DETROIT
DIESEL

ELEMENTS OF MARINE PROPULSION

MARINE
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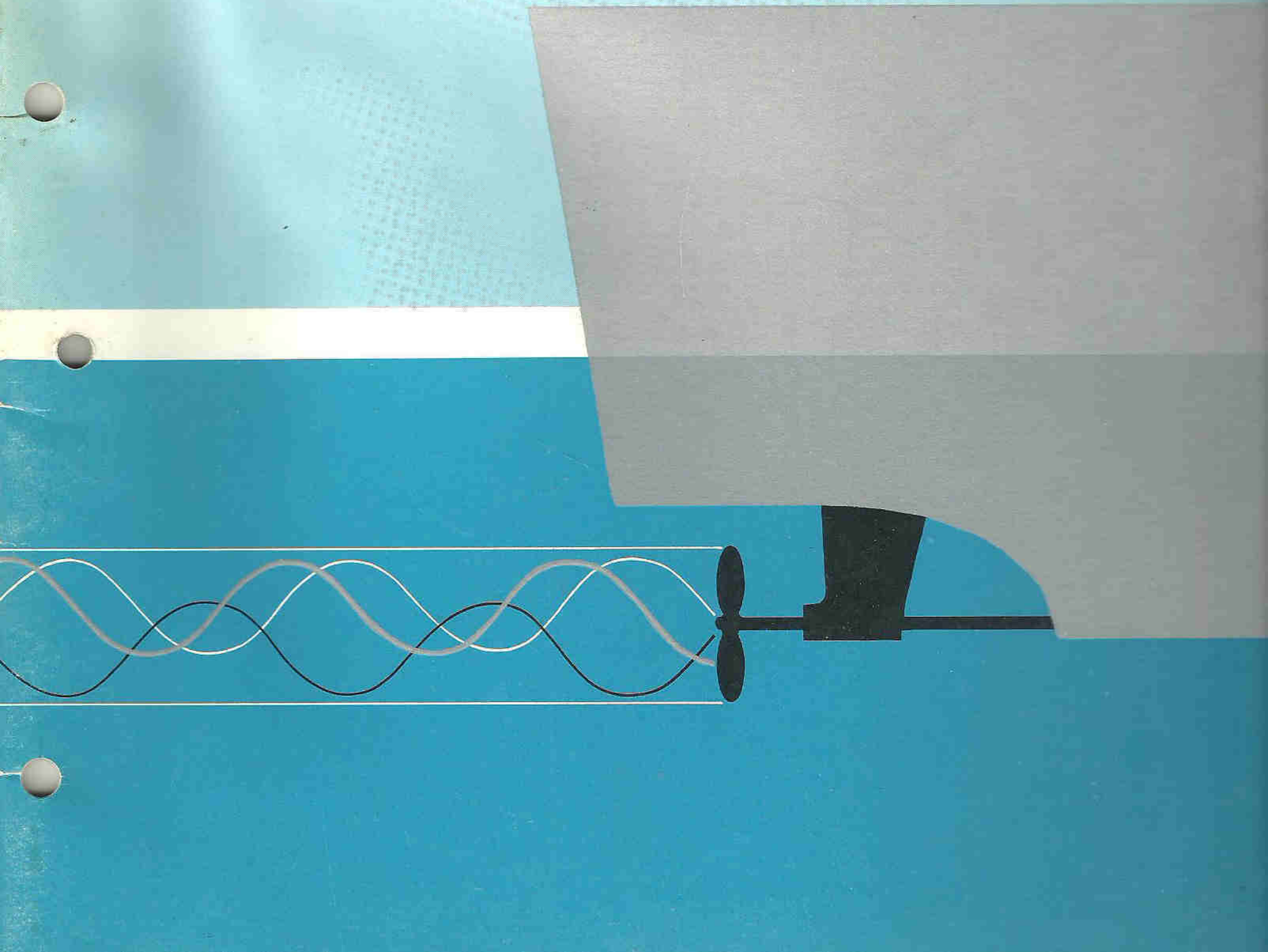
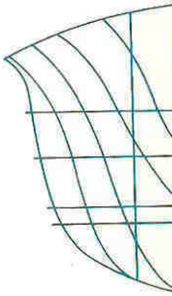
BOOK 1





Foreword

Marine applications are all too frequently shrouded in mystery, with dubious rules and complicated formulae which only tend to confuse the layman. On the other hand, the science of naval architecture abounds with predetermined methods for obtaining precise installation and performance information . . . much of which is equally inappropriate and unnecessary for laymen's use.

This manual is designed to reduce a wealth of technical data to a small compilation of pertinent, practical and understandable information for installations requiring power within the horsepower range of Detroit Diesel engines.

The single intent of this manual is to provide the most basic marine information possible. The materials and examples contained on the following pages were drawn from many knowledgeable sources and chosen for their simplicity of presentation. Any conclusions reached should be essentially of a general nature. The services of a naval architect or a Detroit Diesel engine specialist are emphatically recommended to obtain the most precise performance information and technical advice.

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Hull Conformations

The first subject to be covered in a discussion of marine design and power is hull conformation. Within this subject there are only two general hull types:

1. Displacement
2. Planing

However, there are hulls which have some characteristics of both, known as semi-displacement hulls.

In addition, there are three general classifications of hull bottom shapes. These are:

1. Flat bottom
2. Vee bottom
3. Round bottom

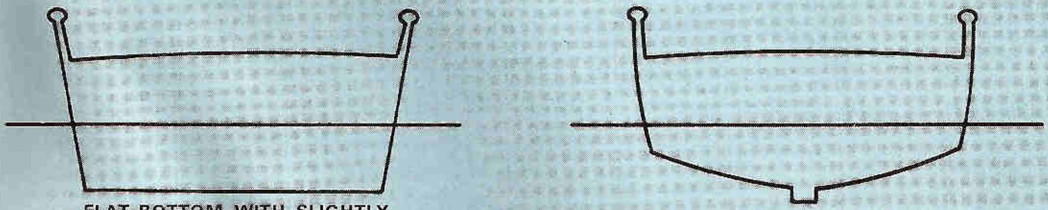
Figures 1 & 2 provide side views of the types of hulls and cross sections of various bottom conformations.

[Figure #1]

DISPLACEMENT TYPE HULL

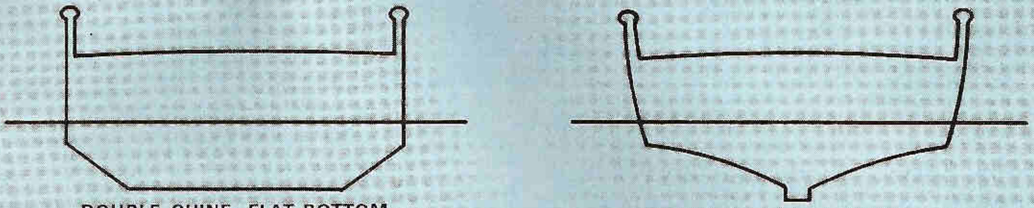
PLANING TYPE HULL

Various Hull Sections



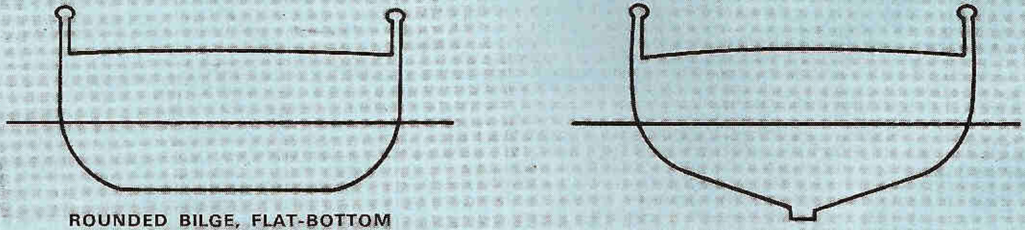
FLAT-BOTTOM WITH SLIGHTLY FLARING, STRAIGHT SIDES

CONVEX V-BOTTOM



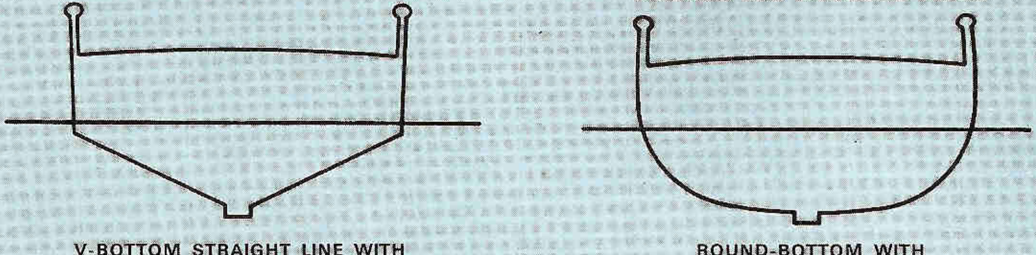
DOUBLE CHINE, FLAT-BOTTOM

CONCAVE V-BOTTOM



ROUNDED BILGE, FLAT-BOTTOM

ROUND-BOTTOM WITH MODERATE DEADRISE AND MODERATE BILGES



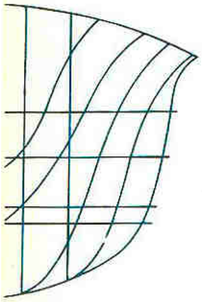
V-BOTTOM STRAIGHT LINE WITH FAIRLY LARGE DEGREE OF DEADRISE

ROUND-BOTTOM WITH NO DEADRISE AND EASY BILGES

[Figure #2]

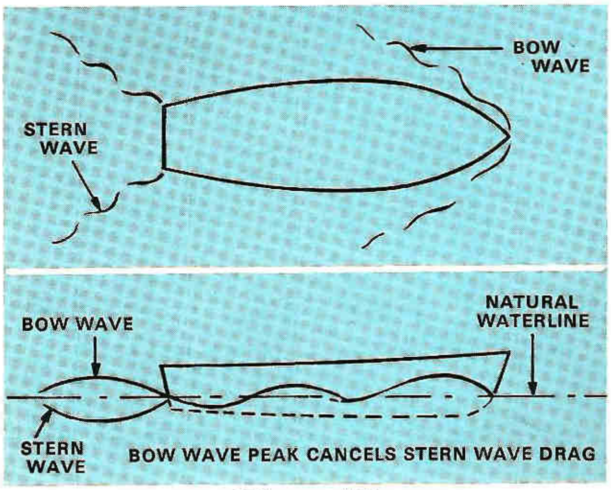
Primary Conceptions Regarding Displacement Hulls

A displacement type hull replaces an amount of water equal to its own weight no matter what its speed through the water. It is so shaped that the bow cuts a wedge in the water which the forebody then moves aside to the extent of the midsection. Aft of the midsection, the hull is shaped to allow the water to converge at the stern in a natural flow and reduce drag to a minimum.



When a hull is propelled through the water at low speeds, its forward motion causes a system of waves to be formed along the length of the boat. The length between one wave crest and another is directly proportional to the speed at which the boat is propelled through the water. A second series of waves emanates from the stern of the vessel. If the speed is such that the forward wave is at its highest point when the wave formed by the stern is at its lowest, cancellation of the two systems will occur, thereby neutralizing the drag carried by the wave set up from the stern. This is considered the most efficient condition for propelling a boat through the water (see Fig. 3).

SCHEMATIC DRAWING OF HULL IN WATER



[Figure #3]

These "optimum" conditions are, as a rule, achieved when the speed in knots divided by the square root of the waterline length (in feet) equals either .9 or 1.10.

$$\frac{V}{\sqrt{LWL}} = 0.9 \text{ or } 1.1$$

Where V = Speed in knots, and
LWL = Loaded Waterline length (in ft.)

This assumes the hull to be of a normal displacement form with a reasonable beam to length ratio.

The "optimum" of $\frac{V}{\sqrt{LWL}} = 0.9$ or 1.1 is simply used as a base to establish the most practical speed of a displacement hull. Beyond this point the horsepower per knot increase becomes economically unfeasible. Thus, from data taken on a large sample of displacement hulls, a general formula for estimating a boat's "maximum feasible" speed was developed where 1.34 times the square root of the loaded waterline length (in feet) equals the boat's speed in knots.

$$1.34\sqrt{LWL} = V$$

LWL = Loaded waterline length
V = Speed in knots.

Speed and Power

In order to properly estimate speed and power requirements, it is first necessary to understand the terms and components used in making these calculations:

LWL = Loaded waterline length, in feet. This is the actual length of the immersed portion of the vessel —*not total length.*

B = Loaded waterline beam or beam at maximum width of vessel at loaded waterline, in feet.

D = Moulded draft. Depth at midship from waterline to bottom of boat in feet. Do not include keel (which protrudes below hull), propeller shafting, propellers, rudders, or skin thickness.

C_b = Block coefficient. The ratio of a vessel's weight (displacement) to that of a rectangular block of water having the same length, width and depth as the underwater portion of the hull. See following table, Fig. #4.

$$C_b = \frac{WxQ}{LxBxD}$$

Q = Cu. ft. of water per long ton. (Salt water 35, fresh water 36.)

W = Displacement. Weight of volume of water displaced by vessel and equal to weight of vessel in long tons (2240 lbs.). Displacement must *not* be confused with gross or net tonnage which are measurements of a ship's internal volume in units of 100 cu. ft.

Estimating Block Coefficient (C_b) [Figure #4]

	C_b Range
Semi-displacement and Planing Hulls	
Yachts and Crew Boats	.40 to .50
Displacement Hulls	
Light Cargo and Fishing Vessels	.40 to .55
Heavy Cargo, Fishing Boats and Tugs	.50 to .65
River Tow Boats	.55 to .70
Self-propelled Barges	.70 to .90
Barges	.85 to .90

Displacement, as used in the following formulas, is the actual weight of the loaded vessel. Gross and net tonnage are volume measurements and should never be used.

Displacement is calculated as follows:

$$W = \frac{LxBxDxC_b}{Q}$$

With the above information we can proceed to discuss estimated speed formulas.

Displacement Hull Speed

To approximate the speed of this type of hull, use the Nomograph as shown in Fig. #5. The displacement, loaded waterline length and S.H.P. must be known quantities. Using these known factors and applying them in Steps 1 through 5, it is comparatively easy to obtain an *approximate* speed for any standard type *displacement hull.*

A practical application would be as follows:

Light cargo vessel
Length overall—80′
Loaded waterline length—73′
Loaded waterline beam—18.6′
Moulded draft (amidship)—7.2′
Shaft horsepower—340

Using block coefficient table, (Fig. #4) and general knowledge of the particular boat, the block coefficient (C_b) would be approximately .50, chosen arbitrarily between .40 and.55.

Then, calculating for displacement,

$$W = \frac{73' \times 18.6' \times 7.2' \times .50}{35} = 138 \text{ long tons}$$

Nomogograph See Page 6 [Figure #5]

1. Convert displacement (W) to $W^{7/6}$ on scale A.

2. To obtain S.H.P. displacement coefficient, divide shaft horsepower by $W^{7/6}$

$$\frac{S.H.P.}{W^{7/6}} = \text{S.H.P. displacement coefficient.}$$

Top Scale—A:

Convert W to $W^{7/6} = 310$

Divide $\frac{340}{310} = 1.1$ S.H.P. displacement coefficient

3. Convert S.H.P. displacement coefficient to speed length ratio on scale B, below S.H.P. displacement coefficient.

Middle Scale—B:

Convert S.H.P. displacement (1.1) to speed/length ratio.

Reading 1.15

Speed-Length ratio

4. Convert loaded waterline length in ft. to its square root on scale C.

$$\sqrt{LWL}$$

Bottom Scale—C:

Convert load waterline length to $\sqrt{LWL}$ or $\sqrt{73} = 8.55$

5. Multiply $\sqrt{LWL}$ by speed length ratio to obtain speed in knots. To convert to miles per hour multiply speed in knots by 1.152.

Final step, multiply speed length ratio by $\sqrt{LWL}$ or 1.15 x 8.55 = 9.9 knots.

One knot = 1.152 MPH. To convert knots to miles, simply multiply 9.9 x 1.152 = 11.4 MPH

NOTE:

When installing a replacement engine in a boat *the speed prior to change should be carefully checked* and run comparatively through the nomograph to give a more accurate speed prediction. This will provide a correction factor for use when comparing the nomograph's predicted speed and the boat's actual speed.

Actual speed (previous power) = 12 knots
Chart speed (previous power) = 14 knots

$$\text{Correction factor} = \frac{12}{14} = .86$$

Chart speed (new power) = 18 knots
Actual Speed (new power) = .86 x 18 = 15.4 knots.

Figure #6 is a chart which, for estimating purposes, is reasonably good. It shows the influence of length, displacement, etc. and is easy to use for rapid estimates. The chart is explained below and can be used as shown by the example.

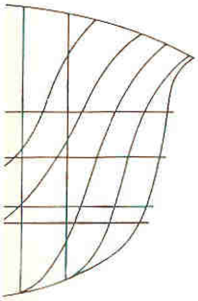
The curved line indicates the average of a great many forms and trials over a period of years. For repowering vessels, the results of previous installations can be plotted on the chart. If the results do not coincide with the reference curve shown, a curve of similar characteristics can be drawn through an established performance point and parallel to the existing curve. This new curve, then, will apply to that specific hull and can be used for the basis of subsequent repowering calculations.

This chart is for displacement type hulls *only.* When information indicates that it falls outside the range of the chart, it should not be used because the boat may be in transition between displacement type and planing (semi-planing) or may even be of the planing type. If the hull is of the planing type the Nomograph in Fig. #7 must be used.

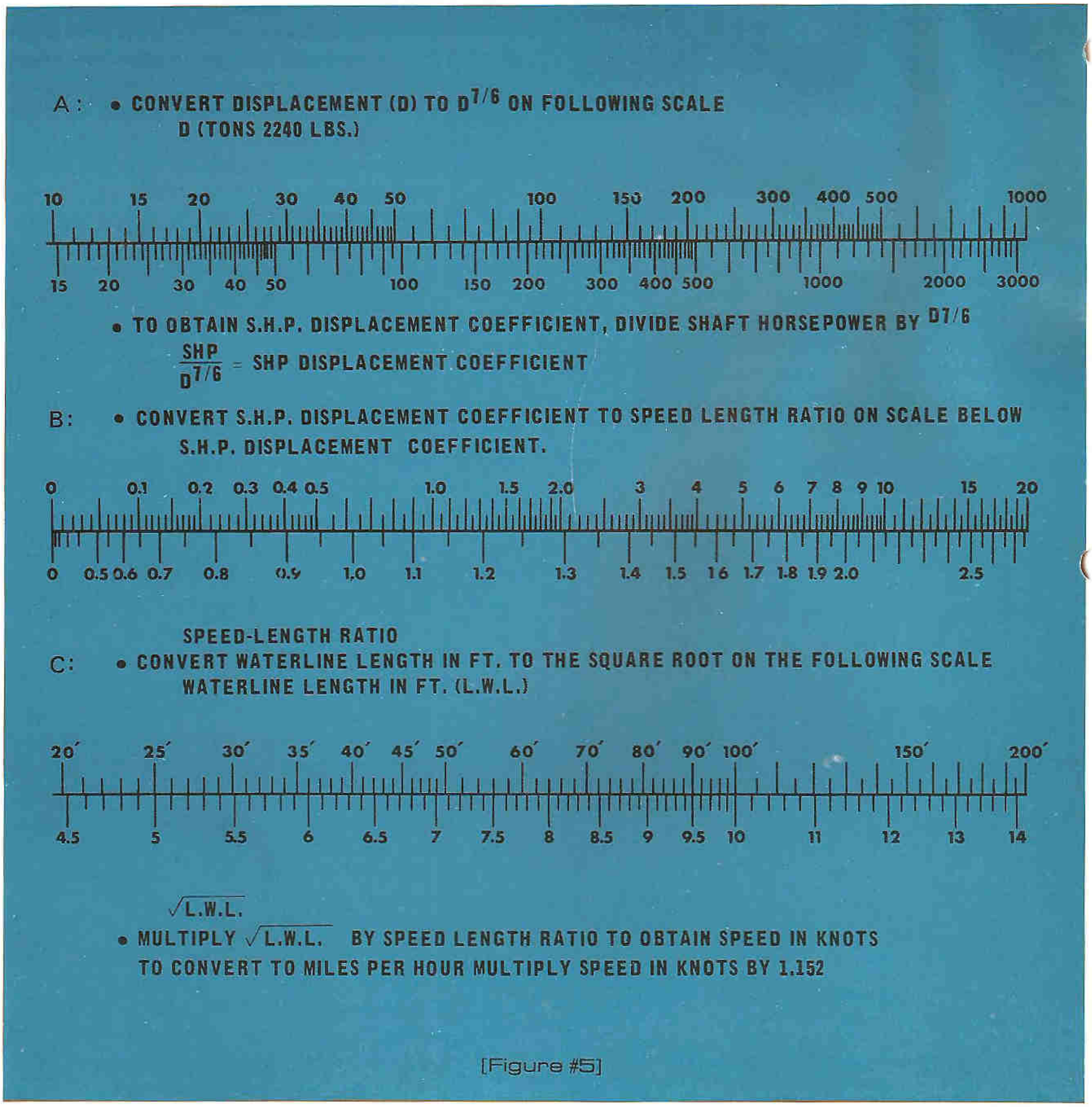
The following example illustrates how Fig. #6 may be used. Given a set of boat specifications such as:

Shaft Horsepower—230
Displacement—40 long tons
Loaded Waterline Length—100 feet

Select the given S.H.P. at the bottom of the nomograph. Then follow the curved line to the horizontal line corresponding to the LWL of this particular boat. Follow an imaginary vertical line up until it intersects with the displacement of this boat (lines angling up and to the right). At this point, proceed on a horizontal straight line until intersection with the broad base line curve. Again proceed on a vertical straight line until intersecting with the proper boat's LWL line (angling up and to the left). Finally, follow a straight horizontal line to the left-hand margin, which gives the boat's predicted speed. Figure #6 has a dotted line which traces the path of this example.



Nomograph for Approximating Speed of Displacement Hulls



A: • CONVERT DISPLACEMENT (D) TO $D^{7/6}$ ON FOLLOWING SCALE

D (TONS 2240 LBS.)

• TO OBTAIN S.H.P. DISPLACEMENT COEFFICIENT, DIVIDE SHAFT HORSEPOWER BY $D^{7/6}$

$\frac{SHP}{D^{7/6}}$ = SHP DISPLACEMENT COEFFICIENT

B: • CONVERT S.H.P. DISPLACEMENT COEFFICIENT TO SPEED LENGTH RATIO ON SCALE BELOW

S.H.P. DISPLACEMENT COEFFICIENT.

SPEED-LENGTH RATIO

C: • CONVERT WATERLINE LENGTH IN FT. TO THE SQUARE ROOT ON THE FOLLOWING SCALE

WATERLINE LENGTH IN FT. (L.W.L.)

$\sqrt{L.W.L.}$

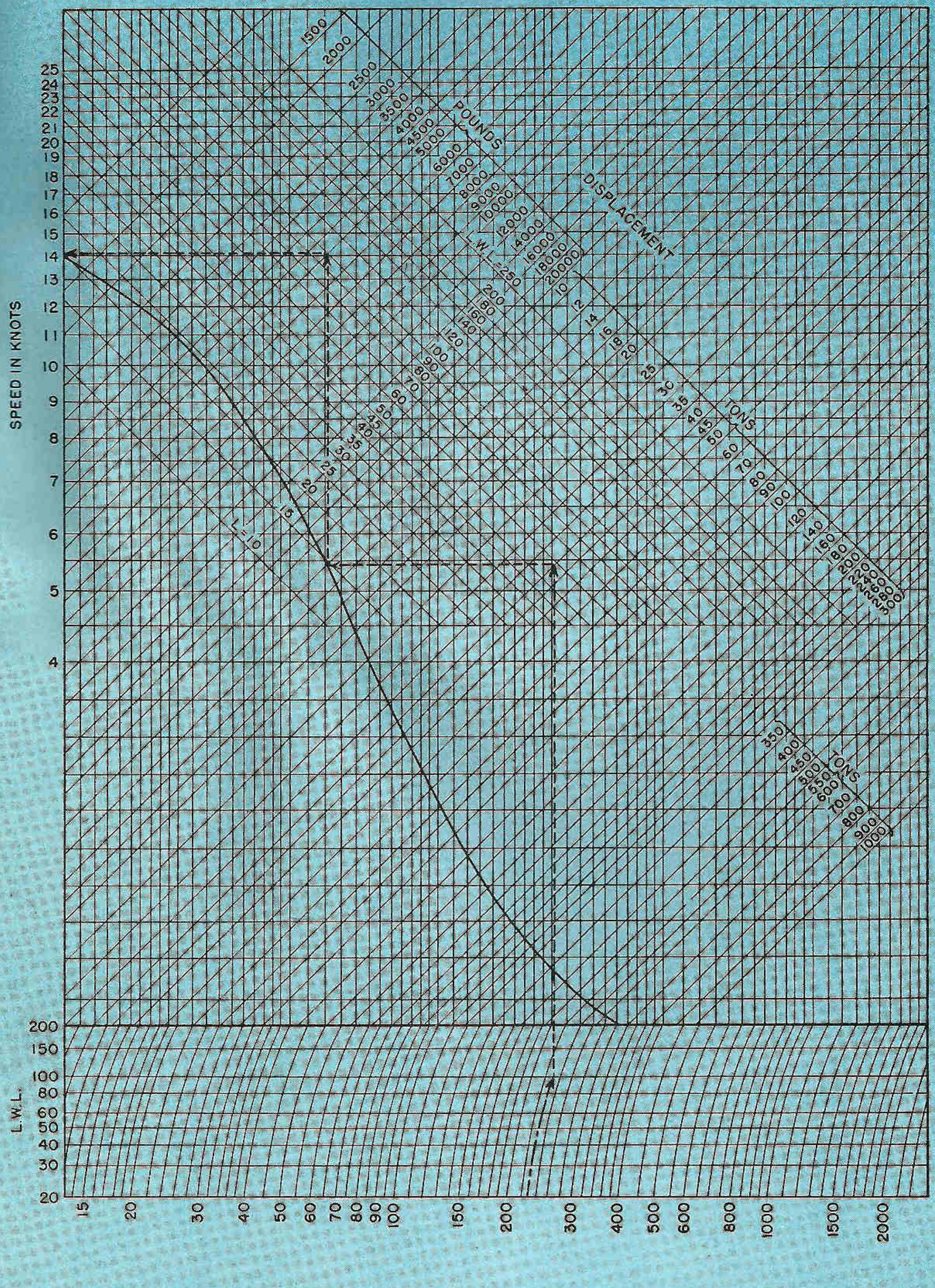
• MULTIPLY $\sqrt{L.W.L.}$ BY SPEED LENGTH RATIO TO OBTAIN SPEED IN KNOTS

TO CONVERT TO MILES PER HOUR MULTIPLY SPEED IN KNOTS BY 1.152

[Figure #5]

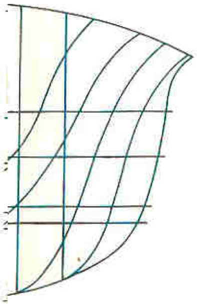
Shaft Horsepower Chart for Speed and Power—

Displacement Type Vessel



[Figure #6]

Primary Conceptions Regarding Planing Hulls



When a boat's speed becomes sufficient to drive it towards the surface, the bottom of the hull acts as a plane. When these conditions prevail, the boat is said to be "planing."

Planing can be defined as the stage at which the dynamic forces caused by the motion of the hull through the water begin to make their lifting influence felt.

There are, of course, many degrees of planing, ranging from the stage where the water ceases to close in immediately behind the stern, to the stage where almost nothing of the boat is actually in the water as it skims over the surface.

Formulas for calculating the speed of planing hulls are many and varied because of the complexity of factors that affect performance at higher speeds. One of the more widely used is the coefficient "K" method. This method is comparatively easy to use and produces sound, "in the ballpark" estimates for higher speed craft.

$$V = K\sqrt{\frac{SHP}{W}}$$

"K" is a coefficient depending on hull form and speed/length ratio.
The following table lists the values of "K" for various type hulls.

	Values of "K"		
		Vee Bottom Hard Chine	
Loaded Water Line in feet	Round Bilges, Flat at Transom	Not Stepped	Stepped
20	2.25	2.75	3.60
25	2.40	2.90	3.80
30	2.60	3.15	3.96
35	2.80	3.40	4.15
40	3.05	3.65	4.30
45	3.24	3.85	4.48
50	3.34	4.00	4.60

Approximate speed of planing hulls

$$V = K\sqrt{\frac{SHP}{W}}$$

V = Speed in Knots
W = Displacement in Long Tons
K = Hull Coefficient

As an example, here is an actual case history—a 32 ft. aluminum crew boat, Vee Chine hull, 12,400 lbs. displacement and powered by a pair of Detroit Diesel 6V-53N engines.

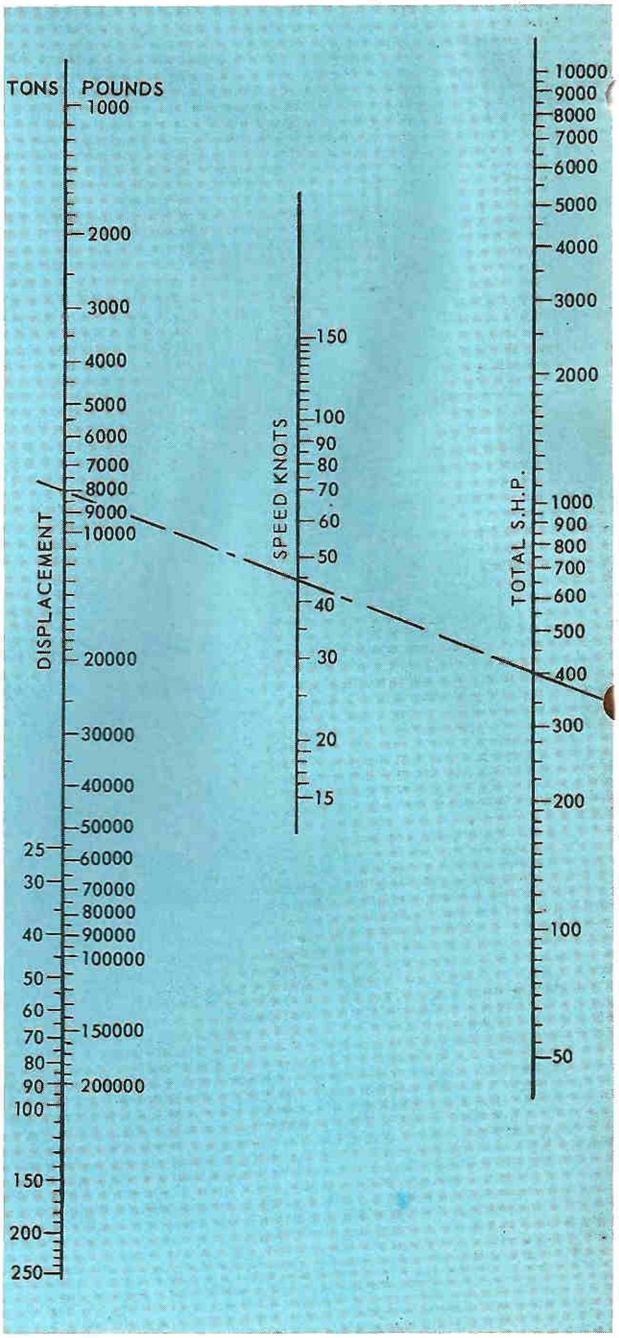
$SHP = 180 \times 2 = 360$
$W = 12{,}400$ lbs. or 5.53 long tons
$K = 3.4$ (taken from preceding table, Vee Chine)

$$V = \sqrt{\frac{360}{5.53}}$$

$$3.4 \times \sqrt{65} = 3.4 \times 8.05 = 27.4 \text{ knots}$$

$V = 27.4$ knots $\times 1.152 = 31.5$ MPH

Figure 7: Marine Nomograph



As the calculations predicted, the boat actually did 32 MPH during its trial runs.

As an assist in performing the square root computation,

$$\sqrt{\frac{SHP}{W}} = \sqrt{\frac{360}{5.53}} \doteq \sqrt{65} = 8.05$$

the bottom "C" scale of Fig. #5 may be used. Perform the division indicated inside the square root sign first. Then read 65 on the top side of scale C and its square root, 8.05, will be directly beneath.

Another method for estimating the speed of planing hulls is shown on the nomograph labeled Fig. #7. To obtain an estimated speed in knots, simply draw a straight line between two known factors.

For example, if a boat weighs 8000 pounds and has 400 SHP, draw a straight line between 8000 pounds on the first scale (left) and 400 SHP on the third scale. Mark the point where this line intersects the middle scale and read the speed, 45 knots. To convert to miles per hour, multiply by 1.152.

PLEASE REMEMBER THAT THESE FORMULAS ARE FOR GENERAL GUIDANCE ONLY AND CANNOT BE USED TO GUARANTEE PERFORMANCE.

Propulsion

The most basic problem of marine propulsion is the transformation of engine power into thrust by means of some form of propulsive device. Because of its efficiency and simplicity, the propeller has become the most widely used propulsive device.

A screw propeller is basically an axial flow pump.

The rotation of the propeller shaft (RPM) and the angle of the propeller blade, known as pitch, combine to form a thrust force on the propeller shaft. Thrust is transmitted through the shaft to the thrust bearing, which is the principal point where the forces generated by propeller rotation act upon the hull.

Propellers

There are many factors to be taken into account in selecting a propeller, from the practical to the very theoretical. The thing to remember is that there is no known formula which will automatically give the ideal propeller size for a given boat. You can merely approximate. The only *true* test is the "trial and error" method.

To permit the reader to more intelligently reason through a specific propeller problem, a better understanding of the factors involved is necessary.

The major terms used when discussing propellers are:

1. Diameter
2. Pitch
3. Slip percent [illegible]
4. Pitch Ratio

DIAMETER is twice the distance from the centerline of the propeller hub to the tips of the blade, or the diameter of the circle scribed by the tips of the blades.

PITCH is the angle the blade makes in relationship to the center line of the hub and is normally expressed as the distance, in inches, that the blade would advance in one revolution, if the propeller were a screw working in a solid substance. Thus, the theoretical distance in inches covered in one minute could be measured by RPM x pitch. However, we are not dealing with a solid and it is here that a loss of forward motion occurs known as "slip."

SLIP is the difference between the theoretical distance and actual distance covered in a given period of time. This relationship is usually expressed in a percentage calculated as follows:

$$\%\ \text{slip} = \frac{\text{Theoretical distance} - \text{Actual distance}}{\text{Theoretical Distance}}$$

$$\begin{array}{l}\text{Where}\\ \text{theoretical}\\ \text{distance}\end{array} = \frac{\begin{array}{c}\text{Engine}\\ \text{RPM}\end{array}}{\begin{array}{c}\text{Reduction}\\ \text{Ratio}\end{array}} \times \frac{\begin{array}{c}\text{Pitch}\\ \text{(inches)}\end{array}}{12} \times \frac{60}{5280}$$

PITCH RATIO expresses the relation between the diameter and the pitch of the propeller. To obtain pitch ratio, divide the pitch by the diameter. If a 60" wheel has a pitch ratio of .7, it has a pitch of 42" (60 x .7) and is known as a 60 x 42 propeller.

A general guide in the selection of an approximate pitch ratio for various types of applications is as follows:

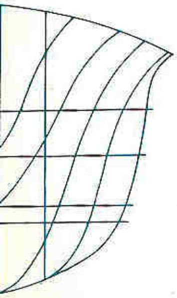
Deep water tug boat	.50—.55
River towboat	.55—.60
Heavy round bottom work boat . . .	.60—.70
Medium round bottom work boat . .	.80—.90
Planing hull	.9—1.2

Of course, there are many variations of the above to meet operating conditions.

Remember, all propellers are a compromise. However, it is generally good practice to utilize the largest propeller diameter at its most appropriate turning speed, within practical limitations. These limitations are:

1. Size of aperture in which propeller is to be installed.

2. Type of operation—towboat, crewboat, etc.
3. Shaft angle required for larger propeller.
4. Weight of propeller, shafting and gear boxes relative to boat's size.
5. If vessel operates in limited draft, wheel size must be governed accordingly, resulting in many cases in a loss of efficiency.



Number of Propeller Blades

Three-bladed propellers are more efficient over a wider range of applications than any other propeller. Therefore, most of our calculations are based on this type of wheel.

In theory, the prop with the least number of blades (i.e. two) is the most efficient. Diameter and technical limitations, in most cases, make a greater number of blades necessary. Four and sometimes five-bladed propellers are used in cases where an objectionable vibration peak is developed within the operating range when using a three-blade propeller.

Four-bladed propellers are often used to increase blade area on tow boats operating in limited draft. They are also used on wood vessels where dead wood ahead of the propeller restricts water flow.

All other conditions being equal, the efficiency of a four-blade propeller is approximately 96% that of a three-blade propeller having the same pitch ratio and blades of the same proportion and shape.

A "rule of thumb" method for estimating four-blade propeller requirements is to select a proper three-blade propeller from propeller selection charts, then multiply pitch for the three-blade propeller by .914. Maximum diameter of a four-blade propeller should not exceed 94% of the recommended three-blade propeller's diameter. Therefore, we multiply diameter by .94 to obtain the diameter of a four-blade propeller.

For example, if a three-blade recommendation is:

48 x 34
Multiply pitch (34") by .914" = 31"
Multiply diameter (48") by .94" = 45"
Four-blade recommendation = 45" x 31"

As a word of caution, remember that this is a *general* rule . . . for estimating only. Due to the wide variation in blade area and contour from different propeller manufacturers, consult your particular manufacturer before final specifications are decided upon.

An old waterfront rule of the thumb for all propeller selection is:

"Towboats—big wheel, small pitch"
"Speedboats—little wheel, big pitch"

All other applications can be shaded between these two statements of extremes.

Propeller Tip Speeds

Propeller tip speed is the speed, in MPH, travelled by the tips of the propeller blades. The greater the tip speed, the more power consumed in pure turning effort. A 30" propeller with a tip speed of 60 MPH will absorb about 12 horsepower in pure turning effort. This, in itself, is a horsepower loss because it contributes nothing to the forward thrust. Generally, propellers greater than 30" in diameter should not have a tip speed over 60 MPH. On smaller propellers, under 20", tip speeds should not exceed 120 MPH.

$$T = \frac{D \times \text{Shaft RPM} \times 60 \times 3.14}{12 \times 5280}$$

Where T = Tip speed in MPH
D = Propeller diameter in inches

Cavitation

When propeller rpm is increased to a point where suction ahead of the propeller reduces the water pressure below its vapor pressure, vapor pockets form, interrupting the solid flow of water to the propeller. This condition is known as cavitation.

One of the more common causes of cavitation is excessive tip speed (a propeller turning too fast for water to follow the blade contour). Cavitation can usually be expected to occur at propeller tip speeds exceeding 130 mph. Cavitation results in a loss of thrust and damaging erosion of the propeller blades.

Reduction Gears

Selection of the reduction gear ratio is one of the important decisions to be made in any marine power installation. A range of reduction ratios is normally provided to assure optimum performance under a given set of operating conditions. Consideration should be given to the following factors when selecting a gear ratio, as shown in Fig. #5.

- The best pitch-shaft RPM ratio to use for the application
- Size of aperture in which propeller is to be installed
- Tip speed to avoid cavitation

Propeller Overhang

The maximum distance from the stern bearing to the propeller should be limited to no more than one shaft diameter. Propeller shafts are apt to vibrate and produce a whip action if these limits are exceeded. This condition is greatly accelerated when a propeller is out of balance due to faulty machining or damage.

Multiple Propellers

The most efficient method of propelling a boat is by the use of a single screw. However, there are other factors which, when taken into consideration, make the use of a single propeller impossible.

Shaft RPM Recommendations

VEE AND ROUND BOTTOM PLANING PLEASURE BOATS

BOAT LENGTH

MPH	11.5	13.8	16.1	18.4	20.8	23.0	25.4
KNOTS	10	12	14	16	18	20	22
30′	1200	1500	1500	1600	1800	2000	2000
40′	800	900	1000	1100	1300	1400	1500
50′	750	800	800	900	1000	1000	1000
60′	600	650	700	750	800	850	850
70′	500	500	600	600	700	700	700
80′	400	450	500	550	600	600	600
90′	300	350	400	450	500	500	
100′	300	300	350	400			

LIGHT-ROUND BOTTOM PLEASURE BOAT OR COMMERCIAL BOAT

BOAT LENGTH

MPH	6.9	8.1	9.2	10.4	11.5	13.8	16.1
KNOTS	6	7	8	9	10	12	14
30′	800	900	1050	1200	1300	1400	1500
40′	800	900	1000	1100	1200	1300	1400
50′	500	550	600	700	800	900	1000
60′	400	400	450	550	650	700	800
70′	300	325	350	400	450	500	600
80′	300	320	320	360	400	450	550
90′	300	300	310	350	400	425	500
100′	275	300	300	350	400	425	450

MEDIUM ROUND BOTTOM COMMERCIAL BOAT

BOAT LENGTH

MPH	6.9	8.1	9.2	10.4	11.5	12.7	13.8	15.0
KNOTS	6	7	8	9	10	11	12	13
30′	600	650	700	800	900	1000	1100	1200
40′	600	650	675	750	800	900	1000	1100
50′	400	450	500	550	650	700	750	800
60′	350	375	400	450	500	550	600	650
70′	300	325	350	375	400	450	500	550
80′	300	310	330	340	360	400	450	500
90′	280	300	310	325	340	380	420	450
100′	260	280	300	300	320	350	380	400

HEAVY ROUND BOTTOM COMMERCIAL BOAT

BOAT LENGTH

MPH	6.9	8.1	9.2	10.4	11.5	12.7	13.8	15.0
KNOTS	6	7	8	9	10	11	12	13
30′	400	450	500	550	600	650	700	800
40′	400	425	450	475	500	575	650	700
50′	350	375	400	425	450	500	550	600
60′	300	325	350	375	400	450	500	550
70′	300	300	310	330	350	400	450	500
80′	280	300	300	320	325	360	400	450
90′	260	280	280	300	300	340	360	400
100′	250	265	280	300	300	325	350	375

[Figure #8]

If a boat has to operate in shallow water, the diameter of the propeller is limited. Therefore, it can be necessary to install two and sometimes three propellers to permit a proper pitch ratio for efficient propulsion.

Another condition requiring multiple propellers is encountered when higher speed yachts need more horsepower than a single engine can develop and still be accommodated in the engine space.

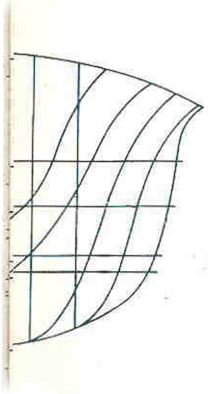
As a general rule to follow for calculation in this text, total SHP of *all* engines is used when making estimated speed calculations. For calculating propeller size, SHP of *each* individual engine is used.

Propeller Rotation

Propeller rotation is determined from behind the vessel, facing forward. The starboard side is on the right and the port side on the left. Rotation of the propeller is determined by the direction of the wheel when the vessel is in forward motion. Thus, a clockwise rotation would describe a right-hand propeller and a counter-clockwise rotation would be a left-hand propeller (Fig. 9).

Right-hand propellers are most frequently used in single screw installations. Twin screw vessels in the U.S. are normally equipped with outboard turning wheels. However, there are some installations where inboard turning wheels will be found.

A rotating propeller tends to drift sideways in the direction of the rotation. In a single screw vessel this can be partially offset by the design of the sternpost and the rudder. In a twin screw vessel this can be completely eliminated by using counter-rotating propellers.

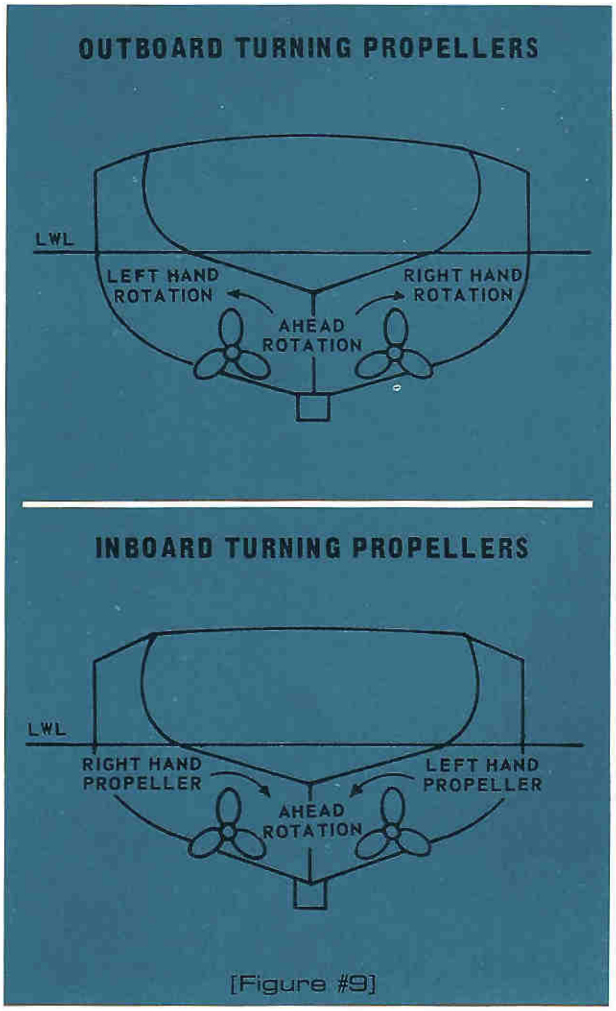


The question of inboard and outboard rotating propellers has been debated many times. Authorities on the subject have agreed that there is little or no adverse effect in maneuverability with either rotation.

Propeller Shafts

The connecting link in a boat's propulsion package is the propeller shaft. This portion of the drive train serves the dual function of transmitting engine torque to the propeller and propeller thrust to the thrust bearing.

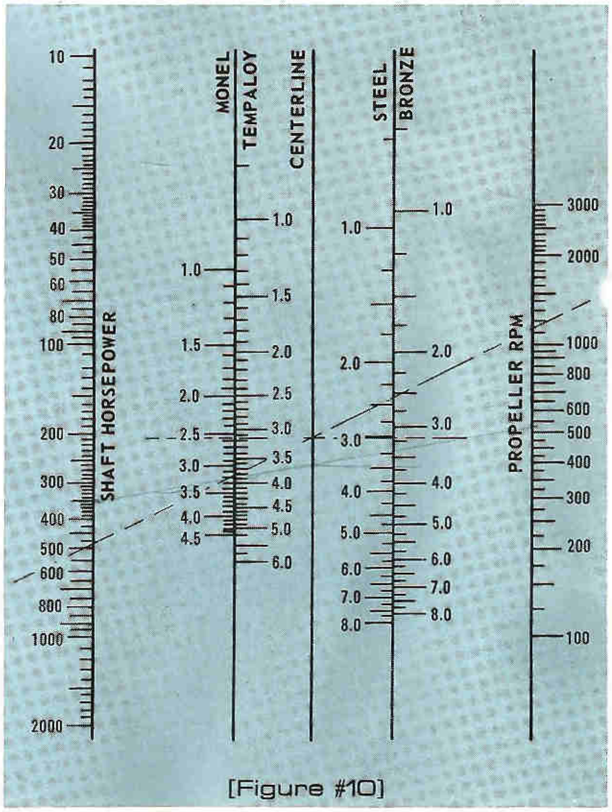
Propeller shafts are classified into two groups, tailshafts and lineshafts. The section or sections of the shafting totally within the hull are termed lineshafts.



[Figure #9]

Tailshafts are that portion which is partially or totally exposed to water outside the hull. Because this section of the shaft is subjected to such erosive forces as water, sand, and bending movements due to propeller overhang, it is generally good practice to use a tailshaft that is heavier than the lineshaft.

Recommended shaft sizes for various shaft materials will be found in the nomograph labeled Figure #10.



[Figure #10]

Instructions:
Rule a line connecting the selected S.H.P. an propeller RPM. At the point where this line intersects the center line, draw a horizontal line through the scales indicating tailshaft diameter, in inches, for the material to be used. Lineshaft diameters can generally be reduced by 5% from these values.

Example:
Select a bronze shaft for an engine with a rated S.H.P. of 478 at 2300 RPM, Light duty (Yacht) service, and 2:1 gear.

Solution: Using rated S.H.P. of 478

$$\text{Shaft RPM} = \frac{2300}{2} = 1150$$

Draw a line connectng 478 S.H.P. and 1150 RPM. From the point where this line intersects the centerline, draw a horizontal line through vertical shaft size scales as shown. Read 3.25 inches on scale marked bronze. Where necessary, correct to nearest standard shaft size.

Hull Vibration

When the vibration frequency of a boat's machinery or propeller synchronizes with the natural vibration frequency of the hull, or some portion of the hull, it can reach a very objectionable sound and motion level.

If the disturbance can be attributed to an engine or generator set, the most effective way to eliminate the trouble is to physically isolate the offencing equipment by the use of vibration mounts. When using vibration mounts on main engines, it is usually mandatory to use a flexible coupling on the driveshafts.

A boat has many vibration forces other than those caused by the engine. In checking for causes of vibration, the following sources should be investigated:

1. Misalignment between engine and propeller shaft or improperly machined propeller coupling.
2. Bent propeller shaft.
3. Hull appendages such as struts, sternpost and rudder, if not properly faired into flow stream.
4. Too much power for boat design.
5. Propeller disturbances.
    a. Wheel clearance (sternpost and hull)
    b. Cavitation
    c. Worn stern bearing
    d. Improperly pitched propeller
    e. Propeller not dynamically balanced

If an undesirable vibration is still noticeable after these potential causes have been checked, it is possible that the impulses are induced by the propeller blades passing the sternpost. This may be eliminated by modifying the shaft-propeller system to alter its natural frequency and/or changing the number of propeller blades. These modifications will move the objectionable vibratory frequency out of the operating range of the engine. The system frequency may also be modified by changing the mass of the propeller, the diameter of the shaft, or relocating the shaft bearing supports.

Specific Type Hulls

Tugs and Tow Boats:

Special consideration is given to the power ratio of this type of vessel because of its unique operating requirements. It is first desirable to know the load requirements, number of barges, displacement of each for average run, the towing or pushing speed required, and current is also a factor.

Towing speed should be 25% to 30% below the natural speed of the hull. Vessels of this type tend to bury their bow in their own waves when running free. In square ended "pusher" boats, this may occur at speed length ratios close to 1.0.

Propeller slippage on most towing vessels is approximately 45% to 50%. Low speed propellers having maximum diameter and a moderate pitch are the most desirable.

Fishing Boats:

Vessels in this classification that fish by means of nets drawn through the water offer a special problem. For example, a shrimp boat may travel as far as 500 miles or more to the fishing grounds. Owners usually want to cut this travel time as much as possible. However, when fishing, the boat has to tow large doors and heavy nets at slow speeds. The broad variation in performance requirements calls for a compromise in the propeller selection and reduction ratio to obtain the maximum usable power under both operating conditions.

Repowering

The two major reasons for repowering a boat are to restore worn out equipment to its original efficiency or to improve upon the original performance. In most instances, it has been found that owners will request additional horsepower whenever a change is made. However, the length of a displacement type craft limits its speed. The power required to drive the boat faster than a speed length ratio of 1.34 will be found to be greatly out of proportion to the results obtained. This should be given very careful consideration before complying with a request for additional power. By recalling the previously discussed formula,

$$\frac{V}{\sqrt{LWL}} = \text{Speed/Length Ratio,}$$

this factor can be easily checked.

One of the most important steps to be taken in repowering a boat is to obtain all the information possible on the boat in its present condition; i.e., type of hull, condition of hull, SHP of old engine as is, loaded waterline length measurements, gear reduction, engine room size, maximum speed with the present engine, fuel consumption, etc. All this information should be carefully recorded and presented along with a repower request.

There are numerous forms and methods of tabulating the information that supports a successful marine engine installation. Detroit Diesel employs a "Marine Engine Application Data Sheet," a sample of which is shown as Fig. #11. This sheet, properly filled out and presented to a Detroit Diesel marine engine specialist or a naval architect, will aid them in making the most accurate engine recommendations and new performance predictions.

One of the most important repowering considerations is to establish the vessel's speed and propeller efficiency *before* an engine change. If it cannot be done on a measured mile, it should be approximated by noting elapsed time of operation between points of known distances. Fuel consumption should also be checked.

With a known speed, checking the nomograph in Fig. 2 to obtain a speed-length ratio of the hull will result in a closer estimated speed with the new power plant.

Boat Drawings

Major plans of boats drawn by boatbuilders usually include the following:

1. Inboard profile—section through boat structure if it were cut in half lengthwise.
2. Outboard profile—side view showing all of vessel above waterlne as it might appear in a photograph.
3. Deck plans—that view of section through vessel at various heights above keel.
4. Line drawings—set of imaginary outlines used to indicate the shape of the hull.
5. Miscellaneous detail drawings—engine room layout, etc.

There are other calculated data, such as displacement curves and stability curves, which are usually not made up for the size vessel being discussed.

Important Elements of Marine Propulsion

1. Initial Cost—gasoline versus diesel:

The initial cost of a diesel engine is approximately twice that of a gasoline engine.

- *The true* cost of a marine engine can be clearly seen only by comparing SHP and cruising speed.

Because of their automotive-type ratings, gasoline engines must sacrifice as much as 50% of their SHP output for an acceptable level of engine durability.

Detroit Diesel engines, however, can be run at full rated output and still maintain their high level of diesel durability. If the maximum in durability is desired, it can be achieved with less than a 10% drop in engine SHP output.

Under these conditions, a 130 hp Detroit Diesel engine will compare very favorably with a gasoline engine in the 180-210 hp range, both from the standpoint of cost and boat cruising speed.

2. Maintenance Cost—gasoline versus diesel:

- Out-of-pocket expenses are lower with a diesel engine since fuel costs run 25% to 50% less than gasoline. In addition, it is possible for a diesel to travel 1½ to 2 times as far as a gasoline engine, using the same horsepower.

Gasoline—100 gals. @ 36¢ ($36) and cruise 1 mile/
gal. = 100 miles or 2.8 miles per dollar.

Diesel—100 gals. @ 26¢ ($26) and cruise 1½ miles/
gal. = 150 miles or 5.8 miles per dollar.

- Diesel engines are precision built and designed for a much greater life expectancy. Diesel maintenance is far less per year, in terms of both time *and* money. Gasoline engines generally need overhaul in 500 to 1000 hours, while diesels in pleasure boats normally go from 2500 to 5000 hours before overhaul.

- The inherent safety and dependability of a diesel engine is added assurance that a diesel powered boat will return to shore safely. Diesel fuel accounts for part of this extra security factor because it is naturally less volatile than gasoline and safer to run. This feature is an ingredient that simply cannot be measured in dollars and cents.

3. Residual Value—gasoline versus diesel:

- There is little doubt that a diesel powered boat provides its owner with a much better return on investment than a gasoline powered boat at the time of resale. Diesels are not only less hazardous to operate but they are in greater demand.

- Banks are willing to finance a larger portion of the purchase price of a diesel powered boat because they *do* have a higher residual value and *are* in such demand.

DETROIT DIESEL ENGINE DIVISION

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IN CANADA GENERAL MOTORS DIESEL LIMITED ▮ LONDON ONTARIO

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