price fluctuations are such that the primordial factors are no longer quantity, but:

- Quality
- Search for unusual species (relatively or momentarily)
- Savings in operating costs

In this case, the naval architect will aim at optimum production. These three essentially different objectives and subsequent problems correspond in turn roughly to:

- The large, standard trawlers of British or German type (fish hold capacity of 200 to 250 tons)
- The factory trawlers
- The recent types of medium-sized trawlers

It takes, on an average, a three weeks' cruise to fill the hold of a large standard trawler with 200 to 250 tons of fish. Three weeks is the maximum period allowable for fish to be kept on ice so that it will not spoil. Experience, however, shows that this limit is often exceeded. After this length of time, the bacteria develop very rapidly until, finally, the average quality is too poor to be acceptable.

The very serious consequences of poor quality landings cannot be stressed too strongly. There can be no poor quality insofar as fish is concerned. The consumer rejects poor quality fish or, if he is obliged to eat it in times of food shortage, inevitably he will never touch it when his standard of living improves.

A higher standard of living is an ideal, not only from the moral but also from the economic aspect. It has been found (especially in France) that this phenomenon was accompanied by a disinclination for food commodities that, although wholesome, are not relished, such as salted, dried and smoked fish. Taste becomes more fastidious when a wider choice is possible. How much greater will be the disinclination of the consumer in the future to buy fish of doubtful freshness?

To remedy these drawbacks, the naval architect must orient his research towards:

- Improving the fish preservation facilities on board ship
- Increasing the ship's speed in order to reduce cruising time

It must be admitted, however, that studies of this kind will not bring about any progress unless, at the same time, the shipowners of all countries take the necessary steps to organize their markets. It must not be forgotten that it is infinitely more difficult to set economic progress going than to introduce technical improvements.

While the large trawlers aim solely at maximum production, the factory trawlers seek and obtain optimum quality landings as well as maximum production. Mr. Soublin had an opportunity to spend two days on the Soviet trawler, *Kabarovsk*. The fish which is frozen, either whole or filleted, immediately after it is caught is obviously of top quality. The technique is faultless. His comments concern other aspects. For fishing operations of this kind to pay, two conditions seem to be necessary:

- A home market that provides for the large consumption of frozen products, and fully equipped with a chain of refrigeration plants—this condition is met in some countries but not in others
- Regular, abundant catches to supply the factory and maintain the personnel—both equipment and workers cost much more on board ship than on land

The resources of the sea, however abundant they may be, are not inexhaustible. It is to be feared that the increasing number of factory trawlers will contribute towards the depletion of these resources and so cause their own ruin.

This brings up the question in industrial fisheries which is the maritime catastrophe of modern times. The idea of utilizing the scrap left after gutting, heading and filleting fish is excellent and, in this respect, the technical processing methods used to obtain meal, proteins and fertilizers are highly satisfactory. What is less commendable is the systematic catch for these purposes of fish too small for human consumption. Small fish will naturally grow bigger or else become the feed of larger fish. In either case, their destruction is a sort of genocide.

There is the classic example of the North Sea herring: its destruction is being accelerated because every year the Danes, fishing off their shores, catch nearly 200,000 tons of one- and two-year-old herring which pass their growing period in these waters.

Obviously, the factory trawlers at present have nothing like the same responsibility in this destruction, but it is to be feared that they will inevitably be impelled to fish more and more intensively. This will endanger the future fish supply for men.

One cannot speak of factory trawlers without thinking of trawling over the stern which, in the present status of technological progress, calls to mind a very large trawler and so inevitably a factory trawler. The hoisting of the trawl over a parabolic slipway requires a wide space between the winch and the stern because the tendency is to use ever longer lengthening pieces and codends. Hoisting also requires a space at least 30 to 33 ft. (9 to 10 m.) wide in order to keep a working deck clear and the landings usable. Add to this the long superstructure and the result is a very large trawler.

The naval architects will decide whether these two conceptions will inevitably remain interdependent in the future, or if perhaps stern trawling does not necessarily depend on the ramp or on the dimensions of a large ship. The advantages of trawling over the stern would make for wider use of this method if it could be adapted to medium-sized trawlers. This would be a good subject for study by naval architects.

There is no world-wide ideal type of craft. First of all, a trawler is always a compromise, and, above all, it must be adapted to meet the needs of the home market. And in this respect, it may said that the purpose of the latest French trawlers landing fresh fish is no longer merely maximum but also optimum production. In fact, the fish market in France could be considered "saturated". The trade is endeavouring to increase fish consumption but France is a highly agricultural country where home production feeds nearly 40 per cent. of the population. Under these circumstances the two essential requirements of the shipowner are: obtaining quality fish for the consumers, and finding more highly prized species.

The technicians must conform to these demands and must therefore provide for:

- Speedier craft
- Greater tractive power
- Boxing of fish on board ship
- Cruises not to last more than 12 or 15 days
- Medium-sized holds (catches of over 150 tons being rare)

It goes without saying, that putting the problem in this way, the solutions appear difficult. And it is here that the technicians' scope becomes unlimited, because technology is still far from meeting the shipowners' demands. Here also, there is a risk of the demands of "labour" (maximum remuneration) clashing with those of "capital" (more profits) because the shipowner alone bears expenses, while the wage earners (in France) take, on an average, nearly a third of the proceeds. To satisfy both sides—which is both necessary and possible—it is essential to:

- Improve the performance of the craft and the trawl
- Find means of effecting savings

It is this latter point which is the most difficult. In what way can savings be made? For want of a considerable saving, which can be expected only in consequence of a really revolutionary discovery, efforts must be directed at obtaining multiple small savings. As a point of reference, the following fields are the most likely to be explored with successful results:

Navigational and sounding instruments. Greater precision required in all research apparatus, i.e. detection of exact location of shipwrecks, correct estimation of the quantity of fish caught in the trawl, etc.

Fishing equipment and gear. Better synthetic fibres, greater resistance of cables to wear, pelagic trawls, special trawls, etc.

Fuel. Over the last ten years, little improvement has been made in the fuel consumption per h.p. of diesel engines. Much better results have been obtained with petrol engines. but in this case it has been a question of better fuel which has made it possible to increase the compression ratio. For fishing craft, research should perhaps be directed towards the use. where possible, of heavier and consequently cheaper fuels.

Manpower. Automation with regard to fishery is only just beginning if, in fact, it has started at all. The field of investigation is immense. The first objective should be reduction in the number of mechanics because it is unthinkable that a modern craft requires the constant attendance of a machinist merely to carry out an order from the wheel-house. The trawler must. or should, be run directly by its captain as tramcars are driven by conductors.

Maintenance. More often than not, the improvements made in the last few years have been achieved at the cost of a complex technical setup which entails higher expenditure on maintenance. The opposite trend should be the case.

Naturally, all this is very contradictory, and it will be difficult to find a solution. But, if the solutions were easy. there would be no need for naval architects.

Planning the craft for the developing countries

MR. H. I. CHAPELLE (U.S.A.): In an area where expansion of the fisheries is still possible, it is normal to find fishing craft to be more or less primitive, and often inefficient, in type. It is almost too easy to formulate a programme of rapid improvement and complete mechanization, based upon the concept that all that is needed is highly mechanized boats having every modern improvement. This can create economic disaster and delay the sound, commercial fisheries' growth. Improvement of fishing boats, particularly extensive mechanization. is very expensive, compared to the cost of primitive craft in any area. It follows, then, that the development of improved fishing boats should have a close relationship to the economic developments in a fishing area. The utmost caution should be exercised so that the fishing boat owner is not over-capitalized in an effort to get the most developed boat. Thus, to some extent at least, the development of the fishing boat of a given area must be slightly behind that of the improvement in other factors—the retail and wholesale market, distribution. fish handling and storage, fish supply and possibilities for exploitation. An integrated fisheries improvement plan is an absolute necessity.

There is no proper justification for developing a relatively costly boat for a fishery, when there is not a market that will be profitable enough to permit the owner to pay for his boat and also show a profit. This is also the case if the fishing grounds are not capable of receiving exploitation. These matters can and must be explored and judgments reached before any extensive development can take place in the production of improved boats, particularly where mechanization is concerned.

Different countries have varying fishery conditions, in which there is a variety in the range of fishing grounds, in market possibilities, in handling of the catch and, in short, in the immediate possibilities of creating highly developed fisheries and fishing boat types. It seems apparent, therefore, that each country requires special consideration of its problems and individual proposals for boat improvement.

It is not enough to consider the fisheries alone as a criterion for the improvement of fishing craft and extensive mechanization. The construction of the boats is a test of the skill of local boatbuilders. The repairs of mechanized equipment is likewise a test of local mechanics and of the sufficiency of their tools. It is not practical to employ boats of such designs and of such degree of mechanization that repairs and maintenance cannot be done locally during the initial stages of the employment of such boats. A boat laid up for repair or maintenance is a loss, not a gain, to the fishery, no matter how well developed she may be.

These problems should be discussed, country by country, and the pertinent information assembled. In many instances it will have to be recognized that all necessary requirements for beginning the development of improved boats and gear are not met. This will infer that the missing requirements must be planned and a definite commitment made to create these requirements before the improved boat and gear are in being.

The proper type of boat, engine and fittings cannot be decided offhand for any country. The boat type most suited for a given fishery is not merely a technical and theoretical problem; it is an economic and practical matter of the highest importance in the successful prosecution of a commercial fishery.

While it is desirable to begin consideration of the improved fishing boat and of greater mechanization free of preconceived prejudices and opinions, there are certain practical matters involved that must not be forgotten. For example, there are many areas in the Caribbean in which the trade winds blow, and the direction, duration and force of these can be foretold with great accuracy. Therefore, in such an area the use of sail should not be automatically discarded in the process of improving a fishing boat type. As a matter of economical operation and maintenance sail may still play an important part in boat design, for fuel costs are relatively great in the Caribbean area. In addition in such an area where the mechanical skill of the fishermen is limited, sails may well be a matter of safety.

Another matter which should be considered is the live-fish well. This mode of preserving the catch aboard the boat may be worth examination where ice and refrigeration are not likely to be available in time, or where economics do not permit these to be considered in the foreseeable future. This matter is also controlled by the size of the boat used and by the type of fishing gear employed. It is necessary to dismiss the idea that, under all circumstances, mechanization is the sole mode of improvement for the production of an economic and effective fishery, and the only evidence of progress and betterment.

When it appears practical to motorize local fishing boats, the choice of engine and horsepower required must be decided only after careful study of the individual fishery and of local conditions. The use of engines and of improved boats, in preference to existing craft, will produce a heavier capital investment for the individual fisherman and, in the initial stages at least, will increase the cost of the catch to the fisherman. It is obvious that immediate supply and demand must be carefully examined, in a given fishery, as well as the probabilities of market expansion, in determining what is to be done to avoid a market glut and economic disaster in the fishery.

It is proper in this stage to the preliminary study to remark that the choice in an individual fishery is so controlled economically that it must be decided whether to proceed gradually by first improving and motorizing existing craft, and then gradually introducing larger, more powerful improved designs, or whether to introduce a new type of high development and mechanization at once. This is not a matter that should be decided by local pride or desire, but by the hard economic facts.

In rowing boats, canoes and small sailing craft, the use of the outboard motor may be a practical step in semi-motorization. These motors have proved useful in many small boat fisheries throughout the world. Since only gasoline motors are now available, fuel becomes an important factor. Without discussing the technical details at length, it is proper to say that the economic employment of the outboard motor in commercial operations requires rather low power and well-originated maintenance and repair facilities complete with skilled mechanics. The outboard motor is not very economical in fuel and, therefore, is not inherently suitable where long runs to and from the fishing grounds are necessary. Usually existing boats can be readily fitted with outboard motors up to about 7 h.p., depending upon the size and form of boat. In a few instances motors up to 10 h.p. may be practical. The outboard motor is an extremely important tool in mechanization of small fishing boat types, particularly of the primitive canoe class.

Inboard gasoline motors may be divided into two basic types, marine and automobile. In North America the converted automobile motor is employed in the majority of fishing launches, in hulls up to about 45 ft. (13.7 m.) overall length. Such engines are readily available, and are relatively inexpensive at first cost. They have high rated horsepower at a high revolution-per-minute rate and, for their rated power, are light and compact. They can be readily repaired and maintained by local mechanics. On the other hand, they are subject to corrosion and are short-lived if any attempt is made to approach the maximum power output. They are not capable of making long runs in a boat requiring long "continuous" operation. Such engines may be worthy of consideration in some areas. These motors are, however, wasteful of fuel and when installed in a heavy fishing boat, are relatively inefficient in propulsion.

Marine gasoline engines available for fishing launches include some that are relatively slow-turning, heavy or medium duty motors. These are capable of long "continuous" operation, and require less maintenance and repair than the converted automobile engine. On the other hand, they are heavier and more expensive at first cost—in North America at least. They vary in rate of fuel consumption, but require far less fuel per operating hour at, say, 60 per cent. of total horsepower output than the automobile engine in a boat. Some of these launch engines are capable of using kerosene as a fuel, though in general this fuel necessitates more maintenance of a motor than when gasoline alone is used. The marine gasoline engine is from one-half to two-thirds the first cost of a diesel of the same horsepower in launch size and power in North America.

In recent years there has been much interest in the use of diesel engines in fishing boats. There is no question of its superiority over heavy and medium duty gasoline engines in fishing boats over 35 to 40 ft. (11 to 12 m.) length, requiring more or less "continuous" operation. Its relatively high first cost and the short runs required in most North American fishing launches have prevented it from becoming popular

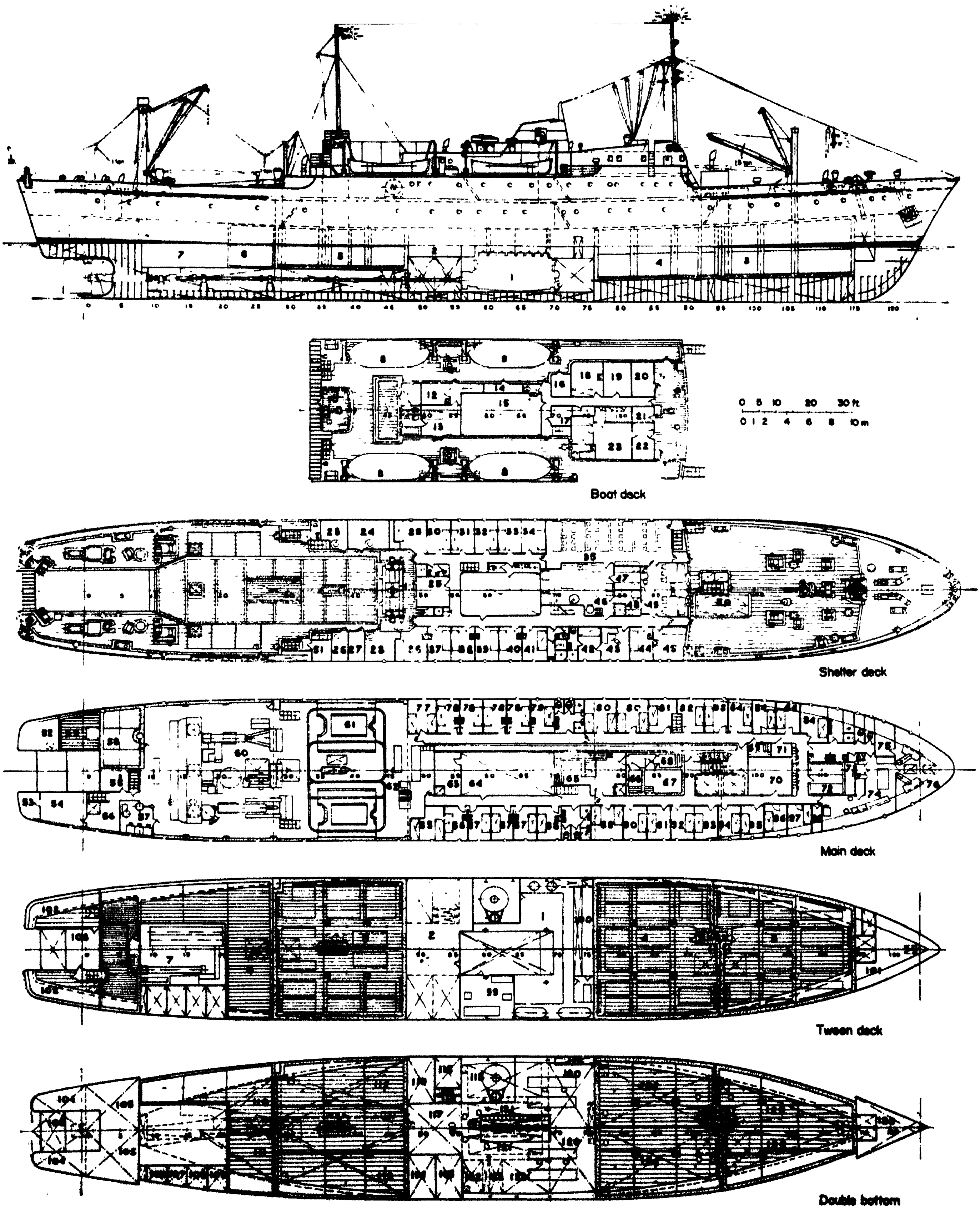

Fig. 787. General arrangement of factory trawler, B.15

in North American fishing launches under 45 ft. (13.7 m.) length, but it is otherwise in Europe. Nevertheless, the need or the preference for diesel engines in small fishing craft should be carefully examined. These small diesels are relatively heavy for their power as a general rule and require skilled maintenance mechanics. Someone skilled in gasoline engine repair and maintenance requires training to repair and maintain diesels. In small fishing craft the air-cooled diesel appears to have advantages over the liquid-cooled type.

Small air-cooled industrial gasoline engines are employed in some small fishing launches. These are similar in requirements to the outboard motor in repair and maintenance. As a marine engine it is good for limited operation at less than full output in a small fishing boat.

If special deck machinery is required in any fishing boat type under improvement, this must be considered in the design. If limited mechanization is the objective, but with the possibility of the use of such machinery as a later development, then the initial boat design must be suitable for the deck machinery and gear which affect size and displacement of the boat at least, and perhaps engine power.

In order to assist naval architects with experience in the design of fishing boats to make sound recommendations for size and type of boats for new countries, it is suggested that fisheries officers collect data on the existing types of fishing boats and on requirements for boats, including those for new types, in the form of a questionnaire something on the following lines:

Fishing conditions

(a) Are grounds prolific enough to warrant possible expansion in catch?
(b) What mode of catching is considered most suitable?
(c) How distant are the fishing grounds from the fishing ports?

Operational requirements

(a) What types of boats and propulsion are now in use? Photographs and models would be useful references, also sample dimensions.
(b) Are there piers, quays, harbours or coves giving complete shelter, or are beach hauling operations required?
(c) Are boats built locally?
(d) What repair facilities are available?
Hauling ways, accommodation for heaving down; mechanical maintenance, sail making, marine hardware and supplies.
(e) Is there any formal effort to teach boatbuilding?
(f) What fuels are available?
(g) What lumber is used in local boatbuilding and where and how obtained?
(h) What are wind conditions in the fishing area and what are the usual sea conditions in general? Is sail useful in the local fisheries and can sailing boats be profitably employed for the present?

Economic factors

(a) Is the present demand for fish greater than supply?
(b) Can demand be readily increased? Is market space available?
(c) Can fish be exported profitably? Is it being done now?
(d) Are cold storage facilities and canneries in existence?
(e) Is ice available for icing catch at sea?
(f) Is the existing fishery profitable with present gear and boats?
(g) Are improved pier and quay accommodation planned or under consideration?

Miscellaneous factors

(a) Are improved boats or experimental boats under trial? What are the dimensions and power? If so, what design, and are plans or half-model in existence?
(b) Can local builders work from plans or half-model?
(c) What engines are now in use in fishing boats, and what is price of fuel in litres or gallons?
(d) Are fishermen now skilled in operation of boat or automobile motors?
(e) How would improved boats be paid for?
(1) Government subsidies or loans?
(2) Private banks? Dependent on own savings and capital?
(3) Co-operative ownership?
(4) Rental or charter?
(5) Private ownership?

1. Engine room
2. Refrigerating machinery
3. Hold no. 1
4. Hold no. 2
5. Hold no. 3
6. Fish meal hold
7. Fish meal factory
8. Lifeboat—46 persons
9. Motorlifeboat, 42 ft. (12.82 m.)
10. Wheelhouse
11. Separate room
12. Infirmary
13. Hospital
14. Accumulator
15. Engine casing
16. Convertors
17. Preheaters
18. Radio officer
19. Wireless room
20. Chart room
21. Radar
22. Pilot
23. Captain's day room
24. Carbondioxide, CO_2
25. Trawl winch motor
26. Lamp room
27. Drying room
28. Net workshop
29. Two fishermen
30. Boatswain
31. Two fishermen
32. Cook
33. Two factory masters
34. Doctor
35. Crew's mess
36. Refrigeration technician
37. Mechanic, electrician
38. 4th engineer
39. 3rd engineer
40. 2nd engineer
41. 3rd officer
42. Chief engineer's bedroom
43. Chief engineer's dayroom
44. 2nd officer
45. 1st officer
46. Galley
47. Crew's pantry
48. Officers' pantry
49. Officers' mess
50. Work-boat
51. Paint room
52. Ammonia, NH_3
53. Contactors
54. Workshop
55. Steering wheel
56. Workshop
57. Cod liver oil room
58. Temporary store
59. Net store
60. Fish treating compartment
61. Refrigerating tunnel
62. Packing room
63. Engine store
64. Engine casing
65. Provision store
66. Provisions
67. Provisions, refrigerating chamber
68. Fruits
69. Linen
70. Emergency set
71. Linen
72. Potatoes
73. Preheaters
74. Laundry
75. Contactors
76. Boatswain's store
77. Four fillet men
78. Two fillet men
79. Two head-cutting men
80. Four eviscerating men
81. Two workers
82. Cod liver oil man
83. Four factory men
84. Two fishermen
85. Four factory men
86. Two refrigeration engineers
87. Two motor men
88. Two electricians
89. Three loaders
90. Sailor
91. Two motor men
92. Two stewards
93. Cook
94. Two weighing men
95. Two loaders
96. Two factory men
97. Two factory men
98. Store
99. Workshop
100. Switchboard
101. Boatswain's store
102. Net store
103. Steering gear compartment
104. Tank no. 9, sanitary water
105. Tank no. 16 and 8, fresh water
106. Tank no. 15, cod liver oil
107. Tank no. 14, cod liver oil
108. Tank no. 13, cod liver oil
109. Tank no. 13, cod liver oil
110. Tank no. 7, feed fresh water
111. Tank no. 7, sanitary fresh water
112. Tank no. 6, diesel oil
113. Tank no. 6, diesel oil
114. Tank no. 11, diesel oil
115. Tank no. 10, diesel oil
116. Diesel oil settling tank
117. Tank no. 5, separated diesel oil
118. Tank no. 4, feed fresh water
119. Lubricating oil tank
120. Tank no. 3, diesel oil
121. Lubricating oil circulating tank
122. Diesel oil overflow tank
123. Tank no. 2, ballast water
125. Tank no. 1, diesel oil
126. Forepeak, fresh water

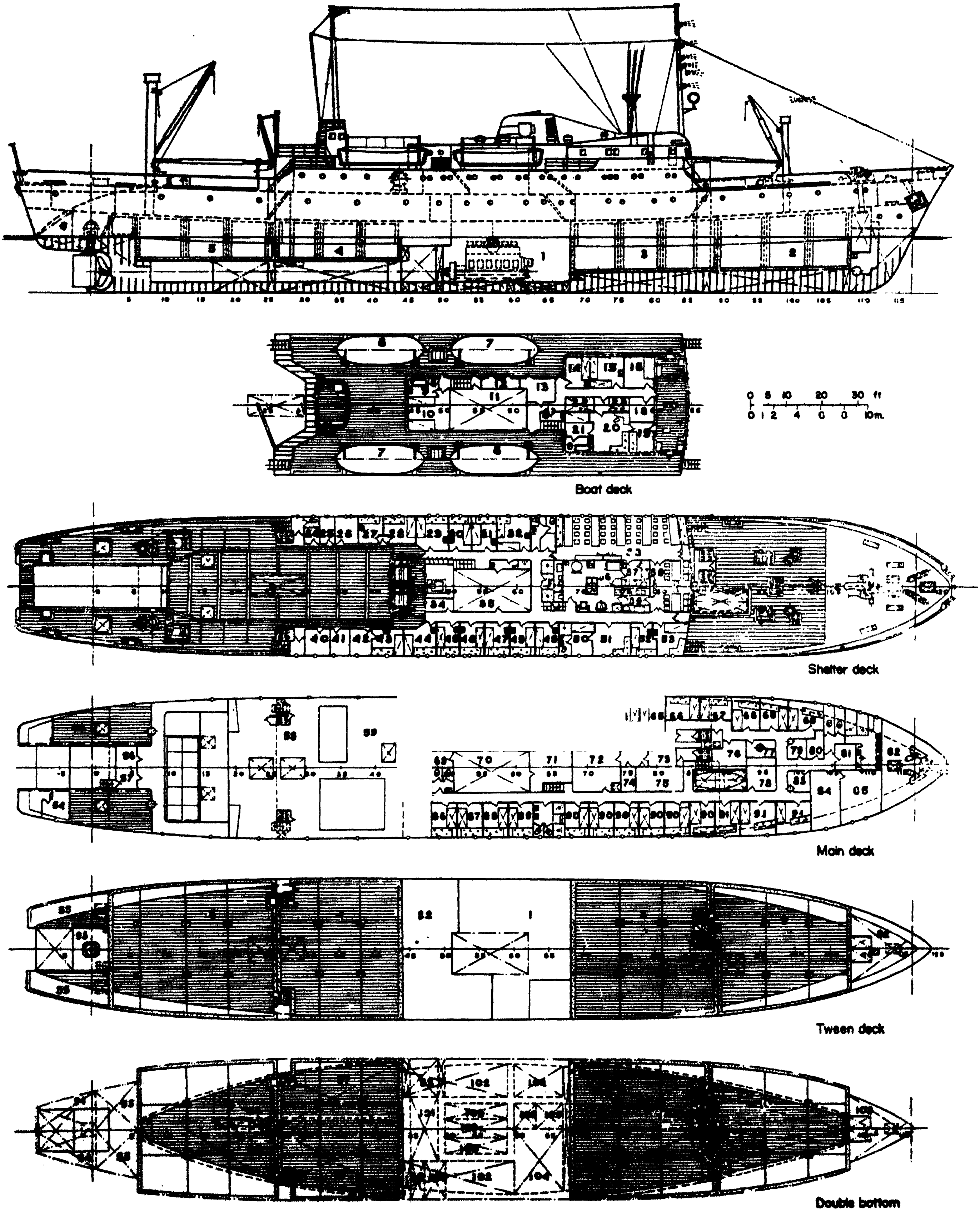

Fig. 788. General arrangement of freezer trawler, B.18, 1,030 ton deadweight

(f) How would improved boats be obtained?
  (1) Built locally?
  (2) Imported?
(g) If improvement is now in progress, is it the intention to use standard boats in each fishery?
(h) Who would design improved boats, or how would such designs be obtained?
(i) Are there local taxes based on value of boat or catch?
(j) Are there now sufficient fishing crews available to man boats larger than now employed? Can labour co-operation be expected?
(k) Are there special safety requirements in view?
(l) If sail is carried, give dimensions with those of hull.
(m) What fishing gear is used, and what new gear is under consideration in the boat?

It would be desirable if line drawings, models, photographs and measurements of existing boats could be submitted for study. Plans would be most desirable, but are probably now unavailable except in cases of experimental craft now being tested.

Information thus collected could be improved with photographs, line drawings, sketches, etc., for individual boat types. The questionnaire could be a permanent method of securing information for publication or circulation on the individual problems of types of boats, and would also be an historical record on which to base improvements.

Particular attention should be given to the problems of motor selection, introduction of new types of boats, the relation of boats and engines to new types of fishing gear and fishing methods; the possibility of standardization of boat engines and gear design; the economic and technical considerations involved in the construction of boats; the fitting of engines, and the suitability of boats in the area of use and the practical aspects of the control of boat construction. The need for more extensive design-study of boats suitable for outboard motors was apparent.

Polish experience

MR. W. ORSZULOK (Poland): He gave a brief description of the types of ships designed on the basis of the investigations discussed in Swiecicki's paper. Three main types of fishing vessels were developed:

● The processing-freezer trawler, type B.15 (fig. 787)
● The freezer trawler, type B.18 (fig. 788)
● The freezer drifter-trawler, type B.19 (fig. 789)

Poland's main fishing grounds are far distant from home ports. Only a small proportion of fish can be brought to the market in iced or fresh condition.

Polish market research showed that frozen fillets are preferred to whole fresh fish by the consumers, and salted herring is always looked for by buyers. Various kinds of canned fish also find a good market in Poland.

The three types of ships were designed on the basis of these consumer preferences.

Besides the three types, a normal motor side-trawler (type B.20 according to fig. 790) is in the design stage, which will land the first catches in frozen condition (contact freezers are provided) and the later catches in iced condition.

He pointed out that they had no practical experience with stern trawling but in their opinion stern trawling was the answer for big fishing vessels like the B.15 and B.18 types. For the medium-size trawler operating in rough North Sea and North Atlantic conditions, they found side trawling to be more convenient.

Details of the processing and freezer trawlers are given in table 191.

The B.15 and B.18 types are fitted with controllable-pitch propellers, the B.19 type with diesel-electric drive and a bow rudder of the water-jet reaction type, the B.20 trawler with fixed-blade propeller. All types of ships, except the B.20 type, are to be built as prototypes and are to be put into experimental service for one to two years. After this period it will be decided what changes are to be made in the design, and series production will start. The first of the processing-freezing trawlers—B.15—under construction will be commissioned in early 1960.

COMMANDER M. B. F. RANKEN (U.K.): Swiecicki's paper was a very modest account of the vast amount of work carried out at the Marine Institute in Gdansk. One of their economic surveys "A Revised Study of Fish Processing Trawler—based upon the experience gained in operation the *Poushkin* class trawlers", written 1957, had been translated privately into English and it was a most valuable report.

It would be interesting to know why the Poles had decided that base ships were unsatisfactory, especially in view of the long distance from Polish ports to the fishing grounds.

Propulsion methods

MR. P. F. DILNOT (U.K.): He had read Eddie's paper with great interest. When dealing with controllable-pitch propellers, Eddie said some people consider it necessary to fit a

1. Engine room
2. Hold no. 1
3. Hold no. 2
4. Hold no. 3
5. Hold no. 4
6. Aft tank
7. Lifeboat—45 persons
8. Lifeboat—34 persons
9. Hospital
10. Washroom
11. Engine casing
12. Accumulator
13. Preheaters
14. Pilot
15. Radio officer
16. Wireless room
17. Wheelhouse
18. Convertors
19. Chart room
20. Captain's saloon
21. Captain's bedroom
22. Skylight
23. Telephone exchange
24. Lamp room
25. Fire extinguishing equipment
26. Laboratory
27. Infirmary
28. Doctor
29. Boatswain
30. 3rd officer
31. 2nd officer
32. 1st officer
33. Crew's mess
34. Electricians' workshop
35. Engine casing
36. Galley
37. Pantry
38. Officers' mess
39. Officers' pantry
40. Carbondioxide, CO_2
41. Paint room
42. Drying room
43. Locksmith
44. Chief steward
45. Two refrigeration engineers
46. Two electricians
47. Refrigeration engineer
48. Electrician
49. 4th engineer
50. Chief engineer's bedroom
51. Chief engineer
52. 3rd engineer
53. 2nd engineer
54. Ammonia, NH_3
55. Net store
56. Cargo winch contactor
57. Store
58. Fish treatment compartment
59. Packing room
60. Two factory masters
61. Two sorters
62. Two factory men
63. Two controllers
64. Two factory men
65. Two factory men
66. Two loaders
67. Two factory men
68. Two factory men
69. Store
70. Engine casing
71. Engine workshop
72. Provisions
73. Fruit
74. Provisions
75. Meat
76. Emergency set
77. Gyrocompass
78. Potato store
79. Cargo winch contactors
80. Linen
81. Drying room
82. Boatswain's store
83. Soiled linen
84. Ironing room
85. Laundry
86. Cook
87. 2nd Cook
88. Two seamen
89. Two stewards
90. Two fishermen
91. Two motormen
92. Refrigerating machinery
93. Steering gear
94. Tank no. 9, drinking water
95. Tank no. 8, drinking water
96. Tank no. 7, ballast water
97. Tank no. 6, fuel oil
98. Tank no. 5, fuel oil
99. Tank no. 5, fuel oil
100. Tank no. 5a, fuel oil
101. Separated diesel oil tanks
102. Tank no. 4, fuel oil
103. Lubricating oil, spare tank
104. Tank no. 3
105. Oil overflow tank
106. Tank no. 2, ballast water
107. Tank no. 1, ballast water
108. [illegible]

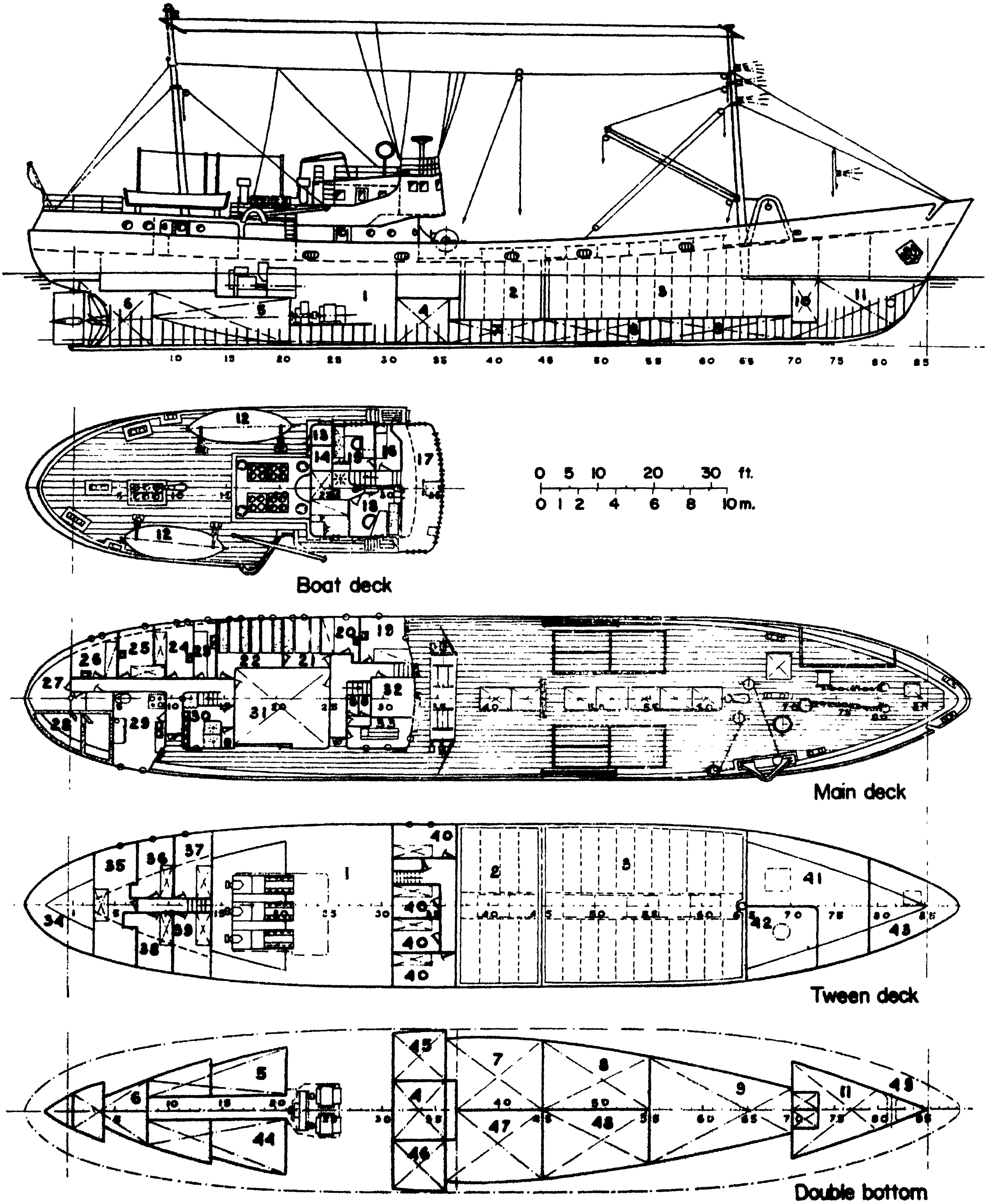

Fig. 789. General arrangement of ocean drifter-trawler, B.19

TABLE 191

Particulars of Polish processing and freezer trawlers

		Factory trawler	*Freezer trawler 1,030 tons dead weight*	*Ocean drifter-trawler*	*Freezer trawler*
		B.15 *Fig. 787*	*B.18* *Fig. 788*	*B.19* *Fig. 789*	*B.20* *Fig. 790*
Length overall	ft. (m.)	278.9 (85.0)	265.1 (80.8)	166.8 (50.86)	201.9 (61.55)
Length between perpendiculars		246.1 (75.0)	231.3 (70.5)	150.9 (46.0)	180.8 (55.1)
Breadth		45.27 (13.8)	42.98 (13.1)	31.17 (9.5)	32.15 (9.8)
Depth		31.99 (9.75)	29.86 (9.10)	15.42 (4.70)	17.06 (5.20)
Draught		17.72 (5.40)	16.73 (5.10)	13.12 (4.00)	14.47 (4.41)
Freeboard		5.17 (1.578)	—	—	—
Block coefficient		0.56	0.65	0.541	—
Main engine power		2,000 h.p.	1,440 h.p.	700 kW	1,080 h.p.
Trial speed	knots	12.5	11.5	12.5	12.0
Crew		93	73	26	33
Trawl pull at 5 knots	ton	—	—	9	—
Capacity of hold I	cu. ft. (cu. m.)	—	—	—	10,230 (290)
Capacity of hold II	,, ,,	—	—	—	8,460 (240)
Capacity of ice	,, ,,	—	—	—	1,410 (40)
Capacity of temporary fish store	,, ,,	—	—	—	705 (20)

clutch between the engine and propeller to ensure that the propeller and ship are stationary when the trawl is alongside. He had had the good fortune to do two trips in the *Kingston Beryl*: when hauling and shooting the trawl, no difficulty is experienced in keeping the ship stationary nor does the revolving propeller prove an embarrassment; on the contrary, the ease and precision with which the ship can be manoeuvred is a great advantage especially when getting a "double bag" on board.

With diesel trawlers of 1,400 to 1,800 h.p., Eddie made the point that they may run too cool when fishing. By fitting a controllable-pitch propeller, this problem can be surmounted by operating the engine at a slower speed and obtaining the horsepower at an increased torque by increasing the pitch.

The outstanding performance of diesel-electric ships, together with the fast response required by skippers, can also be obtained with a controllable-pitch propeller at a smaller capital outlay.

Eddie's paper very fairly put the case for the various types of propulsion machinery. **It would seem the best compromise to achieve the most edible fish at the cheapest cost, is a freezer trawler with constant torque machinery provided by either a diesel-electric installation or a large diesel driving a controllable-pitch propeller and the winch, as well as the ships' lighting generator, and the refrigeration machinery.**

The former has the advantage of increased reliability because the failure of one propulsion engine does not bring the ship to a standstill, while the latter is cheaper and takes up less engine room space as well as reducing the number of moving parts requiring maintenance. With modern diesel engines, a main engine failure is a rare occurrence.

A further alternative, having advantage of both systems, is the geared "father and son" layout. The coupling gears can incorporate a reduction chain and isolating clutches. This allows high-speed diesel engines to be used, and for one engine to be de-clutched to drive the winch on arrival at the ground. By fitting engines of, say, 1,000 and 500 h.p., the 500 h.p. coupled to the winch generator at its forward end, the 1,000 h.p. engine will be of ample capacity to deal with the power requirements when fishing so long as a controllable-pitch propeller is fitted. This arrangement obviates the need for a diesel engine, only of use to drive the winch and idle for at least 80 per cent. of its life, as well as giving the increased reliability of two propulsion engines.

Safety factors in diesel-electric equipment

MR. E. L. N. TOWLE (U.K.): It is suggested that the main purpose of using a double armature propulsion motor is to reduce the diameter, thus enabling the motor to be installed further aft than would be the case if a single armature motor were used. Actually, this is not the primary reason for the choice of a double unit motor, although it is one of the advantages incidental to this type of unit. The principal reason is that a trawler, of all ships in service, cannot afford to take the slightest chance of total failure of propulsion, as on a lee shore this might mean the loss of the ship.

Electrical failures are almost non-existent, but very occasionally a failure does occur which it is almost impossible to guard against, and the provision of a double armature motor with a suitable switching cubicle, enables either half of the motor to be isolated in less than 30 sec., should there be a

1. Engine room
2. Spare hold
3. Main hold
4. Deep tank
5. Side tank
6. Afterpeak
7. Tank no. 3
8. Tank no. 2
9. Tank no. 1
10. Chain locker
11. Forepeak
12. Lifeboat—12 persons
13. Accumulator
14. Convertors
15. Wireless room
16. Chart room
17. Wheelhouse
18. Captain's day room
19. Chief engineer
20. 1st officer
21. Officers' mess
22. Crew's mess
23. Pantry
24. 2nd officer
25. 2nd officer
26. 1st officer
27. Provision store
28. Refrigerating chamber
29. Galley
30. Washroom
31. Engine casing
32. Trawl winch motor
33. Compartment for removing fish throats
34. Steering gear
35. Two-person cabin
36. Two-person cabin
37. Two-person cabin
38. Two-person cabin
39. Two-person cabin
40. Two-person cabin
41. Net room
42. Rope store
43. Boatswain's store
44. Side tank
45. Deep tank
46. Deep tank
47. Tank no. 3
48. Tank no. 2
49. Stream rudder

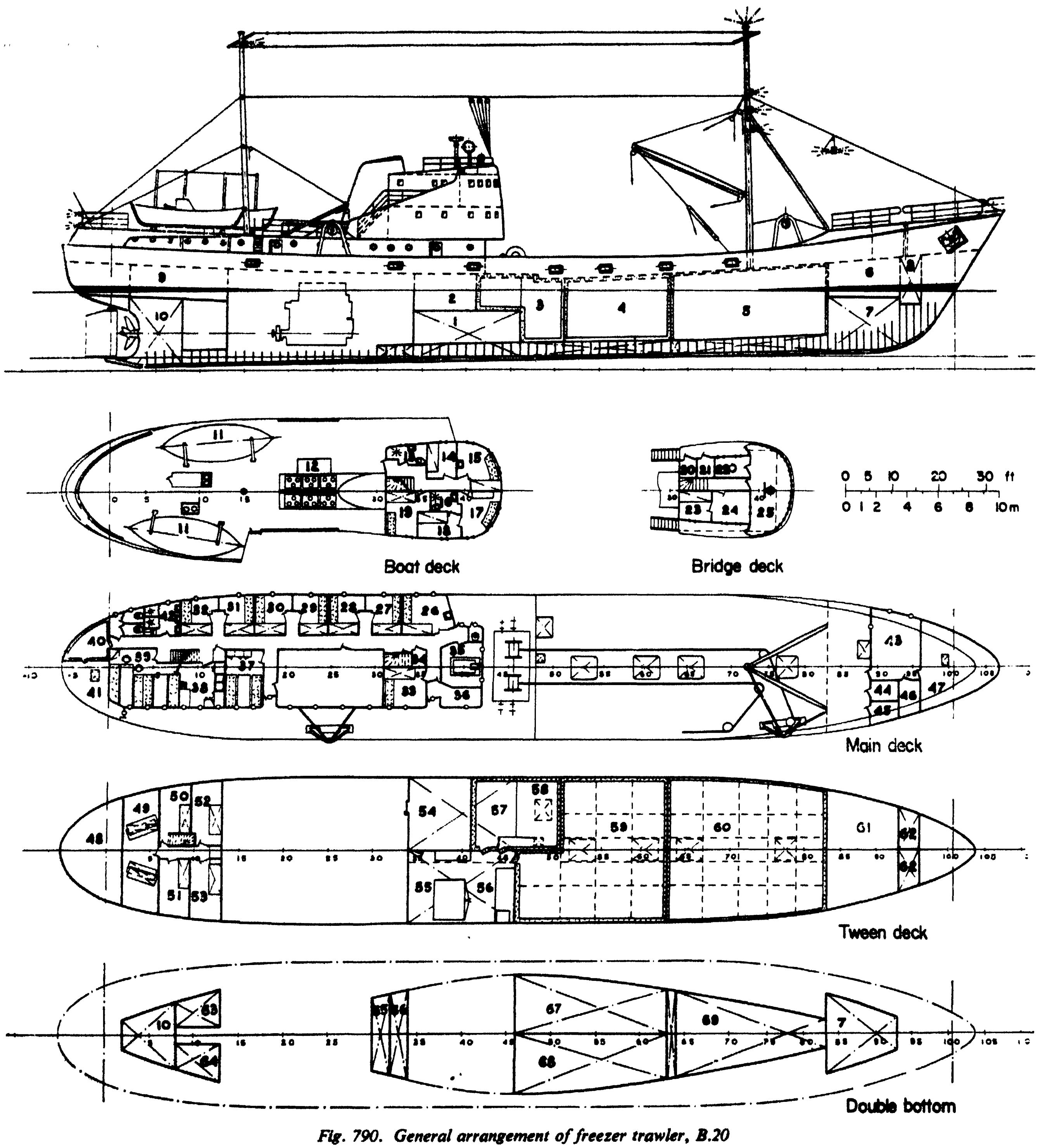

Fig. 790. General arrangement of freezer trawler, B.20

1. Fuel oil tank
2. Refrigerating machinery
3. Ice store
4. Fish hold no. 2
5. Fish hold no. 1
6. Net compartment
7. Forepeak

10. Afterpeak
11. Lifeboat—33 persons
12. Lifebuoys
13. W.C.
14. Pilot
15. 1st officer

17. Captain's saloon
18. Captain's bedroom
19. Two-person cabin
20. Accumulator
21. Convertors
22. Chart room
23. Radio officer
24. Wireless room
25.
26. Chief engineer
27. Two-person cabin
28. Two-person cabin
29. Two-person cabin
30. Two-person cabin
31. Two-person cabin
32. Two-person cabin
33. Two-person cabin
34. Store
35. Trawl winch motor
36. Drying room
37. Officers' mess
38. Galley
39. Crew's mess
40. Provisions—refrigerating chamber
41. Provisions
42. W.C.
43. Net workshop
44. Lamp room
45. Paint room
46. Custom's store
47. Boatswain's store
48. Steering gear compartment
49. Four-person cabin
50. Two-person cabin
51. Two-person cabin
52. Two-person cabin
53. Two-person cabin
54. Refrigerating machinery
55. Freezing room
56. Refrigerating chamber
57. Temporary fish store
58. Ice store
59. Fish hold no. 2
60. Fish hold no. 1
61. Net room
62. Chain locker
63. Side tank
64. Side tank
65. Machinery oil tank
66. Cylinder oil tank
67. Tank no. 2
68. Tank no. 2
69. Tank no. 1

breakdown and in spite of a somewhat greater first cost, he had always considered it essential to use a double armature motor for single-screw sea-going vessels.

A minor advantage of the double armature motor is that it enables a higher overall voltage to be used in the system, and consequent reduction in the circulating current, with resultant saving of cables, and generally speaking a slight overall increase in efficiency.

Regarding the engine room ventilation and dissipation of losses, it is essential to guard against the entry of water under the very worst conditions, but if the ventilation system is considered with the design of the ship, adequate protection can be afforded, and the direct ventilation system forms a simpler system than the use of a closed circuit air system with water cooler, and the attendant risk of leakage from the cooler tubes, allowing water to get into the motor.

Eddie's paper said that for Arctic conditions, precautions had to be taken regarding the cooling water, and that it was possible to do this by means of a thermostatic device. He was of the opinion that the number of automatic thermostatic devices should be reduced to an absolute minimum, as these features, when installed, are liable to be taken for granted, and failure may result in engines being run at an excessively low temperature. It is essential to provide alarms to indicate excessive temperature or failure of lubricating oil pressure, but apart from these features, the only essential automatic device is an underspeed switch to disconnect the generator field in the event of failure of the diesel engine, which otherwise would be motored backwards, and an independent overspeed governor to guard against run-away in the event of failure of the main speed governor.

According to Eddie one of the advantages of electric accommodation heating is that the vessel can be ready for sea half an hour after complete shut-down. The second advantage is that economy results, since, on a diesel-electric ship, the boiler normally burns diesel-oil, which is relatively expensive, and in the case of the *St. Dominic*, it has been found that during the voyage to and from the fishing grounds the boiler is not normally used. It is only lit up when required for liver boiling and deck use. This results in some economy, since the boiler can burn up to one ton of oil per day.

Eddie said that the cost of the constant current system was slightly greater than that of the Ward Leonard system, but generally speaking there was little to choose, as to give equal amount of standby it was necessary to use a four-engine Ward Leonard system, compared with a three-engine constant current system.

For approximately one day during each passage, power is required on deck for the preparation and stowing of the gear. The amount of power required is not great, but is required at frequent intervals during the day. With a constant current system the winch can be left in the loop all day, and used as required, with negligible effect on the propulsion, even on full power. If power is left on the winch all day on a Ward Leonard scheme, the engine will be idling for the whole time, with an adverse effect on lubricating oil consumption, and consequent fire risk. The alternative is for a large number of switching operations to be made by the engine room staff. When using the winch in this manner only three-quarters or two-thirds maximum power of the ship is available.

A course sometimes adopted when a market is at stake is to use the windlass to assist in stowing the gear, but this is not popular with the crew, as the barrels of a trawler windlass are not designed with this operation in view.

A further advantage of the constant current trawl winch is that power can be left instantly available when fishing, without having an idling engine for most of the time. This is particularly advantageous when fishing in rocky grounds, with many potential fastenings, which are likely to pull out the warps occasionally.

Heavy vessel preferred

MR. DWIGHT S. SIMPSON AND MR. JOSEPH W. SLAVIN (U.S.A.): Eddie has made the very important point that it would be best to design and construct a new vessel for freezing fish at sea, rather than to convert existing trawlers. There is no question that successful freezing of fish at sea can best be made by a new, rather than an old vessel. The U.S. Bureau of Commercial Fisheries, therefore, contracted the consulting firm of naval architects of Mr. Simpson, to prepare a preliminary design of a new trawler for brine-freezing fish at sea.

Fig. 791 and 792 show a vessel 170 ft. (52 m.) in length by 32 ft. (10 m.) beam, with a gross tonnage of about 500. Two brine-freezers, each having a holding capacity of 13,500 lb. (6,124 kg.) of fish, are provided to assure freezing of the fish

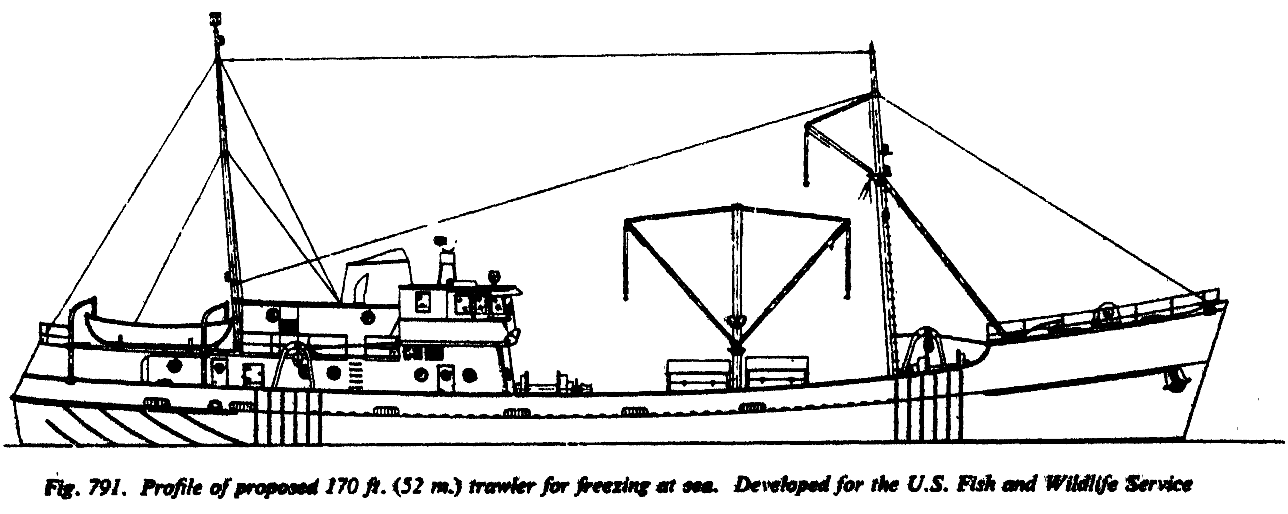

Fig. 791. Profile of proposed 170 ft. (52 m.) trawler for freezing at sea. Developed for the U.S. Fish and Wildlife Service

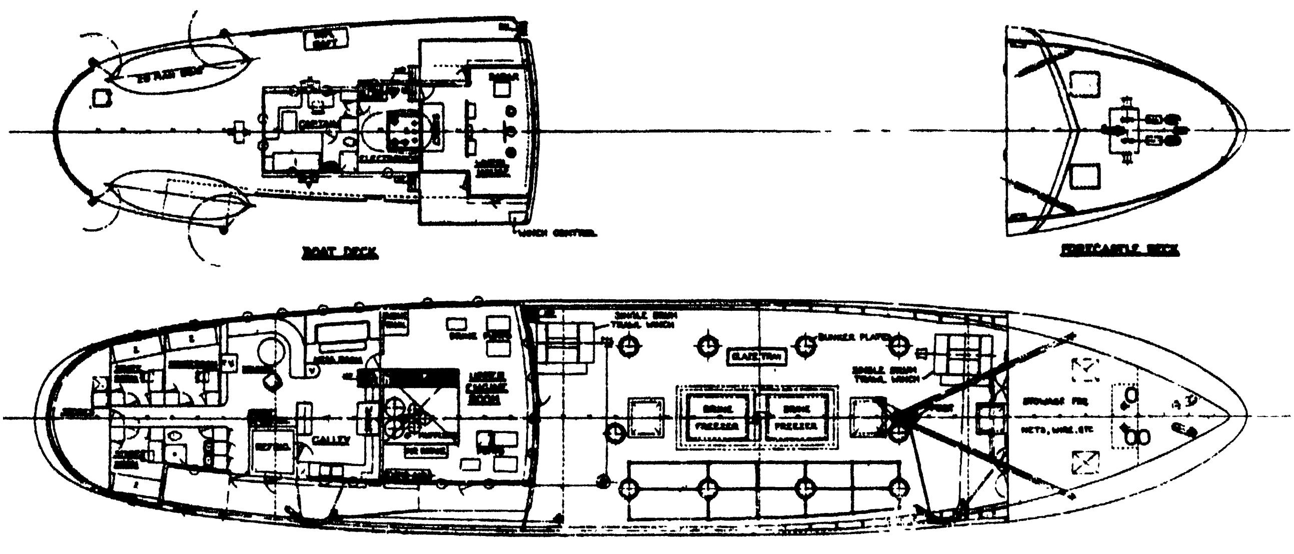

Fig. 792. Arrangement of proposed 170 ft. (52 m.) freezer trawler showing off-centre one-drum trawl winches and brine-freezing arrangement

as soon as they are landed on the vessel. Each freezer will continuously freeze both large and small groundfish at a rate of about 3,000 lb. (1,360 kg.) per hour.

The refrigeration equipment consists of:

- Four freon 12 compressors having a combined capacity of 80 RT (242,000 kcal.) at 0° F (–18° C) suction temperature for freezing, and
- Two similar type freon 12 compressors with a capacity each of 5 RT (15,000 kcal.) at 0° F (–18° C) suction temperature for maintaining the holds at 0° F (–18°C)

All compressors are driven by 220 volt 3 phase AC electric motors supplied by diesel-driven generators. Three such generators supply some 600 kW for all of the vessel's electrical services.

The vessel has a storage capacity for 250 tons (254 ton) of round frozen fish in the two 0° F (–18° C) refrigerated holds. Large hatch openings will permit rapid handling of the fish.

The propulsion plant consists of two 750 h.p. diesel engines driving a single propeller through reduction gears. The vessel has an estimated speed of 13.5 knots and a cruising radius of about 6,000 miles. Other features of this design are a hydraulically-driven winch, elimination of danger from trawl wires crossing the deck, one-side fishing and excellent accommodation for the crew.

Speed factors considered

Mr. D. J. Doust (U.K.): Eddie's paper gave a wealth of practical information on the general economic requirements of the fishing industry, and also a clear picture of the composition of the British trawler fleets at the present time.

As far as recent designs of deep-sea trawlers are concerned, Eddie rightly drew attention to the fact that many of the advantages in reduced resistance and increased propulsive efficiency achieved in these new designs have resulted mainly in increased ship speed to and from the fishing grounds. This use of the hydrodynamic research which has gone into these designs is understandable with present methods of preserving the catch, but with the proposal to freeze part of the catch there is the attractive alternative of utilizing these benefits, by installing smaller engines and running these vessels at reduced speed. At these lower speeds, allowed by the improved preservation processing of part of the catch, there are interesting and new possibilities for the naval architect to produce trawler forms which give better economic returns. These new designs will, of course, have to maintain a free-running speed as high as possible with the reduced powers contemplated, and must still fish as efficiently as their higher-powered counterparts. In this connection it would appear to be axiomatic that they must be fitted with a propulsion system having constant power and not constant torque characteristics. The ability of the constant power propulsion system to deliver its maximum rated power in adverse weather should help materially in minimising the speed losses which inevitably occur relative to calm water performance and thus reduce the risk that the quality of the normally-stored catch be impaired on arrival at the home ports.

In undertaking any new design study of this nature it is, of course, essential to conduct both resistance and propulsion experiments in smooth water and in waves. In the case of the bulbous bow trawler, the evidence so far obtained at NPL suggests that such a form has optimum performance in both smooth and rough water conditions and it is therefore ideally suited to the requirements desirable in a semi-freezer trawler.

One of the main difficulties at the present time is that there is little or no reliable information on the sea conditions most frequently encountered on the deep-sea trawler runs. Once information of this sort is readily available, coupled with service data of power, revolutions of the propeller, fuel consumption, ship speed and catching rate, the way is open to the statistical approach mentioned by Eddie. It is to be hoped that this urgent need will soon be met and the economics of trawling operations placed on a sound basis.

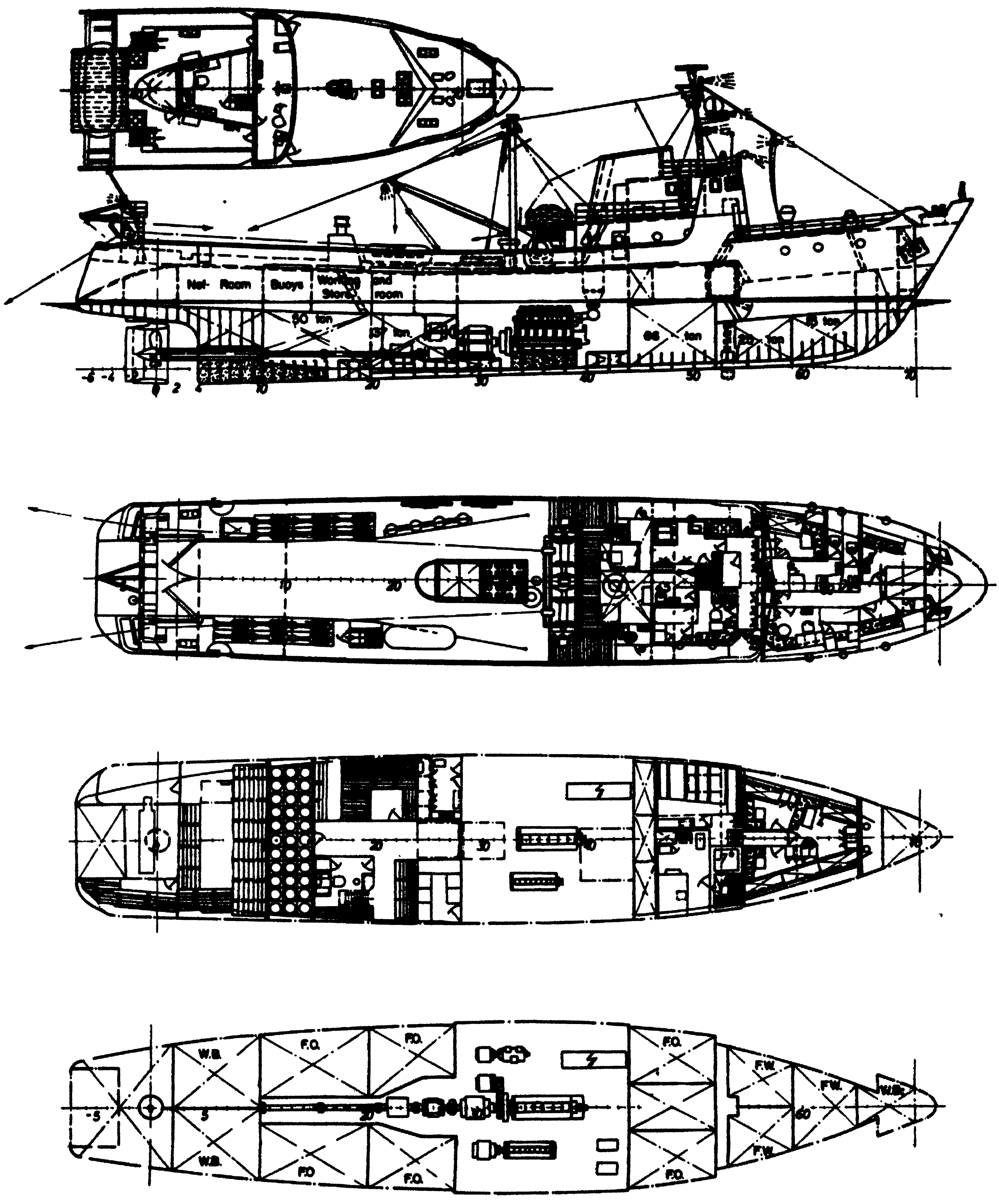

Fig. 793. Proposed catcher trawler which will only tow the trawl and leave the catch to be taken care of by motherships

CAPTAIN W. COSTA (Italy): He referred to Eddie's paper which very clearly illustrated and compared various systems of propulsion machinery for long distance trawlers and factory ships.

It seems that the diesel-electric constant power propulsion system appears to be the ideal for a trawler and is very much liked by skippers.

From the owner's point of view, this enthusiasm fades because of cost considerations:

- The first cost of a diesel-electric propulsion system is higher than that of the traditional installations
- The maintenance of DC diesel-electric equipment runs very high
- Highly specialized engineers are needed in the engine room

He felt that DC was responsible for the situation. The increasing use made of AC auxiliary machinery on board modern merchant vessels and tuna-clippers, prove the value of AC installations. He believed it should be possible to use AC for diesel-electric trawlers or diesel-electric factory ships. The flexibility of the system would not change. The manoeuvrability could be assured by coupling the high-speed electric motor to a controllable-pitch propeller. First cost of installation would be substantially lower if high voltage and frequency were adopted. He realized that the adoption of a controllable-pitch propeller—the cost of which would be about double that of a fixed-blade one—would consume a good deal of the savings, but he thought the combined AC installation should be about 15 per cent. cheaper. Maintenance cost would be reduced to a minimum. Equipment could be simplified so that ordinary engine-room personnel could run it safely. Centralization of ships' controls could be realized.

The 1965 fishing boat

MR. C. BIRKHOFF (Germany): His contribution was something between the up-to-date matters already discussed, and the last subject the 1975 fishing boat, and his comments could be called "The 1965 Fishing Boat".

Many of the aspects of fisheries that are debated ultimately lead to the processing of the catch, and whenever there is a discussion about fishing vessels with complete processing plants, the factory trawler is mentioned as the possible optimum. One of the arguments advanced is that this type has best withstood the severe conditions in northern Atlantic waters.

Experience has proved that these vessels can continue fishing operations in a wind at Beaufort 10, although with not infrequent loss of their trawling gear. Nevertheless, the question arises whether the big investment and the need to employ a crew of 100 or more is still economical in relation to the increased value of the landed products.

If it was possible to use much bigger nets the expenses for such factory trawlers might be justified. On an average, however, the individual hauls between Iceland and Greenland are not more than 40 to 60 cwt. (=baskets), or 30 to 40 kits or 2 to 2½ ton. The larger hauls in Newfoundland waters cannot as yet be considered normal.

Therefore, as long as bigger trawl nets cannot be used in order to get bigger catches, it appears more reasonable to increase the catching capacity by using a number of pure catchers in co-operation with a "Pure Factory Vessel". The [illegible]at that it is impossible to transfer the catch from the catcher trawler to the factory ship in severe weather conditions is today no more valid.

Fig. 793 shows a pure catcher trawler, given to stimulate discussion on this subject. The boat is much smaller and cheaper than the conventional trawler—in this case the new small type is of about 120 ft. (36.6 m.) length, speed is of minor importance and the necessary traction power for trawling can be obtained with comparatively small engine power when using a propeller nozzle.

The 120 ft. trawler is the smallest to be provided with a ramp for Atlantic conditions, as far as is known.

It must be conceded, however, that the limit for fishing will be reached at about Beaufort 8 or 9, but the average catch decreases of the individual boat will be more than counterbalanced by the possibility of using a greater number of catcher trawlers. The capital cost and running expenses for them are small compared with the value of the total catch, while the pure factory vessel offers wide possibilities for a most economical way to process the accumulated catches at sea.

The main problem is how to finance such combined fleet operation and to establish the necessary sales organization. The technical problems now can be considered as completely solved. It seems the matter is now ripe for serious consideration by an enterprising personality or firm.

If we wish to secure the further economical employment of our present vessels it appears certain that in 1965 this question will not arise and that a part of our fishing fleet will be working as a combined operation.

Experience with *Fairtry*

MR. L. M. HARPER GOW (U.K.): Swiecicki's paper touched on the question of freezing fillets. His firm had earlier filleted about 30 per cent. of the catch, whilst now between 75 and 95 per cent. This had contributed to an improvement in the economy of the trips. He felt that considerable thought should be given to filleting the whole catch of all round-fish in the northern waters, as machinery is available to do this. Although in the early days it was costly and difficult to maintain, there has been a remarkable improvement in that direction. On the three vessels which they should have in operation by the end of 1959, they would have four or five filleting machines on each vessel, aiming to fillet all the main varieties of round-fish caught in the northern waters including the red-fish.

Hatches and winches

MR. H. KUMMERMAN (France): Whereas almost revolutionary methods are being introduced together with improved instruments for detecting and determining the density of the shoals of fish, etc.; operational methods, especially for handling nets. have changed very little. He felt that fisheries could benefit from the very great experience which was acquired in the field of hatches, hoisting gear, etc., in the large ships, and from the manufacture of satisfactory winches.

He referred to the trawler model, fig. 114, incorporating ideas from England and France. He invited everyone—naval architects, shipbuilding and outfitting yards—to give suggestions for further improvement because he did not claim this to be a rigid or sole solution, but rather an adaptation of known and understood methods to future requirements.

It was said that it is difficult to find experienced crews. At least a partial solution can be found to this problem. All the essential elements of a fishing boat should be concentrated in a small space, not merely with a view to increasing the efficiency of the boat and reducing the final cost, but above all to reduce the hardships of the men operating. Because, where 20 men are now working under difficult conditions these men, except for 4 or 5 of them, will be able to work inside on entirely mechanical operations, directed by remote control from the deck.

As for price, there is absolutely no reason for it to be higher than that of the conventional arrangement of stern fishing trawlers used; it was also learnt from the discussion, that this price was not more important than the cost of the arrangement of side trawlers.

The fishing boat of 1975 will be discussed. He did not know whether at that date, all that has been seen here will not have been overtaken, but if we want to rationalize, we must start from now replacing some old or recent traditions, some of them often being obstacles to possible progress.

Without being more definitive than Harper-Gow, owner of the *Fairtry* "family", he hoped before 1965 to be in a position to show a group of ships using whole or part of the ideas included in the model presented.

COMMANDER M. B. F. RANKEN (U.K.): Sato implied in his paper that the Japanese froze whale meat in the same way as fish, in plate freezers. In British whale factory ships, the meat was frozen in moulds in brine tanks producing blocks about 4 in. (102 mm.) thick. This was a good method as whale meat forms into moulds very easily due to its jelly-like consistency. Similar results had been achieved in the U.K. and in Norway with fish both in tanks and in vertical plate freezers, and the latter would appear to offer an attractive alternative to the horizontal units described in the paper. The arrangement of the hydraulic rams on either side of the plate freezers instead of on top was a neat way of saving valuable head room in the ship.

The temperatures used at present in Japan for salmon and trout appeared much too high; they seemed even too high for whale meat. In British experience, temperatures as low as −20°F (−29°C) were essential to obtain results comparable with fresh fish, and temperatures below −5°F (−21°C) were currently used for whale meat.

Birkhoff had remarked that the transferring of the catch from catchers to carriers in heavy weather was largely solved. Perhaps he would care to elaborate on the method he would recommend as transferring anything by conventional means was by no mean an easy matter.

In answer to Slavin, a single-stage refrigerant 12 plant was fitted in *Fairtry I* and a two-stage refrigerant 12 plant in *Fairtry II*. Brine-cooling was used in both cases, both for the holds and for the freezing tunnels and plate freezers. Brine was also used in the majority of British refrigerated ships and provided a very flexible system. No difficulty was experienced with corrosion provided the brine was kept reasonably clean and slightly alkaline. He agreed with Slavin that freezing at sea was seldom an economic proposition in a ship which had not been specifically designed for it.

Transferring the catch

MR. C. BIRKHOFF (Germany), in answer to Ranken, gave some supplementary remarks regarding the method of transferring the catch from catcher-trawlers to carriers or factory vessels in heavy weather.

The trawl has an exchangeable rear part (codend plus lengthener), fig. 794. The opposite circumferential meshes, where the main net and the codend meet, carry strong rings through which alternately a rope is reeled. No more than three minutes are required for getting a reliable connection, and only a few seconds are needed to detach the codend after the forward main part of the net has been hauled.

Before removing the connection rope, the rear part containing the catch is bound tight, and attached to a barrel or ball-shaped rubber balloon filled with air with a displacement of 18 cu. ft. (0.5 cu. m.) and carrying a radar-reflector. Experience has shown that this displacement is sufficient to keep the codend with the catch afloat also in most unfavourable cases. This balloon is then connected to another of the same size, carrying a small radio transmitter and a storm lamp, by a strong rope about 66 ft. (20 m.) long, and the whole combination is dropped into the sea. The drift of the wind keeps the two balloons apart so that, even in rough weather, it is not difficult to fetch the connecting line from the transport vessel. Both balloons are coated with fluorescent paint. On board they are easy to handle and when deflated require only little storage space.

After the codends are emptied on board the transport—or factory vessel—they are bundled up and, together with the balloons, thrown back into the sea for return to the catcher boats at a pre-arranged position.

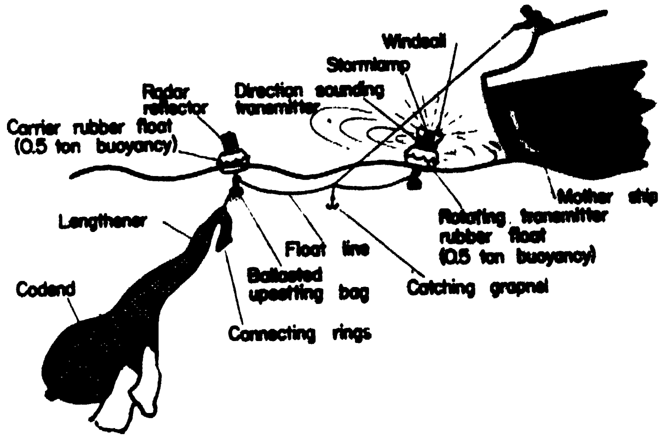

Fig. 794. Arrangement for loose codends to be used by catcher trawlers

This method has been tried out with satisfactory results on the German fisheries research vessel *Anton Dohrn* and in commercial practice near Newfoundland by trawlers of the "Gemeinwirtschaftliche Hochseefischerei Gesellschaft", Bremerhaven. The catch after drifting for six hours was still in a good condition for processing, though in appearance somewhat below normal standard of wet fish for market. Whenever the method is used for complementing the hold capacity of another homebound trawler—which was also tried—much less time is required for the transfer of the catch, which means no quality deterioration.

Due to its "pelagian" principle, the transfer method has the advantages of saving much time between the hauls and of being applicable in all weather conditions which are still suitable for fishing operations.

MR. J. W. SLAVIN (U.S.A.): He wondered in connection with Sato's paper whether freon 12 or freon 22 had been considered instead of ammonia, in order to eliminate some of the possible safety hazards that are associated with the use of ammonia. Does not brine circulation decrease the life of the pipe coils? He mentioned that they have found an ethanol solution quite satisfactory for this purpose.

MR. W. A. MACCALLUM (Canada): He raised two questions relating to Sato's paper:

- How were the thermal conductivity values in table 190 determined?
- What method was used to lower and raise the boats; from what height did they have to be lowered and raised, and in what weather conditions could they be operated?

MR. G. S. MILNE (U.K.): The refrigerant used on *Fairtry* was freon 12, and brine-cooling was employed throughout. He felt that factory ships in the North Atlantic fisheries will increase in numbers but that there will be plenty of room for iced-fish trawlers. The main advantage of the factory ship seemed to be her ability to fish far distant grounds for a longer period than the conventional trawler.

PROF. A. TAKAGI (Japan): Japanese salmon and trout factory ships are from 5,000 to 7,000 GT and they operate in the Pacific. There might be some differences between the Japanese and European factory ships.

The Japanese salmon and trout factory ships fulfil two main functions: canning and freezing. Salmon is a fairly flat fish and as such is suitable for plate freezing, by which the fish is pressed on both sides. This system lends itself to mass production of frozen salmon. The Japanese canning methods are just the same as those used in European countries.

MR. S. TAKAHASHI (Japan): The plate freezer was cooled with circulating brine. The fish were pressed between the plates, and after freezing the plates were separated by an oil pressure mechanism without any difficulty.

MR. W. ORSZULOK (Poland): A processing trawler of the B.15 type could produce a maximum of 50 tons of fillets per day. The processing unit was made up of three lines: the first line to take fish of a length of 19.7 to 67 in. (50 to 170 cm.), the second line to take fish from 12 to 22 in. (30 to 55 cm.) in length—this unit having a filleting and skinning machine—and the third line was for white fish of from 12 to 24 in. (30 to 60 cm.) in length. A canning factory, producing 1,500 cans in 8 hr., was also included. Further, the trawler could produce 127 Imp. gal. (580 l.) of liver oil from each of two boilers and 25 tons of fish meal per day. Ammonia was used for freezing.

MR. G. C. EDDIE (U.K.): Freon was used for freezing in their ships. It was found better to use brine than a calcium chloride solution for freezing. He agreed with Slavin on cost. There should be no difficulty with refreezing the fish. The capacity of the plant should be large enough to buffer-store the fish for three days before freezing it, in order to be able to cope with a daily rate of four or five times the average.

Conditions vary

MR. P. B. ZIENER (Norway): In any discussion of performance of fishing boats of the world, it should be kept in mind that the factors influencing productivity are usually not of the same nature in well-developed and under-developed fisheries.

In the vast areas where primitive craft are now being replaced by mechanized boats, special factors governing the development rise to dominant power. They may overthrow whatever good engineering the naval architect can contribute and make an excellently designed boat a poor performer, even a failure, judged by catch figures.

The abnormality is due to the fact that mechanized boats usually are introduced in such areas before the technical facilities for their proper operation are fully developed.

The troubles are many, from lack of landing facilities to tropical lethargy, unsuitable fuel oils, Custom's regulations that hamper departure, no reserve capacity of workshops during peak seasons, or laying up for several months as in the monsoon areas. But every technician who has worked in these developing countries knows that badly organized supply facilities and the lack of trained personnel are the most obstinate bottle-necks to sustained performance of otherwise good and suitable fishing boats.

Against these overwhelming difficulties the boat designer has no chance to influence the productivity to any discernible degree.

There are, however, encouraging perspectives. Fisheries leaders are becoming increasingly aware that boat designs for developing countries must compromise with special factors characteristic for such areas.

If fishing boat naval architects would part from traditional approach and take up, hand in hand with the fisheries leaders, the task of considering the operational facilities and promote technical training, an important rise in the productivity of fishing boats in such areas would result.

MR. S. OMEALLAIN (Ireland): In his opinion vessels up to 70 ft. (21.3 m.) long have a bigger future than is generally realized. Returns on capital invested are more advantageous than with large craft.

Russian stern trawlers

MR. A. F. JOUDINSTEV (U.S.S.R.): The fishing fleet of the U.S.S.R. consists of many types of ships designed for different methods of fishing. Russian fishing boats are normally built many to one design, which makes personnel training easier, and building and reparing cheaper and faster. There are, as well as trawlers, many other types such as herring factories, refrigerating ships, seiners, crab-canning factory ships and whale catchers.

Besides the old type of trawlers, there are two groups of stern chute factory trawlers—the *Poushkin* and the *Mayakowsky* types, which give very good results. When designing this type, the intention was to create a new, profitable and up-to-date fishing ship. In addition to other researches, many model investigations in still water and in waves were conducted by the Kryloff Shipbuilding Research Institute.

The stern chute factory ships have been in service since 1955 and the experience obtained during this period has shown that, in comparison with the old type, they have these advantages:

- They can operate in rather rough weather, that is in winds of Beaufort 6 to 8, and big catches can be lifted through the chute
- Stern trawling improves the catching efficiency of the trawl owing to the better towing conditions
- Production lines—both catching and processing—can be arranged in them with maximum mechanization
- All operations, such as gutting, producing fish-meal and frozen fillets, extracting liver oil, can be done on the ship itself
- The main manual work is eased to a great extent because the crew are under shelter and do not have to work on the open deck
- They are provided with the most modern navigation and radio equipment, as well as special devices for fish searching, and the crew's comfort has received attention

These ships have given much better results in comparison with side trawlers, in particular in the following respects:

- The productivity per operating day is 63 per cent. higher
- The catching per crew unit is 16.5 per cent. higher
- Production costs are 18 per cent. lower

It will be remembered that the side trawling method has been steadily improving for many decades and today is well developed; whereas stern trawling is rather new and there is no doubt that it will be continuously improved. For example, the system of trawling now adopted on the *Mayakowsky* type is more convenient than on the *Poushkin* type. Again, the German trawler *Sagitta* uses a rather different system.

A new type of factory stern trawler has recently been designed in U.S.S.R. for construction within the country. The profile is shown in fig. 795.

Special stress has been placed on preserving catches by means of ice cooling and/or freezing. The taste and nutritive qualities of iced fish are much higher than that of frozen fish, yet the transport of iced fish to markets is limited by the safe storage time which unfortunately is not very long. Therefore, delivery of the iced fish from distant fishing grounds to the port and then its transport to the consumers, in the present state of preservation technology, are practically impossible. The only suitable method for long storage in such cases is by freezing at temperatures of 0° to −13°F (−18° to −25°C).

It is hoped that future scientific work on the prolongation of the preservation time of iced fresh fish may considerably improve transport possibilities and the quality of the delivered fish.

The exchange of opinions and the fruitful discussion of the very interesting papers presented will be useful for the further development of fishing boats. He expressed gratitude to Soublin, for the friendly remarks he had made on the fishing industry in the U.S.S.R.

Author in reply

Mr. G. C. Eddie (U.K.): He thanked the contributors to the discussion of his paper; their comments give valuable additional information and together with the remarks by Arcoulis, p. 249, they reinforce his views on the economics of preservation and speed. Doust's support of the plea for more work on rough water performance is timely. From the context Dilnot presumably means that a constant-power characteristic is desirable rather than constant-torque.

Answering Costa, he said that British experience of maintenance of DC propulsion equipment for ships is generally held to have been good. Completely satisfactory trawler propulsion systems based on AC generators await the commercial development of rectifiers which can operate at high temperatures and high efficiencies. Engineers with a knowledge of electrical machinery are not required. In fact they can do a lot of harm. The British trawlers, like British diesel-electric ferries and dredgers, are manned by the type of engineer normal to that service. In the case of trawlers this means that the engineers have had no formal training whatsoever. The owner of *Saint Dominic* has paid a considerable tribute to these men and to the diesel-electric machinery in *World Fishing* for February 1959.

Simpson's and Slavin's design by its use of high-speed engines demonstrates the idea put forward in his paper that when the method of preservation is powerful enough, engines of the smallest possible physical size have an economic advantage. The use of geared engines is interesting; for Arctic fishing it would be necessary to have a change-speed box as described by Chardome if it was desired to trawl on one engine in all weathers. He agreed that only in a new vessel can the optimum balance between speed and preservation be achieved and would repeat a remark he made at the Paris Congress: there is no one solution to the problems of freezing at sea—they will have to be solved afresh for every fishery.

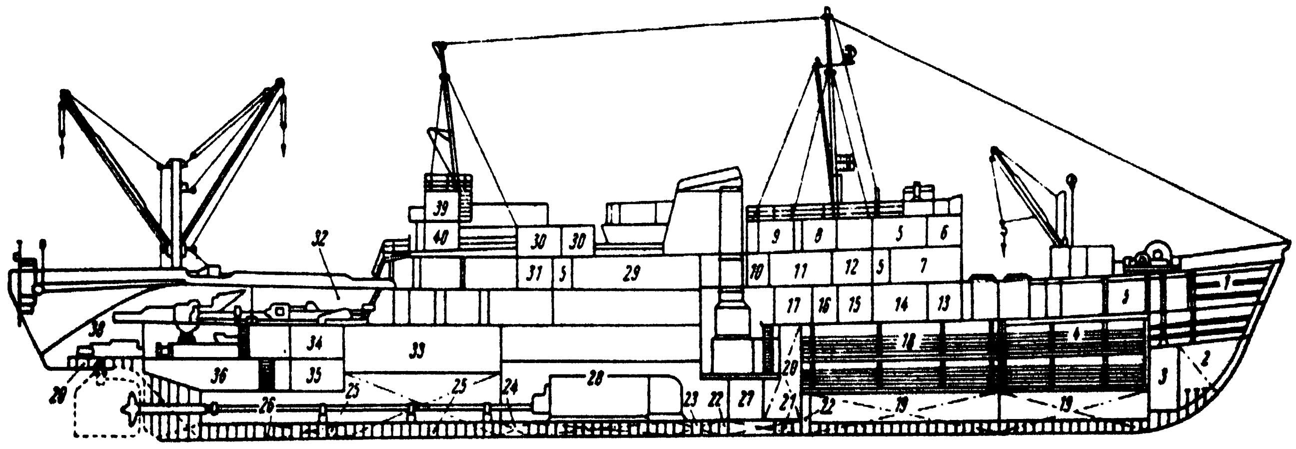

Fig. 795. Profile of the new factory ship type designed for construction in U.S.S.R. The hauling of the gear will be different from the Pushkin factory ships so that up to 10-ton catches can be hauled without damage to the fish. The main dimensions are: LOA, 279 ft. (85 m.); LBP, 246 ft. (75 m.); B, 46 ft. (14 m.); D to shelterdeck, 33 ft. (10 m.); T, 19.6 ft. (5.98 m.); Δ, 3,712 ton; V, 12 knots

Courtesy Schiffbautechnik

1. Rope store
2. Foredeck
3. Chains
4. Refrigerated hold No. 1
5. Passageway
6. Wheelhouse
7. Mess
8. Emergency generator
9. Washroom
10. Scullery
11. Galley
12. Pantry
13. Provision store
14. Refrigerated provision store
15. Entrance room
16. Freon refrigeration engine room
17. Fish meal hold
18. Refrigerated hold No. 2
19. Diesel oil
20. Fresh water
21. Speed log
22. Coffer dam
23. Settling tank
24. Used lubricating oil
25. Heavy fuel oil
26. Collecting tank
27. Gyro room
28. Engine room
29. Engine casing
30. Hospital
31. Trawl winch engine
32. Fish processing room
33. Refrigerated hold
34. Hold for cans
35. Fish meal storage
36. Processing of waste
37. Shaft tunnel (over 25 and 26)
38. Rudder engine room
39. Aft bridge
40. Office

THE FISHING BOAT OF 1975

Several contributors brought a forward look to bear on this important subject in the closing stages of the Congress

MR. M. JUL (Denmark): He had followed quite closely the discussion on white-fish factory ships. It had not always been easy for him as a food technologist to understand the full implications of the problem discussed by fishermen and naval architects because he lacked sufficient experience in these fields. On the other hand, he had come to the conclusion that more attention might well be paid to the nature, appearance, and quality of the product as it reaches the ultimate consumer. Here, the experience of the food technologists may be of some interest. After all, they continuously run large scale consumer acceptance tests and try to predict what will be the market situation 15 years from today.

He thought that, especially in some of the discussions on the combined frozen and iced-fish ships, more attention should be paid to this aspect. Large sectors of populations have long put up with white-fish which has been on ice for two weeks or processed after 10 days on ice. In all advance planning he would start with the assumption that such products will not be acceptable much longer. In first class restaurants in central Europe and in the U.K. fish is served which would have been condemned if put on sale in Denmark. Many people are used to such products and think nothing of it. Yet, once they get used to real fresh fish, they will no longer eat the other product.

Fresh white-fish can be made available today in any corner of the world through the aid of freezing. The change has already taken place in the U.S.A. where iced fish is disappearing rapidly. In addition, but also very important, the frozen fillet in consumer size packages suits modern methods of marketing.

Some say that fish should pass through rigor mortis before freezing. This is incorrect and extensive experience points rather to the opposite. It is a matter of little importance, however. What matters is that fish should have been no more than three days on ice when it reaches the ultimate customer. This means that in all fishing where the trip from the grounds to the base takes more than two days, *all* fish must be transformed into some non-perishable form at sea. A lot of calculations can be made showing, for instance, that it is cheaper to ice the last part of the catch, etc. However, what the calculations do not show is that the result might be an obsolete product. It may be profitable, but only as long as people will buy this products, and that might not be for very much longer.

In all calculations of sea-kindliness, optimum processing capacity, etc., one should remember that there is a certain little lady with whom the final decision rests. She is the ordinary housewife. She is unfaithful (as to the products she buys); she is whimsical (as to her changes in food habits), but she is used to having the final word. She will have it in this case too!

COMMANDER M. B. F. RANKEN (U.K.): So far the emphasis has been on the detailed improvement of current designs with only a hurried and fleeting glance at the more distant future. The object is to try and focus attention on the year 1975 and later, and to provoke discussion on what we must do to meet the world's needs in the latter quarter of the century.

He placed freezing at sea firmly in the forefront of his argument as he is convinced that whatever we may think of frozen fish today as a result of recent past experience, it is the only way in which most countries' demands can be met for an edible cheap food such as the fresh fish of all kinds which used to be landed in England up to 1914, when nearly the whole of her catch was landed within a few hours of catching.

Much has been said for and against factory ships and mother ships, freezer trawlers, part-freezer trawlers, and the like but, whether we like it or not, by 1975 Russia is expected to have well over one hundred fish factory ships, in some cases as large as 4,000 tons, as well as mother ships, many smaller freezing vessels and conventional iced-fish trawlers. Their catch by then is expected to total some 4,500,000 tons against 2,500,000 tons in 1957 and most of this will presumably be landed through Murmansk. Poland is currently expanding her fleet and will probably have at least 45 factory trawlers by 1975 as well as freezer and part-freezer trawlers of more modest size, conventional distant water trawlers, salting, vessels and so on; she aims to quadruple her production to 500,000 tons by 1975.

Similar expansion of production is not so apparent in West European countries but in order to maintain even current production it is becoming essential for them to go further and further for their fish. Thus the U.K. catch in 1956 was 10 per cent. below 1938 but in the same period the distant water catch increased by more than 12 per cent. to some 442,000 tons—just over 47 per cent. of the total 1956 catch. The proportion of distant water fish also increased by 9.4 per cent. in the same period. A distant water trawler in 1956 averaged 2,400 miles for her round trip and spent 20 days at sea of which only an average of nine were spent fishing. This distance meant that most fish was caught no further away than Bear Island and a large part came from Iceland, the Lofoten Islands and other nearer grounds. To return from the Grand Banks or West Greenland at 14 knots takes almost 7½ days which means that fishing must be restricted to about three days if the fish is not to be stale when landed.

All countries want more fish and it seems inevitable that the present so-called distant water grounds will by the 1970's become almost as over-fished as the North Sea is today. If supplies are to be maintained and unless similar extinction of the fish is to occur on these grounds, it is inevitable that fishing vessels will be forced to go much farther for the fish. Iced wet fish will therefore become less and less predominant and frozen fish the only palatable alternative. This has already occurred to a large extent in the Greek market, as all their ships being forced to bring the fish home as far as 2,500 miles from the nearest North African grounds and much further from any of the more distant sub-tropical or Arctic grounds. Similar trends are apparent in Italy, Portugal and other countries.

Many new varieties of fish will have to be introduced to the housewife and new machines will be needed to process them. These varieties will be caught on grounds which many of us have never considered before and it is not looking too far ahead to suggest that we may even have to go to grounds in the Southern Hemisphere and Antarctic where there is still an abundance to be caught; Russia and Japan are already operating off South Africa and at least one European country is considering bringing home frozen fish from the South Atlantic. Many other new grounds will be found but few of them will be accessible unless freezing or some other preserving process can be carried out at sea so that the fish can be kept long enough to bring it home in a palatable condition. A parallel may be drawn with the British meat industry: for more than 50 years this has had to rely on refrigeration for the majority of its supplies which come from Australia, New Zealand and South America.

Another parallel may be drawn with the whaling industry where freezing is recognized as the only method of preservation which offers any possibility of operating economically. One hopes however that it will be many years yet before the catching power of fishing vessels necessitates the adoption of similar measures of international conservation to avoid the extinction of supplies.

It is interesting to mention that the first full-scale fish factory trawler, the *Fairtry I* was built by Messrs. Chr. Salvesen and Company, one of the great British whaling companies, and it is perhaps symbolic that the second fish factory trawler *Fairtry II* which sailed on her maiden voyage on 2nd April, 1959 is also owned by Salvesens. Mr. Ranken had the good fortune to visit this ship and would like to say that her design seemed to him to be well ahead of the *Fairtry I* or any other factory or stern trawler either in service or building of which he has seen the details.

Fishing vessels of 1975 and after. The trend therefore seems clear and the following types of vessel appear likely to be in service after 1975 as far as one can see ahead at present, and assuming that there is no major break-through in the applications of irradiation, antibiotics or other similar methods of preservation:

(a) **Fish factory ships** probably mostly of some 2,500 to 3,000 gross tons, but possibly larger if crews can be found to stay at sea longer than the three to four months they do at present.

(b) **Mother ships with catchers and carriers.** These will probably be similar to whale factory ships with equivalent facilities for processing the fish and replenishing and maintaining the associated catchers.

(c) **Freezer trawlers** up to 220 ft. (67 m.) LBP or less to work on the nearer grounds where the distances do not make the operation of such smaller vessels uneconomic.

(d) **Part-freezer trawlers** up to 205 ft. (62.5 m.) LBP or less for operation on still nearer grounds, the proportion of the catch frozen being larger the greater the length of the vessel. These trawlers may be a type peculiar to the British industry where the present docking facilities at the main fishing ports cannot handle vessels longer than 190 ft. (58 m.) LBP. If these facilities are improved or superseded by other ports, as seems essential and inevitable, the part-freezer trawler will presumably become obsolete. In the meantime it could form a stop-gap to give the necessary breathing space during which these long overdue improvements in shore facilities can be made. It would also give the necessary impetus to the development of suitable marketing facilities for sea-frozen fish.

(e) **Near- and middle-water trawlers and other vessels** of conventional design but in reduced numbers. Iced fish will still have its place in the future but it will have to be better than frozen fish to maintain it. This implies that great improvements must be made in its handling both ashore and afloat.

(a) and (b) above must be designed for operation in tropical as well as in Arctic waters. The former is a much more difficult technical problem so far as the processing machinery is concerned particularly on account of the sea temperatures and high ambient humidities involved, but Gianesi and others emphasized that they have already been largely solved, though obviously great improvements can still be made.

Whether future vessels should be stern or side trawlers is open to argument but it should be pointed out that the stern trawler coupled with diesel-electric or some other propulsion system which leaves the greater part of the midship's section clear of machinery, enables a very orderly layout of processing and freezing machinery and frozen fish holds to be achieved. Diesel-electric propulsion offers other advantages as these ships have an enormous power demand, particularly when operating in the tropics (e.g. over 550 installed BHP in one recent projected design), and very flexible operation is made possible. Also the engines can be kept very compact if multiple high-speed units are adopted; the reliability of these will be of great importance but it should be remembered that a breakdown of one unit does not affect the ship's operation as would that of a single direct-drive unit.

A greater degree of automatic control and handling will undoubtedly be adopted in the future, both on deck and in the factory and holds, and this will allow a reduction in the crew perhaps below one half that needed at present.

Whether fish-meal plants at sea are worthwhile or not is a debatable point. The big factory ships today have extensive installations, and plants are also fitted in some smaller ships. However there may be little point in fitting these plants in small freezer ships where every available space can be utilized for frozen fish. Certainly the proportions of frozen fish and fish-meal should always be in favour of the former.

Another feature which is susceptible to improvement is the trawl winch, by far the largest auxiliary in a modern trawler. The possibility of installing in stern trawlers a winch similar to that currently being fitted in some of the large ice breakers under construction in Finland bears investigation. This plays the tow like a skilful angler plays a salmon. With some modification it seems to offer possibilities for recovering the gear and the codend in stern trawlers more economically and more efficiently.

Tremendous possibilities exist for improving fishing methods and gear and it is encouraging that more scientific effort is now being applied to them.

Whatever the preference for fresh fish, it seems inevitable that we shall come to rely more and more on frozen fish, and even today in England a great deal of the so-called "fresh" fish offered in fishmongers' shops far from the fishing ports is not as good as frozen fish whatever the fish merchant may think at the auction.

Fish today in the U.K. and probably other countries as well, is too expensive for many people; much of the fresh fish is not palatable and is often in a form which the modern housewife simply cannot be bothered to prepare and cook. Frozen fish may be more expensive than fresh today in many countries, but it is potentially cheaper if the effects of evening-out supplies, no, wastage and consistently high quality are allowed to make their mark.

As Eddie has said, it is the duty of naval architects and engineers as well as of owners, fish merchants and distributors, to keep firmly in mind the aim of all their work which is to produce edible fish which reaches the consumer in a condition as near as possible to that of freshly caught fish. This implies hygiene, careful handling and above all efficient preservation at all stages from catching to the housewife's kitchen.

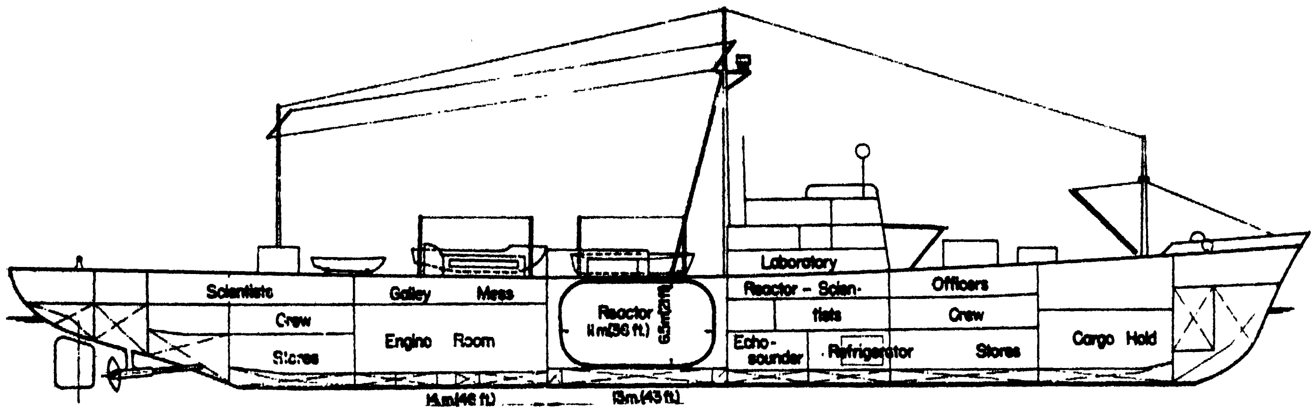

Fig. 796. Oceanographic research vessel with atomic propulsion

Value of new power sources

PROF. A. TAKAGI (Japan): The introduction of equipment by means of which efficient power can be obtained from fuel with high thermal energy sometimes brings about a revolutionary development. This tendency can be noticed in the history of fishing boats. When steam trawlers adopted reciprocating engines, using coal as fuel, distant deep-sea fishing became possible, which extended the fishing area, and made fishing safer. Again, due to developments in the diesel engine, small fishing boats have been powered, extending their operations.

Japan has been no exception to this rule. The number of powered fishing boats now exceeds 157,000. However, the size of the boats and the relationships between fish holds and oil tanks in the distant deep-sea fishing boats seem to have reached their limit, and this consideration necessitates a new fuel, with new proportions.

Through experience of the first atomic bombs just before the end of World War II, and the experience of the *Fukuryu Maru No. 5* (transl. Lucky Dragon), a tuna longliner which got the atomic ashes in the Pacific in 1954, Japan has become one of the nations most interested in the effects of atomic energy. The present trend in the application of atomic energy for marine purposes is to try out the atomic reactors in special ships, particularly in those of a bigger type, since the generating equipment needs space and the shielding is heavy, both being very costly items. However, Professor Takagi felt that one should not be confined to the utilization of atomic energy for these special purposes. Some nations may profit in developing bigger reactors, others in smaller atomic equipment. That is what is intended in Japan. The First Atomic Power Industrial Group (FAPIG) has, together with the Kawasaki Heavy Industry Co. Ltd., conducted research on a trial design of the smallest possible reactor for use in small vessels.

- This plan has two aims; firstly to study and test the atomic-propelled ship and, secondly, to conduct oceanographic research
- The vessel's displacement will be between 3,000 and 4,000 tons, this being considered the minimum size for observations in extremely bad weather, although it is planned to keep the size as small as possible
- The U.S. pressurized water reactor (PWR) type will be used, since it has already given satisfactory results in vessels, and the engine output will be 35 mW, 8,000 SHP. Twin screws will be fitted, as these give better manoeuvrability
- The preliminary plan is shown in fig. 796 and the main specifications are:

Length overall, LOA .	ft. (m.)	310.00 (94.50)
Length waterline, L .	,, ,,	295.00 (90.00)
Length between perpendiculars LBP	,, ,,	285.36 (87.00)
Breadth moulded, B .	,, ,,	46.57 (14.20)
Depth moulded, D .	,, ,,	26.89 (8.20)
Draught, full load T_1 .	,, ,,	16.66 (5.08)
Full load displacement	. ton	3,460
Atomic reactor: Weight	. ton	1,100
Output	. mW	35
Main engine: Type and output	SHP	2 turbine sets, 8,000
Revolutions per min.		200
Speed	knots	19
Duration	months	4
Total number on board, including scientists, officers and crew .		100

The atomic reactor and other equipment of radio activity are sealed in a container. The reactor core is designed for 29 per cent. dioxidized uranium. The weight will be 2,890 lb. (1,320 kg.), of which 75.25 lb. (33.61 kg.) is U-235.

The total weight of the primary system, including the reactor and other equipment which might produce radio activity, is 1,100 tons, including 795 tons of radiation shielding.

For emergency use, a propulsive motor of 120 h.p. will be installed, giving sufficient power to reach port if trouble occurs in the atomic plant. There will be a crew of 50 sailors and 50 research workers. When the boat is used both for study of the reactor and for observations, there will be 30 researchers for the reactor study and 20 for oceanographic observations.

There is another project planned by the Uraga Dockyard Co. Ltd., also as a preliminary design, fig. 797:

- The aim of this design is the training of people for atomic experiments

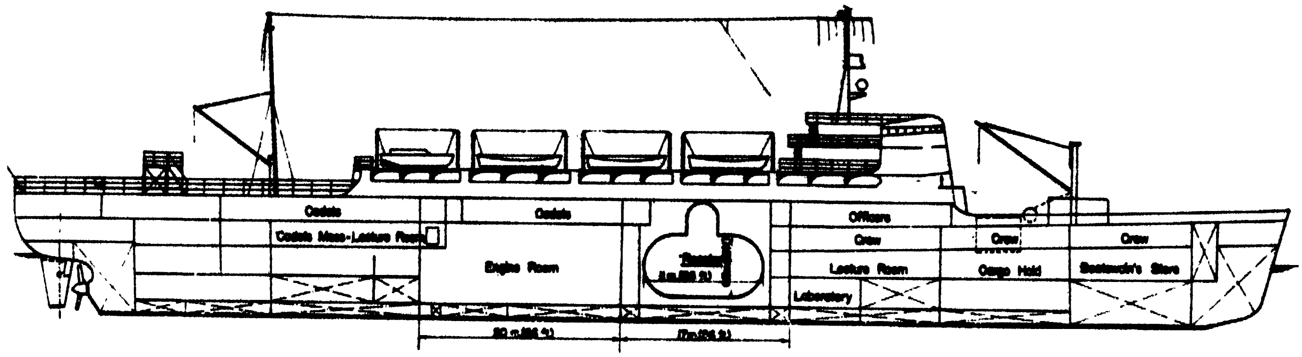

Fig. 797. Fisheries training and research vessel

- The main specifications are:

Length between perpendiculars, LBP	ft. (m.)	394.60 (120.00)
Breadth, moulded, B	„ „	55.76 (17.00)
Depth, moulded, D	„ „	29.52 (9.00)
Draught, full loaded, T_l	„ „	19.74 (6.02)
Gross tonnage, GT	tons	5,000
Atomic reactor output	mW	40
Main engine: Type and output	SHP	Turbine, 10,000
Revolutions per minute		130
Speed	knots	20
Total number on board, including scientists, officers and crew		262

The above are preliminary design data, planned to be as economical as possible. However, decision of this acceptance lies with the Japanese Government as these are very expensive projects, in spite of the modest small scale.

It was Professor Takagi's hope that a large high-speed ship driven by a reactor will be put into general use around 1965 to 1970. Atomic energy might by then not have to be used merely for producing steam but might be directly utilized as power. This transition can be compared with the change which took place when steam engines were replaced by diesel engines. It is quite possible that 1975 will mark the revolution.

If the new plant is compact and light, it may be used in fishing boats. One may imagine even sub-surface fishing vessels with enormous power. The boat may also be able to work in midwater when the sea is rough for surface work, and trawl all the layers of the sea. It seems that one must anticipate such revolutionary changes and prepare for them step by step.

Need for research and training

Mr. F. Minot (U.S.A.): He had been very closely associated with the development and design of research ships over the past 30 years and he is in charge of such work at the Woods Hole Oceanographic Institution (WHOI). Obviously, therefore, he was much interested in Takagi's description of his concept of a combined survey, training and oceanographic research ship which he hoped that the Japanese government will build in the not too distant future.

This is indeed an imaginative and forward looking concept of an all-purpose, long range research facility, whether it be powered by a nuclear reactor or by conventional engines. He should like to congratulate Takagi most sincerely for sharing his imaginative thinking.

Mr. Minot would like to observe that they too, in the U.S.A., appreciate the crying need for providing training facilities at sea for oceanography. Nothing will do more, perhaps, to encourage young scientists to specialize in some of the many aspects of oceanography. In turn, oceanography needs many more skilled and dedicated oceanographers, and welcomes every effort to provide them with opportunity, facilities and practical training at sea.

It is appropriate here to emphasize the vital importance of basic science to the future development of marine resources.

If we are to exploit the fisheries to the optimum degree, if we are to create swifter, safer and more efficient transportation on the sea's surface and beneath it, if we are to utilize the mineral and chemical contents of sea water, if we are to take advantage of the weather rather than talk about it, we must come to know a great deal more about the physical, chemical, biological and geological aspects of the sea than we do today. Oceanography is a relatively newly recognized branch of the earth sciences, yet it is the one which will unlock the secrets of the ocean in which all of us here are interested. We must give our strongest support to oceanographic efforts whenever and wherever it is possible to do so, and whether such efforts be of an international, national or private nature.

Returning to Takagi's concept, he was sure Takagi is aware that it is much more difficult to programme a large multi-purpose oceanographic expedition than it is to organize and manage a number of single-purpose cruises. A research ship such as Takagi visualizes will require expert scientific and operational management.

He hoped that Takagi will be able to tell the 3rd World Fishing Boat Congress that his nuclear powered research ship is afloat and busily employed on some of the basic problems of oceanography which only a large and versatile vessel can successfully undertake.

Mr. J-O. Traung (FAO): Two FAO Boat Congresses and one Gear Congress have aroused much greater interest in the industry than fisheries meetings usually do. The papers and discussions published in the two Boat books and the Gear book have painted a many-contoured picture of the world's fishing industry, but this picture is rough and still unbalanced.

The reasons for this are many. One is that people are both progressive and indifferent. The progressive people have participated in these Congresses, therefore the resulting picture may be too bright and optimistic.

Details of small fishing boats of under 70-ft. in length are

Fig. 798. Electronics have played a great part in speeding up fishing operations during the past fifteen years. Radar has made navigation in fog possible. However the frequency of collisions, possibly due to carelessness, seems to have increased. Ships in 1975 might perhaps be equipped with electronic instruments which will also prevent collisions and make navigation really safe

scanty. Such boats are mostly owned by remote fishing populations in many of the developed countries. They are still built by the rule of thumb method by almost illiterate builders who have seldom studied a boat from another area and who can scarcely read blueprints, and they are owned by fishermen who are not likely to be interested in comparing their own boats with those from other areas.

These small boats have one feature in common: they are all regarded by their builders and owners as "the best in the world". This complacency is one very strong reason why the design and construction of such boats have stagnated. In agriculture, farmers are informed of technical developments by their organizations and the extension services of the Government, but there is no such advice and help for the fisherman. One cause for this state of affairs is the low economic level of a large part of the industry. There is no money available for establishing an "extension service" to remote fishermen. The result of such lack of communication is reflected in many ways. For instance, it has been impossible to attract owners and builders from the remote areas to international gatherings such as these Congresses.

If, therefore, the FAO Congresses have painted a somewhat too bright and optimistic picture of the technical level and interest of the industry in further development, at least they have produced a picture and have made it possible to see the progressive aspects of the industry. That being so, perhaps we might peer into the future to see if we can get a glimpse of the fishing boat of 1975.

To make such an extrapolation, it might be helpful to assess the industry about fifteen years ago—say in 1945, just after, or in 1938, just before, the war. Table 192 gives some figures of the past, present and estimated future world population and the total fish catch for selected years.

TABLE 192

Past, present and estimated world population and fish catch

Year	*World population (millions)*	*Total fish catch (million ton)*	*Per capita (lb.)*	*Per capita (kg.)*
1938	2,194	20.31	20.4	9.3
1948	2,423	19.09	17.4	7.9
1957	2,795	29.96	23.6	10.7
1975	3,830*	60 ?	34.5 ?	15.7 ?
2000	6,280*	100 ?		

*UN estimate

The 1957 catch may be regarded as a representative figure for today although, of course, there is a wide gap between the good fisherman with modern equipment who catches up to 100 tons a year and the fisherman in one of the under-developed countries who catches half a ton a year.

In 1945 few in the fishing industry knew anything of, and still fewer used, echo-sounders, asdic, decca, mechanized purse seining, synthetic net fibres, welding, diesels, freezing equipment or technical journals. The largest trawlers in the U.K. were about 160-ft. long; today they are about 200-ft. Factory ships were not used. Few fishing boats in sub-tropical or tropical areas had an engine; today there are about 10,000 engines in use, and it is known that there are hundreds of thousands of small boats in need of mechanization. Echo-sounders are now in use in the boats of developed countries and asdic is coming, but few boats in sub-tropical or tropical areas possess fish-finding equipment.

It has been estimated that the sea could yield some 60,000,000 tons of fish per annum, and if this total is to be reached by 1975 the catch per capita must be increased by some 50 per cent., or to about 35 lb. (16 kg.) per capita. Despite so much technical development, partly war-inspired, during the past fifteen years, the catch per capita has risen only from 20 to 24 lb., or by 20 per cent. It is evident therefore that technical progress will have to be outstanding if the catch is to be increased by another 50 per cent. in the next fifteen years.

There are many technical developments which have been successfully applied on a laboratory or pilot scale, but which are not in common use by the industry. Here are a few:

- Echo-ranging (asdic)
- Fish attraction (light, electricity, vibration)
- Fish collection (pumps)
- Net design (using synthetic fibres and engineering principles)
- Underwater television (for record of gear behaviour and of fish entering the gear)
- Mechanized handling of trawl gear (by stern trawling or winding the gear directly on the winch)
- Extension of storage time (chilled seawater, anti-biotics and radiation)
- Transfer of crews and cargoes by airplane
- Fishing under ice (submarine)
- Artificial upwellings (by nuclear heating)
- New materials (plastic, aluminium, rubber)
- New power plants (gas turbines, nuclear, Wankel principle)

The fishing boat designer must keep such possibilities in mind, and he must also follow the development of his own profession, and in this he cannot avoid seeing how new boat types are being developed and how knowledge of theoretical naval architecture is being acquired at an accelerated pace.

The hydrofoil principle, for example, is no longer a doubtful proposition. It has been used in sea-going craft which now regularly transport a considerable number of passengers, and some of the designs now in use are definitely more seakindly than conventional designs. Such craft will perhaps be used in 1975 for carrying men to a fishing unit or in transporting expensive fish products. The Hovercraft, which has already crossed the English Channel both ways, has revealed possibilities, and such craft might one day be used as beach landing fishing boats, or, perhaps, to transfer catches from a commercial boat off the breakers straight to the coastal fish market.

Two-hulled craft, also called catamarans, have lately gained popularity in yachting circles because of their high speed and comparatively large deck area in relation to construction and maintenance cost. They have also been adapted commercially as oil drill platforms and fire floats, and work is now in progress to investigate whether this type of design could be used for a fisheries research vessel, which naturally needs a large deck space. As commercial fishing vessels also need a large deck space for handling fishing gear and accommodating fish processing machinery, there may be possible uses for this type of design in commercial fishing.

Aircraft have long been used in the fishing industry for spotting, although their importance has decreased with the development of echo-sounding and echo-ranging. But they might offer other possibilities in the future. For example, helicopters might be used to transfer crews and catches at sea from catching vessels to the mother ships. They might also be used for echo-location of fish. Then there is the possibility of using hydroplanes to carry light surrounding nets, so that when a fish school is discovered it can be immediately imprisoned and kept there until boats arrive to take care of the catch.

Submarines have passed under the Polar ice cap and if there is so much fish in these cold water regions as is normally believed, there is a case for submarine fishing. The U.S.S.R. has already put a submarine oceanographic research vessel into use, and other countries are planning similar vessels.

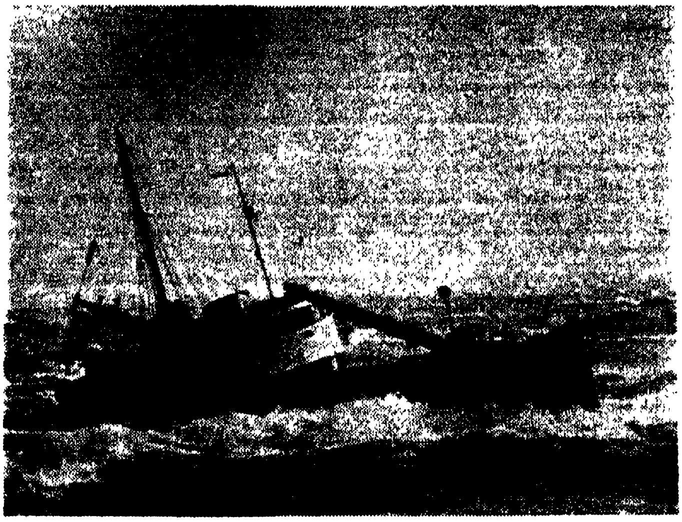

Fig. 799. Many people talk about the importance of making ships, and particularly fishing vessels, seakindlier, safer and more comfortable, so as to improve the conditions for fishing and living. Only during the last fifteen years has some real research been done to understand what is required to make a ship seakindly. There will certainly be much more development in this field during the next fifteen years, and very likely the 1975 fishing boat will be able to operate more comfortably in heavier weather than this drifter-trawler

Submarines could be very useful in studying the behaviour of pelagic fish, say in tropical waters. They could also be used in detecting fish under the ice caps, and for experimenting to find out whether there is a future for submarine fishing.

The success of the U.S. nuclear powered submarines has initiated research into the possibilities of using submarines for the transport of cargoes. It is felt that such cargo ships could be made much more hydrodynamically efficient than surface craft. They would also be more independent of weather and could, perhaps, be built of lighter scantlings. While it might take years before commercial cargo submarines are in operation, their development should be watched because they might be helpful in evolving the design of a submarine fishing vessel.

Other developments in general shipbuilding may influence the design of the fishing boat of 1975. Container traffic, for example, is being developed more and more, and one could easily visualize that large fishing boats might have their holds arranged for containers, so that the fish could be loaded directly into them for immediate transport to individual retailers, thus avoiding unnecessary handling and exposure to air in the fishing harbours.

Since ships have been built they have had to fight against the elements, but it is only recently that the study of their seakeeping qualities has begun. This is now gaining considerable attention, and this Congress has shown how seakeeping research is now being devoted to fishing vessels. In the next fifteen years there will undoubtedly be confirmation of some of today's hypotheses on good seakeeping qualities. There will also be much more information available on the subject of damping ship movements, such as rolling and pitching, and practical rules have recently been developed which will be used in the design of anti-rolling tanks for oceanographic research vessels. Such tanks might also have their importance for fishing vessels.

The discussion about the prismatic coefficient reveals how little we know about the practical design of seakindly ships, but it seems likely that such a discussion would be unthinkable in 1975.

Much is expected from the use of nuclear power for the propulsion of small ships. If small nuclear power plants are developed for aircraft, they could probably also be used in large fishing vessels. But it seems that the heavy shielding at present necessary for reactors and the increasing difficulty in disposing of waste might make the application of nuclear power to fishing boats too difficult to accomplish in the next fifteen years.

There is a tendency today to reduce the size of components without eliminating any of their potentialities. The use of transistors in place of tubes is a typical example, which has made possible modern electronic computors and very small radios. Perhaps the power developed by nuclear reactors could be harnessed and accumulated without taking up too much space, or weighing too much, and that such new type accumulators could be used for fishing craft. If radios can be made so much smaller through the use of transistors, why should we have to put up with heavy batteries?

The interest of European fishery technicians seems to be centred around trawling, as though they are fascinated by this fishing method. But when considering the many different methods of fishing described at the Congress one feels that, while trawling is a very active method, the boat towing the trawl along the bottom is very passive during fishing. If it should be possible to reduce the time for handling the catch on board, the large crew of a trawler would have very little to do between hauling and shooting the trawl, and thus one begins to wonder whether it would not be possible to use several trawl nets from the same ship at the one time.

Ringhaver (p. 615) has described the use of two trawls from shrimp trawlers. Birkhoff (p. 748) predicted special catcher trawlers by 1965. He has thus visualized the disadvantage of a very large and expensive trawler with inactive processing and fish storing facilities while the trawl is being dragged along the bottom.

Could one not imagine self-propelled trawl doors towing several trawls in various directions, automatically controlled, so that they would return with their catch at suitable time intervals? Such self-propelled trawl doors might sound rather fantastic, but if it is possible to direct satellites in the universe and to switch their radio apparatus on and off, it should not be too difficult to develop torpedo-type bodies to tow the trawl and bring it with its catch to the vessel.

The capacity of mother ships is limited by the number of catcher vessels that can be stored on board. But what about inflatable rubber catcher boats which could easily be stored and inflated when needed? Rubber rafts and small rubber working boats up to 30-ft. (9 m.) are already produced commercially, so there should not be much difficulty in manufacturing rubber boats of 50 to 60 ft. in length.

Kristjonsson (p. 133) has stressed the necessity of reducing the time for handling the catch. Chilling fish, either by ice or chilled seawater, in the tropics is more efficient than in cold climates because most of the fish spoiling bacteria in tropical and warm waters are of the *mesophilic* type which are inactivated by temperatures below about 50°F (+10°C). In warm waters, normal chilling temperatures of 31° to 39°F (—0.5° to +4°C) are sufficiently below the critical temperature to hamper bacterial activity. In cold waters, *psychrophilic* bacteria play the main part. They can be active in temperatures as low as about 28° to 19°F (—2° to —7°C), and the normal chilling temperatures will only retard the growth of the bacteria for a limited number of days.

Sea water chilling of fish has the advantage that it also decreases the need for labour in packing and unloading. However, it must be admitted that engineering experience of chilled seawater tanks is limited and, perhaps, far more extensive and effective use of sea water chilling will be made in some of the fishing boats of 1975.

The present tendency to fish further and further afield will no doubt continue. The reaction of fish to various bacteria in cold and warm waters might play an important role in the design of the 1975 fishing boats, those operating in warm areas might be using chilled sea water while those in cold areas will have to freeze the catch. A chilled sea water type of boat would resemble a tanker and the unloading might be facilitated if some brine were pumped into the fish tanks after arrival at port. Because of the density of the brine, the fish would float up and could easily be sucked ashore by pumps. Work is in progress for the development of this type of unloading technique which requires very little labour. The cost of using brine would be moderate if it were used over and over again.

It is not only through introducing new ideas and new techniques that the fishing boats of 1975 might be considerably different from those in use today, but through a general improvement in technical practices. Controllable-pitch propellers, for instance, were almost unknown outside Scandinavia fifteen years ago. They are beginning to be used elsewhere today. So, perhaps, in fifteen years from now the majority of fishing boats will use controllable-pitch propellers. They are no more expensive than the present arrangements with reverse gears, but they improve the handling and manoeuvrability of a boat and lead to more economic operation.

Some fishing fleets are built with hulls near optimum with regard to resistance, propulsion and seakindliness. If that knowledge could be transferred to the many boats built in other parts of the world, it could lead to a vast improvement in efficiency and economy of operation. This Congress showed how wooden ships could be made cheaper by using lighter scantlings which would also enable the boats to have easier motions in a seaway, be more seakindly and cost less to operate.

The diesel engine has proved its superiority over other engines in the fishing fleets; even in the under-developed countries fishermen are quick to learn how to operate small diesel engines. However, there are millions of boats which cannot be mechanized with an inboard diesel but they could be fitted with an outboard engine. For several reasons, excellent gasoline-driven outboards are not always practical for this purpose, but if a diesel outboard were developed it would meet a special need felt in many countries. It would increase the efficiency of existing boats and lead to a considerable increase in fish production. Such an innovation would set in motion a chain of events, resulting in a higher standard of living for the fishermen, and, later, the construction of even more efficient boats.

The world population is increasing at a very fast rate—almost explosively, as shown by table 192—but there are gloomy people who think, despite the population increase, that there will be difficulty in marketing any increased catch of fish. But is marketing really such a problem? A Scandinavian firm has shown how they can freeze quality fish in Northern Scandinavia and sell it in Central Europe cheaper than locally-landed fish. The big difficulty this firm faces is to produce enough fish to meet the demand.

Then there is the case of the U.S.A. where good marketing has made tuna so popular that almost all tuna fishermen in the world today catch for that market. The same is true, in a way, of shrimp, which is even being caught and frozen in Asia and many other places in the world for export to the U.S.A. If meat can be sent from Australia and the Argentine to the U.K. why could not fish be transported long distances, and why should the fish be processed to resemble the fresh state anyway?

Techniques have been developed for making fish flour for human consumption. A small percentage mixed in normal flour would meet the protein requirement for many people who have an insufficient protein intake. Plants making fish meal for livestock and poultry feeding could easily be switched to such production and so make more fish available for human consumption.

If fish flour is thus going to be an important source of animal protein in the future, it will no doubt have a great influence on the design of individual fishing boats and on the composition of large fishing fleets by 1975.

The real problem in developing the world's fisheries is to break down ignorance and spread understanding. Fisheries journals should and could play a major role in this respect. In fact, one could reasonably claim that a good technical press and a good fisheries literature, thoroughly read, is essential if the development of fisheries over the next fifteen years is to meet the demands envisaged.

Another essential is money for plain development and extension work.

Whatever the shape of things to come, one thing is certain: there never will be a time when there is one fishing boat type in the world. On the contrary, in the future there will probably be more and more specialized types and perhaps one could do no better than repeat the closing statement made by Jul in the book of the first Congress: "Some have said that the factory ship is the fishing boat of the future. People have also said that the aeroplane is the means of transport of the future. Both may be true, but only in this sense: for a long time to come the world will probably have cargo liners, river barges, bicycles and mules, as well as aeroplanes. In the same way, it will have factory ships along with trawlers, purse seiners, longliners, catamarans and other fishing craft."

Fig. 800. Gasoline outboards have played a great part in the development of fisheries in those nations where the Government has exempted the fishermen from paying the normal road taxes on gasoline—such as in Jamaica—and where they have organized courses on how to operate and maintain outboards. Arrangements to help the fishermen acquire such outboard motors on easy terms have been very successful, and the financial losses have been negligible. Gasoline outboards, however, are still sensitive, and there is a demand for a heavy-duty diesel outboard. Many small coastal fishing boats might perhaps be fitted with such diesel outboards in 1975

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Figures in italics relate to the FIRST volume; those in ordinary roman refer to the contents of THIS volume.

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ADVERTISEMENT SECTION

THE selection of advertisements given in the following pages is included in order that fishermen the world over may secure prompt knowledge of where to buy their requirements either in specialized craft or equipment for operating such vessels with the greatest efficiency.

The prime object of the Fisheries Division, FAO (United Nations) in organizing these *Fishing Boats* Congresses (in Paris and Miami in 1953 and the second in Rome during April 1959) was to bring together the leading experts from all major fishing countries in order to give and exchange information that would improve the technical capacity and efficiency of the fishermen engaged in their local industries.

To supplement that knowledge this section is designed to give commercial information of where fishing craft of various types can be built, reliable engines bought and particular gear and equipment purchased. The co-operation of the firms who thus advertise renders a double service: in addition to giving information about their wares, their support enables this book to be produced at a materially lower figure than would otherwise be possible.

Therefore, the publisher of this book bespeaks for these firms such goodwill and support as can be given by appreciative fishermen in the expanding industries of Asia, Africa, the Pacific, South America, North America, as well as in all European areas.

Fishing News (Books) Ltd.
110 Fleet Street, London, E.C.4.

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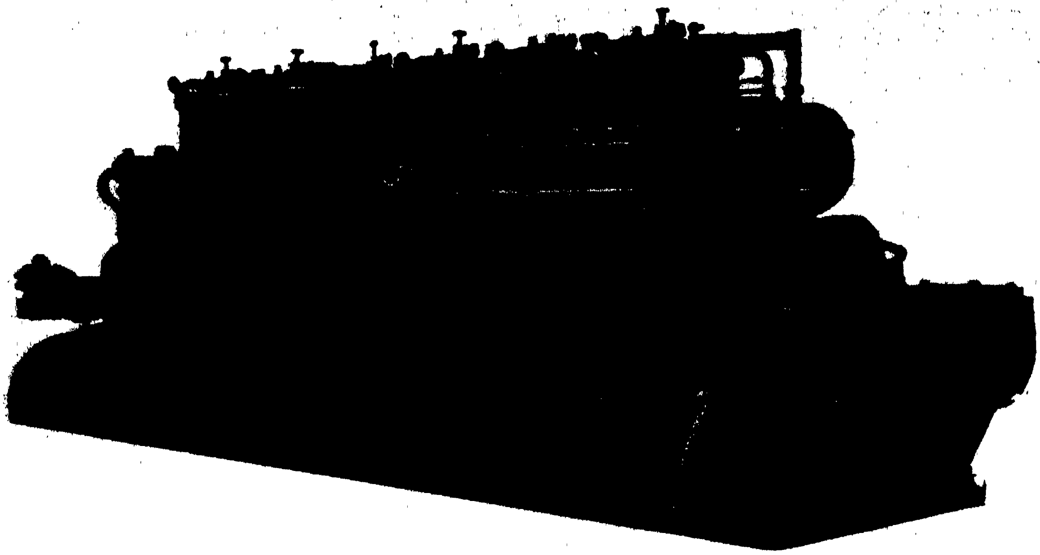

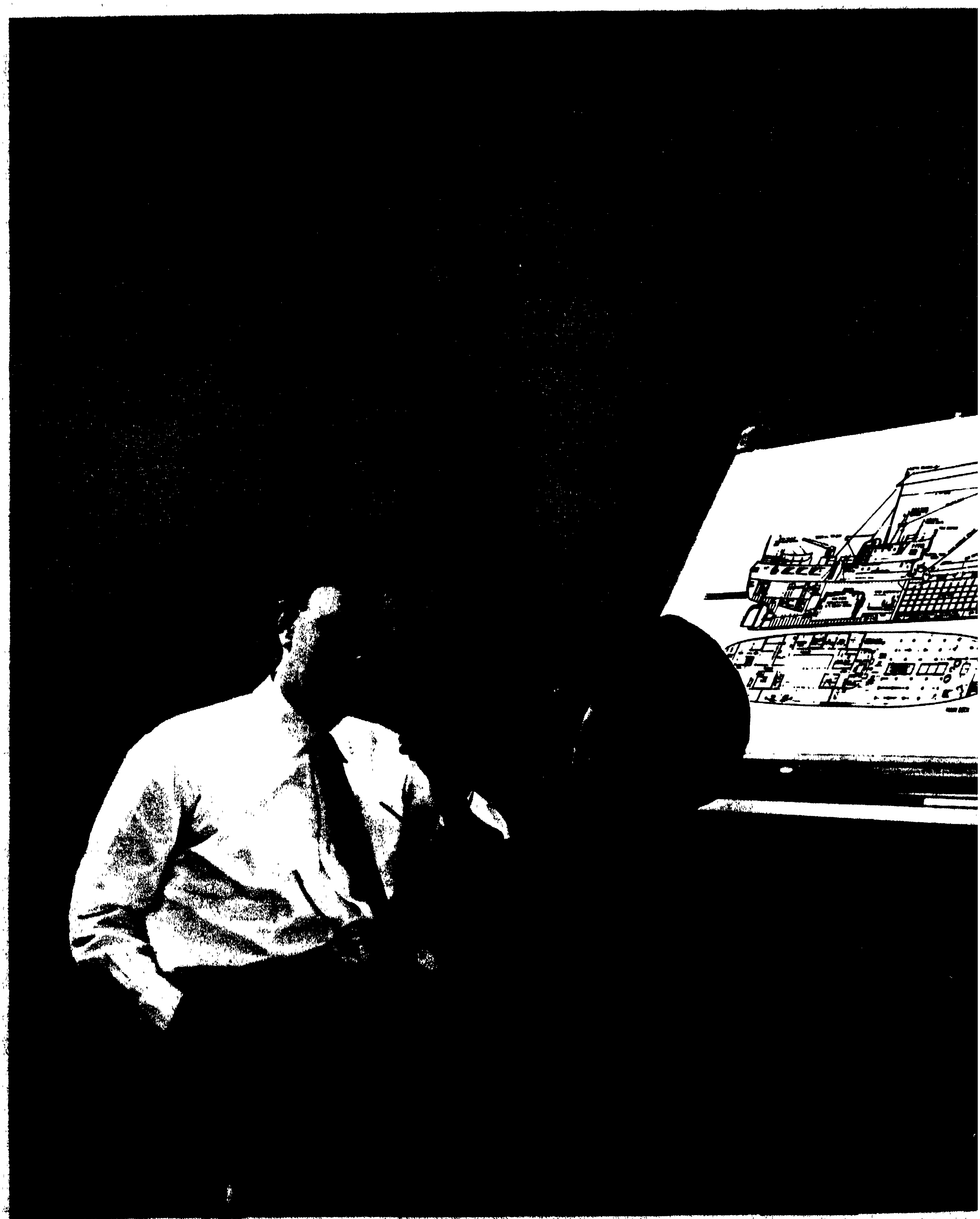

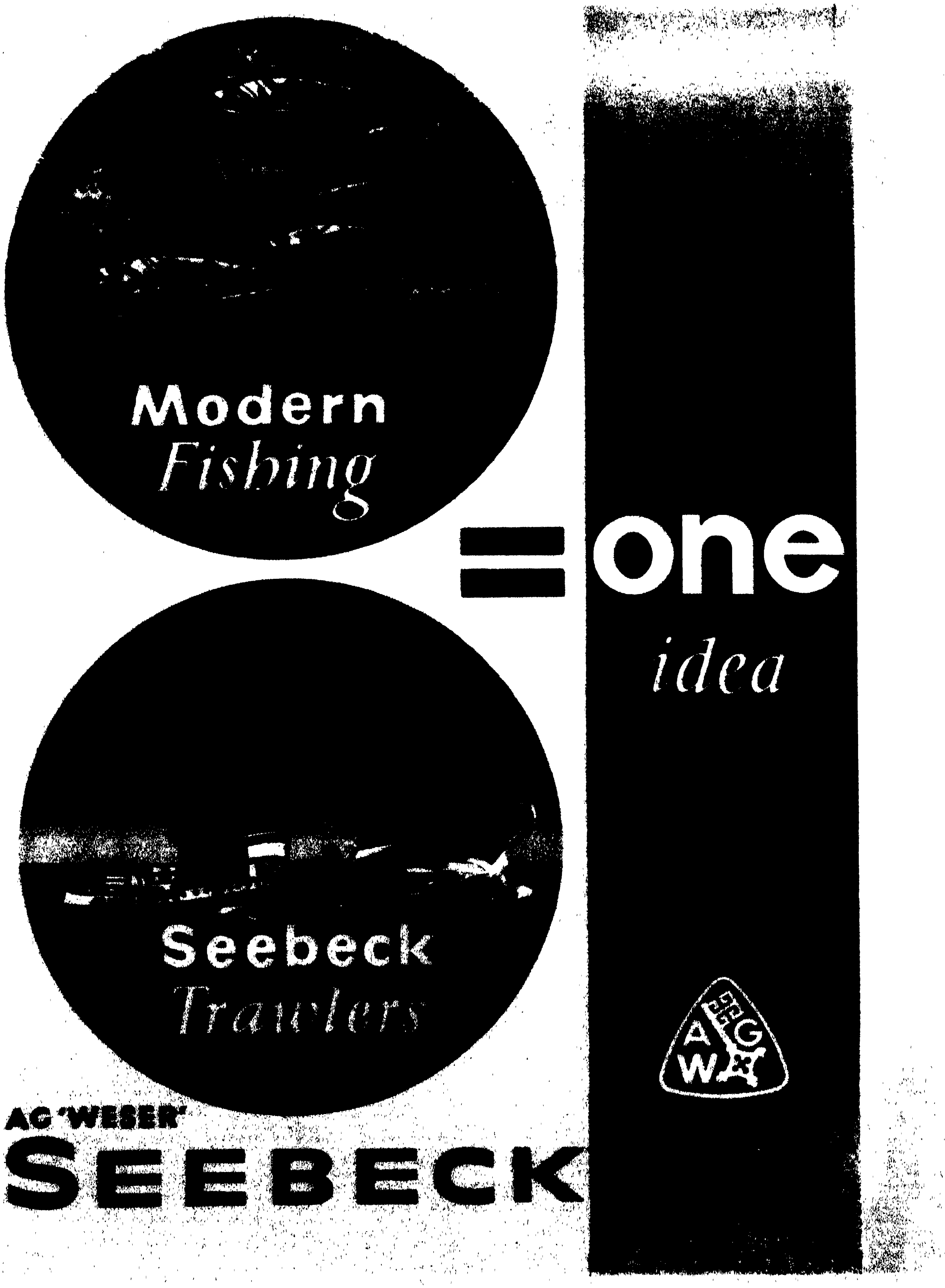
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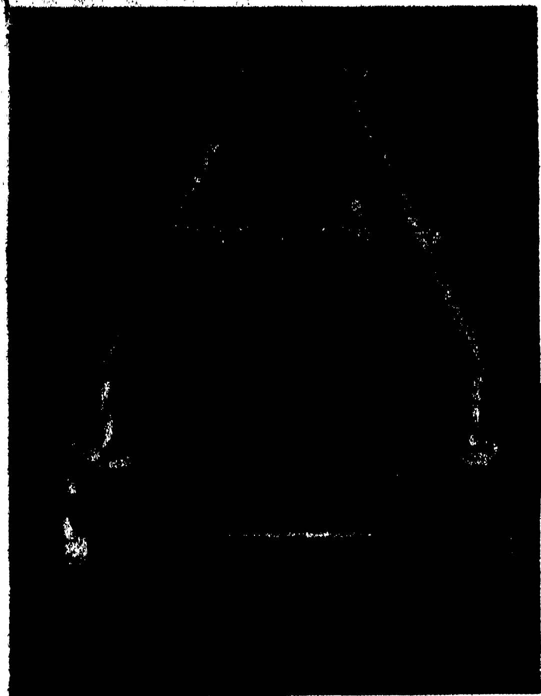
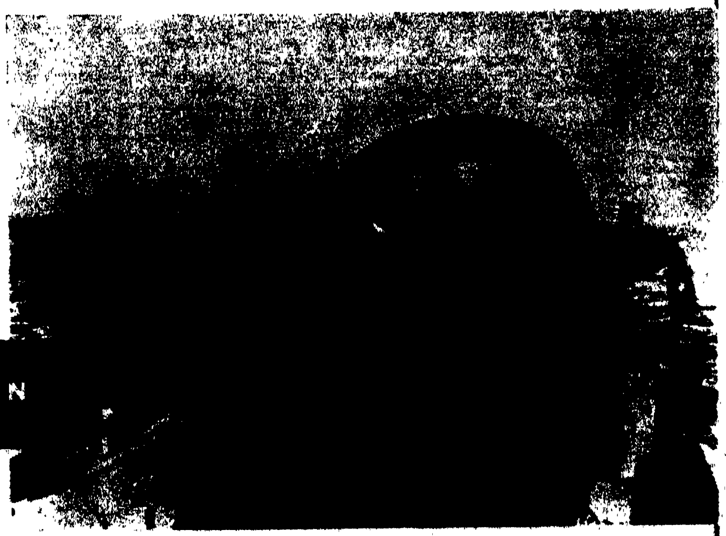
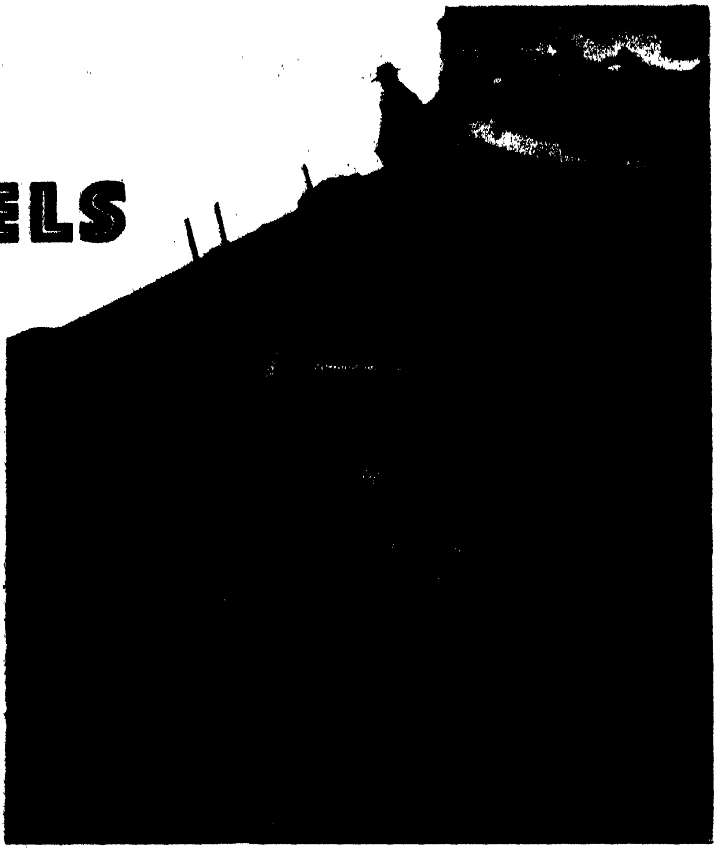


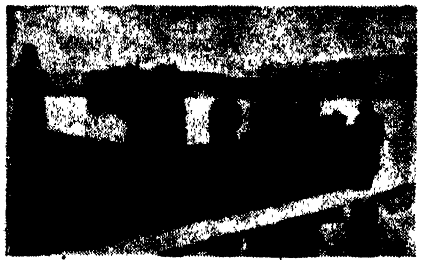


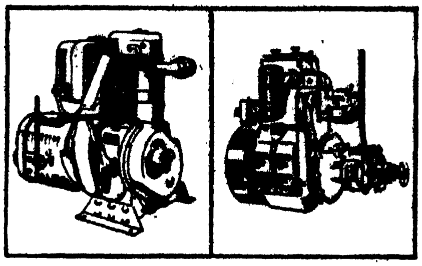



Brazilean trawler equipped with 30 HP watercooled SAMOFA auxiliary engines.


Greek fishing boat equipped with a 15 HP watercooled SAMOFA engine.


French trawler fitted with a 30 HP watercooled SAMOFA auxiliary engine.


Turkish fishing boat equipped with a 15 HP watercooled SAMOFA engine.

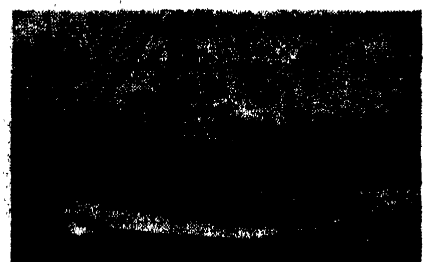


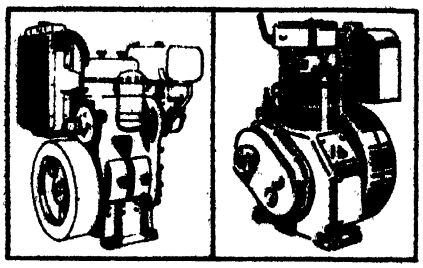

Dutch fishing boat fitted with a 25 HP watercooled SAMOFA engine.


Fishing boat from Barbados equipped with a 15 HP SAMOFA engine.

SAMOFA HOLLAND


Dutch seiner equipped with a 10 HP watercooled SAMOFA auxiliary engine.


Fishingboat from Curaçao equipped with a 30 HP SAMOFA engine.



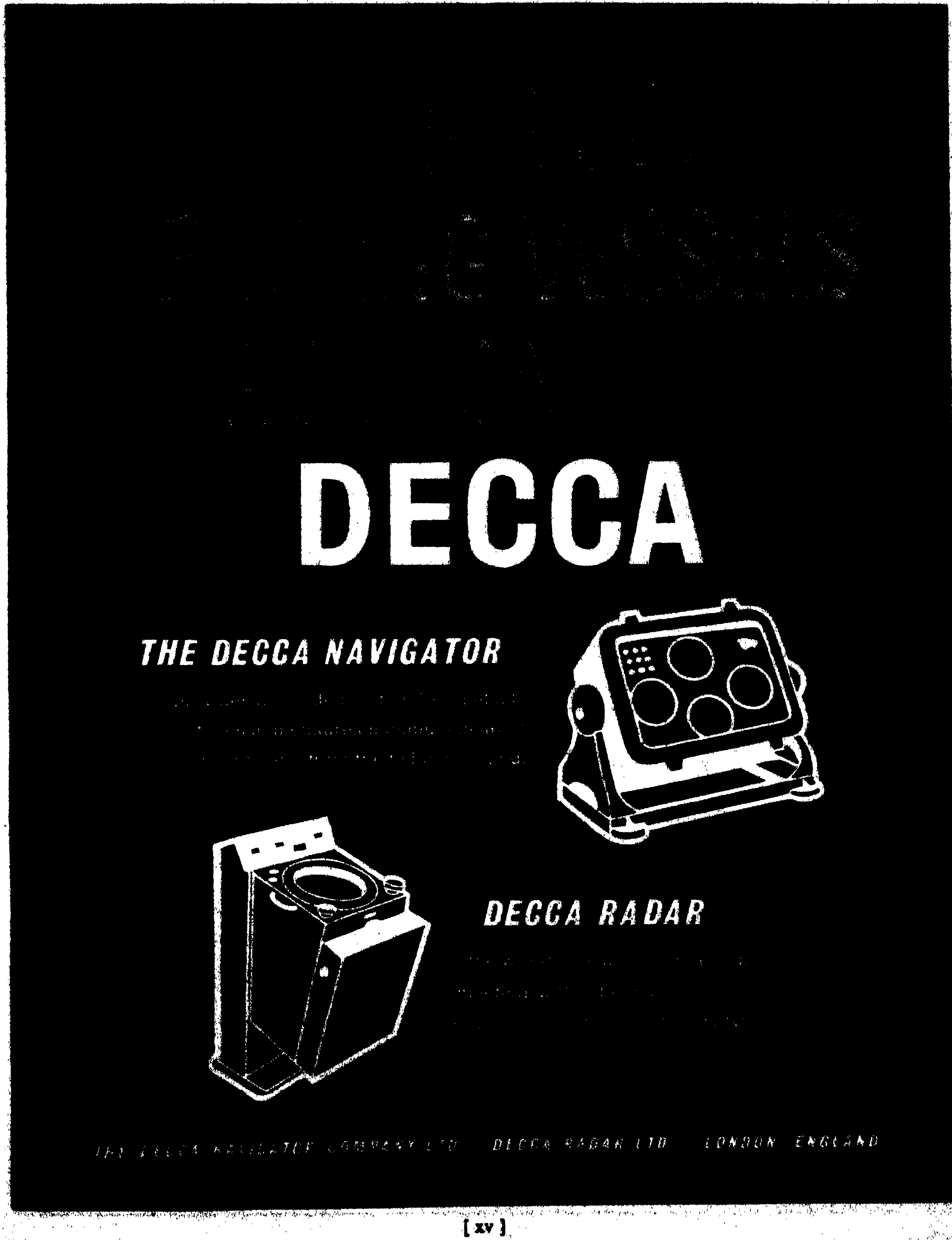

Danish seiner equipped with an 8 HP aircooled SAMOFA auxiliary engine.


Tug in Siam, Thailand equipped with a SAMOFA marine diesel engine, 2-S-105 model.


Spanish seiner equipped with a 30 HP watercooled SAMOFA auxiliary engine.


Portuguese fishingboat equipped with a 30 HP watercooled SAMOFA engine.

MOTORENFABRIEK „SAMOFA" N.V., P. O. BOX 28. HARDERWIJK-HOLLAND. CABLES: „SAMOFAMOTOR"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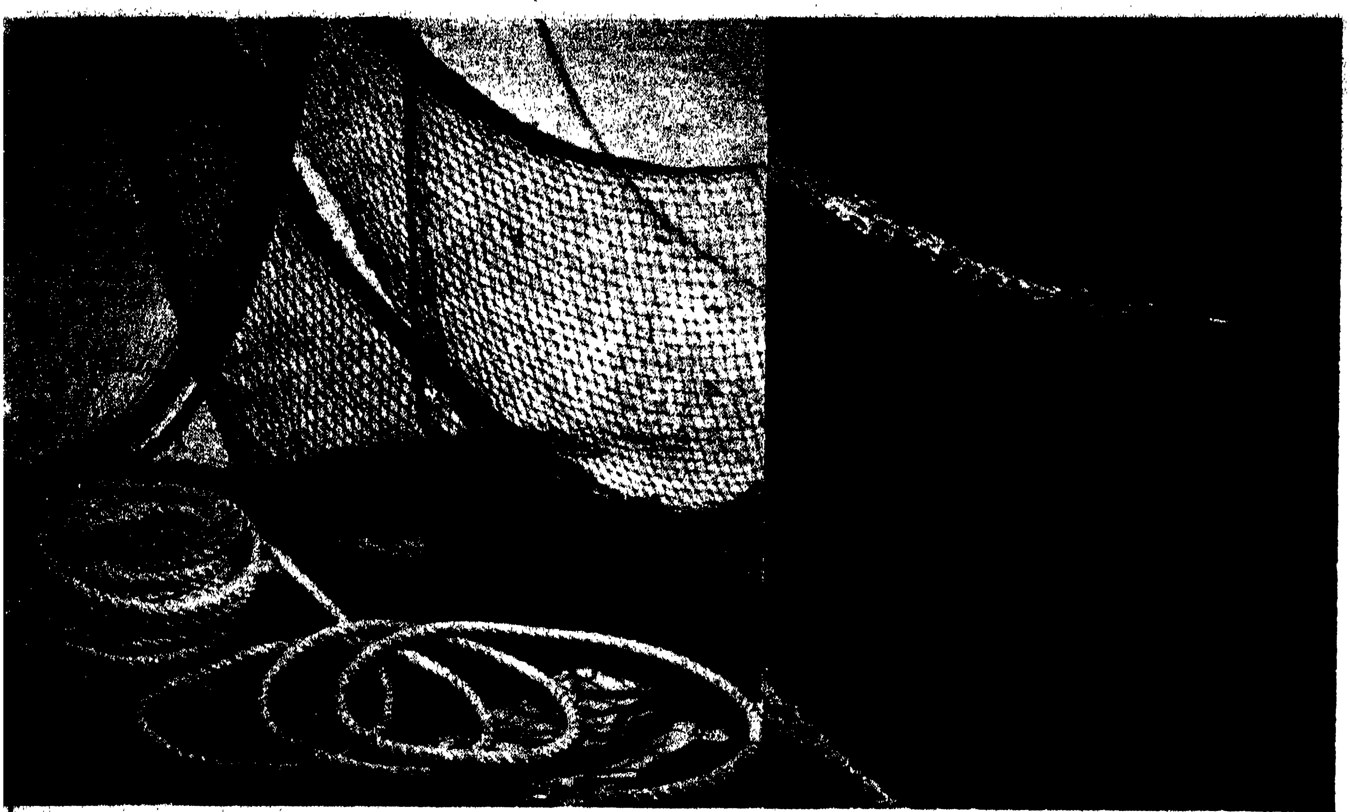

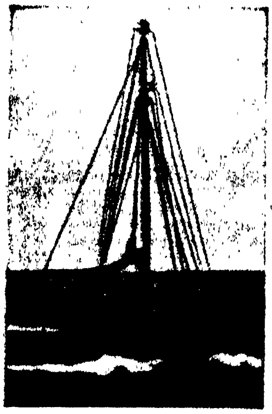

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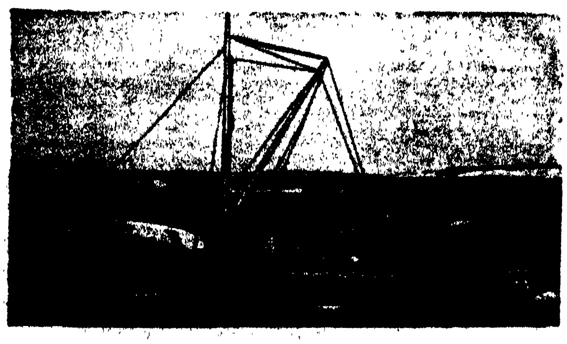

DETAILS	Four 99(M)	P3/144(M)	P4(M)	Six 305 (M)	Four 270D(M)	S6(M)
Cylinders	4	3	4	6	4	6
Bore	3"	3½"	3½"	3.6"	4¼"	4½"
Stroke	3½"	5"	5"	5"	4¾"	5"
Swept Volume: Litres	1.62	2.36	3.14	5	4.42	7.26
Cu. Ins.	99	144.3	192.4	305	269.5	[illegible]
S.H.P.	12/41	21/36	27/43	43/84	[illegible]	60/120
R.P.M.	1,300/2,400	1,200/2,250	1,200/2,000	1,200/2,400	1,200/2,000	1,200/2,100
Weight with Accessories ...	480 lbs.	1,082 lbs.	800 lbs.	1,130 lbs.	1,150 lbs.	1,300 lbs.

All engines may be supplied to Lloyd's classification and P Series engines are approved for class 'A' ships lifeboats by M.O.T. *Alternative Reduction Gears are available for all engines.*

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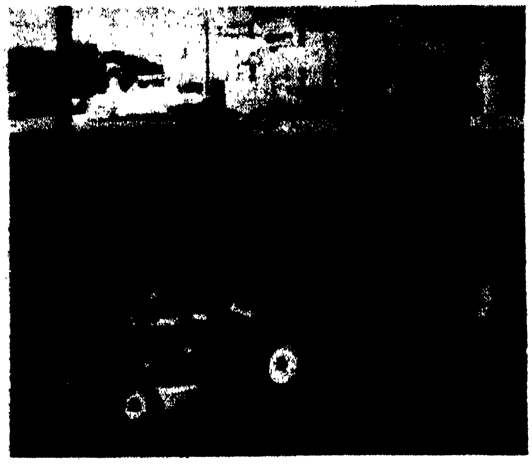

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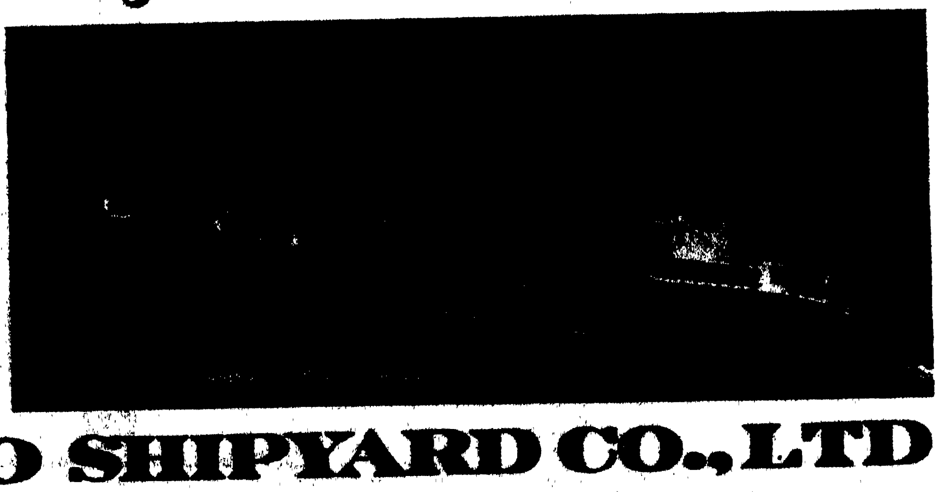

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Single-unit powers up to 3,000 h.p. (water-cooled) and up to 460 h.p. (air-cooled)

Engine Mark	b.h.p.	r.p.m.
1YBAM	4–6½	1000–1800
2YBAM	8–12½	1000–1800
1YWAM	6–9½	1000–1800
2YWAM	12–19	1000–1800
2YDAM	16–[illegible]	1000–1800
3YDAM	[illegible]–43½	1000–1800
4YDAM	[illegible]	1000–1800
6YDAM	48–87	1000–1800
8YDAXM	84–114	1000–1800
1YBM	4–6½	1000–1800
2YBM	8–13	1000–1800
2YDM	16–30	1000–1800
3YDM	24–45	1000–1800
4YDM	[illegible]–60	1000–1800
6YDM	48–90	1000–1800
4YEM	50–75	1000–1800
5YEM	63–94	1000–1800
6YEM	75–125	1000–1800
6YEXM	97–170	1000–1800
• 4RPHM	[illegible]–140	750–1800
• 6RPHM	140–255	750–1800
• 8RPHM	186–340	750–1800
• 12RPHM	335–[illegible]	900–1500
• 16RPHM	446–667	900–1500
• 6YHXM	300–370	1000–1500
• 12YHXM	600–740	1000–1500
• 16YHXM	800–[illegible]	1000–1500
• 6YHCM	[illegible]	1000–1500
• 12YHCM	[illegible]	1000–1500
• 16YHCM	[illegible]–1050	1000–1500
• 8YGAM	180–245	1250–1800
• 12YGAM	270–370	1250–1800
• 8YGAXM	[illegible]	1250–1800
• 12YGAXM	347–480	1250–1500
• 12YJXM	763–1020	1000–1500
• 16YJXM	1020–1360	1000–1500
• 12YJCM	855–1200	1000–1500
• 16YJCM	1140–1600	1000–1500
• 8YLM	451–570	800–1000
• 12YLM	677–854	800–1000
• 8YLXM	564–761	800–1000
• 12YLXM	846–1141	800–1000
• 16YLXM	1128–1522	800–1000
• 8YLCM	780–[illegible]	800–1000
• 12YLCM	1165–1480	800–1000
• 16YLCM	1560–1974	800–1000
4VCBM	125–135	600–650
5VCBM	160–170	600–650
6VCBM	190–205	600–650
5VCBXM	240–255	600–650
6VCBXM	286–305	600–650
5VEBM	280–315	500–600
6VEBM	335–380	500–600
7VEBM	390–440	500–600
8VEBM	445–505	500–600
5VEBXM	415–[illegible]	500–600
6VEBXM	502–600	500–600
7VEBXM	585–700	500–600
8VEBXM	670–800	500–600
5VEBCM	605	600
6VEBCM	725	600
7VEBCM	850	600
8VEBCM	970	600
5ATXM	[illegible]	500
6ATXM	785	500
7ATXM	915	500
8ATXM	1050	500
9ATXM	1180	500
5ATCM	835	500
6ATCM	1000	500
7ATCM	1170	500
8ATCM	1340	500
9ATCM	[illegible]	500
5VOXM	1280	450
6VOXM	1535	450
7VOXM	1790	450
8VOXM	2050	450
9VOXM	2305	450
5VOCM	1610	450
6VOCM	1935	450
7VOCM	2260	450
8VOCM	2580	450
9VOCM	[illegible]	450

Significance of letters in Engine Mark:
[illegible]

All the above engines are also available as marine auxiliary units

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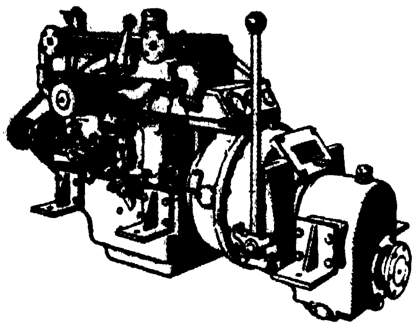
announce
BIG PRICE REDUCTIONS
for heavy duty
MARINE DIESEL ENGINES



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25-30 h.p.	,,	£400
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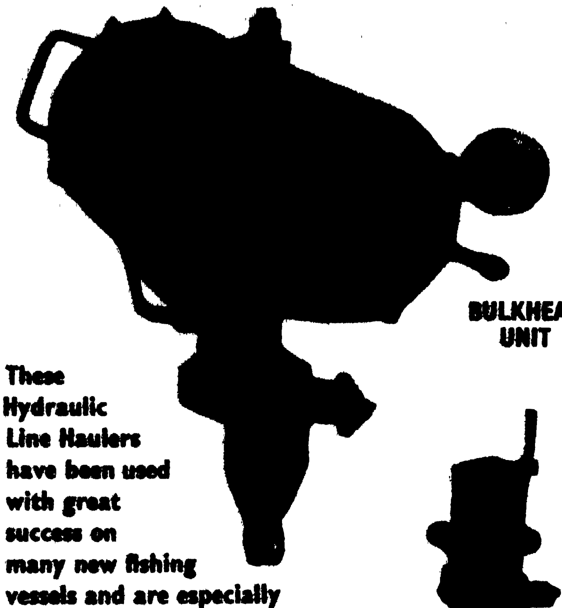

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These Hydraulic Line Haulers have been used with great success on many new fishing vessels and are especially useful on diesel powered boats.

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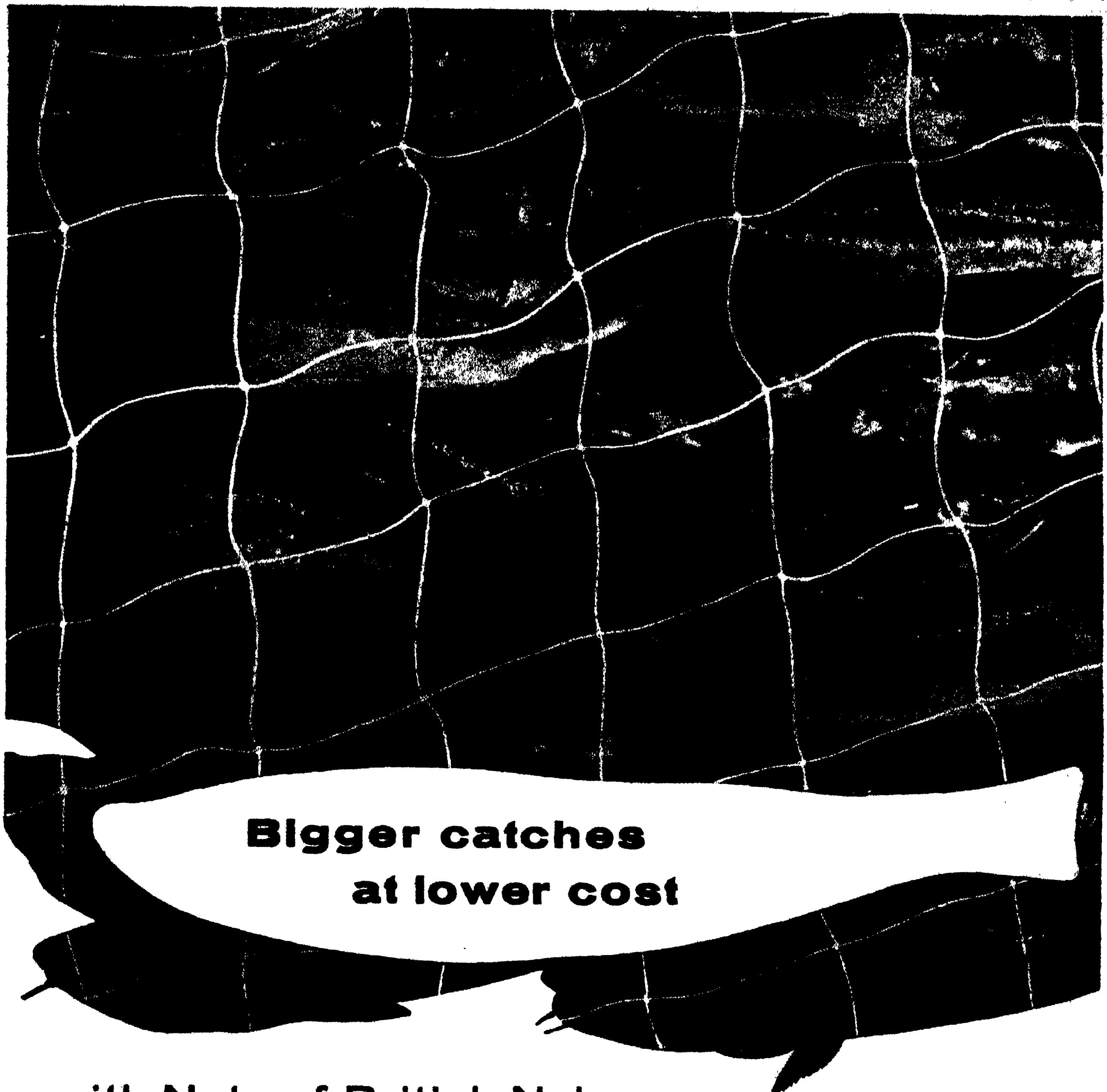
TELEGRAMS "VALVE" LOANHEAD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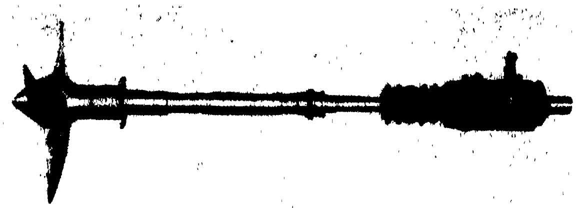
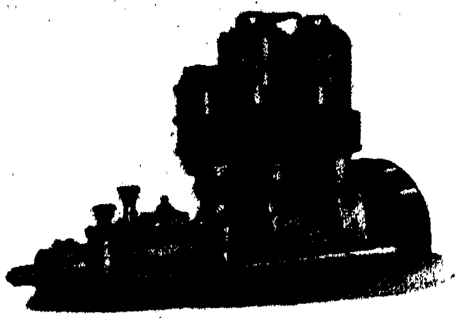
H.M.F. semi-diesel engines ranging from 12-360 b.h.p. are ideally suited for all types of fishing vessels, tugs and coasters. These engines are heavily built, slow running, giving the owner absolute reliability and economies in running and maintenance and are easily operated.
All engines are fitted with our simple and robust propeller unit, giving the owner maximum efficiency under all conditions.





The above illustration shows a complete fully reversible propeller unit. We also manufacture several types of controllable pitch propellers, to vary the pitch in the ahead position, either by remote control or on the propeller shaft when it is stopped.
In addition we manufacture a wide range of feathering propellers for yachts. These propellers in addition to feathering, i.e. when the blades are in a fore and aft position, can be adjusted to any position from full ahead to full astern.

WE SPECIALISE IN SUPPLYING PROPELLER UNITS FOR ALL DUTIES AND TO ANY TYPE OF MARINE ENGINE

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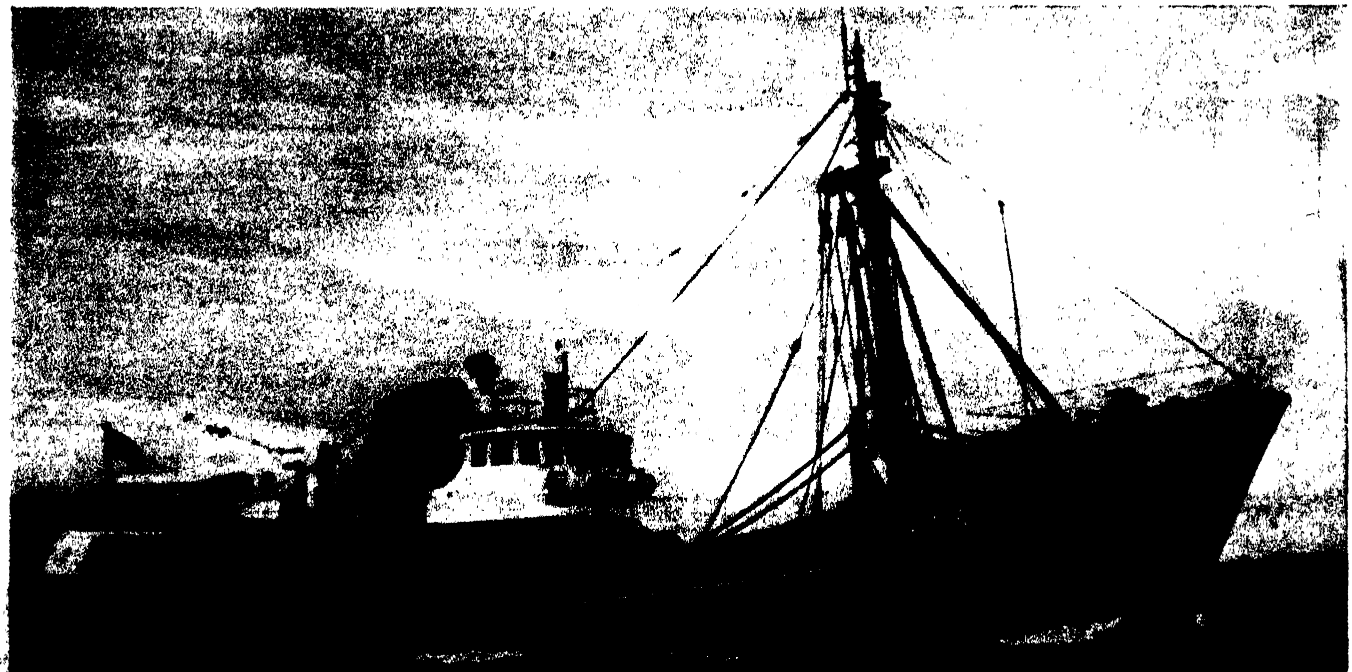

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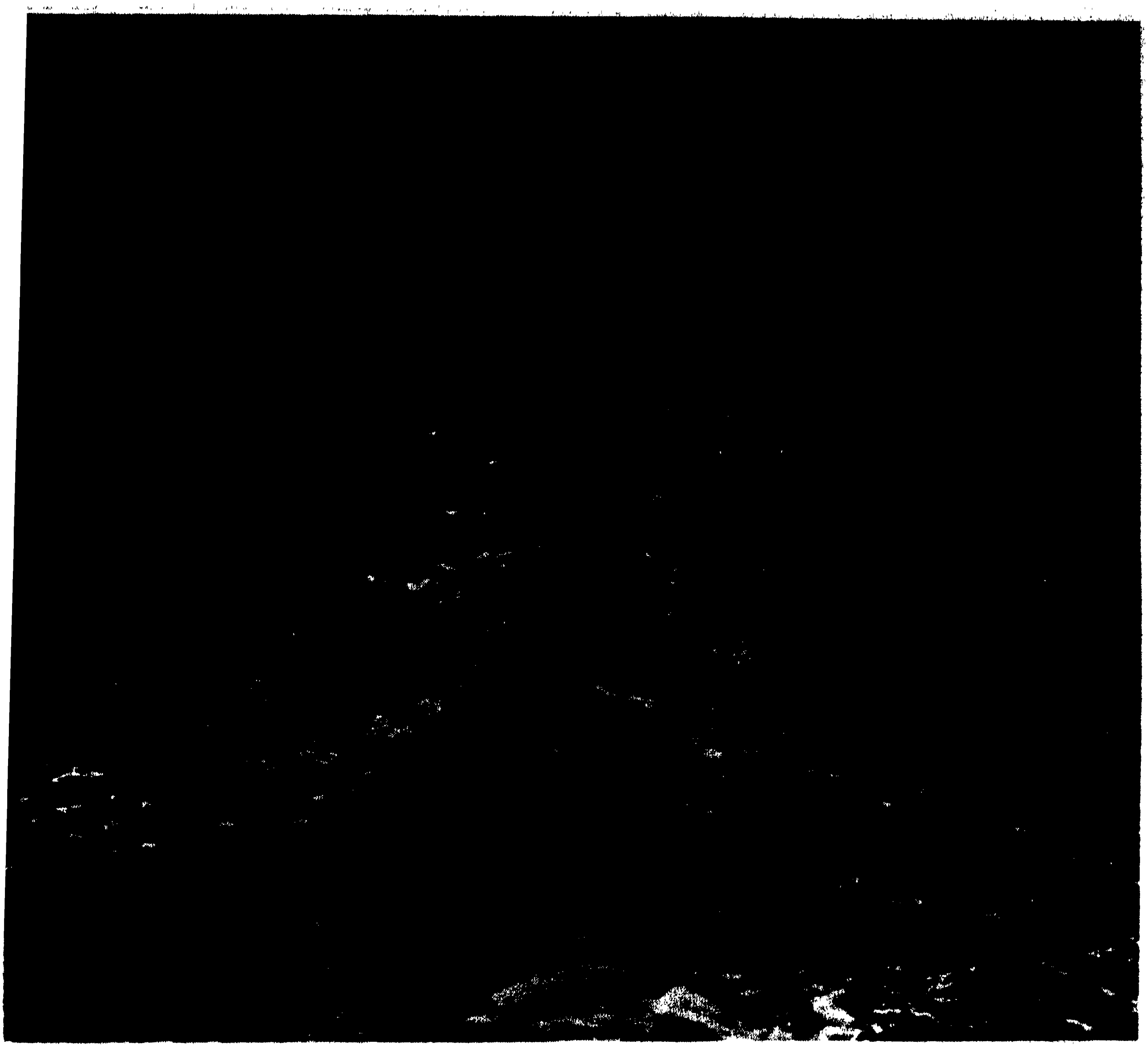
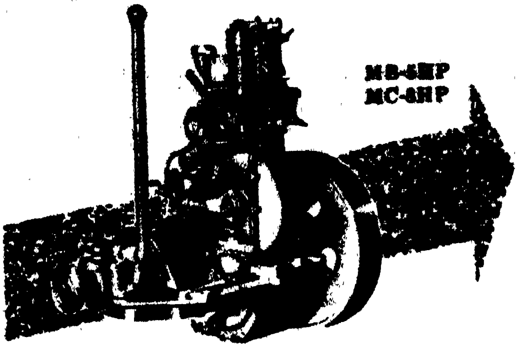
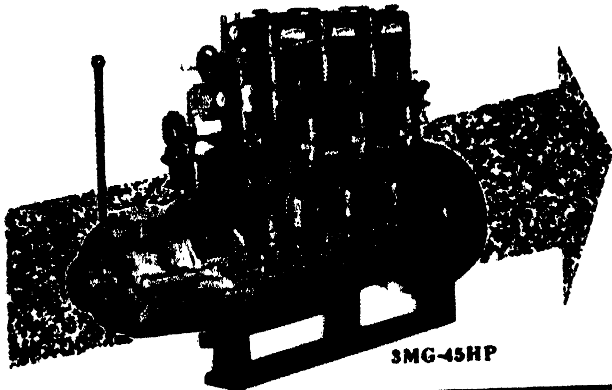
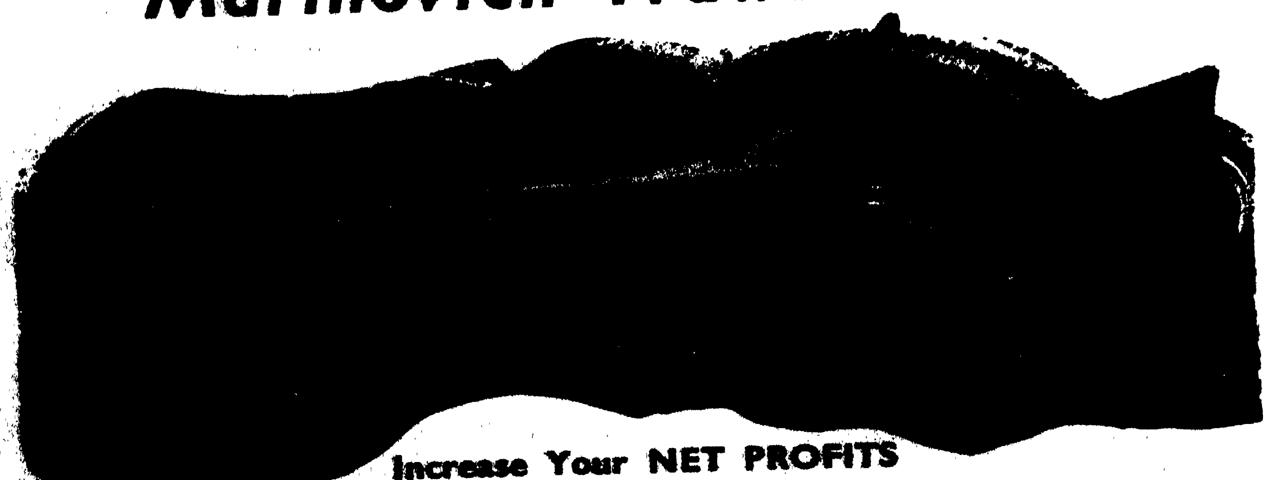
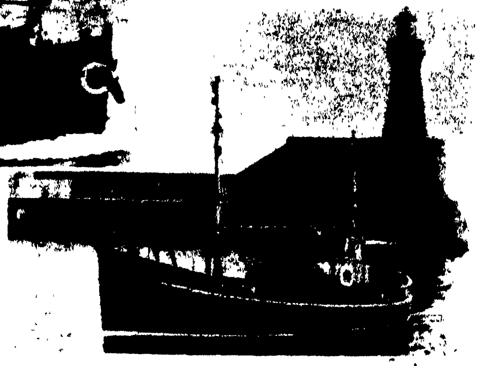



MB-5HP
MC-8HP


3MG-45HP





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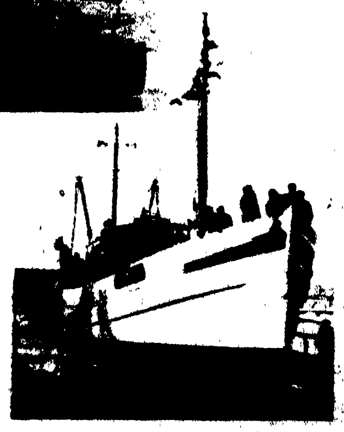

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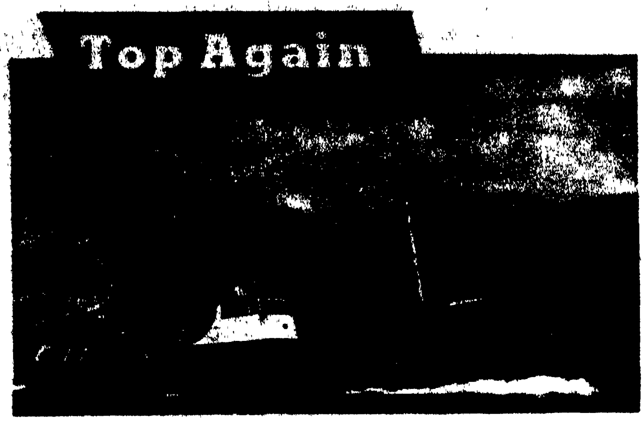

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TOP SHIP OF THE PORT OF LOWESTOFT FOR 1958

the "LOWESTOFT LADY" is powered by a Crossley Diesel Engine. She achieved her title with record earnings, even surpassing the record set up by the TOP SHIP FOR 1957, "BOSTON SPITFIRE"—another Crossley-engined vessel. "BOSTON SPITFIRE" with 328 days at sea in 1957 and "LOWESTOFT LADY" 342 days at sea in 1958, testify to the outstanding reliability of the Crossley two-cycle Scavenge Pump Diesel engines by which they are powered. Both ships are owned by Boston Deep Sea Fisheries Limited and each has for her propulsion machinery a six cylinder "HRN" type engine rated at 440 b.h.p. at 300 revolutions per minute. With the introduction of exhaust gas turbo-charging the range of Crossley engines in powers up to 3200 b.h.p. per unit covers the needs of vessels both large and small.

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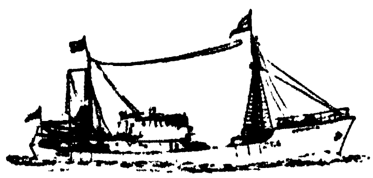

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CROSSLEY BROTHERS LIMITED · OPENSHAW · MANCHESTER 11

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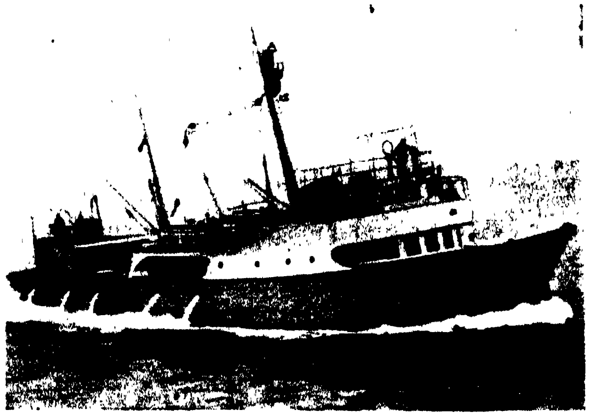
MARINE DIESEL ENGINES

from 300 to 1,500 hp



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—Engines for tugs, trawlers, dredgers, etc.

—In auxiliary sets for destroyers, cruisers, aircraft-carriers, tankers, etc.

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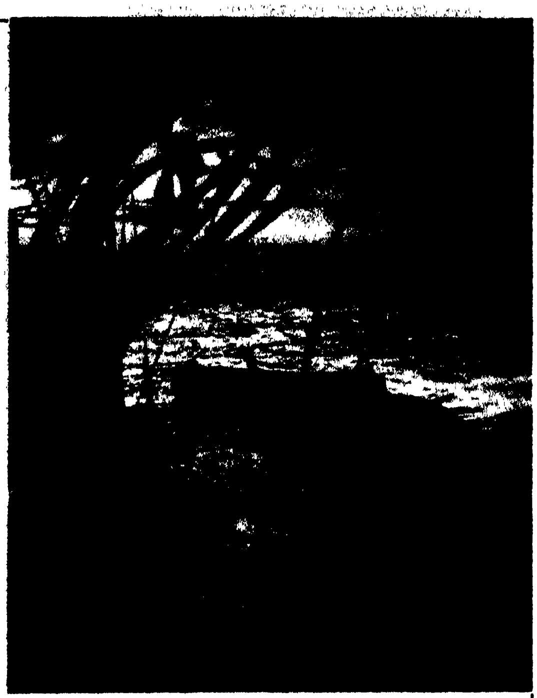

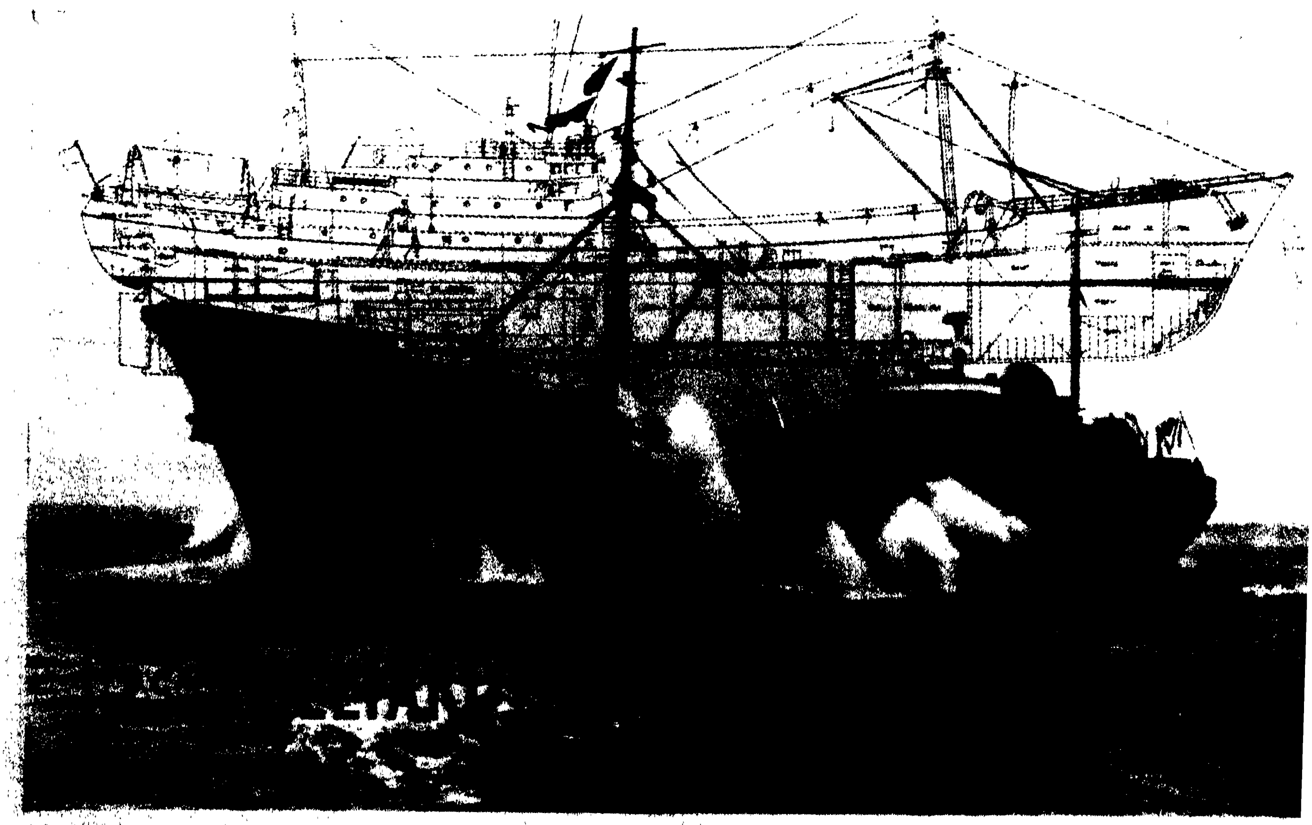

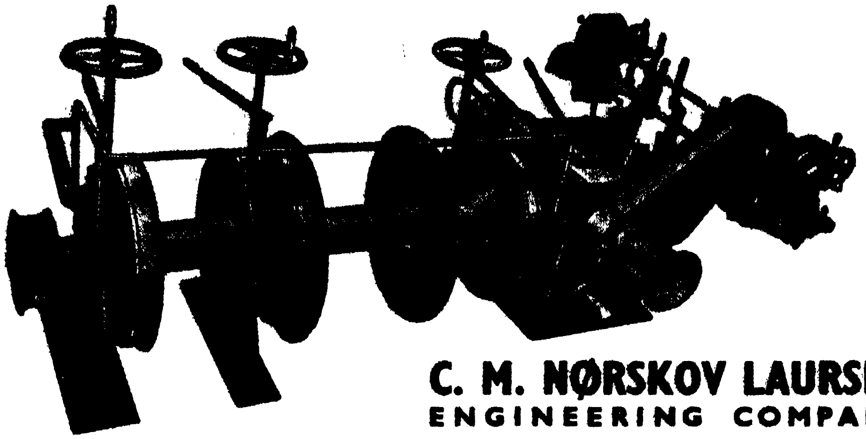

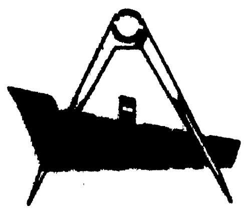

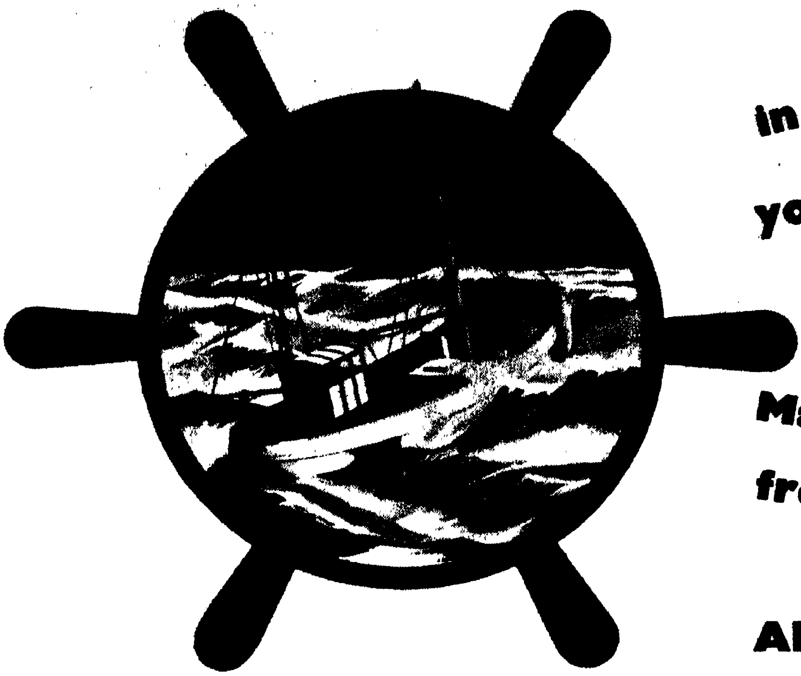

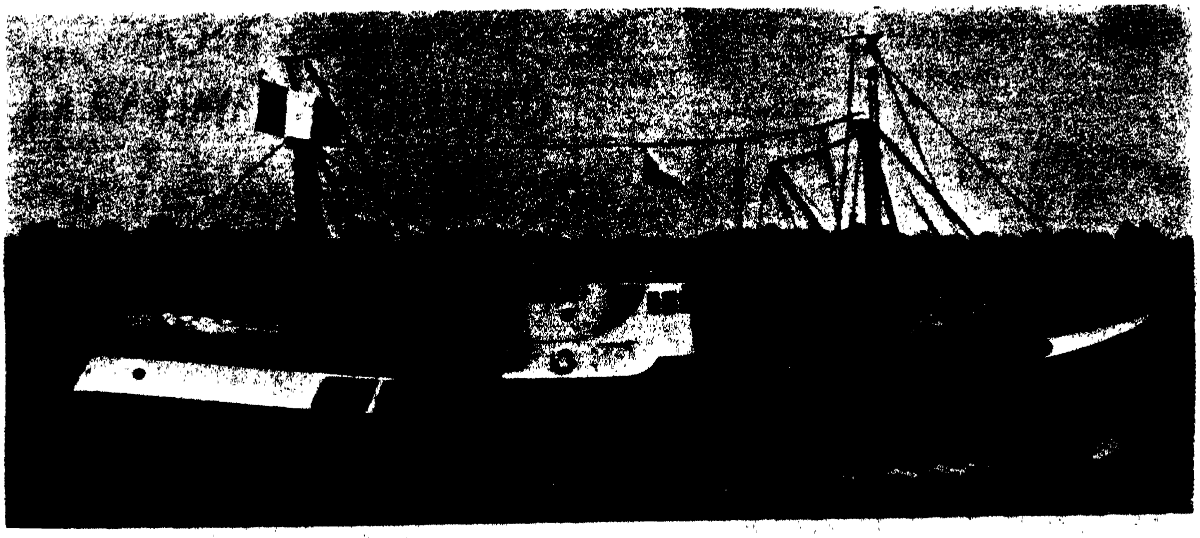

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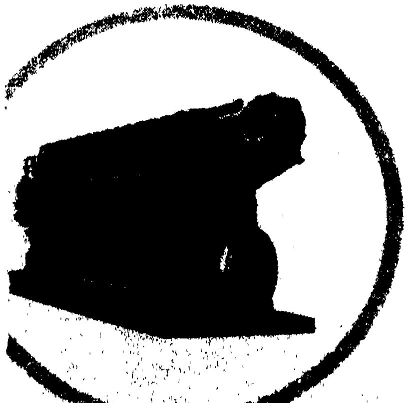

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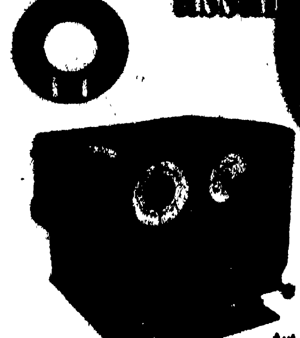

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