THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING
Department of Naval Architecture and Marine Engineering

RESISTANCE AND PROPULSION TEST RESULTS ON TWO MODELS

1. Series 60, C_B = .80
2. High Speed Cargo Ship PD 108-S5-0

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ORA Project 04652

under contract with:

DEPARTMENT OF COMMERCE
MARITIME ADMINISTRATION
CONTRACT NO. MA-2564
WASHINGTON, D.C.

administered through:

OFFICE OF RESEARCH ADMINISTRATION ANN ARBOR

March 1962

I. INTRODUCTION

This report presents the results of resistance and self-propulsion tests of two models carried out at the Ship Model Towing Tank of The University of Michigan from October to December, 1961, as an extension to two model tests previously performed under the sponsorship of the Maritime Administration.[1] These earlier tests showed that good results could be obtained with a 14-foot (LBP) model size as compared to the 20-foot size normally used at David Taylor Model Basin. It was decided, however, to investigate further the correlation of results obtained with these two model sizes, specifically for a fuller model, such as Series 60, C_B = .80. In addition, a finer model, the Maritime Administration design PD 108-S5-0, was tested so that correlation data for a complete range of block coefficients would be available. This model was tested at two draft conditions.

H_1: Loaded Displacement
H_2: Light Displacement

The model numbers are as follows:

Series 60, C_B = .80: U of M 932 (DTMB 4214)
PD 108-S5-0: U of M 933

II. SUMMARY

Results of the resistance tests are summarized in Figs. 1-4, and of the open-water and self-propulsion tests in Figs. 5-9.

The 1947 ATTC friction formula is used throughout. Figures 2 and 4 show the C_r versus speed-length ratio for models 932 and 933, respectively, after blockage effects have been corrected for. Blockage corrections are based on Dr. Hughes' recently published paper.[2] Instead of a constant K value of 1.7, as recommended by Dr. Hughes, a variable K value depending upon speed-length ratio and block coefficient was used, however. The functional relationship between K and these variables was derived from the differences between test results as obtained at DTMB and at The University of Michigan. A plot of K for various block coefficients is shown in Fig. 10.

Turbulence stimulation was the same as for previous models,[1] with an additional trip wire placed at the aft shoulder in model 932. At low speeds this wire seemed to decrease the resistance slightly.

Model data are shown in Tables 1 and 2, the line drawing of model 933 in Fig. 11, propeller data in Table 3, and propeller drawings as Figs. 12 and 13.

III. MODELS, EQUIPMENT, AND TEST PROCEDURES

A. MODELS

It is believed that a model size of 14 foot (LBP) has now been tentatively established as a standard size at The University of Michigan. For conventional ship forms this choice normally results in a propeller size sufficiently large so that propeller scale effects are negligible. Blockage effects of models of this size are not too large and can furthermore be properly accounted for.

Both models tested were of 14 foot length and made from wax of the same composition as the wax used at DTMB.

B. EQUIPMENT

The only major change in equipment used for this test series is the new towing carriage installed during the summer of 1961. This new carriage permits a much better speed selection for the self-propulsion tests. The speed variations are still larger than desirable, however, and it is therefore the practice to take instantaneous simultaneous readings at moments when the carriage speed is fairly constant.

C. TEST PROCEDURES

Test procedures with the new carriage are the same as before. Details of these are given in Ref. (1).

Open-water propeller tests were run with the 1-horsepower dynamometer, whereas for the self-propulsion tests the smaller 1/8-horsepower dynamometer was found to have sufficient capacity. Propeller number 5 was checked for open-water characteristics with the 1/8-horsepower dynamometer over a limited range of advance coefficients.

IV. DISCUSSION OF RESULTS

A. MODEL 932

For this model full-scale predictions for a 600-ft ship have been plotted together with the DTMB data. Where only one line appears in the figures complete agreement between the two data exists. The main reason for the differences in rpm can be attributed to a discrepency in pitch ratio of propeller number 4. In other respects the agreement between our results and DTMB results is good. It should be pointed out here that blockage corrections were made on the basis of a speed increment rather than a resistance increment as done previously. This resulted in a very good correlation in C_r which could not be obtained if a resistance increase was used. It is therefore felt that the method employed now is sound. Both approaches will lead to essentially the same EHP. The blockage correction is described in more detail below.

B. MODEL 933

It is believed that the EHP tests of this model at the two drafts are good. The self-propulsion tests gave a considerable amount of trouble, however, and unless an unusual flow condition exists at the propeller disk it is difficult to believe the data obtained. To eliminate any possibilities of errors in the interpretation of test results, the model was tested at three different times. The propeller was also tested several times, twice with the large dynamometer and once with the small one. As far as the propeller is concerned, a good agreement exists between individual tests, and in regard to self-propulsion tests relatively good agreement was reached, although the scatter of test points was a little more than usual. On the basis of overall results, it is obvious that this model will require a great deal of more detailed investigation; in particular, a study of flow conditions in the neighborhood of the propeller should be undertaken. Such a study will be made as soon as additional instrumentation becomes available. Under the circumstances results presented on this vessel must therefore not be considered as final.

V. BLOCKAGE EFFECT

Recently Dr. Hughes has published a paper on blockage effects in which he proposes a slightly changed version of the method for accounting for these effects.[2] From a theoretical consideration he proposes that the increase in velocity due to potential flow around the ship should be given by

$$\frac{\delta V}{V} = \frac{m}{1-m-F_h^2} \tag{1}$$

where

$$m = \frac{\nabla}{LA}$$

$$F_h = \frac{V}{\sqrt{gh}}$$

with

∇ = volume displacement of model

L = length of model

A = cross sectional area of tank

V = model velocity

h = depth of tank.

To make Eq. (1) give velocity increments in agreement with experimental results, Dr. Hughes proposed to multiply the right hand side of the equation by an empirical constant K = 1.7. His results indicated a great deal of scatter, and it was realized the K was probably a function of the speed-length ratio. It was therefore decided that on the basis of the Michigan and DTMB results obtained for the Series 60, C_B = .60, .75, and .80, the required value of K for correlation of data should be plotted to determine if any empirical functional relationship between K, C_B and $V/\sqrt{L}$ could be found. Fortunately the data seemed to reveal definite trends which are shown in Fig. 10. An empirical equation derived from the data mentioned above has been formulated so that the EHP calculations could be programmed for the digital electronic computer.

VI. REFERENCES

1. Resistance and propulsion tests on two Series 60 models, Finn C. Michelsen, R. B. Couch, and Hun Chol Kim, The University of Michigan ORA, Ann Arbor, Report No. 03509-1-F, April 1961.

2. "Tank Boundary Effects on Model Resistance," G. Hughes. _Transactions of Royal Institution of Naval Architects_ (submitted for publication).

APPENDIX

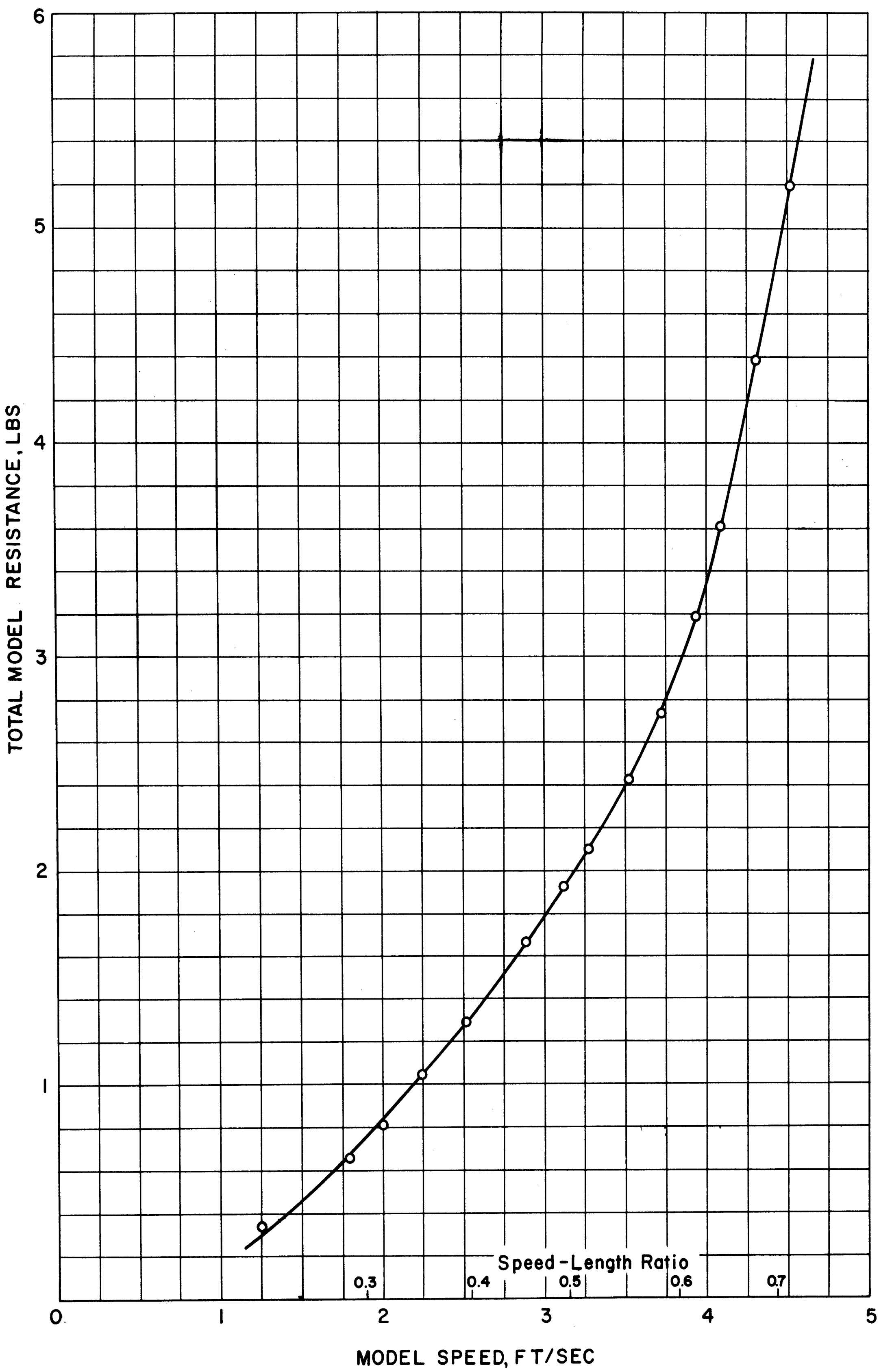

Fig. 1. Total resistance vs. model speed, Series 60, .80 block, U of M 932, 14-foot model with rudder (corrected for blockage effects). Water temperature 73°F.

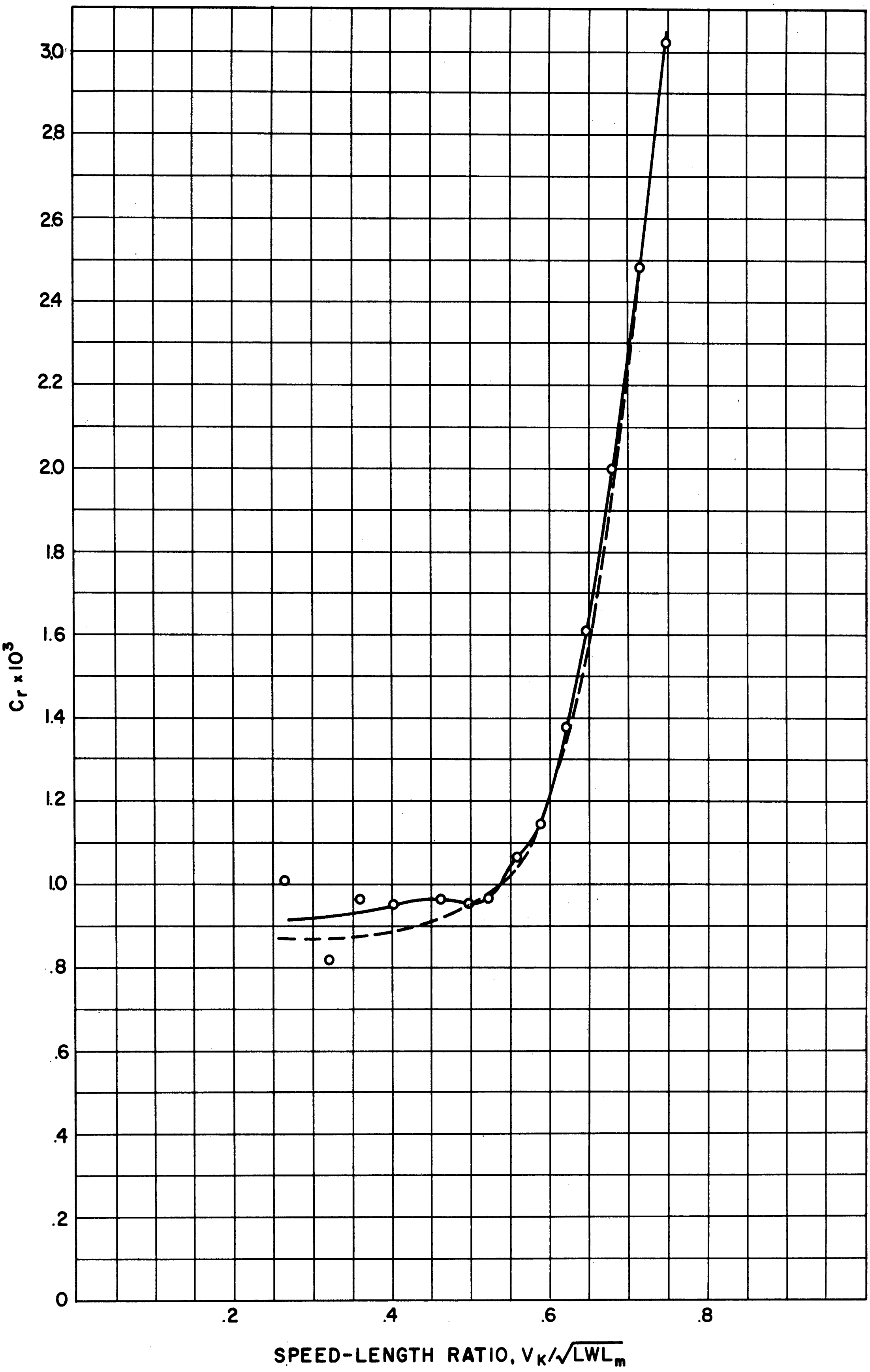

Fig. 2. C_r vs. speed-length ratio, Series 60, .80 block. —o— U of M 932; ---- DTMB 4214.

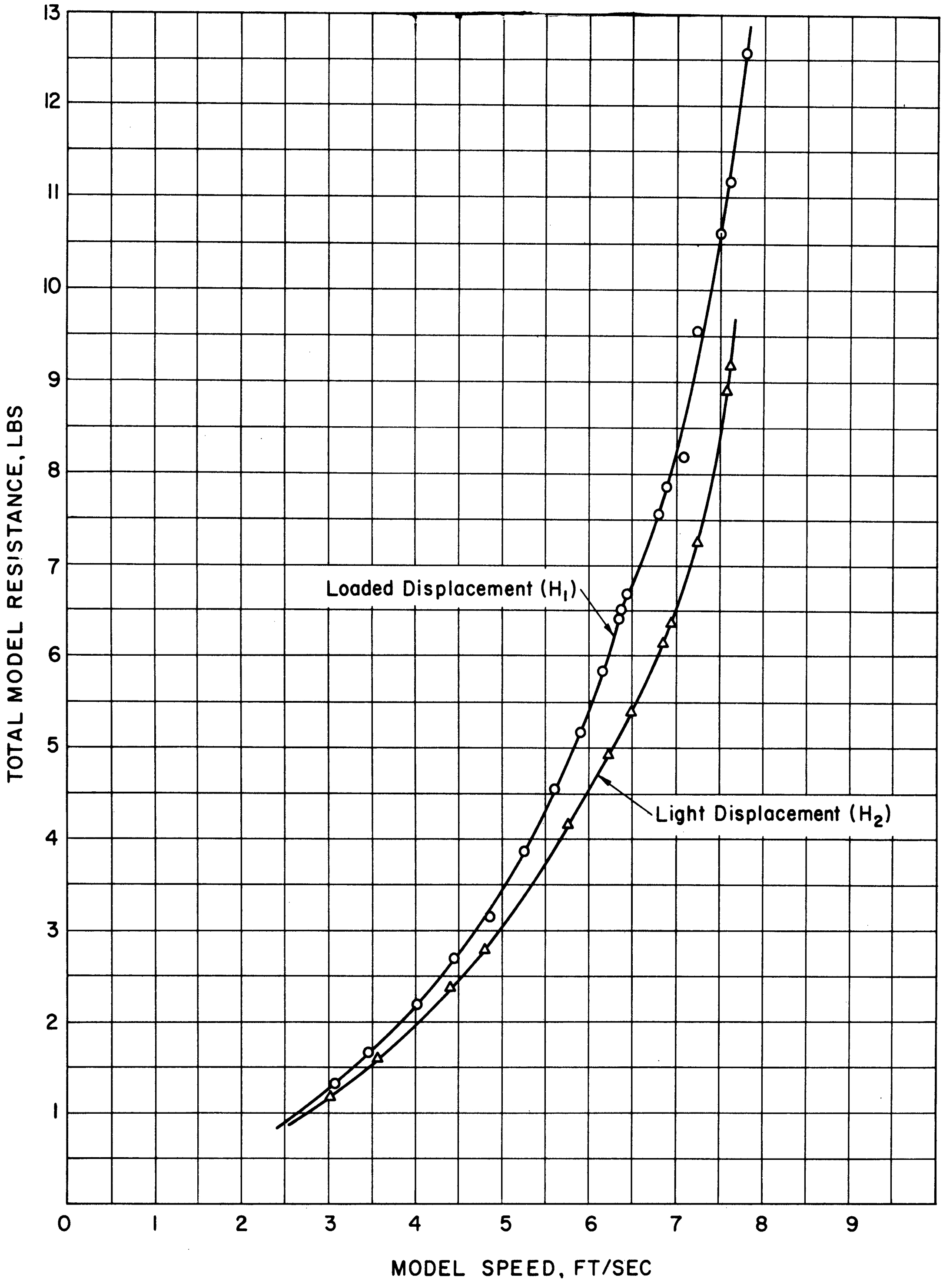

Fig. 3. Total resistance vs. model speed, PD 108-S5-0. U of M 933, 14-foot model with rudder (corrected for blockage effects). Water temperature 74°F.

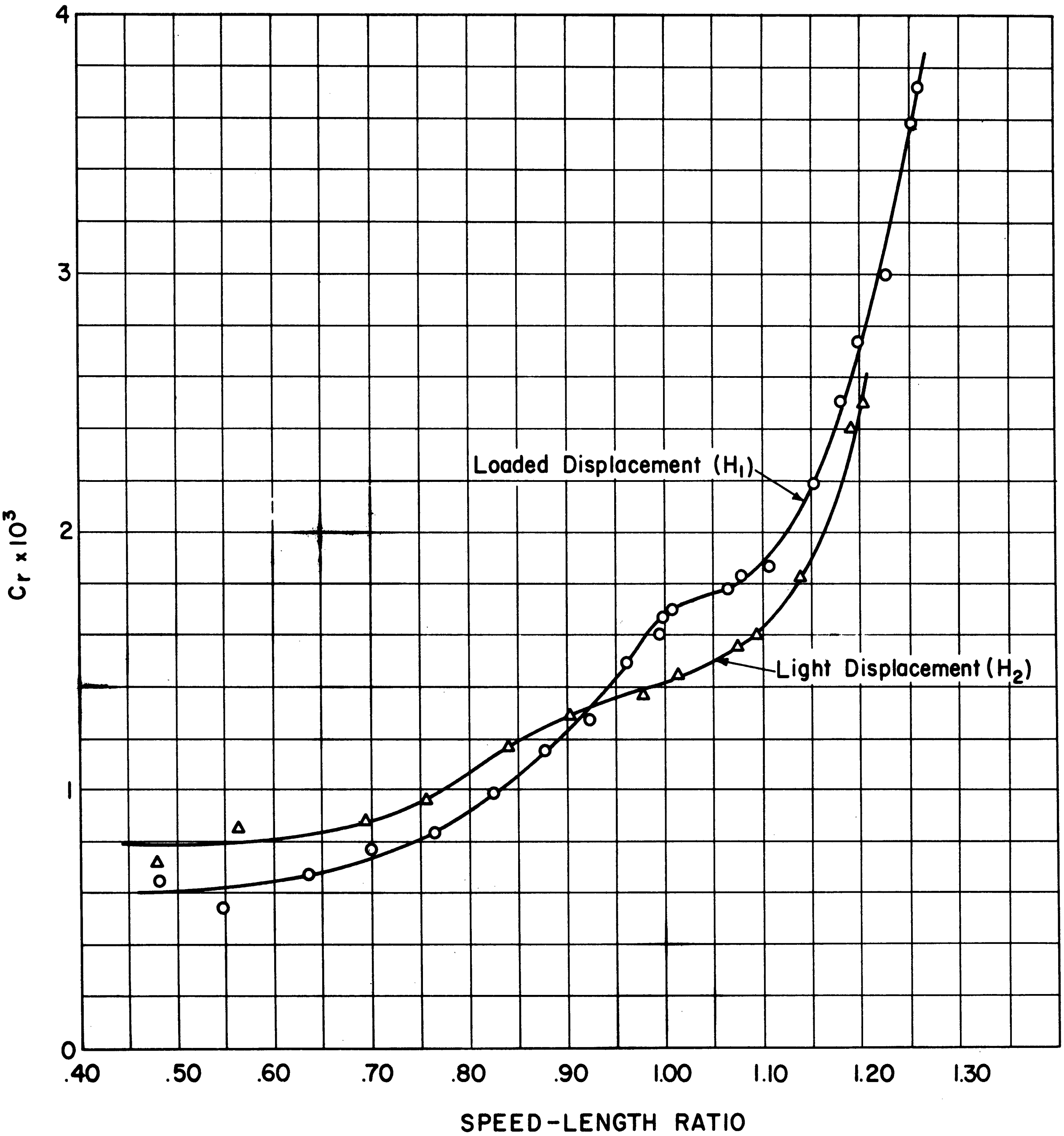

Fig. 4. C_r vs. speed-length ratio, PD 108-S5-0.

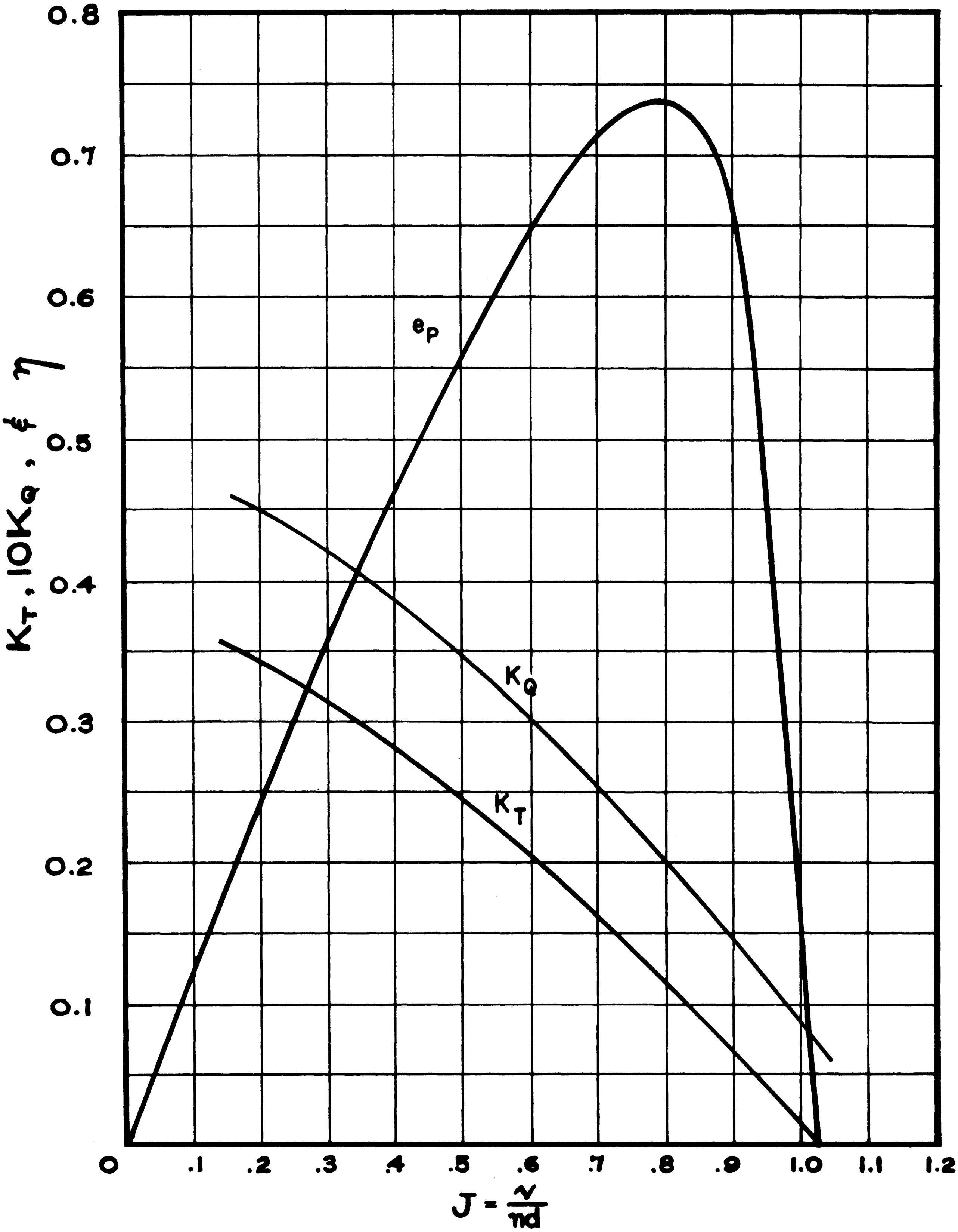

Fig. 5. Propeller open-water test results, U of M propeller No. 4 (Series 60, C_B = .80).

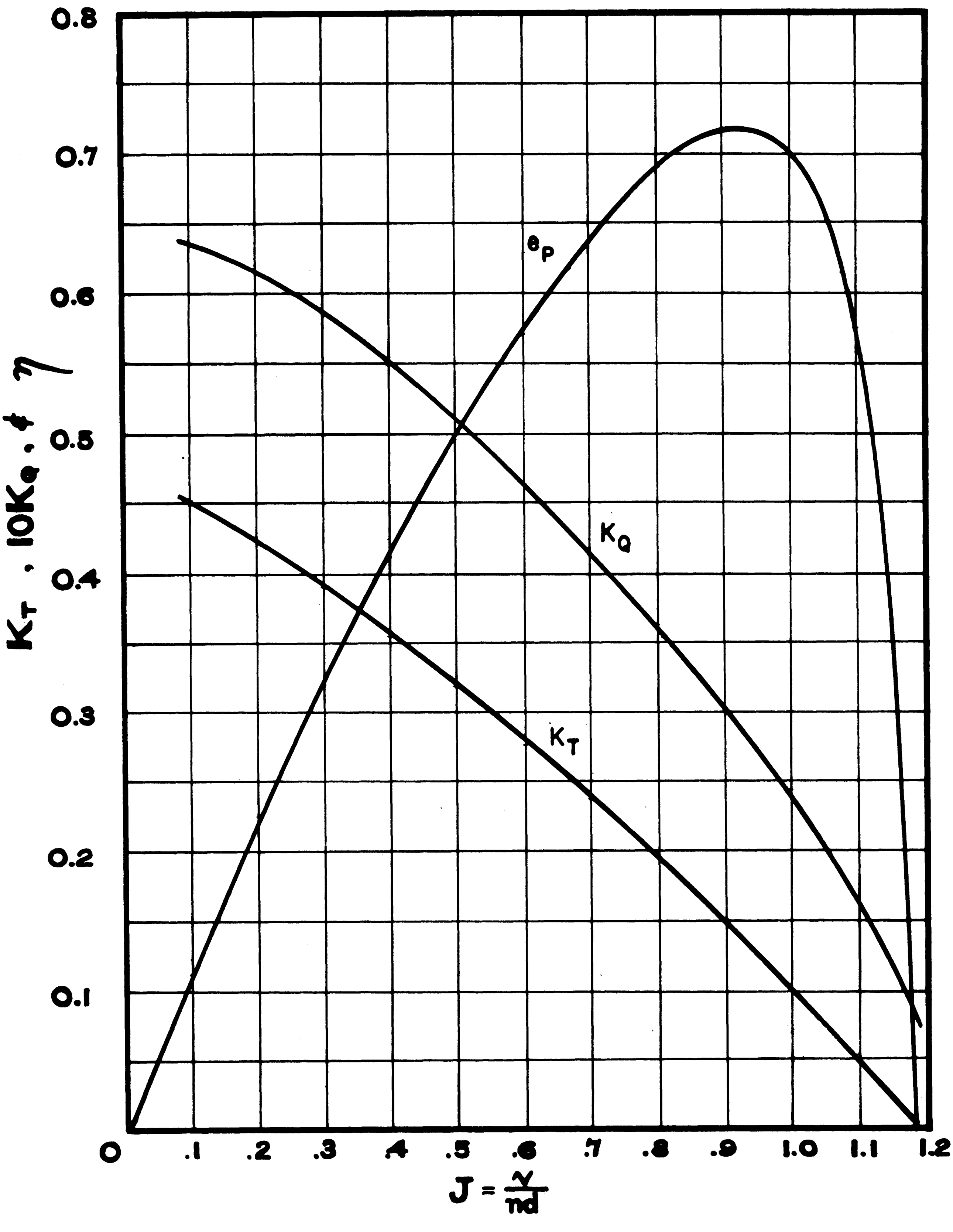

Fig. 6. Propeller open-water test results, U of M propeller No. 5 (PD 108-S5-0).

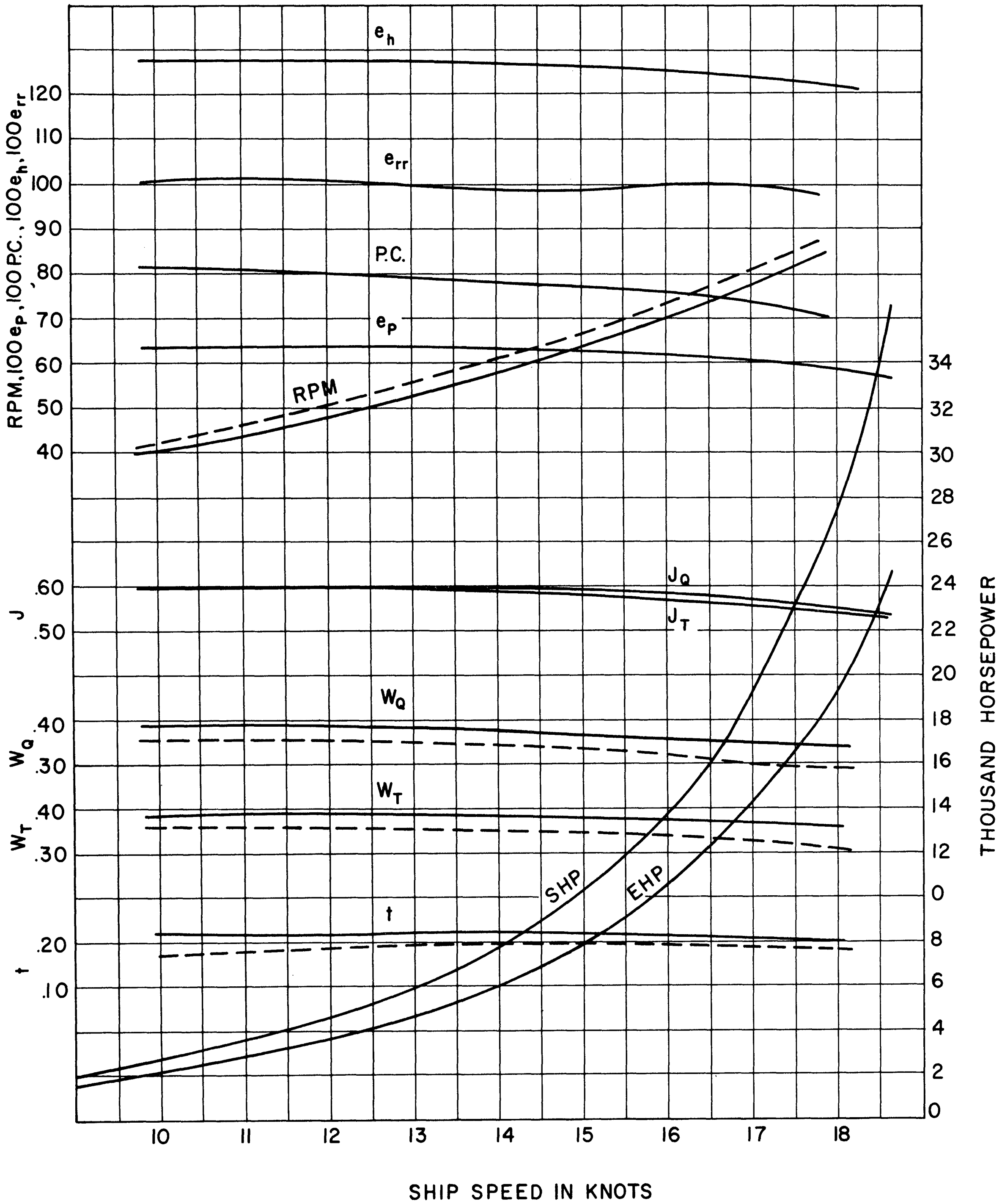

Fig. 7. Ship propulsive characteristics for 600-foot ship. C_B = .80, U of M propeller No. 4. ---- DTMB results.

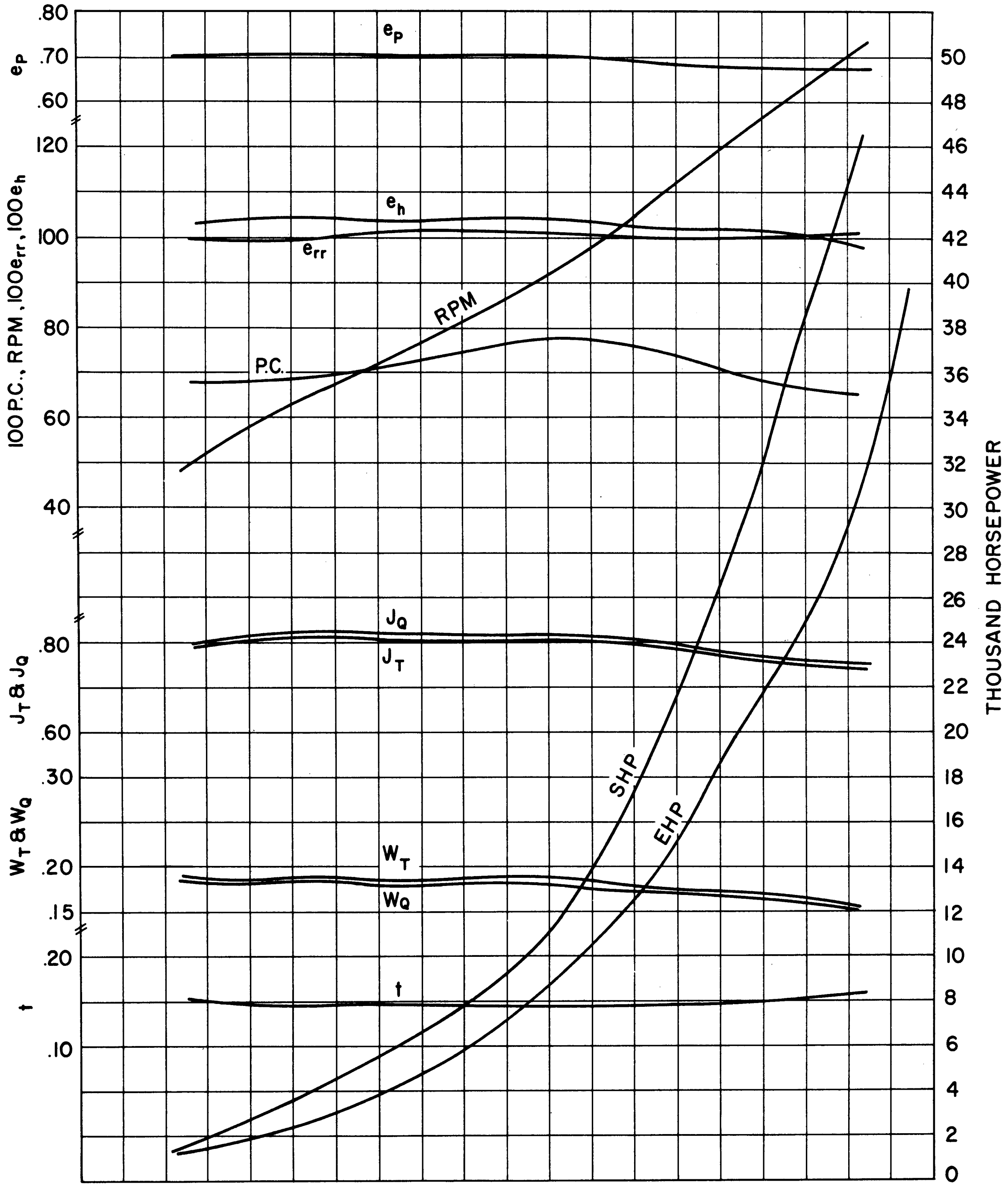

Fig. 8. Ship propulsive characteristics, U of M propeller No. 5 (PD 108-S5-0), loaded displacement.

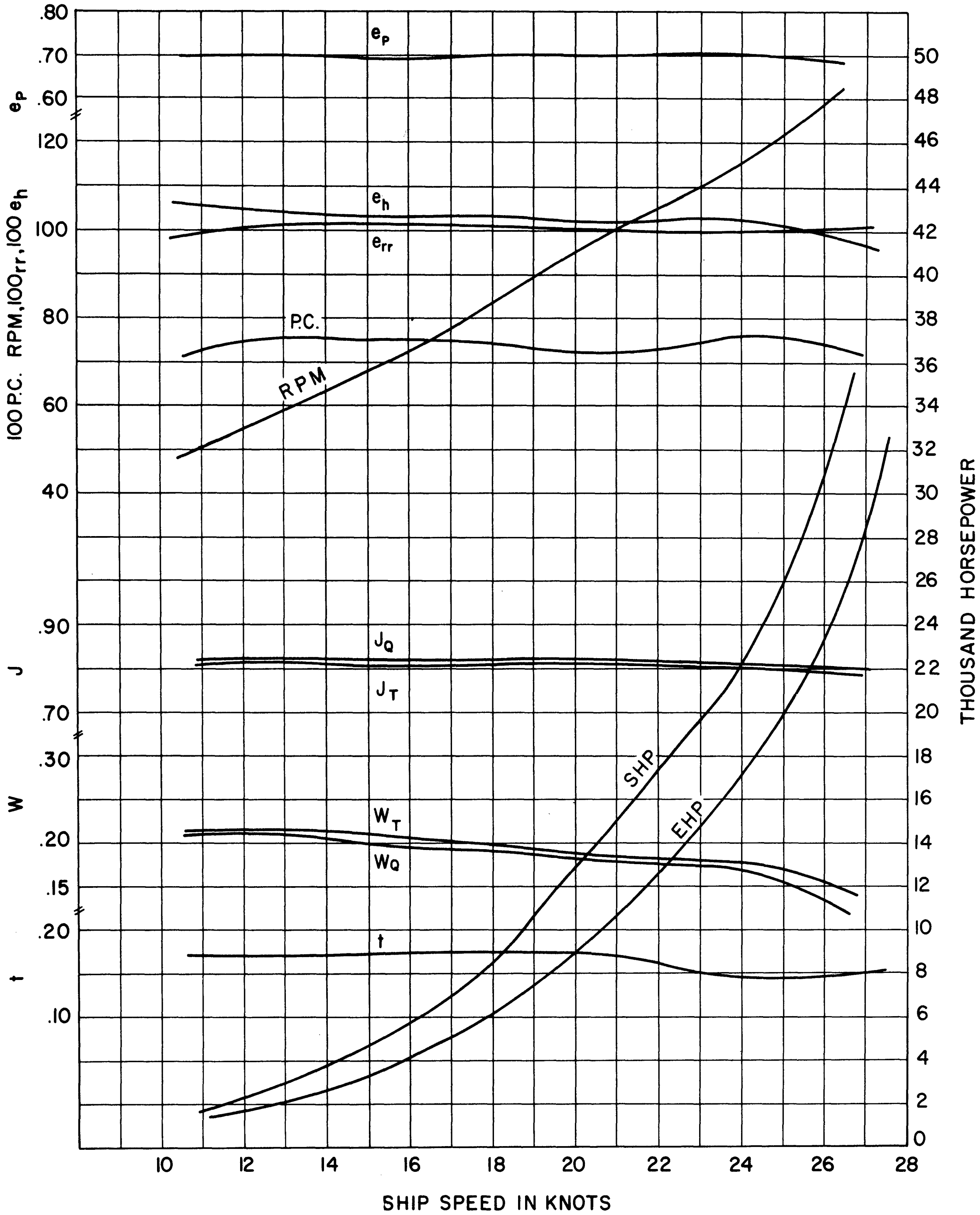

Fig. 9. Ship propulsive characteristics, U of M propeller No. 5 (PD 108-S5-0), light displacement.

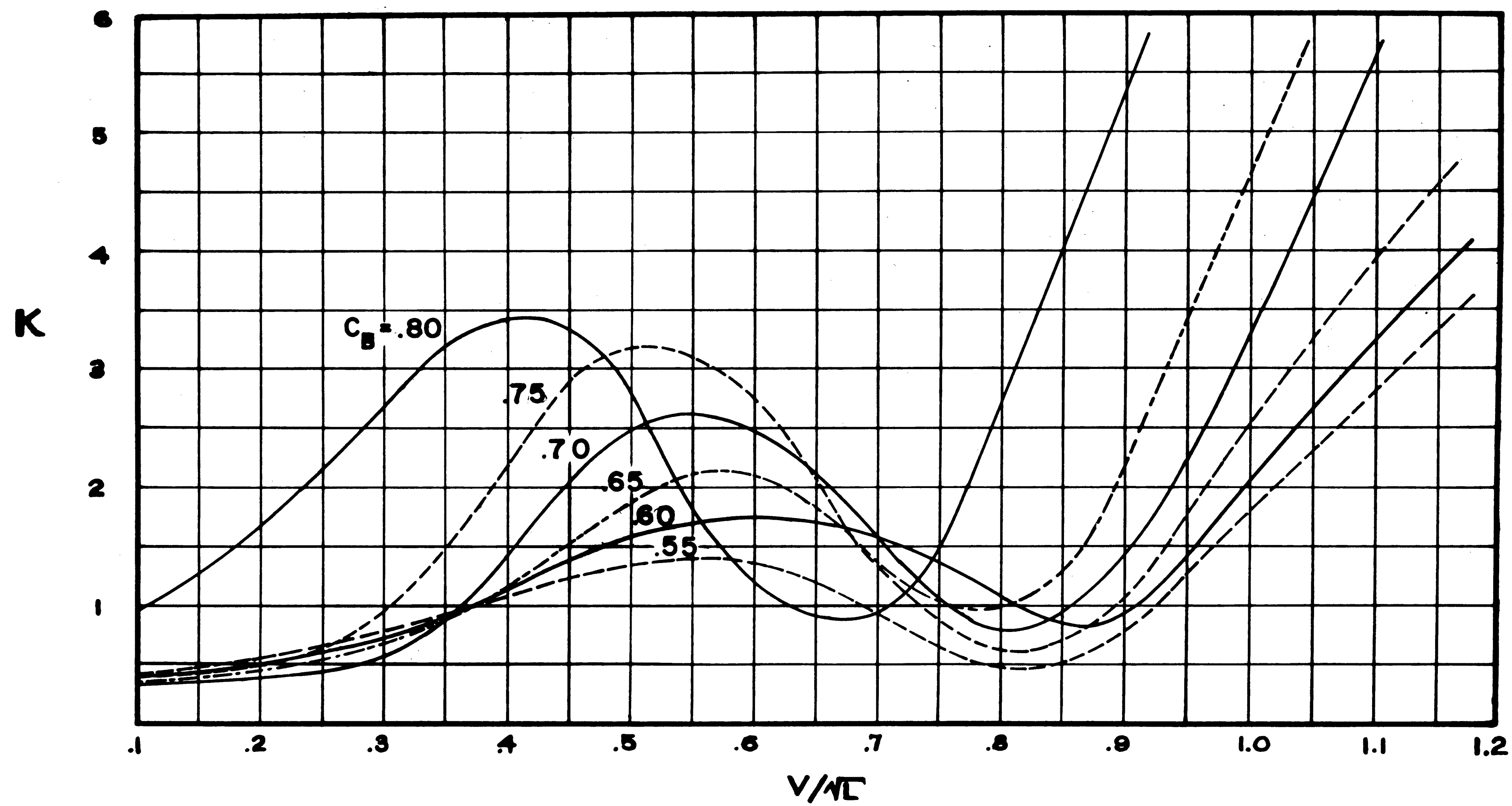

Fig. 10. Blockage correction factor K.

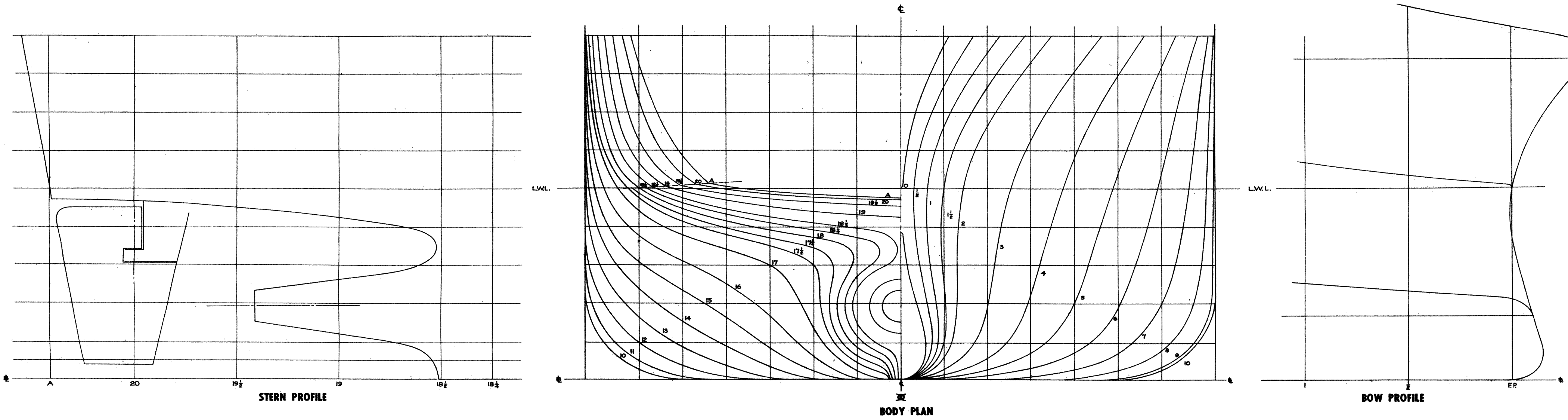

Fig. 11. The line drawing of model 933.

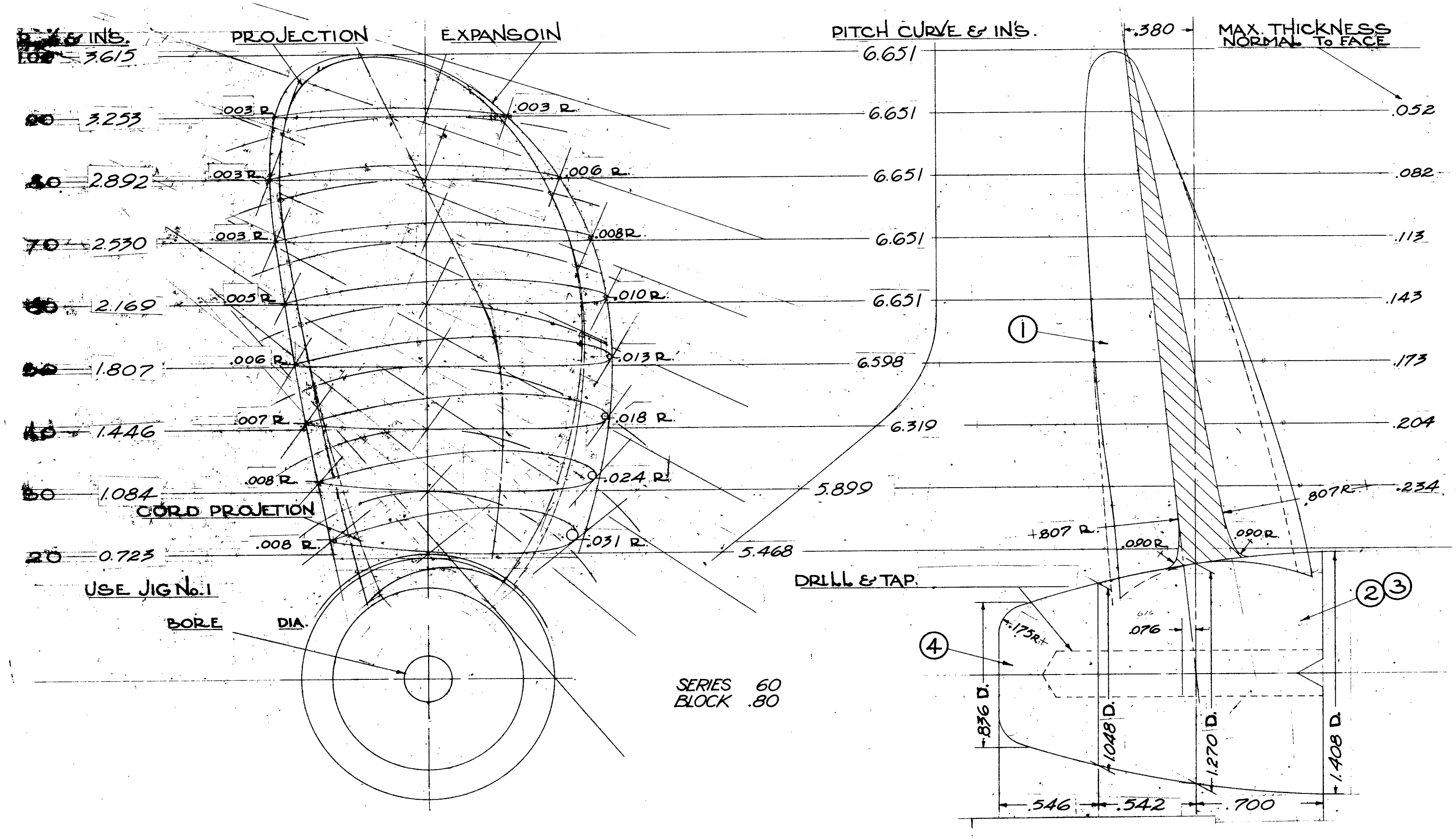

Fig. 12. Propeller drawing, U of M Propeller No. 4.

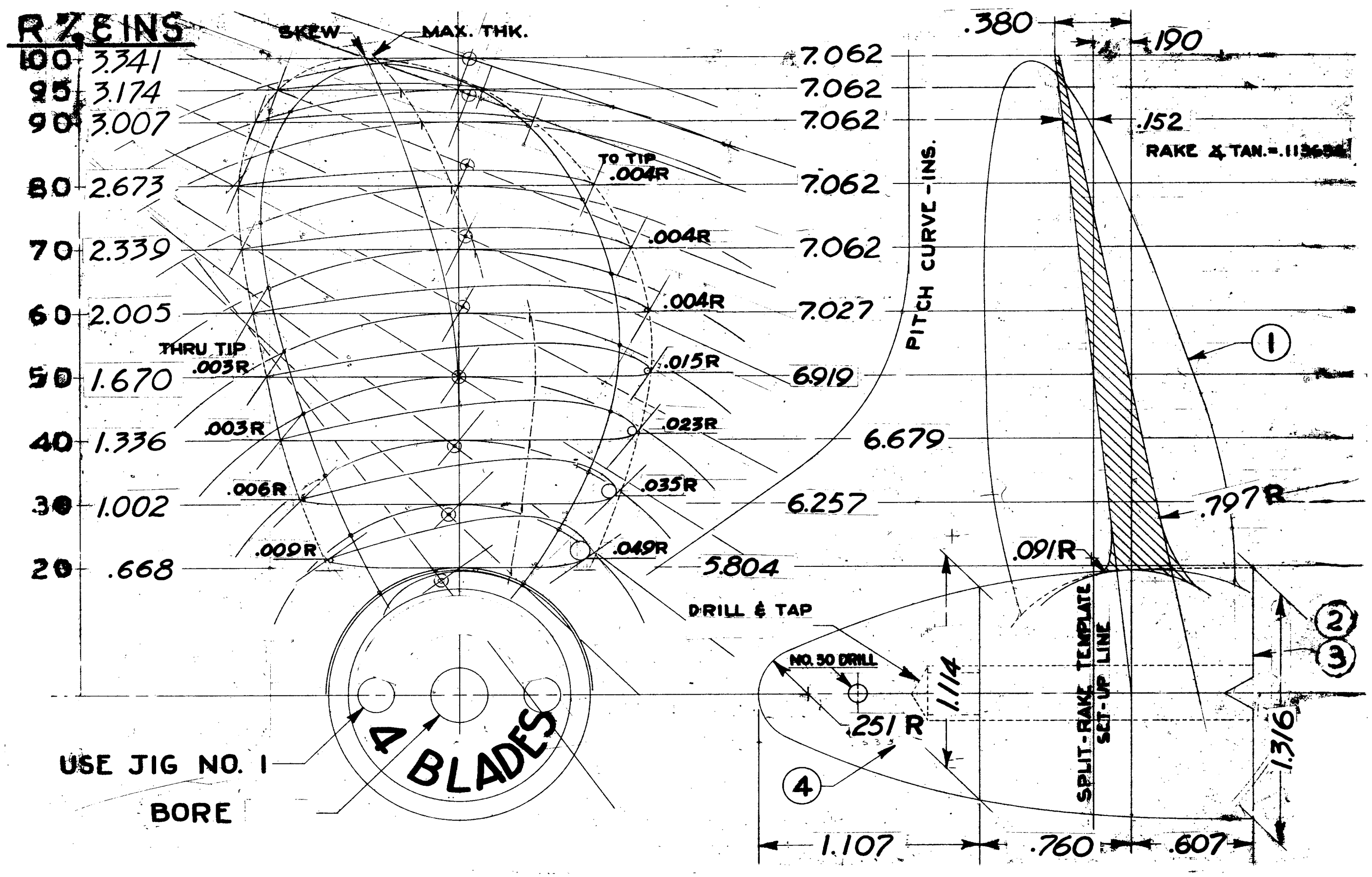

Fig. 13. Propeller drawing, U of M Propeller No. 5.

TABLE 1

MODEL DATA

Model No. 933-H_1 (Loaded Displacement)
Ship PD 108-S5-0
Ship Owner MARAD ORA No. 04652 Material: Wax

	Model: λ = 37.714	Ship
LOA	15.065 ft; 180.780 in.	568 ft - 2 in.
LWL	14.292 ft; 171.504 in.	539 ft
LBP	14.000 ft; 168.000 in.	528 ft
B	2.148 ft; 25.772 in.	81 ft
H mean	0.715 ft; 8.578 in.	26 ft - 11-1/2 in.

Δ = 774.4 lb at 8.578 in. Draft, 74°F 18,544 tons, S.W.

	Model	Ship
W.S. bare	35.399 sq ft	50,350 sq ft
rudder	0.316 sq ft	450 sq ft
Total	35.715 sq ft	50,800 sq ft

A_X/Tank Area 0.782% Friction Basis: 1947 ATTC
Designed Speed 6.325 ft/sec ΔC_f ... 0.4 x 10^{-3}
Trial Speed 6.875 ft/sec $V/\sqrt{L}$ = 0.99; 23 KTS
$V/\sqrt{L}$ = 1.08; 25 KTS

MODEL TEST CONDITION

Draft Mean: 8.578 in.
Turbulence: Trip Wire

MODEL CHARACTERISTICS

LBP/LWL		C_{PA}	0.58	B/H	3.004
L_E/LWL	0.465	C_{PV}	0.755	$S/\sqrt{\Delta L}$	15.9
L_X/LWL	0.025	C_{PVF}	0.85	$\Delta/(L)^3$	118
L_R/LWL	0.510	C_{PVA}	0.68	1/2 α_E	6.50
C_B(LWL)	0.553	C_W	0.732		
C_X	0.968	C_{WF}	0.64		
C_P	0.582	C_{WA}	0.82		
C_{PF}	0.56	L/B	6.65		

LCB, %LWL 0.004 of ⨂

Model No. 933-H_2 (Light Displacement)
Ship PD 108-S5-0
Ship Owner MARAD ORA No. 04652 Material: Wax

	Model: λ = 37.714	Ship
LOA	15.065 ft; 180.780 in.	568 ft - 2 in.
LWL	14.292 ft; 171.504 in.	539 ft
LBP	14.000 ft; 168.000 in.	528 ft
B	2.148 ft; 25.772 in.	81 ft
H mean	0.557 ft; 6.684 in.	21 ft
fwd	0.477 ft; 5.724 in.	18 ft
aft	0.636 ft; 7.632 in.	24 ft

Δ = 554.5 lb at 6.684 in. Draft, 74°F 13,660 tons, S.W.

	Model	Ship
W.S. bare	29.543 sq ft	42,020 sq ft
rudder	0.316 sq ft	450 sq ft
Total	29.859 sq ft	42,470 sq ft

Friction Basis: 1947 ATTC
ΔC_f ... 0.4 x 10^{-3}

TABLE 2

MODEL DATA

Model No. 932 (Parent DTMB 4214-B4)
Ship Series 60 C_B = 0.80
Ship Owner MARAD ORA No. 04652 Material: Wax

	Model: λ = 42.857		Ship
LOA			
LWL	14.2345 ft;	170.76 in.	610.05 ft
LBP	14.000 ft;	168.00 in.	600.00 ft
B	2.154 ft;	25.85 in.	
H mean	0.862 ft;	10.340 in.	
fwd			
aft			

Δ = 1,293.5 lb at 10.34 in. Draft, 73°F 46,774 tons, S.W.

		Model	Ship
W.S.	bare	45.571 sq ft	83,701 sq ft
	rudder	.362 sq ft	665 sq ft
	appendage		
	Total	45.933 sq ft	84,366 sq ft

A_X, LWL	1.857 sq ft	Friction Basis:	ATTC 1947
A_W, LWL		ΔC_f:	0.4×10^{-3}
A_X/Tank Area	0.9774%		
Designed Speed	3.161 ft/sec	$V/\sqrt{LWL}$ =	.496; 12.25 KTS
Trial Speed	3.543 ft/sec	$V/\sqrt{LWL}$ =	.556; 13.72 KTS

MODEL TEST CONDITION

Draft: Mean: 10.34 in. Aft: Fwd:
Turbulence: Trip Wire Temp:

MODEL CHARACTERISTICS

LBP/LWL		C_{PA}	0.750	B/H	2.5	LCB, %LBP + 2.5 of $\varnothing$	
L_E/LBP	0.290	C_{PV}	0.920			LCF, %LBP	
L_X/LBP	0.300	C_{PVF}	0.971			$L/\nabla^{1/3}$	5.092
L_R/LBP	0.410	C_{PVA}	0.867			$S/\nabla^{2/3}$	6.028
C_B	0.80	C_W	0.871			$K_R = R/\sqrt{BH}$	0.118
C_X	0.994	C_{WF}	0.881	C_{iT}	0.776		
C_P	0.805	C_{WA}	0.860	C_{iL}			
C_{PF}	0.861	L/B	6.5	$1/2\ \alpha_E$	43		

TABLE 3

PROPELLER DATA

PROPELLER	UM No. 4	UM No. 5
PARENT	DTMB No. 3377	DTMB NO. 3566
DIAMETER (d), inches	7.230	6.658 (6.682)*
PITCH (p), inches	6.977 (6.650)*	7.250 (7.062)*
<u>CHARACTERISTICS</u>		
PITCH-DIAMETER RATIO, P/D	.965 (.920)*	1.090 (1.057)*
MEAN-WIDTH RATIO, MWR	.213	
EFFECTIVE AREA-DISC AREA RATIO, EA/DA	.450	.514
BLADE THICKNESS FRACTION, BTF	.045	
RAKE, DEGREES ARC	6.00	
NO. OF BLADES	4	4

*Indicates values corresponding to parent propellers.