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A SIMPLIFIED METHOD FOR CALCULATING THE CRUISING SPEED AND PROPELLER DIMENSIONS OF A SMALL FISHING BOAT

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PREFACE

Choosing the optimum size propeller for a small boat is no easy task, because it involves rather complicated factors and calculations. Moreover, sufficient tank test data are harder to obtain than for a large boat. There is often a need to have an approximate estimate of the boat speed and propeller dimensions. This paper will provide an aid to obtaining such information and will give a general idea of this matter. However, detailed information on a specific boat design and propeller dimensions should be obtained from the manufacturers.

This paper is an abstract of the course of elementary lectures given to SEAFDEC trainees of the 1st year class during the 1980-81 academic year. In the first section of the paper we offer a method of estimating the speed of boat with displacement tonnage from 50 - 1,000 tons. The second section deals with the speed of small FRP (Fiberglass Reinforced Plastic) boats of 3-15 tons and of 1-15-ton boat which are popular in Japan. In the third section of the present paper a more general method of calculating the speed of boat and dimensions of propeller is presented. This method is the commonly used one in the case of small fishing boats. The third section also contains a diagram of the propeller touring power, which will be useful to a more expert reader.

It must be pointed out that the values for the speed of boat and propeller dimensions obtained by the methods described in this paper should allow for a margin of error. This is inevitable, as no two boats built according to the same design run at equal speed.

I wish to thank Mitsubishi Heavy Industries Ltd., Mr. Y. Kato of Mikado Propeller Works and other authors of reference books, for their kind permission to use the data from their books, manuals and technical reports in my lectures and in the present paper.

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Contents

1. HOW TO ESTIMATE THE CRUISING SPEED AND PROPELLER DIMENSIONS APPROXIMATELY BY THE GRAPHIC METHOD; 50 - 1,000 TON VESSELS

Introduction

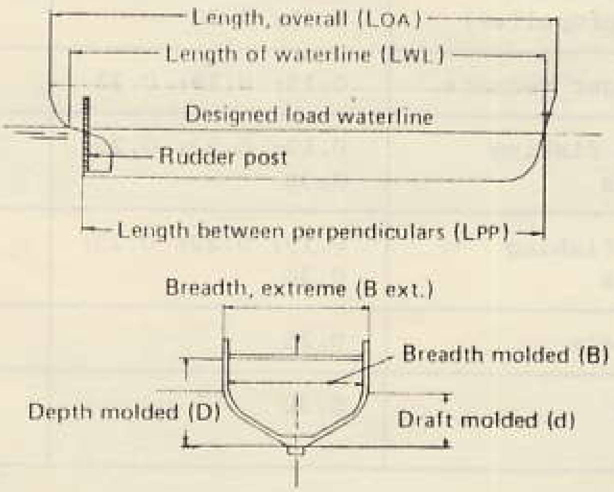
It often becomes necessary for us in the field of marine engineering to estimate offhand the cruising speed and propeller size for a particular vessel on the basis of a few known factors, some of which may not be specific or defined precisely.

Suppose the size of the vessel under consideration is known to you in terms of length (L) and breadth (B) only: then you have two known factors to work with. One factor is the size of the vessel represented by its length and breadth, and the other factor is that of the engine you would propose for that vessel. The latter factor is in terms of rated horsepower output (PS/rpm) and reduction ratio (the ratio of propeller shaft speed to engine crankshaft speed).

A large volume of theoretical and empirical data contained in the present paper are laid out in the form of graphs (see Appendix) to enable you to make estimates in the above-stated situation.

Given factors

In the present estimating procedure, the size of a vessel is represented by only two dimensions, length (L) and breadth (B). Normally, length between perpendiculars (Lpp) and molded draft (d) are considered to calculate and determine the size requirements of the propeller. In the present case, however, we take overall length (LOA) for the length and extreme breadth (Bext) for the breadth.



The 23 graphs, each constructed on the ratio of B to L as the given variable, are devided in seven categories, one for each kind of vessel ranging from cargo vessels to barges. For example, five graphs are given for the single-propeller cargo vessel as one category, five graphs for the twin-propeller cargo vessel, etc.

The engine as the other factor takes two values to be used in this estimating procedure. One value is the rated horsepower and the other is the r.p.m (revolution of the output), both of which are to be derived by you from a marine engine catalog.

Reference data

As stated before, each of the 23 graphs is for a certain value of B/L suggestive of a rough idea of the shape, not physical size, of a vessel. Cruising speed is taken as a parameter, that is, several curves are drawn, each curve representing a definite value of speed in knots.

These graphs, titled "Quick reference diagrams of cruising speed" are followed by three more graphs titled "Quick reference diagrams of propeller dimensions" for 50 - 1,000-ton vessels.

(a) Quick reference diagrams of cruising speed

Category	B/L	Page
Cargo vessels (single-propeller)	0.15; 0.19; 0.22; 0.25; 0.30	22, 23
Cargo vessels (twin-propeller)	0.15; 0.19; 0.22; 0.25; 0.30	24
Passenger vessels	0.15; 0.19; 0.22	25
Wooden fishing vessels	0.19; 0.22; 0.25; 0.30	26
Steel fishing vessels	0.19; 0.22; 0.25; 0.30	27
Tug boats	0.25	28
Barges	0.30	28

(b) Quick reference diagrams of propeller dimensions

Estimating procedure

How to go about with known factors and in reference to the attached graphs will be explained by way of two examples.

Example 1

In the first example, a cargo vessel measuring 50 meters in length and 7.5 meters in breadth is assumed. It is also assumed that its displacement tonnage is unknown. To be fitted to this vessel is an engine unit of 750 PS/900 rpm and 0.354 reduction ratio. What, then, is the cruising speed to be expected? What about the propeller diameter and blade pitch?

(a) Estimating the cruising speed

First compute the B/L.

L = 50 m, and B = 7.5 m, so that B/L = 0.15.

The vessel being a cargo carrier, we go to the graph marked "B/L = 0.15", which is given on page 22. (Example)

In the relevant graph, put your pencil tip to the 50-m point on the horizontal axis, move upward until you come to the level corresponding to 750 PS on the vertical axis. The point where the pencil tip is now at, is between two parameter curves, one for 11 knots and the other for 10 knots. You can easily determine by proportioning that the speed Vs arrived at is approximately 10.9 knots. Cruising speed Vs = 10.9 knots.

(b) Estimating the propeller diameter and pitch

Determine the propeller shaft speed Np from the given reduction ratio, which is 0.354.

$$Np = 900 \times 0.354 = 318.6 \text{ rpm}$$

Next, determine the ratio of horsepower to speed:

$$Hp/Vs = 750/10.9 = 68.8$$

Assuming that the propeller is a four-blade one, go to the graph on page 29 and draw a new vertical line (for Np of 318.6 rpm) along the 300-rpm line. Locate the intersection of the 318.6-rpm line and the horizontal 68.8-Hp/Vs line. The intersection happens to be right on the D = 1.8 parameter. Thus:

Approximate diameter D = 1.8 meters

To estimate the needed pitch of this propeller, go to the graph on page 29 with the value of Np × D/Vs.

$$Np \times D/Vs = 318.6 \times 1.8/10.9 = 52.6$$

In this graph, the ratio of pitch to diameter for a single propeller is 0.715.

Since P/D = 0.715
approximate pitch P = 1.8 × 0.715 = 1.29 m

NOTE: Problems such as the developed area ratio and cavitation limit are not dealt with in this paper.

To summarize, the required propeller (4-blade) is approximately 1800 mm in diameter and 1290 mm in pitch.

Example 2

The same vessel as that of Example 1 is assumed with one additional known factor, which is its displacement. Here, a displacement of 600 tons is assumed.

NOTE: Our reader is reminded here that the graph of page 22 based on the B/L of 0.15, refers to 900-ton displacement as the standard, and that this standard displacement tonnage is represented by a curve designated as such.

Since the speed of 10.9 knots arrived at in Example 1 is for a 900-ton vessel, the speed of a 600-ton vessel would be higher, all other conditions remaining constant. So, the first step in Example 2 is to determine the equivalent of 750 SHP (shaft horsepower) in a 600-ton vessel.

Equivalent SHP/750 SHP = 900/600;

equivalent SHP = 750 SHP × 900/600 = 1125

Back in the graph on page 22, locate the intersection of the 1125-PS horizontal line and the 50-m vertical line.

The new intersecting point is between 11-knot parameter and 12-knot parameter. By proportionality as in Example 1, the cruising speed represented by this point is approximately 11.8 knots.

Vs = 11.8 knots

2.1 How to estimate the cruising speed an propeller dimensions of a small FRP boat (3-15 tons)

In this section we shall see how to estimate the speed of small Fiberglass Reinforced Plastic boats, especially those with displacement of 3 to 15 tons, which have not been dealt with in the first part of this paper. In this section we shall also discuss FRP boats of 1-15 tons.

(1) Estimation of Displacement Tonnage (Δ)

If the displacement tonnage (Δ) is known we should use this information in our calculations. If no information on Δ is available, we should make an estimate of this. Displacement tonnage (Δ) of a small boat, such as an FRP boat, is easily affected by the load condition, and the speed depends on Δ.

Figure 3 has been prepared as a quick reference diagram for finding Δ by using the given values for L × B × D (m^3) (Page 31)

(2) Standard displacement tonnage (Δ_o)

Standard displacement tonnage is given in Fig. 2 in accordance with the length of the boat. (Page 30)

(3) Correction of horse power ($\acute{BHP}$)

The ratio of standard Δ_o and estimated Δ (derived from Fig. 2) should vary in proportion with the given propulsive breaking horse power (BHP).

Thus the nominal corrected horse power ($\acute{BHP}$) for the estimation of speed is indicated by

$$\acute{BHP} = BHP \times \frac{\Delta_o}{\Delta}$$

(4) Propeller diameter (D)

$$D^2 = \frac{155}{Np} \times \sqrt{\frac{\acute{BHP}}{Vs}} \quad \text{(for 3-blade)}$$

The above formula indicated in Fig. 4 shows that the optimum diameter of propeller will be obtained by the same method as discribed in Section 1. (Page 32)

(5) Pitch ratio P/D

Figure 5 shows $\frac{Ns \times D}{Vs}$ and $\frac{P}{D}$ relation

Type of Stern equipment:

Keel Type:

- Where (1) $L/\Delta^{\frac{1}{3}} \leqq 4.5$ w = 0.25
- (2) $4.5 < L/\Delta^{\frac{1}{3}} < 5.0$ w = 0.15
- (3) $5.0 < L/\Delta^{\frac{1}{3}}$ w = 0.10
- w = wake

Bracket type .... w = 0.05
Lifting type .... w = 0

Example 1. LoA = 13.0   B = 3.0   D = 1.25   (given)

main engine maximum horse power 1.10 (GHP)

Np = 790 rpm

Loading condition : Light

Speed of boat Vs = ? Propeller Diameter, Pitch (?)

Answer:

$L \times B \times D = 48.8$

From Fig. 3, on the graph line for light load, we can read

$\Delta = 12$ tons

From Fig. 2, from boat length 13 m read standard $\Delta_o = 6.7$ tons

So, correction of horsepower ($B\acute{H}P$) :

$$B\acute{H}P = BHP \times \frac{\Delta_o}{\Delta} = 110 \times \frac{6.7}{12.0} = 61.4 \text{ ps}$$

From Fig. 2, $Vs = f\ (L - B\acute{H}P)$

Read the Vs by L = 13 m and BHP = 61.4

Then we can read Vs = 11.1 kt.

From Fig. 4, $D = f\ (K \sqrt{\frac{BHP}{Vs}})$

$$\frac{BHP}{Vs} = \frac{110}{11.1} \doteqdot 10$$

$$Np = 790 \text{ (rpm)}$$

Thus, we obtain $D \rightarrow 0.78$ m.

$$\frac{Np \times D}{Vs} = \frac{790 \times 0.78}{11.1} = 55.5$$

$$L/\Delta^{\frac{1}{3}} = \frac{13}{12^{\frac{1}{3}}} = \frac{13}{2.289} = 5.7$$

Thus, w = 0.1

From Fig. 5 $\{ \frac{P}{D} = f \frac{(Np \times D)}{Vs} \}$

read $\frac{P}{D} = 0.71$

Then, Propeller Pitch (P)

$$P = \frac{P}{D} \times D = 0.71 \times 0.78 \text{ m} = 0.55 \text{ m}$$

2.2 A simplified method for calculating the speed and propeller dimensions of a small FRP boat (1-15 tons)

This section describes a simplified method rather than the usual accurate calculation of the speed for a medium or high speed small boat, such as Fiberglass Reinforced Plastic fishing boat, passenger boat (steel or anti-corrosive light alloys) or cruiser. This method is applicable for boats of 1-15 tons displacement.

By this method we also aim to obtain better approximate speed value which would approach, as much as possible, the value obtained by the accurate method, and would make it possible to determine the propeller dimension more easily. The essential items needed to estimate the boat speed are as follows:

Hull
- Length of waterline Lwl (m)
- Displacement tonnage Δ

Engine
- Max brake horsepower BHP (PS)
- Maximum revolution of engine at maximum horsepower Ne (rpm)
- Reduction ratio of engine ε

2.2.1 Estimation of Displacement tonnage

In the case when the displacement tonnage is not known, it can be estimated by means of the following formula:

Δ = Lwl × Bwl × T × Cb × 1.025

Overall length	LOA
Registered length	Lreg
Registered breadth	Bmld
Breadth of waterline	Bwl
Registered depth	Dmld
Draft (Draught)	T

These dimension are connected to each other approximately as follows:

Lwl = C1 × LOA

Lwl = C2 × Lreg

Bwl = C3 × BMAX

Bwl = C4 × Bmld

T = C5 × Dmld

Coefficient / Type of boat	C1	C2	C3	C4	C5
Fishing boat	0.87	1.13	0.90	1.00	0.45
Passenger "	0.87	1.13	0.85	0.90	0.35
Cruiser	1.00	1.25	0.85	0.90	0.35

The following values have been adopted for block coefficient C_b:

Fishing boat (pole-and-line fisheries, gill netting, sport fishing) $C_b = 0.50 - 0.55$

Small passenger boat (patrol boat) $C_b = 0.45 - 0.50$

Pleasure motor boat $C_b = 0.40 - 0.45$

By applying these estimated values we can obtain estimated displacement tonnage, as shown in the example for a pole-and-line fishing boat:

Δ = Lwl × Bwl × T × C_b × 1.025

= (1.13 × Lreg) × (1.0 × Bmld) × (0.45 × Dmld) × (0.50 ~ 0.55) × 1.025 = (0.26 ~ 0.28) × Lreg × Bmld × Dmld

2.2.2 Estimation of Speed

The speed of the boat will depend on its resistance, which in turn is determined by the shape of the boat, i.e. whether the hull is wide or narrow. Resistance should be found by testing, if possible. Alternatively, the following value should be used:

$Lwl/\Delta^{\frac{1}{3}}$ $\Delta^{\frac{1}{3}}$ show Fig. D (Page 37)

The above value reflects the amount of resistance; the larger its value, the smaller the displacement tonnage, i.e. better shape of the boat and consequently higher speed can be attained.

Figure A shows the relation between:

$\frac{BHP}{\Delta\sqrt{Lwl}}$, $\frac{Lwl}{\Delta^{\frac{1}{3}}}$ and $\frac{Vs}{\sqrt{Lwl}}$ (Page 34)

Figure D shows the relation between Δ and $\Delta^{\frac{1}{3}}$

Calculate α : $\alpha = BHP/\Delta\sqrt{Lwl}$

Using Fig. A read β : $\beta = Vs/\sqrt{Lwl}$

where Vs = boat speed

$\alpha \rightarrow$ Parameter $Lwl/\Delta^{\frac{1}{3}}$ $\beta = Vs/\sqrt{Lwl}$

Then, calculate $\beta \times \sqrt{Lwl} = Vs$

2.2.3 Simple calculation of propeller dimensions

(1) Given conditions

(a) Power transmission efficiency $\eta s = 0.95$

(b) Sea margine of propeller rpm 2 %

(c) Wake fraction w (from the following table)

Type of stern	Coefficient of fineness	Wake (w) fraction
keel	$L/\Delta^{\frac{1}{3}} \leqq 4.5$	0.25
	$4.5 < L/\Delta^{\frac{1}{3}} < 5.0$	0.15
	$5.0 < L/\Delta^{\frac{1}{3}} < 6.5$	0.10
	$6.4 < L/\Delta^{\frac{1}{3}}$	0.05
bracket		0.05
lifting		0

(2) Calculation of diameter of propeller

Calculate $B_p = \sqrt{\frac{BHP}{V_p}} \times \frac{N}{V_p^2}$ .... (2)

then, $B_p \rightarrow \sqrt{B_p}$ .... (2´)

where, $DHP = BHP \times \eta_s = 0.95 \times BHP$

$N = N_p \times 1.02$ (Sea margine)

$V_p = V_s \times (1-w)$.... (Propellers speed)

Figure B shows coefficient of diameter of propeller and B_p graph

Read from $\sqrt{B_p} \rightarrow \delta$

calculate $D(m) \ \frac{\delta \times V_p}{N}$ .... (3)

(3) Calculation of pitch (P_m)

Figure C shows $\sqrt{B_p} - d\frac{D}{P}$ pitch ratio

read $\sqrt{B1} \rightarrow \frac{P}{D}$

Calculate $P(m) = \frac{P}{D} \times D$ .... (4)

D can be obtained from (3)

(4) The values of diameter (D) and pitch (P) should be expressed in round numbers; up to 10 per cent variation in the value of the propeller diameter has no effect on its efficiency, provided that the sum of D and P remains constant.

Examples of calculation

Example 1.

Small FRP fishing boat

Lreg = 6.43 m Bmld = 1.6^m Dmld = 0.4^m

Maximum horsepower BHP = 28

Max. revolution 3,000 r.p.m

Reduction ratio i = 3.12 or ε = 0.320

Lifting type stern

Find the boat speed and propeller dimensions.

Estimate Δ by using the table on page 9:

Lwl = 1.13 × 6.43 = 7.3 m

Bwl = 1.0 × 1.0 = 1.6 m

T = 0.45 × 0.4 = 0.2 m

= 7.3 × 1.6 × (0.2 × 0.5 × 0.55) × 1.025

= 1.2 × 1.32 ton

From Fig. D :

Δ = 1.32 ton $\rightarrow \Delta^{\frac{1}{3}}$ = 1.096 $\sqrt[3]{1.32}$ (Alternatively, the value of $\Delta^{\frac{1}{3}}$ can be obtained directly by fx-type calculator)

$$Lwl/_{\Delta^{\frac{1}{3}}} = 7.3/_{1.096} = 6.66$$

$$BHP/_{\Delta\sqrt{Lwl}} = 28/_{1.32 \times \sqrt{7.3}} = 7.85$$

From Fig. A read $BHP/_{\Delta\sqrt{Lw}}$ 7.85 $Lwl/_{\Delta^{\frac{1}{3}}}$ 6.66

$$V_s \sqrt{Lw} = 5.5$$

Then, $V_s = 5.5 \times \sqrt{7.3} = 14.8$ knots

N = N_p × 1.02 (2% Sea margin = $3000/_{3.12} \times 1.02$ = 981 rpm

DHP = BHP × ηs = 28 × 0.095 = 26.6 ps

lifting type stern w = 0

$$V_p = V_s = 14.8 \text{ kt}$$

$$B_p = \sqrt{\frac{26.6}{14.8} \times \frac{981}{14.8^2}} = 6.0$$

$$\sqrt{B_p} = 2.45$$

From Fig. B and C to read δ and P/D, from value of $\sqrt{B_p}$ = 2.45

$$\delta = 32.5$$

$$P/D = 1.125$$

From equations (3) and (4)

$$D = \frac{\delta \times V_p}{N} = \frac{32.5 \times 14.8}{981} = 0.490 \text{ (m)}$$

$$P = \frac{P}{D} \times D = 1.125 \times 0.490 = 0.552 \text{ (m)}$$

$$D + P = 1.042 \text{ (m)}$$

$$D = 0.500 \quad P = 0.540$$

Final estimations of speed and dimension of propeller are as follows:

D = 500 mm

P = 540 mm

P/D = 1.08

number of blades = 3

V_s = 14.8 kt where Δ = 1.32 tons

Example 2.

Small FRP fishing boat (Bracket type)

Lreg = 11.3 m Bmax = 4.0 m Dmil = 1.2 m

Main engine BHP = 470 ps

Revolution NE = 2100 rpm

Reduction ratio i = 2.0

Estimating the displacement tonnage

Lwl = 1.13 × 11.3 = 12.8 m

Bwl = 0.9 × 40 = 3.6

T = 0.45 × 1.2 = 0.54

= 12.8 × 14.0 ≒ 13.5

From Fig. D

Δ = 13.5 $\Delta^{\frac{1}{3}}$ = 2.38

$Lwl/_{\Delta}\frac{1}{3}$ = $12.8/_{2.38}$ = 5.38

$BHP/_{\Delta\sqrt{Lm}}$ = 9.73

From Fig. A read:

$Vs/\sqrt{Lwl}$ = 5.0

$Vs = 5.0 \times \sqrt{12.8} = 17.9$ kt

Bracket type w = 0.05

DHP = 470 × 0.95 = 447

N = 1050 × 1.02 = 1071 (Sea Margine 2%)

$V_p = 17.9 \times (1-0.05) = 17.0$

from $B_p = \sqrt{\frac{BHP}{V_p}} \times \frac{N}{V_p{}^2}$

$$B_p = \sqrt{\frac{447}{17.0}} \times \frac{1071}{(17.0)^2} = 19$$

$\sqrt{B_p}$ = 4.36

From Fig. B and C read:

δ = 54.6

P/D = 0.783

$$D = \frac{\delta \times V_p}{N} = \frac{54.6 \times 17.0}{1071} = 0.8667$$

D = 0.8667

P = 0.6786 D + P = 1.545 m

D = 0.850 (D + P ≒ constant)

P = 0.700

3. Estimating the speed of boat by $\frac{BHP}{\Delta} - \frac{V}{\sqrt{L}}$ curves and calculating propeller dimensions and towing power

A more popular and useful method of estimating the speed of a vessel is to apply the empirical curve of $\frac{BHP}{\Delta} - \frac{V}{\sqrt{L}}$. This method was developed by the former Japanese Navy. (Page 38)

For convenience, curves are usually classified into three types, according to the shape of hull.

1. Fair type $L/B \leqq 4$
2. Good type $L/B = 5$
3. Fine type $L/B \geqq 5.8$

You can estimate the speed of the boat by utilizing these curves if the desplacement tonnage (Δ) and the main engine horsepower are known.

Example 1: Trawling boat (135^{GT}) $L \times B \times D = 29.84 \times 5.9 \times 2.85$

light load Δ = 195.6 tons main engine : Diesel, 300 h.p.

heavy load Δ = 250 tons

Find the speed under both conditions of load

$L/B = 5.05$ ..... good type

In light load conditions

$$\frac{BHP}{\Delta} = \frac{300}{195.6} = 1.533$$

In the $\frac{BHP}{\Delta} - \frac{V}{\sqrt{L}}$ curve, if we take the value of $\frac{BHP}{\Delta}$ 1.533

in the longitudinal and crossing point of the good type curve, we can obtain the transverse value of $V/L = 1.05$.

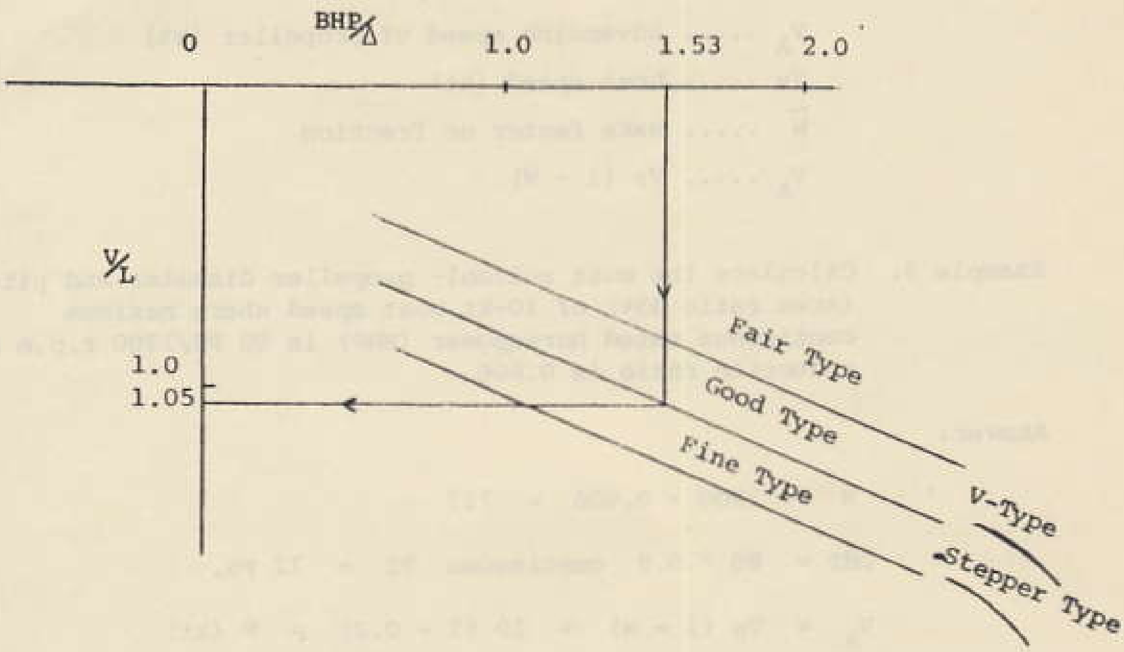
So, $V = \sqrt{L^{m} \times 3.28 \text{ (feet)}} \times 1.05$

$= \sqrt{29.84 \times 3.28} \times 1.05 = 10.37$ kt (light load)

In the same way for full load $\Delta = 250$

we can obtain $V/L = 0.95$

Thus, $V' = \sqrt{29.84 \times 3.28} \times 0.95 = 9.78$ kt (full load)



NOTE: 1. V-type and Stepper Type are also applicable for motor boats.

2. From my experience, for most FRP boats curves between the Good Type and the Fine Type are applicable.

Simple calculation of Diameter and Pitch.

We can calculate these values from the attached diagram more precisely.

$\sqrt{Bp}$: $\frac{H}{D}$ diagram

Bp (Power factor) $= \frac{N \times P^{\frac{1}{2}}}{V_A^{2.5}}$

δ (diameter factor) $= \frac{N \times D}{V_A}$

where, N ..... propeller (r.p.m)

P ..... delivered horsepower (DHP)

V_A ..... advancing speed of propeller (kt)

Vs ..... boat speed (kt)

$\overline{W}$ ..... wake factor or fraction

V_A ..... Vs (1 - W)

Example 3. Calculate the most suitabl- propeller diameter and pitch (Area ratio 35%) of 10-kt boat speed where maximum continuous rated horsepower (MHP) is 80 PS/1200 r.p.m and reduction ratio is 0.606

Answer:

$$N = 1200 \times 0.606 = 727$$

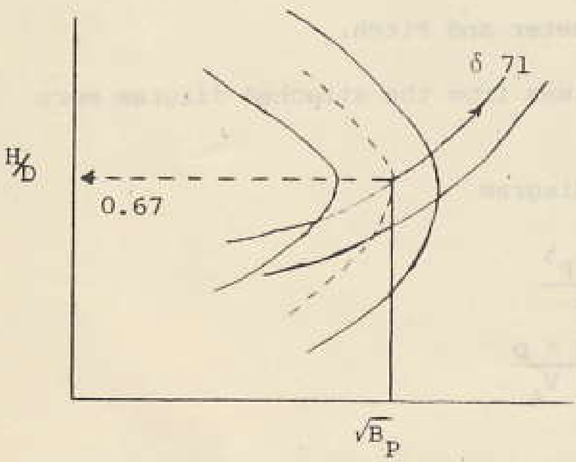
$$DHP = 80 \times 0.9 \text{ continuous PS} = 72 \text{ PS.}$$

$$V_A = Vs\ (1 - w) = 10\ (1 - 0.2) = 8\ (kt)$$

$$Bp = \frac{N.P^{\frac{1}{2}}}{V_A^{2.5}} = \frac{727 \times \sqrt{72}}{8^2 \times \sqrt{8}} = \frac{727 \times 8.48}{181} = 34$$

$$\sqrt{Bp} = \sqrt{34} = 5.82$$

From ($\sqrt{Bp}$: H/D) diagram (page 38) read → δ = 71 H/D = 0.67



$$\delta = \frac{N\ D}{VA}$$

$$D = \frac{\delta \times VA}{N} = \frac{71 \times 8}{727} = 0.78^{m}$$

H/D = 0.67, D = 0.78

H (Pitch) = 0.67 × 0.78 = 0.52^{m}

dia × pitch → $780^{mm} \times 520^{mm}$

We often need to know the towing power of a boat; such as a trawling boat. The $\mu - \sigma$ diagram on page 39 is useful for this purpose.

The procedure for obtaining the towing power is the same as in the example above.

Towing power $(\mu - \delta)$ diagram (page 40)

Towing power

$$\mu = n. \sqrt{\frac{PD^5}{Q}}$$

$$\delta = \frac{TD}{2 \pi Q}$$

$$\rho^{Phai} = VA \sqrt{\frac{P D^3}{Q}}$$

μ ..... torque coefficient

Q ..... torque (kg.m)

P ..... density of sea water $104.5^{kg \, sec^2/m^4}$

T ..... thrust (kg)

VA ..... propeller advancing velocity (m/sec)

n ..... propeller rev/sec (rps)

(1) bollard pulling power

$$\rho = VA \sqrt{\frac{PD^3}{Q}} \qquad VA = 0 \qquad \rho = 0$$

$$Q = \frac{716 \times P}{N} = \frac{716 \times 72^{PS}}{727} = 71$$

$$n = \frac{6}{\sqrt{\frac{P D^5}{Q}}} = 10.3 \quad /sec$$

then N = 60 n = 620 (r.p.m)

$$\text{Engine rpm} = 620 \times \frac{1}{0.606} = 1020 \text{ rpm}$$

$$T = 2 \frac{\pi \delta Q}{D}$$

$$T = \frac{2 \times 3.14 \times 1.52 \times 71}{0.78} = 870 \quad kg$$

maximum thrust ....870 kg

Eng (rpm) 1020

If the boat cruising speed is 3 knots what is its towing power?

$VA = (1 - W)\ Vs = 0.8 \times 3 = 2.4$ kt W = wake fraction = 0.2

$Va\ {}^{m}/_{sec} = 0.5144\ VA = 1.23\ {}^{m}/_{sec}$

$$\wp = 1.23 \times \sqrt{\frac{104 \times (0.78)^3}{71}} = 1.025$$

From the diagram read $\mu = 6.5$ $\delta = 1.46$

$$T = \frac{2 \times 3.14 \times 1.46 \times 71}{0.78} = 835 \text{ kg}$$

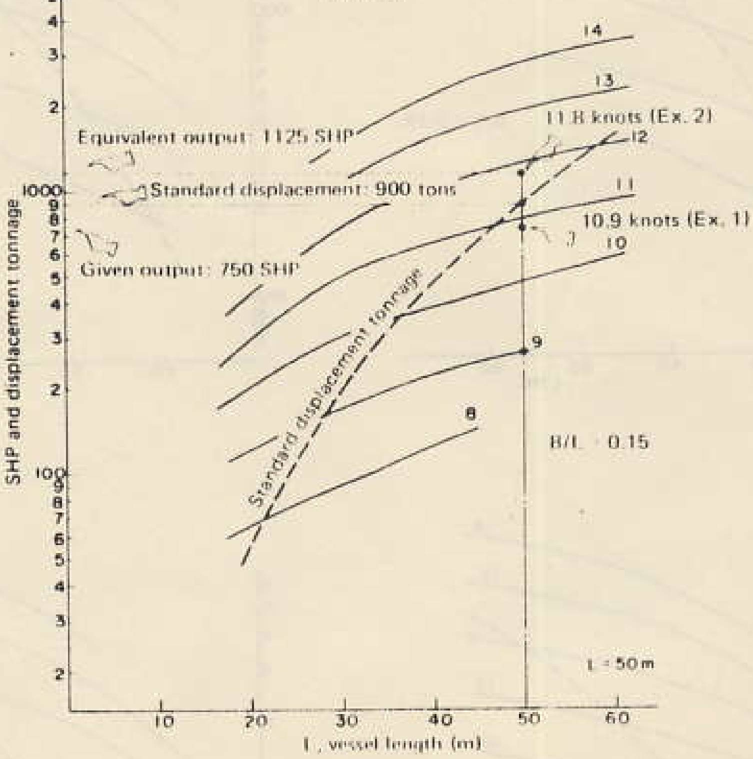
NOTE: Generally speaking, towing power is estimated to be 1 - 1.3 tons for every 100 horsepower of the main engine. Towing power will, of course, decrease rapidly with increased speed of boat

Appendix : Figures

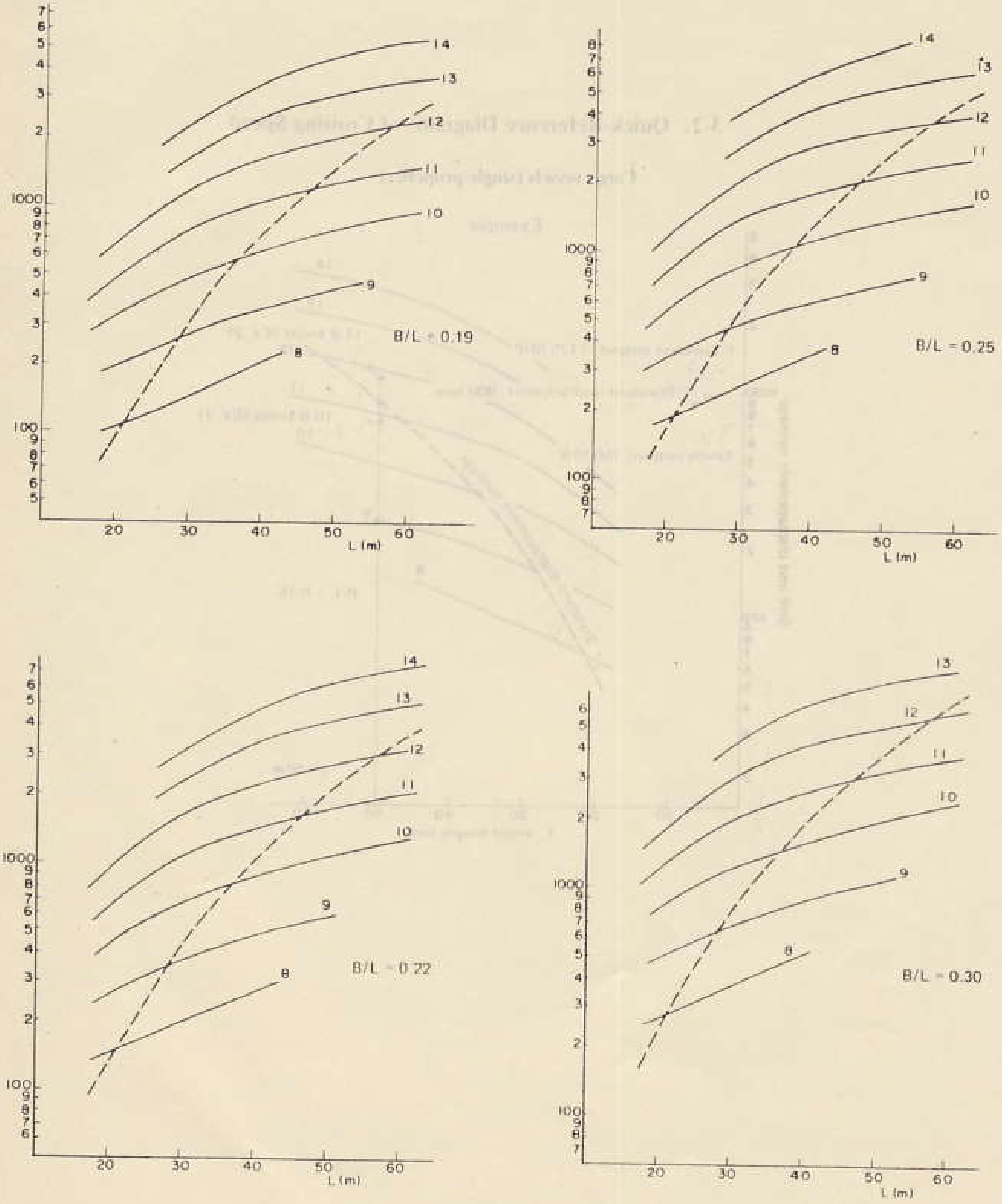
3-2. Quick-Reference Diagrams of Cruising Speed

Cargo vessels (single-propeller)

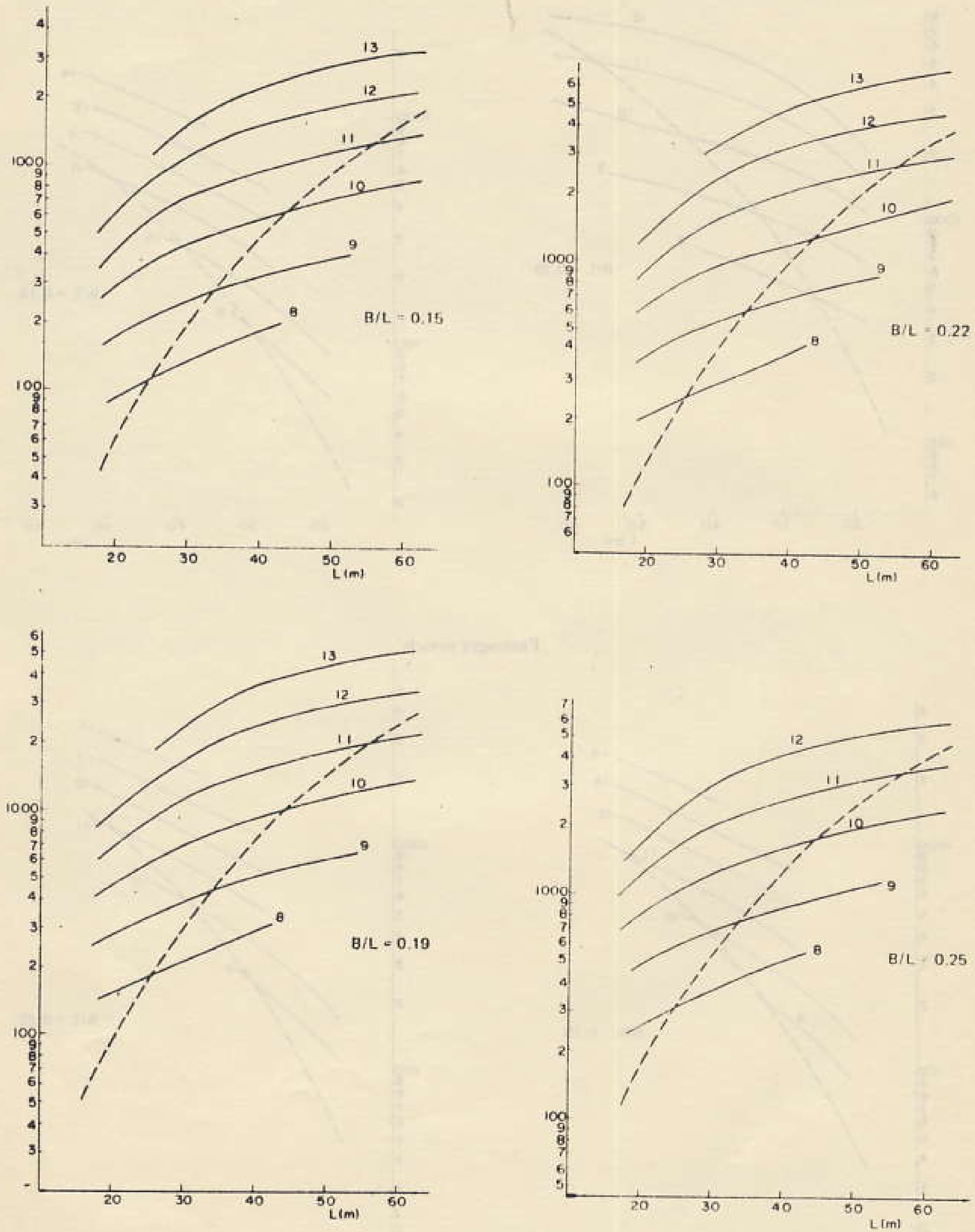
Example



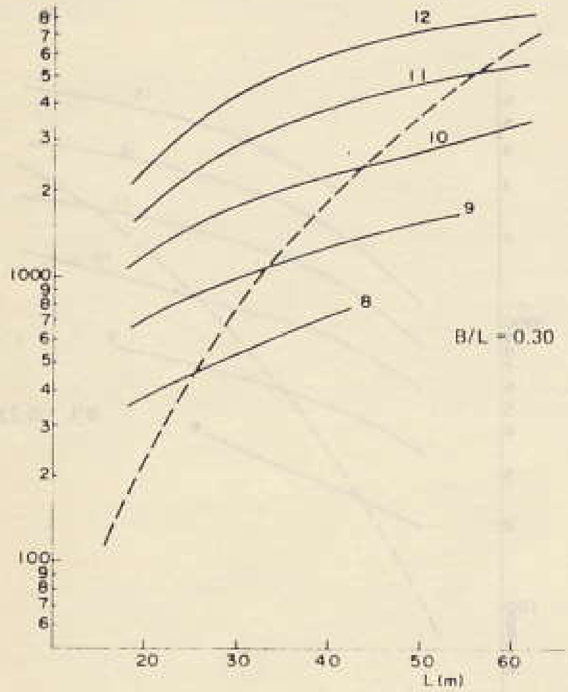
Cargo vessels (single-propeller)



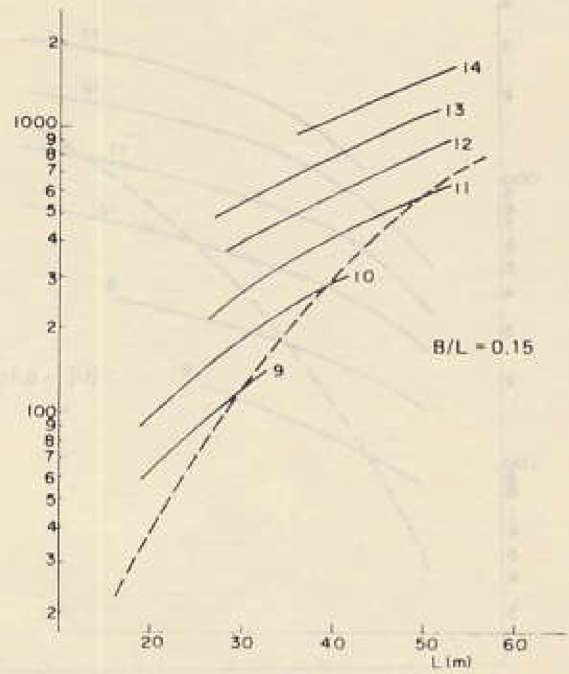
Cargo vessels (twin-propeller)



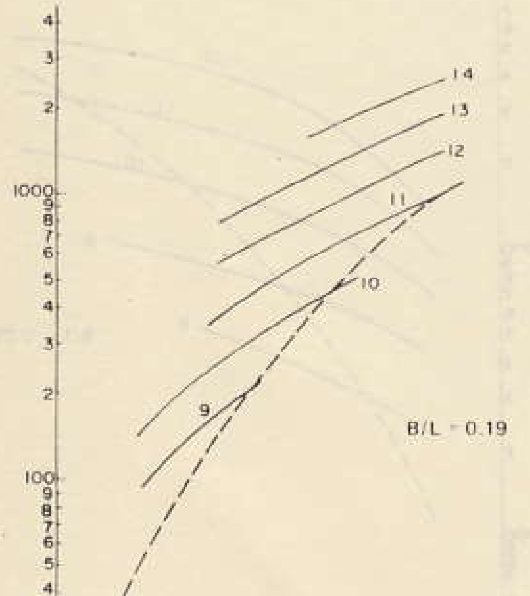
Cargo vessels (twin-propeller)

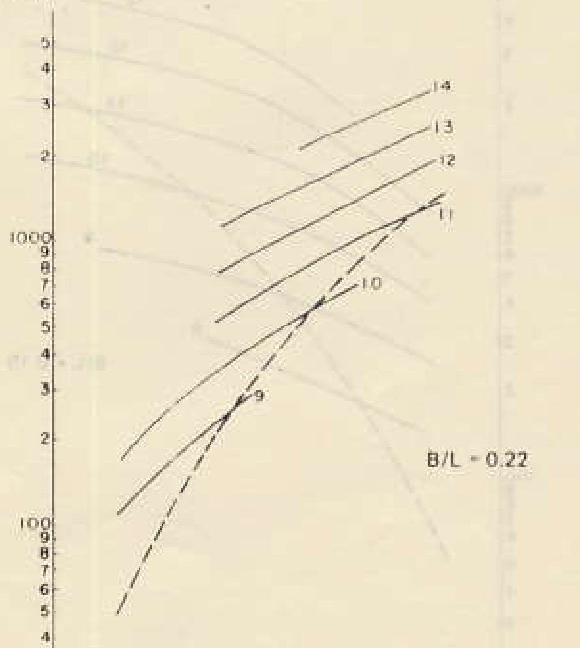


Passenger vessles

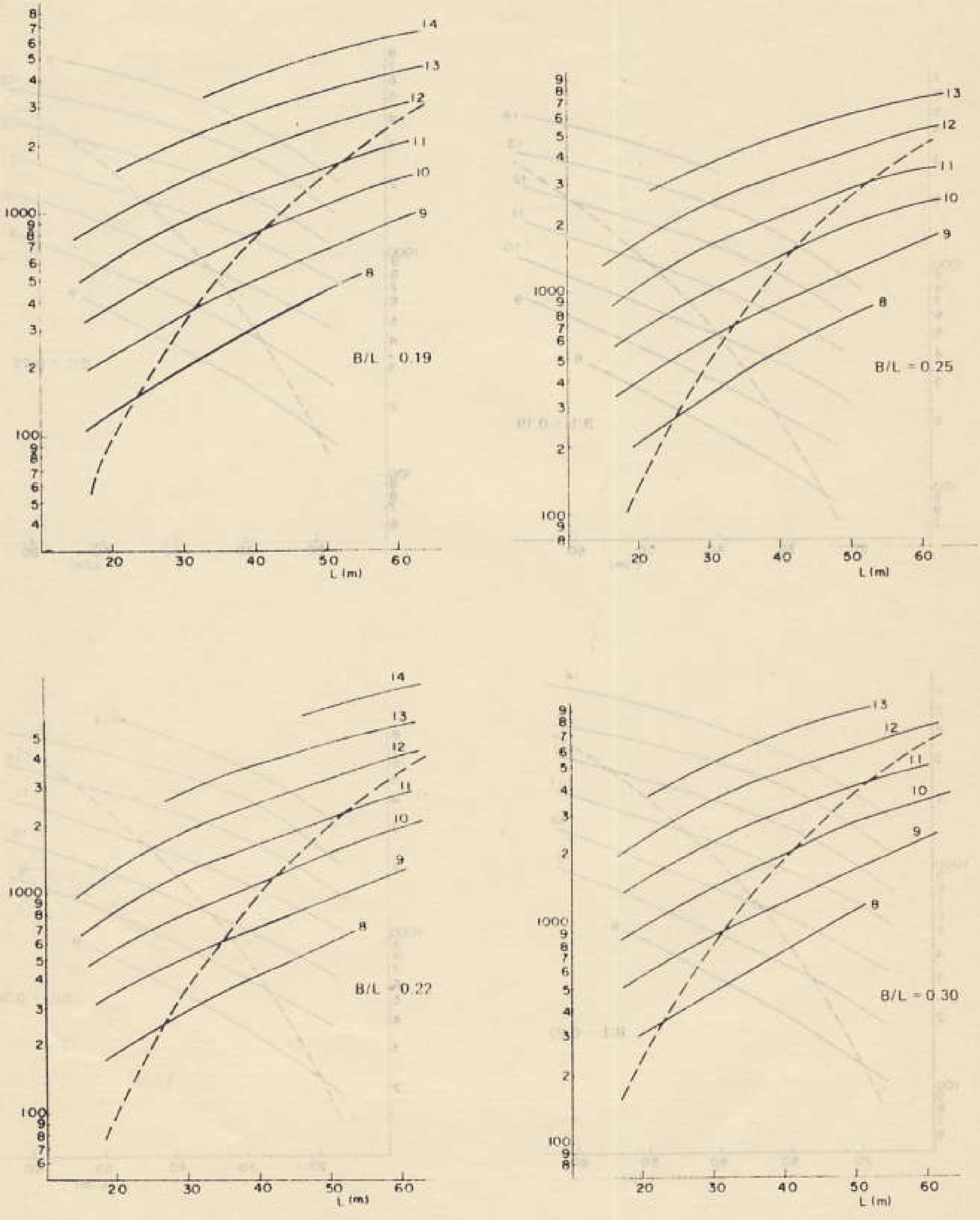


Passenger vessels

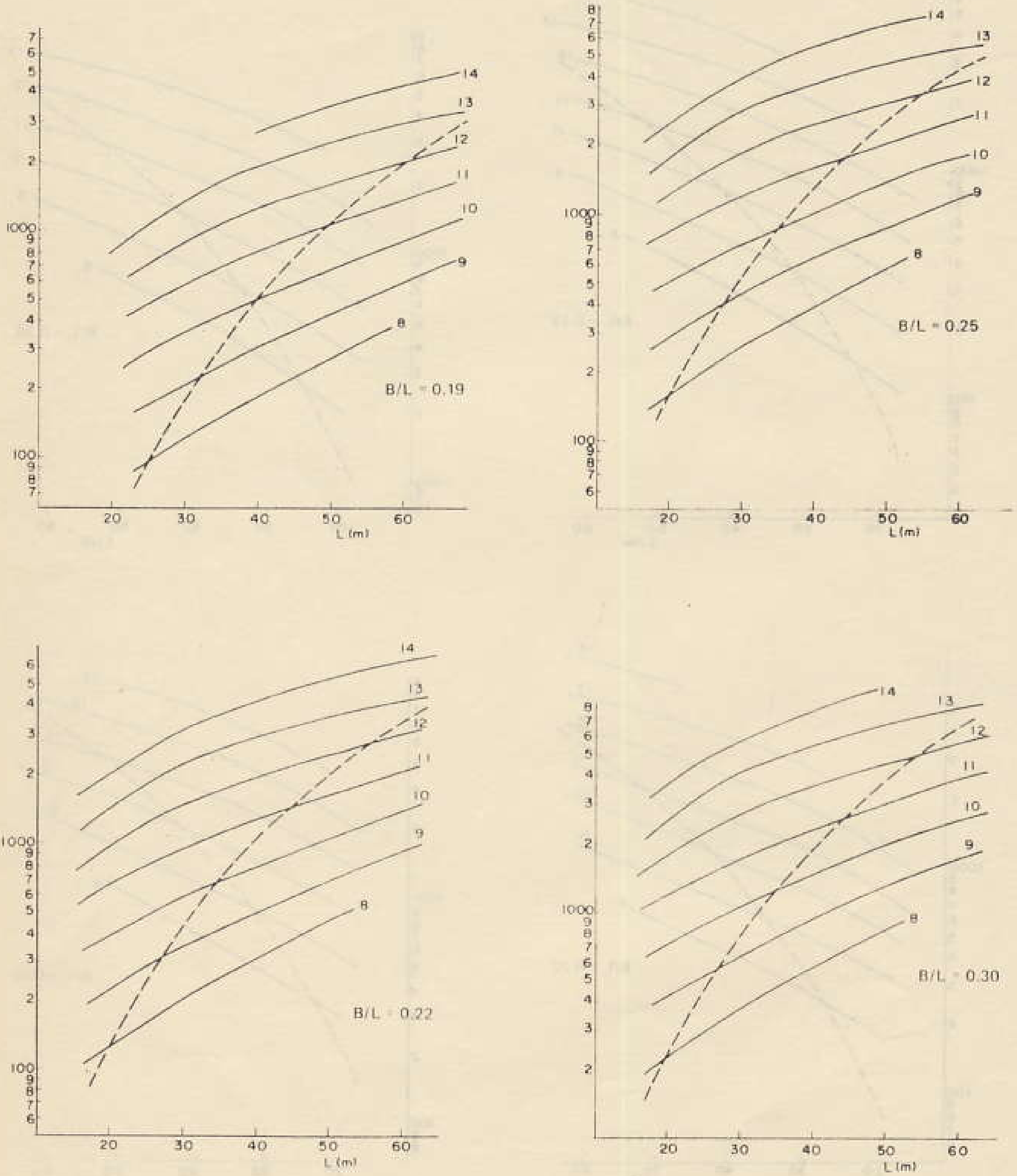




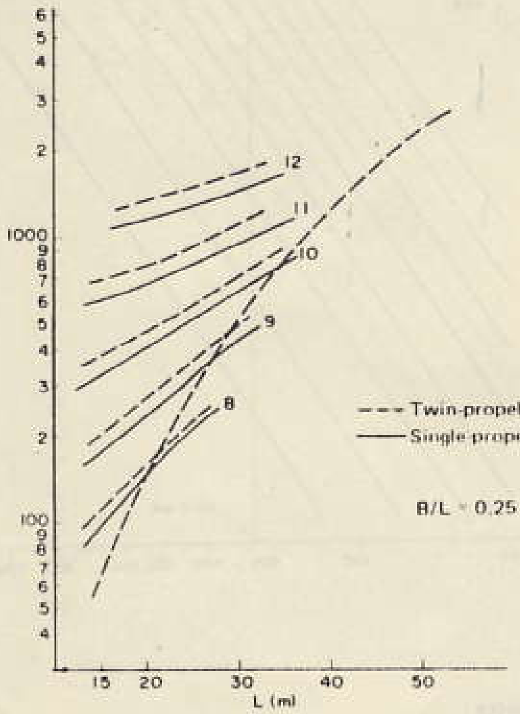
Wooden fishing vessels



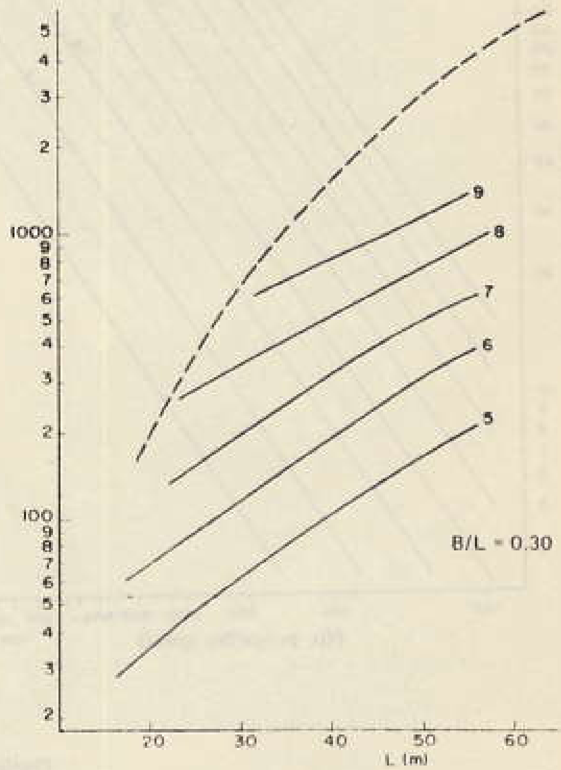
Steel fishing vessels



Tug boats

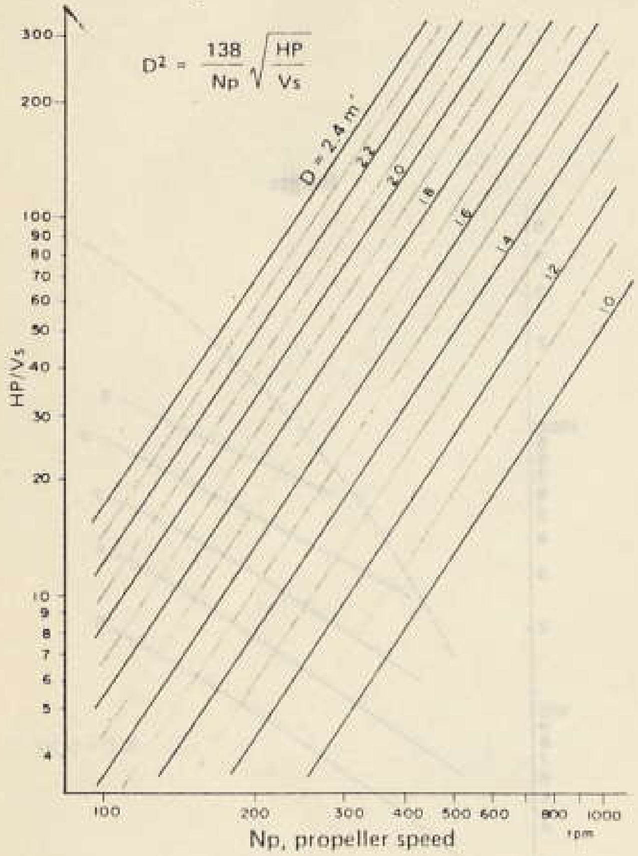


Barges

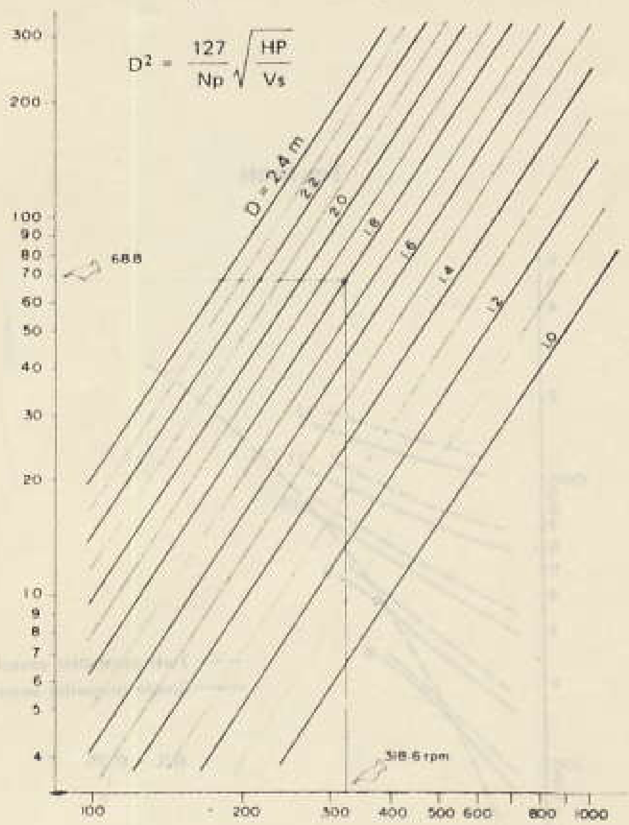


Quick Reference Diagrams of Propeller Dimensions

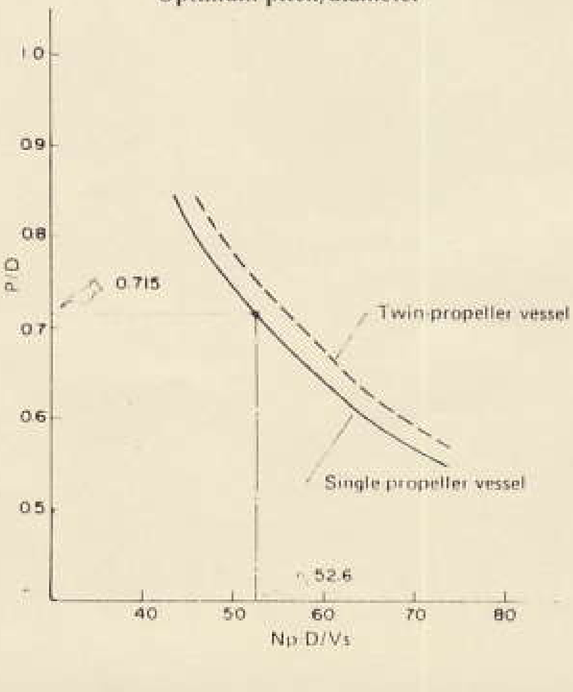
Optimum diameter (3-blade)

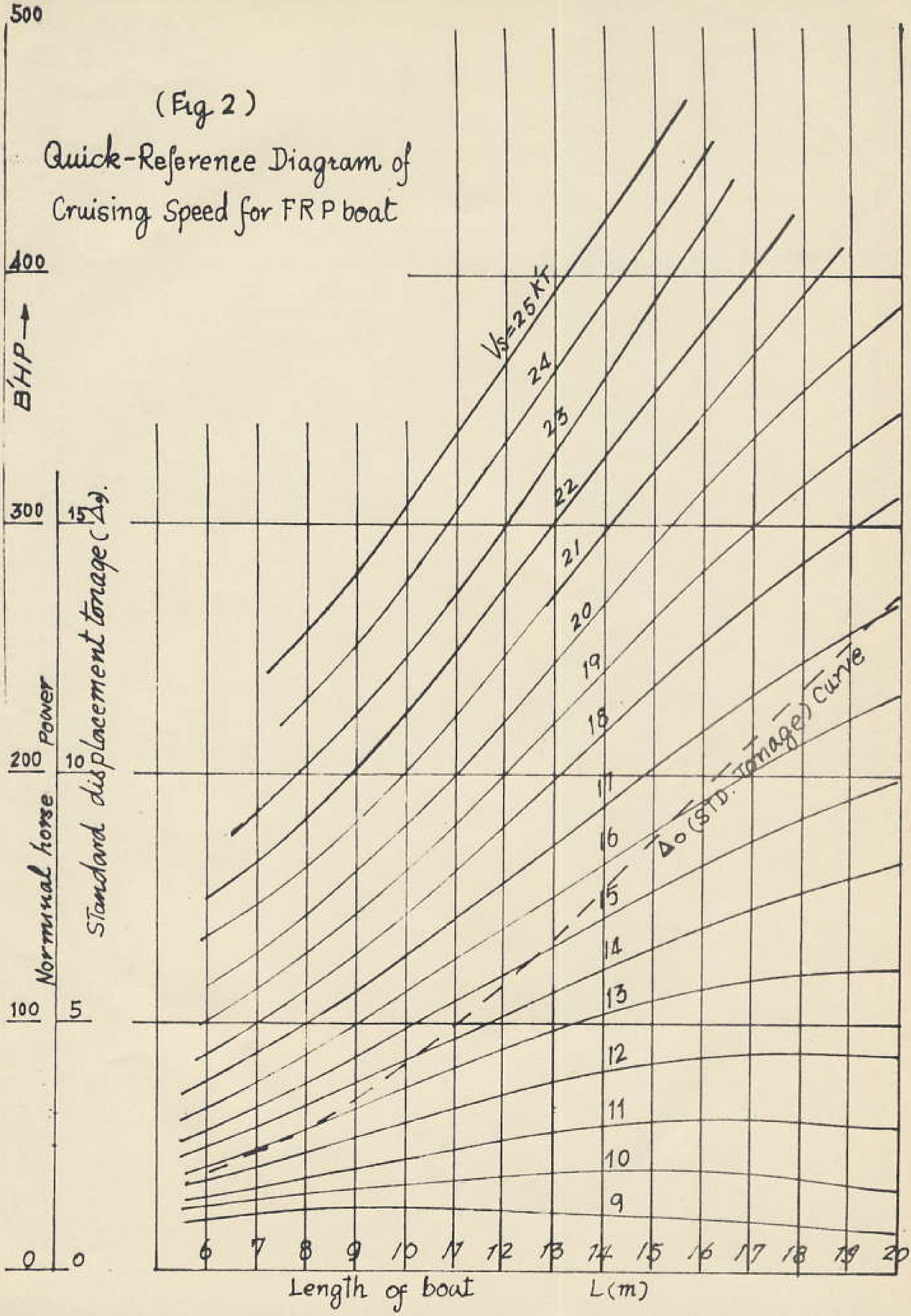


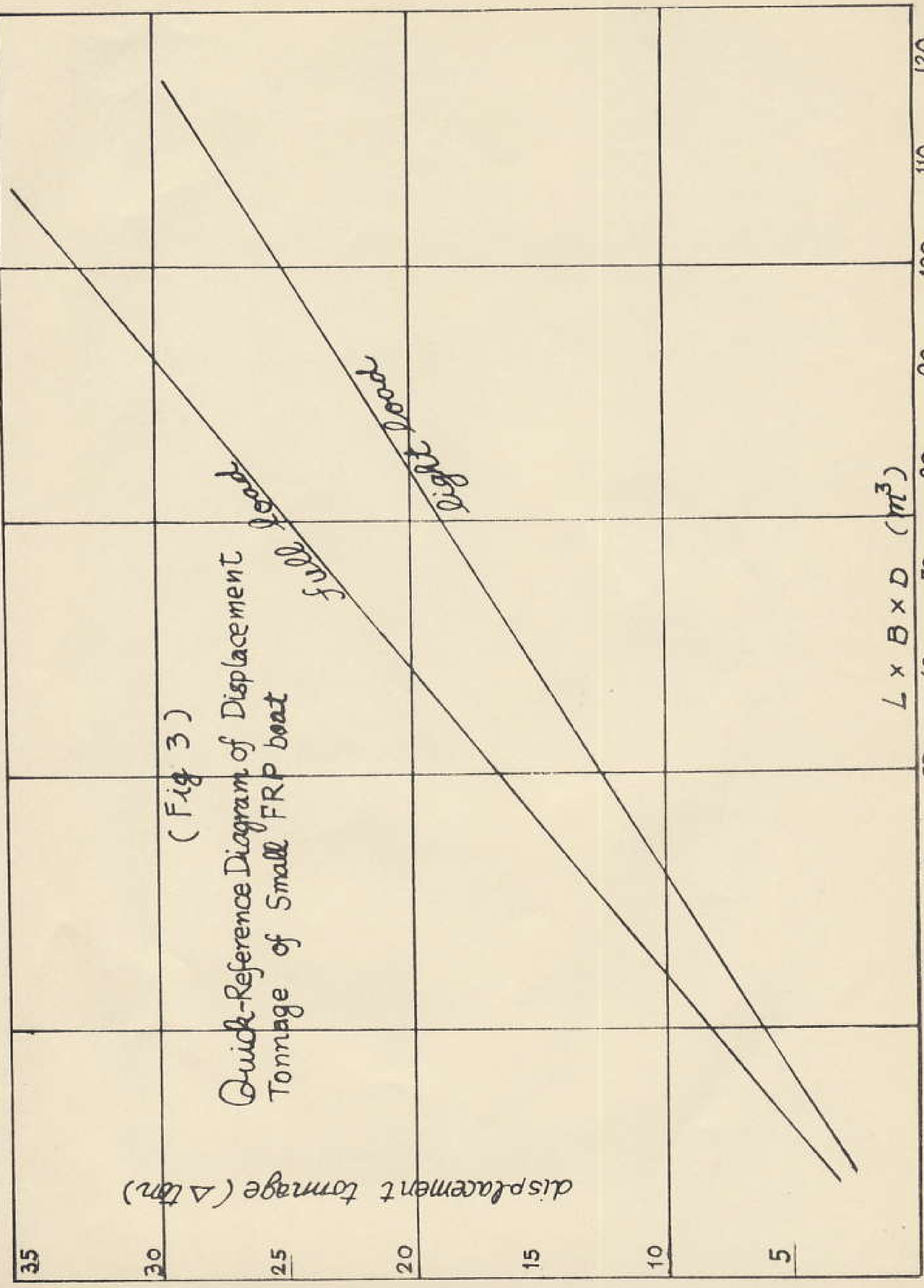
Optimum diameter (4-blade)



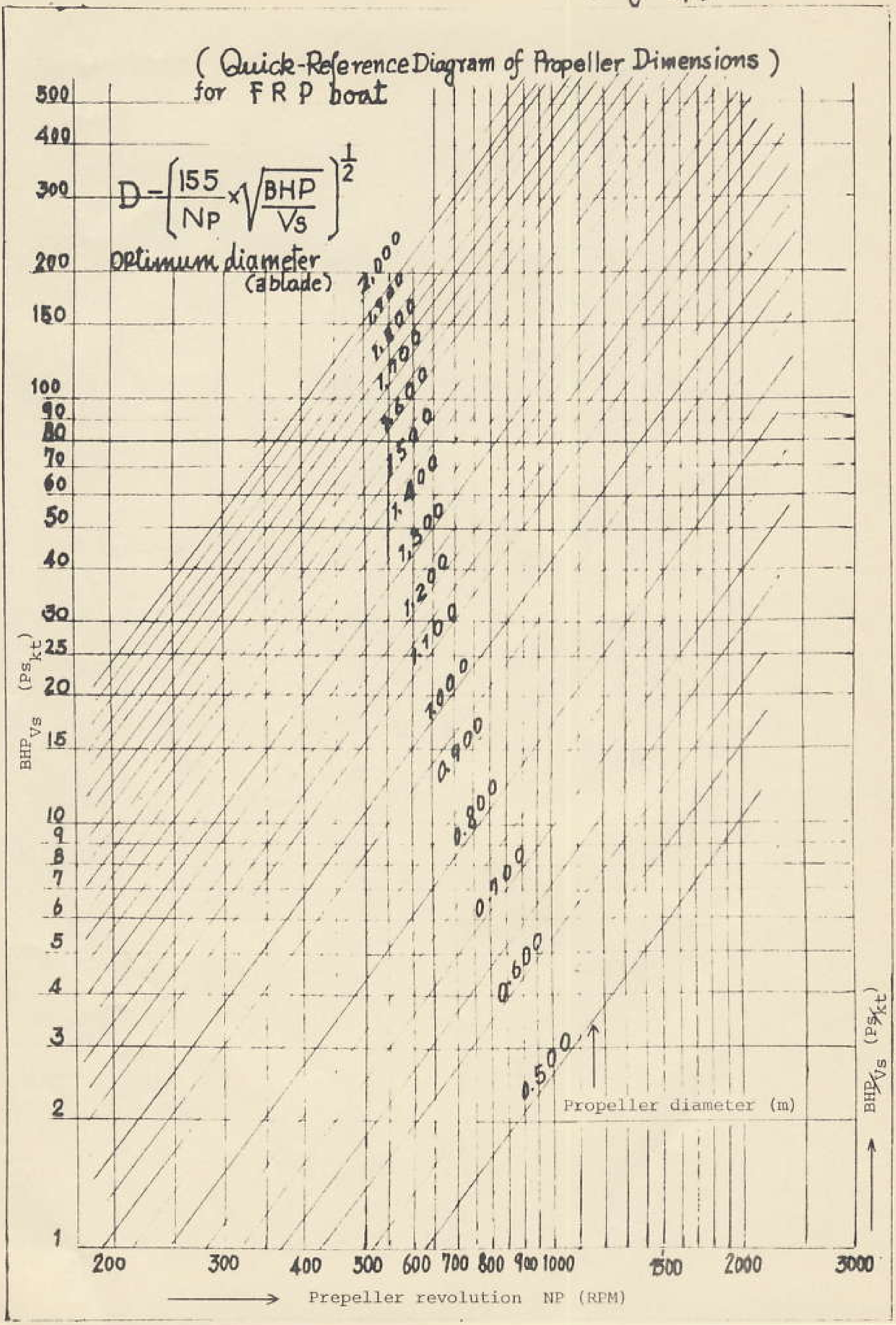
Optimum pitch/diameter




(Fig. 2)
Quick-Reference Diagram of
Cruising Speed for FRP boat
500
400
300
200
100
0
B'HP →
Norminal horse power
15
10
5
0
Standard displacement tonage (Δ_0)
Vs=25 KT
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
Δo (STD. Tonage) Curve
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Length of boat
L (m)


(Fig 3)
Quick-Reference Diagram of Displacement
Tonnage of Small FRP boat
full load
light load
displacement tonnage (Δ ton)
L × B × D (m³)
0
10
20
30
40
50
60
70
80
90
100
110
120
5
10
15
20
25
30
35

(Fig 4)


(Quick-Reference Diagram of Propeller Dimensions)
for FRP boat
D = (155/Np × √(BHP/Vs))^(1/2)
optimum diameter
(3blade)
2.000
1.900
1.800
1.700
1.600
1.500
1.400
1.300
1.200
1.100
1.000
0.900
0.800
0.700
0.600
0.500
Propeller diameter (m)
BHP/Vs (Ps/kt)
500
400
300
200
150
100
90
80
70
60
50
40
30
25
20
15
10
9
8
7
6
5
4
3
2
1
200
300
400
500
600
700
800
900
1000
1500
2000
3000
Prepeller revolution NP (RPM)

(Fig. 5)

(Pitch ratio-Propeller)

P/D

(UB 3-35)

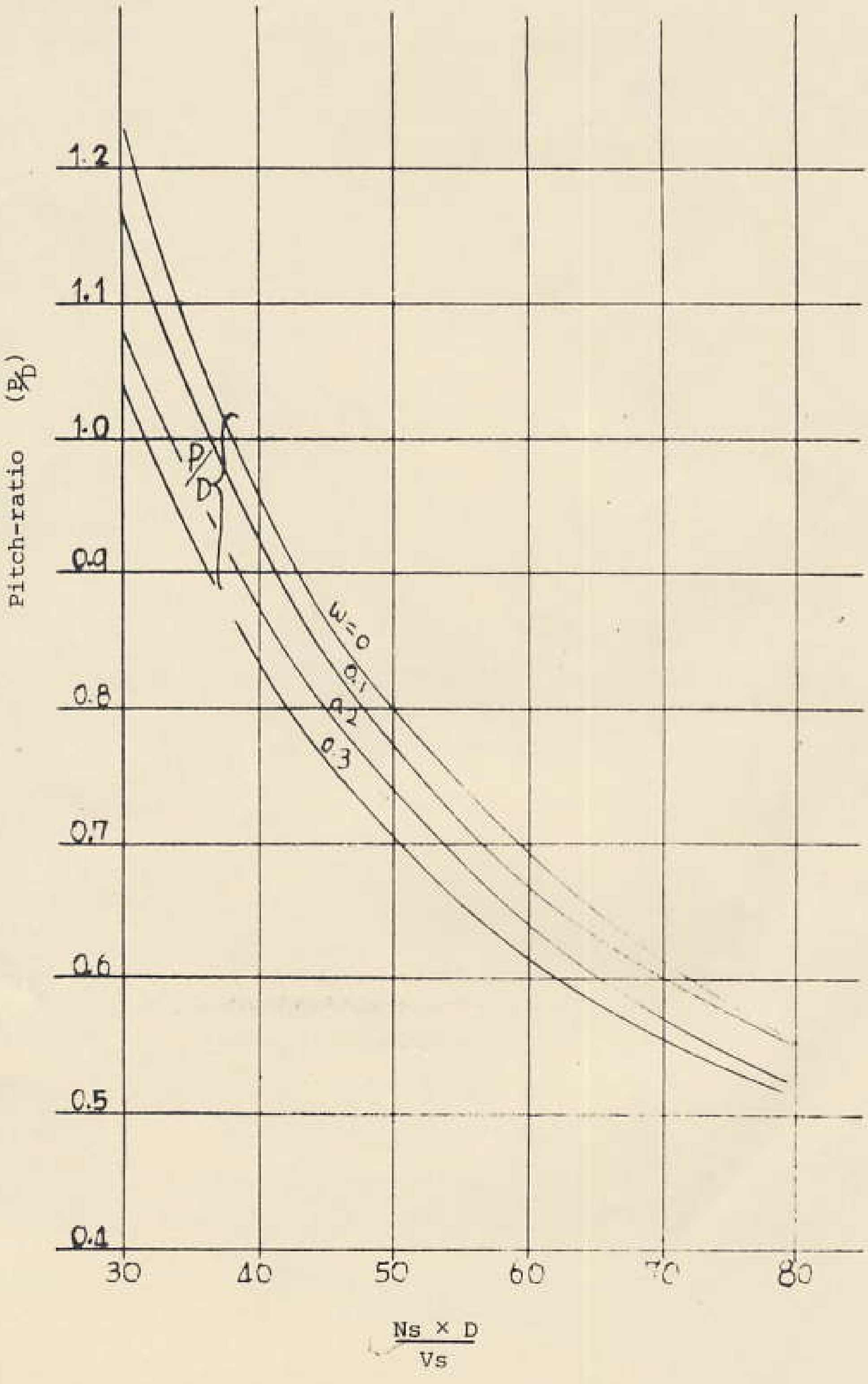
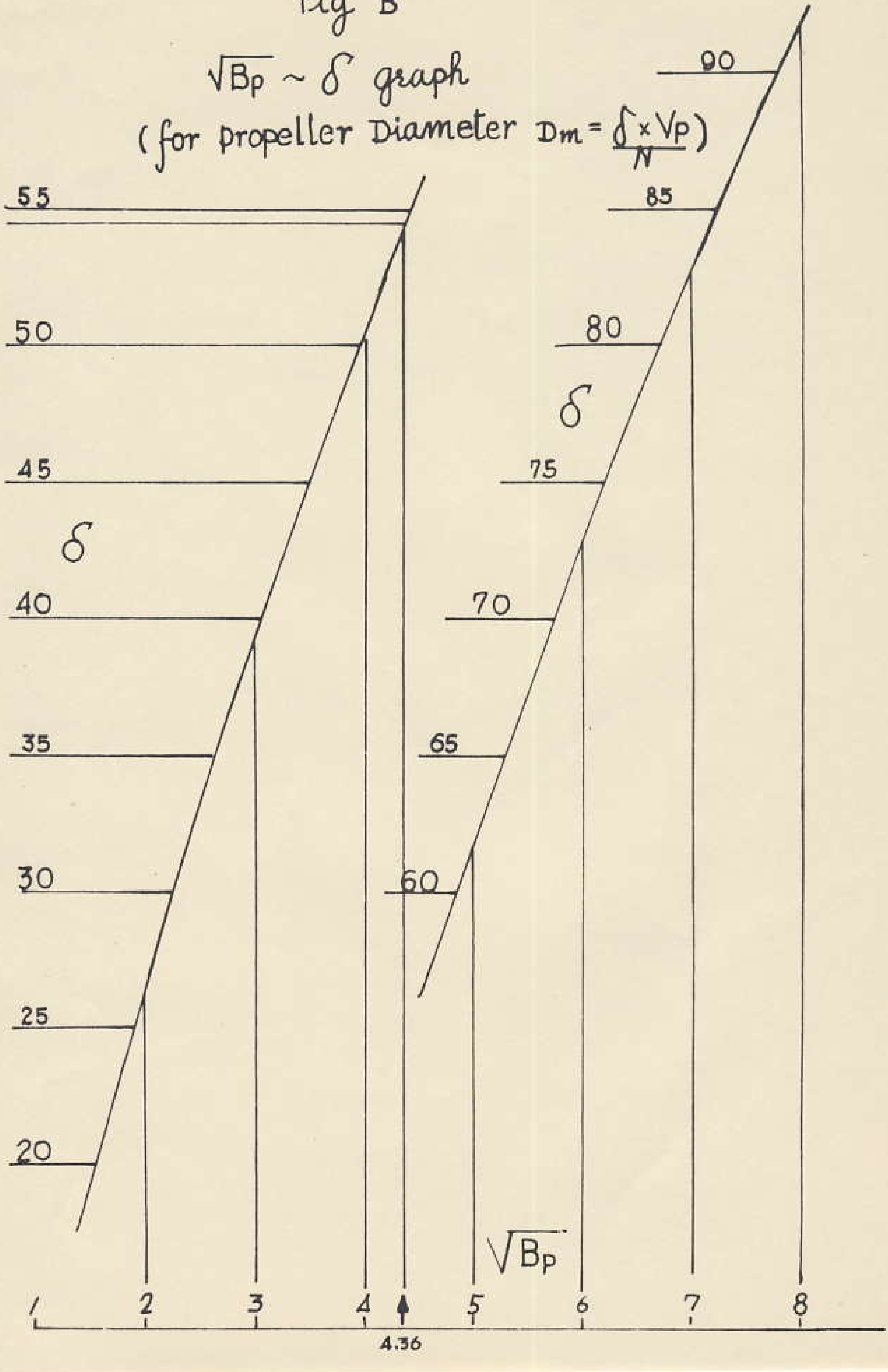


Fig B

$\sqrt{B_p} \sim \delta$ graph

(for propeller Diameter $D_m = \frac{\delta \times V_p}{N}$)



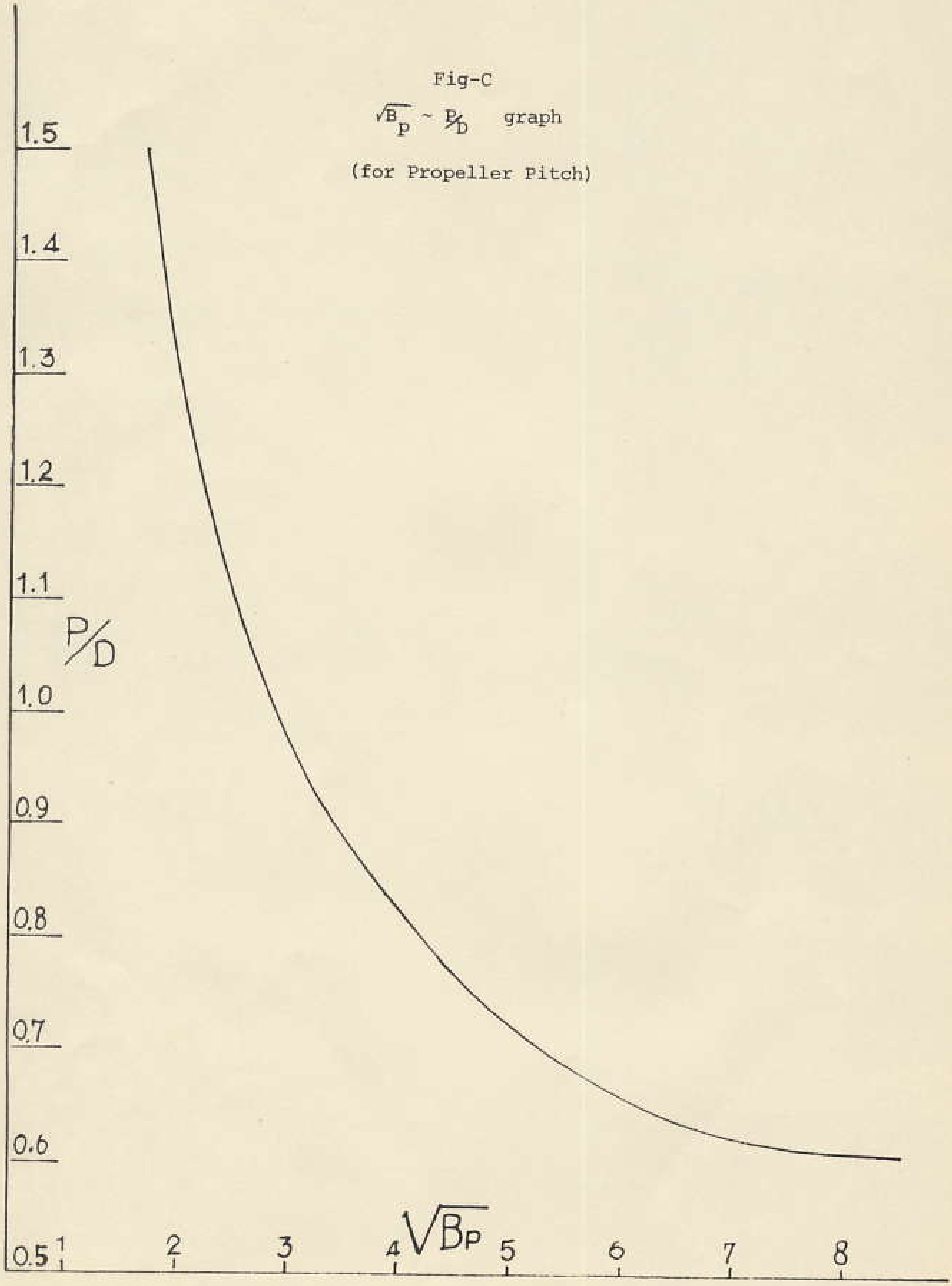


Fig-C

$\sqrt{B_p} \sim P/D$ graph

(for Propeller Pitch)

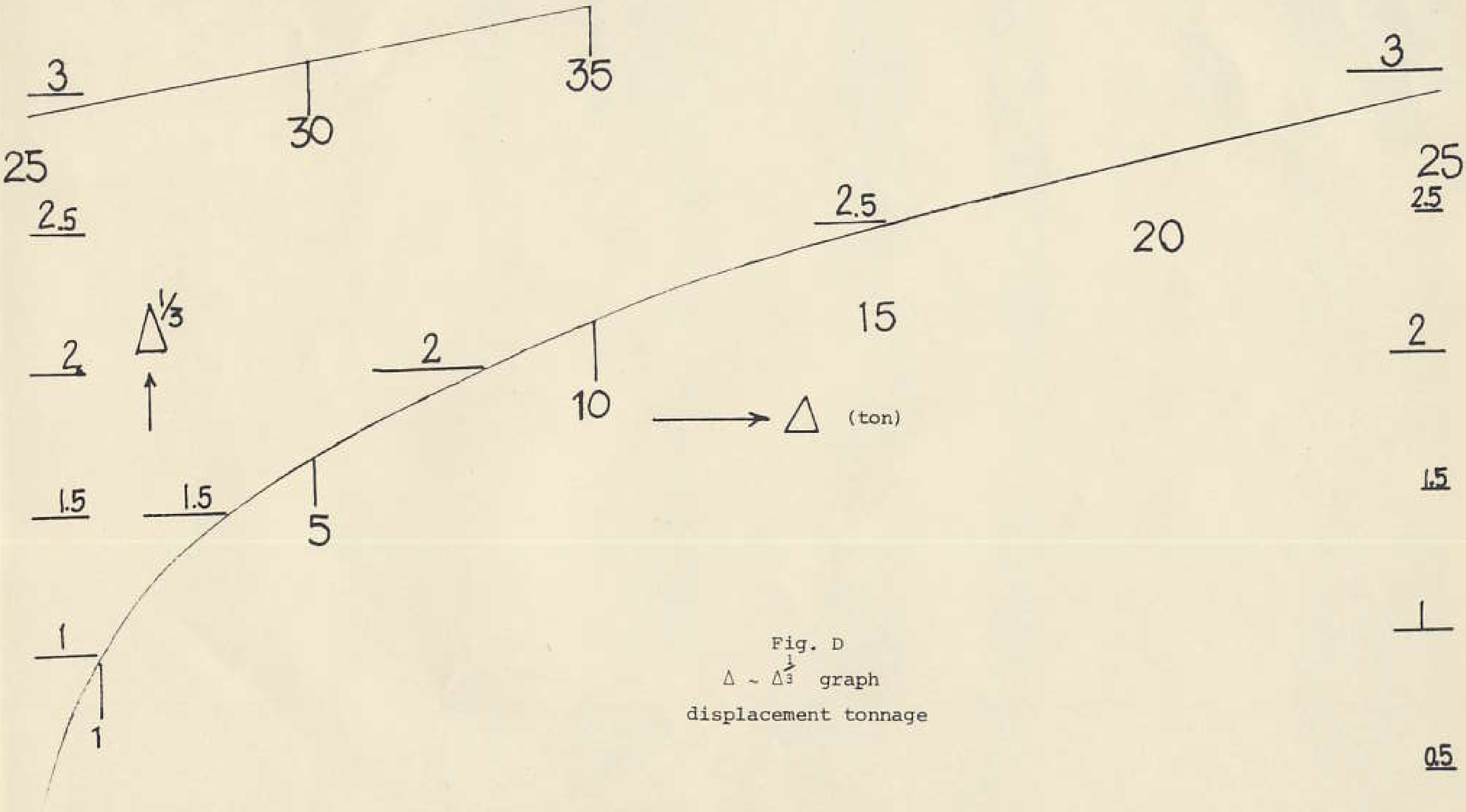
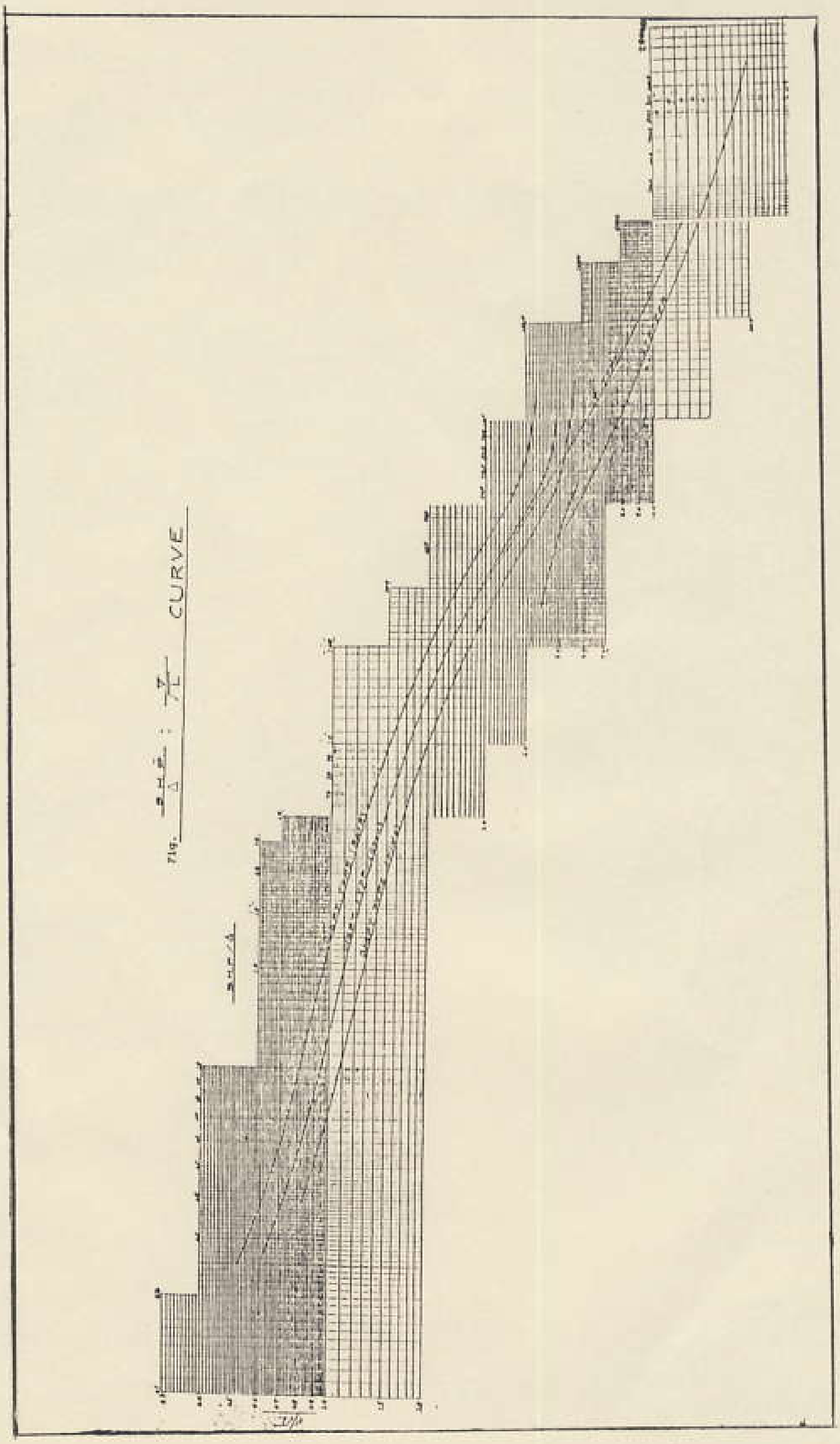
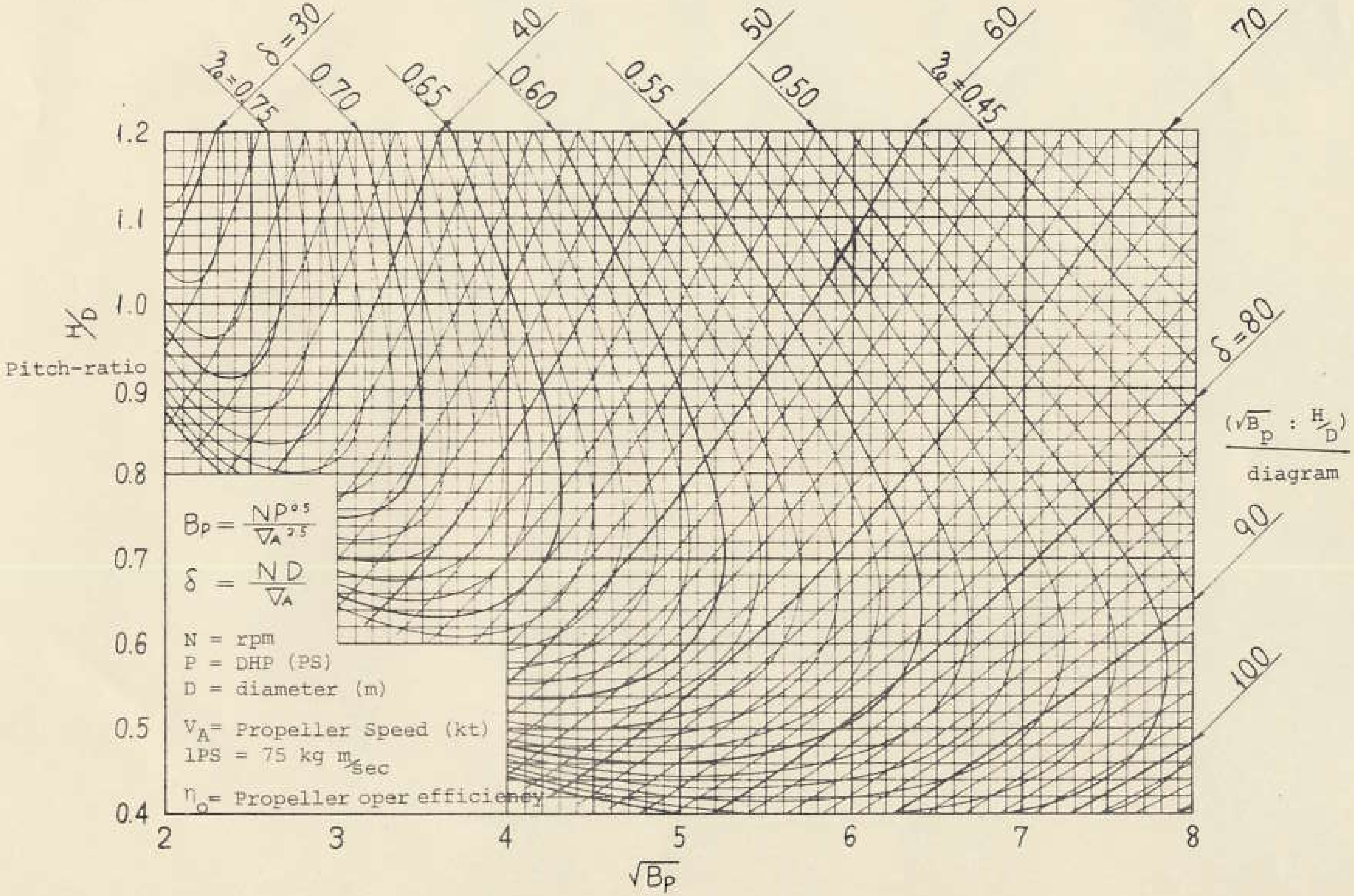


Fig. D

$\Delta \sim \Delta^{\frac{1}{3}}$ graph

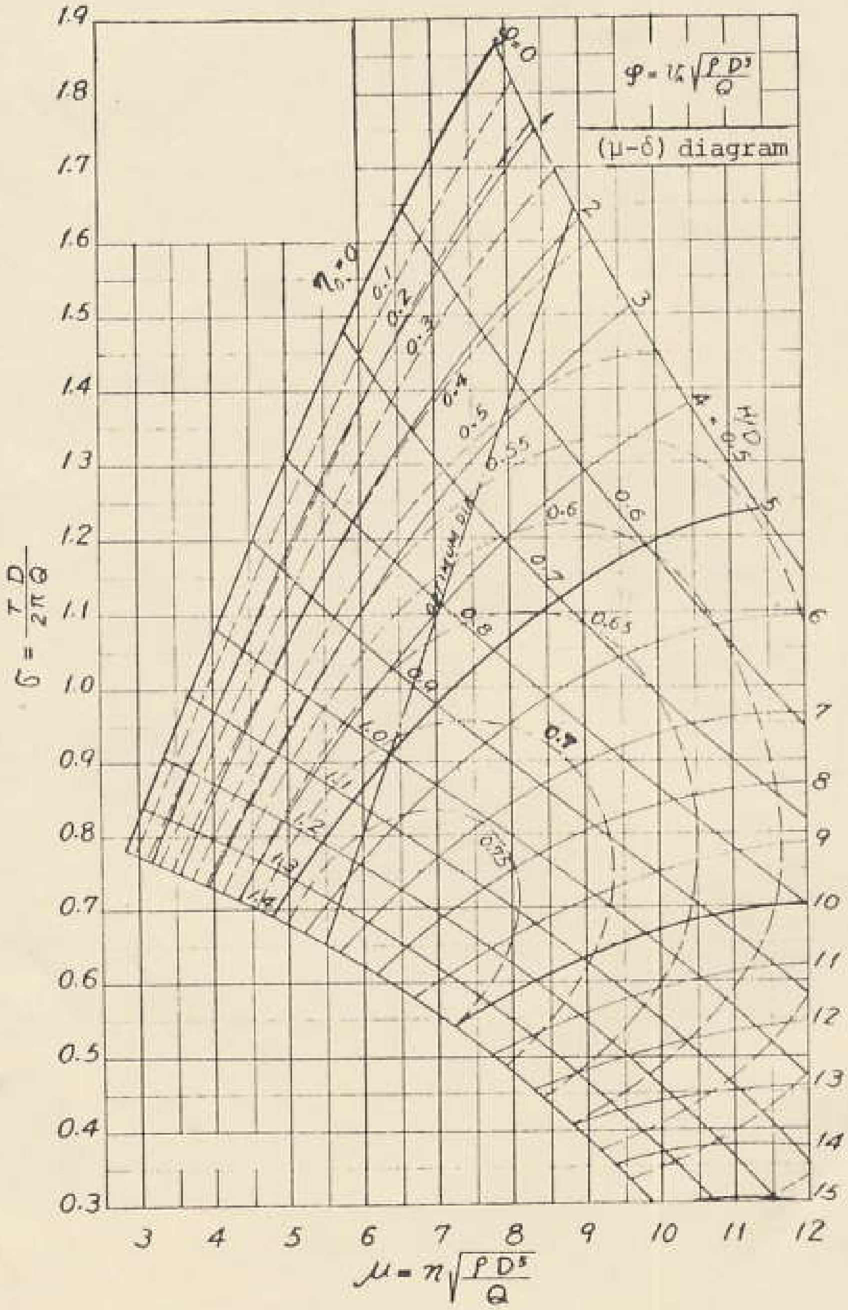
displacement tonnage


CURVE


$\delta = 30$
40
50
60
70
$\delta = 80$
90
100
$\eta_o = 0.75$
0.70
0.65
0.60
0.55
0.50
$\eta_o = 0.45$
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
H/D
Pitch-ratio
2
3
4
5
6
7
8
$\sqrt{B_p}$
$B_p = \frac{N P^{0.5}}{V_A^{2.5}}$
$\delta = \frac{N D}{V_A}$
N = rpm
P = DHP (PS)
D = diameter (m)
V_A = Propeller Speed (kt)
1PS = 75 kg m/sec
η_o = Propeller oper efficiency
($\sqrt{B_p}$: H/D)
diagram

n = revolution per Second (rev/sec)

D = diameter of propeller (m)
T = thrust (kg)
Q = torque (kg-m)
V_A = Advance Speed of Propeller ($m/_{sec}$)
ρ = density of liquid (kg $sec^2/_{m^4}$)



Reference Books

Mitsubishi DAIYA DIESEL Engines (Sales manual)

Mitsubishi Heavy Industries, LTD.

The speed and horsepower for small fishing boat

Mitsubishi Heavy Industries
Nagoya Machinery Works.

Approximate computation of propeller for small FRP fishing boat

YOSHIO Kōno   Fishing boat association

Approximate computation of speed and power

T. HASHIMOTO
SEIZANDO - SHOTEN

Approximate computation of speed and propeller for medium and high speed boats

YOSHIO Kōno   MIKADO Propeller Works, LTD.

MARINE Propeller

NAKAJIMA CHUKO K.K.