Report 1703

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DEPARTMENT OF THE NAVY
DAVID TAYLOR MODEL BASIN

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HYDROMECHANICS

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RESISTANCE TESTS OF A MODEL OF THE GERMAN E-BOAT

by

Eugene P. Clement

HYDROMECHANICS LABORATORY
RESEARCH AND DEVELOPMENT REPORT

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NOTATION

A	Area of a vertical transverse underwater section
A_W	Area of waterplane at the load waterline
A_X	Area of maximum vertical transverse underwater section
℔	Baseline
B_X	Breadth at the maximum-area section, measured at the LWL
C_B	Block coefficient (volume of the underwater body, ∇, divided by the volume of a rectangular parallelepiped, LWL $\cdot B_X \cdot H_X$)
CG	Center of gravity
℄	Centerline
C_P	Prismatic coefficient (volume of the underwater body, ∇, divided by the volume of the prism, LWL $\cdot A_X$)
C_W	Waterplane coefficient (ratio of area, A_W, to area of rectangle, LWL $\cdot B_X$)
C_X	Maximum section coefficient (area, A_X, divided by the area of rectangle, $B_X \cdot H_X$)
EHP	Effective horsepower
SHP	Shaft horsepower
F_∇	Froude number based on volume, in any consistent units, $v/\sqrt{g\nabla^{1/3}}$
g	Acceleration due to gravity
H	Draft of underwater hull, measured from ℔ to LWL
H_X	Draft at the section of maximum area, without skeg
LCG	Longitudinal center of gravity location
LBP	Length between perpendiculars
LWL	Load waterline or length on load waterline
P	Effective power, ft-lb/sec
R	Total resistance, lb
V	Speed, knots
v	Speed
w	Density of water, weight per unit volume
Δ	Displacement at rest, weight of
∇	Displacement at rest, volume of
λ	Linear ratio, ship to model

ABSTRACT

A model of the German E-boat was built and tested at the David Taylor Model Basin shortly after the end of World War II. The results are being published now in order to make them more widely available. The action of the "effect" rudders of the E-boat is described in this report and the effects of these rudders on the resistance and trim of the towed model are shown.

INTRODUCTION

Shortly after the end of World War II a model of the German E-boat was towed at the David Taylor Model Basin to determine resistance and EHP. The results were forwarded to the Bureau of Ships by letter but a report was not published. The German E-boat was produced after a considerable development and testing effort; it had a good performance record in the war and both hull and appendages have some unusual features. Accordingly, the present report is published in order to make more widely available the details of the design and its resistance characteristics.

THE E-BOAT DESIGN

The plans available for building the model were of the E-boat S218, which was one of the later types built during the war. The model was built to a linear ratio of 8.5. The model lines are shown in Figure 1 and drawings of the rudders are shown in Figure 2. Photographs of the model are presented in Figure 3. The principal dimensions of ship and model, the coefficients of form, and the sectional area curve are presented in Figure 4.

The features which distinguish the E-boat design from conventional round-bilge destroyer and small boat forms are the following:

(a) Pronounced flare of the bow sections terminating in a knuckle.

(b) A spray strip along the knuckle line of (a). (It is unusual for a spray strip to be located this far above the waterline.)

(c) Wedges under the bottom of the corners of the transom.

(d) Steps on the inboard sides of each of the outboard "effect" rudders. These steps are shown in Figure 2(b). They are located a short distance aft of the leading edge of the effect rudders, and their height at each rudder section is about 8% the maximum thickness of the section.

ACTION OF THE EFFECT RUDDERS

The trailing edges of the effect rudders on the E-boat were turned out when the craft was running at high speed. The inboard side of each effect rudder then became a region of low pressure. The step on the inboard side caused the flow to separate from this low pressure face. As a consequence, air was drawn down from the surface and an air-filled trough was created behind each effect rudder. The inboard side of each effect rudder was then free of water from the step aft. It was possible during the tests in which the effect rudders were turned to look down the troughs and see the dry inboard sides of the effect rudders. The pressure on the outboard sides of the effect rudders was increased when the trailing edges were turned out; this resulted in an increase of pressure on the adjacent areas of the hull bottom so that the stern was raised and the trim and resistance decreased. It is believed that the reduction in rough-water resistance resulting from the reduced trim angle was probably even greater than the reduction in smooth-water resistance. Furthermore, motions and accelerations in rough water were presumably also reduced by the lower trim angle.

The effect rudders on the full-scale boat were each equipped with both a fixed and a loose tiller arm. The loose tiller arm was linked to the quadrant of the large conventional centerline rudder. By means of a toothed segment on the fixed tiller arm, and a worm gear between the loose and the fixed tiller arm, the setting of each effect rudder could be changed independently of the position of the centerline rudder. In actual operation, at a speed of about 25 knots the effect rudders were turned to an angle of 30° (trailing edges out), to produce the ventilation and trimming effects described above. The rudders were then turned back to an angle of about 17°.

Rudder ventilation persisted at this angle, and this was determined to be the angle for minimum power at high speeds.

DTMB MODEL TESTS

The model was tested at displacements of 370.4 and 406.1 lb, corresponding to full-scale displacements of 104.4 and 114.5 tons. Initial trim was 0° in both cases. At both displacements the model was tested when fitted only with spray strips, wedges and centerline skeg, and when fitted with all appendages (i.e., with spray strips, wedges, skeg, shafts, struts, bossings and rudders). Further details of the model test conditions are given in Table I. The model was tested with the effect rudders set at 0°, and also at angles of 17° and 30° (trailing edges out). The measured values of model resistance, stern rise and trim are presented in Figures 5 and 6. In order to have data in a form suitable for design and comparison, dimensionless coefficients of resistance, speed and power, were also calculated. The usual Model Basin practice for small craft was followed in that the resistance and power coefficients were calculated for a displacement of 100,000 lb. The values of wetted length and wetted surface used for making the frictional resistance corrections were the values when the model was floating at rest. The 1947 ATTC friction coefficients were used with zero roughness allowance. The dimensionless resistance and power coefficients are presented in Figures 7 and 8.

Photographs of the model underway at three different speeds, with the three effect rudder settings tested, are shown in Figure 9. The model was also tested at two conditions of speed and displacement with a large number of effect rudder angles in order to show in detail how the resistance, trim, and rise vary with effect rudder setting. The data from these tests are presented in Figures 10 and 11. It can be seen from these figures that as the trailing edges of the effect rudders were turned out from the 0° setting, the resistance at first increased. Then, when a rudder angle of about 9° was reached, the resistance suddenly dropped. This resistance drop resulted from ventilation of the inboard side of one of the effect rudders.

When the effect rudder angles were increased further to about 11°, the second effect rudder ventilated and the resistance again dropped. The resistance was now appreciably below the value corresponding to 0° effect rudder. Photographs showing the model wake with the three different conditions of ventilation of the effect rudders are presented in Figure 12. It can be seen in Figures 10 and 11 that ventilation of the effect rudders was accompanied by an increase in the transom rise and a decrease in the trim of the model.

HSVA MODEL TESTS

Additional model test data for the E-boat design were obtained from an HSVA report on some resistance and self-propelled tests of a 1/9-scale model of the S26 class (HSVA Model 2081). The principal dimensions of this boat were the same as those of the S218, corresponding to the Taylor Model Basin's Model 3993. However, it is not known if the details of the appendages were identical. Resistance and trim data for the HSVA model are presented in Figure 13.

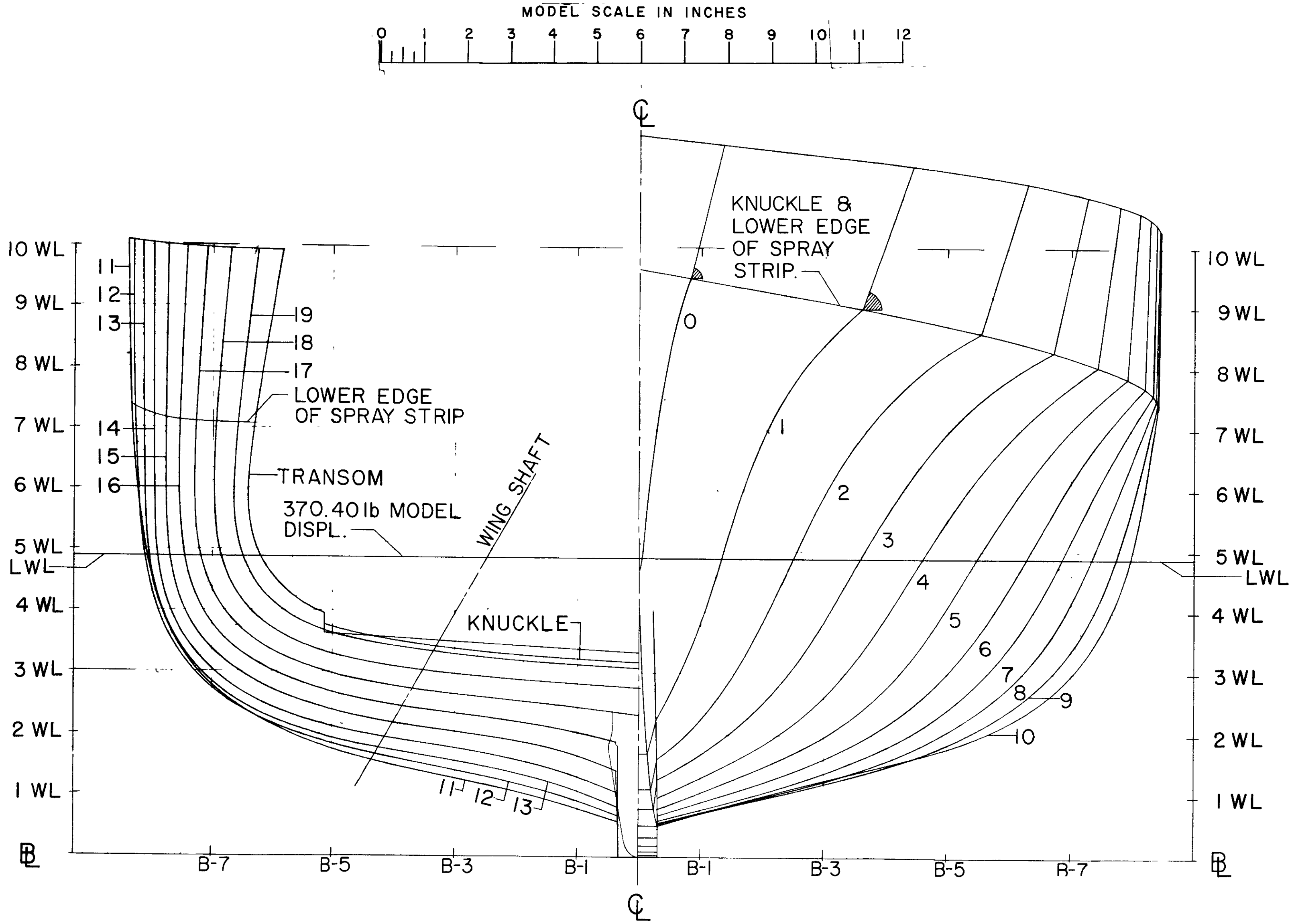
Data showing the influence of effect rudder setting on EHP, SHP, and trim as determined from the HSVA tests of Model 2081, are reproduced in Figure 14. It can be seen that the maximum percentage reduction in SHP (i.e., with optimum effect rudder setting) is appreciably greater than the maximum percentage reduction in EHP. Figure 14 indicates a reduction in EHP of about 1%, and a reduction in SHP of about 6%. Figure 11 shows that the maximum reduction in resistance obtained in the towed tests at the Model Basin by turning the effect rudders was 3%. (Model resistance was reduced from 67.3 lb to 65.2 lb by turning the effect rudders from 0° to 11°.) The HSVA tests indicated that a further significant gain is obtained in the self-propelled condition, which, of course, corresponds to the actual full-scale operating condition.

TABLE I

Model Test Conditions

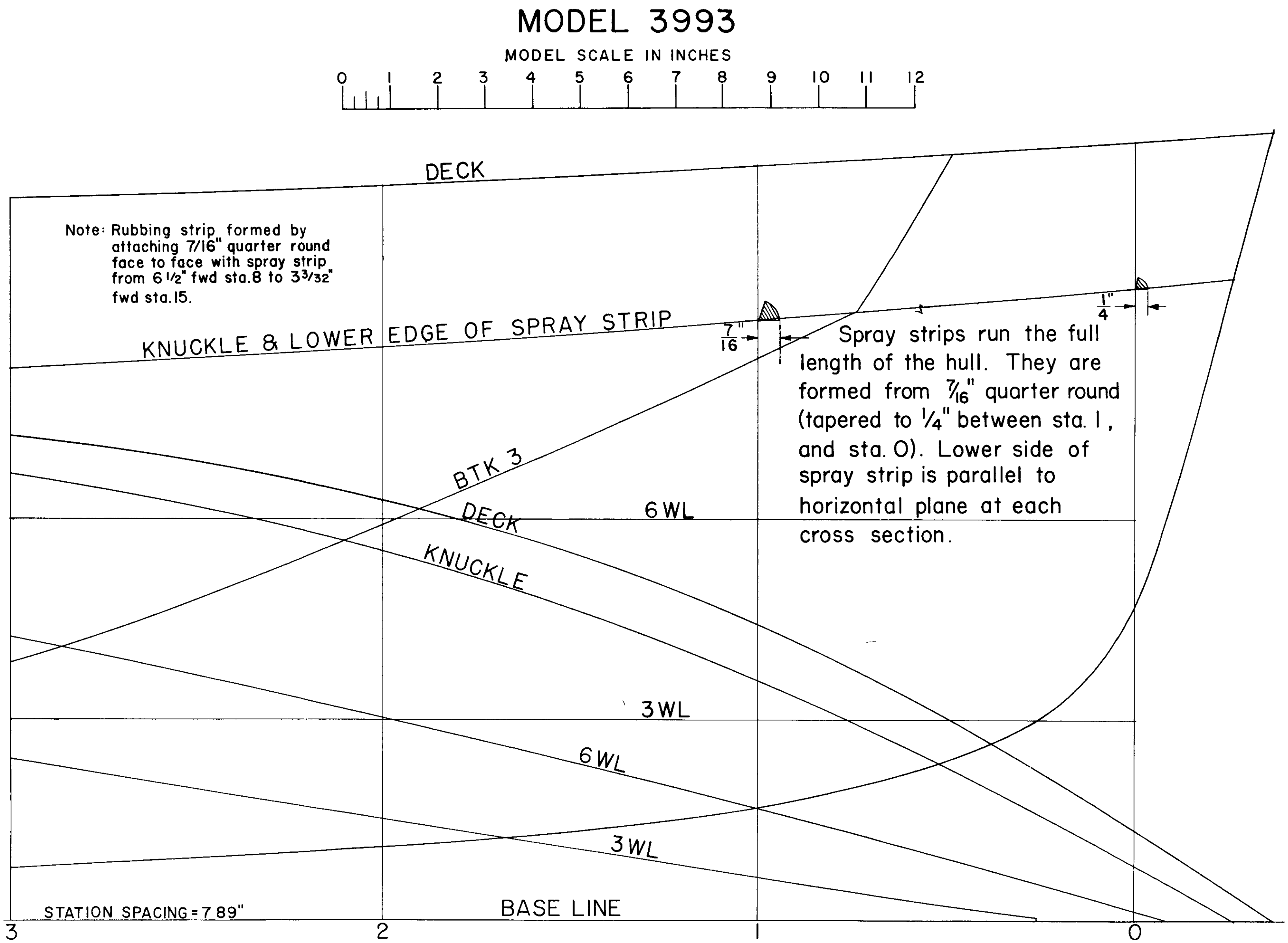
Model	Model displ., lbs	Appendages	Full-scale displ., tons	Model waterline length, ft	Full-scale waterline length, ft	Model wetted surface, ft^2	Model draft, ft*	$\frac{LWL}{\nabla^{1/3}}$
DTMB 3993	370.4	Spray strips and wedges	104.43	13.162	111.88	25.67	.517	7.26
3993	370.4	All	104.43	13.162	111.88	28.58	.517	7.26
3993	406.1	Spray strips and wedges	114.50	13.171	111.95	26.52	.544	7.05
3993	406.1	All	114.50	13.171	111.95	29.44	.544	7.05
3993	336.04	All	94.75	13.150	111.78	27.78	.489	7.49
HSVA 2081	283.0		94.72					

* draft without skeg.



(a) BODY PLAN

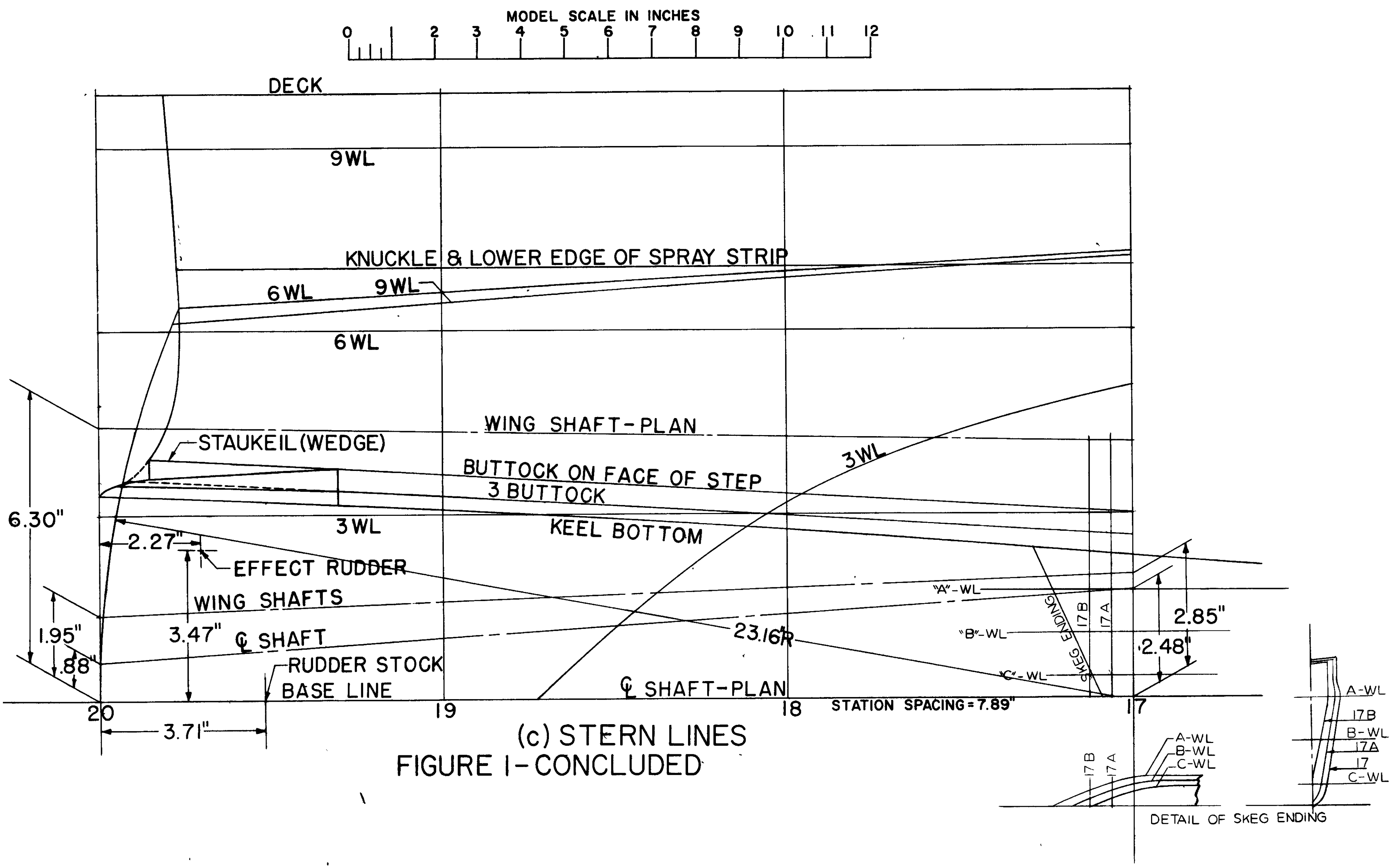
FIGURE 1- LINES OF MODEL 3993, CORRESPONDING TO GERMAN E-BOAT S218



(b) BOW LINES

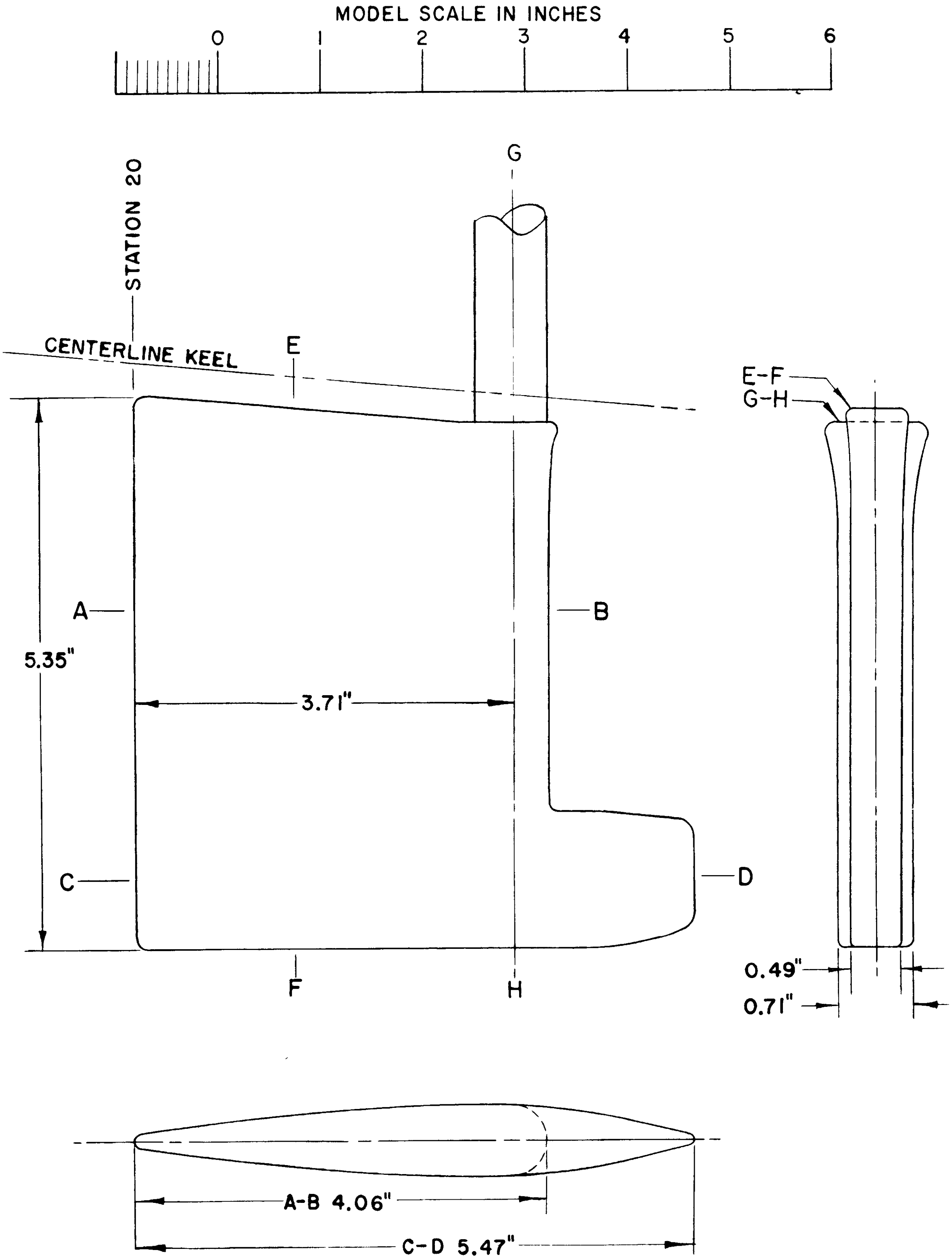
FIGURE 1 - CONTINUED

MODEL 3993



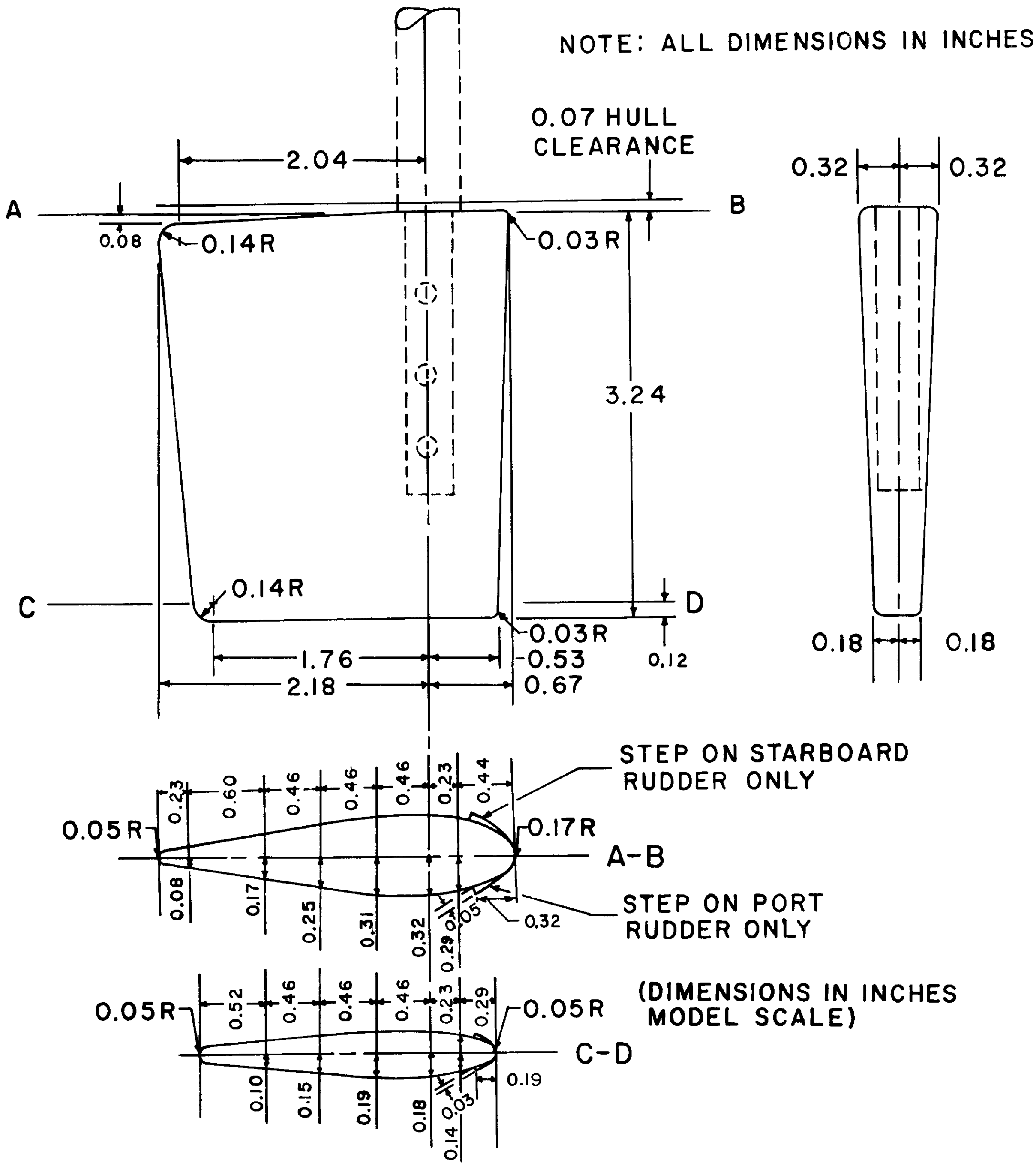
(c) STERN LINES

FIGURE 1 - CONCLUDED



(a) CENTERLINE RUDDER

FIGURE 2— RUDDERS FOR MODEL 3993



(b) EFFECT RUDDERS

FIGURE 2 - CONCLUDED

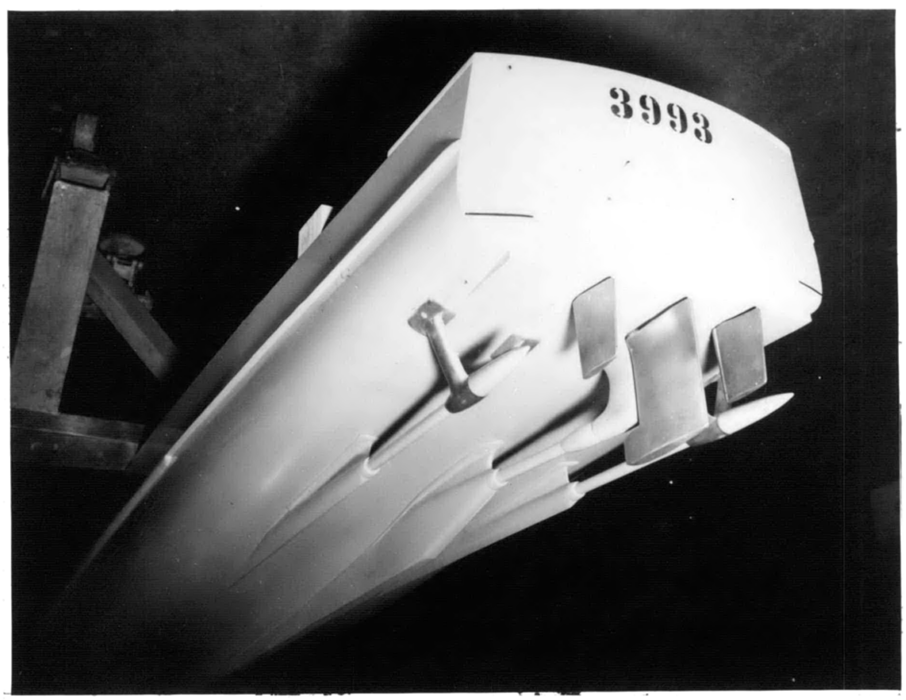


Figure 3 - Photographs of Model 3993

DIMENSIONS AND FORM COEFFICENTS FOR GERMAN E-BOAT S218 (DTMB MODEL 3993)			
APPENDAGES: STERN WEDGES			
DIMENSIONS			
	SHIP	MODEL	LWL COEFFICIENTS
LENGTH (LWL)	111.88′	13.162′	C_B 0.465 *
BREADTH (B_X)	16.167′	1.902′	C_P 0.633 *
DRAFT (H_X)	4.39′	0.517′	C_X 0.981
DISPL. IN LB	233,900	370.4	C_W 0.772
DISPL. IN TONS	104.4	——	$LWL/\nabla^{1/3} = 7.25$
			$A_W/\nabla^{2/3} = 5.84$
LWL AREA	1,395.87 FT²	19.32 FT²	
LCG/LWL = 0.460 FROM STERN		$\lambda = 8.5$	
W.L. ENTRANCE HALF ANGLE = 13°		INITIAL TRIM, EVEN KEEL	

* Volume of skeg not included in calculations

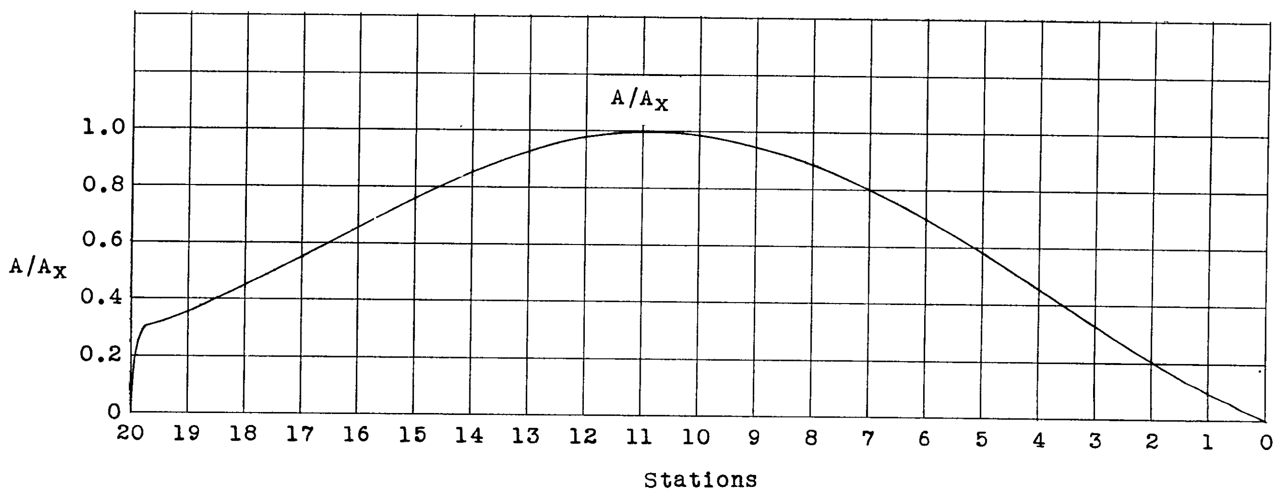


Figure 4 - Dimensions, form coefficients and sectional area curve

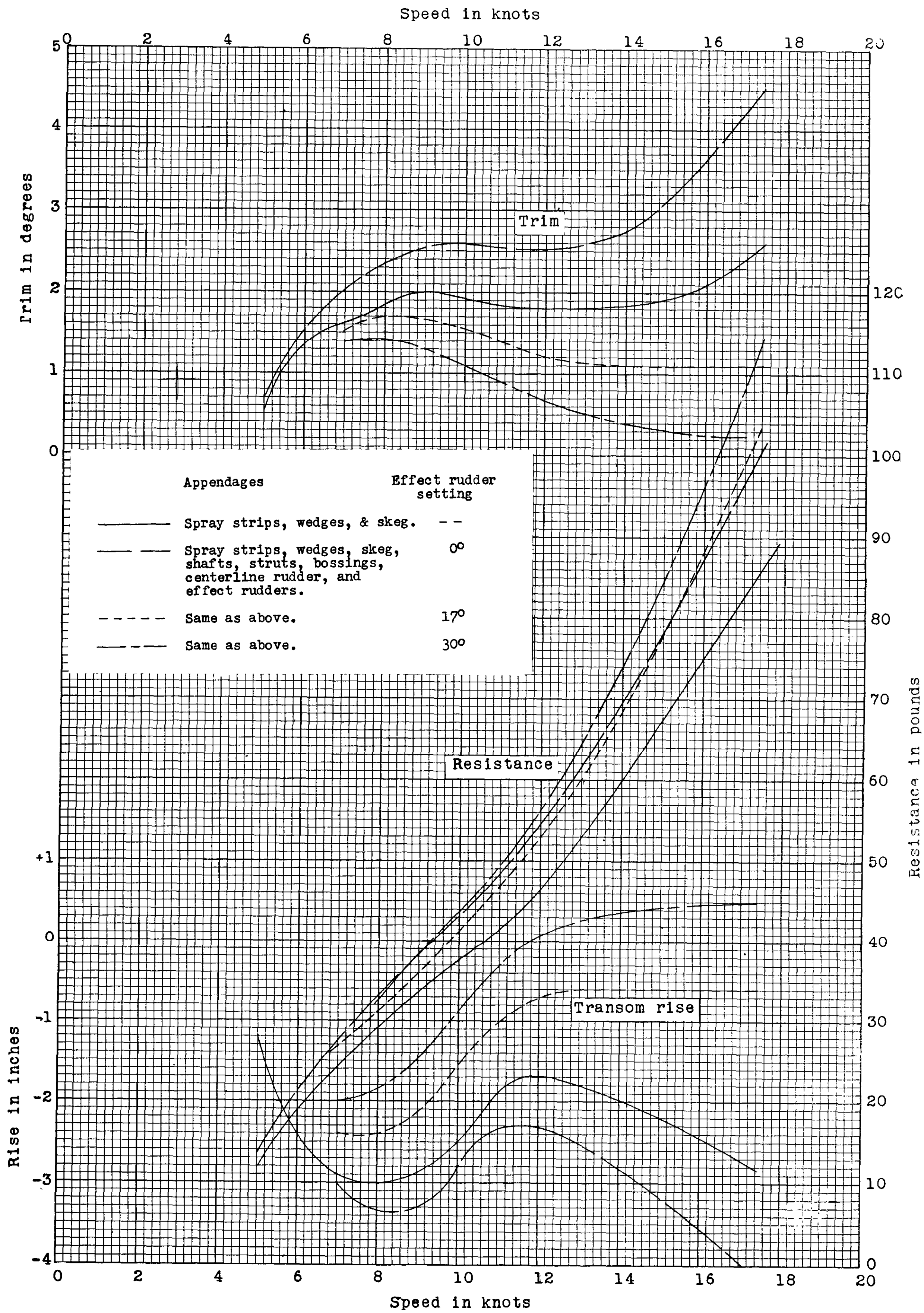


Figure 5 - Model resistance, stern rise and trim.
Displacement, 370.4 lb.

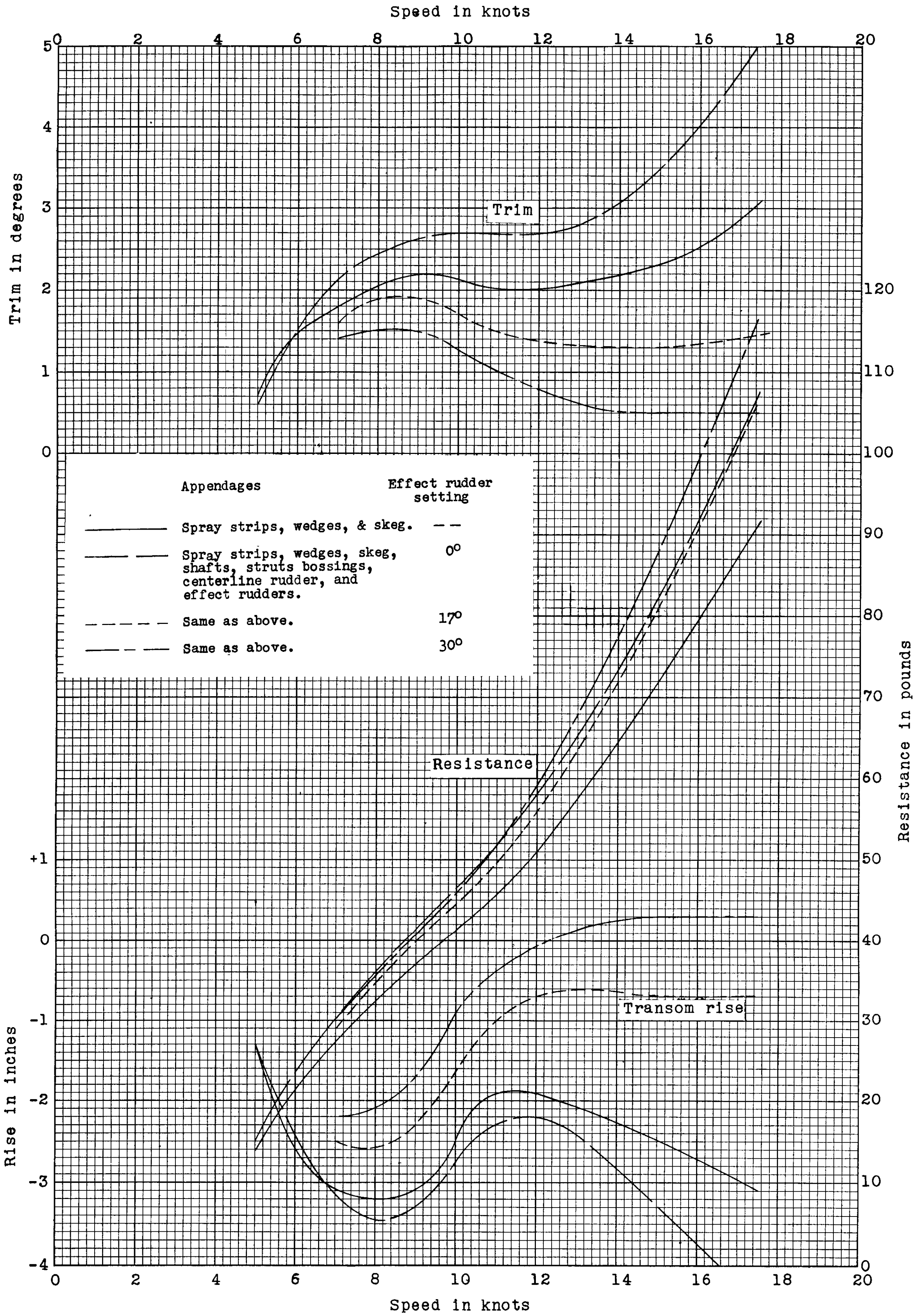


Figure 6 - Model resistance, stern rise and trim.
Displacement, 406.1 lb.

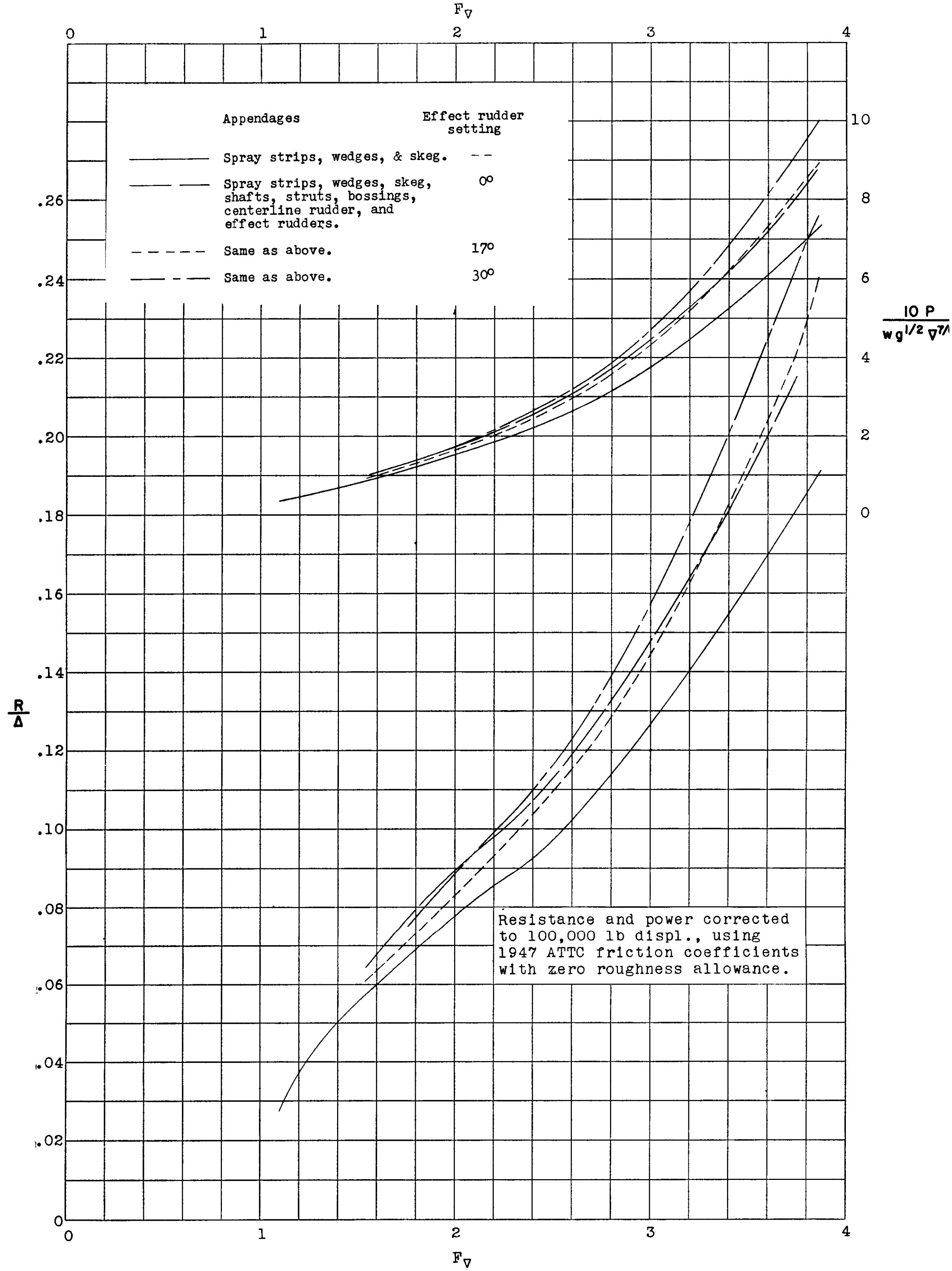


Figure 7 - Resistance and power coefficients versus speed coefficient. $L/\nabla^{1/3}=7.26$ (Model displ.=370.4 lb).

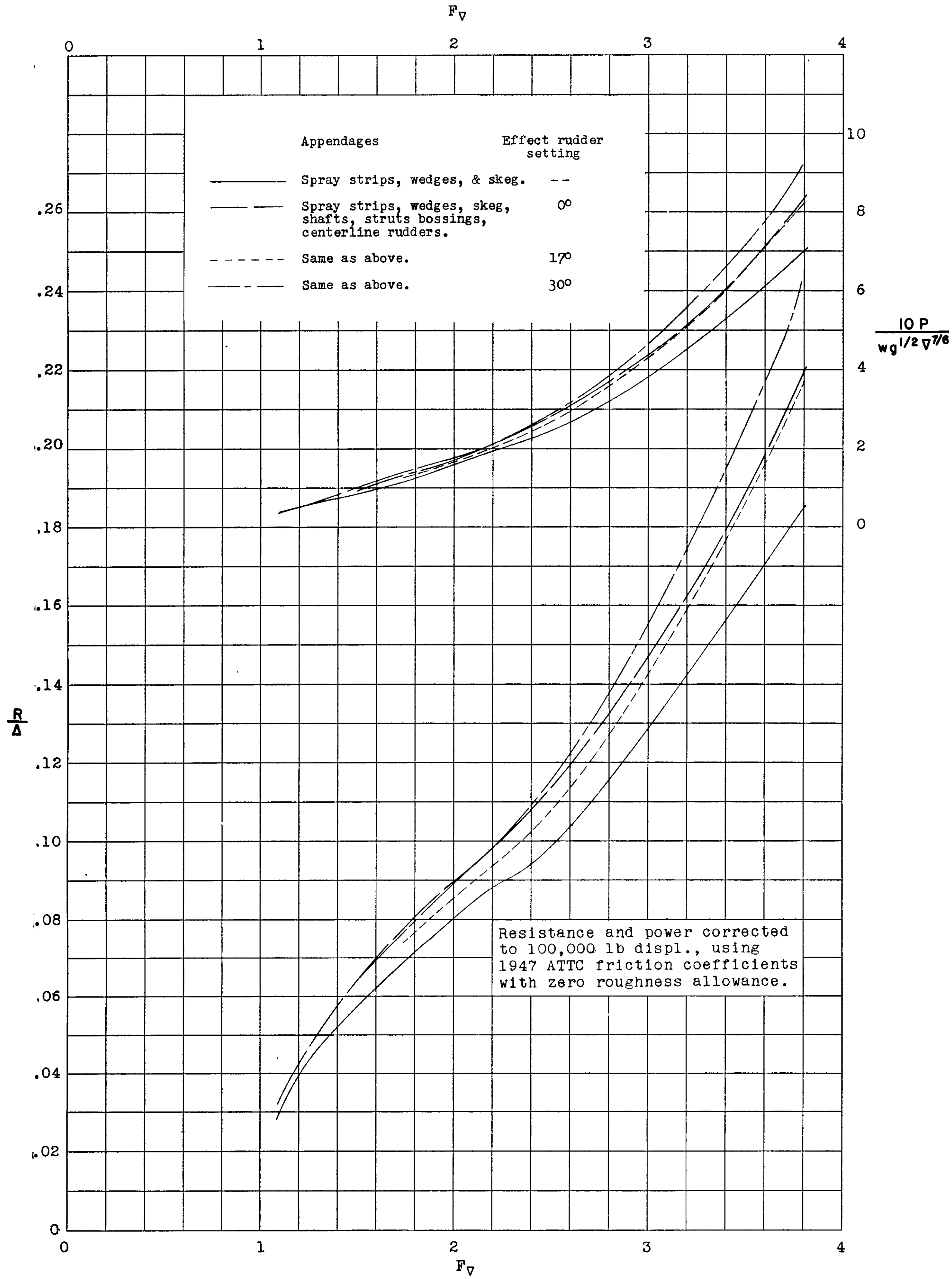
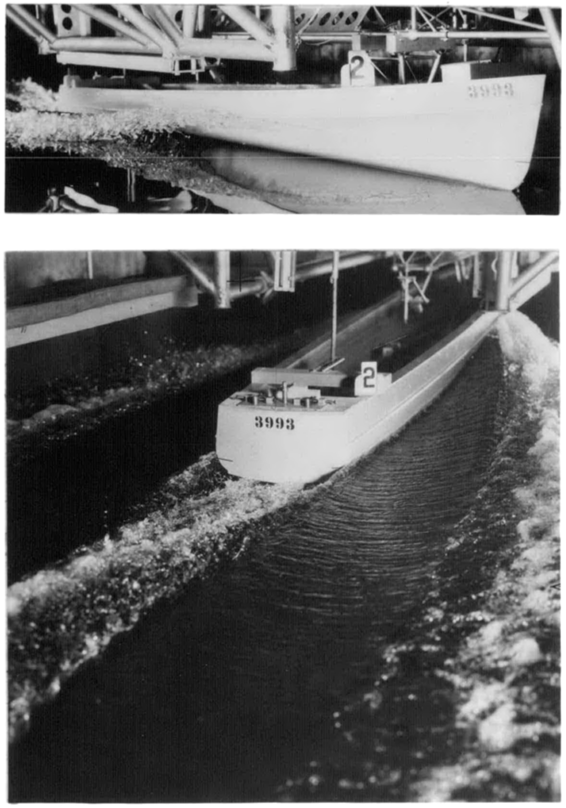
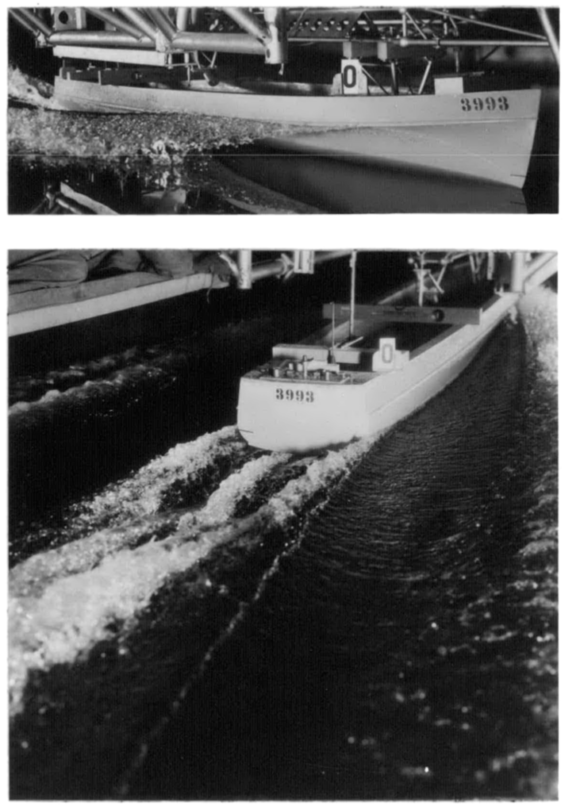


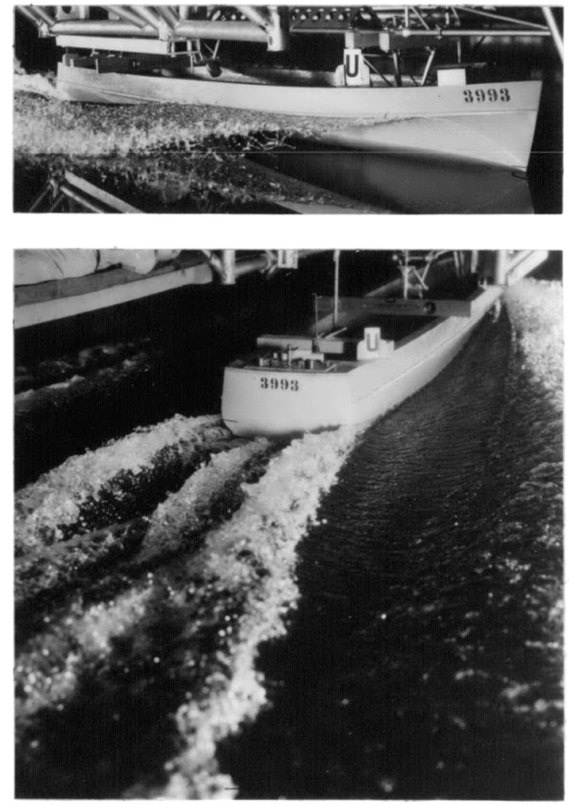
Figure 8 - Resistance and power coefficients versus speed coefficient. $L/\nabla^{1/3}$=7.05 (Model displ.=406.1 lb).



Effect rudders 0°



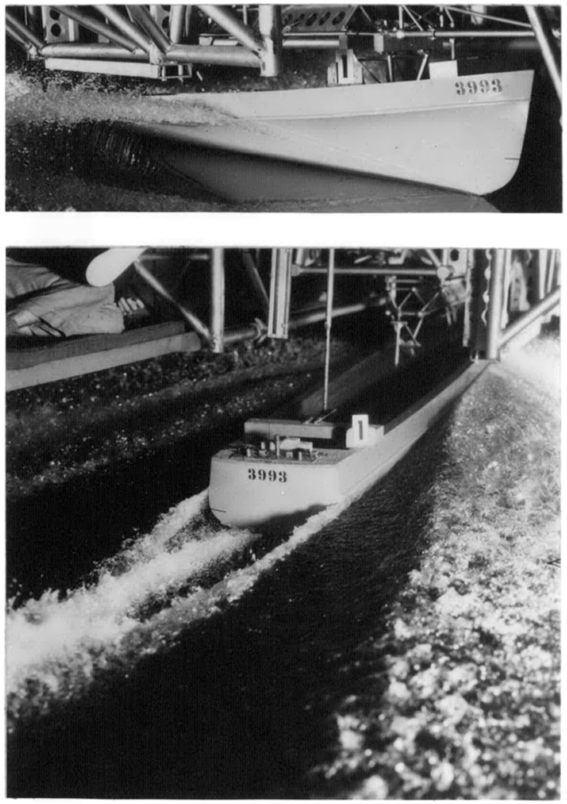
Effect rudders 17°



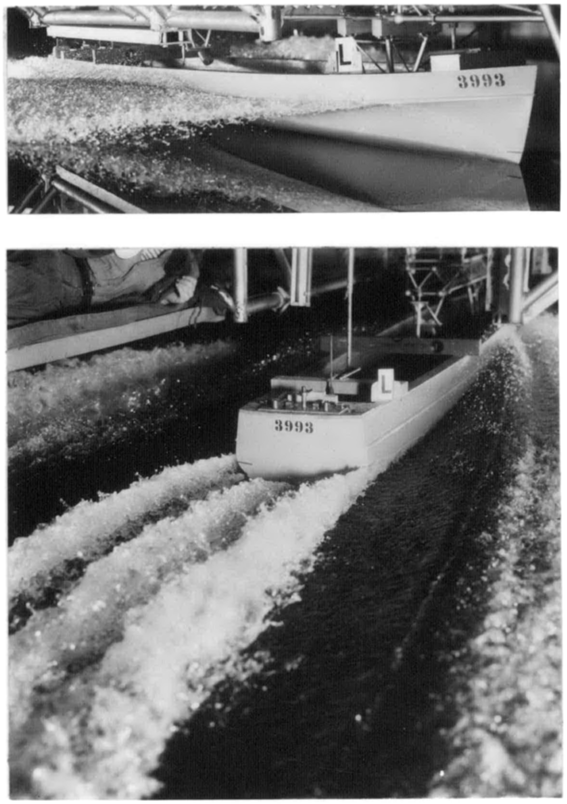
Effect rudders 30°

(b) Model speed, 12.0 knots; F_{∇}=2.66

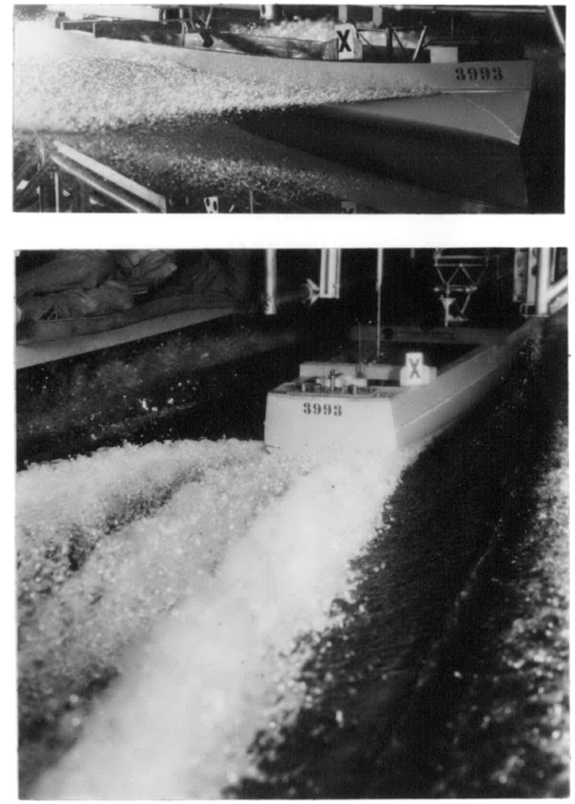
Figure 9 - Continued



Effect rudders 0°



Effect rudders 17°



Effect rudders 30°

(c) Model speed, 17.5 knots; F_∇=3.87

Figure 9 - Concluded

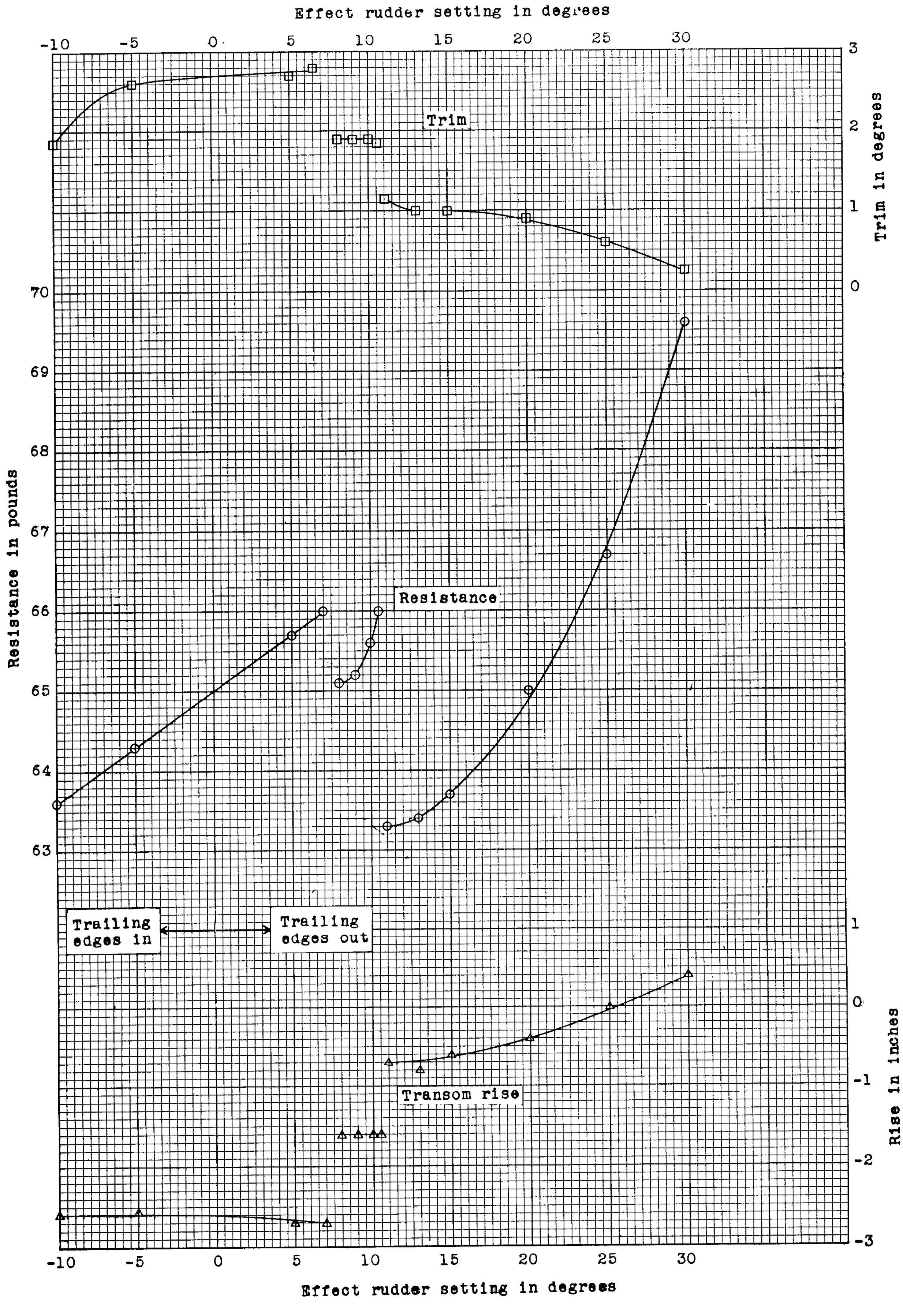


Figure 10 - Variation of model resistance, trim and transom rise with effect rudder setting. Model displacement, 336.04 lb; model speed, 13.72 knots.

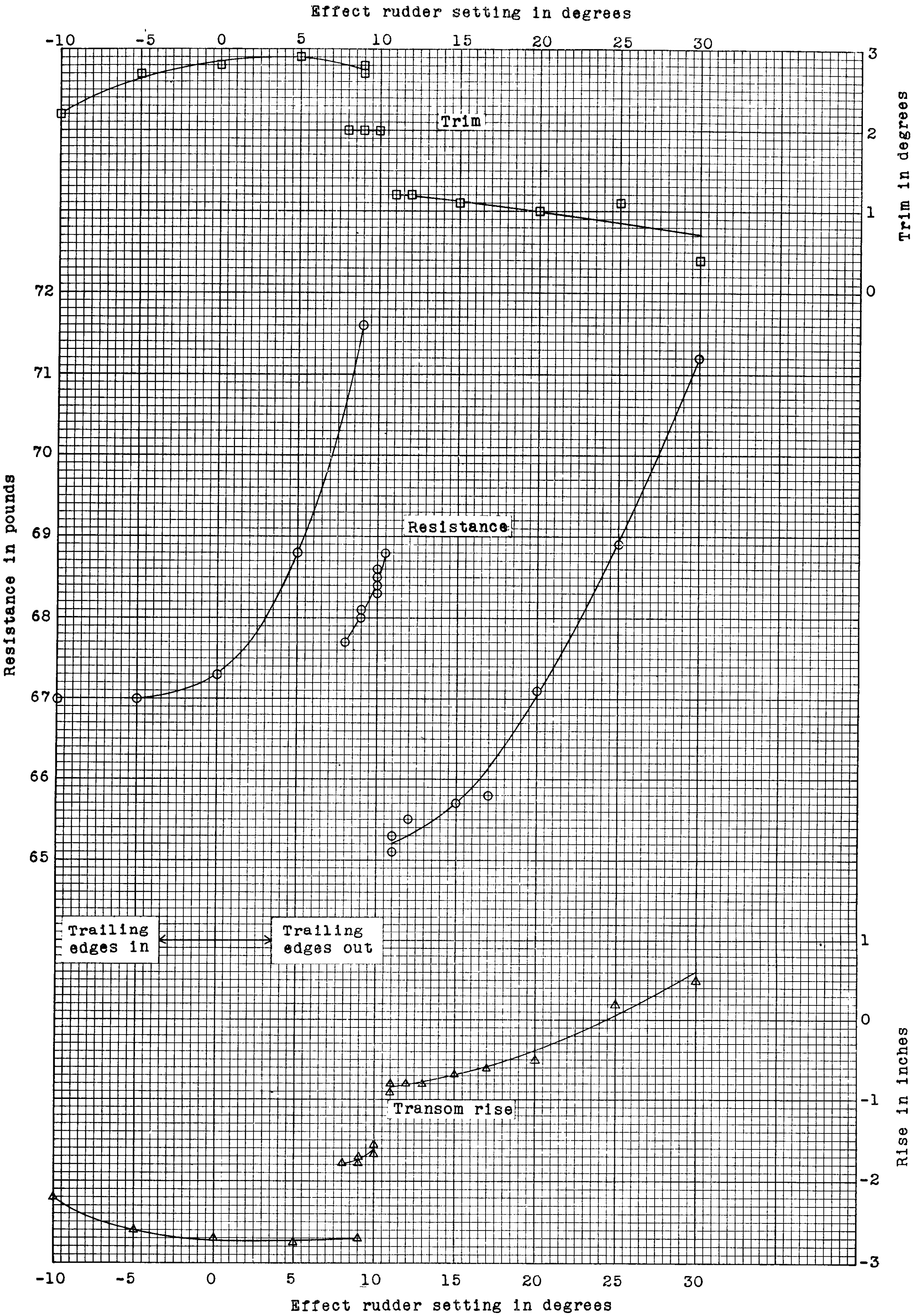


Figure 11 - Variation of model resistance, trim and transom rise with effect rudder setting. Model displacement, 370.4 lb; model speed, 13.72 knots.

Effect rudder setting, 9°;
neither rudder ventilated.

Effect rudder setting, 9°;
Stbd rudder ventilated.

Effect rudder setting, 12°;
both rudders ventilated.

Figure 12 - Photographs showing wake with different conditions of ventilation of effect rudders. Model displacement, 370.4 lb; model speed, 13.72 knots.

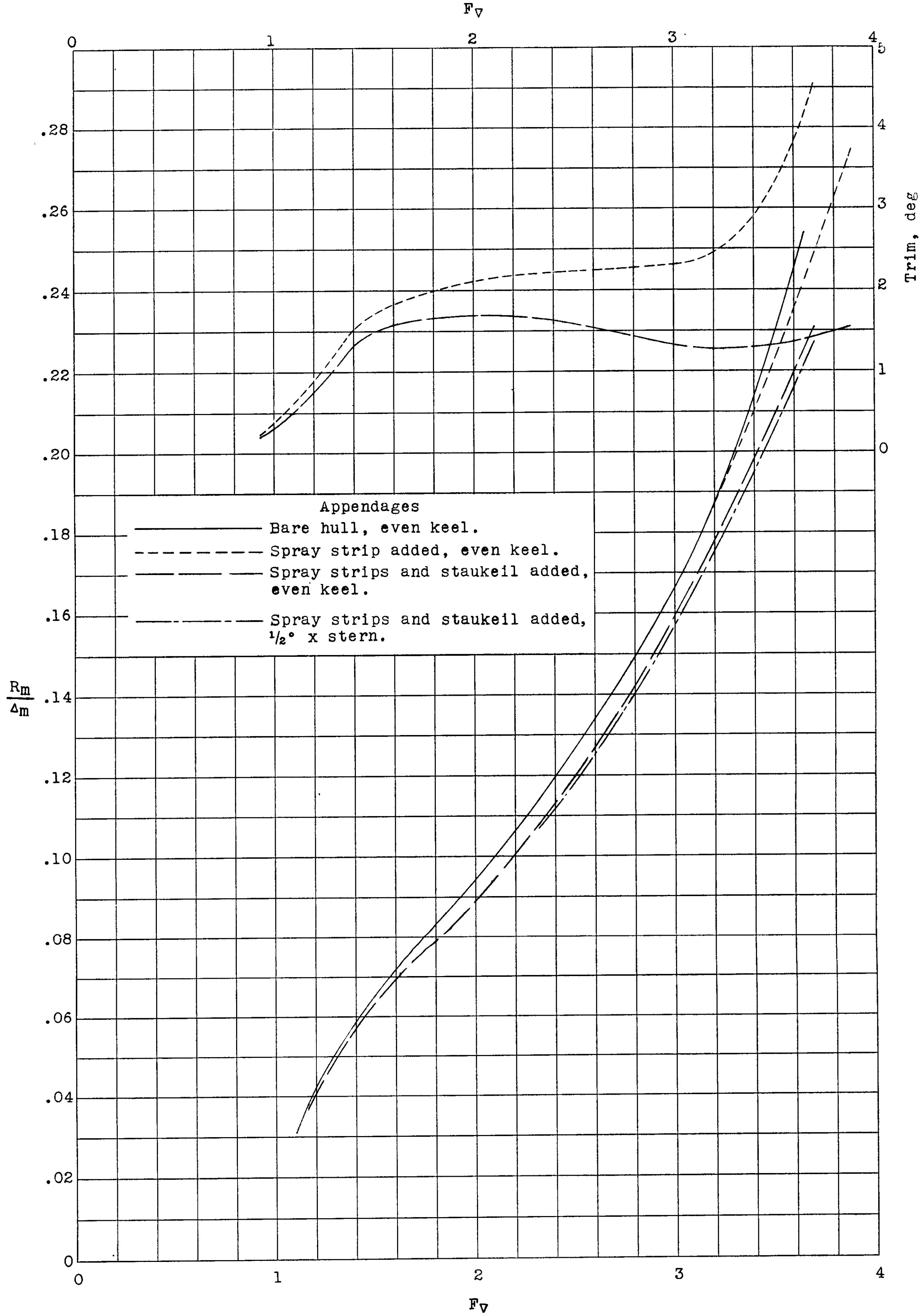


Figure 13 - Resistance and trim of HSVA Model 2081. Displacement, 283.0 lb.

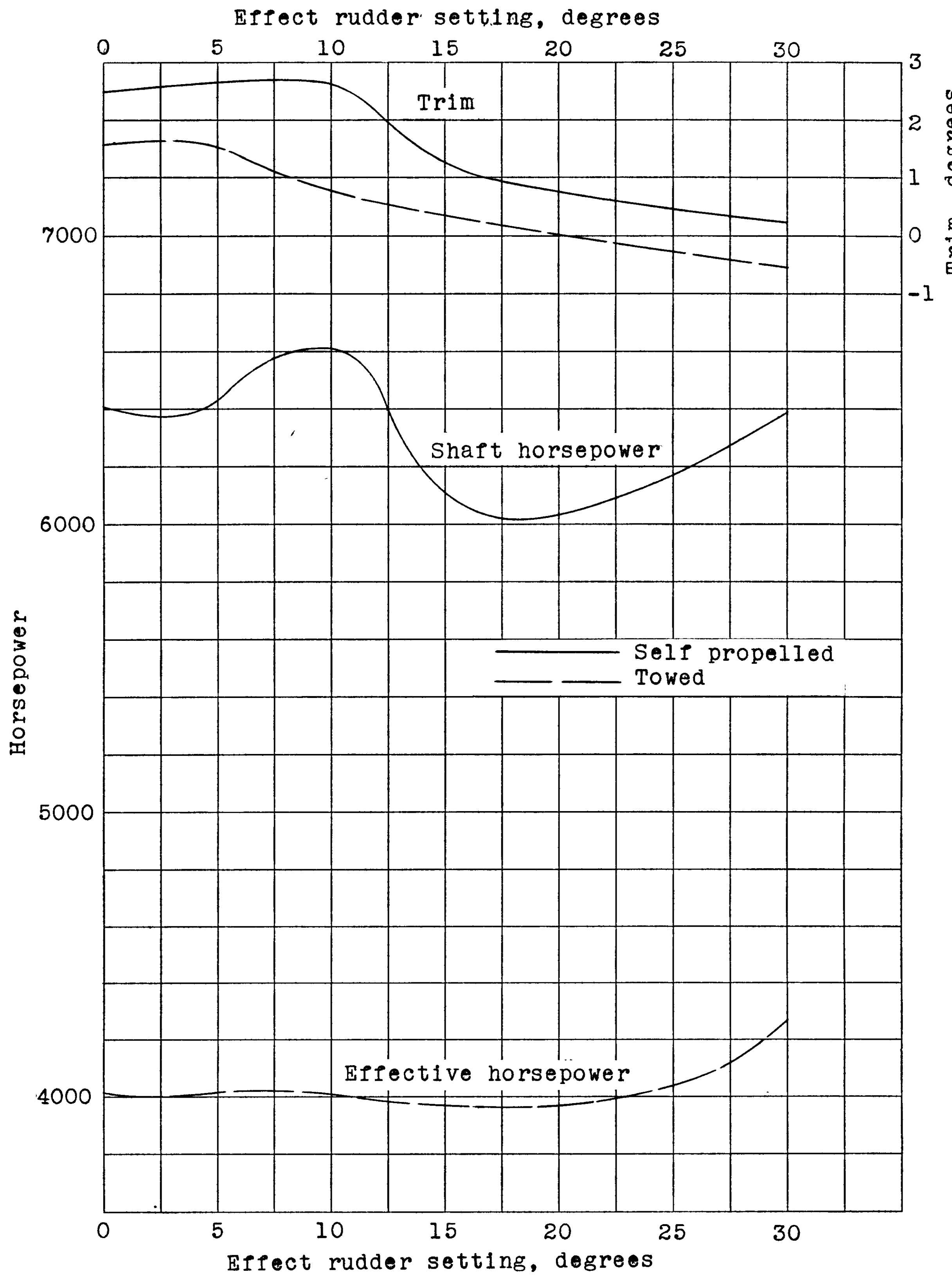


Figure 14 - Variation of EHP, SHP and trim with effect rudder setting, from towed and self-propelled tests of HSVA Model 2081. Full scale displacement, 94.72 tons; speed, 40 knots; appendage arrangement A.

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1. Motor torpedo boats--Resistance--Model tests
2. E-boat (German speedboat)
3. Ship models--Model TMB 3993
4. Ship models--Model HSVA 2081

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