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THE SSPA STANDARD PROPELLER FAMILY OPEN WATER CHARACTERISTICS

BY

HANS LINDGREN AND E. BJÄRNE

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Summary

A family of 3, 4, 5 and 6-bladed conventional merchant ship propellers of simple geometrical shape is presented. Propeller characteristics obtained from open water tests are given. The results from each propeller group are presented on the base of J, K_T/J^4 and K_Q/J^5. The ranges covered by experiments correspond to:

Number of blades	Pitch ratios	Blade area ratios
3	0.55–0.75	0.45
4	0.65–1.15	0.47, 0.53, 0.60
5	0.65–1.15	0.60
6	0.75	0.60

1. Introduction

The SSPA standard propeller family has been developed primarily to be used in connection with preliminary project studies and systematic model tests. At present it consists of about 100 propeller models with different blade numbers Z, diameters D, pitch ratios P/D and blade area ratios A_D/A_O. The dimensions have been chosen so that for every normal merchant ship project, it is possible to find at least one suitable propeller model. For the preliminary determination of wake and thrust deduction factors, studies of the optimum propeller diameter and influence of the number of blades, this propeller family is very useful.

All the propeller models have been tested in the towing tank as well as in the cavitation tunnel and the test program comprises:

Open water tests

Cavitation tests in homogeneous flow

Cavitation tests in different wake distributions

In the present report, the geometric characteristics of the propellers as well as the results of the open water tests are presented.

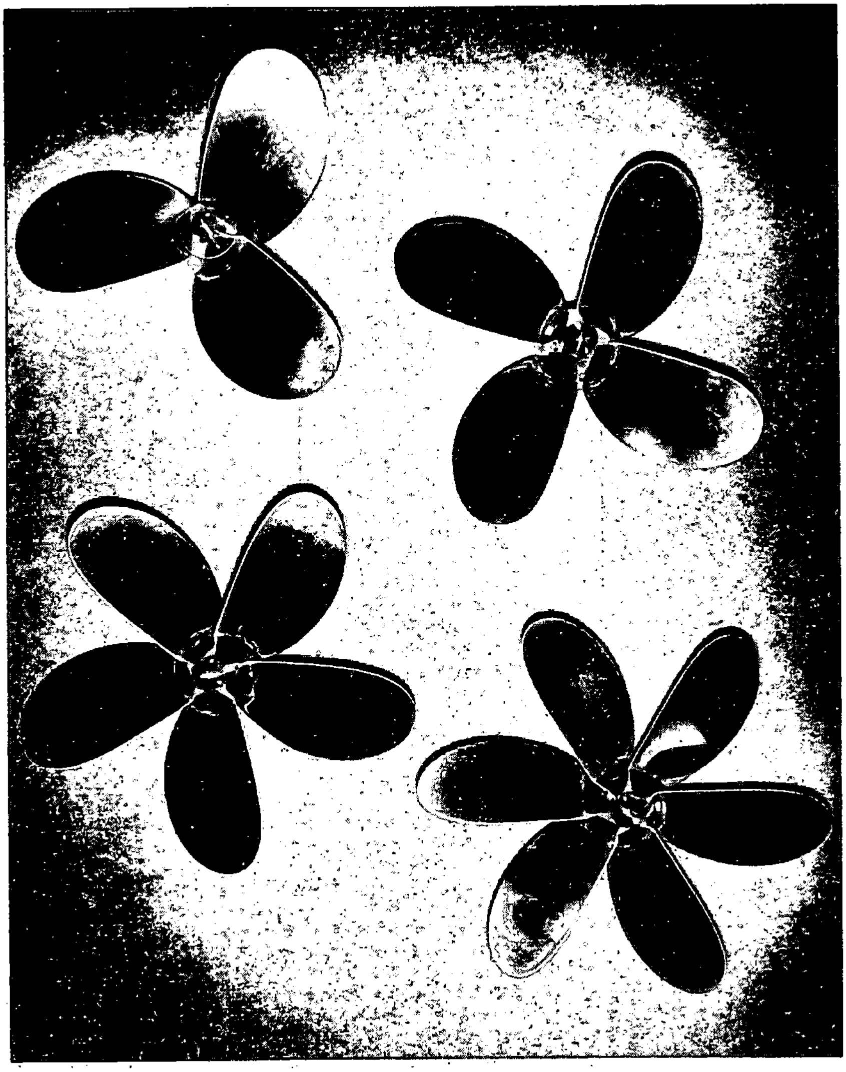

Fig. 1. Examples of propellers in the family.

2. Symbols and Units

A_O = propeller disc area $\left(=\frac{\pi D^2}{4}\right)$

A_D = developed blade area

C_D = drag coefficient

$C_{D\min}$ = minimum drag coefficient

C_L = lift coefficient

c = blade section chord length

D = propeller diameter

D_H = hub diameter

J = advance number $\left(=\frac{V_A}{Dn}\right)$

K_Q = torque coefficient $\left(=\frac{Q}{\rho D^5 n^2}\right)$

K_T = thrust coefficient $\left(=\frac{T}{\rho D^4 n^2}\right)$

n = rate of revolution

P = propeller pitch (mean value = 0.9794 $P_{\max}$)

$P_{\max}$ = maximal propeller pitch

Q = propeller torque

R = propeller radius $(=D/2)$

R_n = Reynolds number. For propellers $R_n=\frac{c}{\nu}\sqrt{V_A^2+(0.75\pi Dn)^2}$

r = blade section radius

s = blade section thickness

T = propeller thrust

V_A = propeller speed of advance

Z = number of blades

α = profile angle of attack

η_o = propeller open efficiency

ρ = mass density of water

ν = kinematic viscosity

Dimensionless coefficients and ratios are used throughout.

3. The Propeller Family

The geometry of the propellers is defined in Appendix I. The outline of the propeller blades is illustrated in Fig. 3 and the profile shape in Fig. 4. Dimensions and profile ordinates are given in Tables 1 and 2.

The radial thickness distribution is almost linear and the thickness diameter ratio, s_i/D is about 0.05.

The hub diameter was kept constant within a group of propellers with different diameters. This means that the hub-diameter ratio D_H/D varies within the ranges $0.15 < D_H/D < 0.20$. This variation does not significantly influence the test results.

4. Tests and Method for Fairing the Test Results

The propellers were tested in the towing tank over the range 0–100 per cent slip. The rate of revolutions was kept constant, whilst the speed V_A was varied.

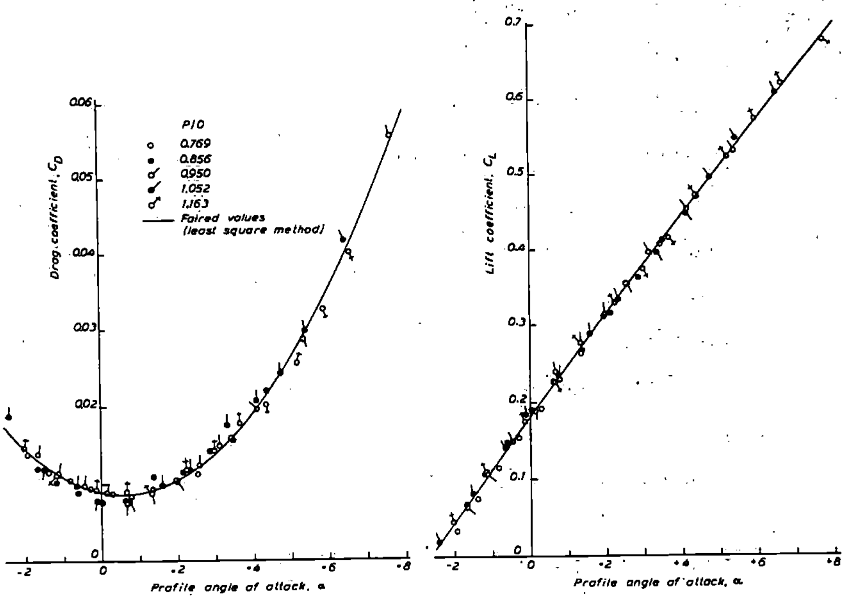

Fig. 2. C_L and C_D coefficients for the SSPA 4.47 group propellers.

The method for fairing the test results follows the scheme outlined in ref. [1][1]. All the material was analysed in accordance with the principles published by Lerbs [2]. For each propeller, lift and drag coefficients for the equivalent profile were calculated. Within each group of propellers, common lift and drag curves were determined by the aid of the least square method. In Fig. 2, the primary test spots converted to lift and drag coefficients for the 4.47 propeller group are presented. The faired mean curves used for the further calculations are also given. The pitch ratio seems not to have any significant influence on the results within the range tested.

Starting from the lift and drag curves obtained as above, faired J, K_T, K_Q and η_o-curves could be calculated for arbitrary pitch ratios. No corrections for Reynolds' number effects have been introduced. The minimum drag values and Reynolds' numbers for the different propeller groups are given in the table below:

Type of propeller	R_n	$C_{D_{min}}$
3.45	4.99 10^5	0.0074
4.47	3.93 10^5	0.0086
4.53	4.68 10^5	0.0076
4.60	5.41 10^5	0.0078
5.60	4.00 10^5	0.0088
6.60	3.63 10^5	0.0103

All the analysis and fairing of the test material has been carried out on an electronic computer of the type FACIT EDB 3. The principles have also been discussed in ref. [3].

5. Presentation of the Test Results

All the test results, faired and partly extrapolated as outlined above, are presented in the diagrams in Appendix II. The presentation is quite dimensionless and the same parameters are adopted as in ref. [1].

[1]) The numbers within brackets refer to the list of references in Section 7.

For each group of 3, 4 and 5-bladed propellers three kinds of diagrams are given. In these diagrams the curves have been based on

$$J, \frac{K_T}{J^4} \text{ and } \frac{K_Q}{J^5}$$

respectively.

The well-known Taylor variables B_u and B_p are related to the abovementioned variables by the equations

$$B_u = \frac{0.05541N}{V_A^2}\sqrt{S} = C_1\sqrt{\frac{K_T}{J^4}} \quad B_p = \frac{N}{V_A^2}\sqrt{\frac{P}{V_A}} = C_2\sqrt{\frac{K_Q}{J^5}}$$

where N = number of revolutions in r/min
P = power in HP (HP=76 kpm/sec), fresh water
S = thrust in lbs, fresh water
V_A = speed of advance in knots

The factors C_1 and C_2 can be obtained from the table below.

	C_1	C_2
Fresh water ($\rho=102.0$ kp sec^2/m^4)	13.19	33.08
Salt water ($\rho=104.5$ kp sec^2/m^4)	13.36	33.48

For the time being only one 6-bladed propeller belonging to the family has been tested. Complete diagrams have therefore not been worked out. Preliminary curves representing 6-bladed propellers with optimum diameters have, however, been determined with the method described in Section 4. These curves are given in Fig. 20 together with the corresponding curves for 4 and 5-bladed propeller with $A_D/A_O=0.60$.

6. Acknowledgement

The authors are indebted to Dr. Hans Edstrand, director general of the Swedish State Shipbuilding Experimental Tank for having stimulated and granted the work with this survey.

Thanks are also due to Mr. Edgar Freimanis, who designed the parent propeller form and worked out the preliminary plans for the propeller family, to Mr. Arne Hansson who assisted in most of the analysis work and to other members of the staff for their assistance in various stages of the work.

7. References

[1] LINDGREN, HANS: "Model Tests with a Family of Three and Five Bladed Propellers", *The Swedish State Shipbuilding Experimental Tank, Publication No.* 47, 1961.

[2] LERBS, H. W.: "On the Effect of Scale and Roughness on Free Running Propellers", *Journal Am. Soc. Nav. Eng. No.* 1, 1951.

[3] LINDGREN, HANS and KILBORN, JAN: "Datamaskinverksamheten vid statens skeppsprovningsanstalt", *The Swedish State Shipbuilding Experimental Tank, Allmän rapport nr* 10, 1965.

Appendix I
Propeller Geometry

TABLE 1

SSPA 3.45	r/R	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Total blade width	Multiplied by: $\frac{Z}{D : A_D/A_O}$	1.936	2.109	2.225	2.271	2.229	2.038	1.591	
Leading edge to generator line		1.195	1.265	1.301	1.279	1.175	0.972	0.617	−0.327
Trailing edge to generator line		0.741	0.844	0.924	0.992	1.054	1.066	0.974	0.327
Length of face lift (lead. edge)	Divided by: c	0.143	0.081	0.025					
Length of face lift (trail. edge)		0.276	0.131	0.014					
Distance of the point of max. thickness from the leading edge		0.360	0.374	0.399	0.430	0.458	0.481	0.500	
Blade thickness	Divided by: D	0.0344	0.0300	0.0256	0.0211	0.0168	0.0124	0.0079	0.0035

Table of back ordinates

Divided by: s

	Distance of the ordinates from the point of max. thickness (p.m.t.)							
	From p.m.t. to trailing edge				From p.m.t. to leading edge			
r/R	1.00	0.75	0.50	0.25	0.25	0.50	0.75	1.00
0.3	0.159	0.488	0.740	0.932	0.945	0.819	0.603	0.219
0.4	0.110	0.469	0.736	0.925	0.950	0.818	0.582	0.148
0.5	0.063	0.456	0.728	0.919	0.949	0.816	0.566	0.074
0.6	0.031	0.464	0.732	0.920	0.955	0.817	0.563	0.031
0.7	0.039	0.472	0.742	0.921	0.955	0.815	0.562	0.039
0.8	0.053	0.521	0.763	0.931	0.954	0.817	0.573	0.053
0.9	0.083	0.607	0.821	0.952	0.952	0.821	0.607	0.083

Radius Divided by: s		
r/R	Trailing edge	Leading edge
0.3	0.041	0.104
0.4	0.035	0.082
0.5	0.026	0.052
0.6	0.031	0.031
0.7	0.039	0.039
0.8	0.053	0.053
0.9	0.083	0.083

TABLE 2

SSPA 4-, 5- and 6-bladed propellers	r/R	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Total blade width	Multiplied by:	1.777	1.976	2.123	2.197	2.177	2.003	1.581	
Leading edge to generator line	$\frac{Z}{D \cdot A_D/A_O}$	1.079	1.172	1.215	1.199	1.115	0.925	0.578	−0.323
Trailing edge to generator line		0.698	0.804	0.908	0.998	1.062	1.078	1.003	0.323
Length of face lift (lead. edge)	Divided by: c	0.115	0.066	0.025					
Length of face lift (trail. edge)		0.180	0.112	0.058	0.013				
Distance of the point of max. thickness from the leading edge		0.360	0.377	0.401	0.430	0.466	0.494	0.500	
Blade thickness	Divided by: D	0.0332	0.0282	0.0235	0.0190	0.0148	0.0107	0.0068	0.0029

Table of back ordinates Divided by: s	Distance of the ordinates from the point of max. thickness (p.m.t.)									Radius Divided by: s		
	From p.m.t. to trailing edge					From p.m.t. to leading edge						
	r/R	1.00	0.75	0.50	0.25	0.25	0.50	0.75	1.00	r/R	Trailing edge	Leading edge
	0.3	0.208	0.538	0.795	0.949	0.958	0.833	0.624	0.208	0.3	0.031	0.130
	0.4	0.128	0.497	0.777	0.944	0.954	0.832	0.582	0.128	0.4	0.022	0.071
	0.5	0.065	0.463	0.761	0.940	0.949	0.797	0.544	0.065	0.5	0.019	0.035
	0.6	0.025	0.441	0.752	0.938	0.946	0.784	0.513	0.025	0.6	0.021	0.025
	0.7	0.027	0.436	0.749	0.937	0.943	0.774	0.491	0.027	0.7	0.027	0.027
	0.8	0.038	0.446	0.754	0.938	0.943	0.771	0.484	0.038	0.8	0.038	0.038
	0.9	0.061	0.493	0.775	0.944	0.945	0.779	0.502	0.061	0.9	0.061	0.061

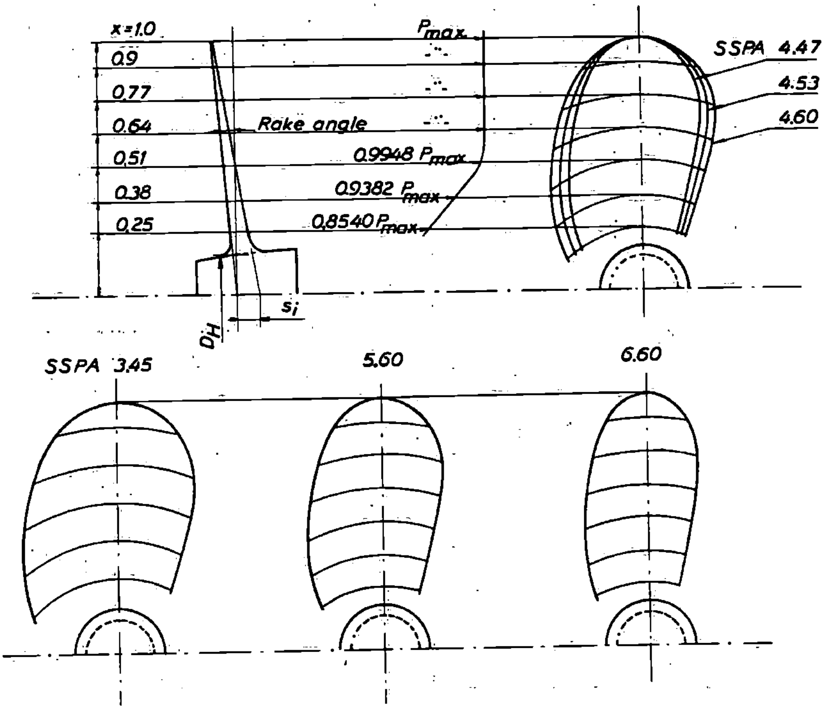

Fig. 3. Outlines of the propellers.

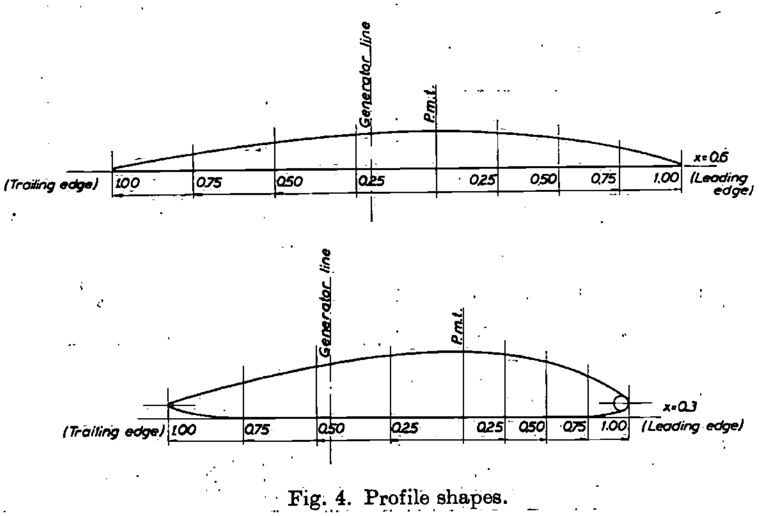

Fig. 4. Profile shapes.

Appendix II
Open Water Diagrams

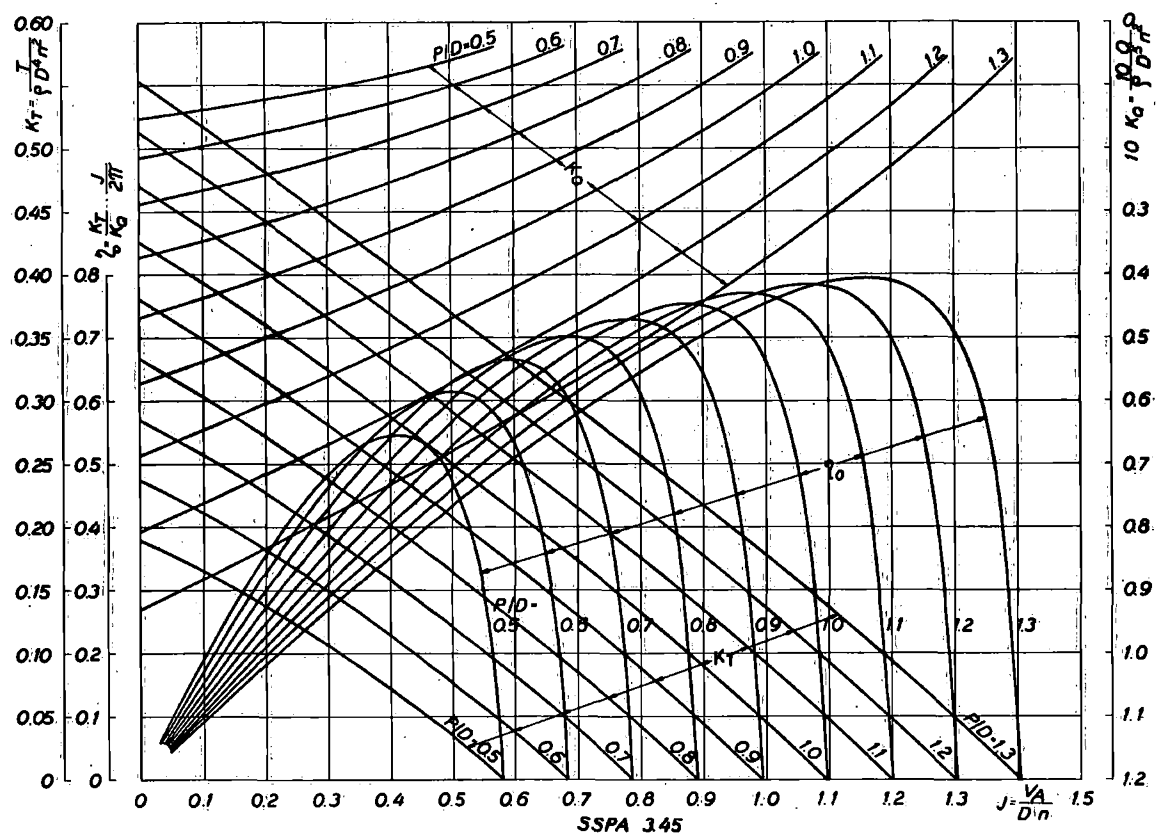

Fig. 5. SSPA 3.45 propellers.

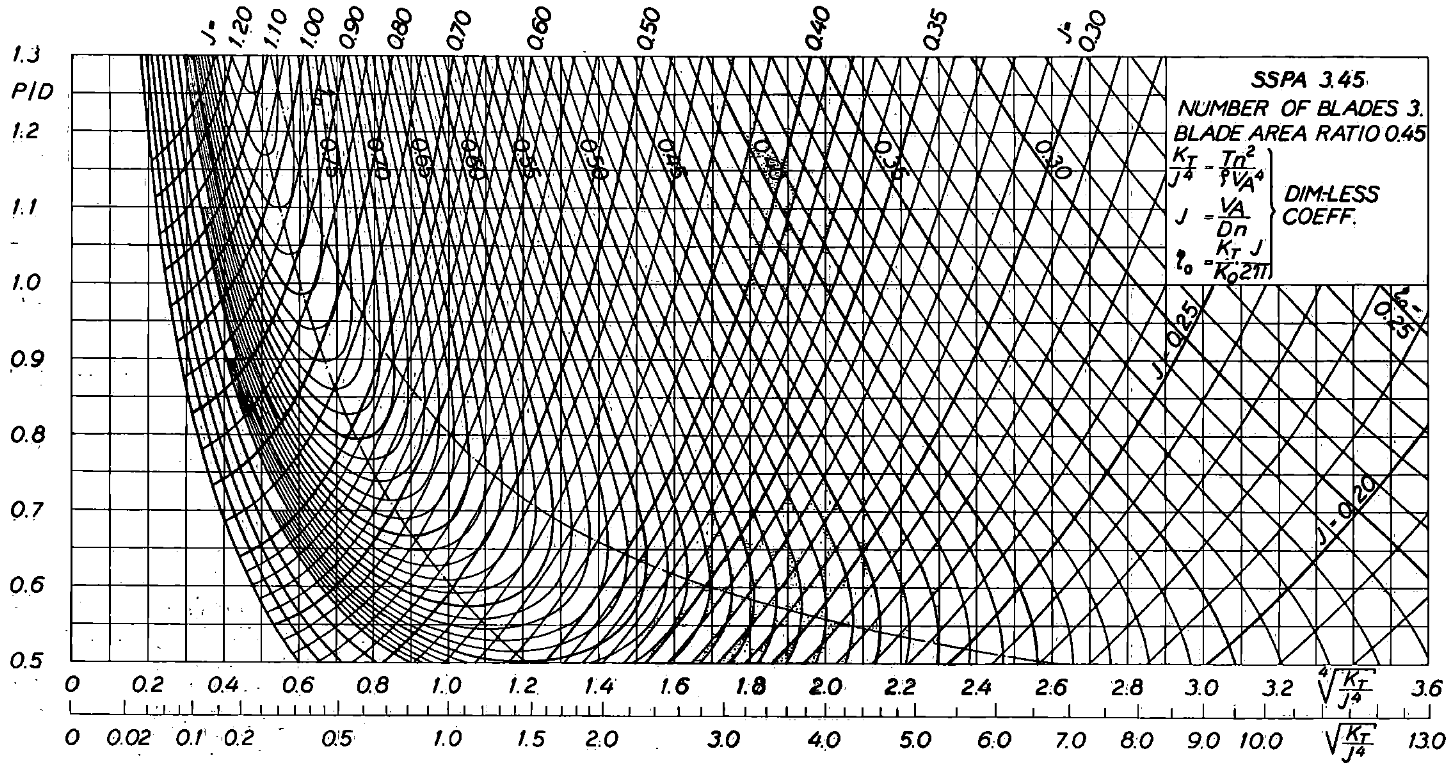

Fig. 6. SSPA 3.45 propellers.

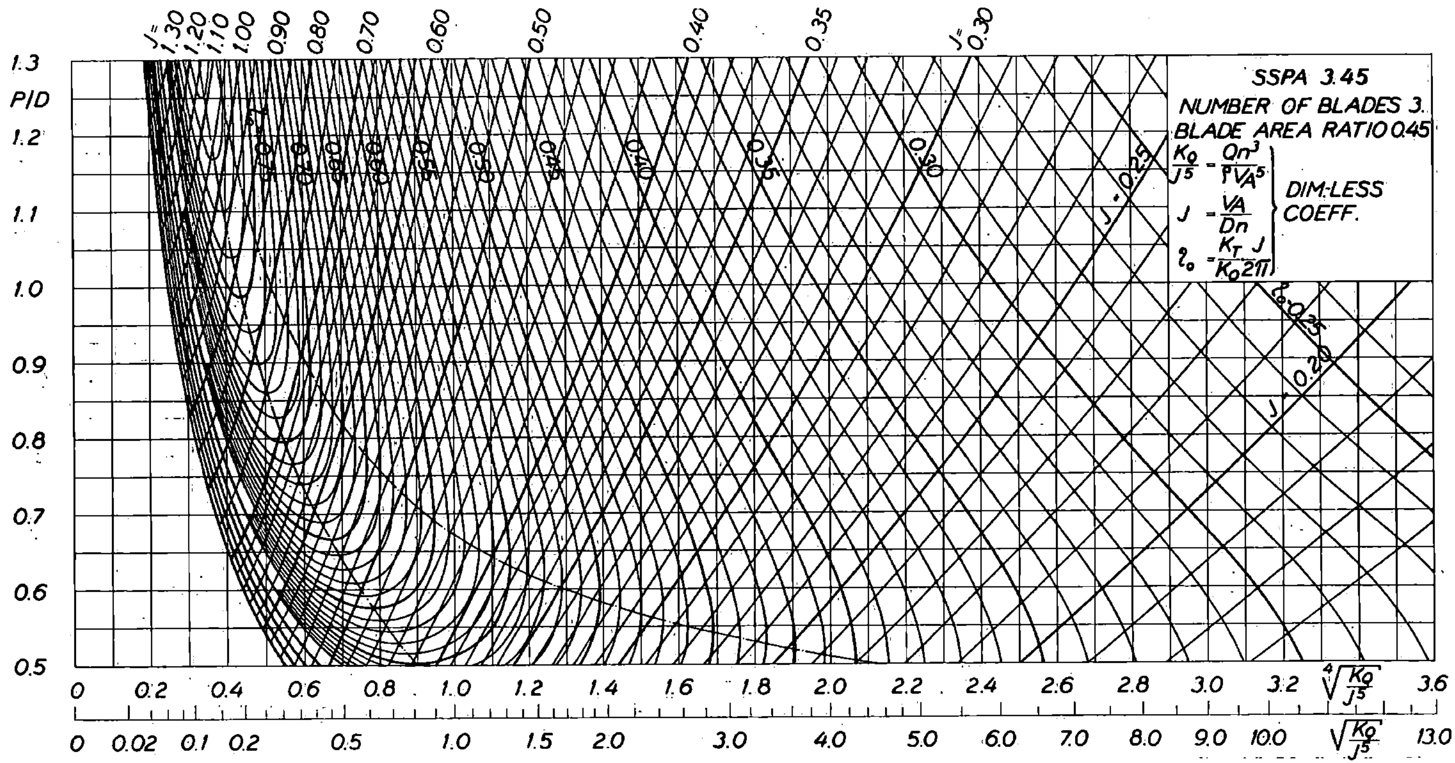

Fig. 7. SSPA 3.45 propellers.

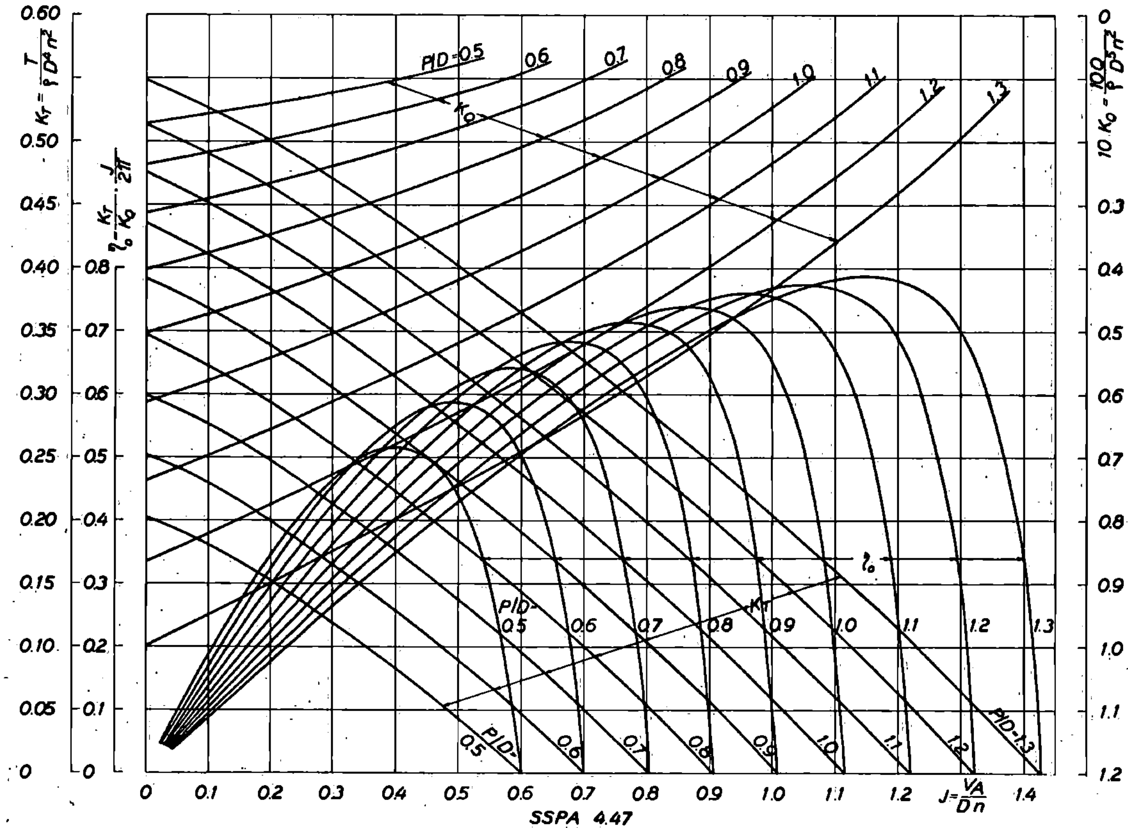

Fig. 8. SSPA 4.47 propellers.

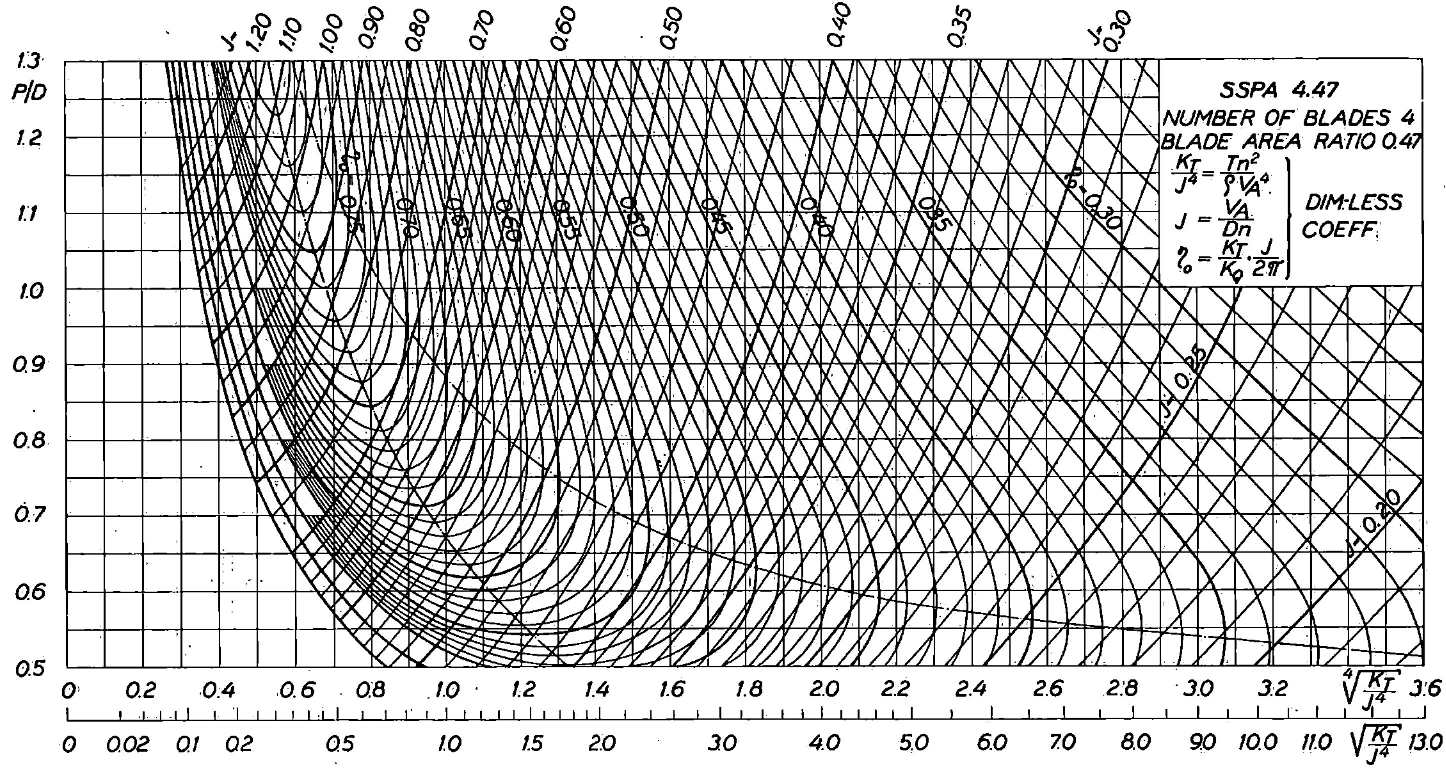

Fig. 9. SSPA 4.47 propellers.

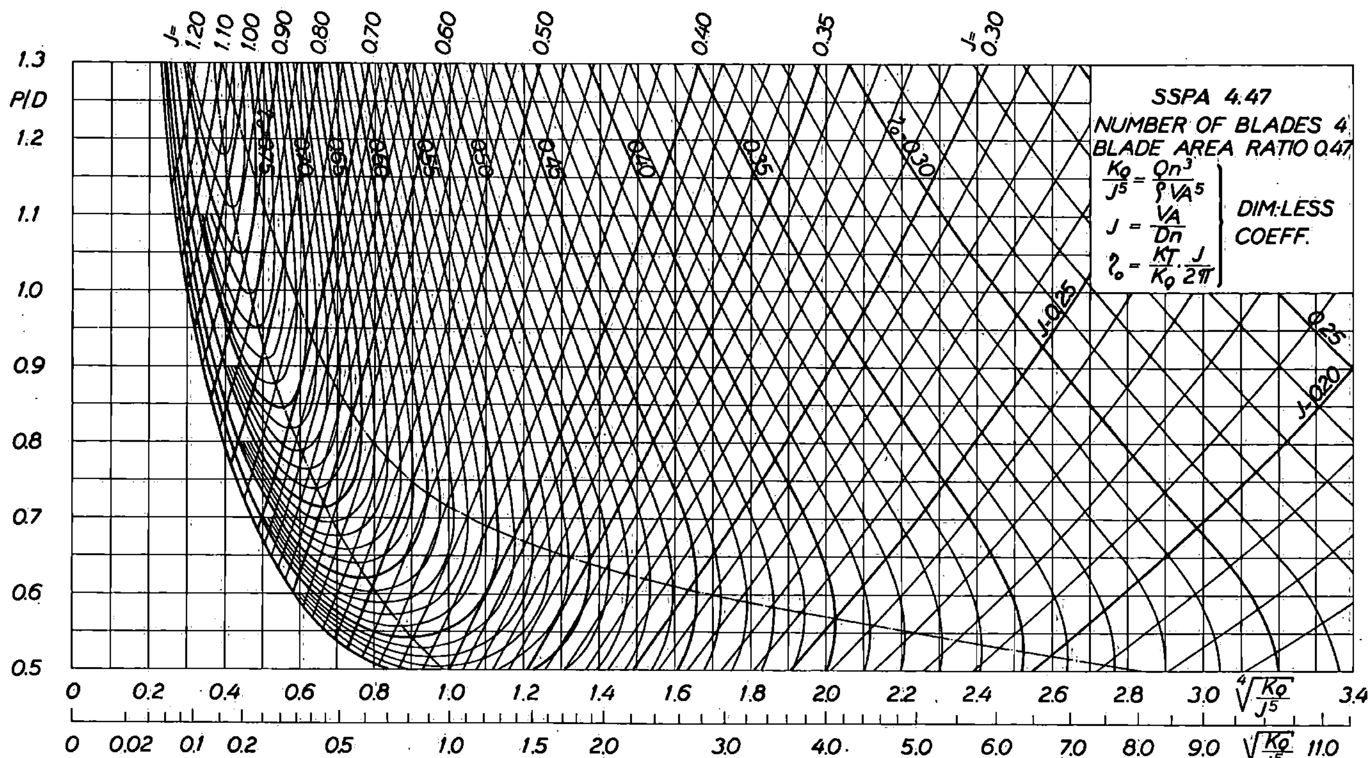

Fig. 10. SSPA 4.47 propellers.

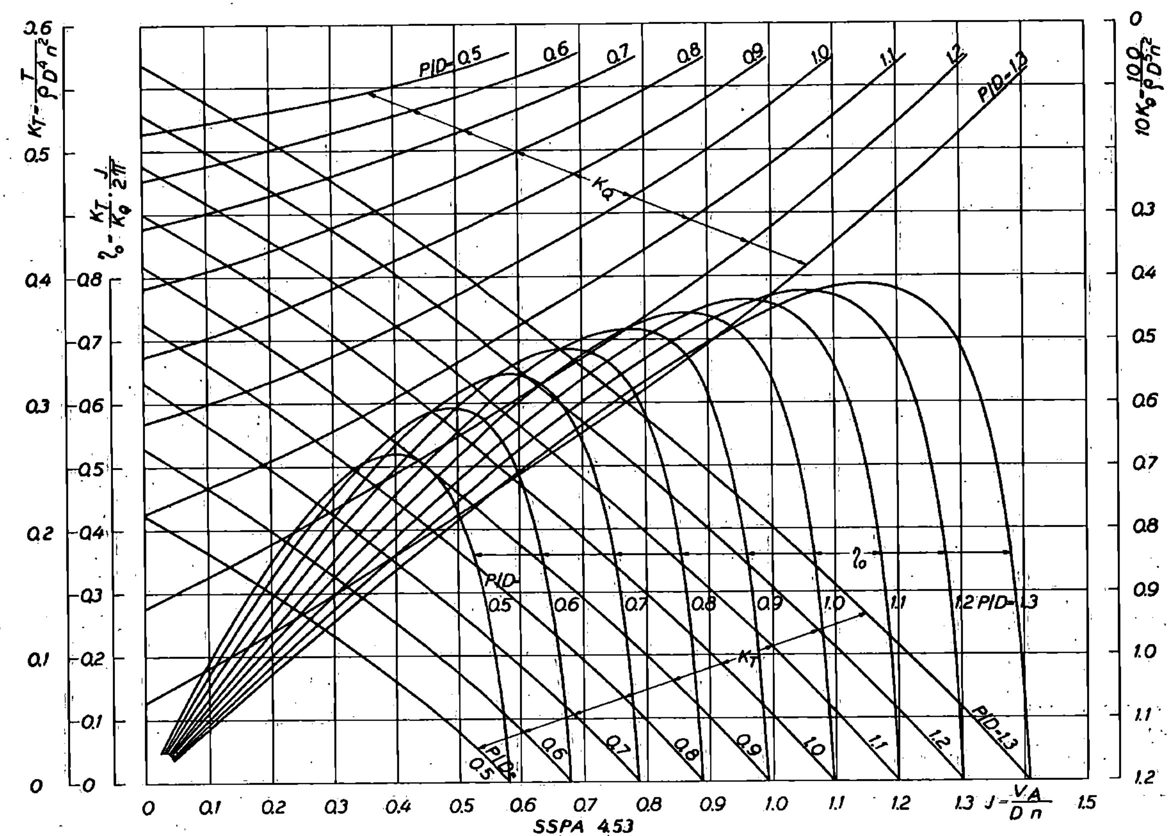

Fig. 11. SSPA 4.53 propellers.

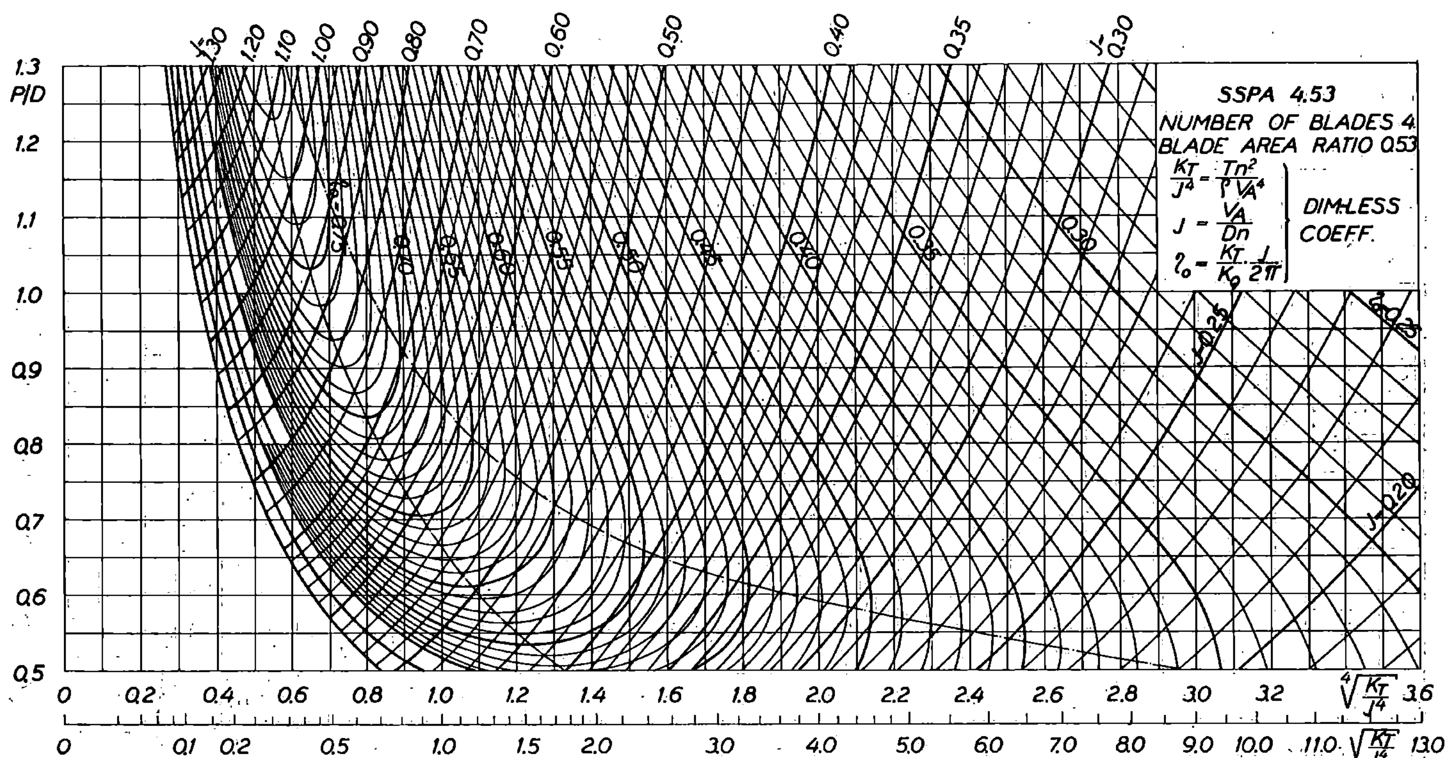

Fig. 12. SSPA 4.53 propellers.

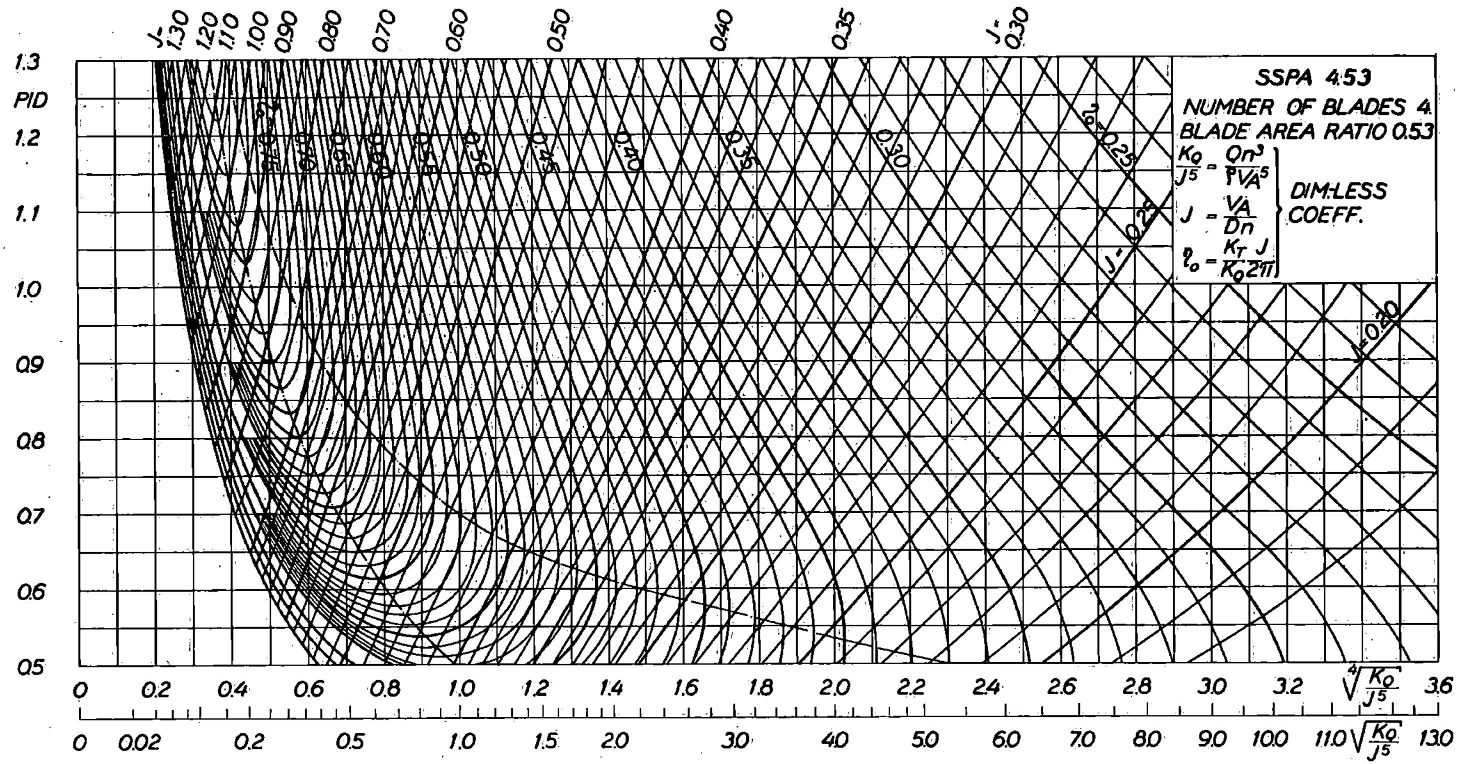

Fig. 13. SSPS 4.53 propellers.

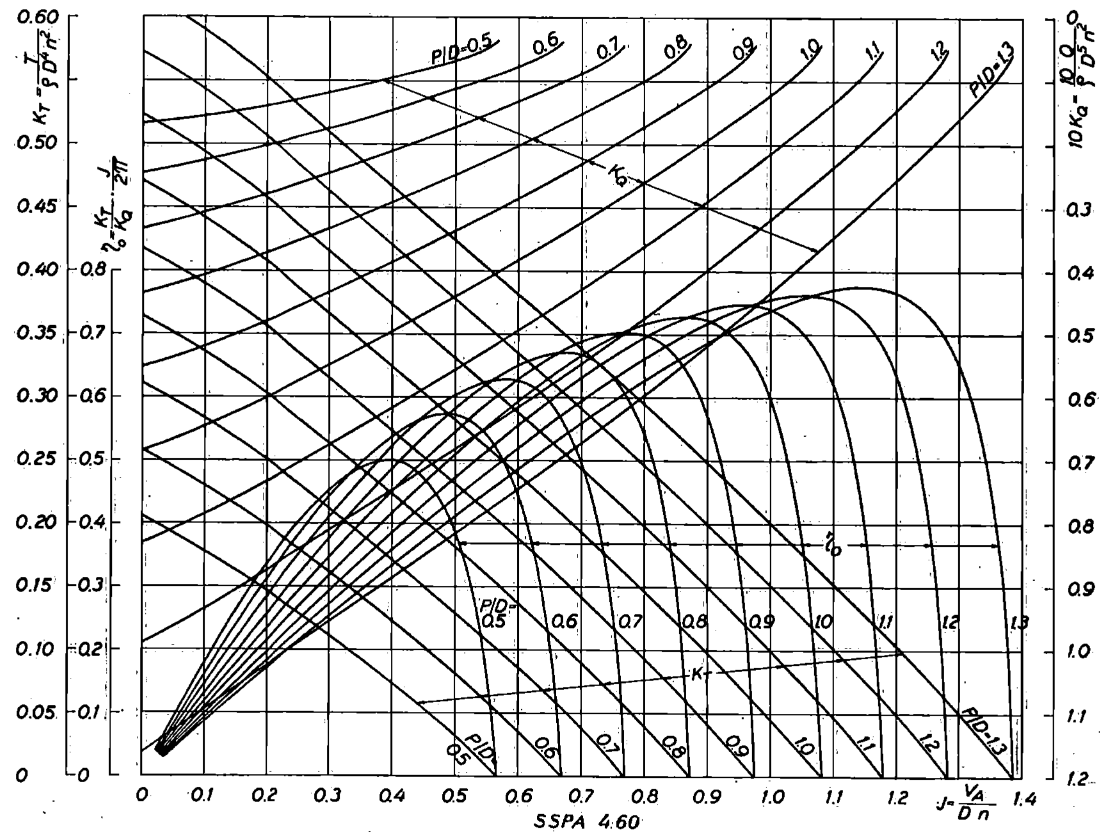

Fig. 14. SSPA 4.60 propellers.

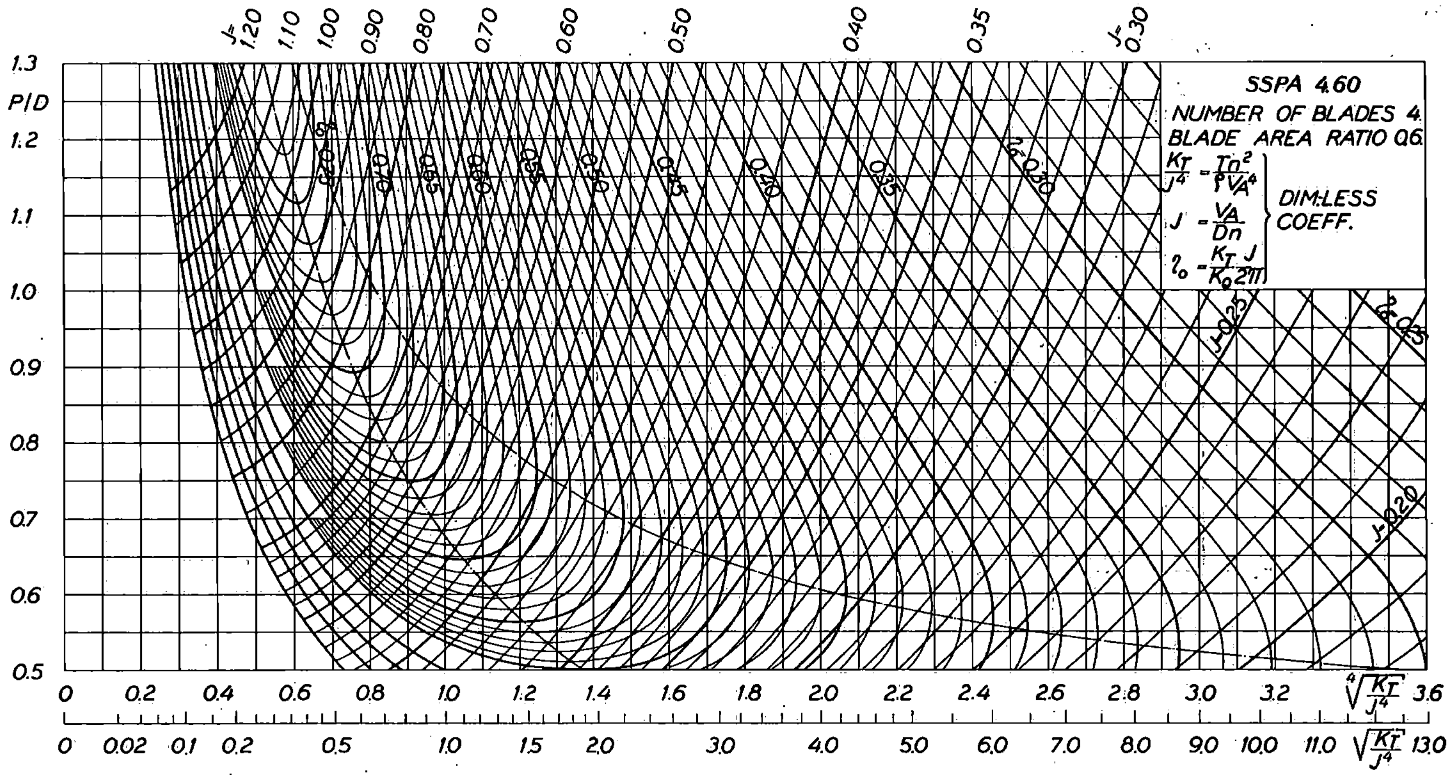

Fig. 15. SSPA 4.60 propellers.

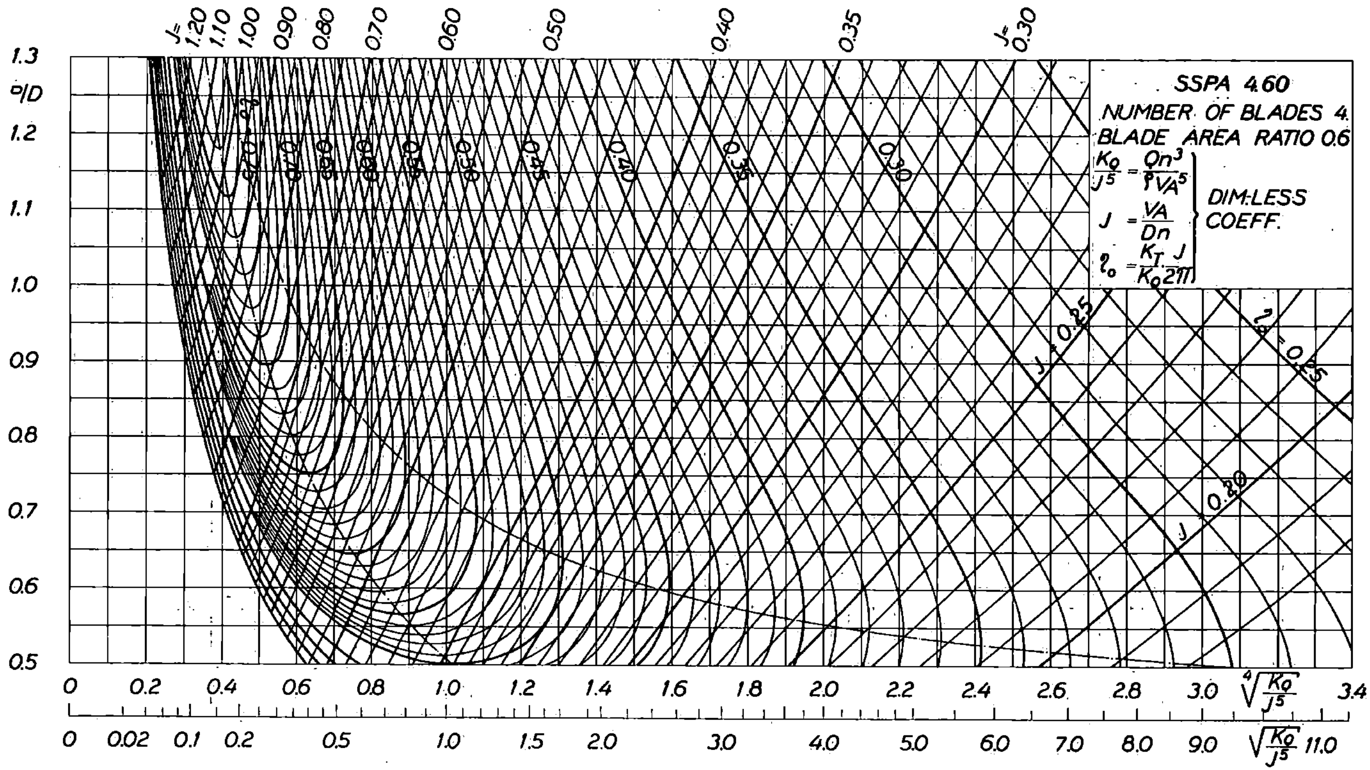

Fig. 16. SSPA 4.60 propellers.

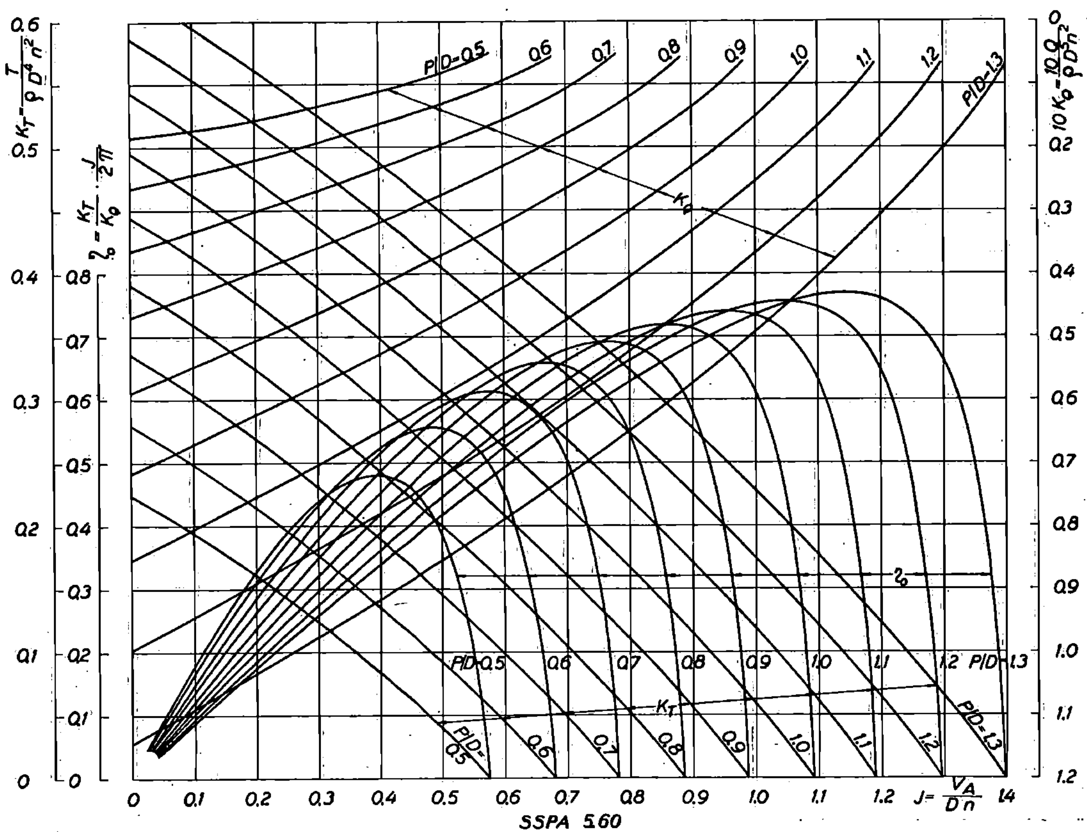

Fig. 17. SSPA 5.60 propellers.

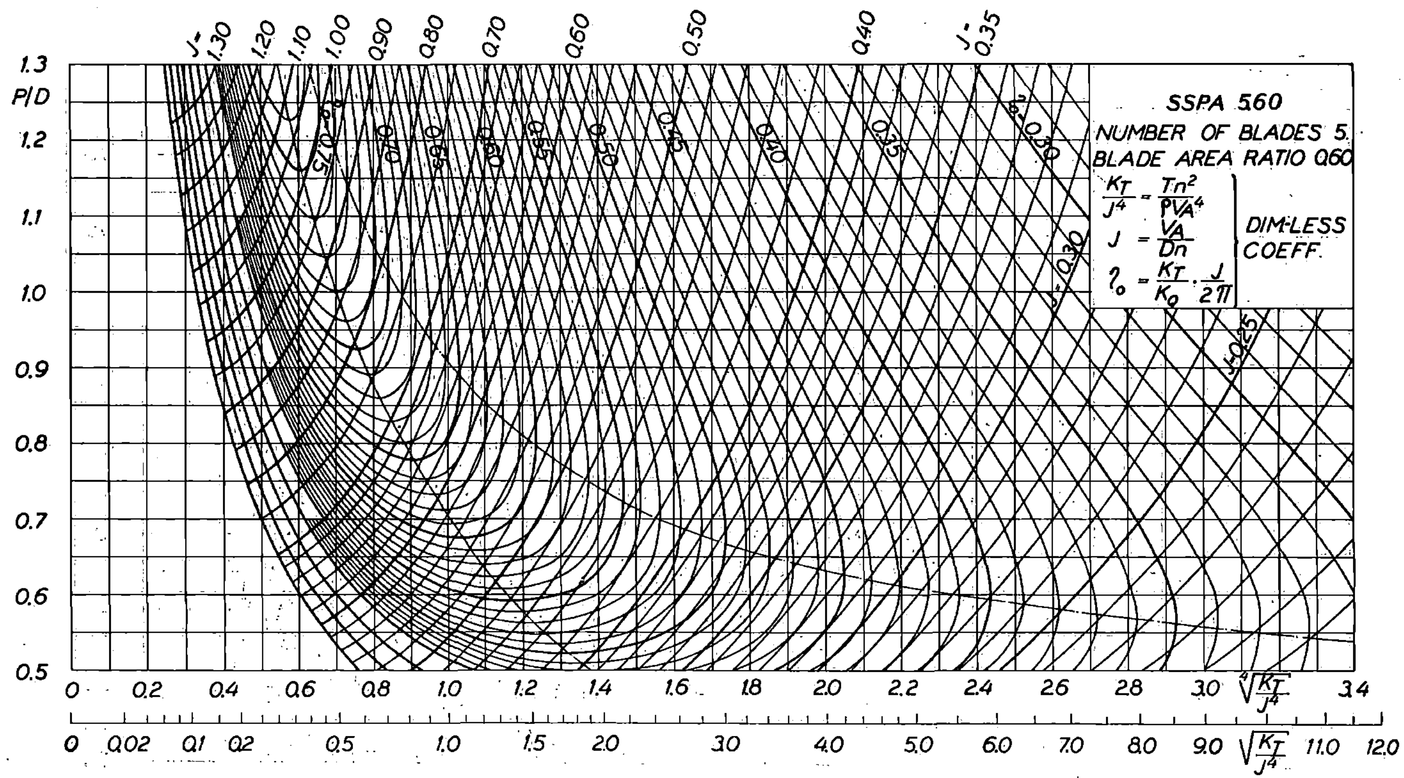

Fig. 18. SSPA 5.60 propellers.

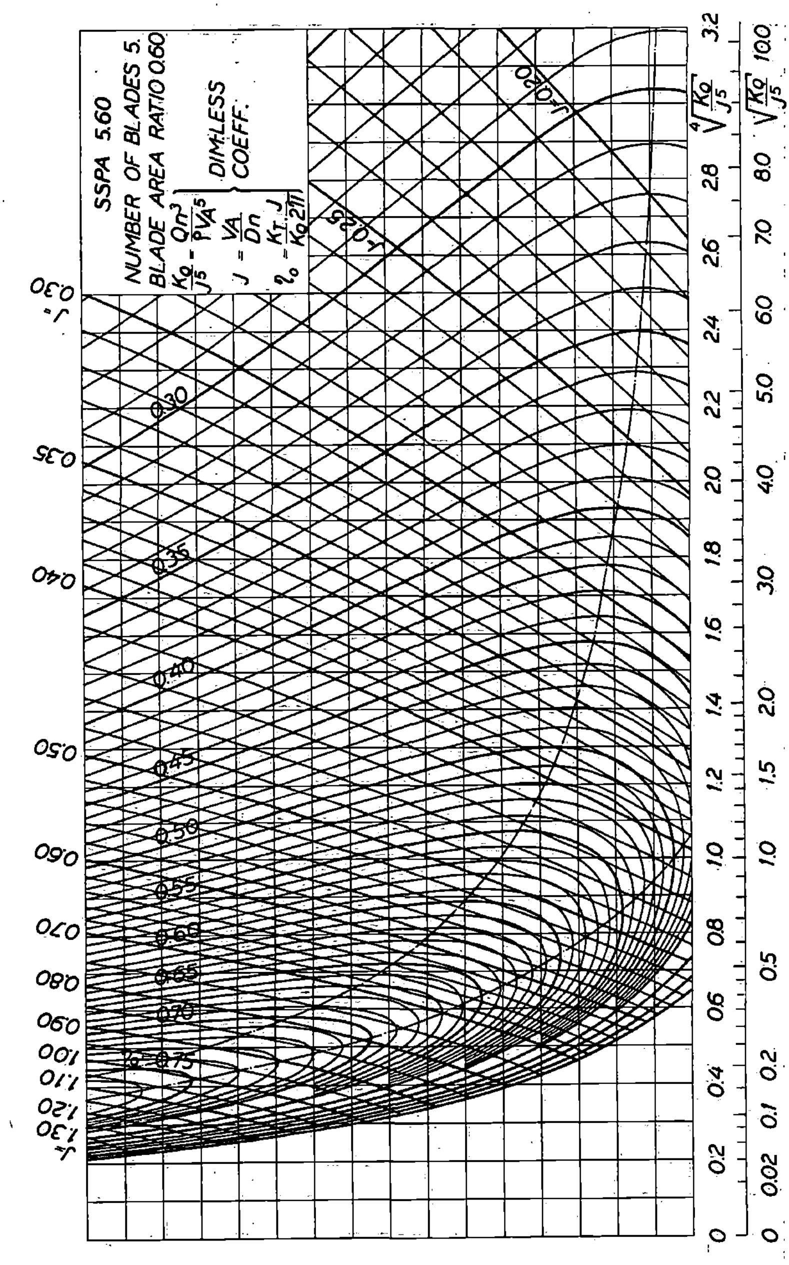

Fig. 19. SSPA 5.60 propellers.

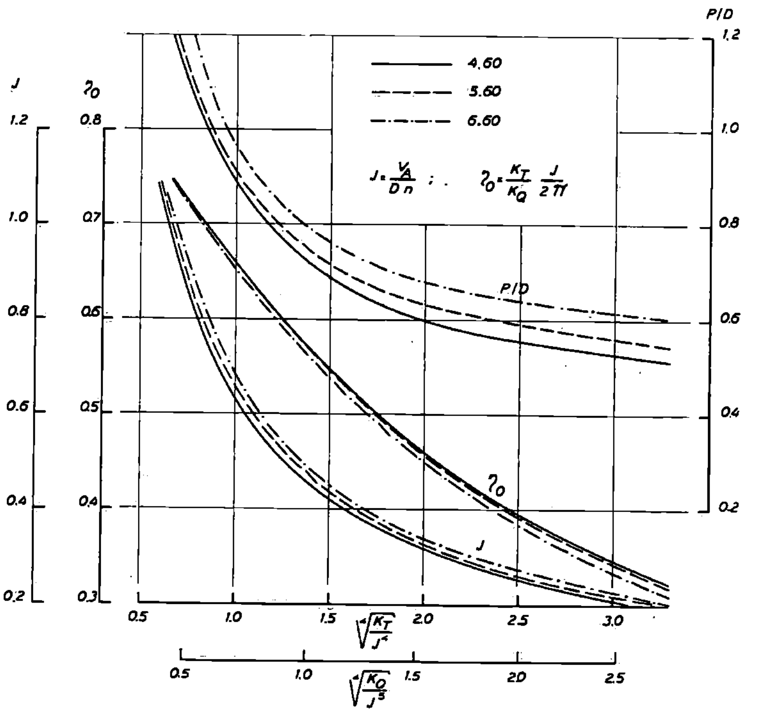

Fig. 20. Curves representing propellers with optimum diameter, $A_D/A_O = 0.60$.