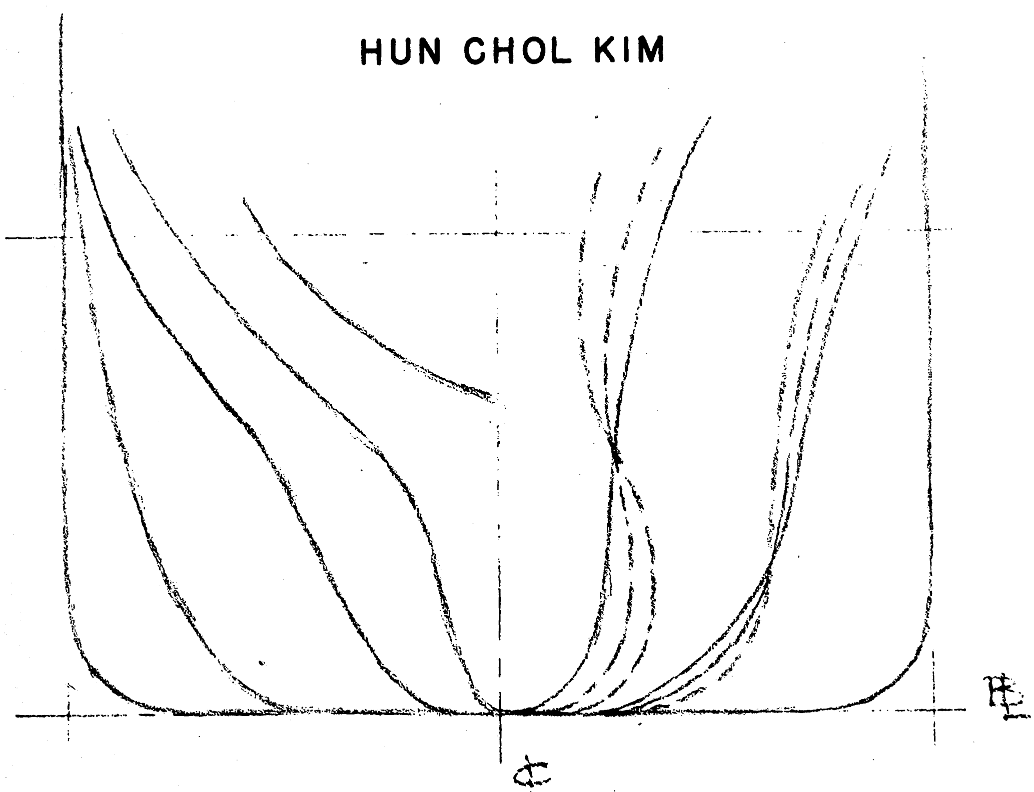
THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING

DEPARTMENT OF NAVAL ARCHITECTURE AND MARINE ENGINEERING

RESISTANCE TESTS ON THREE SERIES 60 BULBOUS BOW MODELS

HUN CHOL KIM



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(Under partial sponsorship of the
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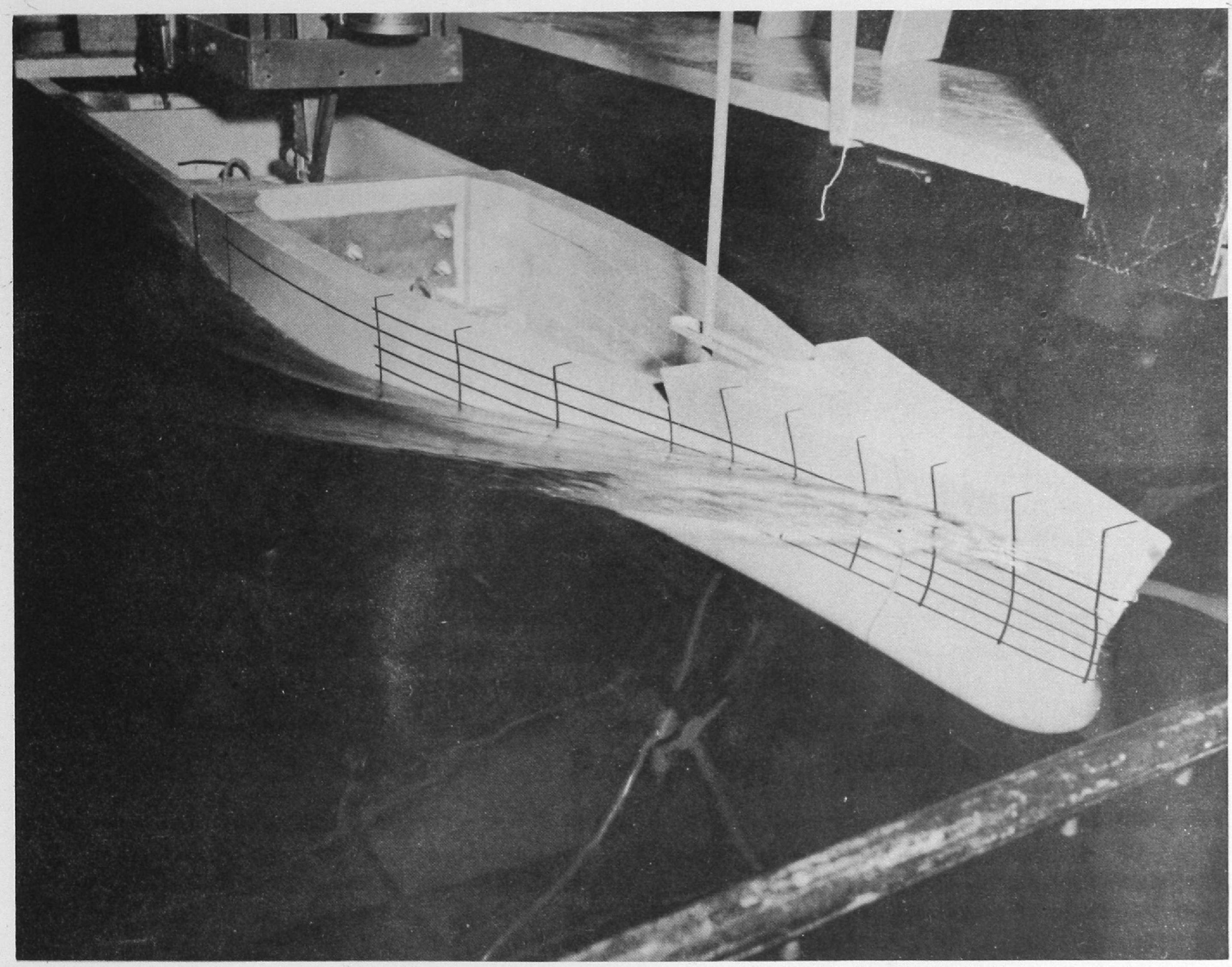

Nine Percent Bulb Model at Trial Speed

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1. INTRODUCTION

The original Series 60 investigations were confined to normal hull forms and it was the intention that variations such as bulbous bows be subject to later research. This report concerns one such project, namely an investigation of a systematic set of variations on the Series 60 form in which bulbous bows of differing size are used. The basic hull form is the Series 60 with block coefficient of 0.70 (DTMB No. 4259). Resistance tests were conducted on the basic hull form as well as on three bulbous bow models with bulb sizes of three, six and nine percent.

All models were $12\frac{1}{2}$ feet (150 inches) long, and the ratio of the model midship sectional area to that of the tank sectional area was 0.52 percent.

Model identification is as follows:

Zero percent bulb model - U of M 902A (Parent)

Three percent bulb model - U of M 902B

Six percent bulb model - U of M 902C

Nine percent bulb model - U of M 902D

Particulars of the U of M 902 Series are given in Table I.

TABLE I

CHARACTERISTICS OF MODELS

	PARENT 902A, 0%	902B, 3%	902C, 6%	902D, 9%
C_{PV}	0.890	0.897	0.902	0.913
C_{PVF}	0.940	0.960	0.977	1.009
C_{PVA}	0.846	0.846	0.846	0.846
C_W	0.8052	0.7990	0.7942	0.7852
C_{WF}	0.6943	0.6795	0.6682	0.6466
C_{WA}	0.8561	0.8561	0.8561	0.8561
C_{IT}	0.6786	0.6662	0.6609	0.6537
LCB, % LBP, ⌀	0.55A	0.53A	0.44A	0.39A
W.S., LWL	28.499 Ft^2	28.576	28.667	28.750
L/B	7.0	7.0	7.0	7.0
B/H	3.0	3.0	3.0	3.0
$L/\nabla^{1/3}$	5.944	5.944	5.944	5.944
$\Delta/(.01L)^3$	136.2	136.2	136.2	136.2
$S/\nabla^{2/3}$	6.444	6.461	6.482	6.501
L_E/LBP	0.420	0.420	0.420	0.420
L_X/LBP	0.119	0.119	0.119	0.119
L_R/LBP	0.461	0.461	0.461	0.461
C_B	0.700	0.700	0.700	0.700
C_X	0.986	0.986	0.986	0.986
C_P	0.710	0.710	0.710	0.710
C_{PF}	0.700	0.700	0.700	0.700
C_{PA}	0.721	0.721	0.721	0.721
C_{PE}	0.642	0.642	0.642	0.642
C_{PR}	0.698	0.698	0.698	0.698
$\frac{1}{2}\alpha_E$	11.6°	11.0°	10.5°	10.0°
Taylor t[1]	1.20	1.19	1.18	1.17

LBP = 150.00 in. ($12\frac{1}{2}$ ft.) Δ = 579.0 lbs. @ 73° F F.W.
LWL = 12.7094 ft.
B = 21.428 in.
H = 7.142 in.

[1] Taylor t as defined in D. W. Taylor, The Speed and Power of Ships, U. S. Government Printing Office, Washington, D.C., 1943, P. 65.

2. CONCLUSIONS

Test results are summarized in Section 4. Especially to be noted are Figures 7 and 9.

At the trial speed and service speed,[1] a four to five percent bulb appears to be optimum, but at speeds above or below this range a smaller bulb appears to be favorable.

The University of Michigan Model 902 correlates well with the DTMB 20-foot model if the 1947 ATTC (Schoenherr) friction extrapolator is used. However, the data obtained from U of M Model 902A are slightly lower than the corresponding values from DTMB model 4259. The best turbulence stimulator in this case appears to be a trip wire of 0.036-inch diameter tacked to the hull at five percent LBP from the fore perpendicular.

The following table is a quick appraisal of bulbous bows for a 400-foot ship at designed speeds as given for Series 60, 0.70 block.

TABLE II

EFFECTIVE HORSEPOWERS FOR 400-FOOT SHIPS

	Bulb	0%	3%	6%	9%
TRIAL	EHP	2,430	2,345	2,296	2,510
SPEED	RATIO	BASE	.965	.945	1.033
SERVICE	EHP	1,819	1,777	1,779	1,959
SPEED	RATIO	BASE	.977	.978	1.077

[1] Designed service speeds and trial speeds are specified in J. B. Hadler et al., "Propulsion Experiments on Single Screw Merchant Ship Forms - Series 60," TSNAME 1954, p. 148.

3. MODELS, THEIR DEVELOPMENT AND TESTS

In developing the bulb models, it was decided to keep the number of variations to a minimum. Variations were made systematically as shown in Figures 1 and 2. Figure 1 shows the composite body plan. It should be noted that ten forward stations (6.3" station spacing), parallel middlebody, and ten aft stations (6.915" station spacing) constitute the total length between the perpendiculars. Figure 2 shows the profiles and designed load waterlines of the bows. Shown on the profiles are buttocks at 20 percent of the half-beam (identified as .2B).

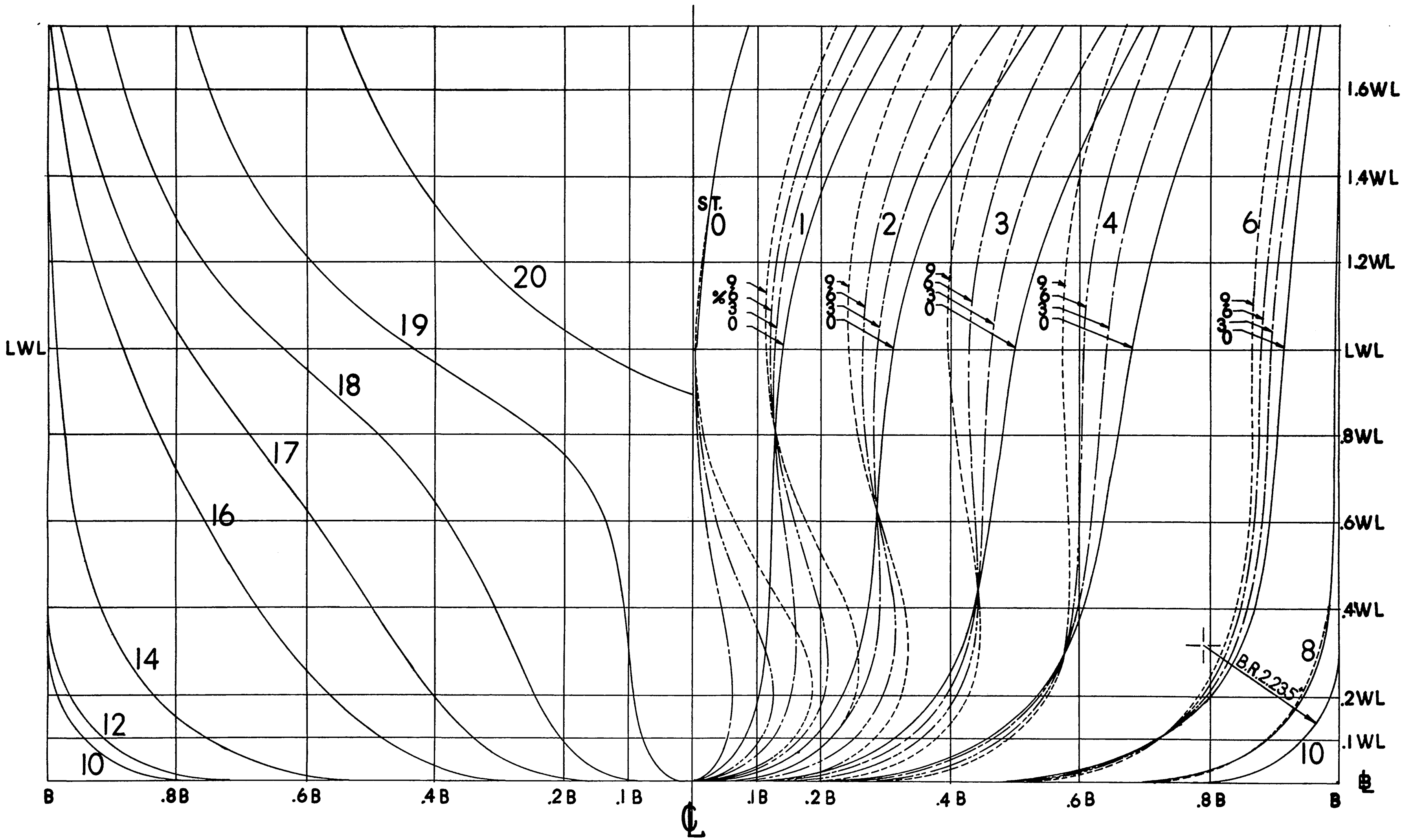
Bulb size is defined as the percentage of the extrapolated sectional area curve at the fore perpendicular divided by the midship sectional area. (All models actually have zero sectional area at the fore perpendicular.)

Figure 3 shows the sectional area curves from which the 902 Series was developed. From the forward shoulder of the parent sectional area curve at the load waterline, a suitable amount of area was removed and a corresponding amount added in the forefoot, keeping the displacement constant. Lines were developed to suit these modified sectional area curves as shown previously. Parallel middlebody and aft body have not been changed.

It was originally intended to provide a fairly high deadrise at the bow[1] since such deadrise is believed to be helpful in the prevention of slamming. On the other hand, a bulb is more effective in reducing resistance if its center is kept at the lowest possible point. As usual, a compromise had to be made, especially for the larger bulb models. Bulb waterlines were given as much parabolic entry as possible.

The models were built of layers of pine lumber joined with synthetic glue. They were hand carved to fit the templates, enamel painted four

[1] Harold E. Saunders recommends a deadrise angle of from 20 to 45 degrees (Hydrodynamics in Ship Design, Vol. II, SNAME, New York, 1957, pp. 510-513.) U of M 902B, 902C and 902D have 25, 15, and 8 degrees respectively.



SERIES 60
BULBOUS BOW VARIATIONS
(PARENT-TMB NO. 4259)

FIGURE 1. COMPOSITE BODY PLANS

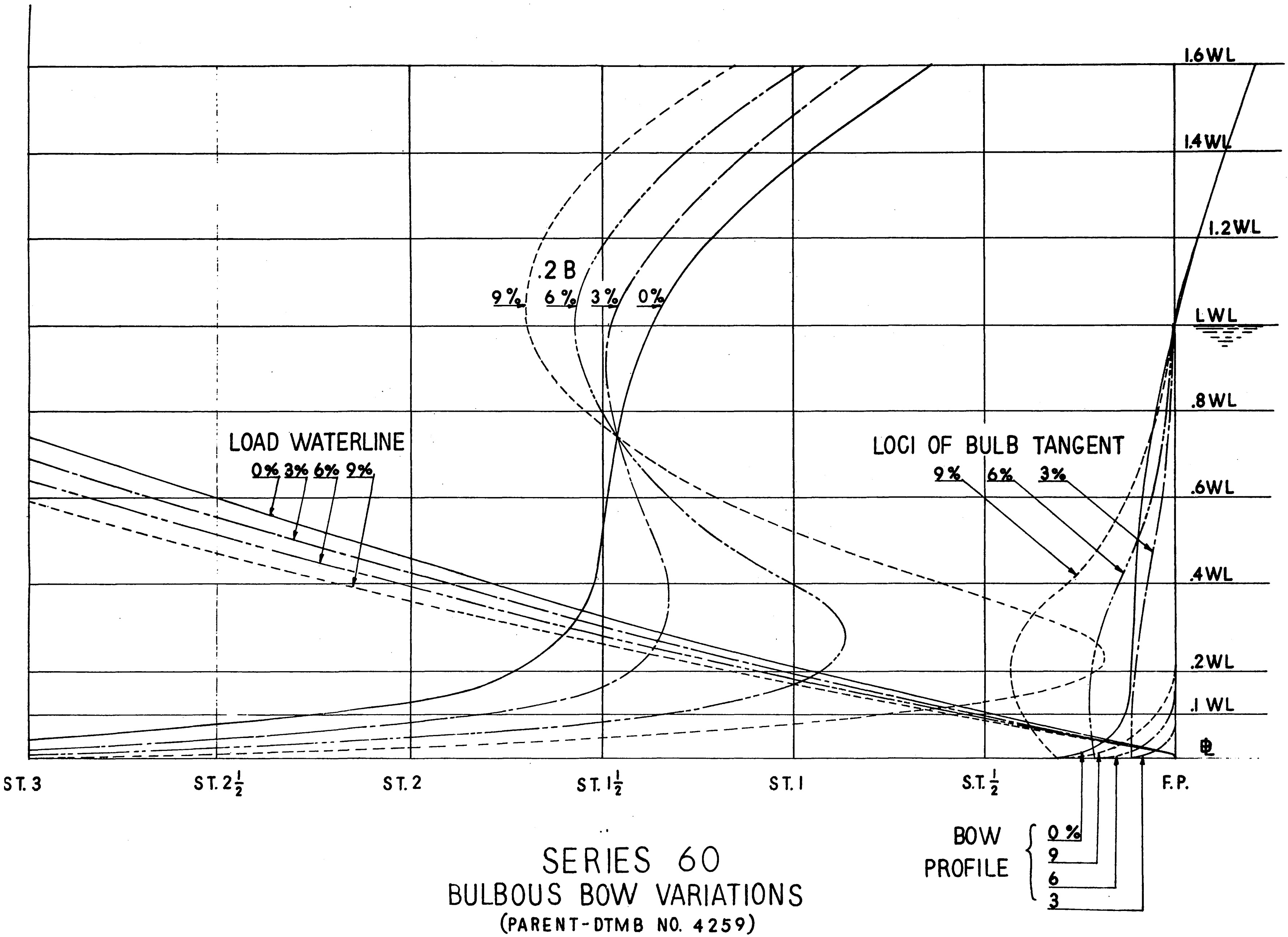


FIGURE 2. COMPOSITE PROFILES AND DESIGNED LOAD WATERLINES

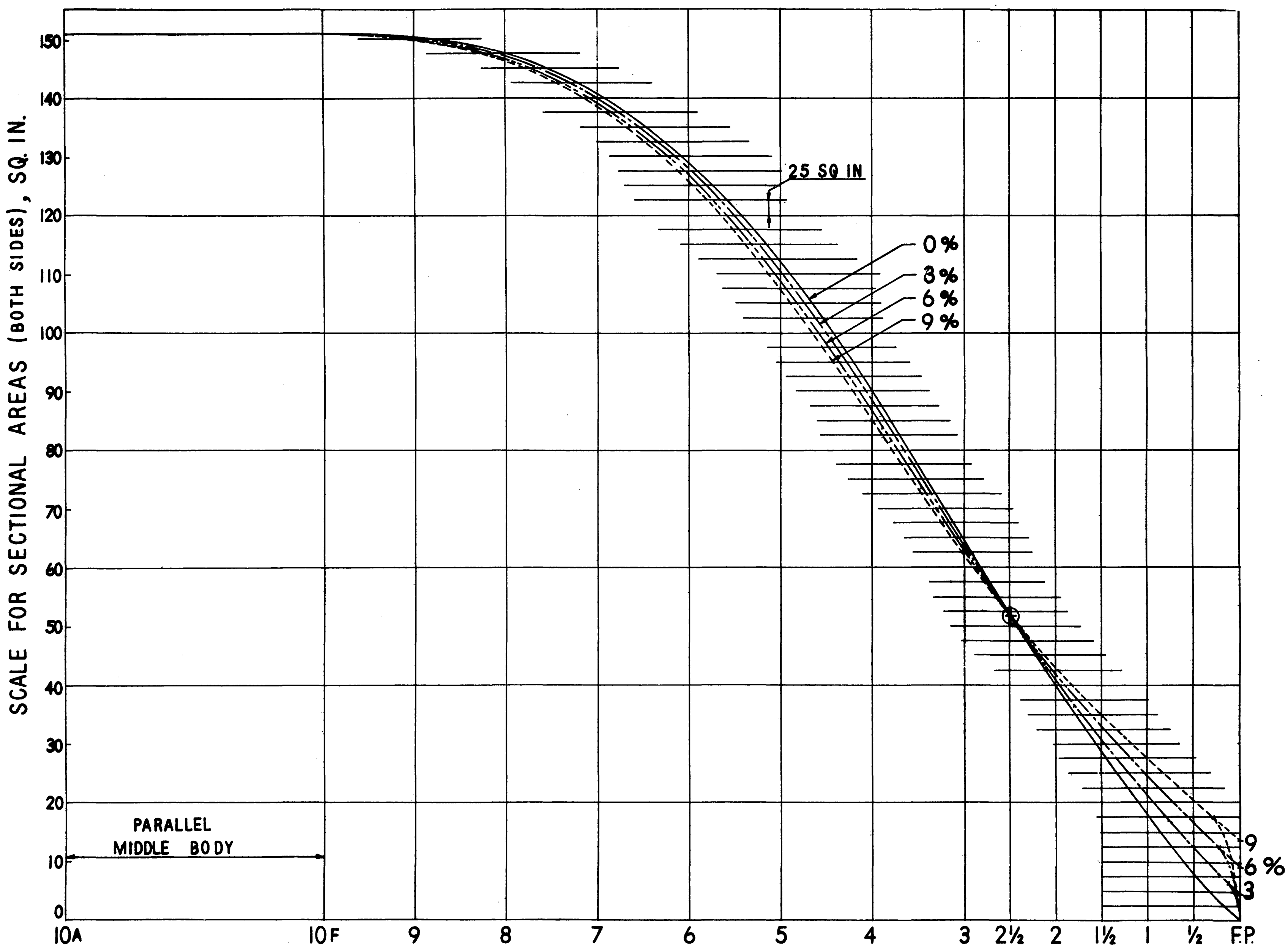


FIGURE 3. SECTIONAL AREA CURVES

to six times, and varnished following the normal practice at the Michigan tank. The connections between bow and the after body were faired by using wax. Figure 4 shows the finished models.

Studs and trip wires were individually tested for effectiveness of turbulence stimulation on the first model (902A). This experience led to the decision to use the trip wire on subsequent models. The details of both stimulators are given below.

1) 1/8 inch diameter, 1/10 inch high studs spaced one inch and placed about 3/4 inch from the stem.
2) 36/100 inch diameter trip wire placed at 5 percent LBP from the fore perpendicular.

Model 902A was also tested without benefit of turbulence stimulator.

Both Schoenherr and ITTC 1957 friction lines were tried in expanding the model 902A data. For other models, however, only the 1947 ATTC (Schoenherr) friction line was used since it gave better correlation with DTMB results.

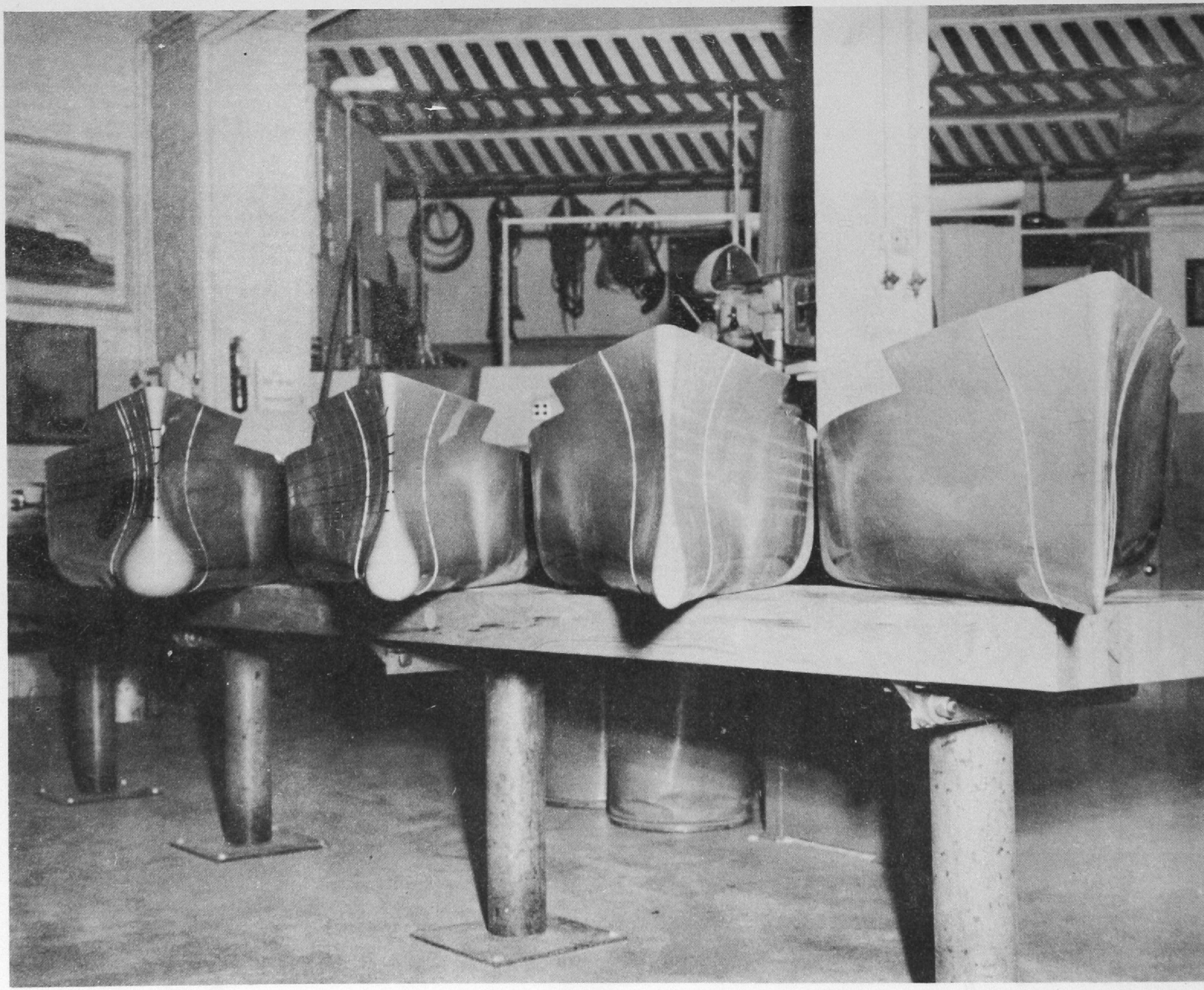


FIGURE 4. FINISHED MODELS. FROM THE LEFT ARE 902D, 902C, 902B, 902A, RESPECTIVELY.

4. TEST RESULTS AND DISCUSSION

The results of the tests at full load draft are summarized in Table III and Figure 5. They show the effect of bulb size on the residual resistance coefficient for varying speed-length ratios. Figure 6 shows the effect of various stimulators on the parent, model 902A, and the correlation with the data from the DTMB 20-foot model.

Figure 7 shows the same result as that of Figure 5 plotted in a different manner. A minimum residual resistance coefficient line may be effectively used to choose the optimum size bulb for a given speed at full-load draft. If the ship is expected to operate for a considerable time at partial displacement, resistance characteristics at reduced draft would also have to be taken into account. For this purpose, all models were also run at reduced draft, and results are shown in Figures 8 and 9. Reduced draft tests for all models were at 60 percent of full-load displacement with 3-3/4 inch trim aft ($2\frac{1}{2}$ percent LBP). At this condition, bulbs were partially exposed, and formation of waves at the forward end of the bulbs was observed. This may partially explain the higher residual resistance coefficients for model 902C (6 percent) and model 902D (9 percent).

Figures 10 and 11 show the bow waves generated at service speed and at trial speed respectively, plotted on the composite body plan. These were obtained from the photographs, similar to the frontispiece, of wave profiles at various speeds. During the tests, bow wave humps and hollows were noted to be more distinct with the larger size bulb. These were noted to shoot up along the surface of the model. In the case of a ship, however, owing to the difference in the relative amount of viscosity, some of this wave, especially the first peaks in Figures 10 and 11 forward of Station 1, would probably break up sooner.

TABLE III

RESIDUAL RESISTANCE COEFFICIENTS x 10^3
U OF M 902 BULBOUS BOW SERIES

BULB / $V/\sqrt{L_{WL}}$	0% 902A	3% 902B	6% 902C	9% 902D
.40	.795	.680	.680	.680
.45	.800	.720	.760	.760
.50	.830	.775	.820	.825
.55	.870	.830	.890	.940
.60	.915	.880	.940	1.050
.65	.960	.910	.965	1.160
.70	1.030	.960	.960	1.220
.75	1.145	1.050	1.000	1.240
.80	1.310	1.170	1.500	1.440
.825	1.430	1.270	1.180	1.270
.85	1.590	1.400	1.310	1.350
.875	1.800	1.600	1.545	1.690
.90	2.200	1.950	2.100	2.200

The wetted surfaces of the models do not change appreciably as the bulb size is changed. Also, the wave profile along the aft body was found to vary little for different bulb sizes. The 6 percent bulb, model 902C, it will be noted, shows comparatively flat wave profiles which may have direct correlation with the superior performance of the model at the trial and service speeds.

It was originally intended that these tests be extended to include other block coefficients. However, the emergence of the Inui bulb offers much more promise than these conventional bulbs and for the immediate future,research should be concentrated in that direction.

FIGURE 5

EFFECT OF BULB SIZE ON RESIDUAL RESISTANCE COEFFICIENT AT FULL-LOAD DISPLACEMENT

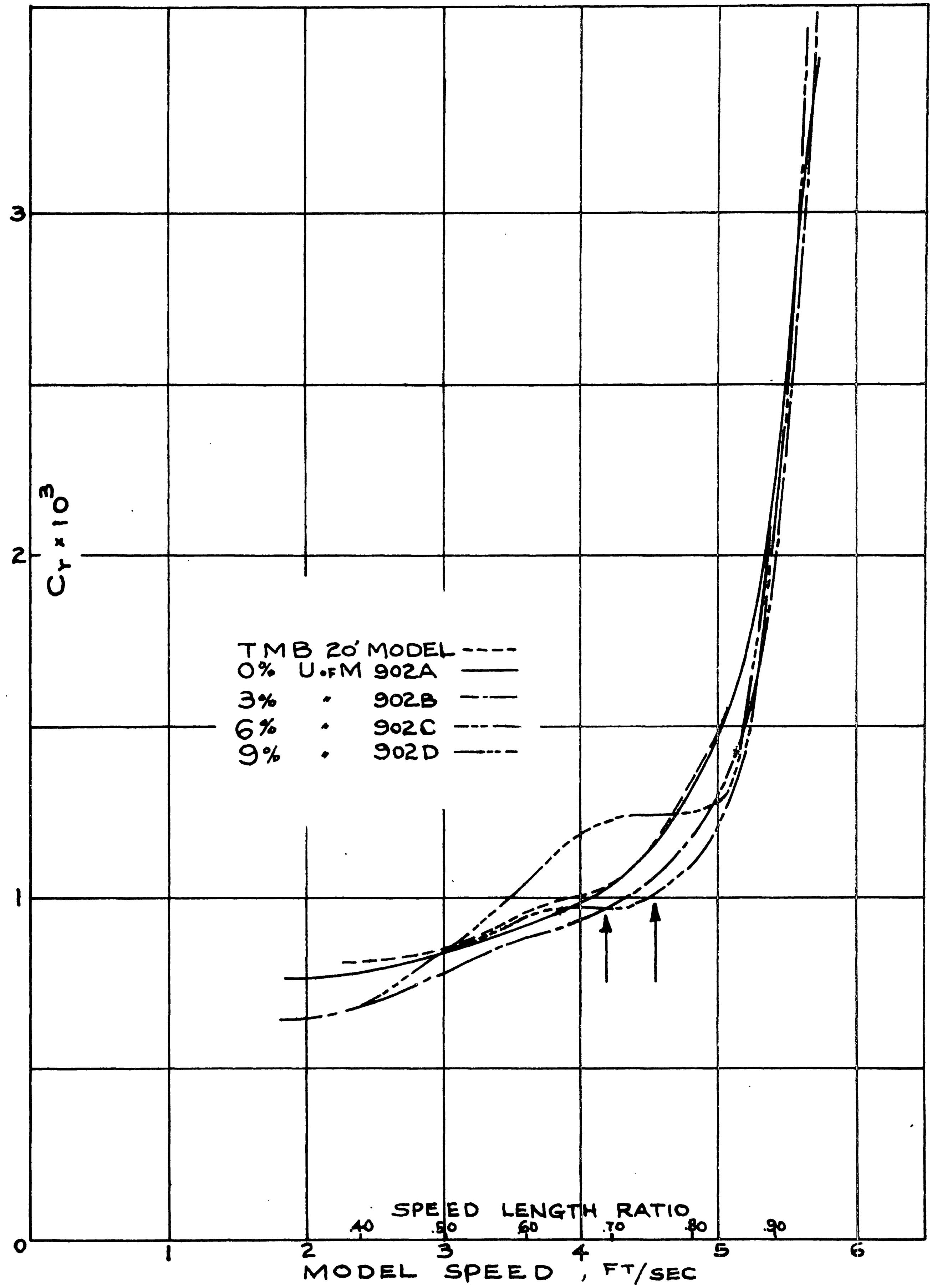


FIGURE 6

EFFECT OF TURBULENCE STIMULATORS ON
RESIDUAL RESISTANCE COEFFICIENT FOR MODEL 902A; 0 PERCENT

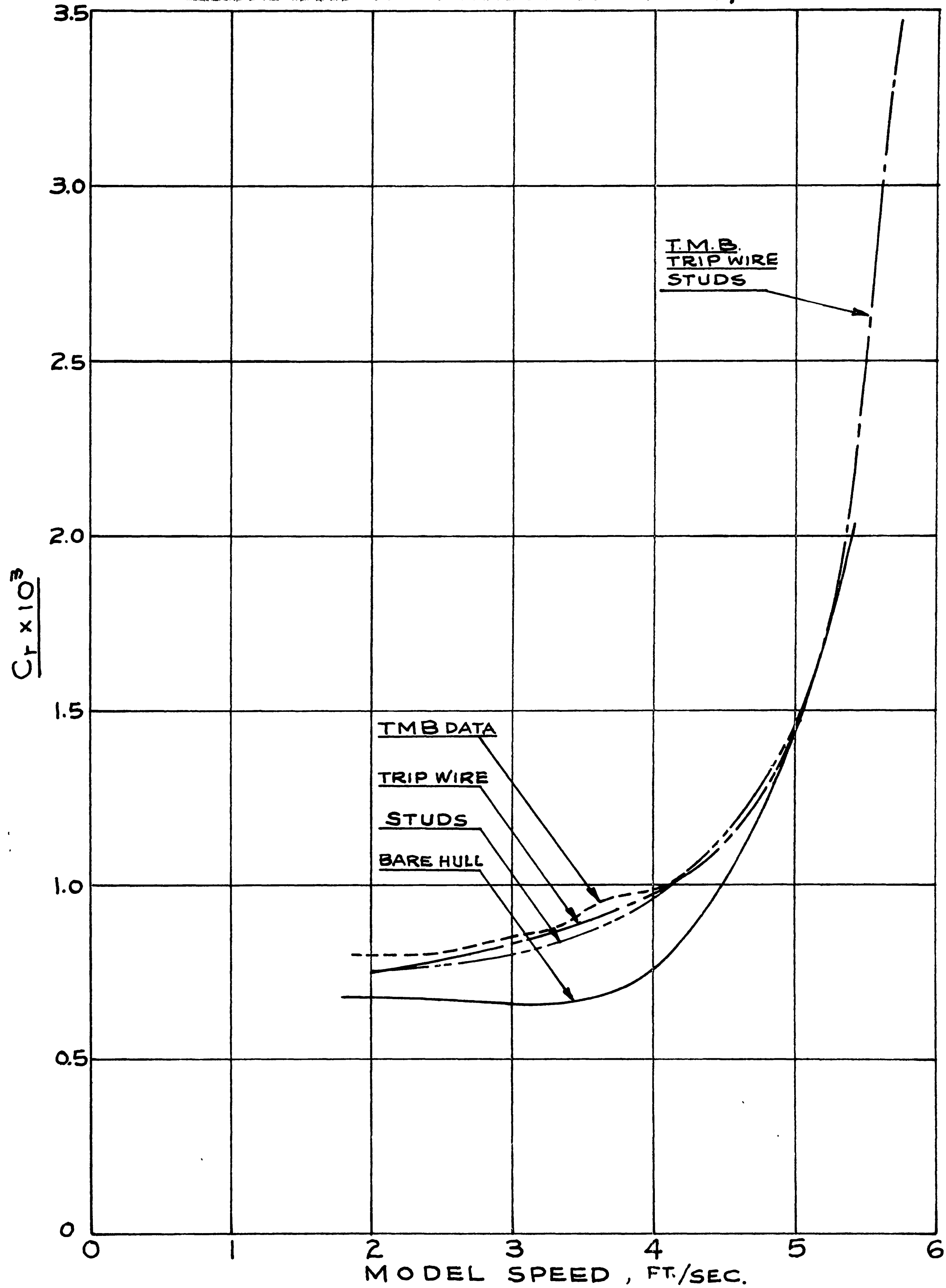
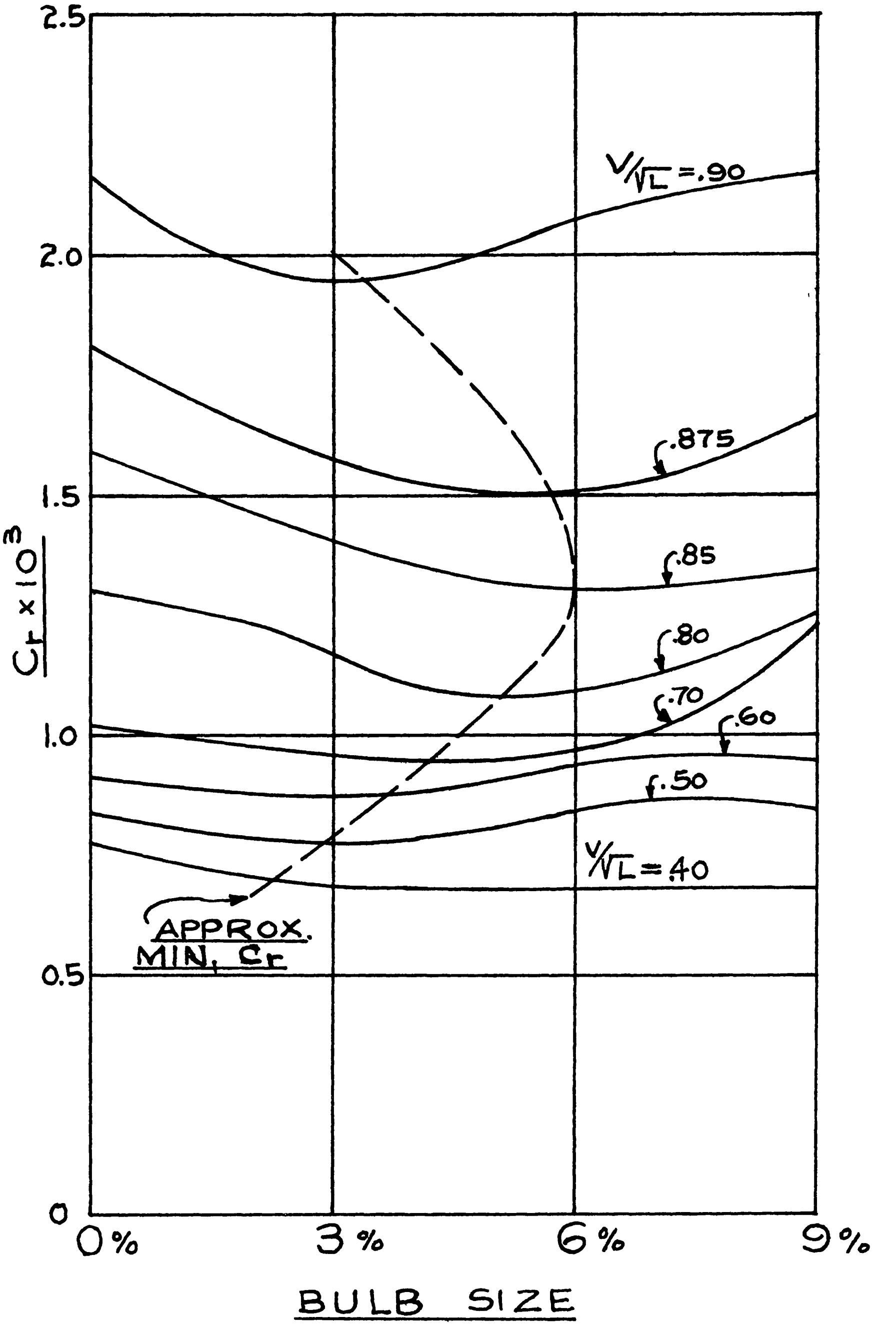


FIGURE 7

EFFECT OF BULB SIZE ON RESIDUAL RESISTANCE COEFFICIENT FOR VARYING SPEED-LENGTH RATIO AT FULL-LOAD DISPLACEMENT



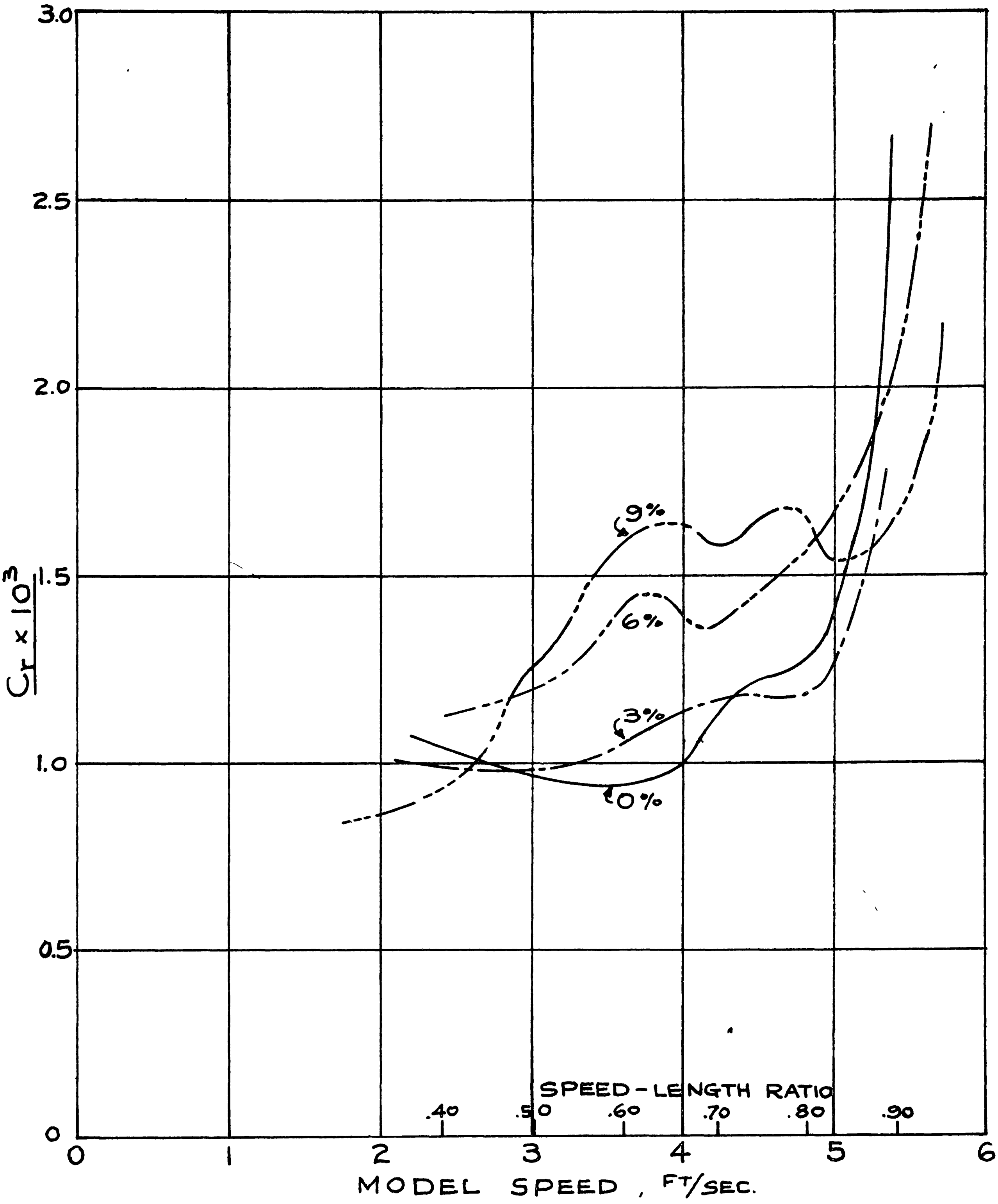
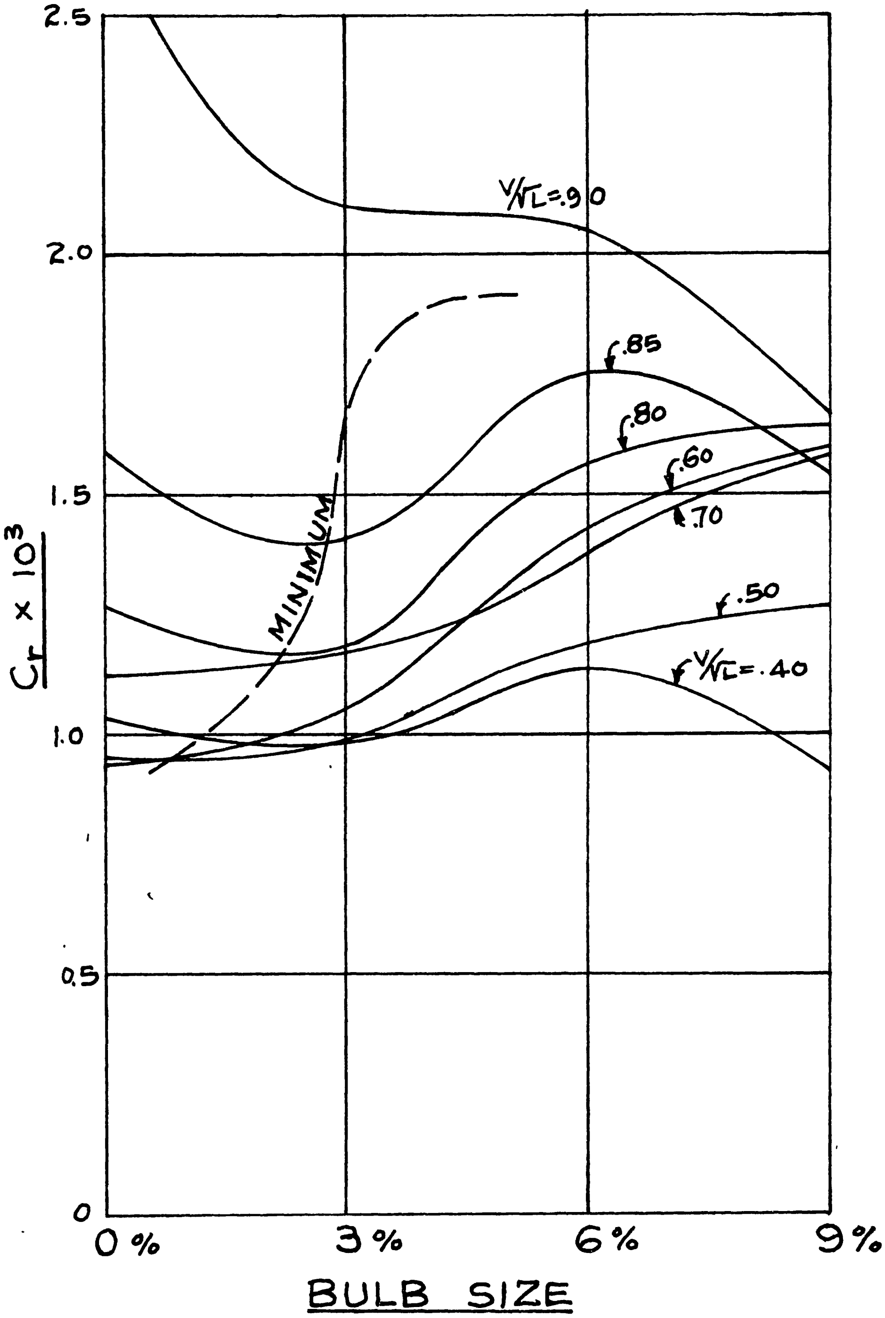


FIGURE 8

EFFECT OF BULB SIZE ON RESIDUAL RESISTANCE
COEFFICIENT AT 60 PERCENT OF FULL-LOAD DISPLACEMENT

FIGURE 9

EFFECT OF BULB SIZE FOR DIFFERENT SPEED LENGTH RATIO AT 60 PERCENT OF FULL-LOAD DISPLACEMENT



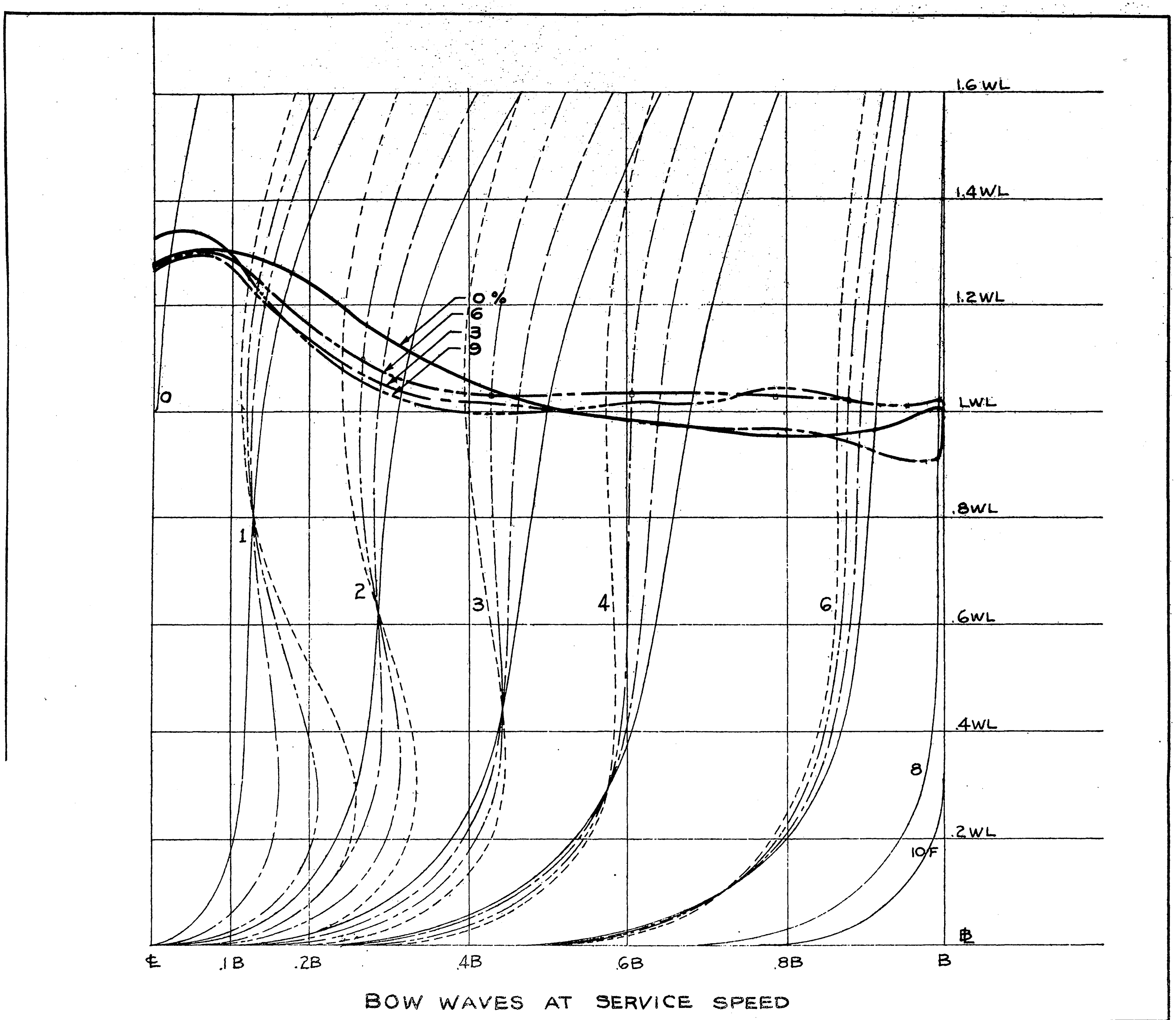


Figure 10. Wave Profiles Generated at the Service Speed on Body Plans

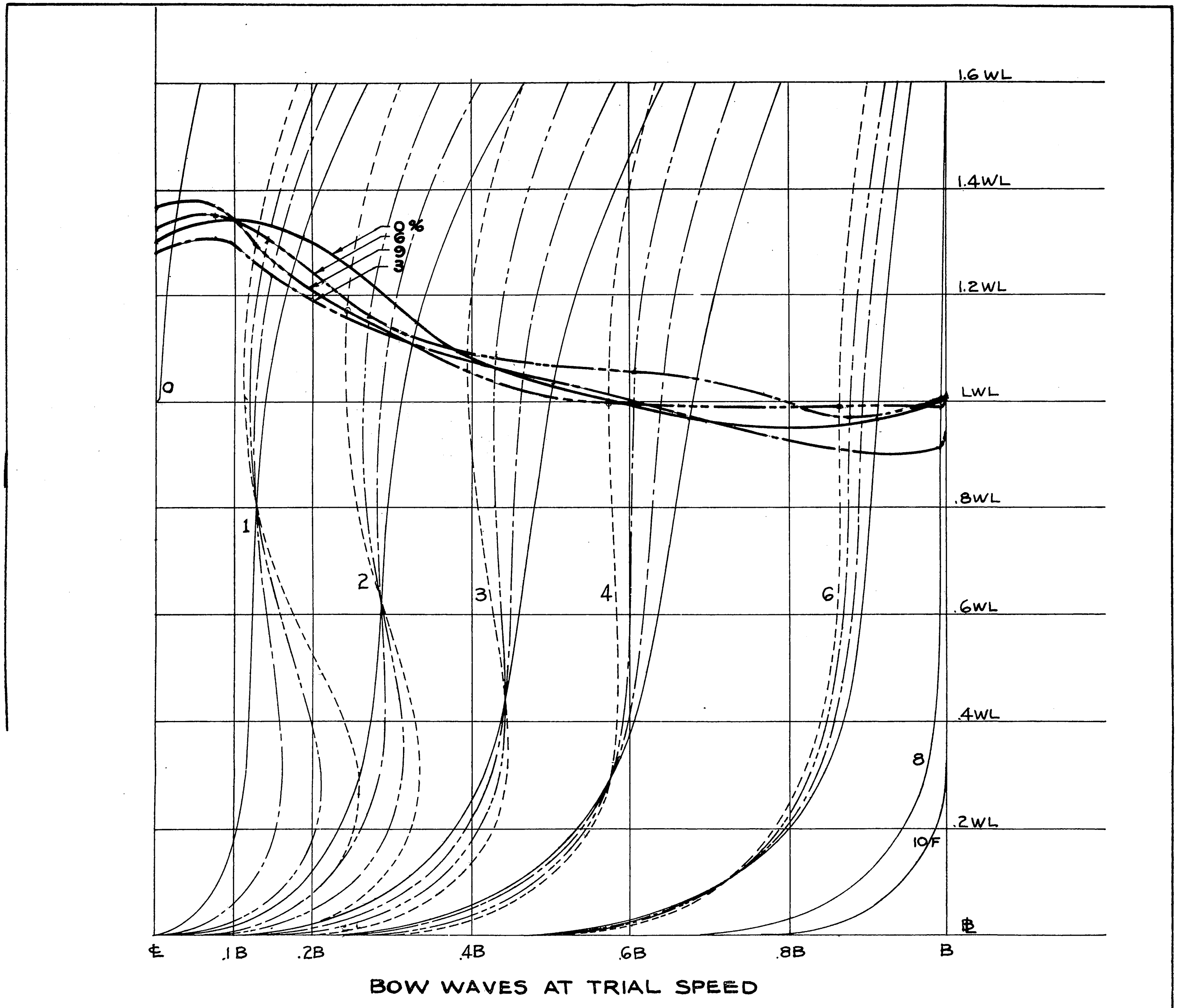


Figure 11. Wave Profiles Generated at the Trial Speed on Body Plans

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