NAME 338: Ship Design Project and Presentation

PROPELLER DESIGN

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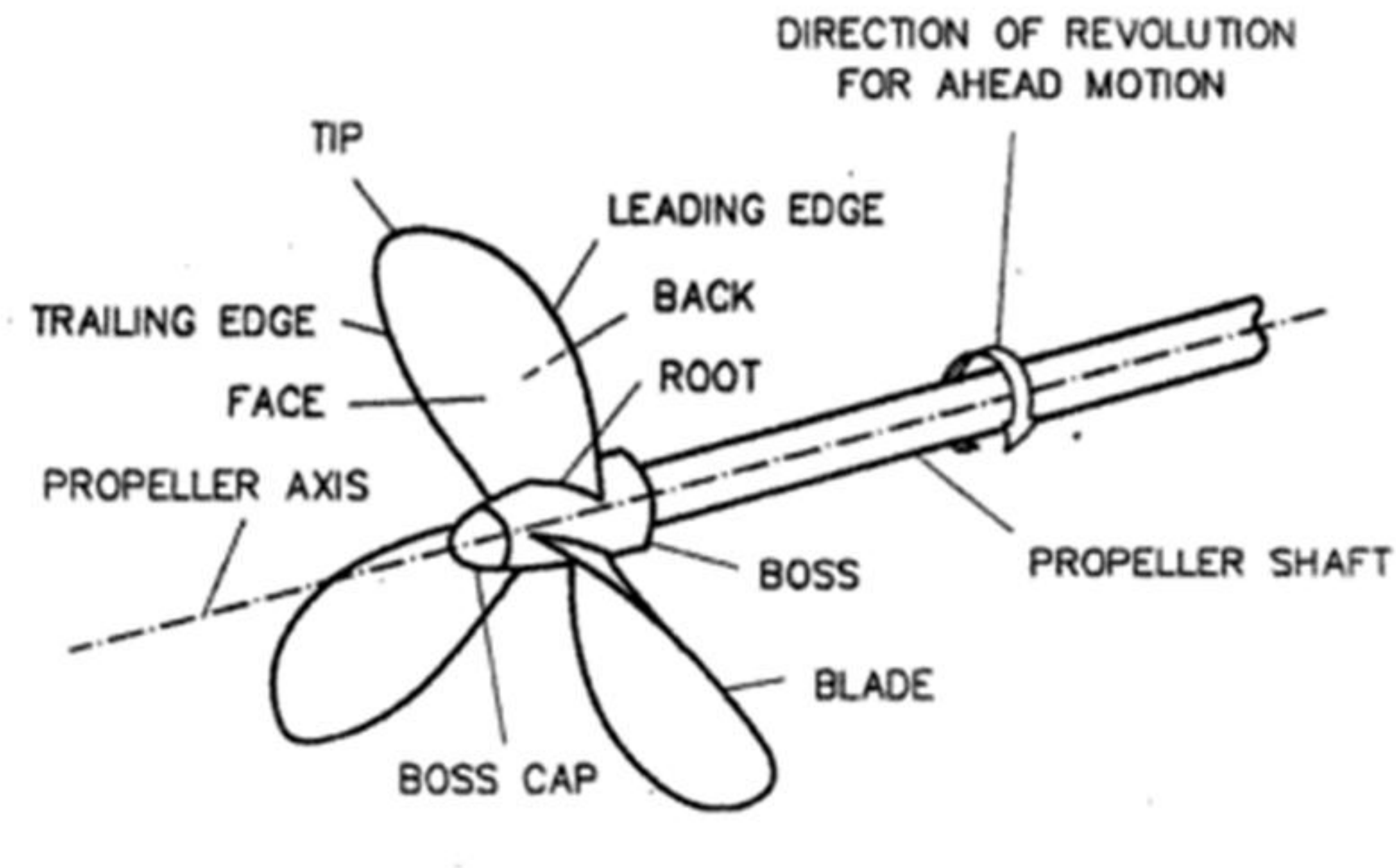


Figure 2.1 : A Three-Bladed Right Hand Propeller.

PROPELLER SPECIFICATIONS

1. Diameter
2. Revolutions per minute (RPM)
3. Pitch
4. Number of Blades
5. Rake and Skew
6. Hand (left/right handed screw)
7. Blade Section Shape
8. Blade thickness
9. Hub diameter
10. Shaft diameter
11. Blade area etc.
12. Supercavitating or noncavitating blades

PROPELLER DIAMETER

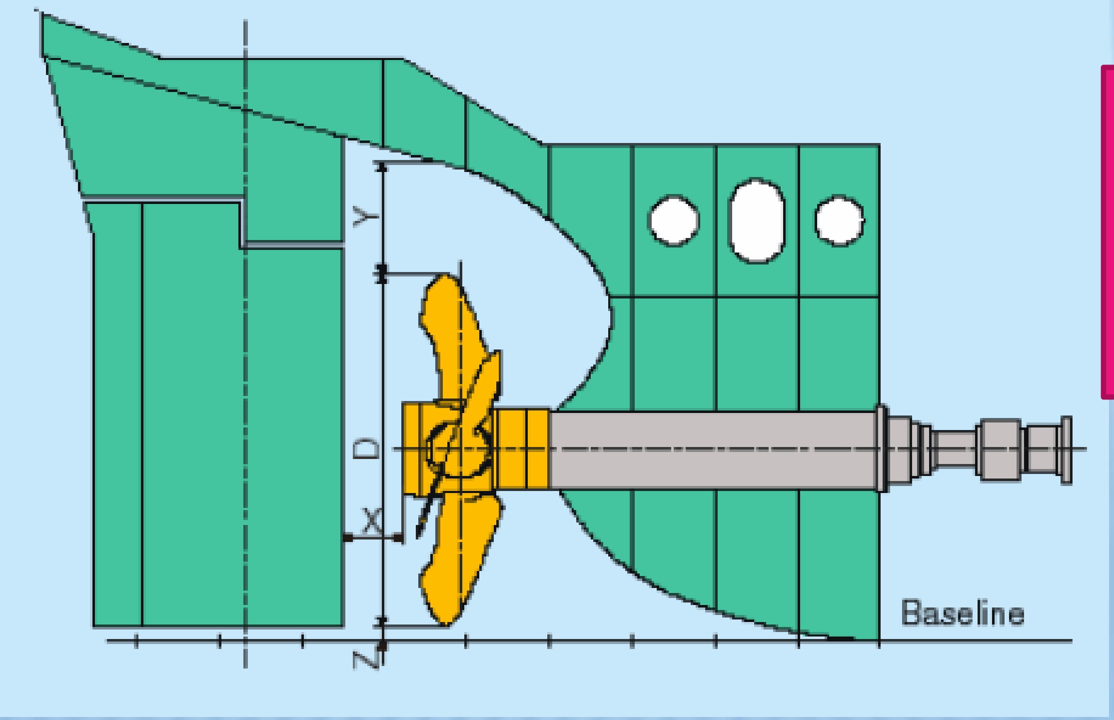
Diameter shoud be as large as possible

$$D_{max} = D_B = aT$$

a < 0.65 for Bulk carriers and Tankers

a < 0.74 for Containers ships

a < 2/3 for single screw



X = 5~10% D

Y = 15~25% D

Z = Up to 5% D

REVOLUTIONS PER MINUTE (RPM)

Torque Formula, Q = (5252 x HP)/RPM

Lower the shaft RPM and higher the HP, the greater the Torque

This is why slower turning propellers deliver more thrust—they are recieiving more torque for the same HP

Low speed engine is heavy and bulky wasting valuable interior hull space whereas high sped engine is light, compact and economical

A **reduction gear** is fitted between the crankshaft and the propeller shaft to reduce shaft RPM so that a larger diameter and more efficient propeller may be used.

PROPELLER DIAMETER

$D_B = 0.95 D_0$ for single screw

$D_B = 0.97 D_0$ for double screw

Where,

D_B = Propeller dia at behind condition

D_0 = Propeller dia at open water condition

NUMBER OF BLADES

One blade: Ideal, it does not have other blades disturbing the water flow ahead of it. Unfortunately, it will be unbalanced.

Two blades: It requires very large diameter to get the blade area required for effective thrust

Three blades: it has been proven to be the best compromise between balance, blade area and efficiency.

Four / Five blades: extra blades create more total blade area with the same or less Diameter. Accordingly, more thrust is produced. However, efficiency decreases due to additional turbulence

PITCH

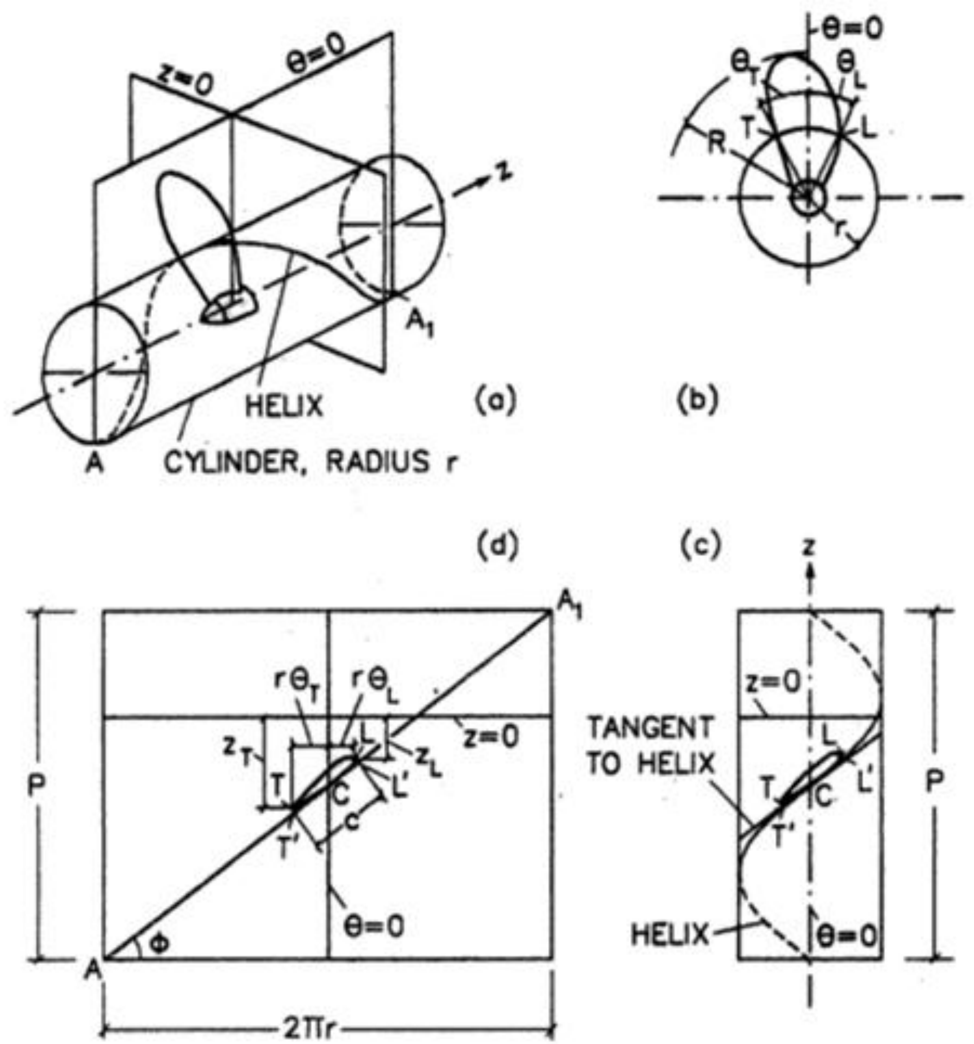


Figure 2.3 : Propeller Blade Cylindrical Section.

EFFECT OF PITCH

Pitch converts the torque of the propeller shaft to thrust by deflecting or accelerating water astern.

The fundamental task in selecting a propeller is to choose a pitch and diameter that will generate the maximum thrust possible at normal operating speed without overloading the engine

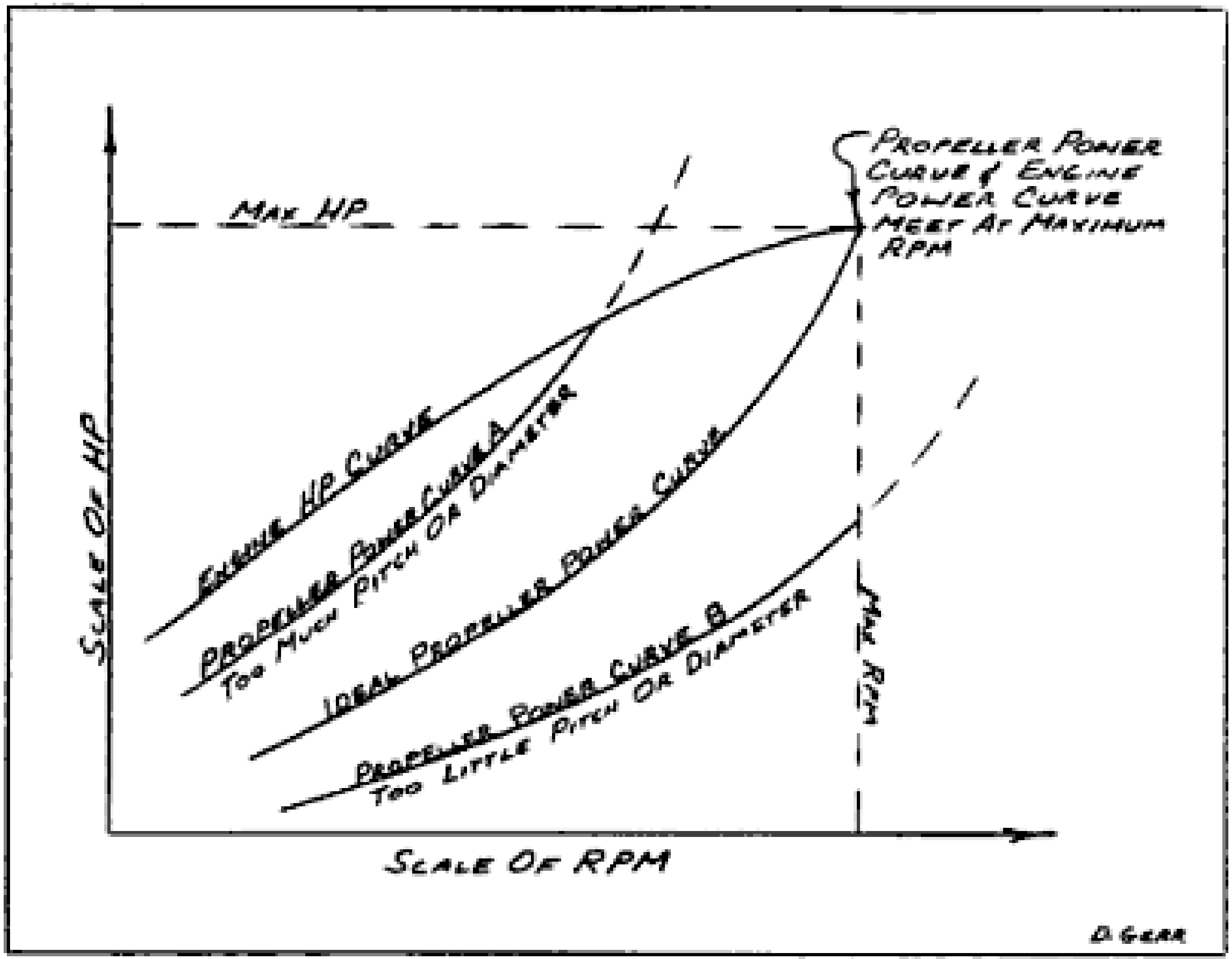
Large diameter, without pitch or angle of attack would not accelerate any water astern

Similarly ordinary blades with too much pitch would attempt to force more water astern more quickly than the engine can accommodate.

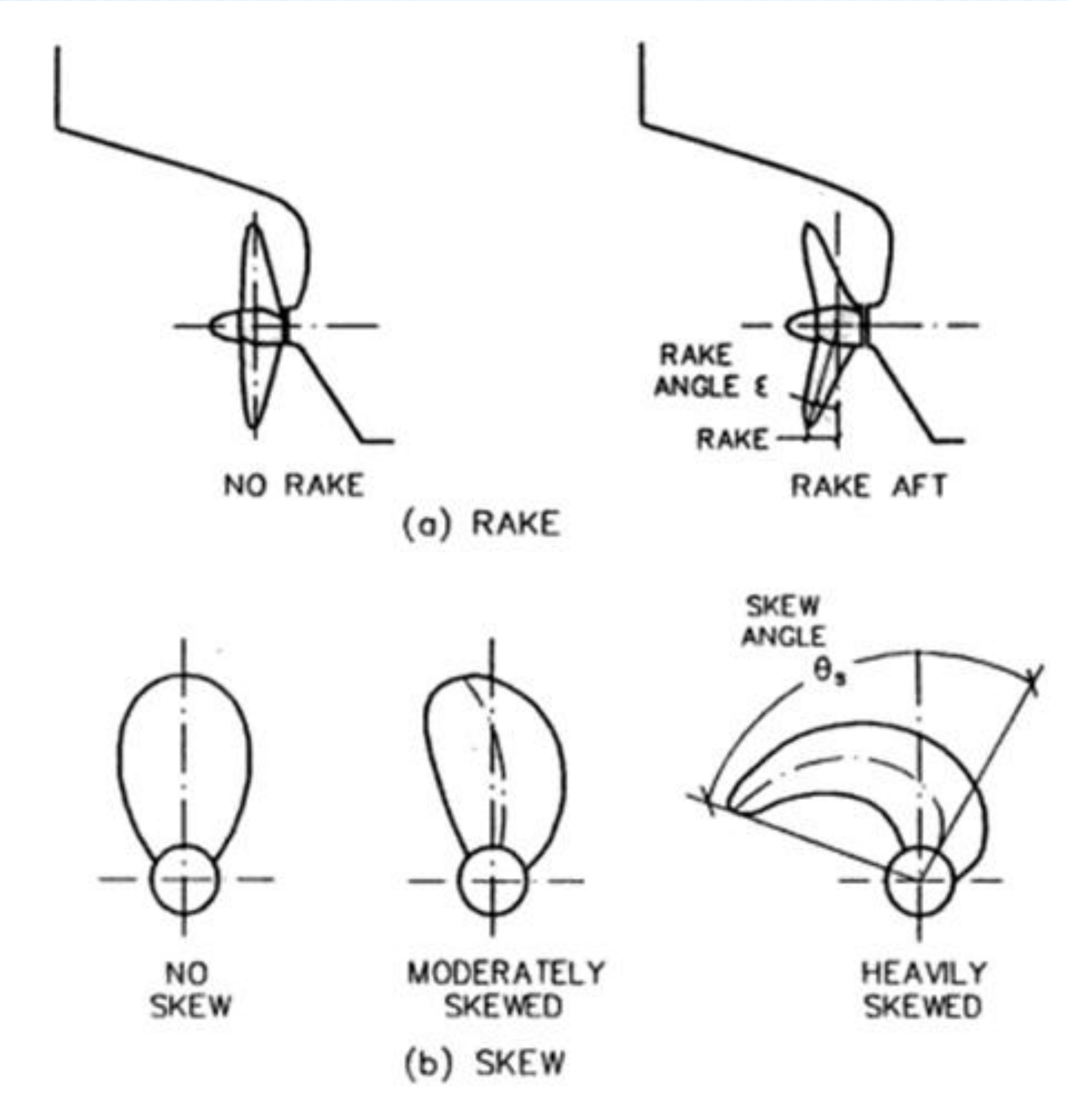
Increasing pitch increases thrust but increasing pitch too much reduces the efficiency of the engine and propeller combination by slowing the engine

On the other hand, while too little pitch will not overload or slow the engine, it will not accelerate as much water astern and thus will not generate maximum possible thrust or speed

RELATIONSHIP OF ENGINE POWER TO PROPELLER POWER



RAKE & SKEW


RAKE
ANGLE ε
RAKE
NO RAKE
RAKE AFT
(a) RAKE
SKEW
ANGLE
θ_s
NO
SKEW
MODERATELY
SKEWED
HEAVILY
SKEWED
(b) SKEW

HAND OF PROPELLER

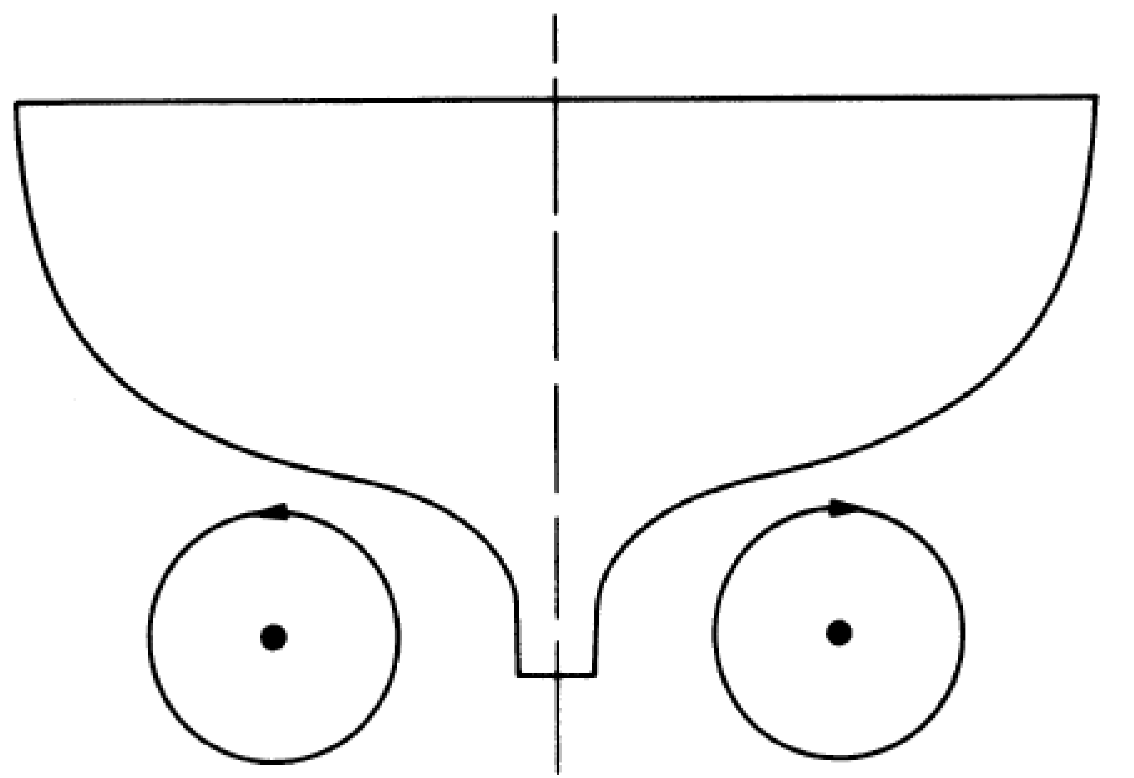


Fig. 10.8 Usual handing of propellers in a twin screw ship. Ship view from aft

If the propeller turn clockwise, it is said to be right-handed; if anti-clockwise, it is said to be left-handed. In a twin screw ship, the starboard propeller is normally right handed and the port propeller left-handed

PROJECTED, DEVELOPED & EXPANDED OUTLINE

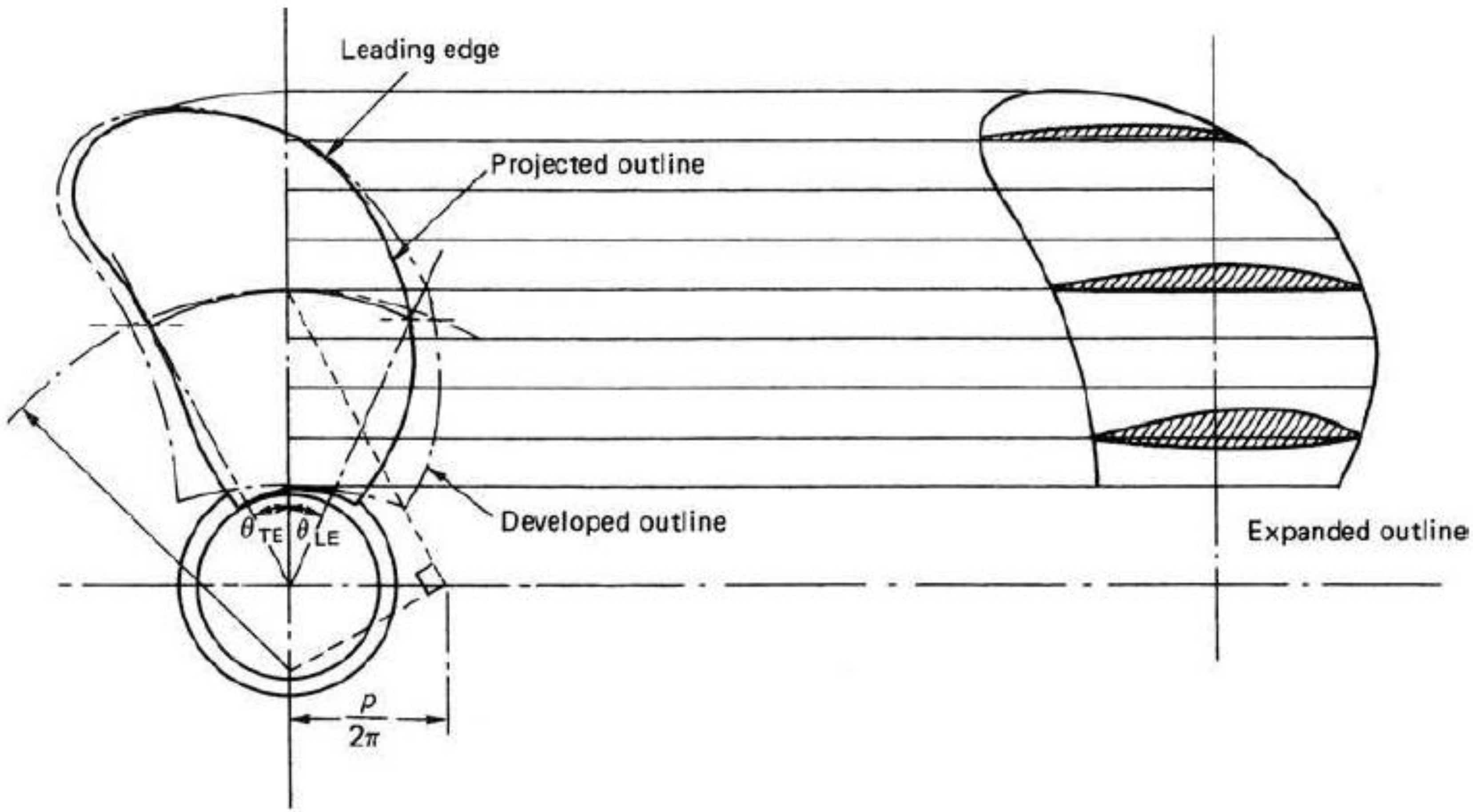


Figure 3.11 Outline definition

BLADE NO. & BAR

Table 6.4 Extent of the Wageningen B-screw series (taken from Reference 6)

Blade number (Z)					*Blade area ratio A_E/A_O*									
2	0.30													
3		0.35			0.50			0.65			0.80			
4			0.40			0.55			0.70			0.85	1.00	
5				0.45			0.60			0.75				1.05
6					0.50			0.65			0.80			
7						0.55			0.70			0.85		

TORQUE & THRUST COEFFICIENTS

$$\left.\begin{aligned} K_Q &= \sum_{n=1}^{47} C_n(J)^{S_n}(P/D)^{t_n}(A_E/A_O)^{u_n}(Z)^{v_n} \\ K_T &= \sum_{n=1}^{39} C_n(J)^{S_n}(P/D)^{t_n}(A_E/A_O)^{u_n}(Z)^{v_n} \end{aligned}\right\} \quad (6$$

where the coefficients are reproduced in Table 6.6.

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COEFFICIENTS OF KT & KQ

Table 6.6 Coefficients for the K_T and K_Q polynomials representing the Wageningen B-screen series for a Reynolds number of 2×10^6 (taken from Reference 7)

Thrust (K_T)						*Torque* (K_Q)					
n	$C_{s,t,u,v}$	$s(J)$	$t(P/D)$	$u(A_E/A_O)$	$v(Z)$	n	$C_{s,t,u,v}$	$s(J)$	$t(P/D)$	$u(A_E/A_O)$	$v(Z)$
1	+0.00880496	0	0	0	0	1	+0.00379368	0	0	0	0
2	−0.204554	1	0	0	0	2	+0.00886523	2	0	0	0
3	+0.166351	0	1	0	0	3	−0.032241	1	1	0	0
4	+0.158114	0	2	0	0	4	+0.00344778	0	2	0	0
5	−0.147581	2	0	1	0	5	−0.0408811	0	1	1	0
6	−0.481497	1	1	1	0	6	−0.108009	1	1	1	0
7	+0.415437	0	2	1	0	7	−0.0885381	2	1	1	0
8	+0.0144043	0	0	0	1	8	+0.188561	0	2	1	0
9	−0.0530054	2	0	0	1	9	−0.00370871	1	0	0	1
10	+0.0143481	0	1	0	1	10	+0.00513696	0	1	0	1
11	+0.0606826	1	1	0	1	11	+0.0209449	1	1	0	1
12	−0.0125894	0	0	1	1	12	+0.00474319	2	1	0	1
13	+0.0109689	1	0	1	1	13	−0.00723408	2	0	1	1
14	−0.133698	0	3	0	0	14	+0.00438388	1	1	1	1
15	+0.00638407	0	6	0	0	15	−0.0269403	0	2	1	1
16	−0.00132718	2	6	0	0	16	+0.0558082	3	0	1	0
17	+0.168496	3	0	1	0	17	+0.0161886	0	3	1	0
18	−0.0507214	0	0	2	0	18	+0.00318086	1	3	1	0
19	+0.0854559	2	0	2	0	19	+0.015896	0	0	2	0
20	−0.0504475	3	0	2	0	20	+0.0471729	1	0	2	0
21	+0.010465	1	6	2	0	21	+0.0196283	3	0	2	0
22	−0.00648272	2	6	2	0	22	−0.0502782	0	1	2	0
23	−0.00841728	0	3	0	1	23	−0.030055	3	1	2	0
24	+0.0168424	1	3	0	1	24	+0.0417122	2	2	2	0
25	−0.00102296	3	3	0	1	25	−0.0397722	0	3	2	0
26	−0.0317791	0	3	1	1	26	−0.00350024	0	6	2	0
27	+0.018604	1	0	2	1	27	−0.0106854	3	0	0	1
28	−0.00410798	0	2	2	1	28	+0.00110903	3	3	0	1
29	−0.000606848	0	0	0	2	29	−0.000313912	0	6	0	1
30	−0.0049819	1	0	0	2	30	+0.0035985	3	0	1	1
31	+0.0025983	2	0	0	2	31	−0.00142121	0	6	1	1
32	−0.000560528	3	0	0	2	32	−0.00383637	1	0	2	1
33	−0.00163652	1	2	0	2	33	+0.0126803	0	2	2	1
34	−0.000328787	1	6	0	2	34	−0.00318278	2	3	2	1
35	+0.000116502	2	6	0	2	35	+0.00334268	0	6	2	1
36	+0.000690904	0	0	1	2	36	−0.00183491	1	1	0	2
37	+0.00421749	0	3	1	2	37	+0.000112451	3	2	0	2
38	+0.0000565229	3	6	1	2	38	−0.0000297228	3	6	0	2
39	−0.00146564	0	3	2	2	39	+0.000269551	1	0	1	2
						40	+0.00083265	2	0	1	2
						41	+0.00155334	0	2	1	2
						42	+0.000302683	0	6	1	2
						43	−0.0001843	0	0	2	2
						44	−0.000425399	0	3	2	2
						45	+0.0000869243	3	3	2	2
						46	−0.0004659	0	6	2	2
						47	+0.0000554194	1	6	2	2

EFFECT OF REYNOLD'S NUMBER

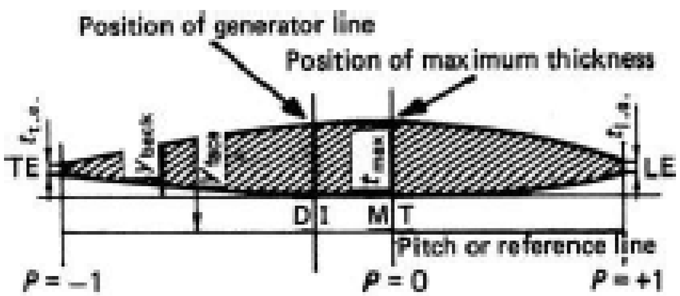
$$\begin{Bmatrix} K_T(R_n) \\ K_Q(R_n) \end{Bmatrix} = \begin{Bmatrix} K_T(R_n = 2 \times 10^6) \\ K_Q(R_n = 2 \times 10^6) \end{Bmatrix} + \begin{Bmatrix} \Delta K_T(R_n) \\ \Delta K_Q(R_n) \end{Bmatrix} \tag{6.18}$$

where

$$\begin{aligned}
\Delta K_T = {} & 0.000353485 \\
& - 0.00333758\,(A_E/A_O)J^2 \\
& - 0.00478125\,(A_E/A_O)(P/D)J \\
& + 0.000257792(\log R_n - 0.301)^2 \cdot (A_E/A_O)J^2 \\
& + 0.0000643192(\log R_n - 0.301)(P/D)^6 J^2 \\
& - 0.0000110636(\log R_n - 0.301)^2 (P/D)^6 J^2 \\
& - 0.0000276305(\log R_n - 0.301)^2 Z(A_E/A_O)J^2 \\
& + 0.0000954(\log R_n - 0.301)Z(A_E/A_O)(P/D)J \\
& + 0.0000032049(\log R_n - 0.301)Z^2(A_E/A_O) \\
& \quad \times (P/D)^3 J
\end{aligned}$$

$$\begin{aligned}
\Delta K_Q = {} & -0.000591412 \\
& + 0.00696898(P/D) \\
& - 0.0000666654Z(P/D)^6 \\
& + 0.0160818(A_E/A_O)^2 \\
& - 0.000938091(\log R_n - 0.301)(P/D) \\
& - 0.00059593(\log R_n - 0.301)(P/D)^2 \\
& + 0.0000782099(\log R_n - 0.301)^2 (P/D)^2 \\
& + 0.0000052199(\log R_n - 0.301)Z(A_E/A_O)J^2 \\
& - 0.00000088528(\log R_n - 0.301)^2 Z(A_E/A_O) \\
& \quad \times (P/D)J \\
& + 0.0000230171(\log R_n - 0.301)Z(P/D)^6 \\
& - 0.00000184341(\log R_n - 0.301)^2 Z(P/D)^6 \\
& - 0.00400252(\log R_n - 0.301)(A_E/A_O)^2 \\
& + 0.000220915(\log R_n - 0.301)^2 (A_E/A_O)^2
\end{aligned}$$

GEOMETRY OF B-SERIES PROPELLER



LE = leading edge
TE = trailing edge
MT = location of maximum thickness
DI = location of directrix

$$\left.\begin{array}{l} Y_{face} = V_1(t_{max} - t_{t.e.}) \\ Y_{back} = (V_1 + V_2)(t_{max} - t_{t.e.}) + t_{t.e.} \end{array}\right\} \text{for } P \leq 0$$

and

$$\left.\begin{array}{l} Y_{face} = V_1(t_{max} - t_{l.e.}) \\ Y_{back} = (V_1 + V_2)(t_{max} - t_{l.e.}) + t_{l.e.} \end{array}\right\} \text{for } P \geq 0$$

Referring to the diagram, note the following:

Y_{face}, Y_{back} = vertical ordinate of a point on a blade section on the face and on the back with respect to the pitch line.

t_{max} = maximum thickness of blade section.

$t_{t.e.}$, $t_{l.e.}$ = extrapolated blade section thickness at the trailing and leading edges.

V_1, V_2 = tabulated functions dependent on r/R and P.

P = non-dimensional coordinate along pitch line from position of maximum thickness to leading edge (where $P = 1$), and from position of maximum thickness to trailing edge (where $P = -1$).

GEOMETRY OF B-SERIES PROPELLER

Table 6.5 Geometry of the Wageningen B-screw series (taken fi

Dimensions of four-, five-, six- and seven-bladed propellers

r/R	$\frac{c}{D} \cdot \frac{Z}{A_E/A_O}$	a/c	b/c	$t/D = A_r - B_r Z$	
				A_r	B_r
0.2	1.662	0.617	0.350	0.0526	0.0040
0.3	1.882	0.613	0.350	0.0464	0.0035
0.4	2.050	0.601	0.351	0.0402	0.0030
0.5	2.152	0.586	0.355	0.0340	0.0025
0.6	2.187	0.561	0.389	0.0278	0.0020
0.7	2.144	0.524	0.443	0.0216	0.0015
0.8	1.970	0.463	0.479	0.0154	0.0010
0.9	1.582	0.351	0.500	0.0092	0.0005
1.0	0.000	0.000	0.000	0.0030	0.0000

Dimensions for three-bladed propellers

r/R	$\frac{c}{D} \cdot \frac{Z}{A_E/A_O}$	a/c	b/c	$t/D = A_r - B_r Z$	
				A_r	B_r
0.2	1.633	0.616	0.350	0.0526	0.0040
0.3	1.832	0.611	0.350	0.0464	0.0035
0.4	2.000	0.599	0.350	0.0402	0.0030
0.5	2.120	0.583	0.355	0.0340	0.0025
0.6	2.186	0.558	0.389	0.0278	0.0020
0.7	2.168	0.526	0.442	0.0216	0.0015
0.8	2.127	0.481	0.478	0.0154	0.0010
0.9	1.657	0.400	0.500	0.0092	0.0005
1.0	0.000	0.000	0.000	0.0030	0.0000

A_r, B_r = constants in equation for t/D.

a = distance between leading edge and generator line at r.

b = distance between leading edge and location of maximum thickness.

c = chord length of blade section ar radius r.

t = maximum blade section thickness at radius r

VALUES OF V_1

Values of V_1 for use in the equations

r/R \ P	−1.0	−0.95	−0.9	−0.8	−0.7	−0.6	−0.5	−0.4	−0.2	0
0.7–1.0	0	0	0	0	0	0	0	0	0	0
0.6	0	0	0	0	0	0	0	0	0	0
0.5	0.0522	0.0420	0.0330	0.0190	0.0100	0.0040	0.0012	0	0	0
0.4	0.1467	0.1200	0.0972	0.0630	0.0395	0.0214	0.0116	0.0044	0	0
0.3	0.2306	0.2040	0.1790	0.1333	0.0943	0.0623	0.0376	0.0202	0.0033	0
0.25	0.2598	0.2372	0.2115	0.1651	0.1246	0.0899	0.0579	0.0350	0.0084	0
0.2	0.2826	0.2630	0.2400	0.1967	0.1570	0.1207	0.0880	0.0592	0.0172	0
0.15	0.3000	0.2824	0.2650	0.2300	0.1950	0.1610	0.1280	0.0955	0.0365	0

r/R \ P	+1.0	+0.95	+0.9	+0.85	+0.8	+0.7	+0.6	+0.5	+0.4	+0.2	0
0.7–1.0	0	0	0	0	0	0	0	0	0	0	0
0.6	0.0382	0.0169	0.0067	0.0022	0.0006	0	0	0	0	0	0
0.5	0.1278	0.0778	0.0500	0.0328	0.0211	0.0085	0.0034	0.0008	0	0	0
0.4	0.2181	0.1467	0.1088	0.0833	0.0637	0.0357	0.0189	0.0090	0.0033	0	0
0.3	0.2923	0.2186	0.1760	0.1445	0.1191	0.0790	0.0503	0.0300	0.0148	0.0027	0
0.25	0.3256	0.2513	0.2068	0.1747	0.1465	0.1008	0.0669	0.0417	0.0224	0.0031	0
0.2	0.3560	0.2821	0.2353	0.2000	0.1685	0.1180	0.0804	0.0520	0.0304	0.0049	0
0.15	0.3860	0.3150	0.2642	0.2230	0.1870	0.1320	0.0920	0.0615	0.0384	0.0096	0

VALUES OF V_2

Table 6.5 (cont)

Values of V_2 for use in the equations

r/R \ P	−1.0	−0.95	−0.9	−0.8	−0.7	−0.6	−0.5	−0.4	−0.2	0
0.9–1.0	0	0.0975	0.19	0.36	0.51	0.64	0.75	0.84	0.96	1
0.85	0	0.0975	0.19	0.36	0.51	0.64	0.75	0.84	0.96	1
0.8	0	0.0975	0.19	0.36	0.51	0.64	0.75	0.84	0.96	1
0.7	0	0.0975	0.19	0.36	0.51	0.64	0.75	0.84	0.96	1
0.6	0	0.0965	0.1885	0.3585	0.5110	0.6415	0.7530	0.8426	0.9613	1
0.5	0	0.0950	0.1865	0.3569	0.5140	0.6439	0.7580	0.8456	0.9639	1
0.4	0	0.0905	0.1810	0.3500	0.5040	0.6353	0.7525	0.8415	0.9645	1
0.3	0	0.0800	0.1670	0.3360	0.4885	0.6195	0.7335	0.8265	0.9583	1
0.25	0	0.0725	0.1567	0.3228	0.4740	0.6050	0.7184	0.8139	0.9519	1
0.2	0	0.0640	0.1455	0.3060	0.4535	0.5842	0.6995	0.7984	0.9446	1
0.15	0	0.0540	0.1325	0.2870	0.4280	0.5585	0.6770	0.7805	0.9360	1

r/R \ P	+1.0	+0.95	+0.9	+0.85	+0.8	+0.7	+0.6	+0.5	+0.4	+0.2	0
0.9–1.0	0	0.0975	0.1900	0.2775	0.3600	0.51	0.6400	0.75	0.8400	0.9600	1
0.85	0	0.1000	0.1950	0.2830	0.3660	0.5160	0.6455	0.7550	0.8450	0.9615	1
0.8	0	0.1050	0.2028	0.2925	0.3765	0.5265	0.6545	0.7635	0.8520	0.9635	1
0.7	0	0.1240	0.2337	0.3300	0.4140	0.5615	0.6840	0.7850	0.8660	0.9675	1
0.6	0	0.1485	0.2720	0.3775	0.4620	0.6060	0.7200	0.8090	0.8790	0.9690	1
0.5	0	0.1750	0.3056	0.4135	0.5039	0.6430	0.7478	0.8275	0.8880	0.9710	1
0.4	0	0.1935	0.3235	0.4335	0.5220	0.6590	0.7593	0.8345	0.8933	0.9725	1
0.3	0	0.1890	0.3197	0.4265	0.5130	0.6505	0.7520	0.8315	0.8020	0.9750	1
0.25	0	0.1758	0.3042	0.4108	0.4982	0.6359	0.7415	0.8259	0.8899	0.9751	1
0.2	0	0.1560	0.2840	0.3905	0.4777	0.6190	0.7277	0.8170	0.8875	0.9750	1
0.15	0	0.1300	0.2600	0.3665	0.4520	0.5995	0.7105	0.8055	0.8825	0.9760	1

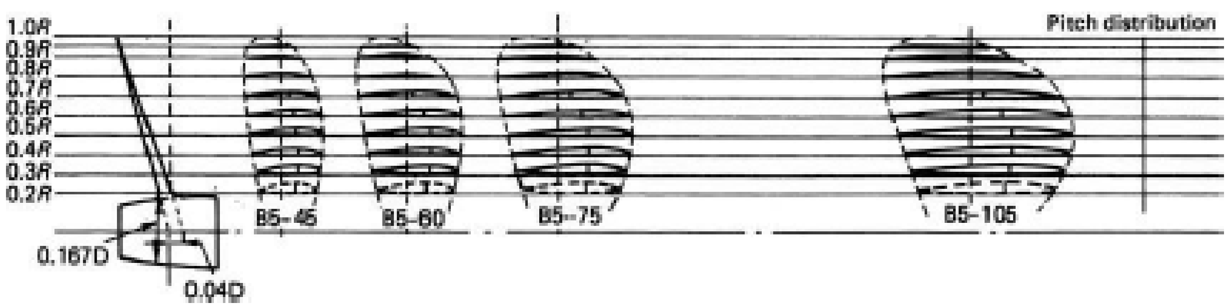


Figure 6.11 General plan of B5-screw series (Reporduced with permission from Reference 6)

HUB AND SHAFT DIAMETER

Assume Hub Diameter Ratio: 0.2

B 3.35 BP-δ CHART

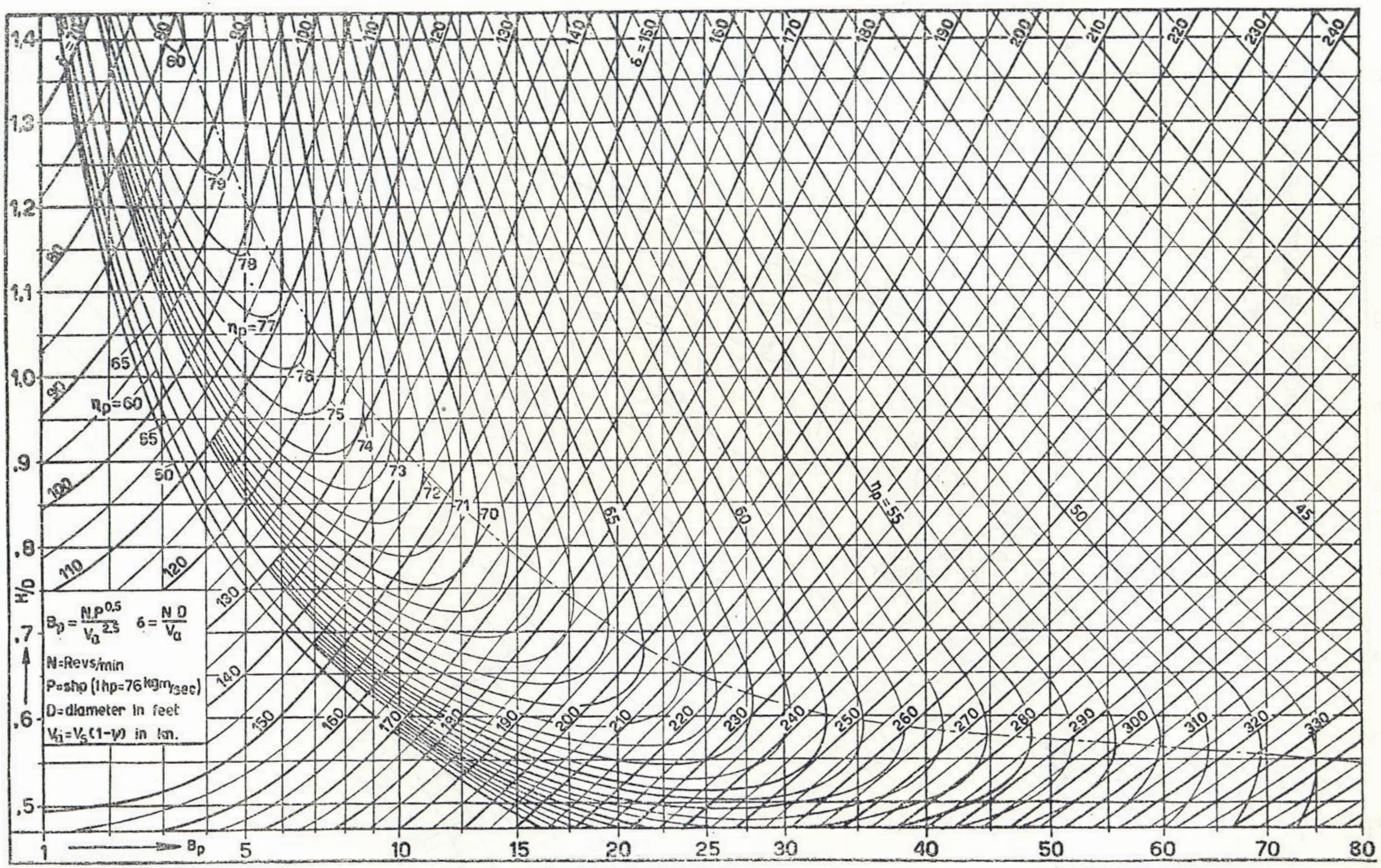


Fig. 3.12 Troost B.3 – 35 *Bp* – δ Chart

B 3.50 BP-δ CHART

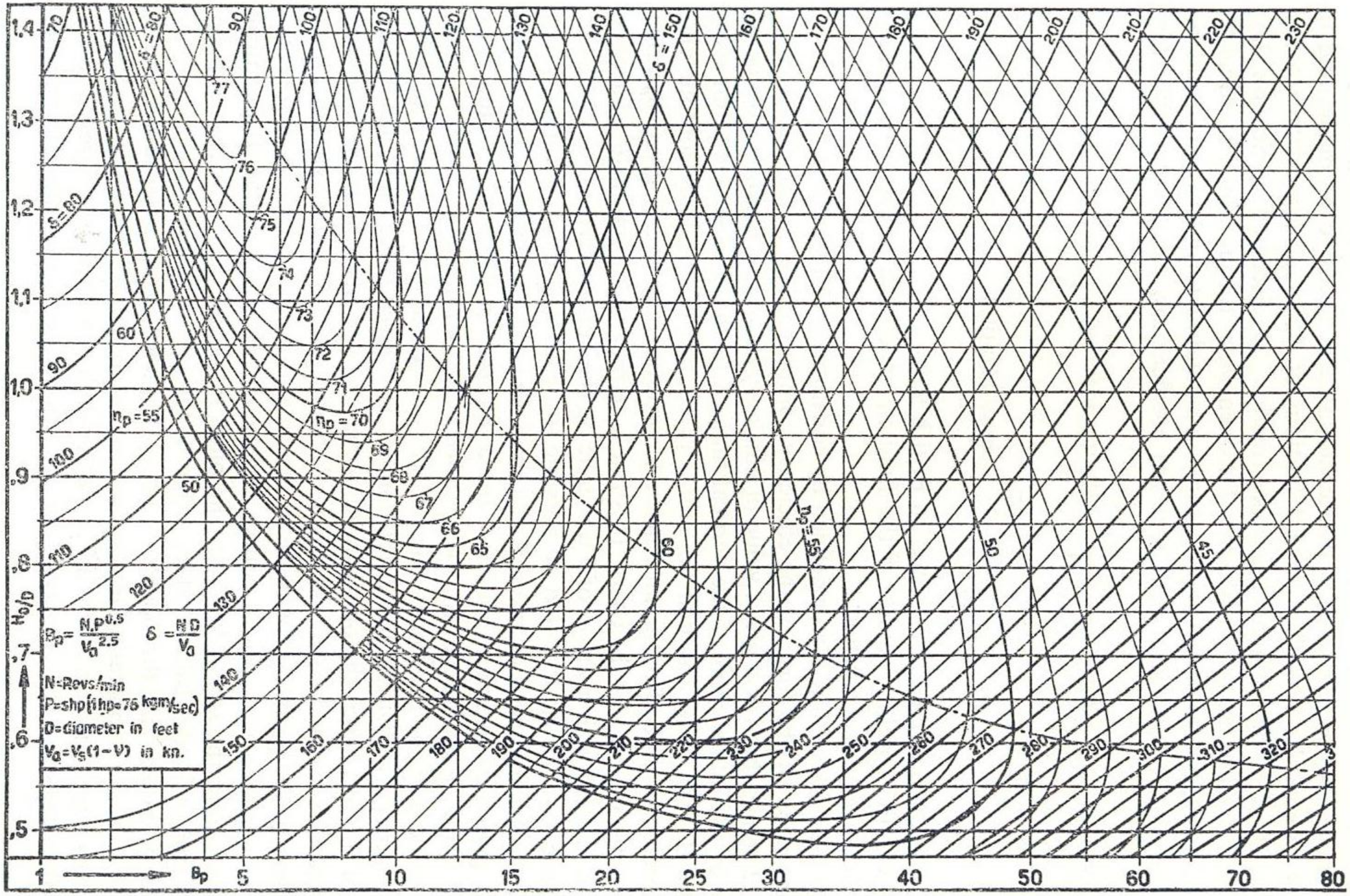


Fig. 3.13 Troost B.3 – 50 *Bp* – δ Chart

B 3.65 BP-δ CHART

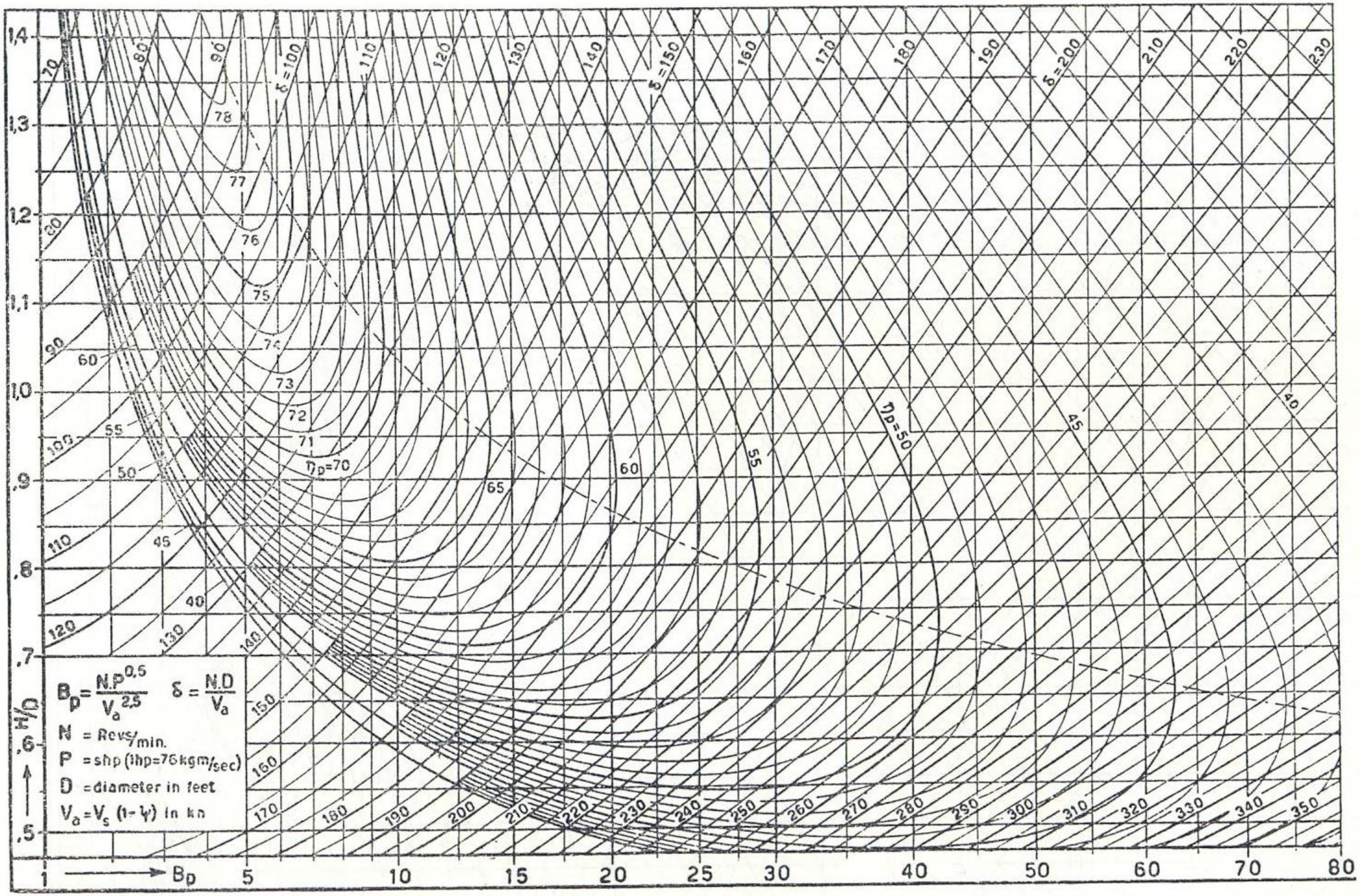


Fig. 3.14 Troost B.3 – 65 *Bp* – δ Chart

B 4.40 BP-δ CHART

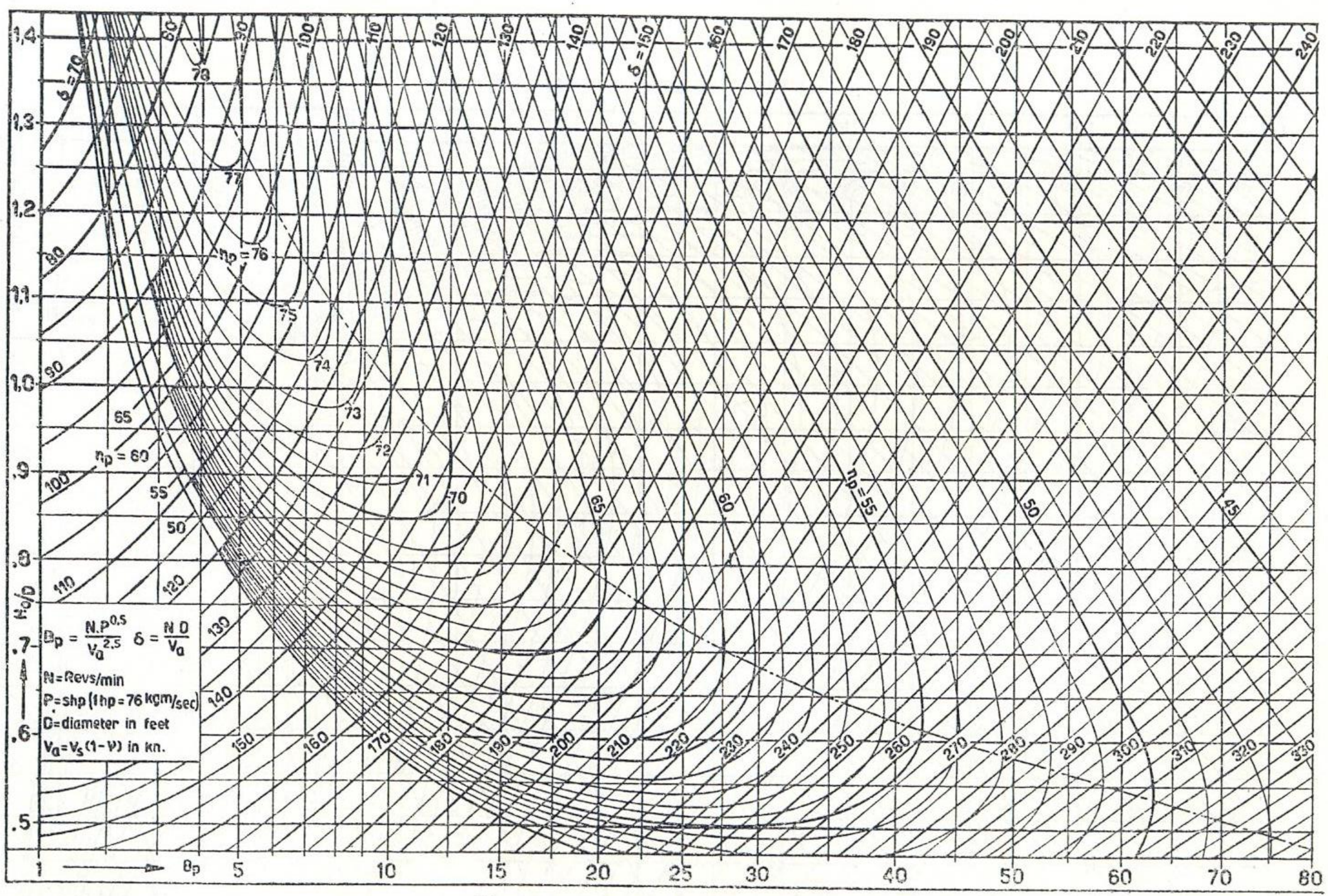


Fig. 3.15 Troost B.4 – 40 *Bp* – δ Chart

B 4.55 BP-δ CHART

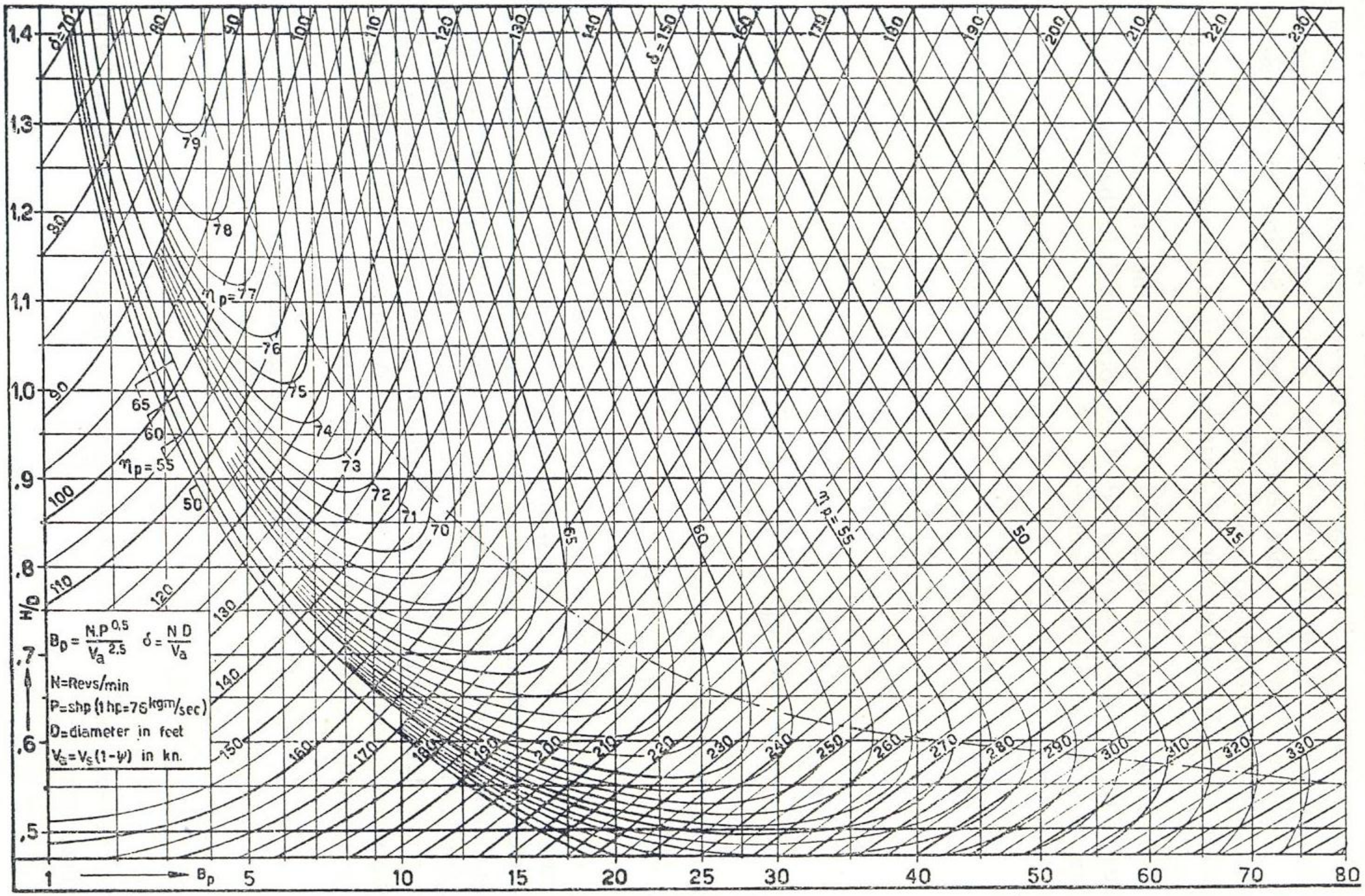


Fig. 3.16 Troost B.4 – 55 *Bp* – δ Chart

B 4.70 BP-δ CHART

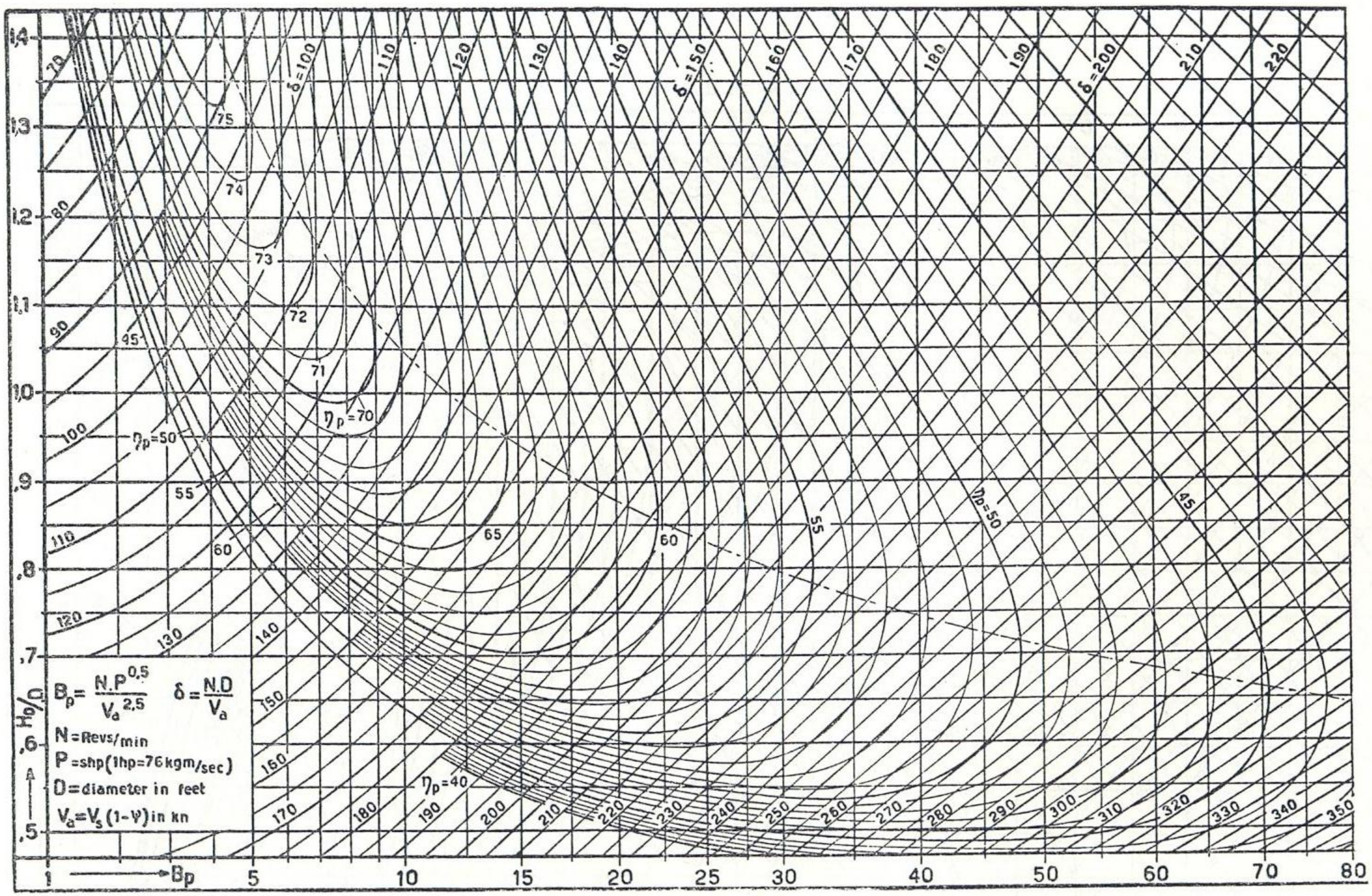


Fig. 3.17 Troost B.4 – 70 *Bp* – δ Chart

B 5.45 BP-δ CHART

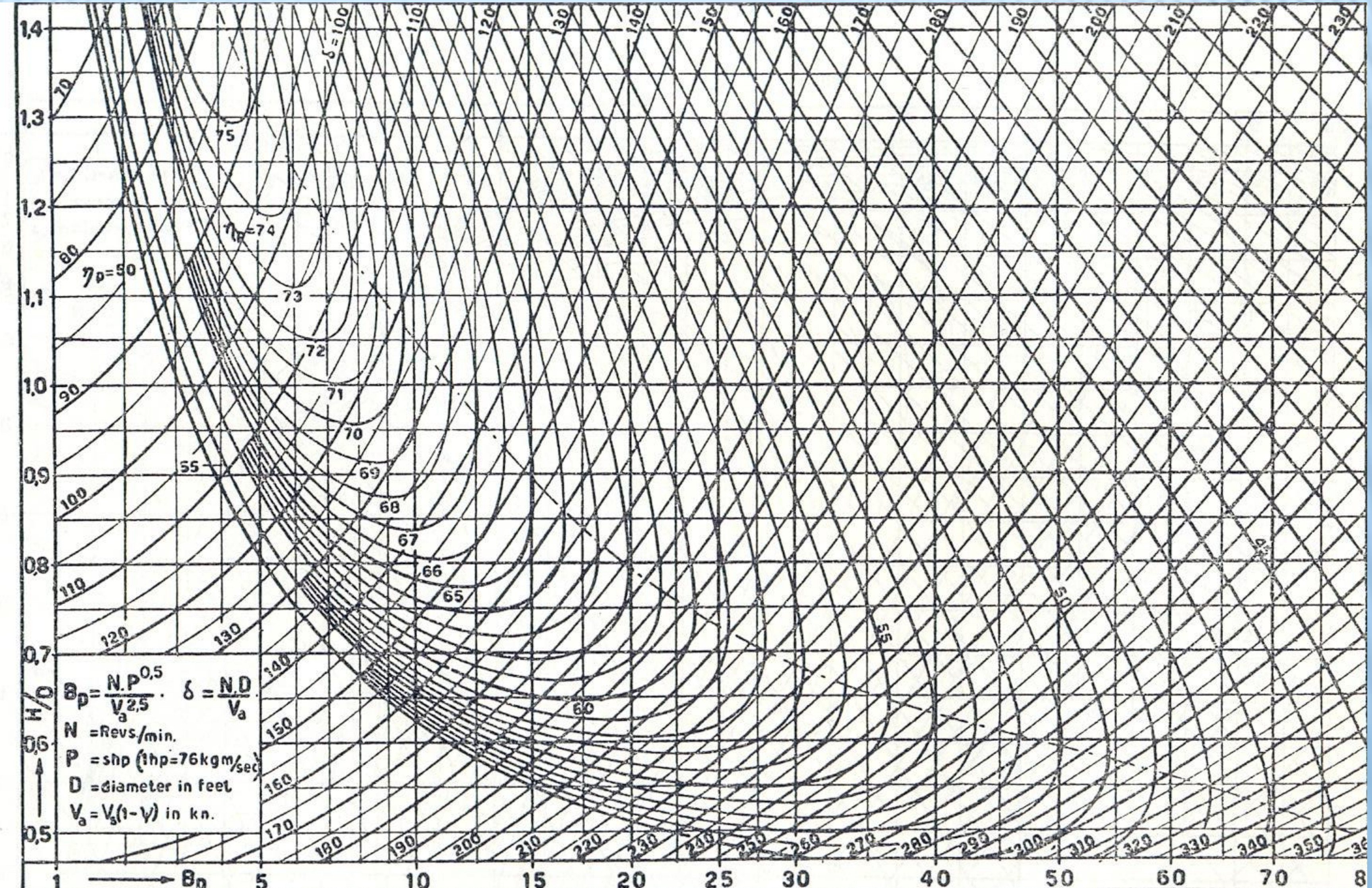


Fig. 3.18 Troost B.5 – 45 *Bp* – δ Chart

B 5.60 BP-δ CHART

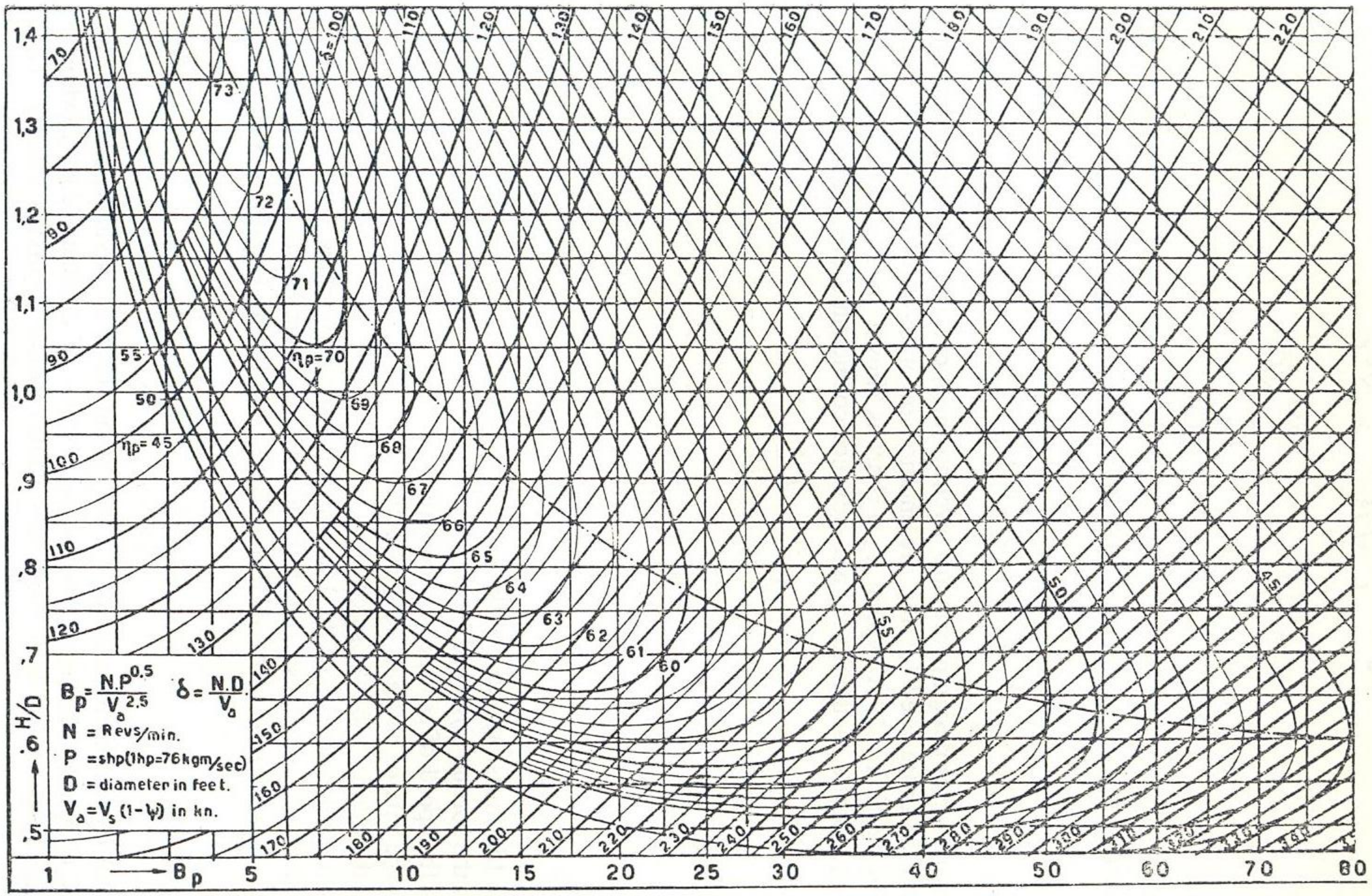
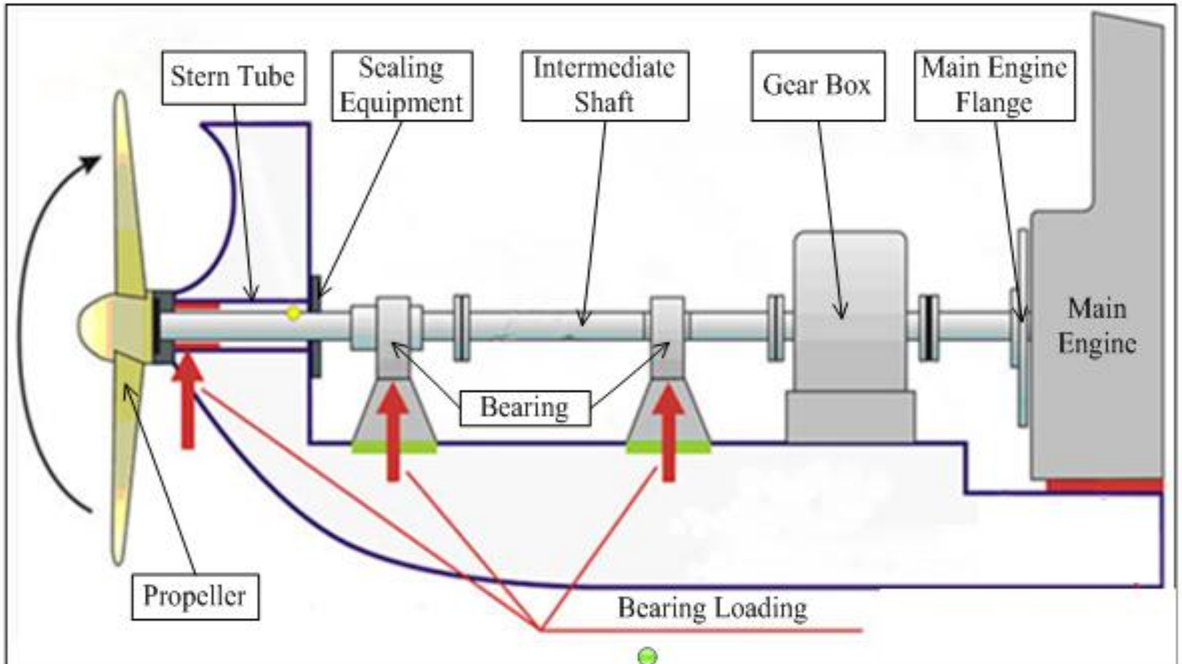


Fig. 3.19 Troost B.5 – 60 *Bp* – δ Chart



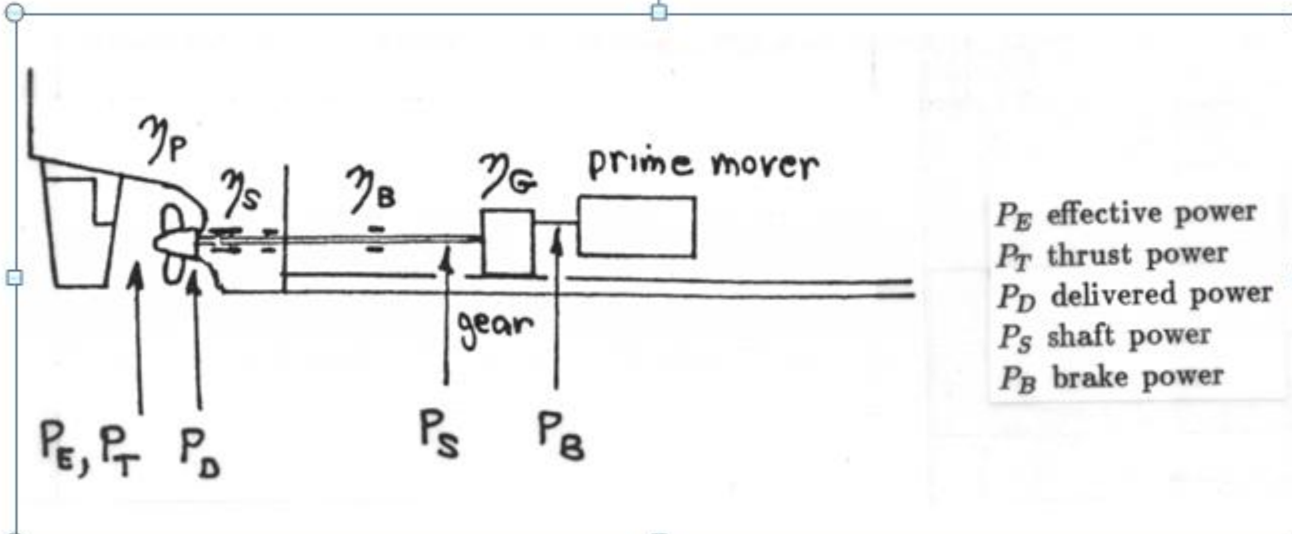


Fig.: Ship Power Definition

HULL EFFICIENCY

$$T(1-t) = R$$

$$TV(1-t) = R.V$$

$$T\frac{V_A}{(1-W_t)}.(1-t) = R.V$$

$$THP\frac{(1-t)}{(1-W_t)} = EHP$$

$$\frac{(1-t)}{(1-W_t)} = \frac{EHP}{THP} = Hull\,efficiency = \eta_H$$

R = Towrope resistance of the hull

T= Thrust of the propeller

Txt = Thrust deduction

t = thrust deduction fraction

1-t = thrust deduction fraction

T.V_A = Thrust power (THP)

R.V = Effective power (EHP)

V_A = Speed of Advance V_S (1-w_t)

V =VA/(1-wt)

Wt = Taylor wake fraction

SHAFT POWER, Ps

$$\eta_D = \eta_o \eta_R \eta_H$$

$$J = \frac{V_A}{nD}$$

$$QPC = \eta_D \eta_S$$

$$P_S = \frac{P_E}{QPC} = \frac{R.V_S}{QPC}$$

CAVITATION CHECK:

The local Cavitation number at 0.7R is given by:

$$\sigma_{0.7R} = \frac{p_A - p_v + \rho g h}{\frac{1}{2}\rho\left[V_A^2 + (0.7\pi n D)^2\right]}$$

An approximate value for which is given by:

$$\sigma_{0.7R} = \frac{188.2 + 19.62h}{V_A^2 + 4.836n^2D^2},$$

A mean thrust loading coefficient given by the following expression

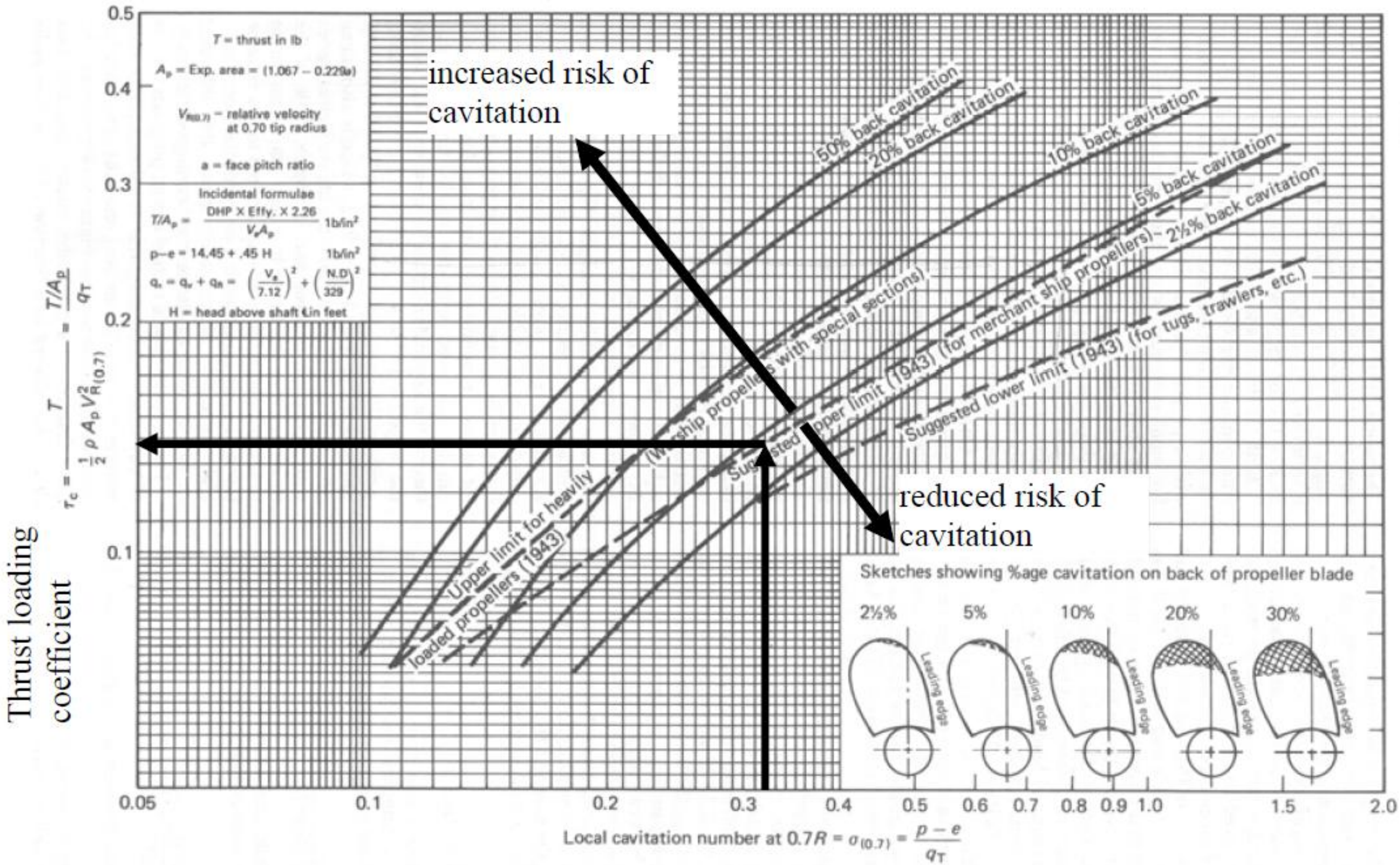
$$\tau_c = \frac{T/A_P}{\frac{1}{2}\rho V_R^2};$$

is then obtained from Burril cavitation chart and AP is calculated. From following expression, AD is calculated

$$\frac{A_P}{A_D} = 1.067 - 0.229\frac{P}{D}.$$

And finally minimum expanded blade area ratio (EAR) required is calculated assuming AD~AE

BURRIL CAVITATION CHART



EAR

$$A_E \cong \frac{A_P}{(1.067 - 0.229\, P/D)}$$

Assuming AE=AD

Expanded blade area ratio, EAR

$$\frac{A_E}{A_0} = \frac{A_E}{\pi D^2 / 4}$$

KELLER'S CRITERION FOR AVOIDING CAVITATION

The alternative blade area estimation is the Keller Formula as

$$\frac{A_E}{A_0} = \frac{(1.3 + 0.3Z)T}{(P_0 - P_V)D^2} + K$$

where P_0 is the static pressure at the shaft C_L in Pa

P_V is the vapour pressure in Pa (~1700 N/m^2)

T is the propeller thrust (N)

Z is the number of blades

D is the propeller diameter in meters

The value of K varies with the number of propellers and ship types as:

K=0.2	for single screws	
K=0.0	for fast naval ships	} Twin screws
K=0.1	for slow merchant ships	} Twin screws

DIA, PITCH & RPM OF 3 BLADED PROPELLER

ASSUME Pressure Loading of 80kN/m.m

$T = R/(1-t)$

$V_A = V_S(1-w)$

AREA OF BLADES $A_D = T/80$

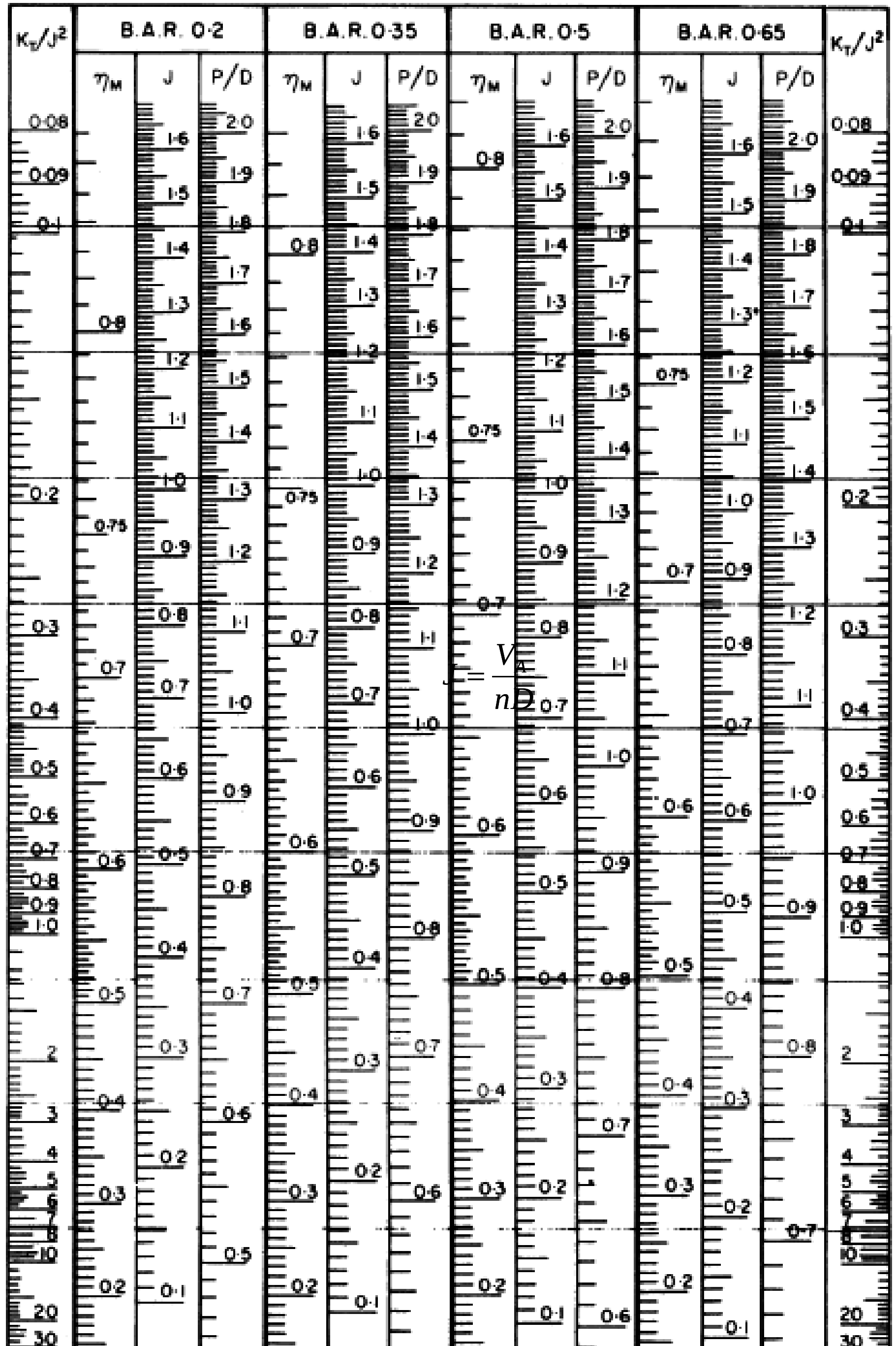
BAR $= 4.A_D/(\pi D.D)$

D =?

$$\frac{K_T}{J^2} = \frac{T}{\rho n^2 D^4} / \frac{V_A^2}{n^2 D^2} = \frac{T}{\rho D^2 V_A^2}$$

Use $\frac{K_T}{J^2}$ Chart and determine P/D, J and η

Number of blade = 3



P/D=?

P=?

Speed of Advance,

$$J = \frac{V_A}{nD}$$

n =?

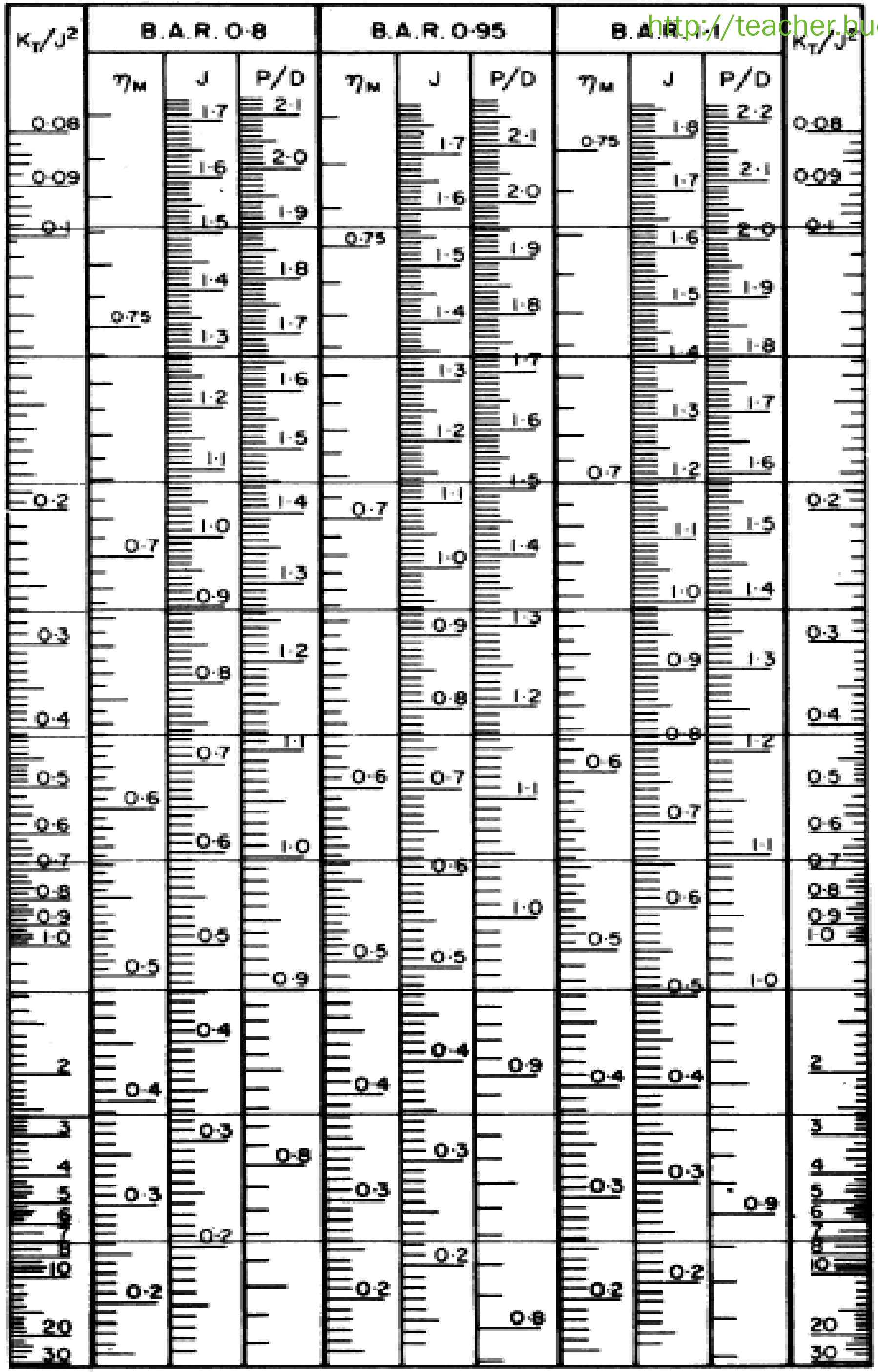


Diagram gives the maximum peller efficiency, η_M, obtainable any known value of K_T/J^2 corresponding values of advance efficient J and pitch ratio

$$\frac{K_T}{J^2} = \frac{36.13}{D^2 V^2} T$$

$$J = \frac{30.88}{nD}$$

where T = thrust in tonnef
D and P are in metres
n is in r.p.m.
V is in knots

NUMBER OF BLADES OTHER THAN THREE

Obtain values of $\frac{K_T}{J^2}$

Prepare a table as follows:

J	$\frac{K_T}{J^2} \times J^2$
0.4	?
0.5	?
0.6	?
0.7	?
…	?

Plot these data on a *KT-KQ-Eta-J* diagram and find the intersection points with *KT* curve. Draw perpendicular at these points and obtain *eta* for different *j* values and finally plot it.

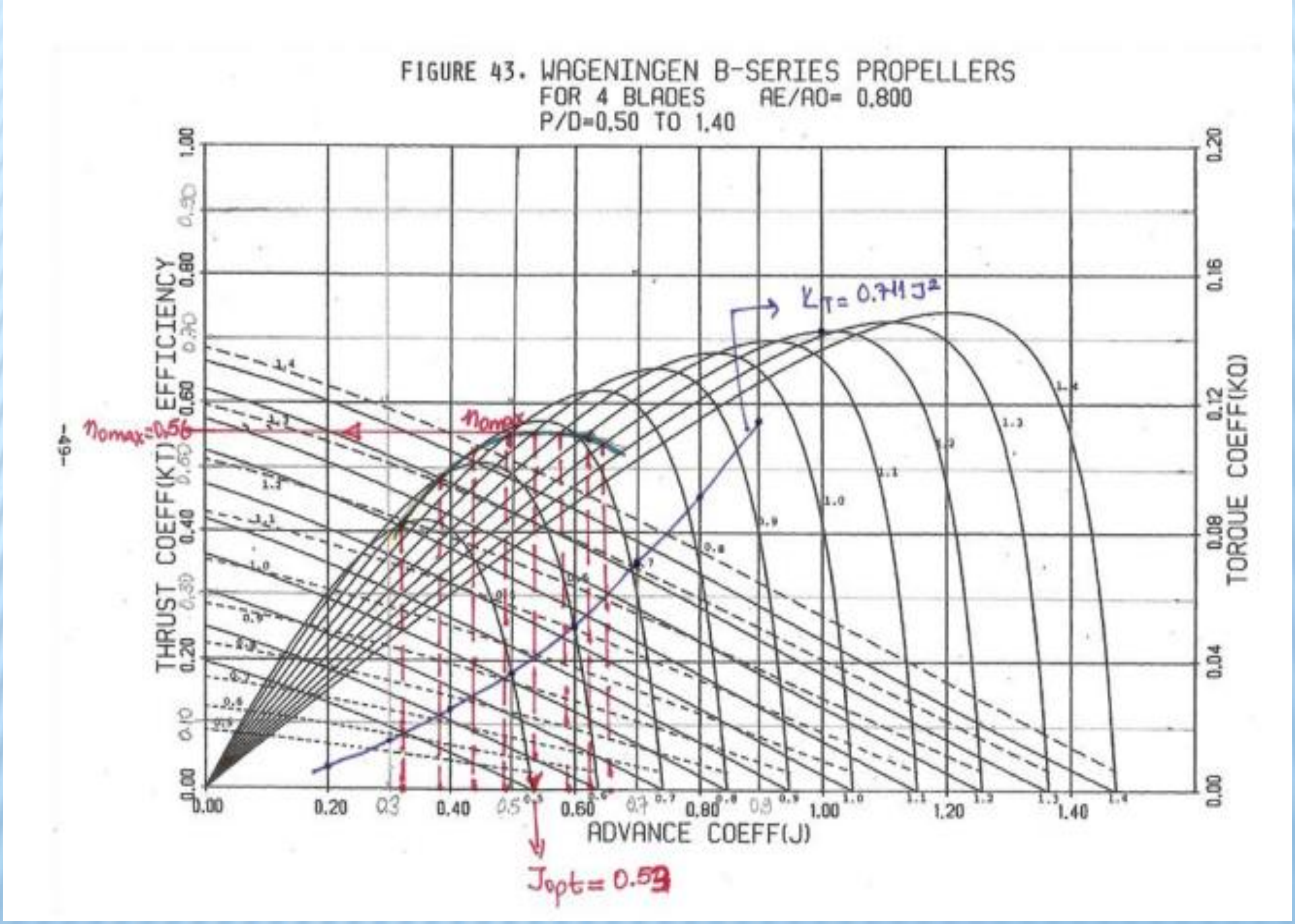
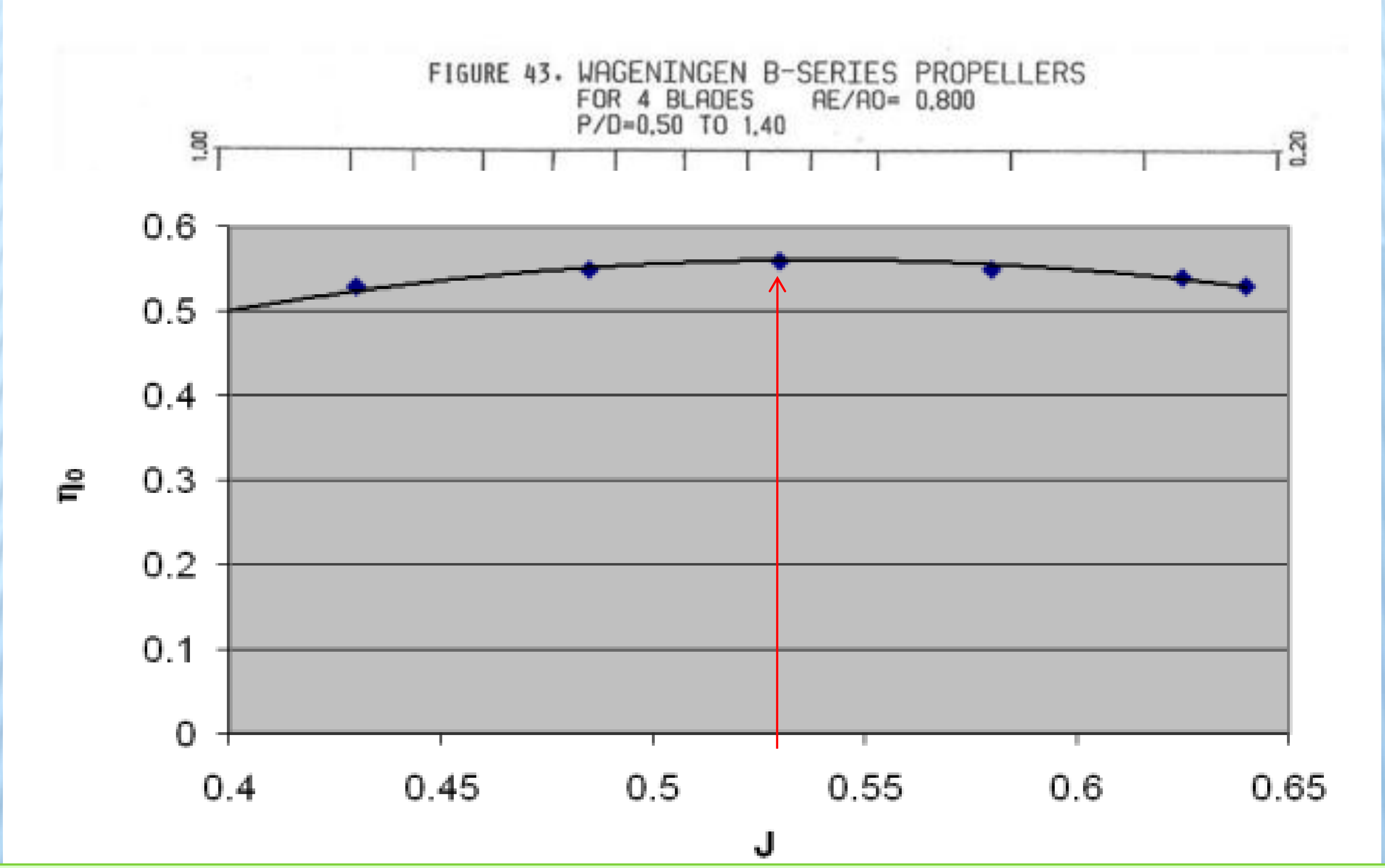


FIGURE 43. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 0.800
P/D=0.50 TO 1.40
THRUST COEFF(KT) EFFICIENCY
TORQUE COEFF(KQ)
ADVANCE COEFF(J)
$K_T = 0.741 J^2$
ηomax=0.56
ηomax
Jopt= 0.53
-49-



The advance coefficient at which eta is maximum is the optimum operating condition. From Jopt, find the optimum rpm of propeller.