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BEHAVIOR OF THREE PLANING BOAT DESIGNS IN CALM AND ROUGH WATER

by

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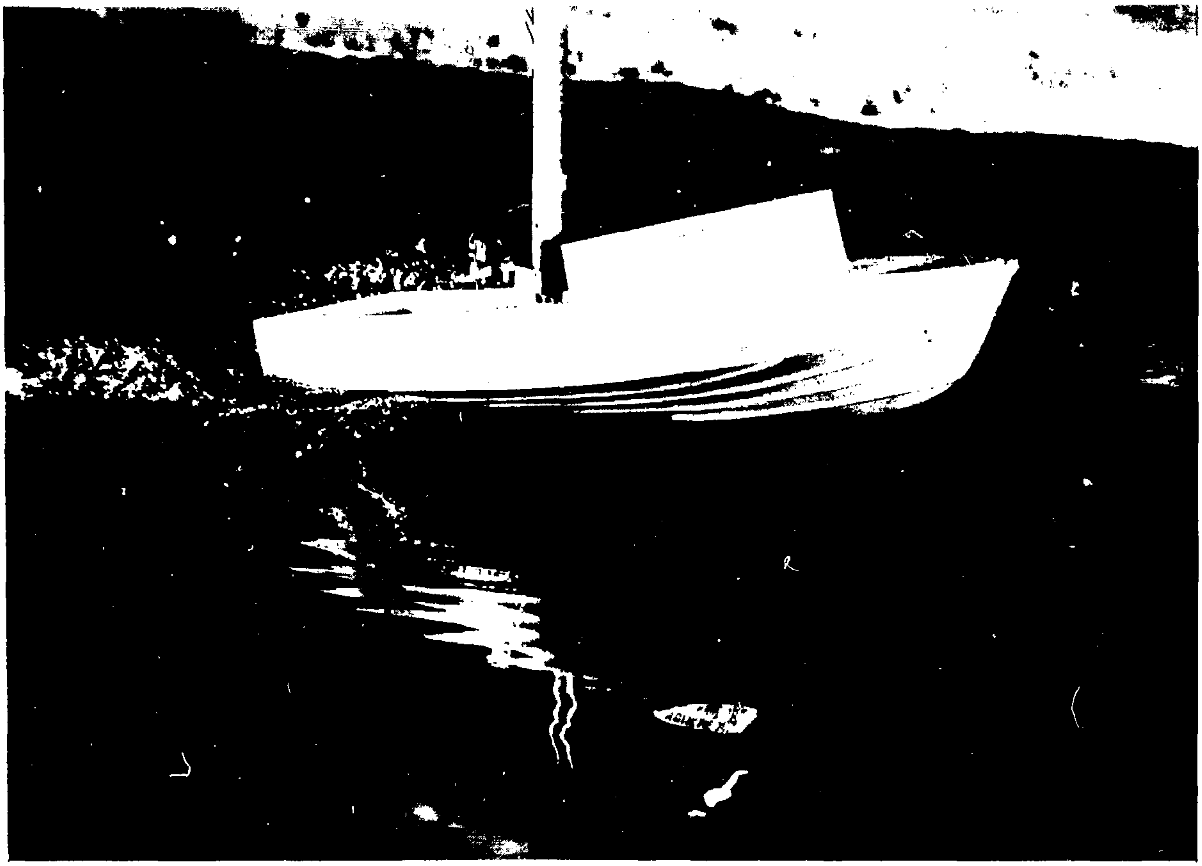
Approved

I. Robert Ehrlich, Manager
Transportation Research Group

TABLE OF CONTENTS



MODEL OF BUSHIPS 52-FT LCSR, SCHEME C,
UNDER TEST IN WAVES
AT DAVIDSON LABORATORY

INTRODUCTION

This report describes 1:16 scale model tests of three competitive planing boat designs for a Bureau of Ships 52-ft LCSR, a high-speed landing craft. Two of the three designs, designated Scheme A and Scheme B, were furnished by the Bureau of Ships and are conventional hard-chine planing boat types. The chief difference between the two designs is the shape of the bottom -- Scheme A has bottom sections that are convex in shape and the bottom sections of Scheme B are concave in shape. The third design, designated Scheme C, was furnished by an independent yacht designer, Mr. C. Raymond Hunt of Marblehead, Massachusetts, under an arrangement with the Bureau of Ships. This design featured a high deadrise bottom with rounded sections at the keel. In addition, the bottom was fitted with longitudinal "hydrolift" strips.

All designs were tested for resistance in calm water at various displacements including a standard condition prescribed by the David Taylor Model Basin. In addition, the Scheme A model was tested with an appendage configuration consisting of twin shafts, struts, rudders, and propeller protective skegs.

Wave tests in irregular, long-crested tank waves simulating a State 3 sea were conducted with all models at several displacement and trim conditions. Model resistance and accelerations at the bow and the center of gravity were measured over a range of speeds from 20 - 40 knots in head seas. Scheme A was also tested in following seas.

Motion pictures of representative wave test runs were taken.

All work was performed under Contract NObs-78349, Task Orders 7, 8, and 10, administered by the David Taylor Model Basin.

DESCRIPTION OF EXPERIMENTS

Models

Scheme A and Scheme B 1:16 scale models were constructed for Davidson Laboratory by a subcontractor. The models were made of sugar pine with a five-coat lightly sanded varnish finish. Brass appendages for the Scheme A model were fabricated and installed by the Davidson Laboratory shop. These models were designated as DL-2389 and DL-2387, respectively. The Scheme C model, designated as TMB-4876 and constructed by the David Taylor Model Basin, was of balsa wood coated with plastic resin and a grey-painted finish. For wave tests, an aluminum foredeck and breakwater were added to each model.

For calm water tests, the models were ballasted statically to freeboards corresponding to the required trim condition, and the LCG was then measured. A similar method was followed for the wave tests; however, following determination of the required LCG, the model was balanced dynamically by the pendulum method to determine the radius of gyration. For the light displacement case, (45,000 lbs), the models were ballasted to a radius of gyration equal to 28% of the LBP, a value assumed to be a realistic representation of conditions on the full-size vessel. The 50,000 lb and 55,000 lb displacements were achieved by adding concentrated weights at the appropriate locations to give the desired LCG. The radius of gyration for these cases was then measured and recorded.

Drawings of the models, together with model dimensions and characteristics, appear in Figs. 1 through 3 (a, b and d of each). A tabulation of model and full-size characteristics for each test appears in Table I. Figure 4 shows a photograph of the appendage configuration on the Scheme A model and the "hydrolift" strips on the bottom of the Scheme C model.

Calm Water Tests

Calm water resistance tests were conducted in Tank No. 1 (100 ft x 9 ft x 4½ ft), using the standard planing boat test procedure followed by Davidson Laboratory. The models were towed in the horizontal plane from a point at the bow on the extended shaft line. A realistic representation of the boats running attitude is achieved by the application of a vertical force at the tow point of sufficient magnitude to give a resultant towing force in the shaft line. Running wetted areas were determined at each speed by observation of waterplane intersections at keel, chine, and transom. Resistance measurements were made by visual observation of a deadweight-spring balance.

Included in the test program were tests of each model at a standard test condition prescribed by David Taylor Model Basin. In this condition, the displacement volume, ∇, is determined by the ratio of projected bottom area A, to ∇. A standard value of

$$\frac{A}{\nabla^{2/3}} = 7.0$$

is used for these tests. Further, the LCG is located 6% of the length aft of the centroid of the projected bottom area.

The Scheme A and Scheme B models were tested at four other displacements, each at level static trim. The Scheme C model was tested at level static trim at one other displacement.

Rough Water Tests

Rough water tests were conducted in Tank No. 3, using the free-to-surge servo-controlled apparatus described in ref. 1. In this apparatus, the application of a towing force to the model and auxiliary subcarriage causes a longitudinal displacement of the subcarriage with respect to the main carriage. This displacement in turn generates a signal through the servo-control system which causes an acceleration of the main carriage. Conversely, if the subcarriage is displaced in the opposite direction, the main carriage decelerated. Thus, in effect, the model proceeds down the tank under the action of a towing force free to check and surge as it encounters waves with the main carriage simply keeping pace with the mean speed of the subcarriage and model. The apparatus also permits the usual freedom in heave and pitch.

The following events were measured simultaneously and recorded on chart paper, using a light beam galvanometer oscillograph:

1) Acceleration at Station 0
2) Acceleration at CG
3) Wave profile at a fixed point in the tank
4) Instantaneous speed of model

Average speed was determined by measurement of elapsed time over 140 ft of run.

Inasmuch as determination of the added resistance due to waves was one of the primary test objectives, it was decided first to make a series of smooth water runs to define a curve of model resistance. This curve was then compared to a similar curve defined by the rough water model resistance, and the resistance increment determined. By following this procedure, it is felt that the effect of internal frictional losses in the apparatus were minimized. No forces were applied to simulate the vertical thrust component in either case.

The wave pattern employed in the rough water tests approximated in full size a State 3 sea whose average height is about 2.5 ft and whose average period is about 4.4 secs.

A fully-developed State 3 sea is generated by a wind of velocity 11-16 knots of about 6 hours in duration. To insure uniformity of the wave pattern, the period of 50 cycles of the wavemaker was measured on each run. Runs with unacceptable deviations of period were repeated. In addition, the model was started at the same point in the wave program for each run. As the model speed increased, the number of encounter cycles decreased; therefore, at the higher speeds (30, 35, 40 knots - full size), two runs were taken at each speed in different parts of the wave program in order to ensure a sufficiently long statistical sample.

Each model was tested at the full-size displacement of 55,000 lbs, level static trim. In addition, the Scheme A and Scheme B models were tested at 45,000 lbs with a bow-down trim and 55,000 lbs with a bow-up trim. Further tests were made with the appendages set shown in Fig. 4 installed in the Scheme A model and with bottom strips, also shown in Fig. 4, removed from the Scheme C model.

Black and white motion pictures were taken of representative test runs.

A summary of the experimental test program for each model, and model and ship characteristics for the various test conditions appear in Table I.

RESULTS

Calm Water Tests

Results of the tests of each model at the DTMB Standard condition are tabulated in model size in Figs. 1b, 2b and 3b based on these tests. Predictions for a ship at the standard comparison displacement of 100,000 lbs are displayed in Figs. 1c, 2c, and 3c.

Figures 5 through 8 compare predictions of EHP, Running Trim, and Rise at Stern for the 60,000 lb, 55,000 lb, 50,000 lb and 45,000 lb displacements. The poor performance of Scheme C led to the abbreviation of its test program; consequently, it appears only in the display for the 55,000 lb test, Fig. 6.

The charts show the following trends:

a) There is little significant difference between Scheme A and Scheme B in powering requirements. The largest differences on the order of 50 EHP, or less, appear at the heaviest displacement, 60,000 lb where Scheme A shows a slight advantage, except at the highest speeds.

b) Scheme B has somewhat larger running trims in the middle speed range of 20 - 30 knots. Differences here vary from about .4° at the light displacement, to .75° at the heaviest.

c) There is little significant difference in the Rise at Stern of Scheme A and B.

d) Scheme C has substantially greater EHP requirements and as much as several degrees larger running trims than the other designs. In the lower speeds, the transom squats as much as .75 ft deeper.

The poor performance of Scheme C model is of interest, particularly in view of its highly publicized design features which have been incorporated very successfully in 25-ft and 31-ft stock boats. First, some scale effects may be present in a model test of this type of design due to possible differences in the degree of ventilation of the bottom strips between model and ship. This is believed to be principally a small reduction in wetted area which may not be reflected in the model test. It is not considered to be a major source of error. The comparison shown in Fig. 6 is most probably quite a valid one.

The Scheme C design incorporates a transom of weak lifting ability, high deadrise, and bottom strips which may generate some additional lift in the lateral flow region of the stagnation line. All these features tend to produce larger trims, and indeed, this boat is a very "high trimmer." Many tests over a long period of time at Davidson Laboratory have indicated that the optimum trim for most planing craft lies in 3° - 4° range. Both Schemes A and B fall in this range over the middle and high speed range but Scheme C lies in 5° - 6° range. In a smaller boat operating at higher speed-length ratios, this might be desirable, for the boat would have a tendency to flatten out to the optimum trim at the high speeds. In a larger boat, however, it does not appear to be attractive.

The formidable array of appendages on the Scheme A model caused some concern. Normally, when the resistance of a ship is predicted from a model test with appendages using the usual extrapolation methods, the prediction is a little high. This tendency is shown by Clement in ref. 2, Figs. 4, 5 and 6. Resistance coefficients of the 1/5 and 1/10 scale appendage sets tend to show larger values at low Reynolds numbers than those indicated by the tests of the larger appendage models.

Since such a large amount of appendage was present on the Scheme A model extrapolation methods were changed in an effort to avoid the overprediction. Model appendage drag was known by simply subtracting Test 1B from Test 2A. The frictional component of this drag was estimated and expanded using an extrapolator line other than the Schoenherr line. The extrapolator line was adapted from information in ref. 3 on the drag of airfoil sections at lower Reynolds numbers and using a mean value of thickness to length ratio of .11. Reynolds numbers of each appendage component were determined using 95% of the free-stream velocity and the length of the appendage component in the direction of the flow. The extrapolator curve is shown in Fig. 9, and the results of the EHP expansion using this method are given in Fig. 10.

A check of this method gives C_r values consistent with those reported by Clement. It is felt, however, that the values are still somewhat high and that a steeper extrapolator curve would further improve the prediction. Further research in this area is certainly indicated.

Photographs of the models underway are given in Figs. 12-17. Of particular note here is the difference in the spray characteristics of the three models. Scheme B throws the spray out and down more than Scheme A, while the bottom strips of Scheme C are quite effective in breaking up the spray.

Pertinent data from all the calm water tests other than the DTMB standard conditions appear in Table II.

Rough Water Tests

The method of determining the increment of model resistance in waves has been described earlier. Results are presented in Fig. 17, showing the effective horsepower increment, ΔEHP, obtained by expanding the model increment by λ^3, and the Total Effective Horsepower obtained by adding ΔEHP to the calm water EHP curves presented in Fig. 6.

The results show that Scheme A has a somewhat lower increment at high speeds than Scheme B. Scheme C has a significantly lower increment but the higher calm water resistance still gives a greater total EHP requirement than either Schemes A or B, except at the highest speed.

Accelerations at the center of gravity were measured by an accelerometer mounted on the servo carriage which was pivoted at the model CG (see frontispiece). Unfortunately, the vibration of the mast generated a background noise on the records which defeated any useful reduction of these data; consequently, no information on CG acceleration is presented.

Accelerations at Station 0 were not subject to the same difficulty. A comparison of these results in head seas is displayed in Figs. 18-20 and for the three basic wave test conditions. Since Scheme C was tested only at 55,000 lbs, level trim, these results appear only in Fig. 20.

The presentation shows two statistics: the average of all acceleration cycles, and the average of the 10% largest acceleration cycles. Accelerations occurring on the half cycle during which the bow is displaced down are identified by "bow pitching down" on the charts. It is during this half cycle that the severe impacts and slams occur. Accelerations on the other half cycle are much more moderate.

In interpreting these wave test results, it should be borne in mind that they do not constitute as precise a prediction of full-size behavior as in the case of the calm water tests. They are valid primarily as a basis of comparison between models. Variations in model construction, wave pattern encountered, and in fact, the accelerometer used - could all have an effect on results in any particular sea state.

The results indicate that for each of the test conditions, the Scheme B model encountered larger bow accelerations than the Scheme A model. In the high speed range, the differences were generally smaller. In the 55,000 lb level trim test, the Scheme C model encountered substantially larger accelerations than either Schemes A or B. This fact was visually evident during the tests and is confirmed by the motion pictures. It is attributed to the high trim characteristics of the Scheme C model. With a large initial angle of attack, the model had a very distinct tendency to lift off the crest of one wave and slow down on the fact of the next. The frontispiece shows such an encounter.

The effect on bow accelerations of adding the appendage set to the Scheme A model is shown in Fig. 21. Lower accelerations are encountered in the high speed range with the appendages installed. There are two factors which probably affect this:

a) the unusually large appendage set which includes a long horizontal skid may introduce some motions damping

b) the appendages caused some reduction in calm water trims at high speeds.

Figure 22 indicates that when the bottom strips are removed from the Scheme C model, lower accelerations are encountered. Again, removal of the strips resulted in a reduction of the running trims. This reduction is the probable explanation for the reduction in acceleration amplitude.

The Scheme A model was tested in following seas at speeds up to 30 knots. The accelerations were virtually zero throughout most of this speed range. It did not seem worthwhile to continue these tests with the Scheme B model.

ACKNOWLEDGMENTS

The assistance of Mrs. Helen W. Sheridan and Mrs. Vera Holland in the preparation and publication of this report is acknowledged.

REFERENCES

1. Savitsky, D.: "High Speed Tests in Waves at Davidson Laboratory," DL Report 756, August 1959.

2. Clement, E. P.: "Scale Effect on the Drag of a Typical Set of Planing Boat Appendages," DTMB Report No. 1165, August 1957.

3. Hoerner, Sighard F.: Fluid Dynamic Drag, c. 1958, Midland Park, N.J.

TABLE I

MODEL CHARACTERISTICS AND
EXPERIMENTAL PROGRAM

SCHEME A	Model	Ship
Length over-all, L, ft	3.25	52.00
Length bet. perps. LBP	2.97	47.50
Projected chine length, L_p, ft	3.031	48.50
Beam over chines, B_{px}, ft	0.732	11.71

Calm Water Tests

	Model	Ship	Model	Ship	Model	Ship	Model	Ship	Model	Ship	Model	Ship
Test No.	1A		1B		1C		1D		1E*		2A	
Displacement, Δ, lbs	14.26	60,000	13.07	55,000	11.88	50,000	10.70	45,000	8.30	34,920	13.07	55,000
Static Trim angle, τ, degs	0		0		0		0		.77° bow up		0	
Draft, mean to ℄, ft	.327	5.24	.317	5.07	.308	4.93	.297	4.75	.273	4.37	.317	5.07
LCG, ft aft Station 5	.174	2.79	.174	2.79	.176	2.81	.183	2.92	.270	4.32	.188	3.01
Appendages	none		none		none		none		none		shafts struts rudders	

Rough Water Tests

	Model	Ship	Model	Ship	Model	Ship	Model	Ship
Test No.	1F		2B		2C		2D	
Displacement, Δ, lbs	13.07	55,000	13.07	55,000	13.07	55,000	10.70	45,000
Static Trim angle, τ, degs	0		0		.66° bow up		.66° bow down	
LCG, ft aft Station 5	.174	2.79	.174	2.79	.238	3.81	.119	1.90
Radius of Gyration	27.6% LBP		27.6% LBP		26.1% LBP		28% LBP	
Appendages	none		shafts struts rudders		shafts struts rudders		shafts struts rudders	

SCHEME B

	Model	Ship
Length over-all, L, ft	3.25	52.00
Length bet. perps. LBP, ft	2.97	47.50
Projected chine length, L_p, ft	3.02	48.40
Beam over chines, B_{px}, ft	0.750	12.00

Calm Water Tests

	Model	Ship	Model	Ship	Model	Ship	Model	Ship	Model	Ship
Test No.	1A		1B		1C		1D		1E	
Displacement, Δ, lbs	14.26	60,000	13.07	55,000	11.88	50,000	10.70	45,000	8.90	37,440
Static Trim angle, τ, degs	0		0		0		0		.66° bow up	
Draft, mean to ℄, ft	.340	5.44	.332	5.31	.320	5.12	.308	4.93	.290	4.65
LCG, ft aft Station 5	.188	3.01	.188	3.00	.192	3.07	.195	3.12	.272	4.36
Appendages	none		none		none		none		none	

Rough Water Tests

	Model	Ship	Model	Ship	Model	Ship
Test No.	1F		1G		1H	
Displacement, Δ, lbs	13.07	55,000	13.07	55,000	10.70	45,000
Static Trim angle, τ, degs	0		.66° bow up		.66° bow down	
LCG, ft aft Station 5	.188	3.01	.251	4.01	.124	1.98
Radius of Gyration	27.2% LBP		26.3% LBP		27.6% LBP	
Appendages	none		none		none	

SCHEME C

	Model	Ship
Length over-all, L, ft	3.25	52.00
Length bet. perps. L_{BP}, ft	2.97	47.50
Projected chine length, L_p, ft	3.12	50.00
Beam over chines, B_{px}, ft	0.89	14.26

Calm Water Tests

	Model	Ship	Model	Ship
Test No.	1A		1B	
Displacement, Δ, lbs	13.07	55,000	11.26	47,370
Waterline length, L, ft	3.01	48.08	2.96	47.37
Static Trim angle, τ, deg	0		1.62	
Draft mean to ℄, ft	.325	5.20	.328	5.25
LCG, ft aft Station 5	.264	4.23	.344	5.51
Appendages	longitudinal strips		longitudinal strips	

Rough Water Tests

	Model	Ship	Model	Ship
Test No.	1F		1G	
Displacement, Δ, lbs	13.07	55,000	13.07	55,000
Static Trim angle, τ, deg	0		0	
LCG, ft aft Station 5	.264	4.23	.264	4.23
Radius of Gyration	25.5% LBP		25.5% LBP	
Appendages	longitudinal strips		none	

TABLE II

RESULTS OF CALM WATER TESTS

SCHEME A

Model Speed ft/sec	Ship Speed Knots	Test 1A - temp 70.0° Model R_t lbs	Model S ft²	Ship EHP	Ship τ deg	Ship Rise at Stern ft	Test 1B - temp 70.5° Model R_t lbs	Model S ft²	Ship EHP	Ship τ deg	Ship Rise at Stern ft	Test 1C - temp 70.5° Model R_t lbs	Model S ft²	Ship EHP	Ship τ deg	Ship Rise at Stern ft
4.16	9.85	.751	2.613	86	.55	- .60	.720	2.562	83	.60	- .53	.686	2.537	78	.50	- .40
8.97	19.58	2.012	2.[illegible]	455	3.80	-1.33	1.830	2.297	411	3.50	-1.00	1.679	2.171	376	3.10	- .93
10.61	25.13	2.308	2.[illegible]	652	4.30	- .80	2.140	2.180	597	4.00	- .80	1.968	2.062	546	3.50	- .67
12.96	30.68	2.402	1.8[illegible]	808	4.45	- .40	2.235	1.830	742	4.20	- .47	2.111	1.730	701	3.50	- .33
14.71	34.85	2.572	1.773	963	4.15	- .13	2.402	1.700	894	3.85	- .13	2.311	1.720	851	3.20	- .07
17.06	40.36	2.924	1.660	1252	3.50	+ .13	2.696	1.700	1129	3.30	+ .20	2.672	1.760	1105	2.90	+ .20

Model Speed ft/sec	Ship Speed Knots	Test 1D - temp 70.5° Model R_t lbs	Model S ft²	Ship EHP	Ship τ deg	Ship Rise at Stern ft	Test 2A - temp 70.5° Model R_t lbs	Model S ft²	Ship EHP	Ship τ deg	Ship Rise at Stern ft
4.16	9.85	.629	2.486	71	.55	- .47	.810	1.858	85	.38	- .27
8.97	19.58	1.498	2.093	331	2.80	- .87	2.155	2.223	443	3.61	- .87
10.61	25.13	1.782	2.040	487	2.90	- .40	2.557	2.100	659	4.23	- .67
12.96	30.68	1.998	1.780	655	3.00	- .20	2.922	1.758	916	3.92	- .27
14.71	34.85	2.237	1.700	820	2.80	0	3.290	1.700	1766	3.61	0
17.06	40.36	2.589	1.630	1084	2.40	+ .27	3.936	1.650	1619	3.15	+ .33

NOTES:

1. EHP predictions based on Schoenherr friction formulation using a roughness allowance of 0.4×10^{-3}.
2. All running trims, τ, measured in respect to attitude of ship as drawn.
3. Rise of stern measured in respect to static waterline.
4. Model wetted area, S, obtained by visual observation of waterplane intersections at keel, chine, and transom.

TABLE II (Continued)

SCHEME B

Model Speed ft/sec	Ship Speed Knots	Test 1A - temp 70.5° Model R_t lbs	Test 1A Model S ft²	Test 1A Ship EHP	Test 1A Ship τ deg	Test 1A Ship Rise at Stern ft	Test 1B - temp 70.5° Model R_t lbs	Test 1B Model S ft²	Test 1B Ship EHP	Test 1B Ship τ deg	Test 1B Ship Rise at Stern ft	Test 1C - temp 70.5° Model R_t lbs	Test 1C Model S ft²	Test 1C Ship EHP	Test 1C Ship τ deg	Test 1C Ship Rise at Stern ft
4.16	9.85	.822	2.649	95	.45	- .47	.759	2.649	87	.55	- .47	.710	2.567	81	.55	- .40
5.92	14.02															
8.97	19.58	2.139	2.390	487	4.15	-1.07	1.901	2.294	428	3.90	-1.07	1.702	2.301	378	3.50	- .87
9.43	22.33	2.248	2.385	571	4.75	-1.07	2.043	2.342	513	4.00	- .80	1.849	2.255	460	3.50	- .67
10.61	25.13	2.369	2.173	671	5.05	- .93	2.112	2.126	590	4.50	- .80	1.931	2.110	532	3.85	- .60
12.96	30.68	2.480	1.690	850	4.75	- .40	2.249	1.730	756	3.90	- .20	2.087	1.740	692	3.85	- .27
14.71	34.84	2.557	1.730	961	4.00	+ .07	2.397	1.670	895	3.75	0	2.268	1.670	838	3.45	0
17.06	40.39	2.819	1.640	1203	3.45	+ .33	2.725	1.620	1156	3.50	+ .07	2.638	1.590	1117	2.90	+ .33

Model Speed ft/sec	Ship Speed Knots	SCHEME B Test 1D - temp 70.0° Model R_t lbs	Model S ft²	Ship EHP	Ship τ deg	Ship Rise at Stern ft	SCHEME C Test 1A - temp 71° Model R_t lbs	Model S ft²	Ship EHP	Ship τ deg	Ship Rise at Stern ft
4.16	9.85	.681	2.542	78	.60	- .47					
5.92	14.02						1.716	2.28	289	4.13	-1.60
8.97	19.58	1.499	2.233	328	3.14	- .80	2.191	2.16	503	5.80	-1.60
9.43	22.33	1.639	2.212	401	3.24	- .53	2.318	1.74	608	6.26	-1.07
10.61	25.13	1.747	2.039	475	3.60	- .53	2.392	1.66	695	6.40	- .93
12.96	30.68	1.952	1.730	639	3.24	- .13	2.527	1.53	873	5.89	- .47
14.71	34.84	2.151	1.640	788	3.06	0	2.633	1.42	1016	5.43	- .07
17.06	40.39	2.582	1.590	1086	2.62	+ .33	2.772	1.27	1219	4.96	+ .27

NOTES:
1. EHP predictions based on Schoenherr friction formulation using a roughness allowance of 0.4×10^{-3}.
2. All running trims, τ, measured in respect to attitude of ship as drawn.
3. Rise of stern measured in respect to static waterline.
4. Model wetted area, S, obtained by visual observation of waterplane intersections at keel, chine, and transom.

Davidson Laboratory
Stevens Institute of Technology

SMALL CRAFT DATA SHEET

Hard-chine boat, $L_p/B_{px} = 4.09$
Model No. DL-2389
Model of BuShips 52ft LCSR, Scheme A

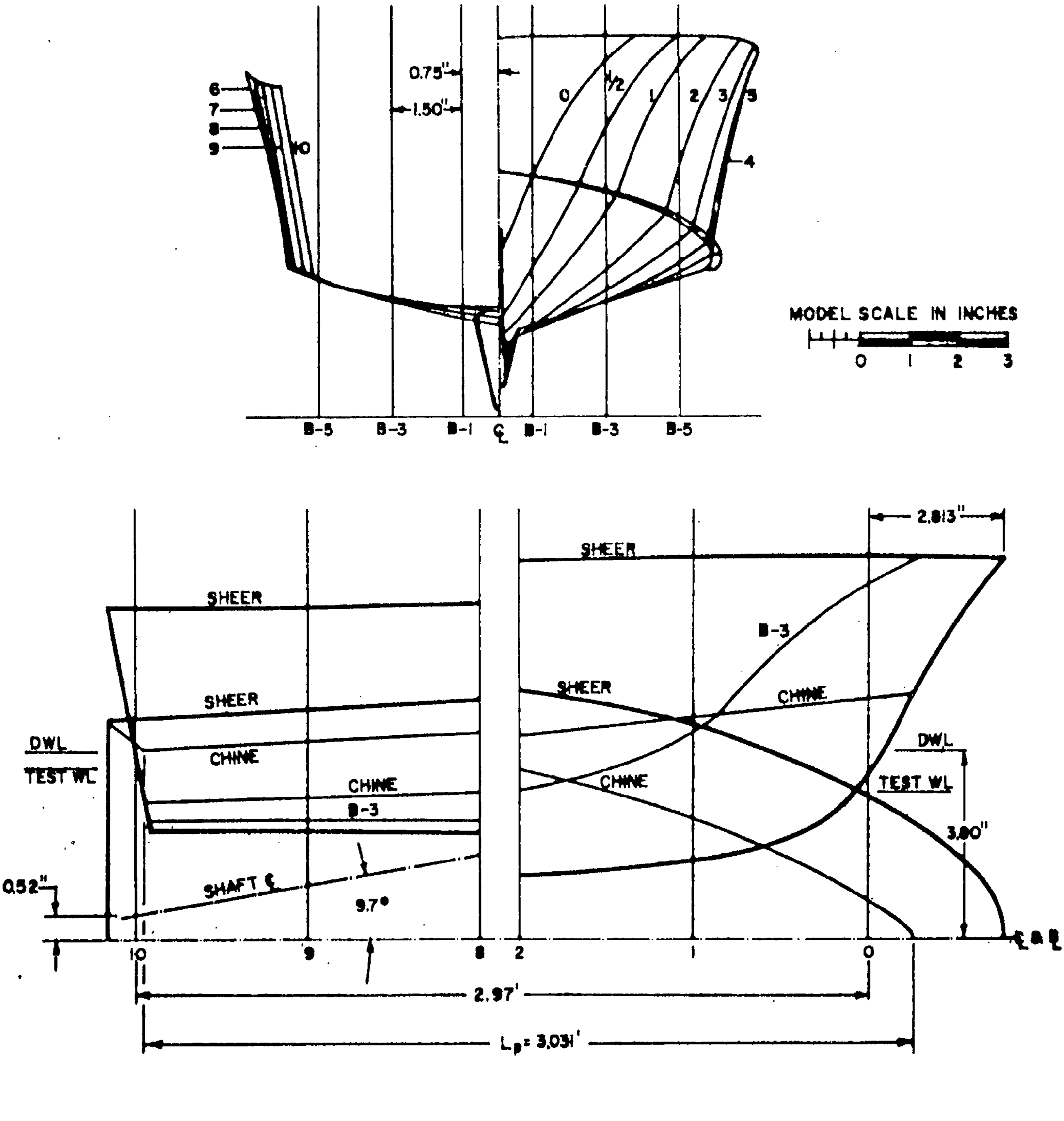


FIGURE 1-A

MODEL PARTICULARS, TEST CONDITIONS, AND RESULTS

Boat 52-ft. LCSR
Scheme A
Model Number DL 2389
Appendages Spray strips

Laboratory Davidson Laboratory
Basin Tank No. 1
Basin Size 100'x9'x4-1/2'
Model Length 3.25 ft
Test 1-E **Date** 4 Jan. 1961

Water Temperature 70 deg.
Specific Weight 62.3 lbs/ft^3
Model Material Pine
Model Finish Varnish
Turbulence Stimul. .04" Strut

Remarks: Model was towed in the shaft line shown in the profile drawing.

Planing Bottom Dimensions and Coefficients

L_P 3.03 ft
B_{PX} 0.74 ft
B_{PA} 0.603 ft
A_P 1.827 ft^2
$A_P/\nabla^{2/3}$ 7.00
$L_P/\nabla^{1/3}$ 5.93
L_P/B_{PA} 5.02

LWL Dimensions and Coefficients

L
B_X
H
L/B_X
$L/\nabla^{1/3}$
C_B
C_P
C_W

Model Test Condition

Δ, lb 8.30 τ_0 .75° α_0 .75°

LCG location 1.214' forward of Station 10
(LCG location 6.0 percent L_P aft of centroid of A_P)

Model Test Results

V, knots	R_t, lb	Wetted length of keel, ft	Wetted length of chine, ft	Re x 10^{-6}	S, ft^2	10^3 C_t	Change of trim, deg	CG rise, in.	F_∇
2.463	.517	2.92	1.00	1.159	1.605	19.92	0.93	-.12	1.026
3.855	.898	2.87	1.92	1.783	1.992	10.98	2.23	+.02	1.605
4.896	1.093	2.83	1.67	2.233	1.899	8.695	2.45	+.23	2.038
5.583	1.228	2.79	1.67	2.511	1.861	7.661	2.30	+.34	2.324
6.283	1.320	2.83	1.50	2.865	1.788	6.773	2.30	+.39	2.615
6.974	1.459	2.75	1.42	3.091	1.642	6.617	2.38	+.51	2.903
7.669	1.561	2.75	1.33	3.400	1.60	6.002	2.15	+.55	3.193
8.015	1.660	2.75	1.33	3.553	1.60	5.843	2.24	+.57	3.338
8.710	1.806	2.75	1.33	3.861	1.60	5.381	2.00	+.61	3.627
9.406	2.038	2.75	1.25	4.169	1.56	5.343	1.77	+.70	3.916
10.097	2.240	2.75	1.25	4.476	1.56	5.097	1.54	+.69	4.205

FIGURE 1-B.

PERFORMANCE CHARACTERISTICS

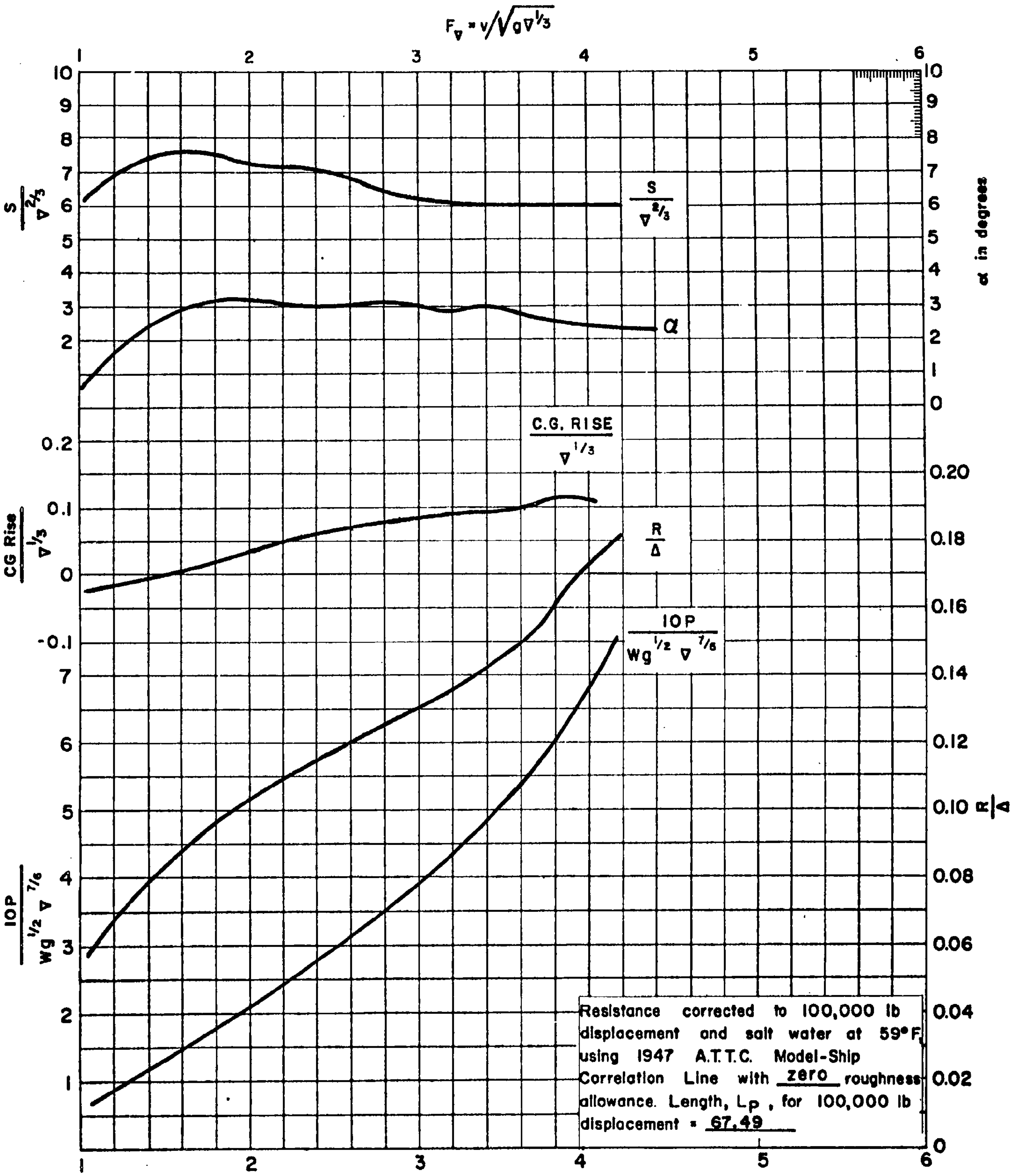
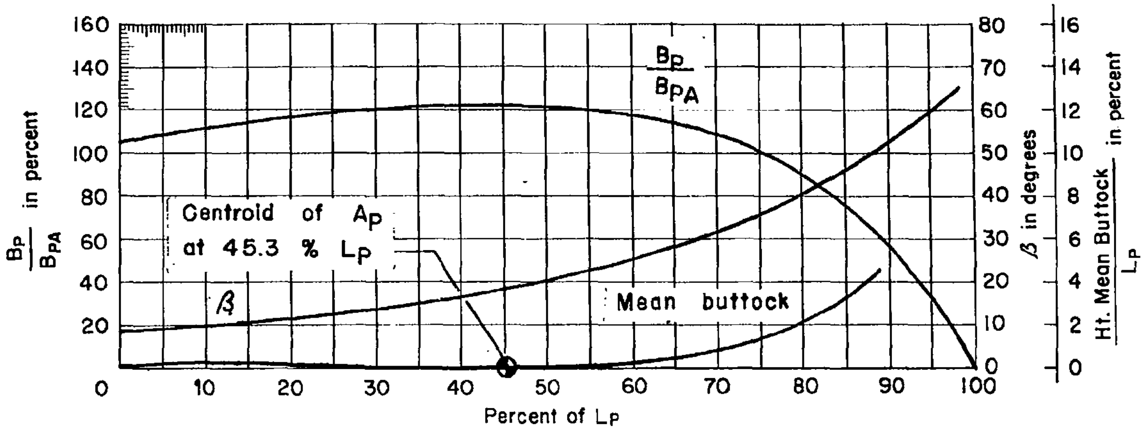
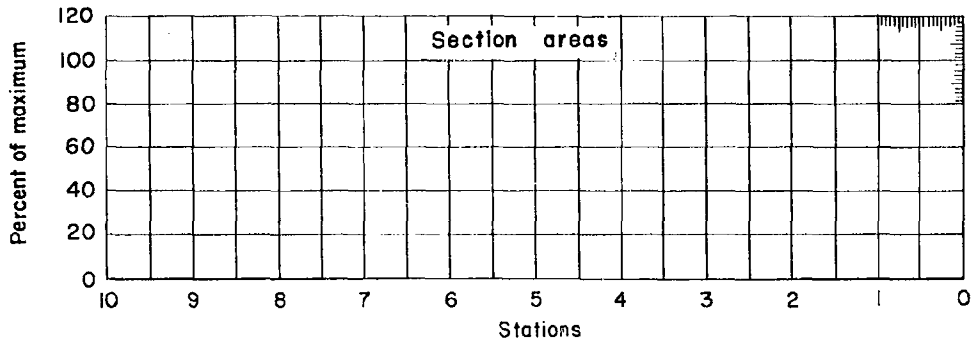


FIGURE 1-C

R-854

FORM CHARACTERISTICS





——— Notation ———

As far as possible the notation used is consistent with the Society's "Explanatory Notes for Resistance and Propulsion Data Sheets" (Technical and Research Bulletin No. 1-13). Exceptions and additions are listed below. The subscript *P* designates the planing bottom which is the portion of the bottom bounded by the chines and transom.

A_P	Projected planing bottom area, excluding area of external spray strips
B_P	Beam or breadth over chines, excluding external spray strips
B_{PA}	Mean breadth over chines, A_P/L_P
B_{PX}	Maximum breadth over chines, excluding external spray strips
L_P	Projected chine length
S	Area of wetted surface (This is the actual wetted surface underway including the area of the sides which is wetted at low speeds and the wetted bottom area of external spray strips; however, the area wetted by spray is excluded).
α	Angle of attack of stern portion of planing bottom in degrees
β	Dead rise angle of planing bottom in degrees. This angle is obtained by approximating each body plan section by a straight line.
Δ	Displacement at rest, weight of
τ	Trim angle of hull with respect to attitude as drawn in degrees
∇	Displacement at rest, volume of

Subscript *0* indicates value when hull is at rest in water.

FIGURE 1-D

Davidson Laboratory

Stevens Institute of Technology

SMALL CRAFT DATA SHEET

Hard-chine boat, $L_p/B_{px} = 4.03$

Model No. DL-2387

Model of BuShips 52ft LCSR, Scheme B

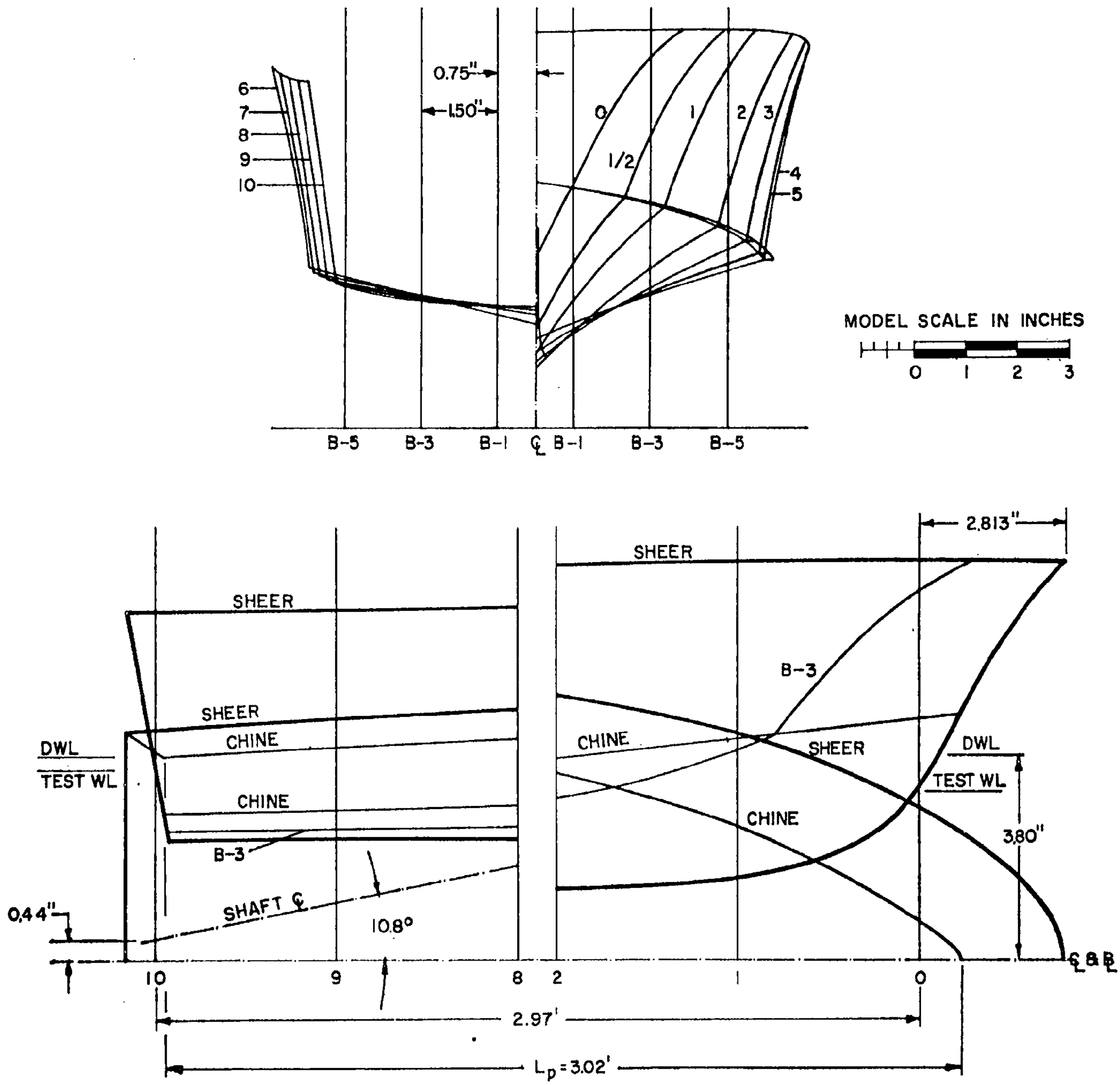


FIGURE 2-A

R-854

MODEL PARTICULARS, TEST CONDITIONS, AND RESULTS

Boat 52-ft. LCSR
Scheme B
Model Number DL 2387
Appendages Spray strips

Laboratory DAVIDSON LABORATORY
Basin Tank No. 1
Basin Size 100'x9x4-1/2
Model Length 3.25 ft.
Test 1-E **Date** 12 Jan. 1961

Water Temperature 70 deg.
Specific Weight 62.3 lb/ft^3
Model Material Pine
Model Finish Varnish
Turbulence Stimul. .04" Strut

Remarks: Model was towed in the shaft line shown in the profile drawing.

Planing Bottom Dimensions and Coefficients

L_P 3.02 ft
B_{PX} 0.75 ft
B_{PA} 0.636 ft
A_P 1.921 ft^2
$A_P/\nabla^{2/3}$ 7.00
$L_P/\nabla^{1/3}$ 5.77
L_P/B_{PA} 4.75

LWL Dimensions and Coefficients

L
B_X
H
L/B_X
$L/\nabla^{1/3}$
C_B
C_P
C_W

Model Test Condition

Δ, lb 8.90 τ_0 .66° α_0 .66°

LCG location 1.212' forward of Station 10
(LCG location 6.0 percent L_p aft of centroid of A_p)

Model Test Results

V, knots	R_t, lb	Wetted length of keel, ft	Wetted length of chine, ft	Re x 10^{-6}	S, ft^2	10^3 C_t	Change of trim, deg	CG rise, in.	F_∇
2.463	.59	2.96	3.02	1.168	2.52	13.97	.93	-.17	1.013
3.855	1.030	2.87	2.00	1.772	2.22	11.30	2.60	+.06	1.586
4.896	1.218	2.83	1.87	2.218	2.05	8.99	2.68	+.23	2.013
6.283	1.432	2.79	1.58	2.806	1.80	7.32	2.90	+.54	2.583
6.974	1.559	2.75	1.42	3.070	1.64	7.08	2.76	+.65	2.868
7.669	1.688	2.75	1.33	3.377	1.60	6.49	2.68	+.68	3.155
8.015	1.762	2.71	1.29	3.478	1.57	6.32	2.38	+.76	3.297
8.710	1.908	2.71	1.25	3.779	1.56	5.83	2.30	+.79	3.582
9.406									
10.097	2.389	2.71	1.21	4.381	1.54	5.51	1.63	+.86	4.153

FIGURE 2-B.
R-854

PERFORMANCE CHARACTERISTICS

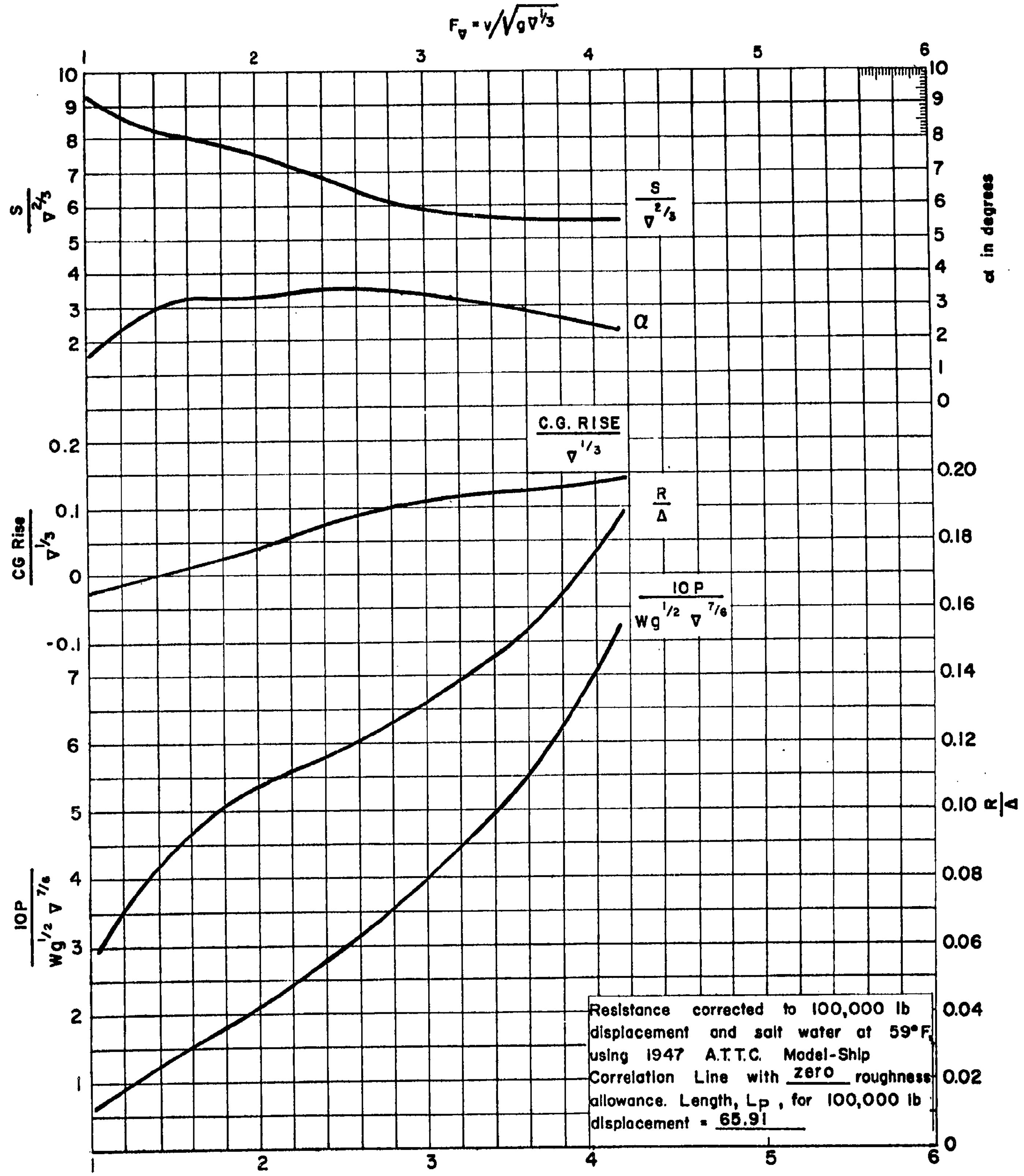
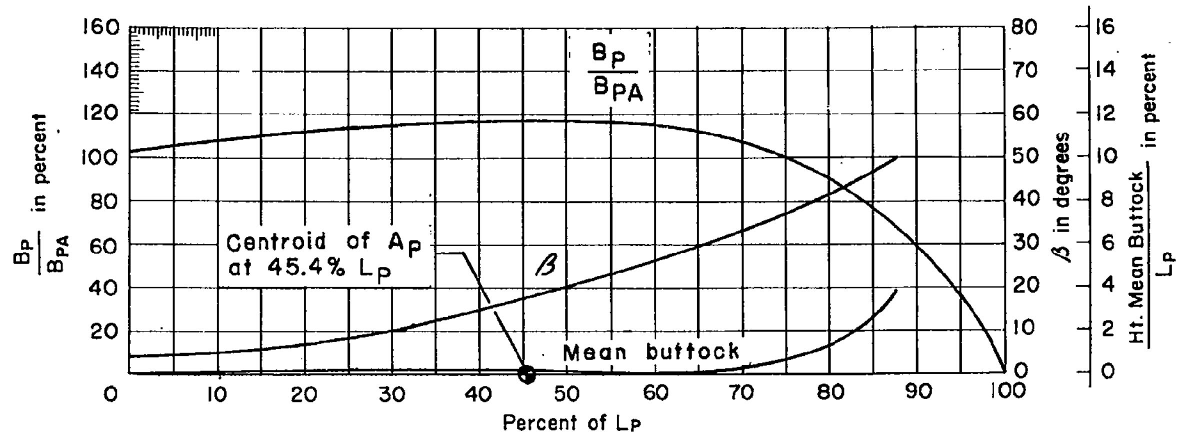
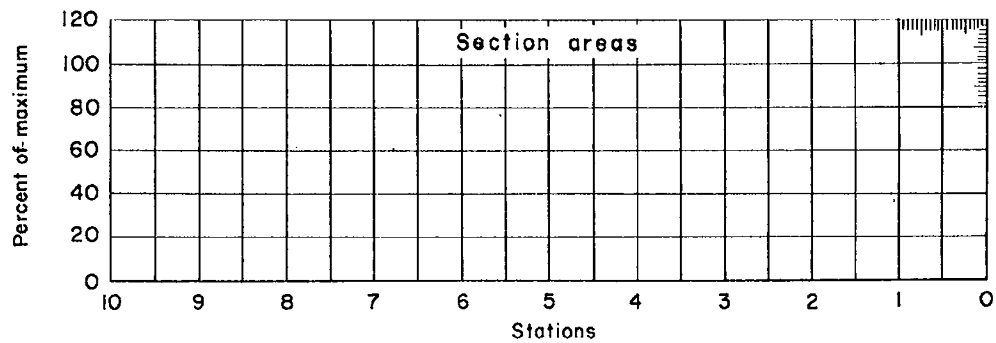


FIGURE 2-C

R-854

FORM CHARACTERISTICS





Notation

As far as possible the notation used is consistent with the Society's "Explanatory Notes for Resistance and Propulsion Data Sheets" (Technical and Research Bulletin No. 1-13). Exceptions and additions are listed below. The subscript *P* designates the planing bottom which is the portion of the bottom bounded by the chines and transom.

A_P	Projected planing bottom area, excluding area of external spray strips
B_P	Beam or breadth over chines, excluding external spray strips
B_{PA}	Mean breadth over chines, A_P/L_P
B_{PX}	Maximum breadth over chines, excluding external spray strips
L_P	Projected chine length
S	Area of wetted surface (This is the actual wetted surface underway including the area of the sides which is wetted at low speeds and the wetted bottom area of external spray strips; however, the area wetted by spray is excluded).
α	Angle of attack of stern portion of planing bottom in degrees
β	Dead rise angle of planing bottom in degrees. This angle is obtained by approximating each body plan section by a straight line.
Δ	Displacement at rest, weight of
τ	Trim angle of hull with respect to attitude as drawn in degrees
∇	Displacement at rest, volume of

Subscript *o* indicates value when hull is at rest in water.

FI 'RE 2-D

Davidson Laboratory
Stevens Institute of Technology
SMALL CRAFT DATA SHEET
Hard-chine boat, $L_p/B_{px} = 3.51$
Model No. TMB-4876
Model of BuShips 52ft LCSR, Scheme C

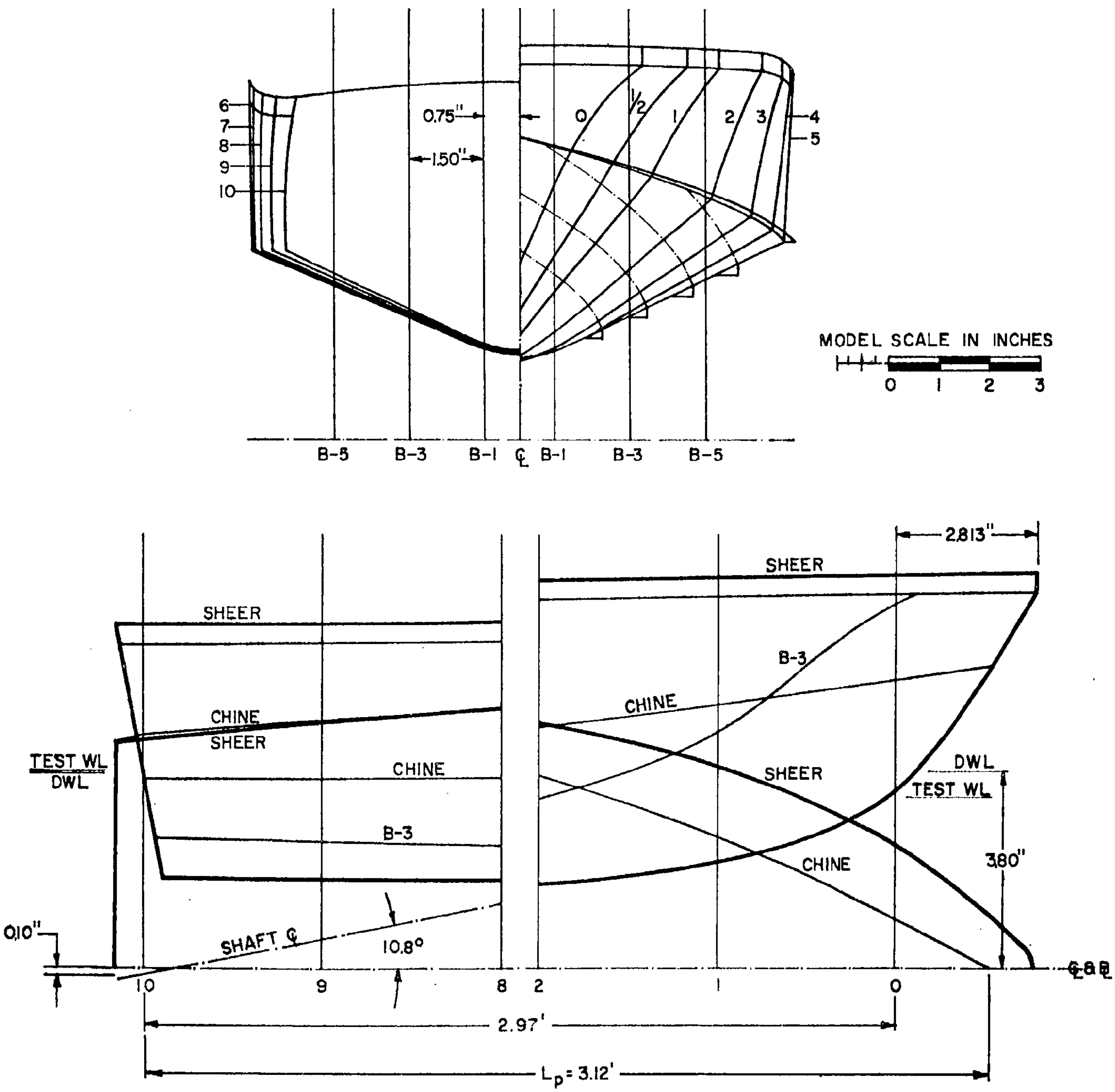


FIGURE 3-A

MODEL PARTICULARS, TEST CONDITIONS, AND RESULTS

Boat: 52-ft LCSR Scheme C
Model Number: DTMB 4876
Appendages: Spray strips

Laboratory: Davidson Laboratory
Basin: Tank No. 1
Basin Size: 100'x9'x4½'
Model Length: 3.25 ft.
Test: 1B Date: 28 Mar 61

Water Temperature: 70.5°
Specific Weight: 62.3 lb/ft³
Model Material: Balsa
Model Finish: Resin and paint
Turbulence Stimul.: .04" strut

Remarks: Model was towed in the shaft line shown in the profile drawing.

Planing Bottom Dimensions and Coefficients

L_P: 3.12 ft
B_{PX}: 0.89 ft
B_{PA}: 0.72 ft
A_P: 2.24 ft²
$A_P/\nabla^{2/3}$: 7.00
$L_P/\nabla^{1/3}$: 5.51
L_P/B_{PA}: 4.33

LWL Dimensions and Coefficients

L
B_X
H
L/B_X
$L/\nabla^{1/3}$
C_B
C_P
C_W

Model Test Condition

Δ, lb: 11.26 τ_0: .80° α_0: .80°

LCG location 1.14' forward of Station 10
(LCG location 6 percent L_P aft of centroid of A_P)

Model Test Results

V, knots	R_t, lb	Wetted length of keel, ft	Wetted length of chine, ft	Re x 10^{-6}	S, ft²	10^3 C_t	Change of trim, deg	CG rise, in.	F_∇
2.463	.700	2.96	1.00	1.174	1.90	21.98	1.4	-.12	.975
3.505	1.545	2.62	1.71	1.479	2.07	21.98	4.3	.09	1.387
4.201	1.791	2.50	1.58	1.691	1.96	18.75	5.4	.31	1.662
4.896	1.928	2.42	1.42	1.908	1.84	15.83	5.9	.57	1.937
5.583	2.011	2.17	1.25	1.950	1.64	14.24	6.0	.89	2.209
6.283	2.059	2.08	1.17	2.104	1.55	12.19	6.2	1.08	2.486
6.974	2.107	2.00	1.04	2.246	1.45	10.82	5.7	1.16	2.760
7.669	2.146	1.96	0.92	2.420	1.37	9.636	5.4	1.29	3.035
8.710	2.240	1.92	0.79	2.693	1.29	8.284	5.0	1.34	3.447
9.406	2.365	1.87	0.71	2.832	1.22	7.928	4.8	1.35	3.722
10.097	2.544	1.87	0.67	3.041	1.21	7.462	4.6	1.36	3.996

FIGURE 3-B.

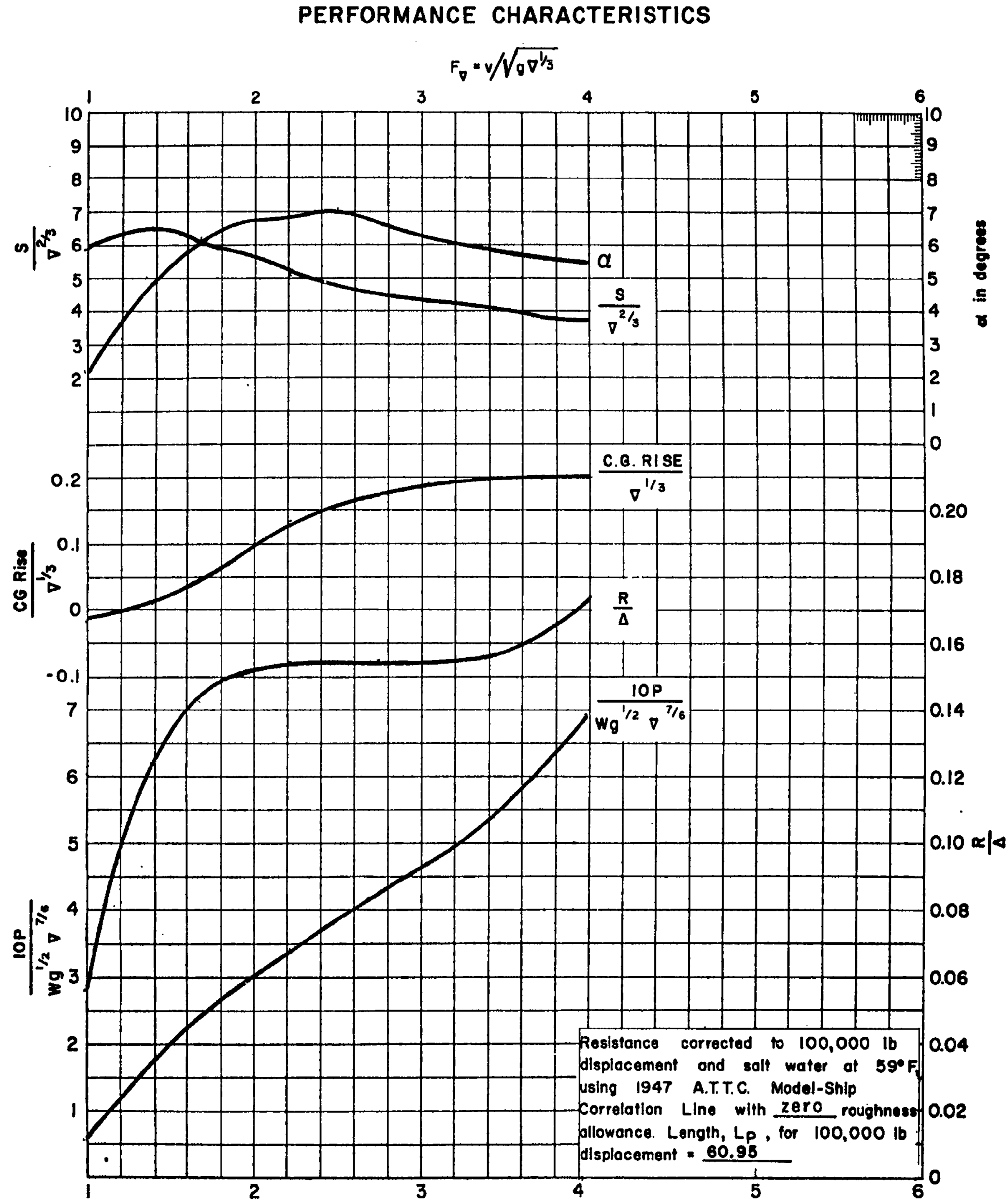
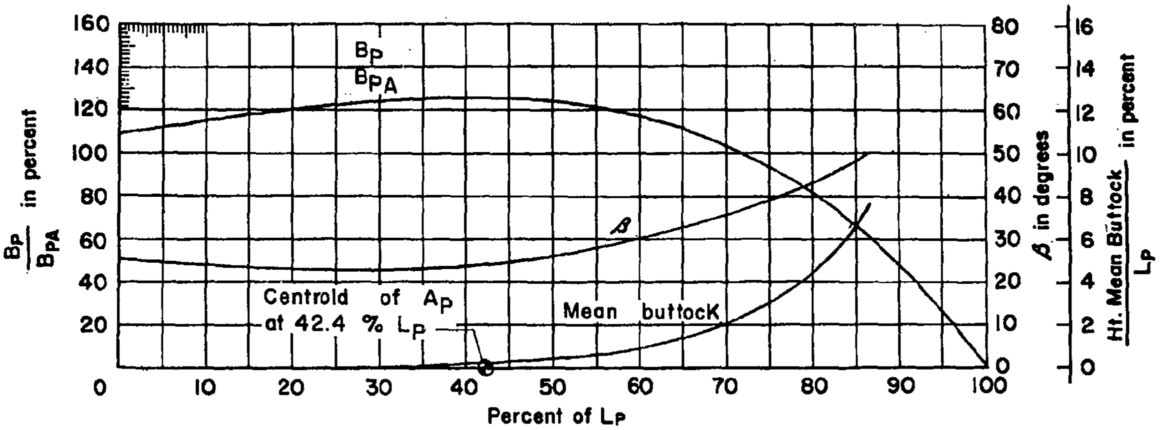
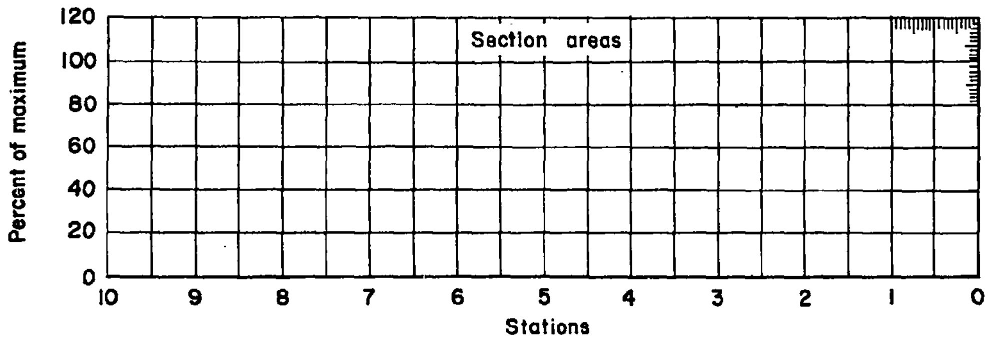


FIGURE 3-C

R-854

FORM CHARACTERISTICS





—— Notation ——

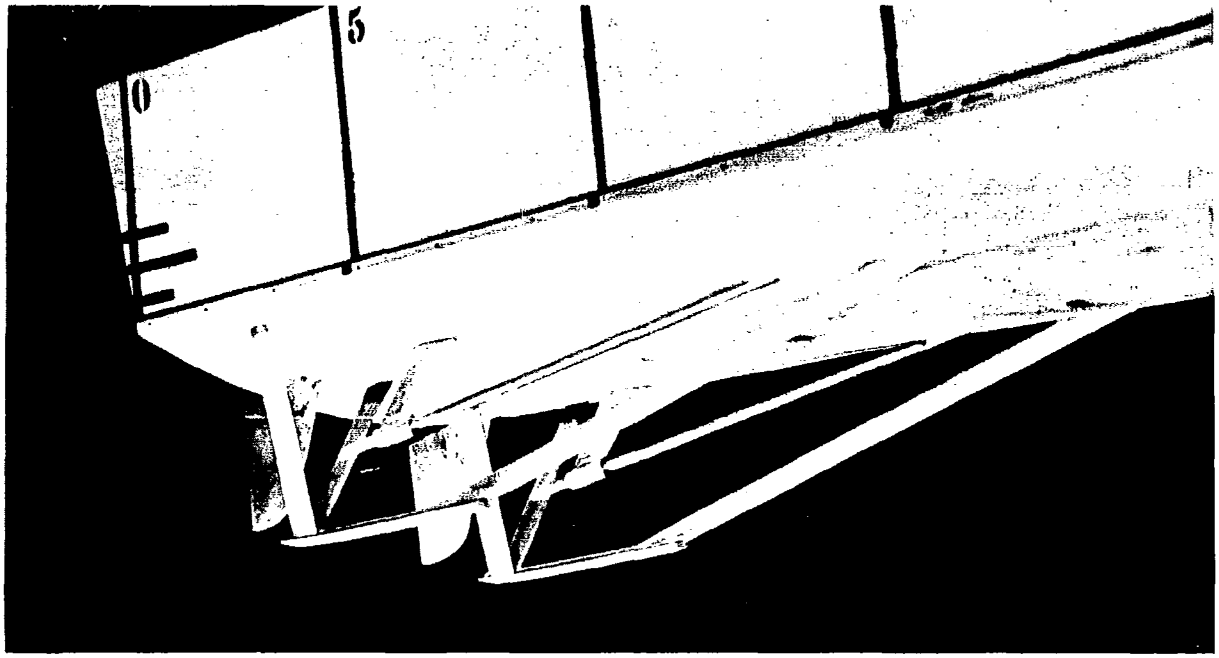
As far as possible the notation used is consistent with the Society's "Explanatory Notes for Resistance and Propulsion Data Sheets" (Technical and Research Bulletin No. 1-13). Exceptions and additions are listed below. The subscript P designates the planing bottom which is the portion of the bottom bounded by the chines and transom.

- A_P — Projected planing bottom area, excluding area of external spray strips
- B_P — Beam or breadth over chines, excluding external spray strips
- B_{PA} — Mean breadth over chines, A_P/L_P
- B_{PX} — Maximum breadth over chines, excluding external spray strips
- L_P — Projected chine length
- S — Area of wetted surface (This is the actual wetted surface underway including the area of the sides which is wetted at low speeds and the wetted bottom area of external spray strips; however, the area wetted by spray is excluded)..
- α — Angle of attack of stern portion of planing bottom in degrees
- β — Dead rise angle of planing bottom in degrees. This angle is obtained by approximating each body plan section by a straight line.
- Δ — Displacement at rest, weight of
- τ — Trim angle of hull with respect to attitude as drawn in degrees
- ∇ — Displacement at rest, volume of

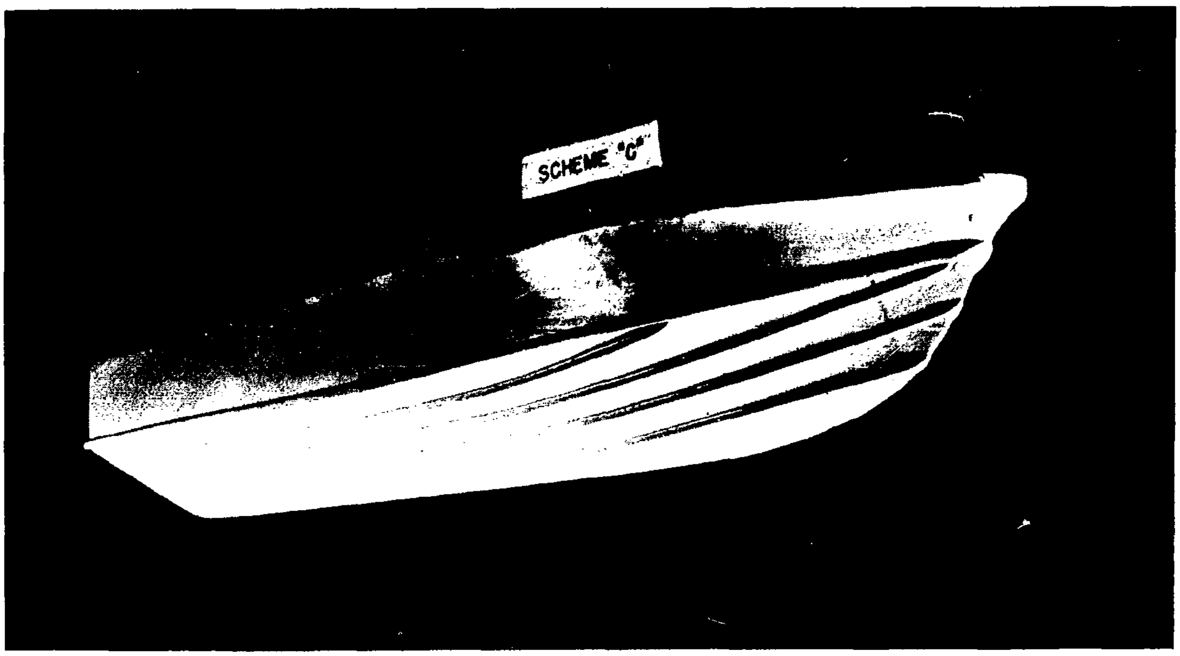
Subscript o indicates value when hull is at rest in water.

FIGURE 3-D

R-854



APPENDAGE CONFIGURATION ON SCHEME A MODEL



ARRANGEMENT OF LONGITUDINAL STRIPS ON SCHEME C MODEL

FIGURE 4.

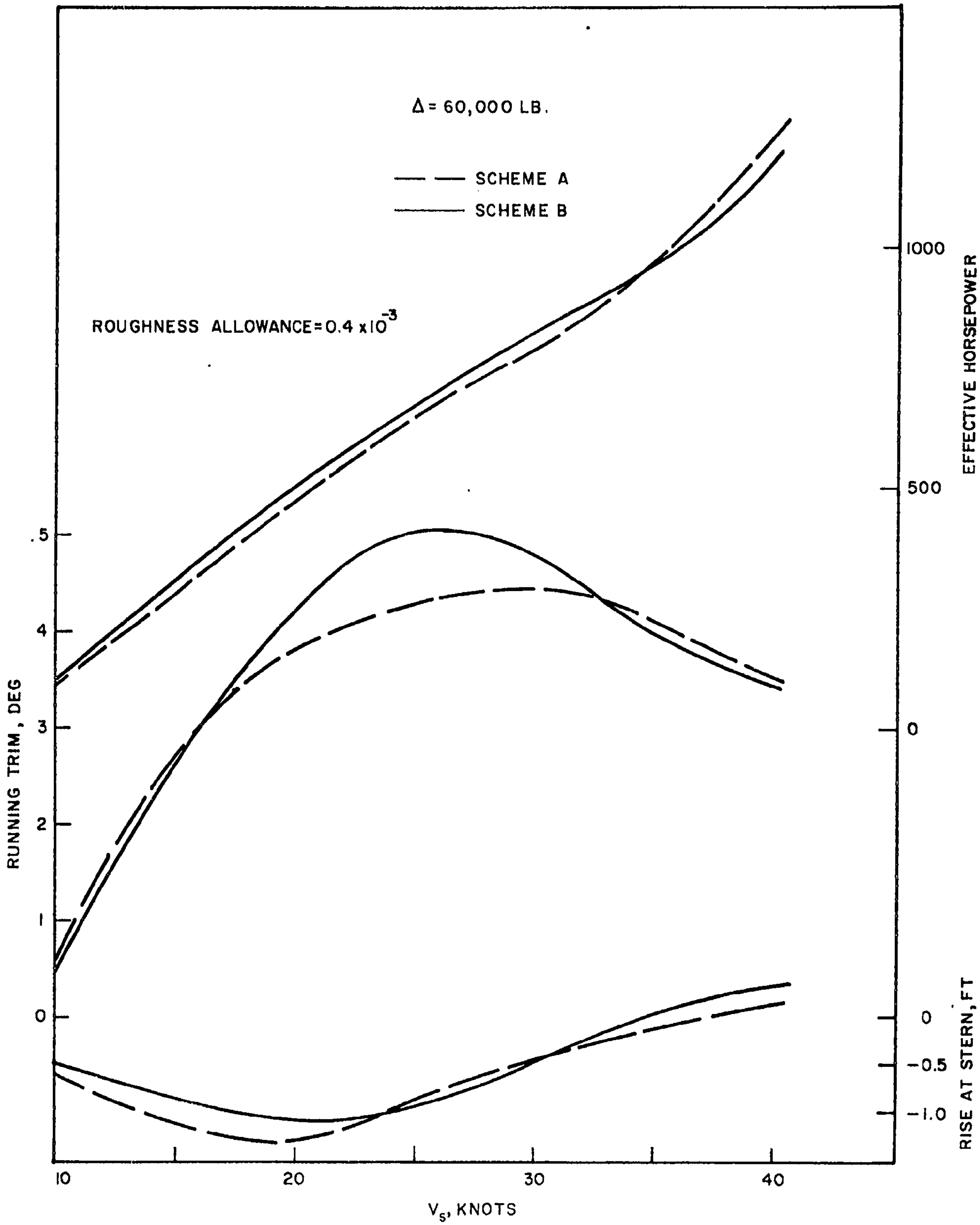


FIGURE 5. COMPARISON OF CALM WATER BEHAVIOR

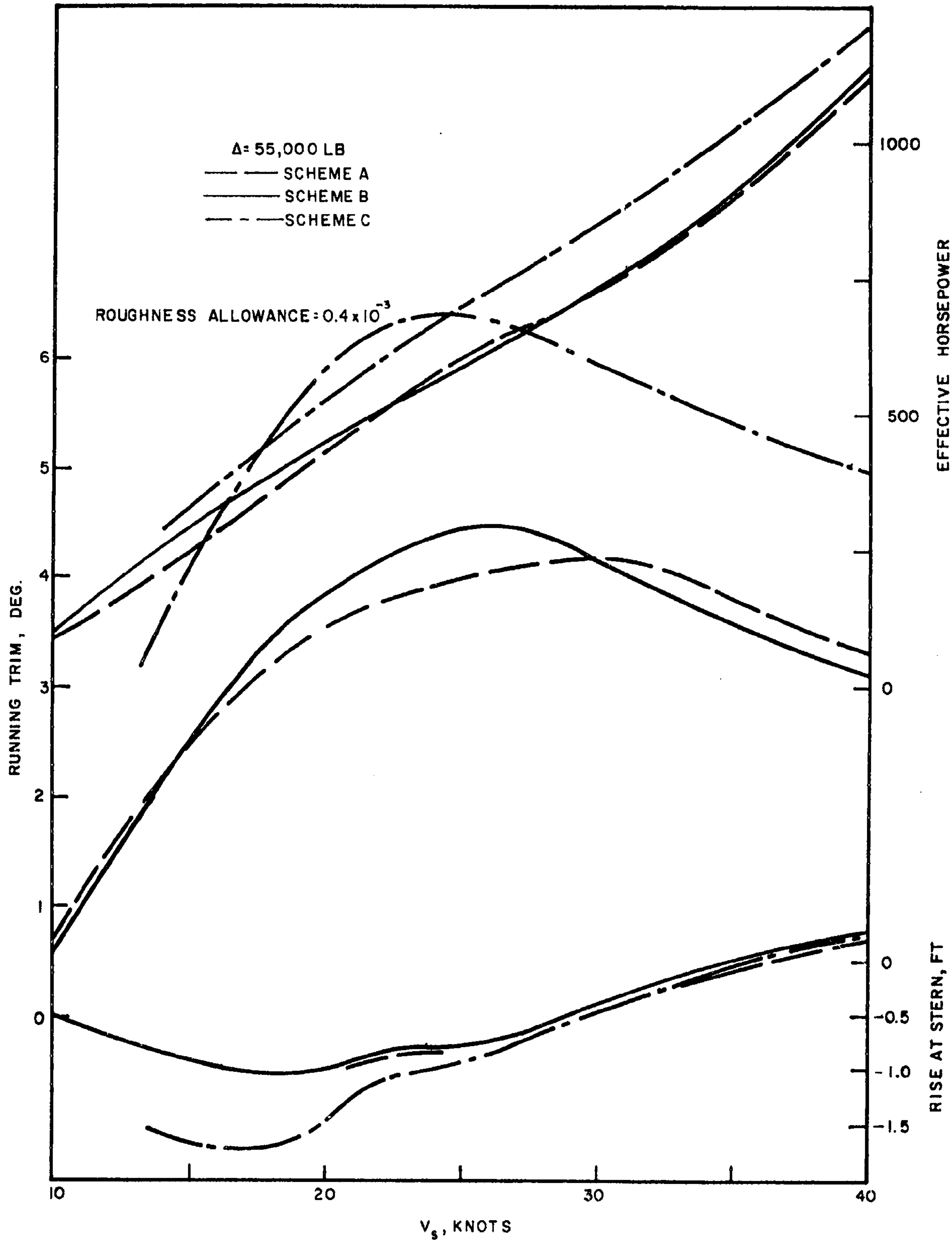


FIGURE 6. COMPARISON OF CALM WATER BEHAVIOR.

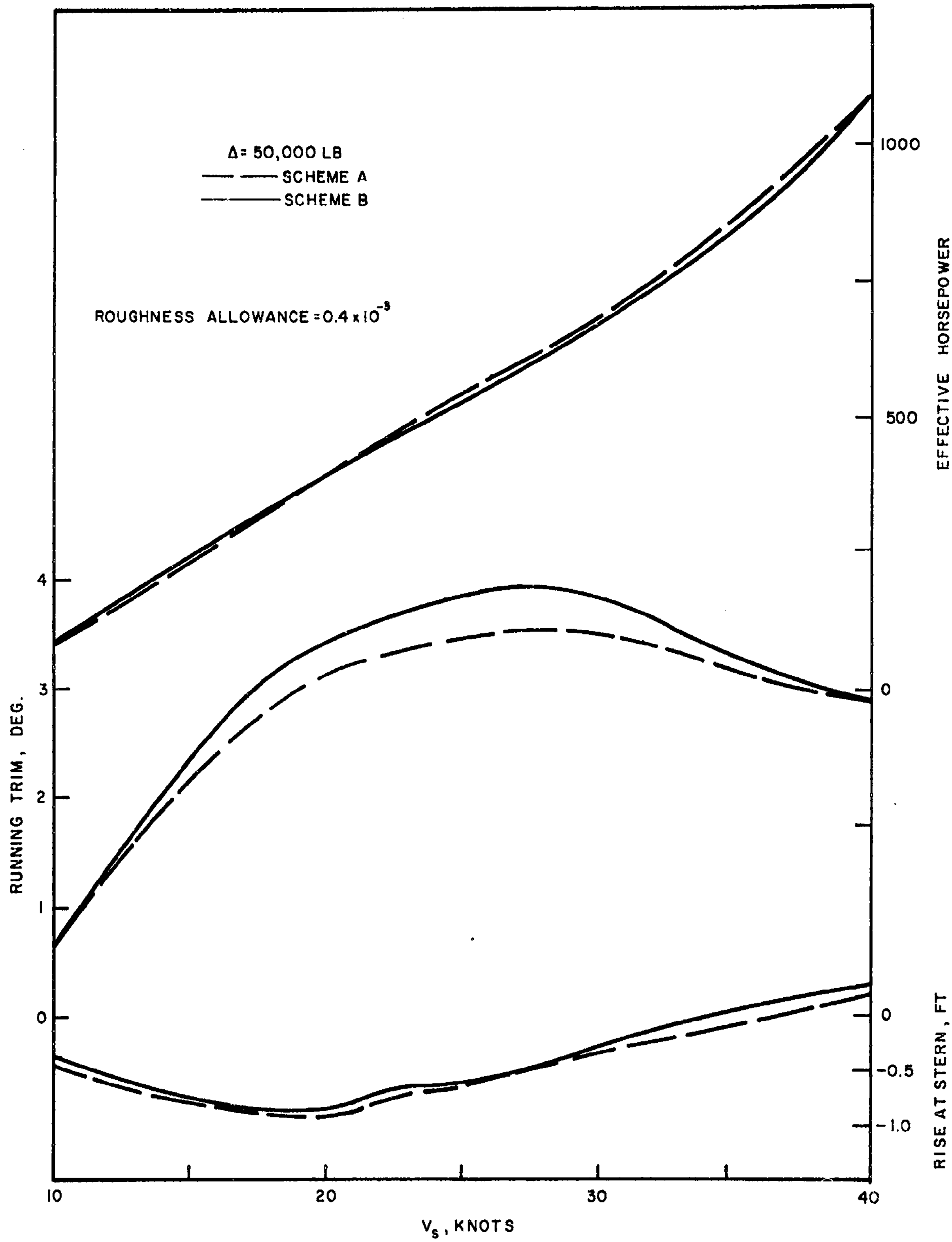


FIGURE 7. COMPARISON OF CALM WATER BEHAVIOR.

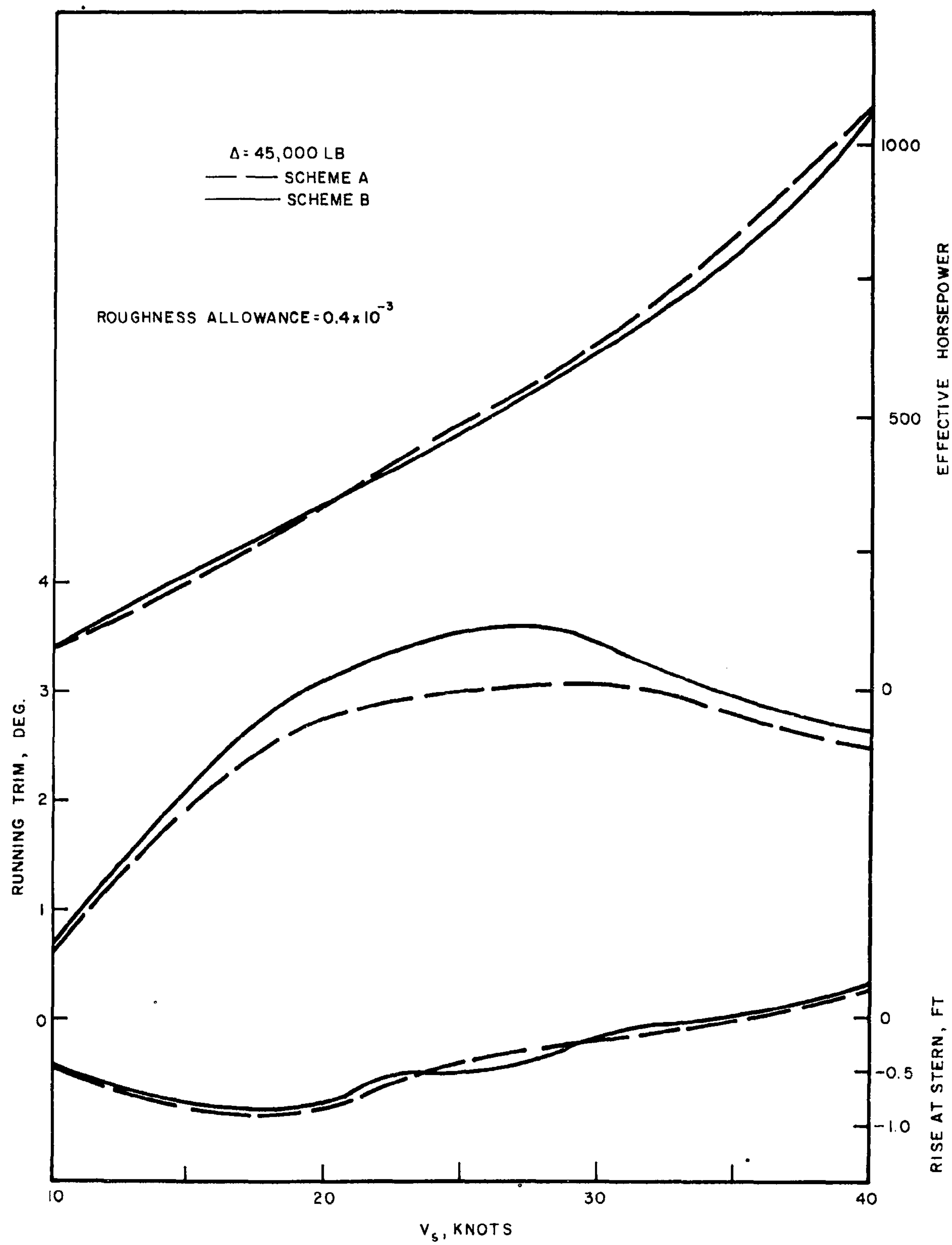


FIGURE 8. COMPARISON OF CALM WATER BEHAVIOR.

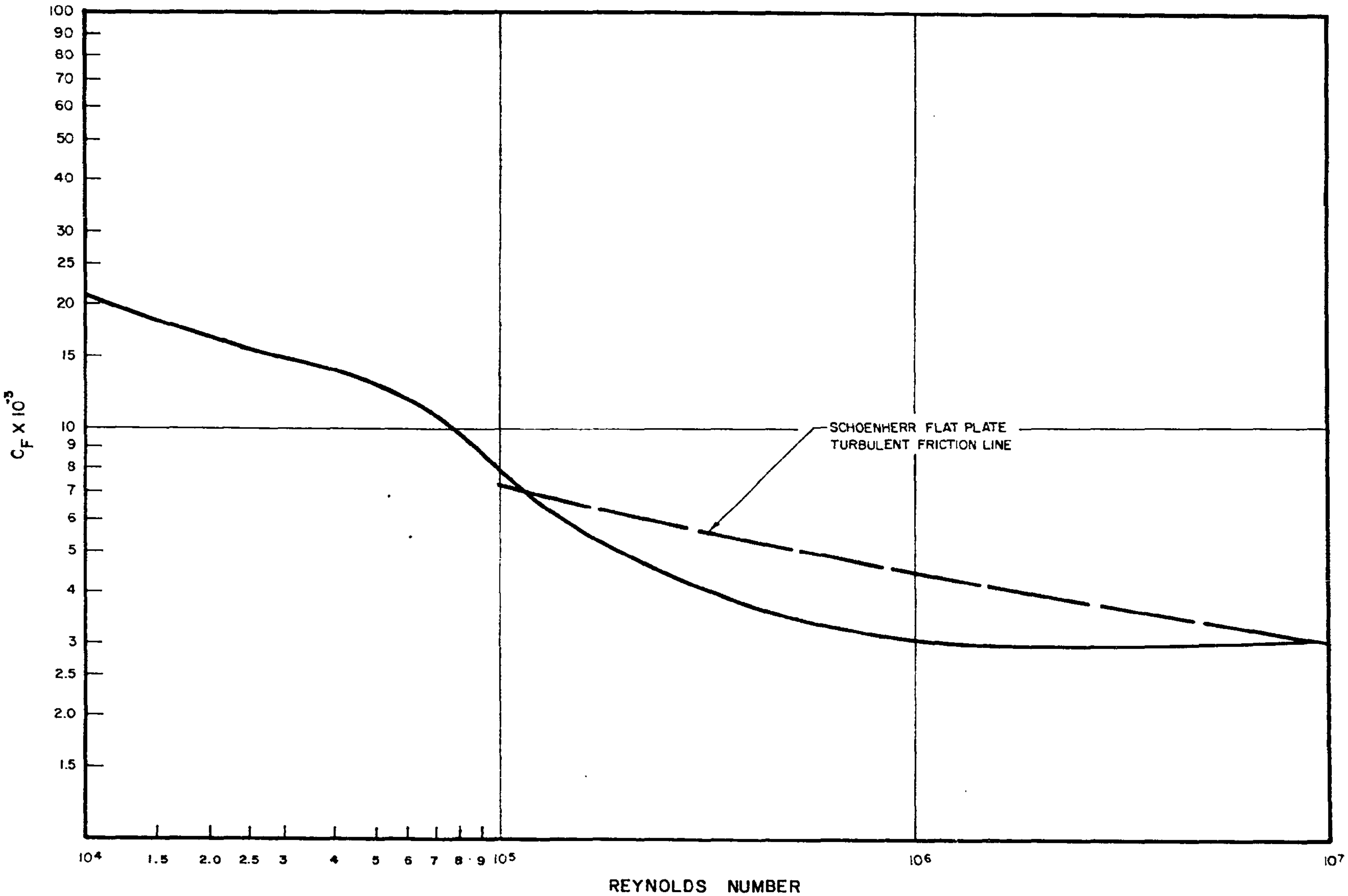


FIGURE 9. EXTRAPOLATOR CURVE USED IN PREDICTING APPENDAGE DRAG

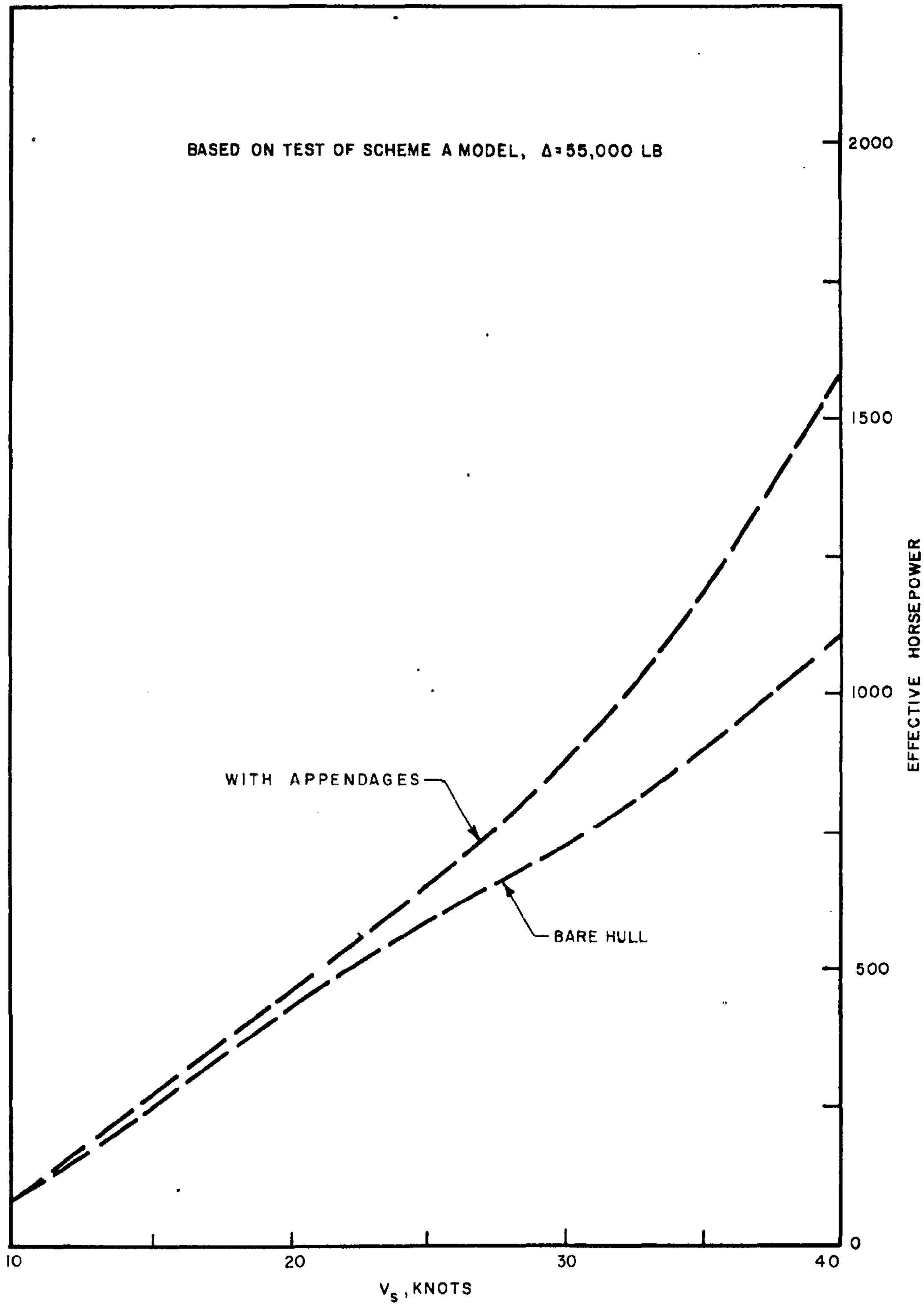


FIGURE 10. . INCREASE IN EFFECTIVE HORSEPOWER DUE TO APPENDAGE RESISTANCE.

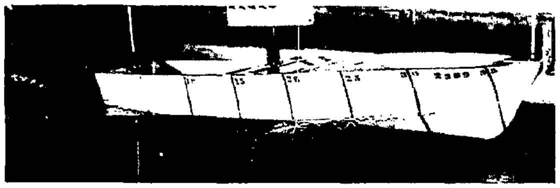
FIG. 11. DTMB STANDARD TEST CONDITION R-854

SCHEME A

Δ = 34,920 lbs.

$L/\nabla^{1/3}$ = 5.12

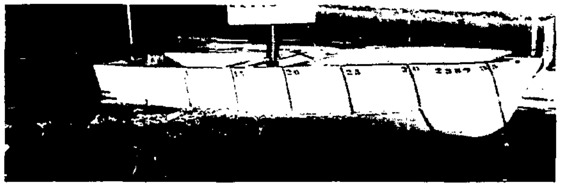
Static τ = .77° Bow Up



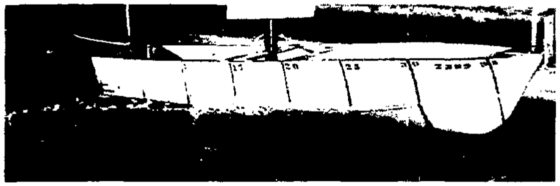
V_s = 19.6 Knots, F_∇ = 2.04

V_s = 25.1 Knots, F_∇ = 2.62

V_s = 30.7 Knots, F_∇ = 3.20



V_s = 34.8 Knots, F_∇ = 3.63



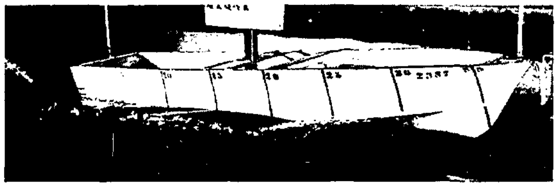
V_s = 40.4 Knots, F_∇ = 4.21

SCHEME B

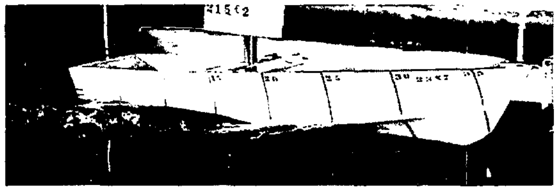
Δ = 37,440 lbs.

L/∇ = 5.66

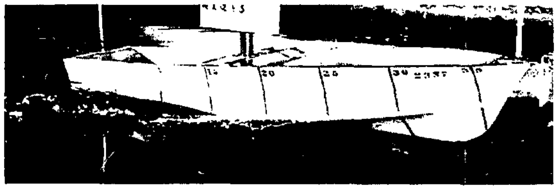
Static τ = .66° Bow Up



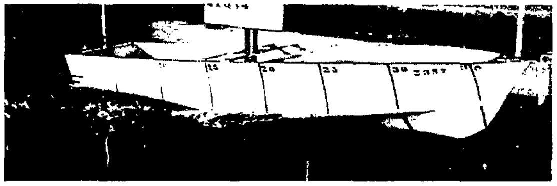
V_s = 19.6 Knots, F_∇ = 2.02



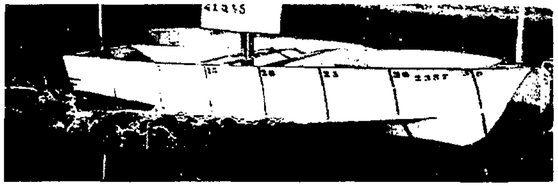
V_s = 25.1 Knots, F_∇ = 2.59



V_s = 30.7 Knots, F_∇ = 3.16



V_s = 34.8 Knots, F_∇ = 3.59



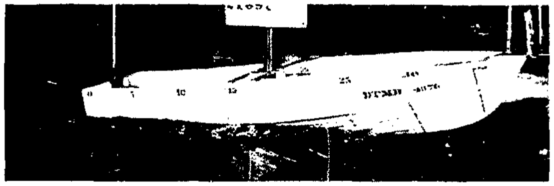
V_s = 40.4 Knots, F_∇ = 4.16

SCHEME C

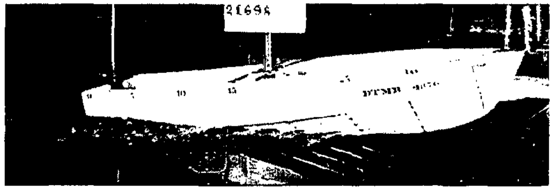
Δ = 47,370 lbs.

$L/\nabla^{1/3}$ = 5.23

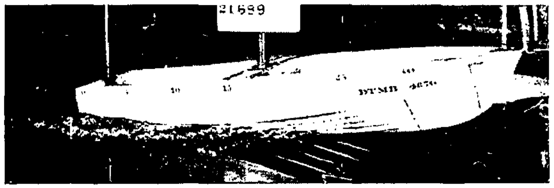
Static τ = 1.62°



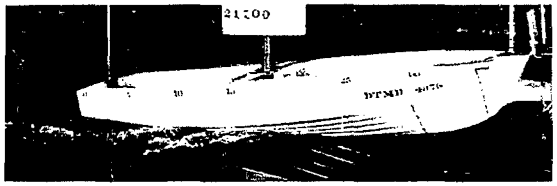
V_s = 19.6 Knots, F_∇ = 1.94



V_s = 25.1 Knots, F_∇ = 2.49



V_s = 30.7 Knots, F_∇ = 3.04



V_s = 34.8 Knots, F_∇ = 3.45

V_s = 40.4 Knots, F_∇ = 4.00

FIG. 13 R—854

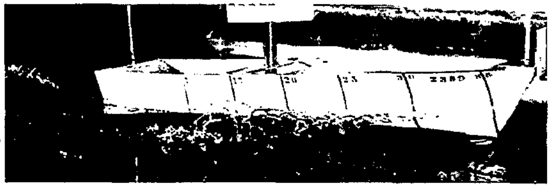
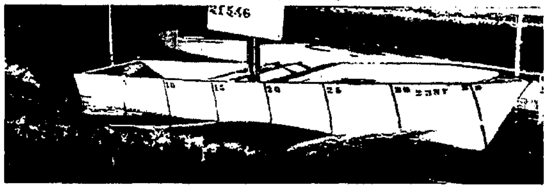
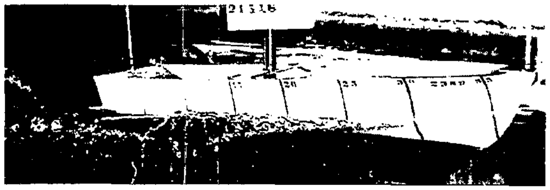
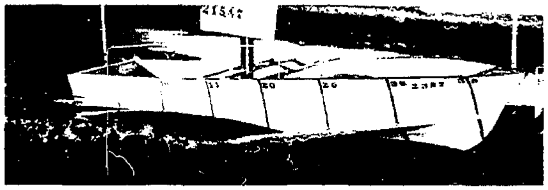
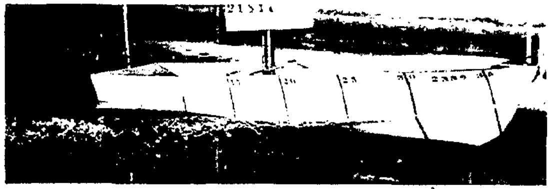
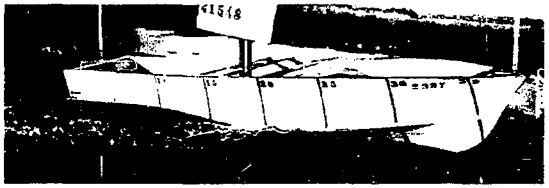
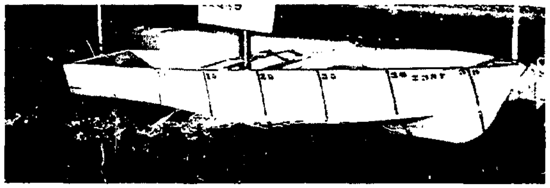
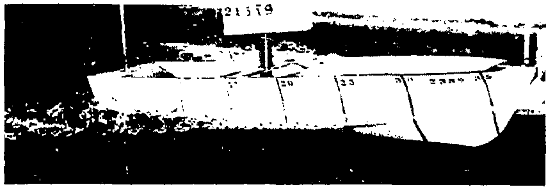
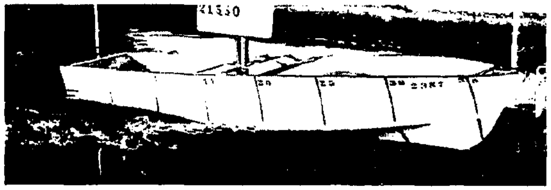
SCHEME A		SCHEME B
Δ = 45,000 lbs. $L/\nabla^{1/3}$ = 5.34 Static τ = 0		Δ = 45,000 lbs. $L/\nabla^{1/3}$ = 5.37 Static τ = 0
	V_s = 19.6 Knots F_v = 1.95	
	V_s = 25.1 Knots F_v = 2.51	
	V_s = 30.7 Knots F_v = 3.06	
	V_s = 34.8 Knots F_v = 3.48	
	V_s = 40.4 Knots F_v = 4.03	

FIG. 14 R-854

SCHEME A

$\Delta = 50{,}000$ lbs.

$L/\nabla^{1/3} = 5.17$

Static $\tau = 0$

SCHEME B

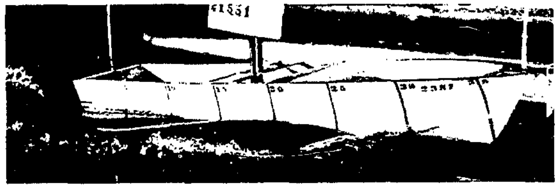
$\Delta = 50{,}000$ lbs.

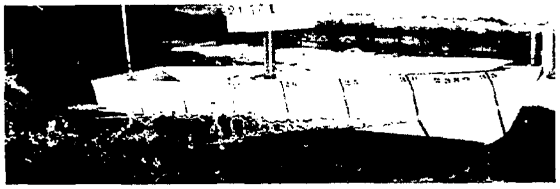
$L/\nabla^{1/3} = 5.20$

Static $\tau = 0$

$V_s = 19.6$ Knots

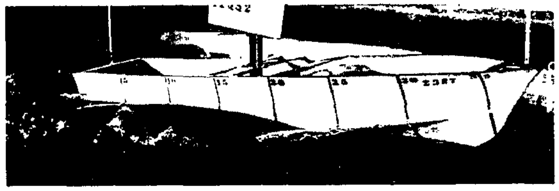
$F_v = 1.92$

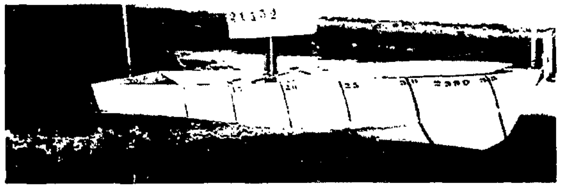




$V_s = 25.1$ Knots

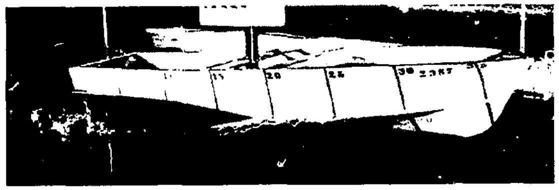
$F_v = 2.47$





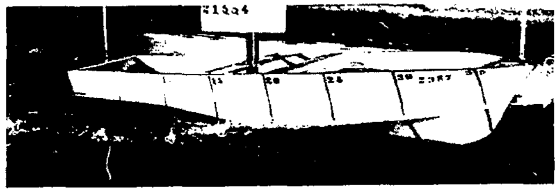
$V_s = 30.7$ Knots

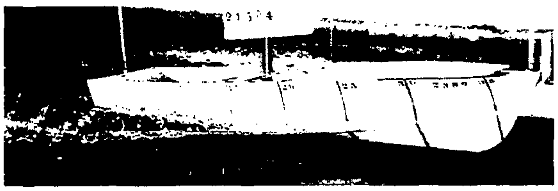
$F_v = 3.01$



$V_s = 34.8$ Knots

$F_v = 3.42$





$V_s = 40.4$ Knots

$F_v = 3.96$

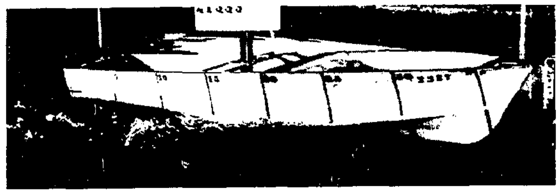


FIG. 16 R–854

SCHEME A

Δ = 55,000 lbs.

$L/\nabla^{1/3} = 5.02$

Static $\tau = 0$

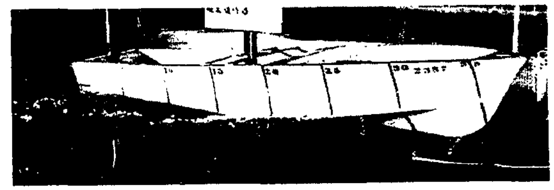
SCHEME A

WITH APPENDAGES

Δ = 55,000 lbs.

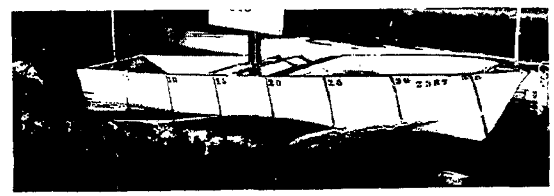
$L/\nabla^{1/3} = 5.02$

Static $\tau = 0$



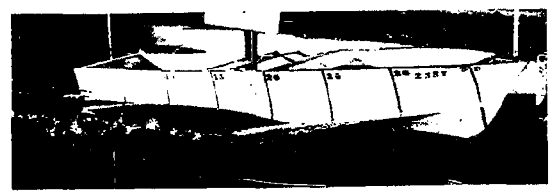
V_s = 19.6 Knots

$F_\nabla = 1.89$



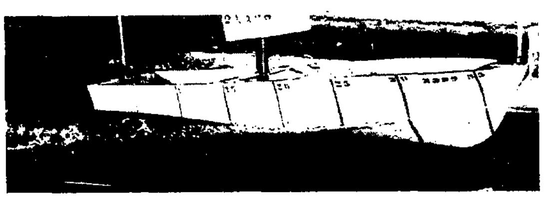
V_s = 25.1 Knots

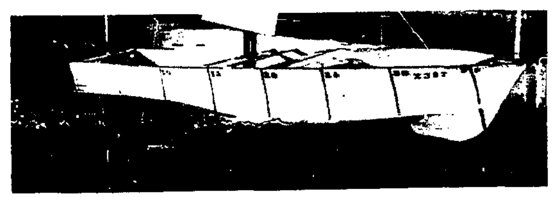
$F_\nabla = 2.43$



V_s = 30.7 Knots

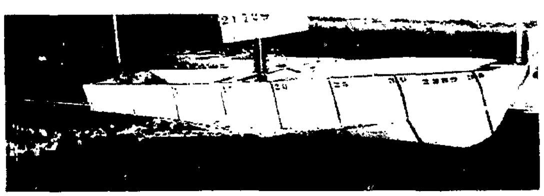
$F_\nabla = 2.96$

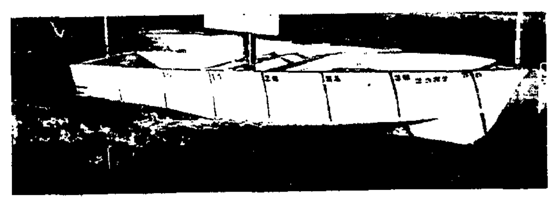




V_s = 34.8 Knots

$F_\nabla = 3.36$





V_s = 40.4 Knots

$F_\nabla = 3.90$

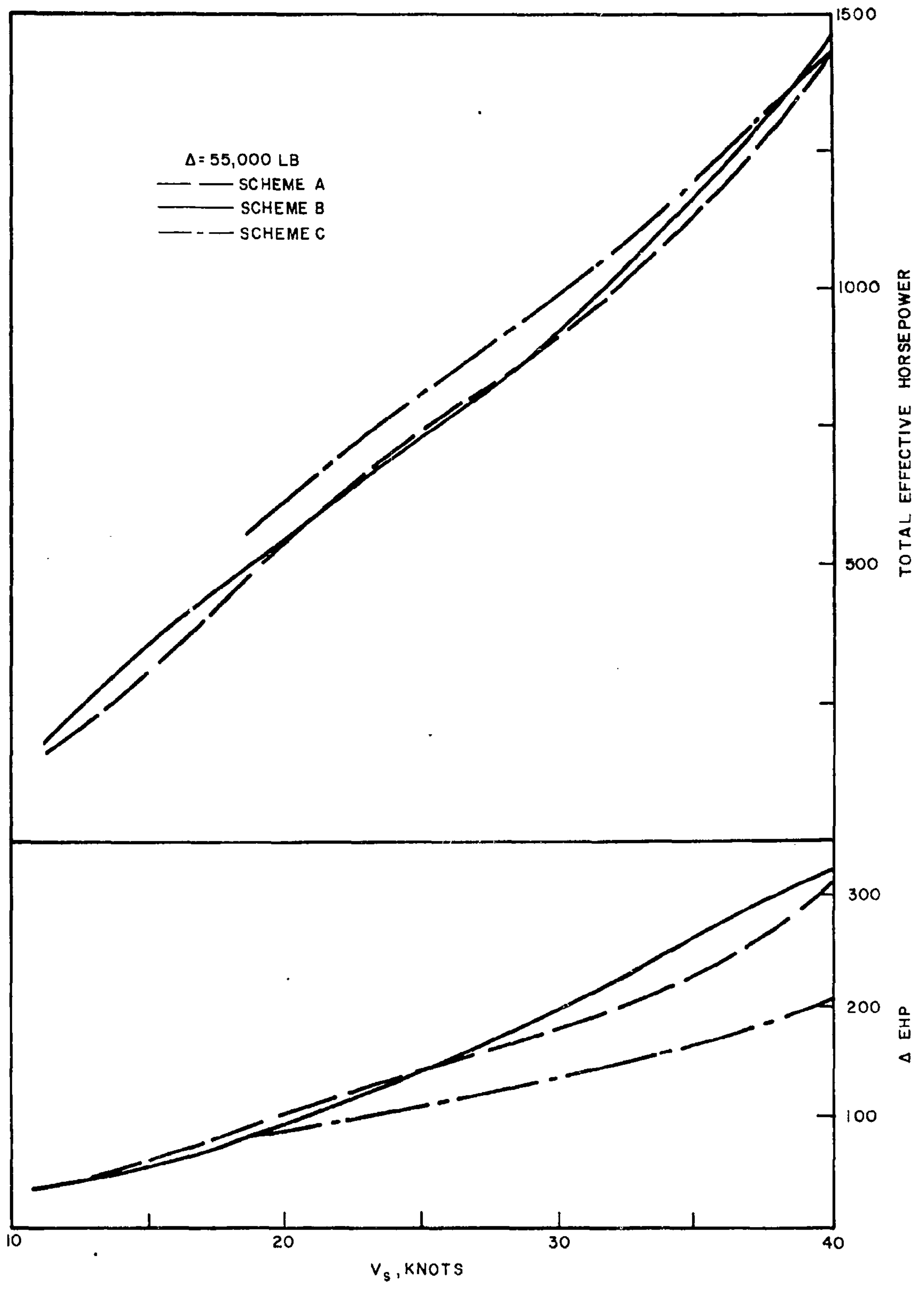


FIGURE 17. COMPARISON OF INCREASES IN EFFECTIVE HORSEPOWER IN A STATE 3 SEA.

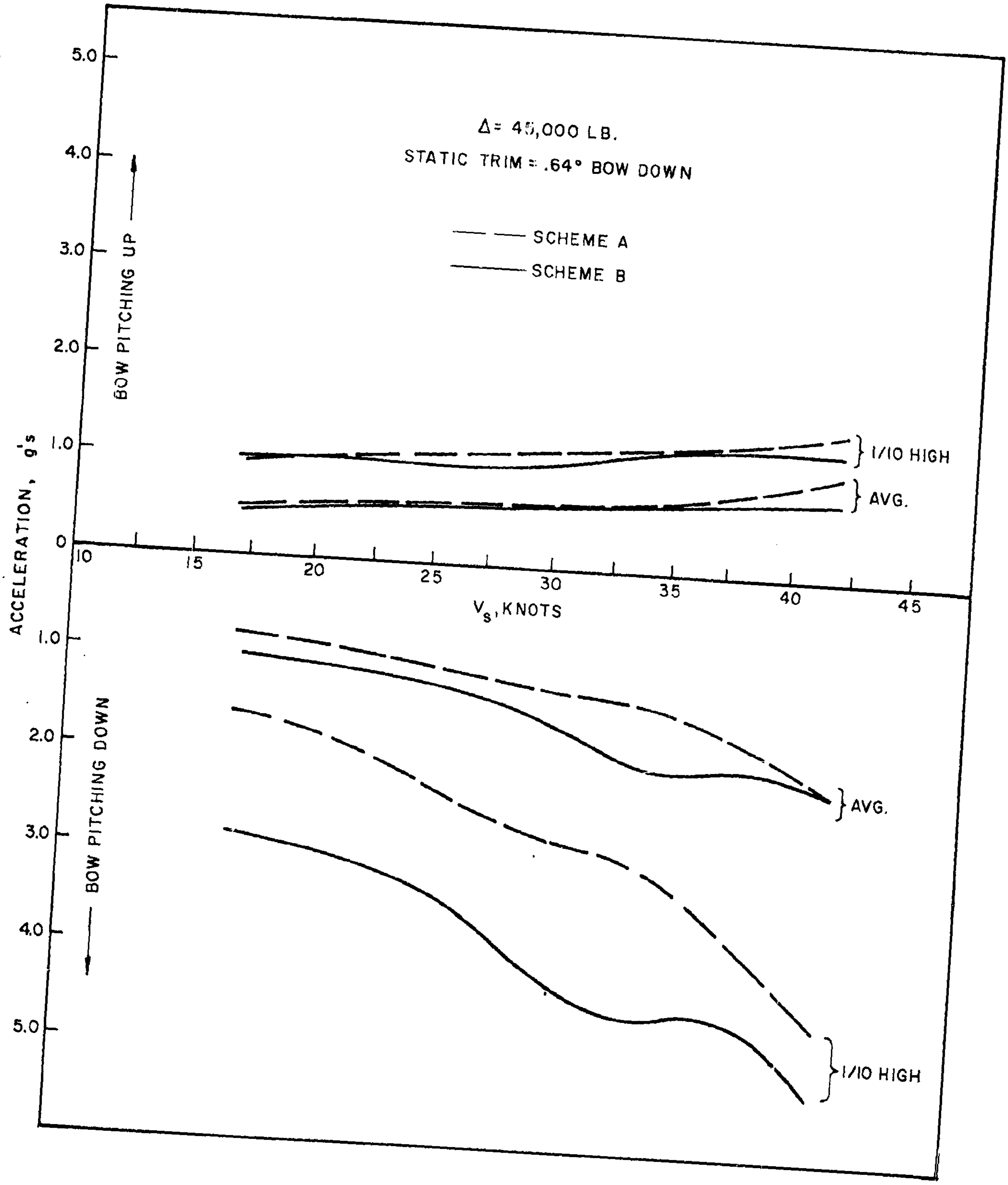


FIGURE 18. COMPARISON OF BOW ACCELERATIONS IN A STATE 3 SEA.

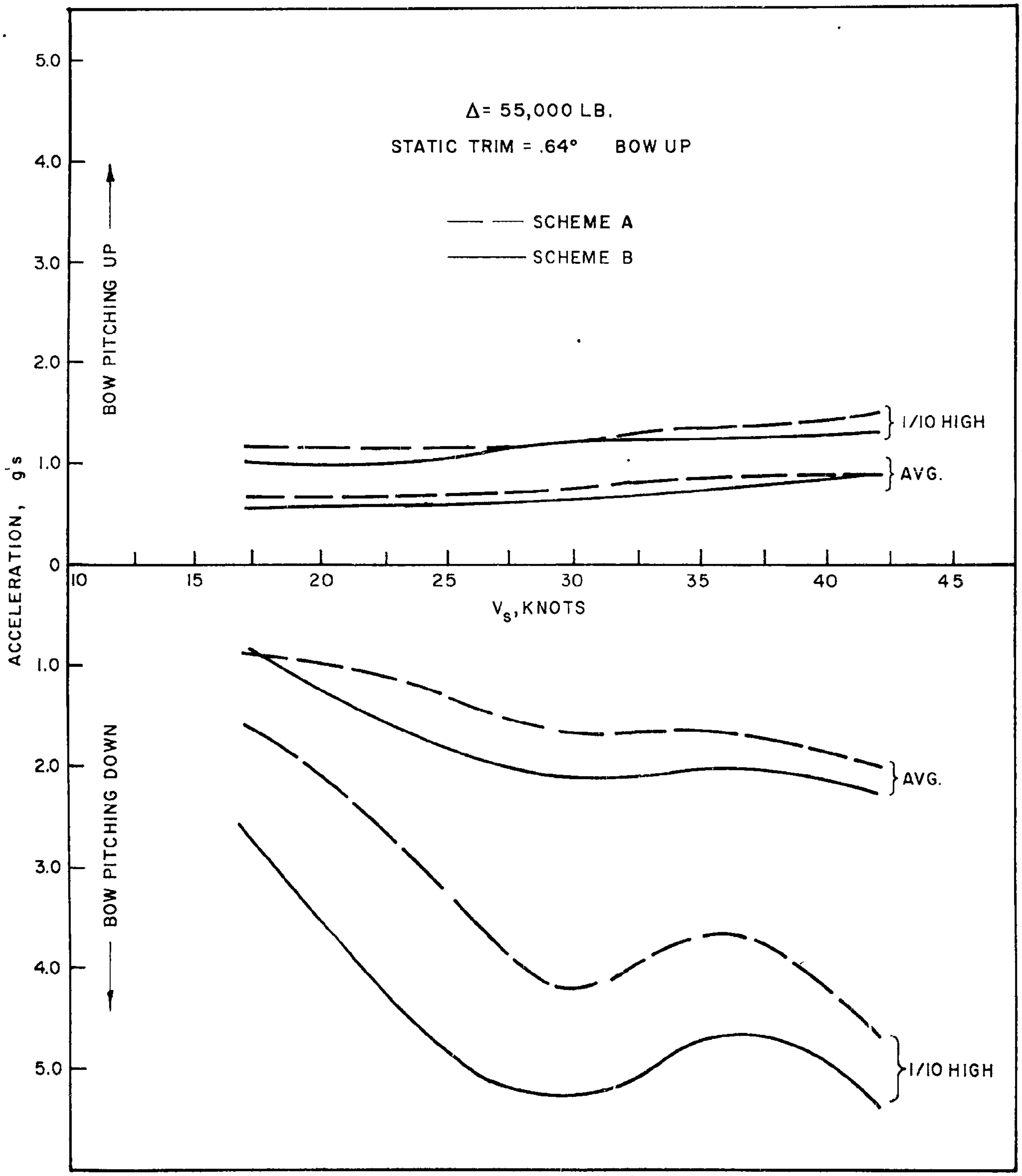


FIGURE 19. COMPARISON OF BOW ACCELERATIONS IN A STATE 3 SEA.

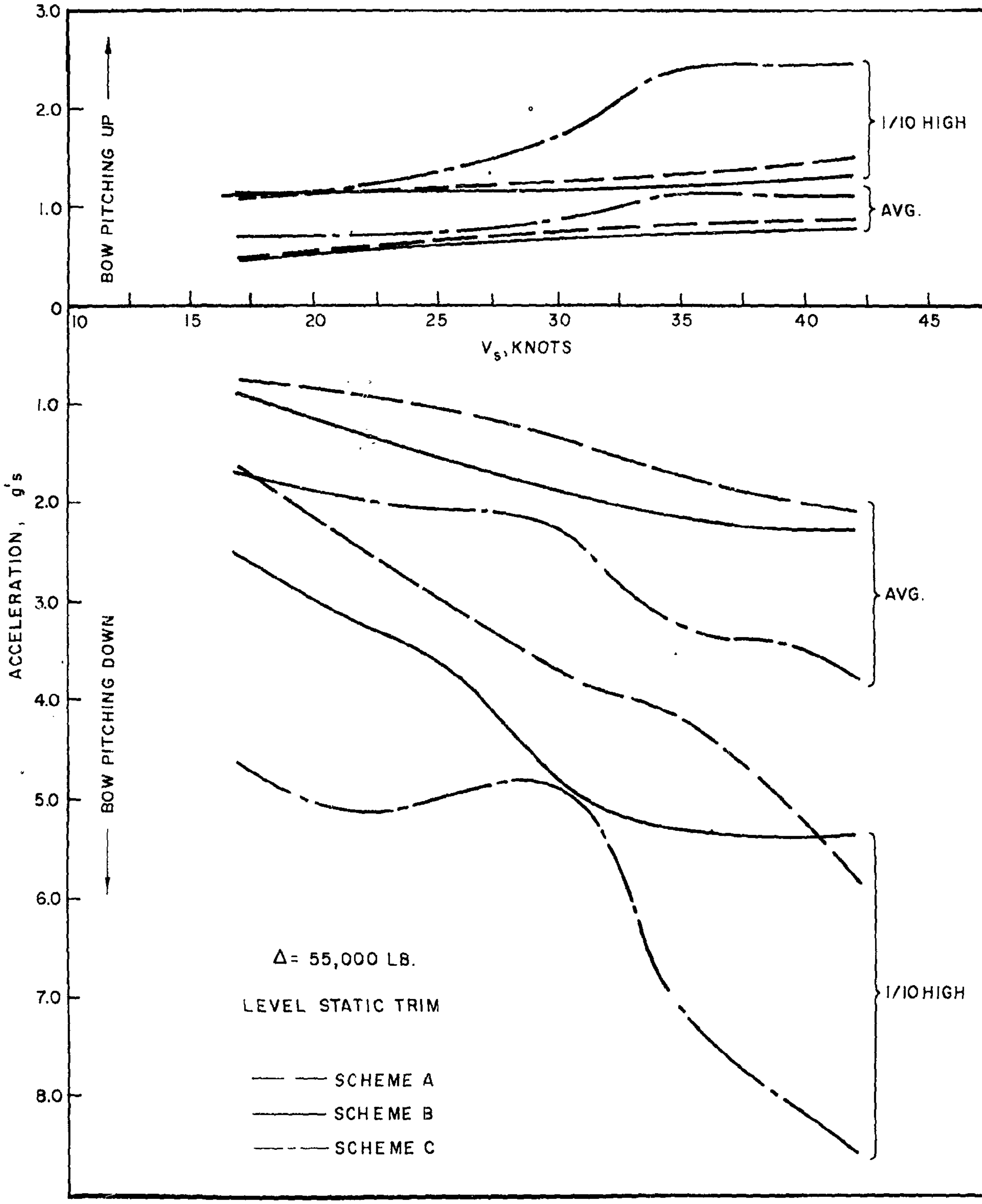


FIGURE 20. COMPARISON OF BOW ACCELERATIONS IN A STATE 3 SEA.

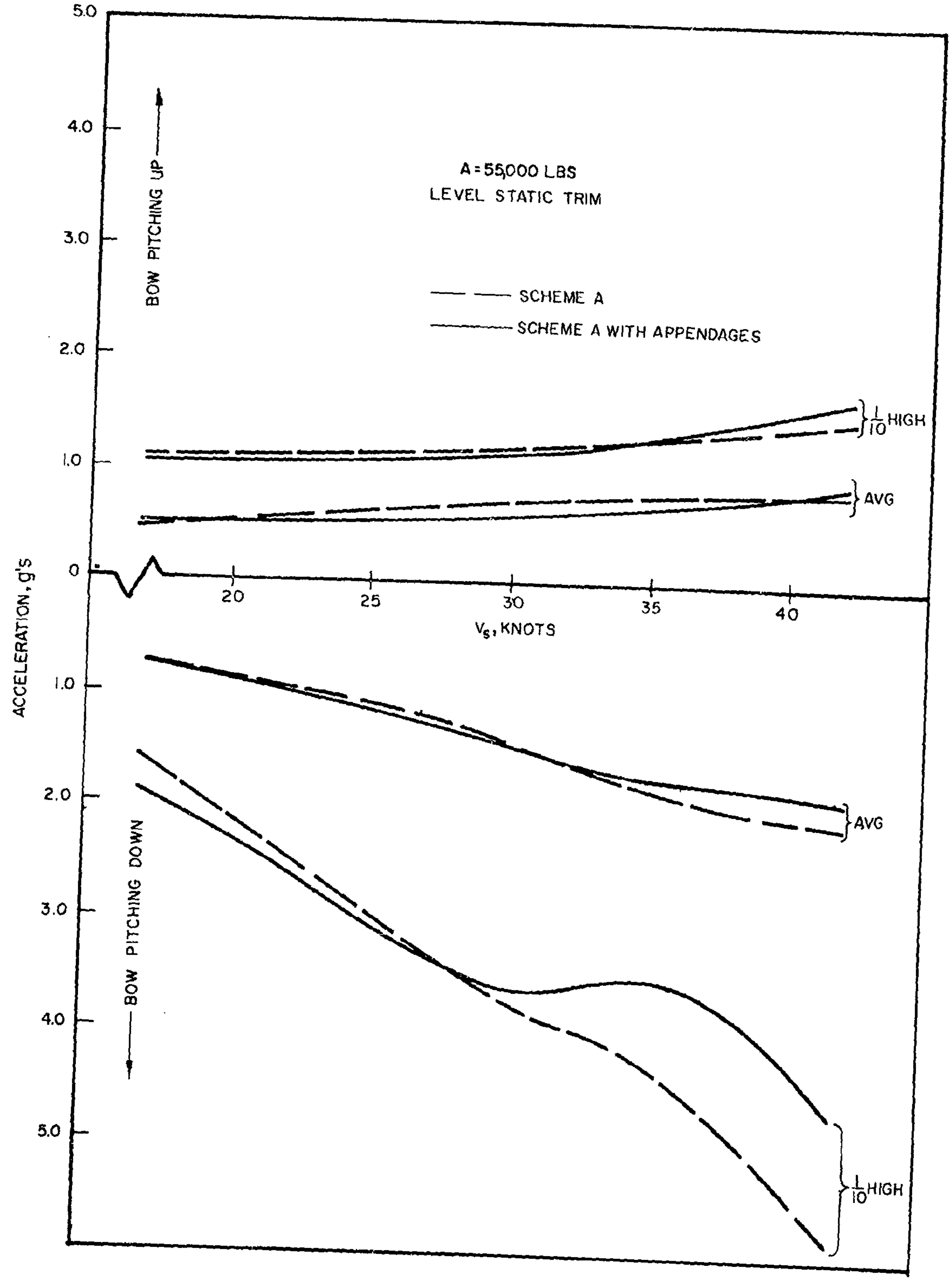


FIGURE 21. EFFECT OF APPENDAGES ON BOW ACCELERATIONS IN A STATE 3 SEA.

UNCLASSIFIED

UNCLASSIFIED