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RESISTANCE AND PROPULSION CHARACTERISTICS OF A ROUND-BOTTOM BOAT (PARENT FORM OF TMB SERIES 63)

by

Donald L. Blount

HYDROMECHANICS LABORATORY
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NOTATION

Symbol	Definition	Unit
B	Maximum beam on waterline	ft
C_B	Block coefficient	
C_P	Prismatic coefficient	
C_X	Maximum section coefficient	
D	Propeller diameter	ft
EHP	Effective horsepower	
e_h	Hull efficiency, $(1-t)/(1-W_T)$	
e_p	Propeller efficiency	
e_{rr}	Relative rotative efficiency	
F_∇	Volume Froude number, $v/\sqrt{g\nabla^{1/3}}$	
g	Acceleration due to gravity	ft/sec^2
H	Maximum draft bare hull	ft
H_M	Draft at midlength	ft
J	Advance coefficient, v/nD	
J_T	Advance coefficient based on thrust wake	

K_T	Thrust coefficient	
K_Q	Torque coefficient	
L	Length on waterline	ft
LBP	Length between perpendiculars	ft
n	Propeller rotational speed	rev/sec
R	Total resistance	lb
R_i	Ideal resistance	lb
S	Wetted surface	ft^2
SHP	Shaft horsepower	
T	Thrust	lb
t	Thrust deduction fraction, $(1-R_i/T)$	
V	Speed	knots
v	Speed	ft/sec
W_T	Taylor's wake fraction based on thrust	
W_Q	Taylor's wake fraction based on torque	
∇	Displaced volume	ft^3
Δ	Displacement	lb
τ	Trim angle with respect to ℄	deg
ρ	Mass density	$lb\ sec^2/ft^4$
ν	Kinematic viscosity	ft^2/sec

ABSTRACT

This report gives the resistance and propulsion characteristics of the TMB Series 63 parent form. The data cover the effects of displacement, initial trim, and appendages. An example of the procedure to be followed in making a horsepower estimate using these data is included.

ADMINISTRATIVE INFORMATION

This model test program was authorized by Bureau of Ships letters, Code 452, Serial 452-M18 of 18 June 1956 and S82(440) Serial 449-48 of 18 November 1956 under Project S-F014 02 02, Task 2062.

INTRODUCTION

Resistance and propulsion data are meager for round-bottom hull forms operating in displacement and semi-planing speed ranges. To provide information in this area, a series of tests of related hull forms was conducted to determine the effects of variation in hull proportions. The U.S. Navy 50-Ft Utility Boat was chosen as the parent form since it is typical of round-bottom navy craft and is considered to be very seaworthy. Four other hulls were systematically developed from the parent form, and the five related hull forms were designated TMB Series 63.

To expedite this test program, the resistance tests of Series 63 were made with 1/16-scale models by the Davidson Laboratory of Stevens Institute of Technology (as a Task Order under Contract Nobs 78349); these tests were reported in Reference 1.* The present report contains propulsion characteristics and associated resistance data for the parent form, measured with a model of larger size.

* Beys, P.M., "Series 63 Round Bottom Boats," Davidson Laboratory Report 949 (Apr 1963).

DESCRIPTION OF MODEL

The parent form, designated Model 4777, was made of wood to a linear ratio of 5.702 in accordance with BuShips Drawing S-8228(4)50-H-1428879, Rev. A. This model was not fitted with rub or spray rails. For the propulsion tests, TMB Propeller 320 was selected to represent a 26-in.-diameter right-hand propeller. Since the supply of small-diameter stock propellers is limited, a propeller of appropriate P/D was not available. However, both the full-scale and the model propellers have constant pitch distributions and similar blade outlines, which should allow reliable dimensionless propulsion data to be obtained from these tests.

Figure 1 is a design data sheet showing model lines, particulars, and resistance characteristics of Model 4777 representing the round-bottom 50-ft utility boat. Figues 2 and 3 show a scale drawing of the appendages and photographs of the model, respectively. A detailed drawing of Propeller 320 is shown in Figure 4, and its characteristics are presented in Figure 5.

TEST PROCEDURE

Table 1 gives the conditions for which the tests were made. In this test program, the model was towed in the shaftline for resistance tests, and thrust, torque, and revolutions were measured at the propeller for propulsion tests. These forces and torques were recorded at the full-scale propulsion point and were expanded according to the usual Model Basin practice. The speed range was varied from about $F_\nabla = 0.7$ until solid water came up to the deck sheer line. No turbulence stimulation device was utilized for these tests.

RESULTS AND DISCUSSION

Resistance

The five smaller models, which were towed at the Davidson Laboratory, were each tested at five different displacements. Accordingly, the range of that test program was broad enough to make it possible to draw general conclusions about the effects of variation of hull proportions and loading.

A comparison of the results of a bare-hull test of a small model, designated as Model 4777A, at the Davidson Laboratory with the results of a test of Model 4777 at the Taylor Model Basin is shown in Figure 6. The slenderness ratios were nearly the same, and Davidson Laboratory Report 949 indicates that the existing slight difference will not appreciably affect the values of resistance-weight ratio. The trim data for the two models agree very well, but the rise coefficients and resistance-weight ratios differ somewhat. Model 4777A runs relatively deeper at intermediate speeds than does Model 4777. This is believed to result from the small model (Model 4777A) being influenced more than the larger model by the adhesion of water to the hull sides (surface tension effects). Since the two models did not rise in the same manner, the resistance data obtained from the two sizes of models show some differences.

Figure 7 shows the trim angle of Model 4777 as a function of model speed for several appendaged conditions. This figure indicates that the presence of the appendages had no measurable effect on the trim of the model. Figure 8 shows the change in trim versus speed for three different initial trims (i.e., three LCG locations). It can be seen that the change in trim at a given speed increases as the center of gravity is moved aft.

Resistance tests were made first with the model fully appendaged, then equipped with the skeg only, and finally, in the bare-hull condition. The results of the resistance measurements are presented in Figures 9 through 12 (details of the test conditions are given in Table 1). The data are given as full-scale ehp versus speed and also in the form of a resistance-weight ratio for a 100,000-lb boat weight versus volume Froude number. The latter form shows the effects of slenderness ratio and of static trim.

Figure 13 presents ratios of appendaged model resistance to bare-hull model resistance versus model speed. The fully appendaged model had about 8 percent more resistance than the bare-hull model, and the presence of the skeg caused about a 6-percent increase.

Propulsion

Propulsion tests were also made for various conditions (see Table 1). The data from Test 2 were very erratic; therefore these data are not reported. In Figure 14, the results of the other propulsion tests are presented as functions of F_{∇}. Examination of this figure shows that the dimensionless propulsion data do not vary a great deal for the different test conditions.

With these data and with e_p of the proper propeller, the propulsive coefficient for this and similar designs can be determined. A sample calculation is presented in the Appendix.

TABLE 1

Model Test Conditions

Test No.	Type Test	ΔC_f	Model Displ. lb	S ft^2	B ft	H* ft	L ft	τ_o deg	$\frac{L}{B}$	$\frac{B^*}{H}$	$\frac{L}{\nabla^{1/3}}$	$\frac{S}{\nabla^{2/3}}$	LCG fwd Sta. 12 ft	Temperature deg	Appendages
1	SHP	0	143.3	16.42	2.19	0.287	8.45	0	3.86	7.63	6.40	9.43	3.58	72	All***
2	SHP	0	435.5	22.82	2.30	0.606	8.60	0	3.74	3.80	4.50	6.24	3.70	71	"
3	SHP	0	284.1	19.88	2.24	0.448	8.54	0	3.81	5.00	5.15	7.23	3.74	72	"
3A	SHP	0.001	284.1	19.88	2.24	0.448	8.54	0	3.81	5.00	5.15	7.23	3.74	72	"
4	SHP	0	284.1	19.78	2.24	0.439**	8.54	1 x Stern	3.81	5.10**	5.15	7.20	3.49	72	"
5	SHP	0	284.1	20.03	2.22	0.454**	8.54	1 x Bow	3.85	4.89**	5.15	7.29	4.00	72	"
6	EHP	0	143.3	16.42	2.19	0.287	8.45	0	3.86	7.63	6.40	9.43	3.88	69	"
7	EHP	0	435.5	22.82	2.30	0.606	8.60	0	3.74	3.80	4.50	6.24	3.70	71	"
8	EHP	0	284.1	19.88	2.24	0.448	8.54	0	3.81	5.00	5.15	7.23	3.74	69	"
9	EHP	0	284.1	19.78	2.24	0.439**	8.54	1 x Stern	3.81	5.10**	5.15	7.20	3.49	69	"
10	EHP	0	284.1	20.03	2.22	0.454**	8.54	1 x Bow	3.85	4.89**	5.15	7.29	4.00	69	"
11	EHP	0	284.1	19.60	2.24	0.448	8.54	0	3.81	5.00	5.15	7.13	3.74	75	Skeg Only
12	EHP	0	435.5	22.55	2.30	0.606	8.60	0	3.74	3.80	4.50	6.17	3.70	75	"
13	EHP	0	279.6	17.67	2.24	0.448	8.54	0	3.81	5.00	5.18	6.49	3.74	75	Bare Hull
14	EHP	0	431.0	20.62	2.30	0.606	8.60	0	3.74	3.80	4.51	5.68	3.70	75	"

* Draft measurement excludes skeg.

** Based on draft at midlength

*** Shaft, struts, rudders, and skeg.

David Taylor Model Basin Small Craft Data Sheet

Round-bottom boat, $L/B_X = 3.83$

DTMB Model No. 4777

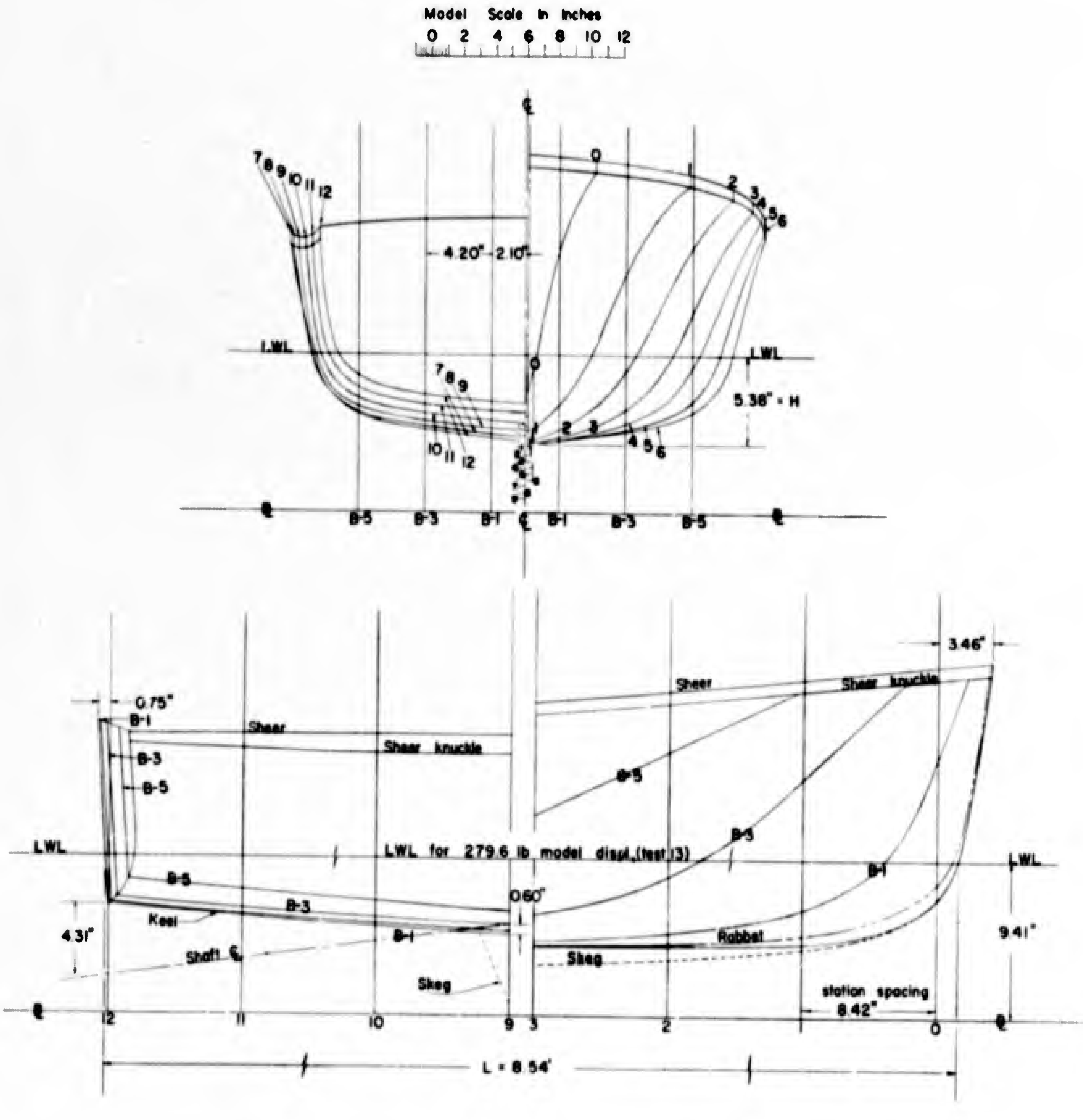


Figure 1A

MODEL PARTICULARS, TEST CONDITIONS, AND RESULTS

Boat 50' Utility Boat
Series 63
Model Number 4777
Appendages None

Laboratory DATMOBAS
Basin High-Speed
Basin Size 2698' x 21' x (10' & 16')
Model Length 8.541 ft.
Test 13 **Date** 4 August 1961

Water Temperature 75 Degrees
Specific Weight 62.222 ft^3
Model Material Wood
Model Finish Paint
Turbulence Stimul. None

Remarks: Model was towed in the shaft line shown in the profile drawing.
Draft measurement excludes appendages

Planing Bottom Dimensions and Coefficients

L_P ____
B_{PX} ____
B_{PA} ____
A_P ____
$A_P/\nabla^{2/3}$ ____
$L_P/\nabla^{1/3}$ ____
L_P/B_{PA} ____

LWL Dimensions and Coefficients

L 8.541 ft
B_X 2.24 ft
H 0.448 ft.
L/B_X 3.81
$L/\nabla^{1/3}$ 5.18
C_B 0.524
C_P 0.679
C_W 0.782

Model Test Condition

Δ, lb 279.6 τ_0 0 α_0 —

Model Test Results

V, knots	R_t, lb	Wetted length of keel, ft	Wetted length of chine, ft	$Re \times 10^{-6}$	S, ft^2	$10^3 C_t$	Change of trim, deg	CG rise, in.	F_∇
0	0	—	—	—	17.672		0		
1.00	0.36			1.458		7.390	-0.03	-0.077	0.232
1.52	0.80			2.216		7.109	-0.03	-0.107	0.353
2.00	1.44			2.916		7.390	-0.03	-0.107	0.464
2.51	2.61			3.661		8.505	-0.05	-0.266	0.583
3.00	4.26			4.375		9.717	0	-0.350	0.696
3.51	6.67			5.119		11.114	0.10	-0.569	0.815
3.99	10.36			5.819		13.359	0.60	-0.268	0.926
4.49	17.05			6.548		17.285	1.83	-0.958	1.042
5.00	23.13			7.293		18.994	3.05	-0.993	1.160
5.49	26.68			8.006		18.176	3.80	-0.757	1.274
5.98	28.78			8.772		16.522	4.10	-0.478	1.388
6.48	29.93			9.451		14.633	4.15	-0.247	1.504
6.99	30.76			10.19		12.924	4.07	-0.0897	1.662
7.49	31.84			10.92		11.651	4.07	-0.0897	1.738
7.98	32.64			11.64		10.536	4.05	0.0717	1.852
8.98	35.22			12.37		10.549	3.95	0.1902	1.968
8.96	37.06			13.07		9.489	3.95	0.2402	2.079
9.46	40.61			13.80		9.316	4.05	0.3717	2.195
9.98	42.31	—	—	14.55	17.672	8.720	4.55	0.6795	2.361

Figure 1 B

PERFORMANCE CHARACTERISTICS

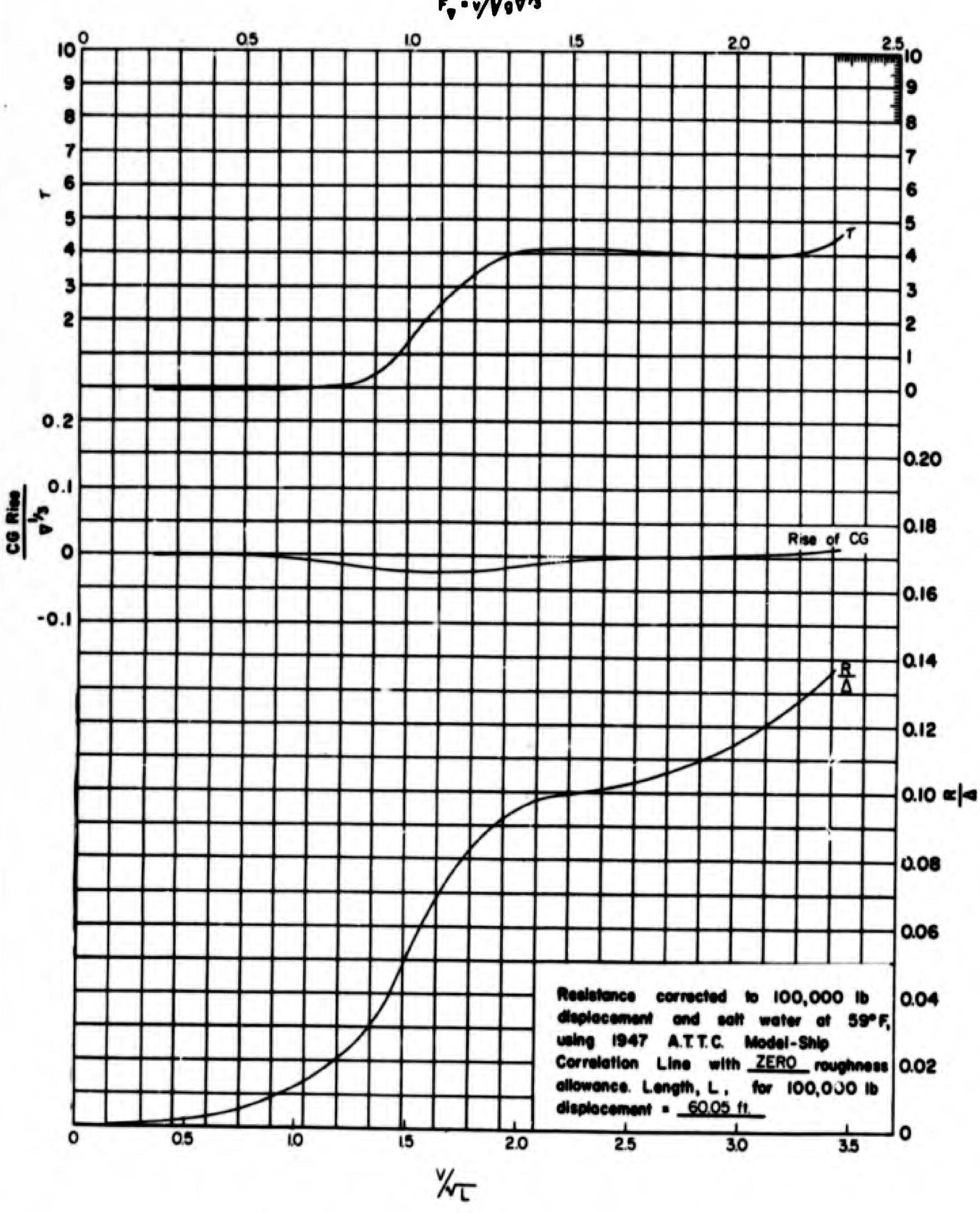
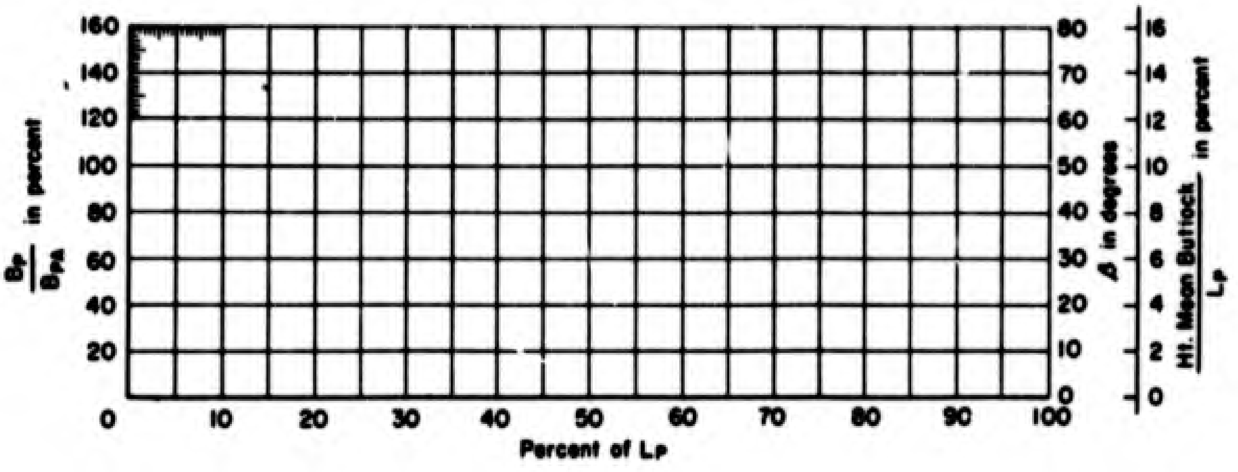
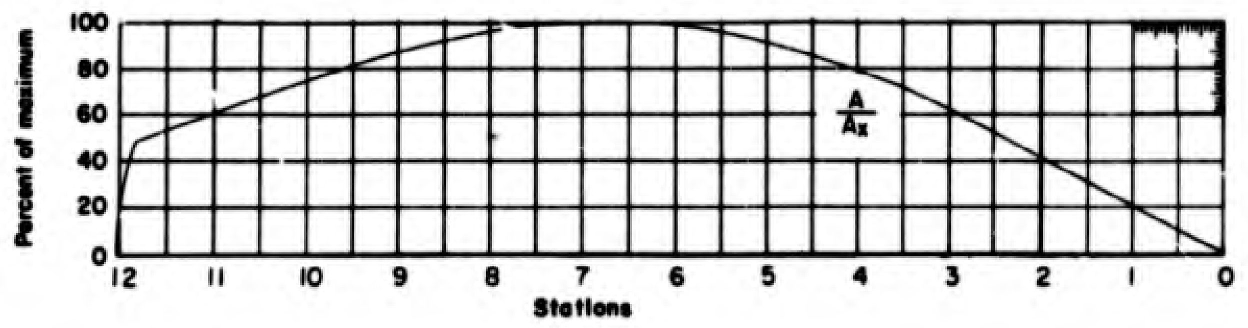


Figure 1C

FORM CHARACTERISTICS





—— Notation ——

As far as possible the notation used is consistent with the Society's "Explanatory Notes for Resistance and Propulsion Data Sheets" (Technical and Research Bulletin No. 1-13). Exceptions and additions are listed below. The subscript P designates the planing bottom which is the portion of the bottom bounded by the chines and transom.

A_P	Projected planing bottom area, excluding area of external spray strips
B_P	Beam or breadth over chines, excluding external spray strips
B_{PA}	Mean breadth over chines, A_P/L_P
B_{PX}	Maximum breadth over chines, excluding external spray strips
L_P	Projected chine length
S	Area of wetted surface (This is the actual wetted surface underway including the area of the sides which is wetted at low speeds and the wetted bottom area of external spray strips; however, the area wetted by spray is excluded).
α	Angle of attack of stern portion of planing bottom in degrees
β	Dead rise angle of planing bottom in degrees. This angle is obtained by approximating each body plan section by a straight line.
Δ	Displacement at rest, weight of
τ	Trim angle of hull with respect to attitude as drawn in degrees
∇	Displacement at rest, volume of

Subscript O indicates value when hull is at rest in water.

Figure 1D

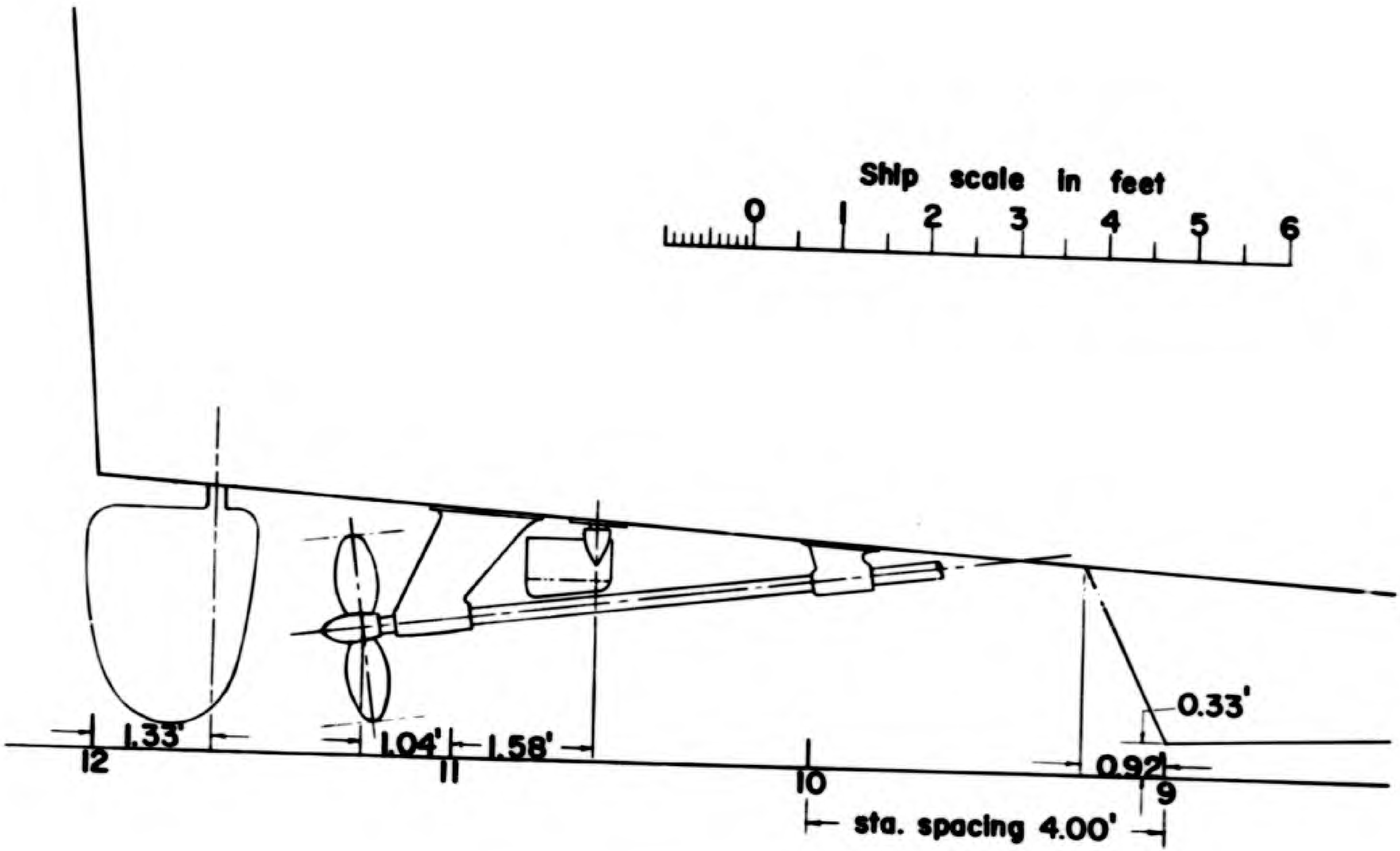


Figure 2 - Appendages of Model 4777

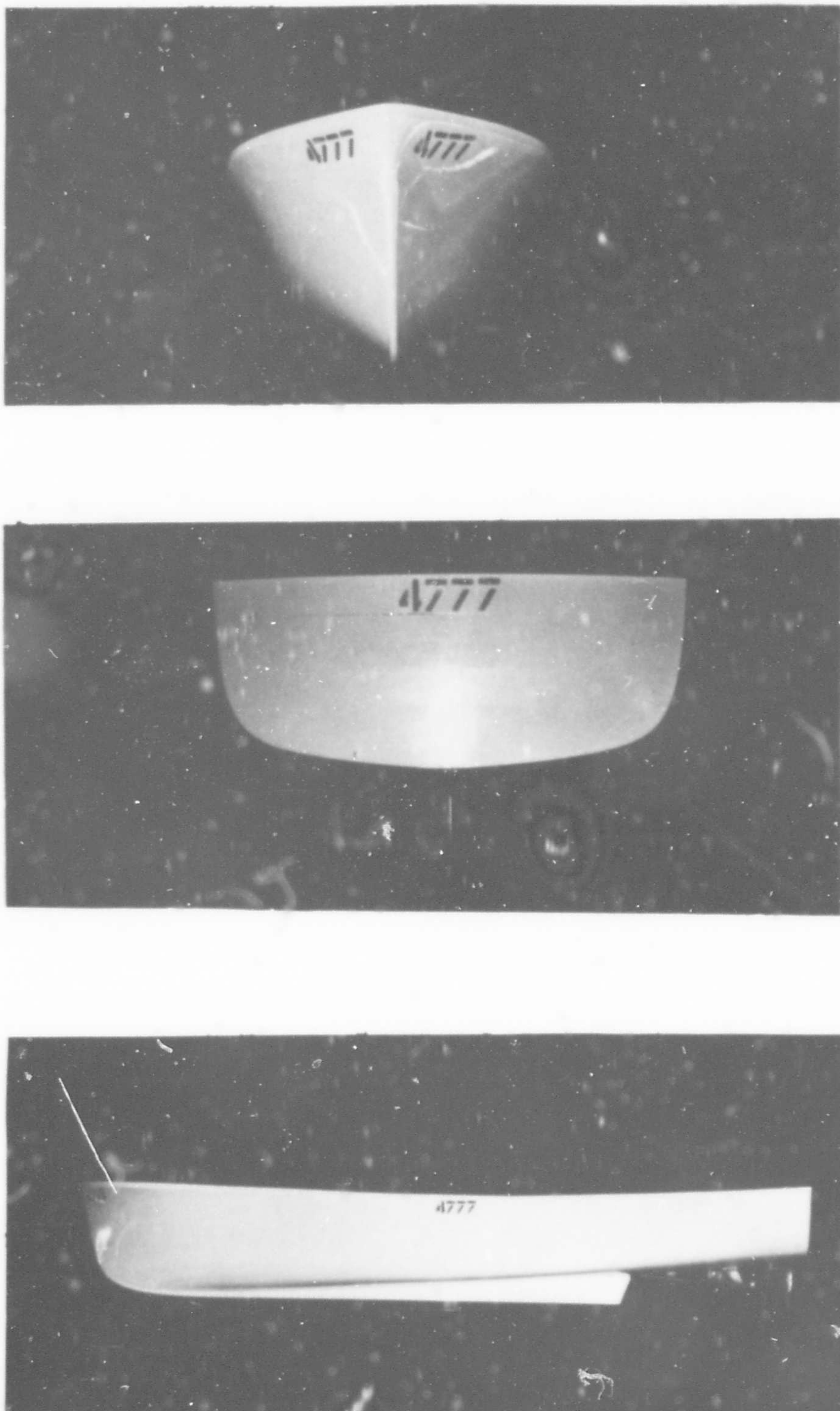


Figure 3 - Model 4777

NO. OF BLADES........ 3	P/D (CONSTANT).......1.254
EXP. AREA RATIO......0.216	DIAMETER.............4.56 ins.
MWR..................0.556	PITCH (CONSTANT).....5.72 ins.
BTF..................0.053	ROTATION............ R.H.

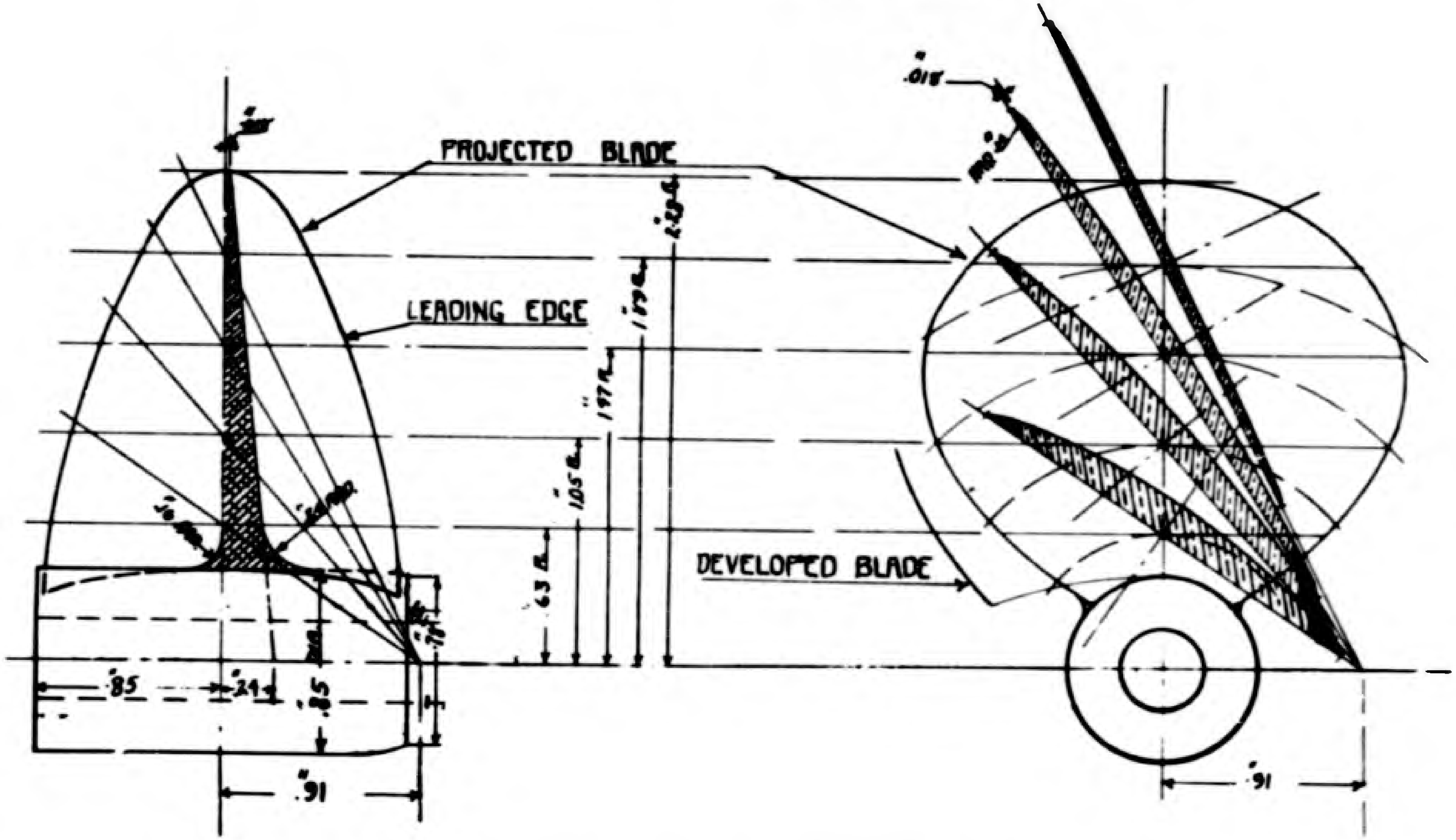


Figure 4 - Propeller 320

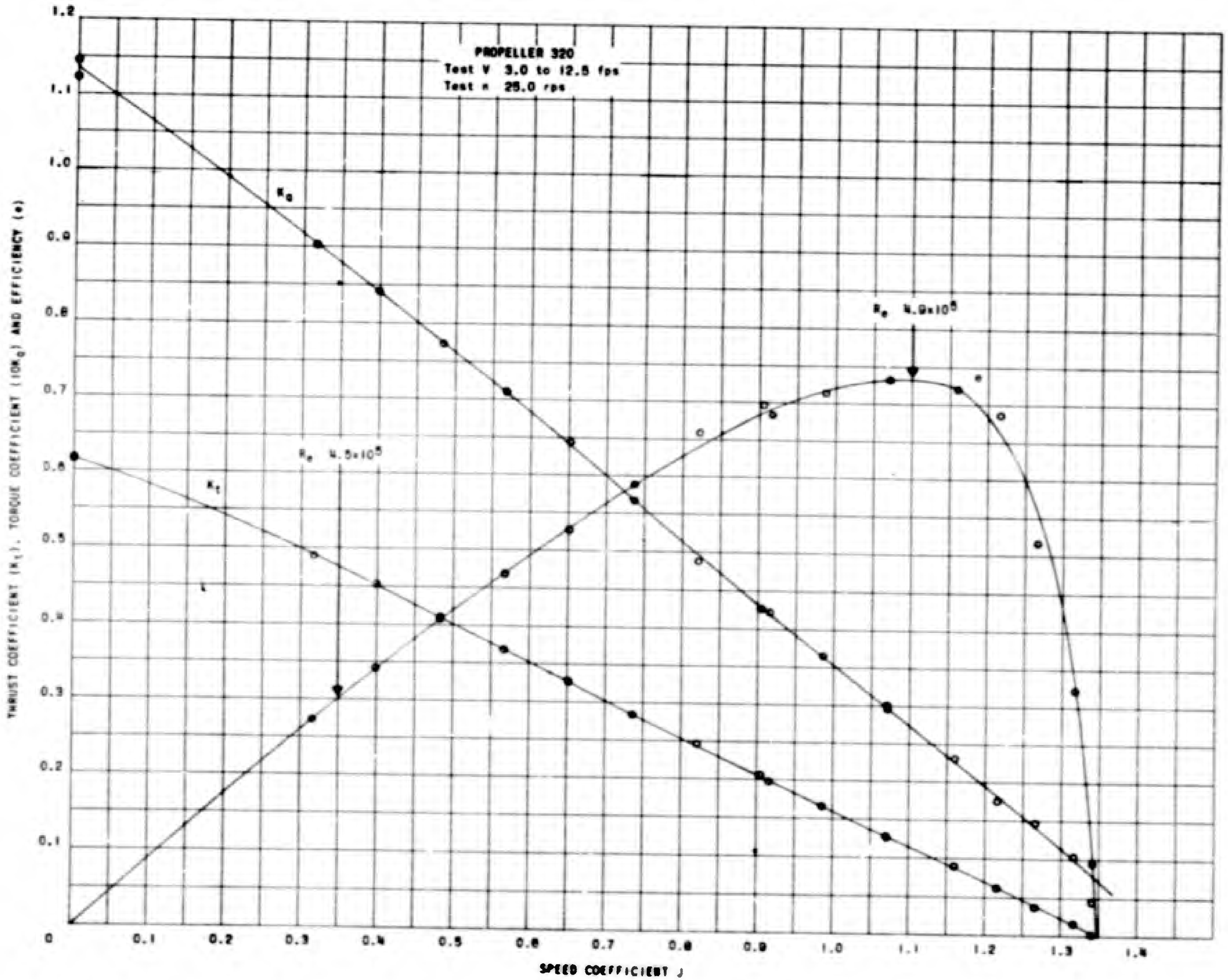


Figure 5 - Characteristics of Propeller 320

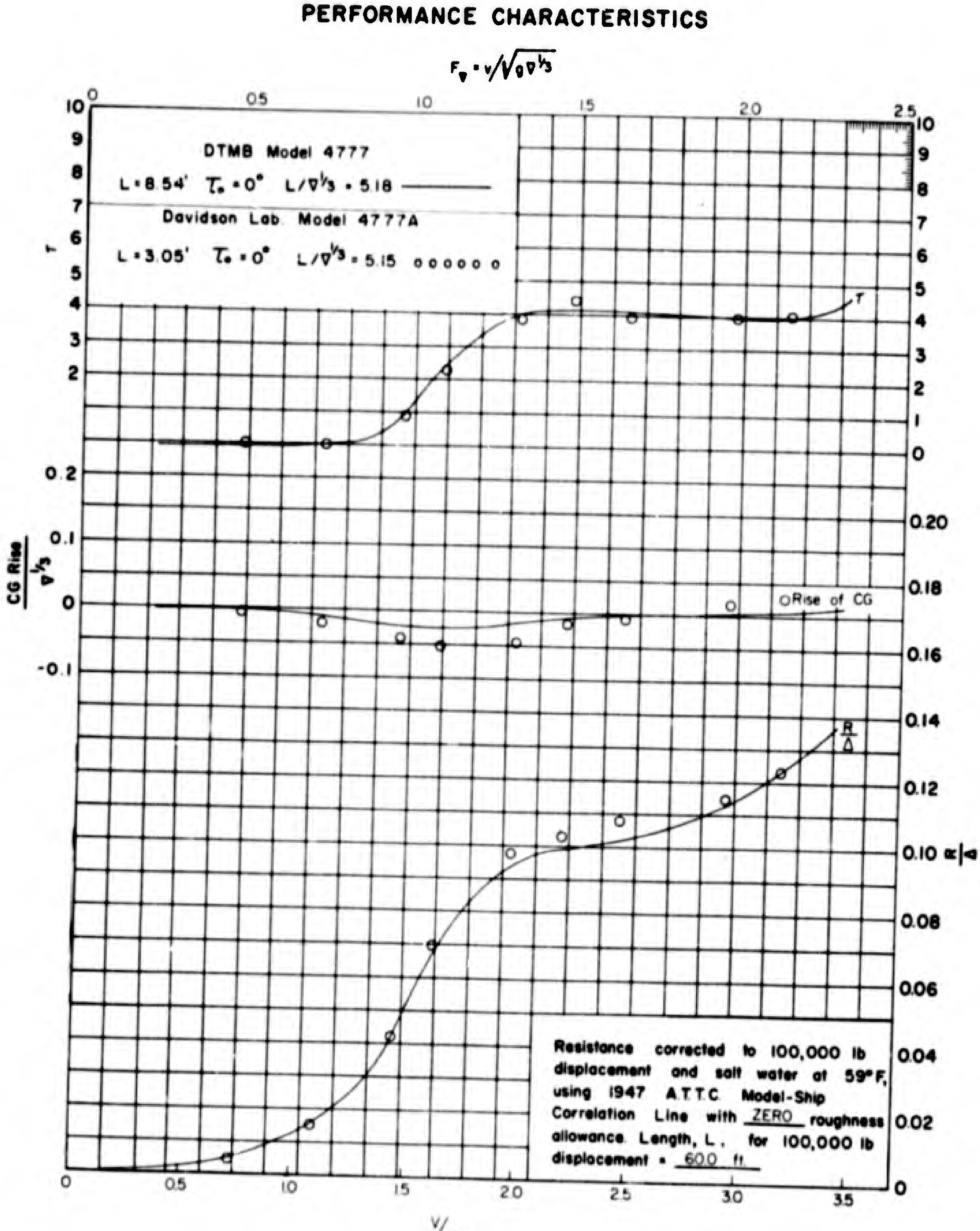


Figure 6 - Comparison of TMB Data with Davidson Laboratory Data

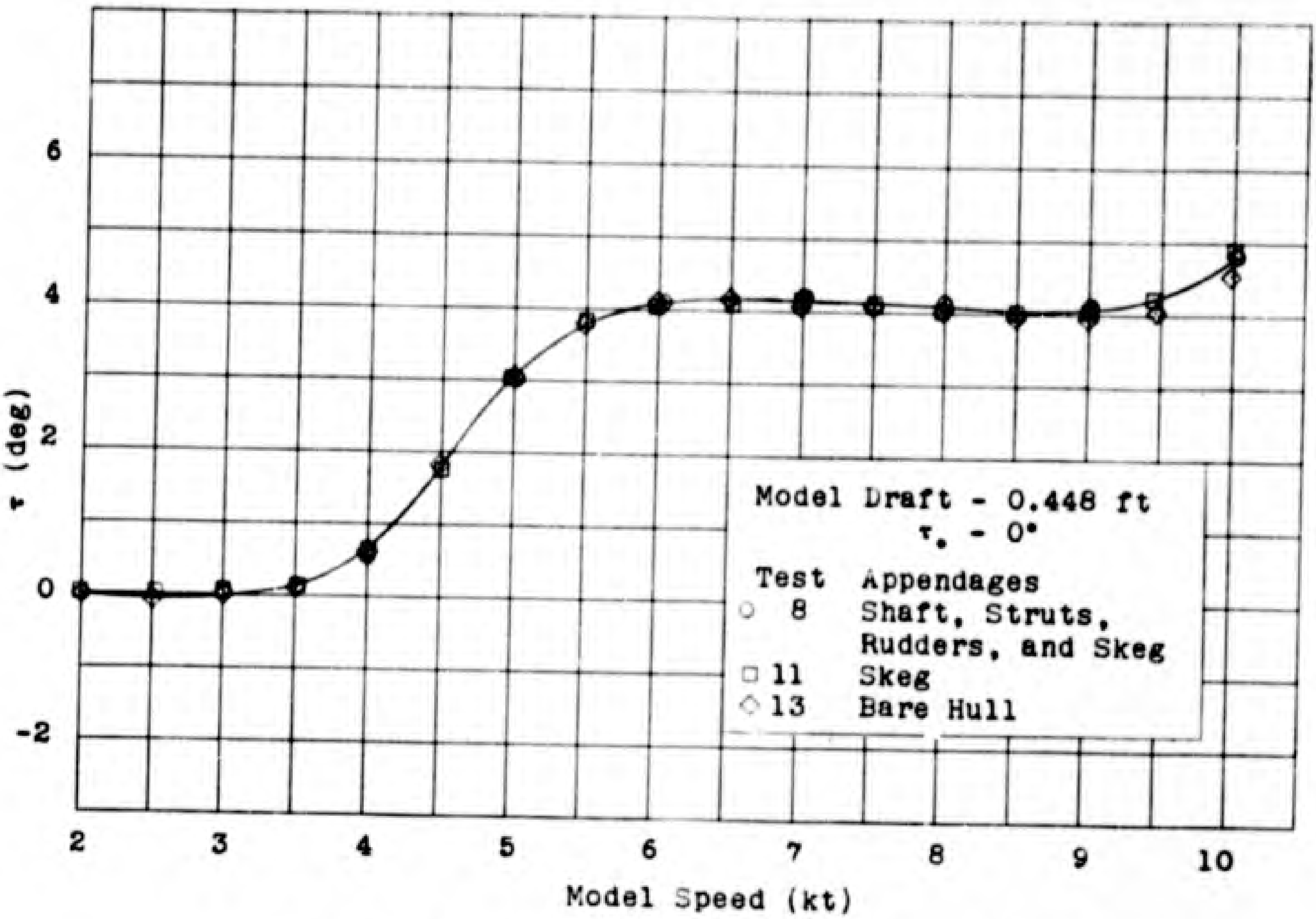


Figure 7 - Effects of Appendages on Trim

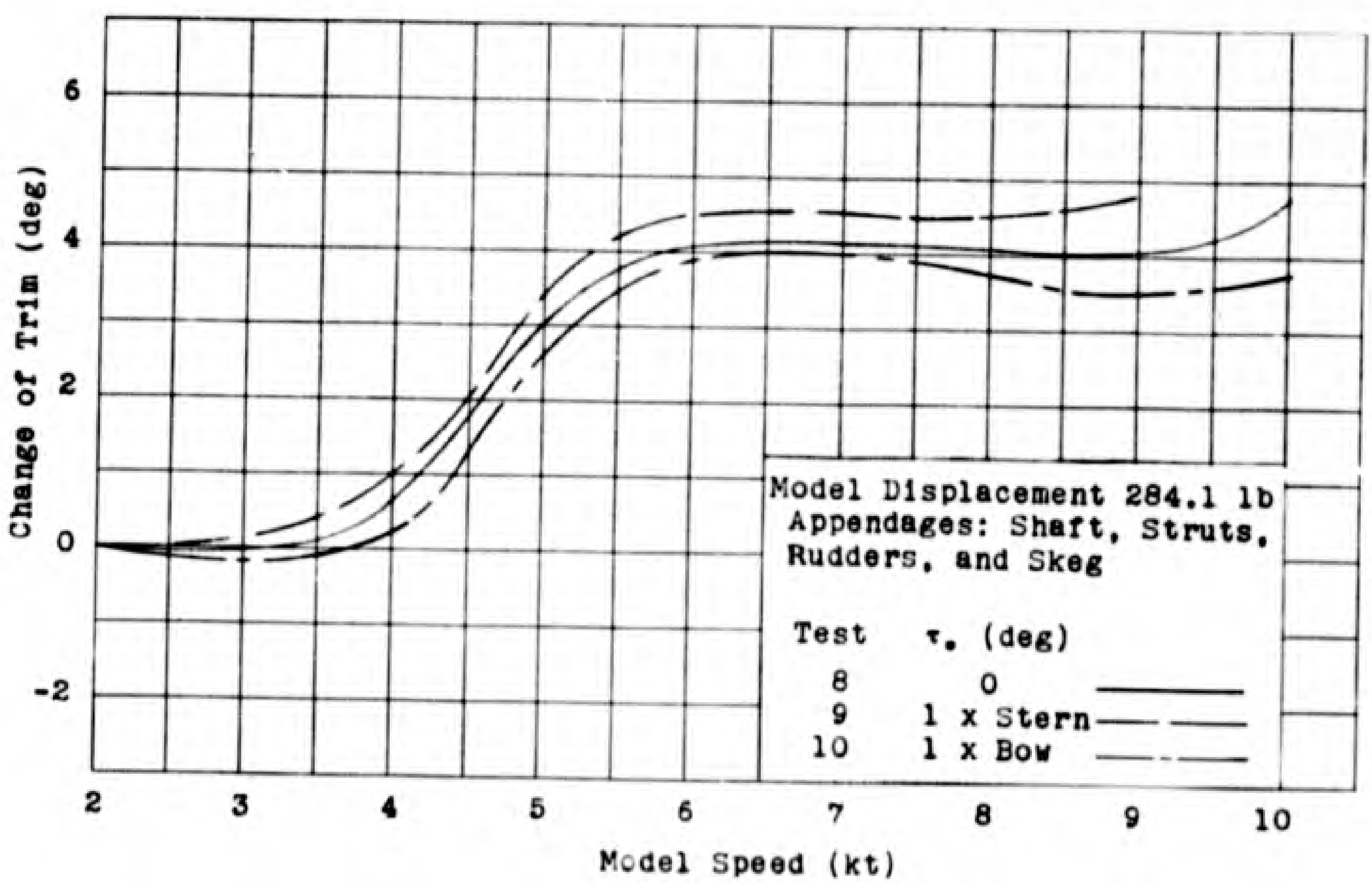


Figure 8 - Effects of Static Trim on Change of Trim

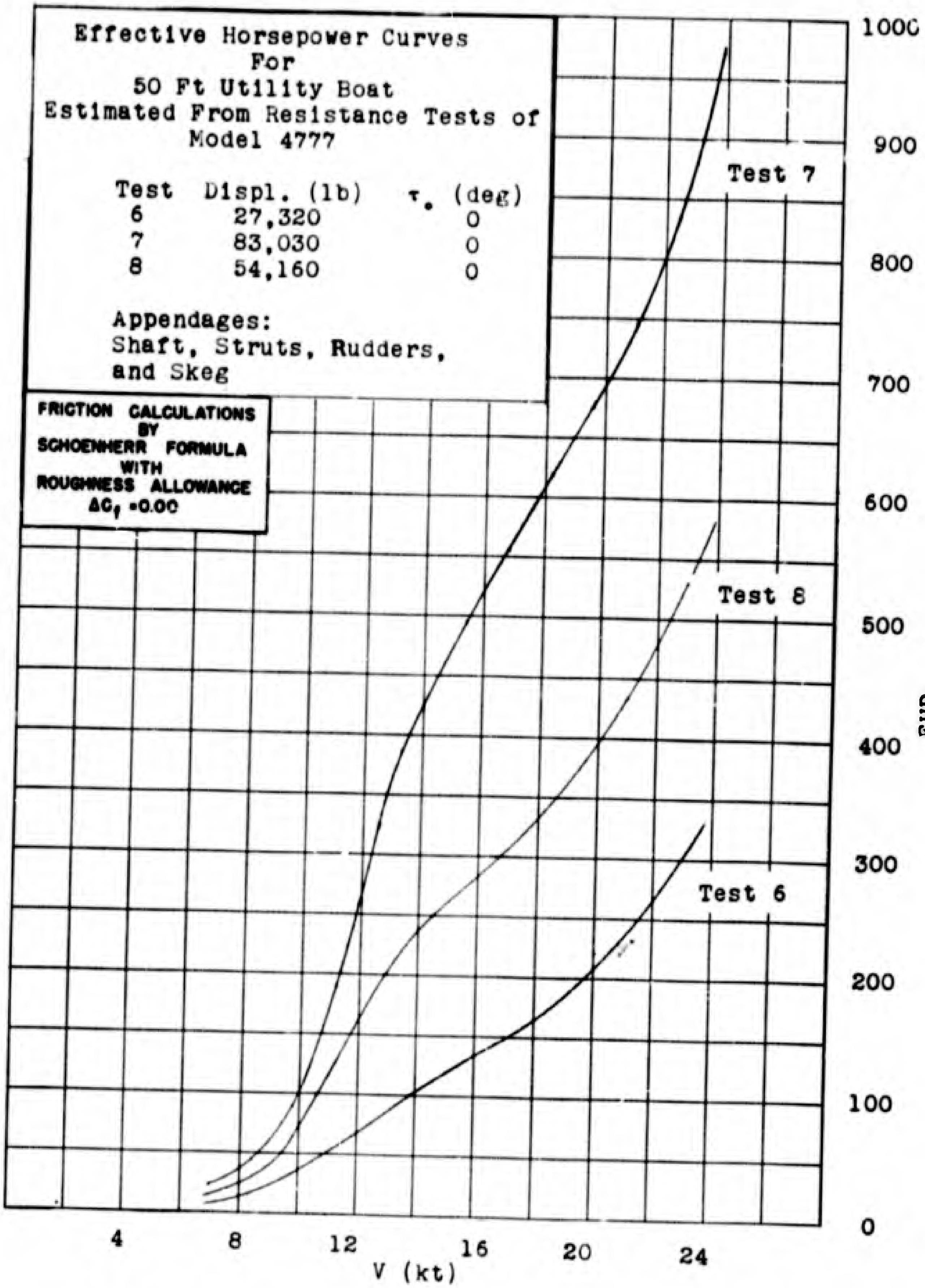


Figure 9 - Effects of Displacement on EHP

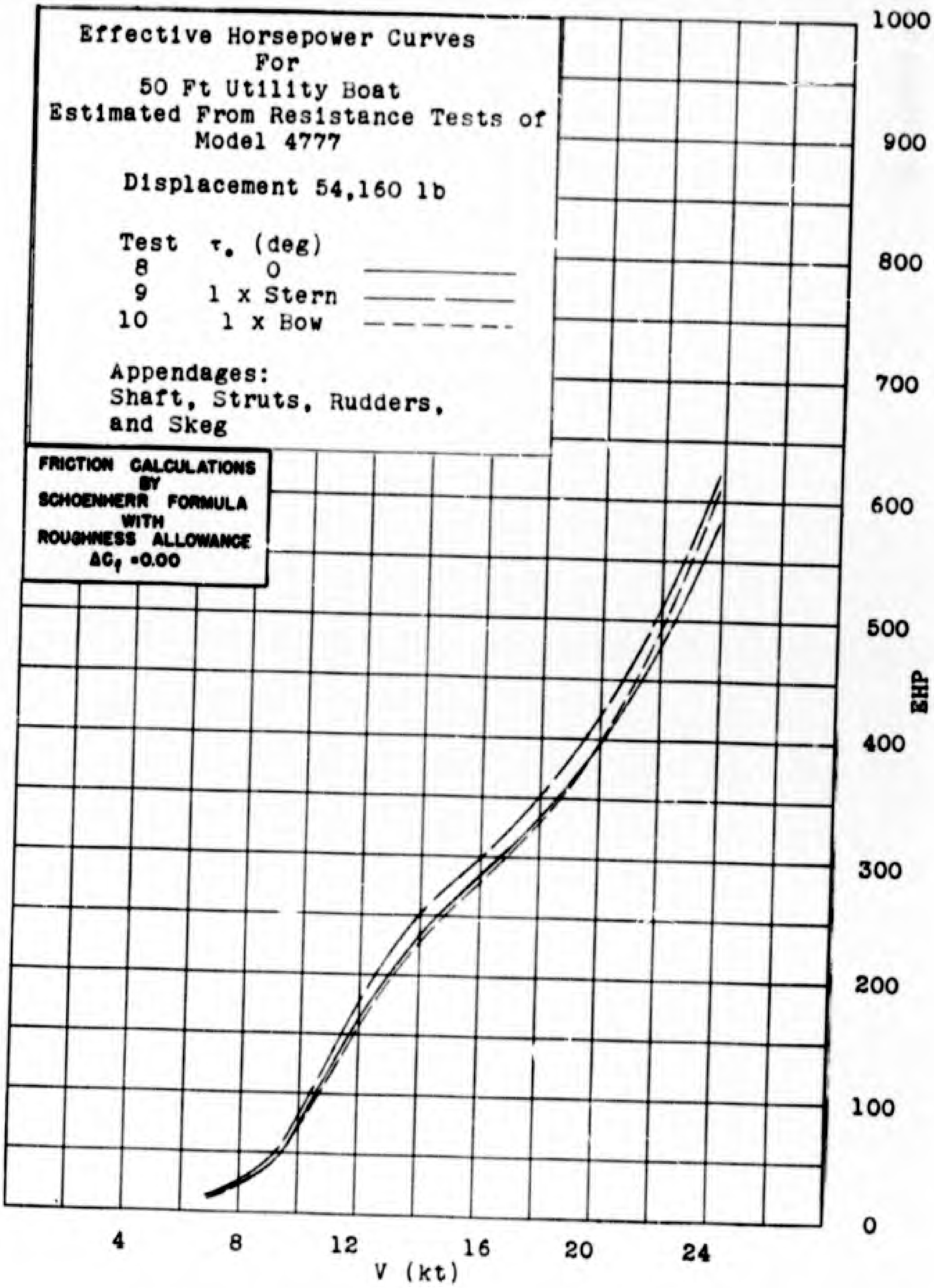


Figure 10 - Effects of Static Trim on EHP

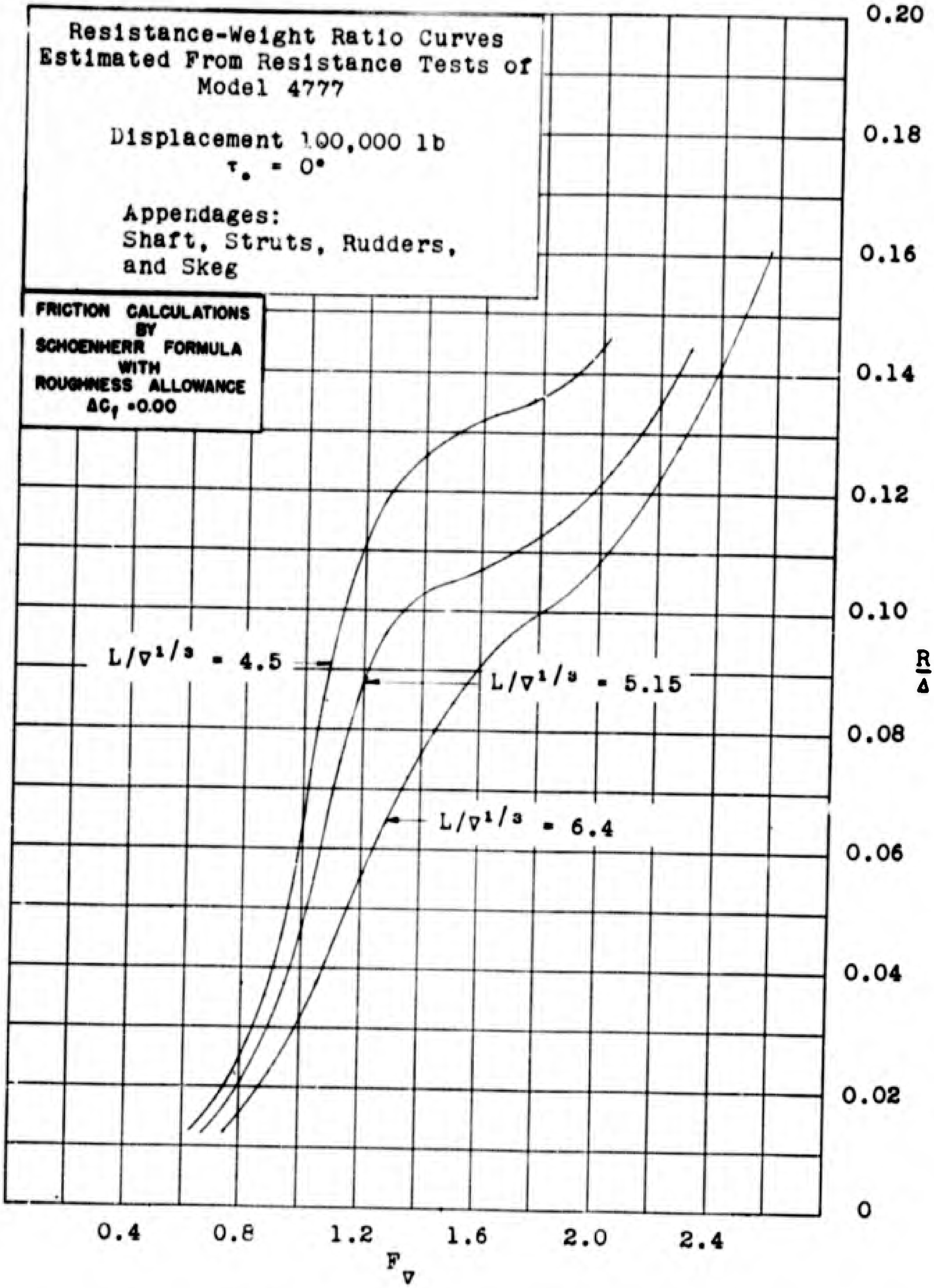


Figure 11a - All Appendages

Figure 11 - Effects of Slenderness Ratio on Resistance-Weight Ratio.

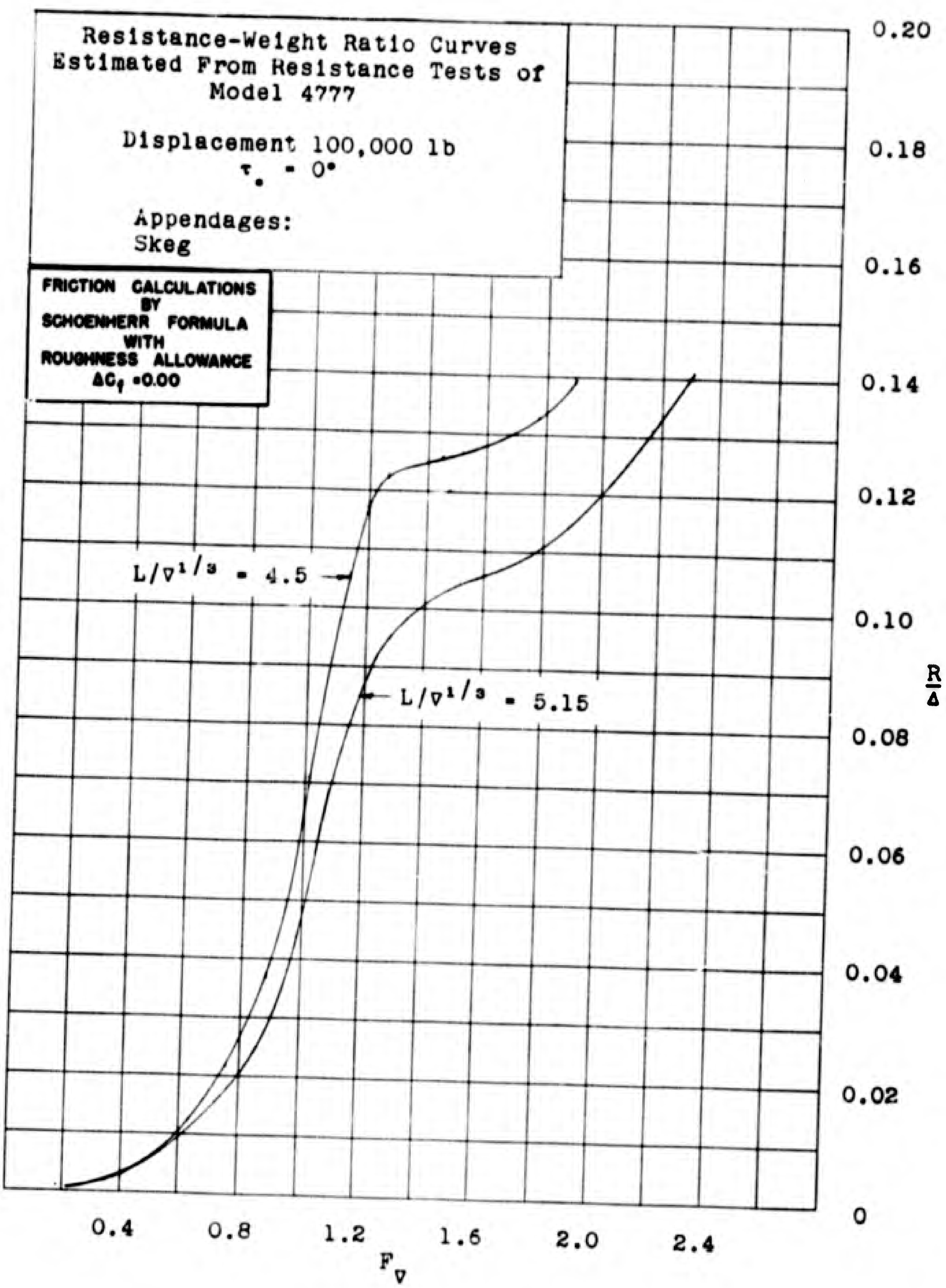


Figure 11b - Skeg Only

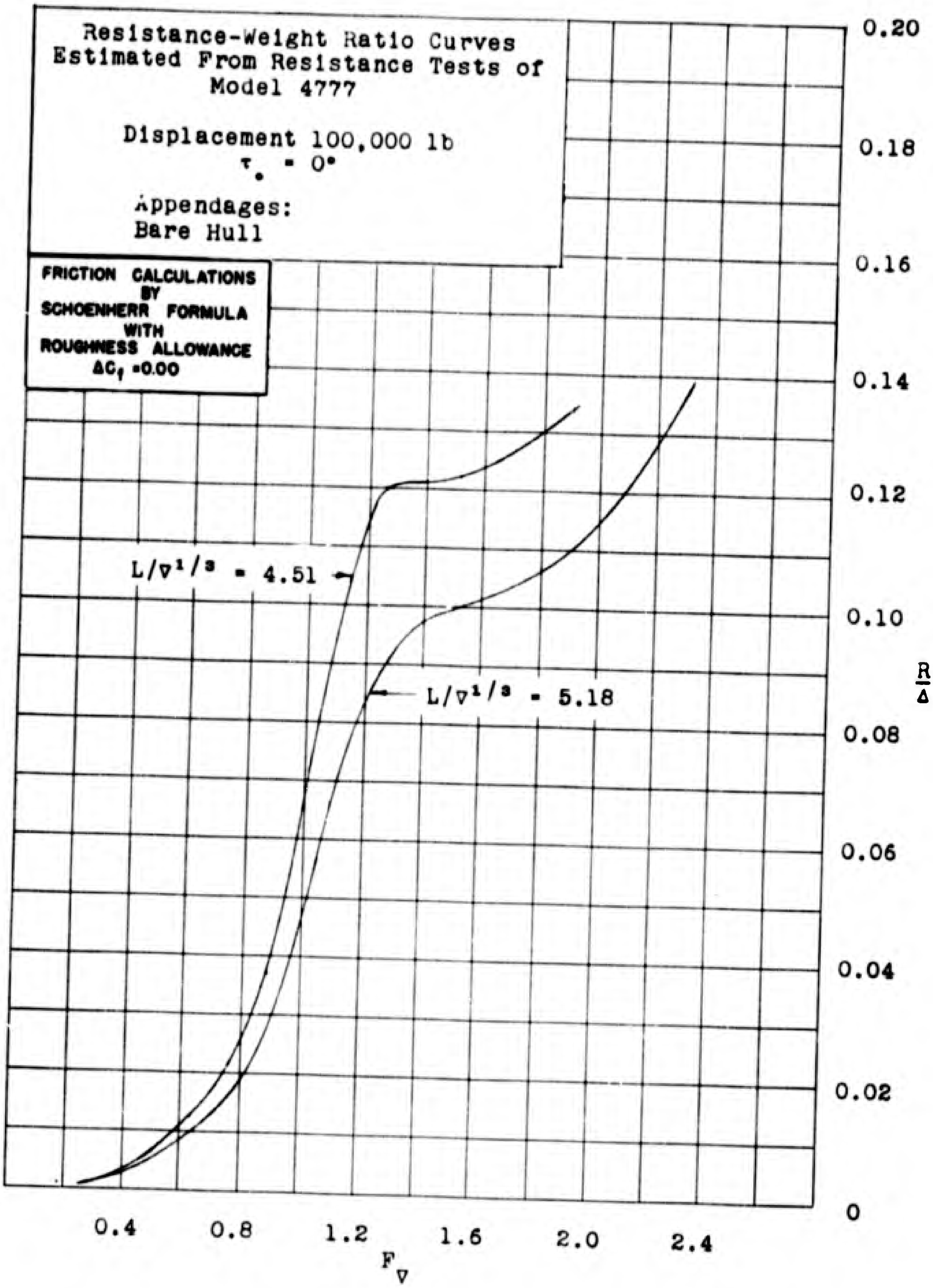


Figure 11c - Bare Hull

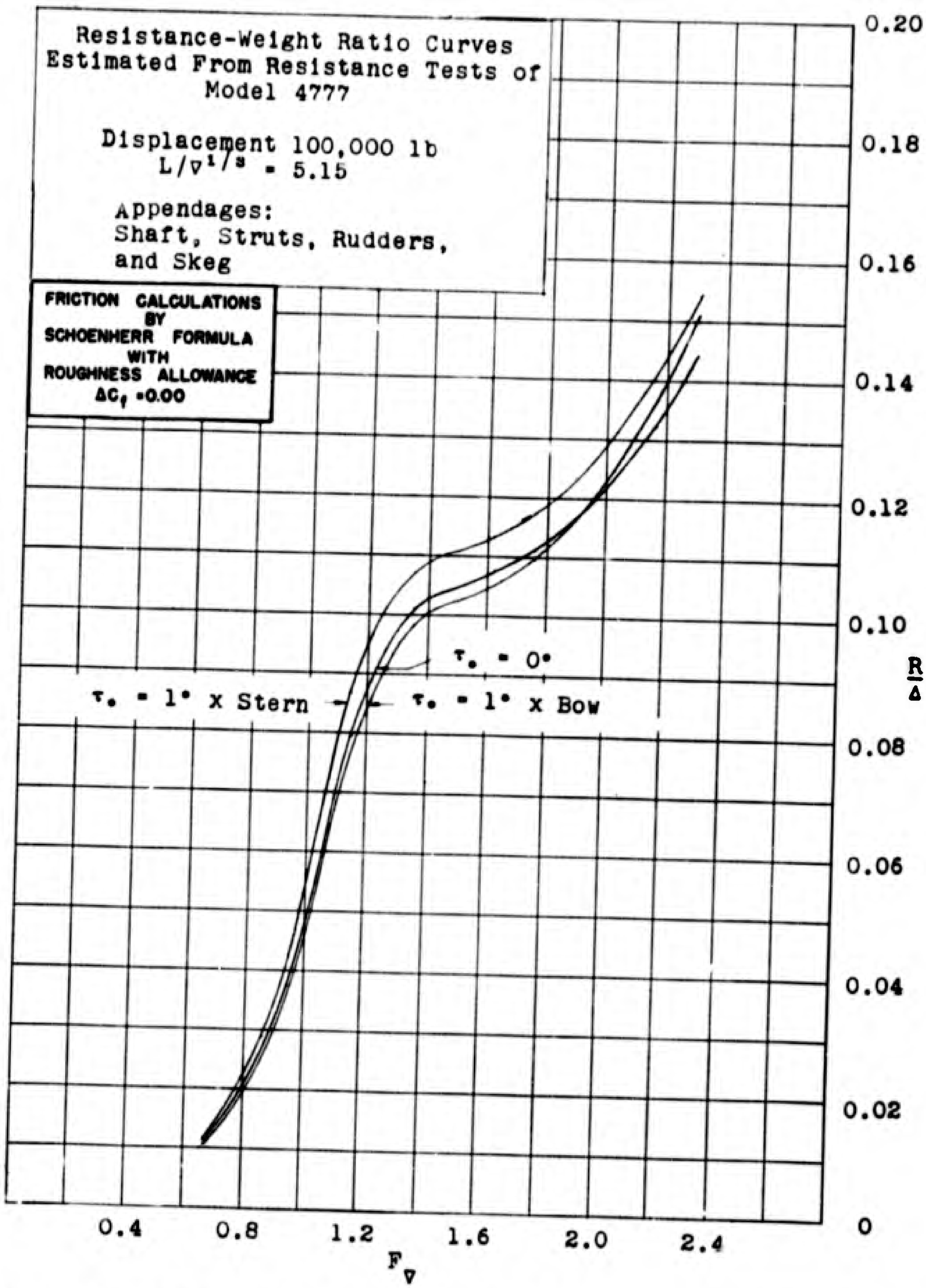


Figure 12 - Effects of Static Trim on Resistance-Weight Ratio

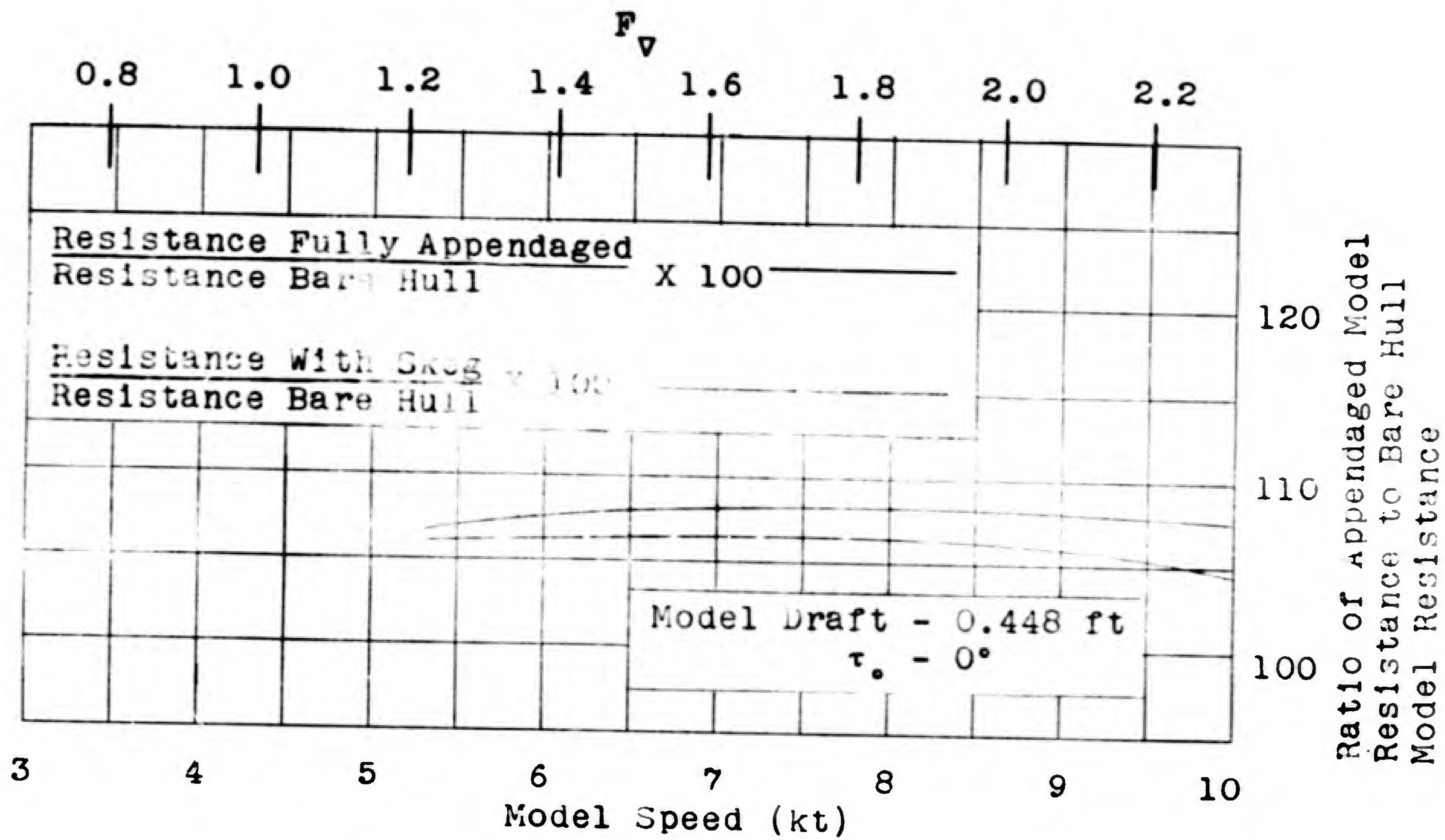


Figure 13 - Appendage Resistance

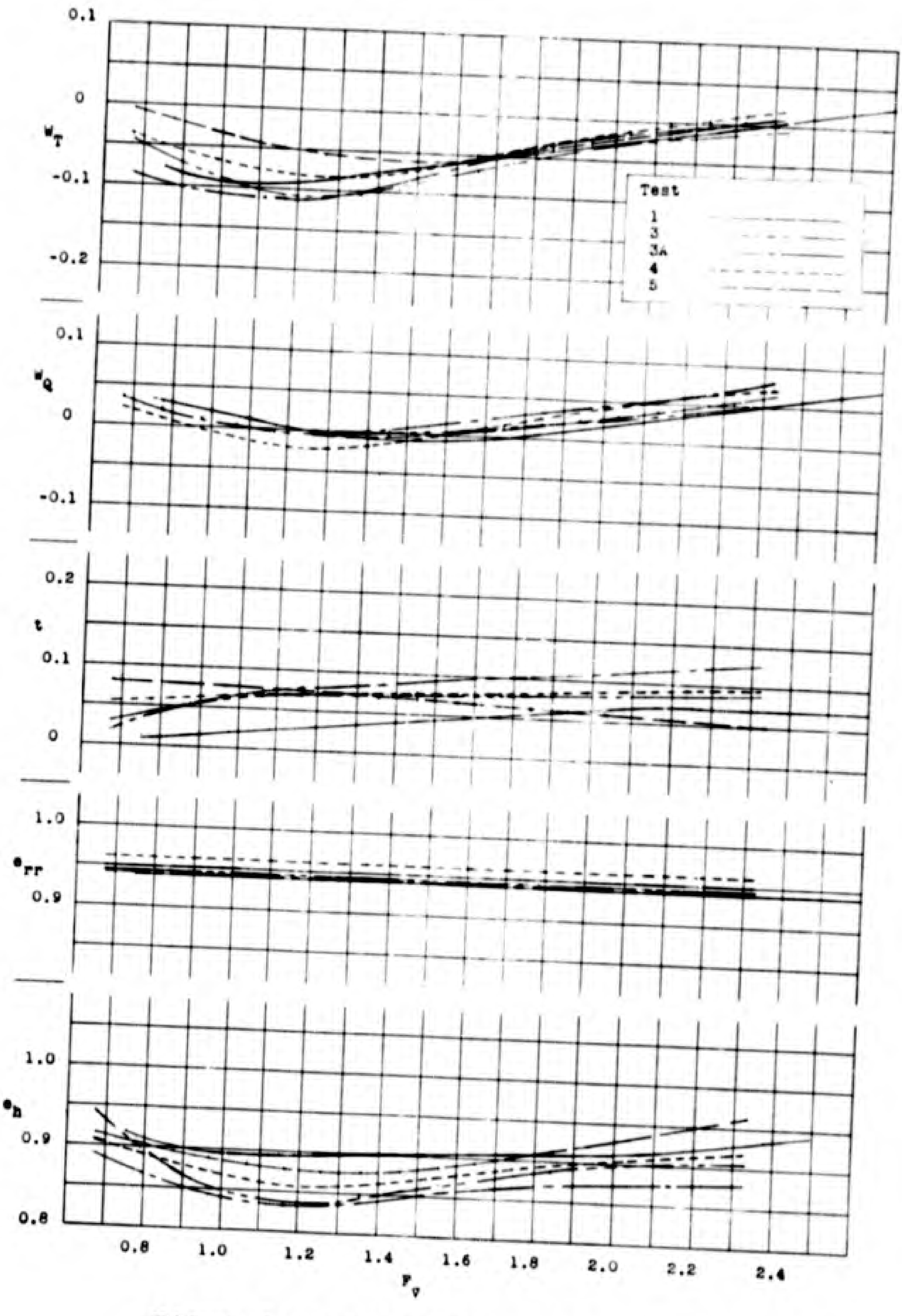


Figure 14 - Propulsive Characteristics

APPENDIX

Horsepower Estimate

As previously mentioned in this report, the propeller used for the tests reported herein was not ideally suited for the hull at its design condition. To make a horsepower estimate for a more suitable propeller, only the characteristics of the propeller to be used and the resistance and propulsion data in this report are needed. Since

$$EHP/SHP = e_p \, e_h \, e_{rr}$$

e_p needs to be determined to obtain shp. Plotting e_p as a function of K_T/J^2 eliminates propeller rpm from the characteristics, and e_p can be uniquely defined for a given hull velocity.

$$\frac{K_T}{{J_T}^2} = \frac{T}{\rho D^2 v^2 (1-W_T)^2}$$

and

$$T = \frac{R}{1-t}$$

so that

$$\frac{K_T}{{J_T}^2} = \frac{R}{\rho D^2 v^2 (1-W_T)^2 (1-t)}$$

An example of a horsepower estimate is included to demonstrate the procedure to be followed. For this example, the displacement will be 100,000 lb and τ_o = 0 deg (Test 8) with $\Delta C_f = 0$. Propeller 306 was selected from Gawn's work; its open-water characteristics are given in Figure 15. The propulsive data for this estimate were obtained from Test 3, shown in Figure 14. The resulting computations are given in Table 2 and the power curve and associated data are presented in Figure 16. The following procedure was used to make these calculations:

CALCULATION PROCEDURE

Column	Designation	Formulation	Procedure
A	F_{∇}		Selected to cover desired speed range
B	R/Δ		Obtained from model test data for desired displacement
C	R	$(R/\Delta)\Delta$	(Col. B) Δ
D	v	$F_{\nabla}\sqrt{g\nabla^{1/3}}$	(Col. A) $\sqrt{g\nabla^{1/3}}$
E	V	v/1.6878	(Col. D)/1.6878
F	t		From test data
G	W_T		From test data
H	e_h		From test data
I	e_{rr}		From test data
J	1-t	1-t	1-(Col. F)
K	$1-W_T$	$1-W_T$	1-(Col. G)
L	K_T/J_T^2	$R/\rho D^2 v^2 (1-W_T)^2 (1-t)$	$\frac{\text{Col. C}}{\rho D^2 (\text{Col. D})^2 (\text{Col. K})^2 (\text{Col. J})}$
M	e_p		From curve of e_p versus K_T/J^2
N	EHP/SHP	$e_p\ e_{rr}\ e_h$	(Col. M) (Col. I) (Col. H)
O	EHP	Rv/550	(Col. C) (Col. D)/550
P	SHP	$\frac{\text{EHP}}{\text{EHP/SHP}}$	$\frac{\text{(Col. O)}}{\text{(Col. N)}}$
Q	J_T	$\frac{v(1-W_T)}{nD}$	From curve of e_p versus J
R	RPM	$\frac{v(1-W_T)60}{J_T D}$	$\frac{\text{(Col. D) (Col. K) 60}}{\text{(Col. Q) D}}$
S	W_Q		From test data

TABLE 2

Horsepower Estimate

Col. A	Col. B	Col. C	Col. D	Col. E	Col. F	Col. G	Col. H
F_{∇}	R/Δ*	R	v	V	t**	W_T**	e_h**
1.0	0.0463	4,630	19.32	11.45	0.063	-0.102	0.849
1.4	0.1028	10,280	27.04	16.02	0.073	-0.087	0.850
1.8	0.1127	11,270	34.77	20.60	0.080	-0.040	0.885
2.2	0.1347	13,470	42.49	25.17	0.087	-0.013	0.903

Col. I	Col. J	Col. K	Col. L	Col. M	Col. N	Col. O	Col. P
e_{rr}**	1-t	$1-W_T$	K_T/J^2	e_p***	EHP/SHP	EHP	SHP
0.945	0.937	1.102	0.775	0.539	0.432	163	377
0.945	0.927	1.087	0.912	0.526	0.422	505	1197
0.945	0.920	1.040	0.666	0.549	0.459	712	1551
0.945	0.913	1.013	0.566	0.557	0.475	1040	2189

Col. Q	Col. R	Col. S
J_T***	RPM	W_Q**
0.390	1232	0
0.372	1783	0.001
0.406	2010	0.021
0.418	2324	0.045

* From Figure 12

** From Figure 14

*** From Figure 15

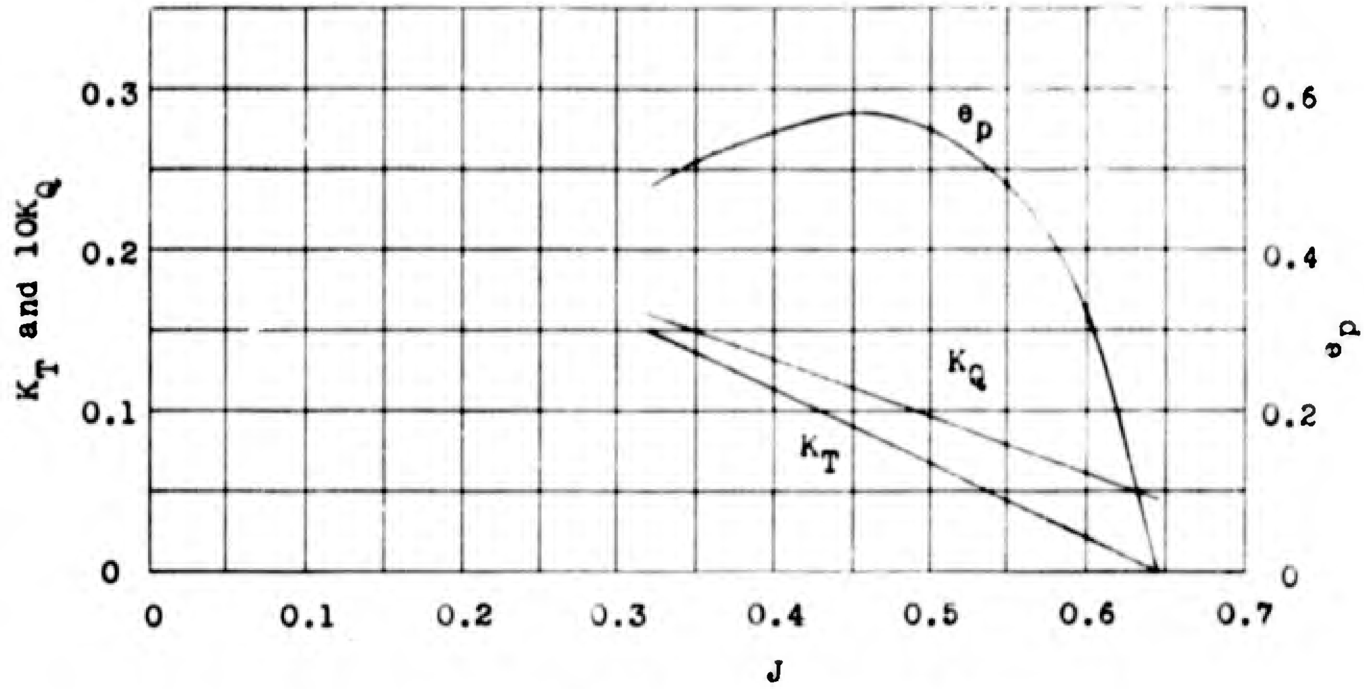


Figure 15a - K_T, K_Q, and e_p versus J

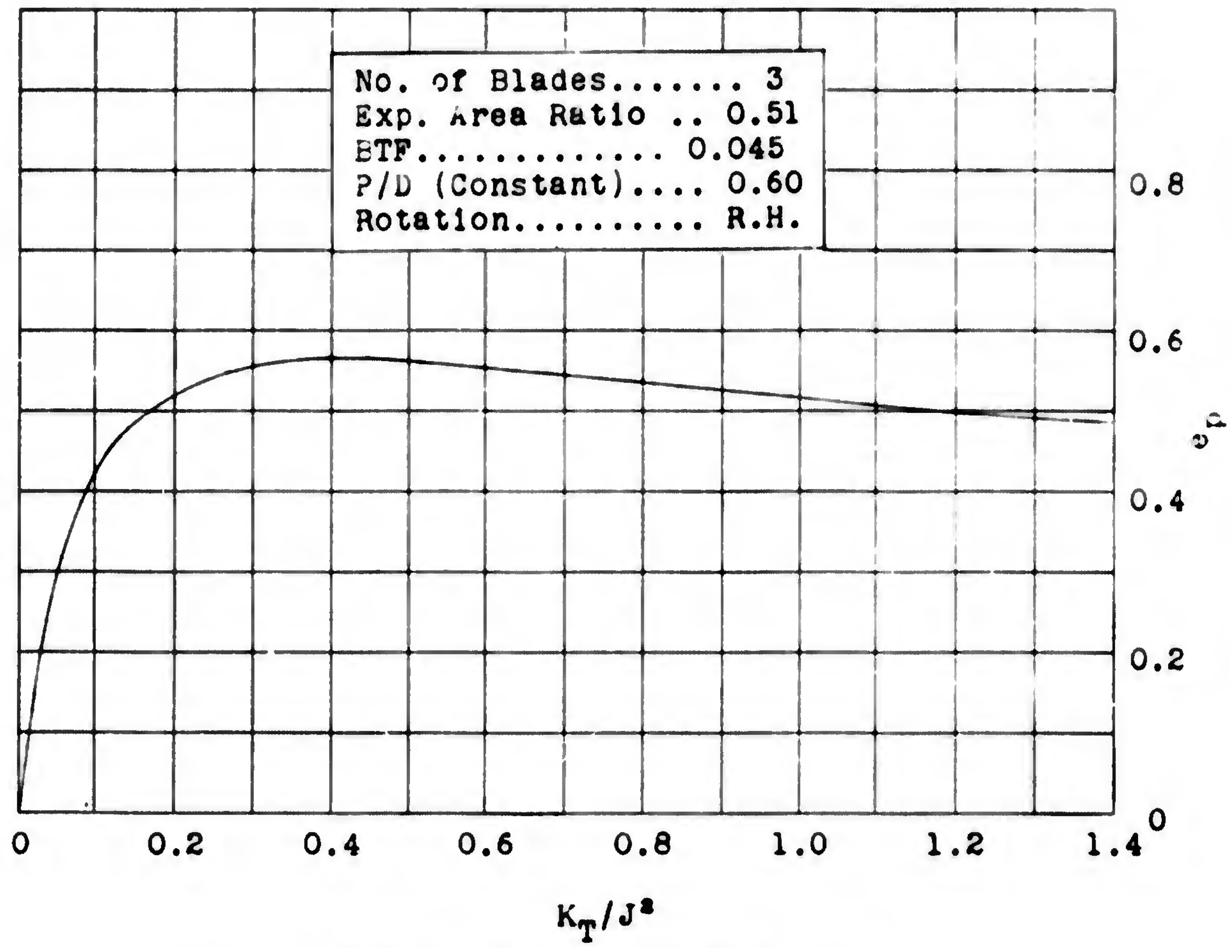


Figure 15b - e_p versus K_T/J^2

Figure 15 - Open-Water Characteristics
for Gawn's Propeller 306

Horsepower Estimate
for
Utility Boat

Hull Dimensions

Length(LWL).....59.7 ft
Beam............15.7 ft
Draft...........3.1 ft
Displacement.100,000 lb
τ_o...............0 deg
Wetted Surface..973 ft^2
Appendages:
Shaft, Struts, Rudders, and Skeg

Propeller Dimensions

Single Screw
Diameter.......31.9 in
Pitch..........19.1 in
No. of Blades.....3
Exp. Area Ratio...0.51
B.T.F...........0.045
Rotation .........R.H.

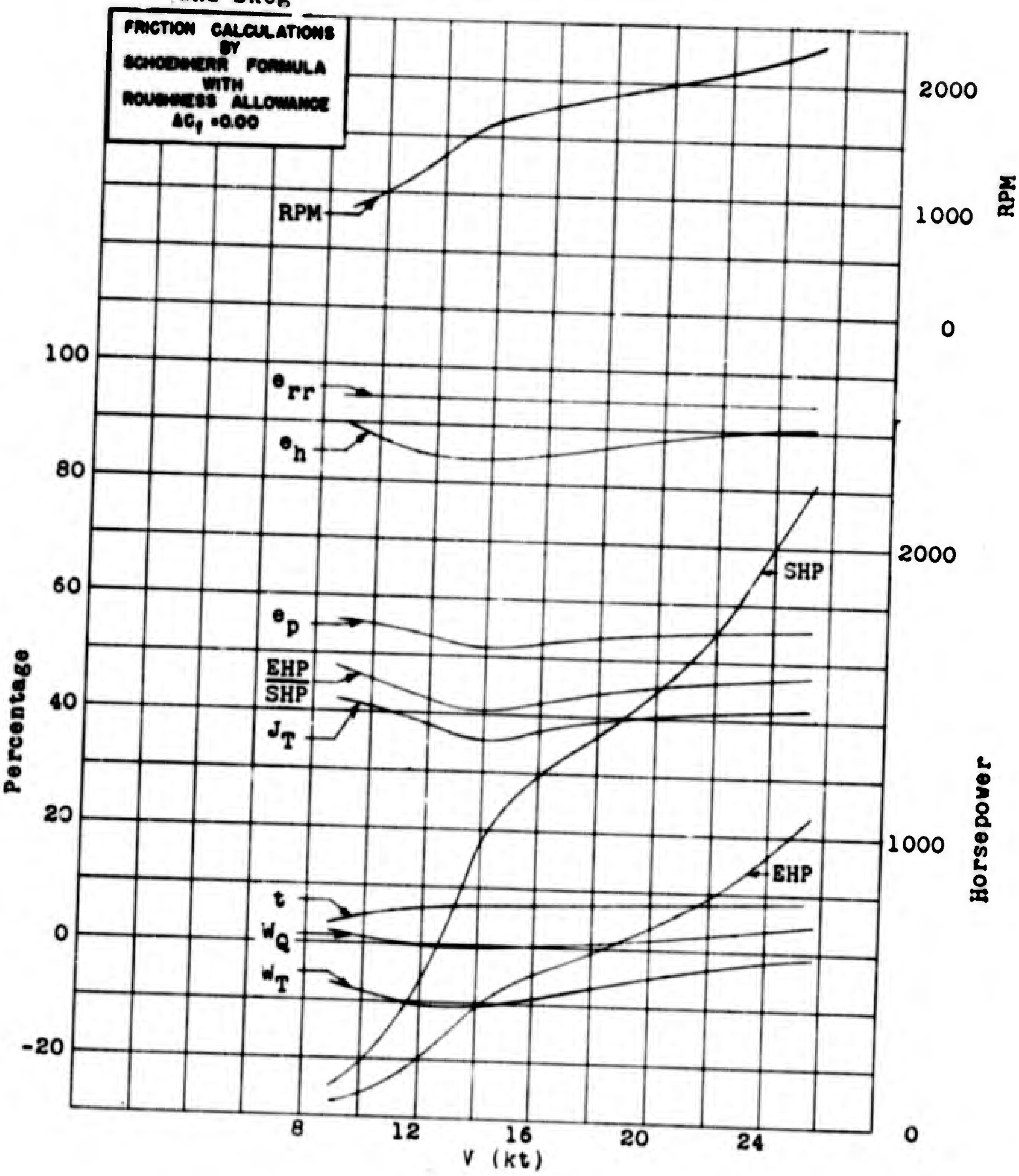


Figure 16 - Horsepower Estimate

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