TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 858

A COMPARISON OF THE RESULTS FROM GENERAL TANK TESTS OF 1/6- AND 1/12-FULL-SIZE MODELS OF THE BRITISH SINGAPORE IIC FLYING BOAT

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SUMMARY

A 1/6-full-size model of the hull of the British Singapore IIC flying boat was tested in the NACA tank. The results are given in the form of charts and are compared with the results of previous tests made in the NACA tank of a 1/12-full-size model, published in NACA T.N. No. 580, and with the results of tests made in the British R.A.E. tank of another 1/6-full-size model of the same hull.

When the data from the tests of the 1/6- and 1/12-full-size models were compared on the basis of Froude's law of comparison, differences were found. This fact supported the belief that the small scale of the model and the use of a model that was too small to suit the equipment of the NACA tank had caused the results of the tests of the 1/12-full-size model to be less reliable than the results of the tests of the 1/6-full-size model. The results of the tests of the two models agreed sufficiently well to show that tests of a small model, if made meticulously and with suitable equipment, may give usable results, but that a larger model should be used whenever feasible.

The results of the NACA tests of the 1/6-full-size model were found to be in good agreement with the R.A.E. tests of a model of the same size.

INTRODUCTION

A 1/6-full-size model and a 1/12-full-size model of the hull of the British Singapore IIC flying boat have been tested in the R.A.E. tank and the results of these tests have been reported in reference 1. The 1/12-full-size model was later loaned to the NACA by the Director of Research, British Air Ministry, for comparative tests in the NACA tank. The NACA tests of the 1/12-full-size model were reported in reference 2. The model, which was 4 feet 7 inches long, was so small that, although the results appeared to be fairly good and to compare well with the results of the tests of the same 1/12-full-size model in the R.A.E. tank, it was thought probable that tests of a model better suited to the equipment of the NACA tank might give somewhat different results. The question involved not scale effect alone but a combination of scale effect with possible error in the measurement of quantities that were very near the lower limit of the capacity of the NACA equipment. It was therefore considered desirable to test a 1/6-full-size model of the Singapore IIC and provide data for comparison with the NACA tests of the 1/12-full-size model and the R.A.E. tests of the 1/6-full-size model as well as comparisons with the NACA tests of a number of other models of approximately the same size. A 1/6-full-size model reproducing as nearly as feasible every feature of the 1/12-full-size model was made and tested in a manner paralleling as far as possible the tests of the 1/12-full-size model. The tests were made in 1936. The results of the tests have been presented in the same form as in reference 1.

THE MODEL

Photographs of the 1/12-full-size model (model 58) are shown in figure 1.

The 1/6-full-size model was constructed from offsets obtained by doubling those of the 1/12-full-size model. The model was made of laminated wood, sanded, varnished, and rubbed. The 1/12-full-size model had been refinished before it was tested and the finish of the present model was made the same as that of the smaller model.

The principal dimensions and ratios of the 1/6-full-size model are as follows:

Over-all length, in.	109.86
Length, bow to second step, in.	97.20
Forebody length, in.	54.78

Afterbody length (main step to second step), in.	42.42
Maximum beam, in.	21.60
Depth of main step, in.	1.04
Depth of main step, percent of beam	4.81
Center of gravity forward of step, in.	5.80
Center of gravity above keel, in.	26.50
Angle of dead rise at main step (angle between horizontal and line drawn from chine tangent to keel), deg.	18.5
Angle between keel aft of main step and keel forward of main step, deg.	7.0
Forebody, percent of length to second step	56.4
Maximum beam, percent of length to second step	22.2

APPARATUS AND PROCEDURE

A description of the NACA tank and the towing carriage is given in reference 3. The towing gear used in these tests is described in reference 4.

The model was tested by the general method in the same manner that the 1/12-full-size model was tested with the center of moments at the position of the center of gravity. The model was tested at the same trims and through ranges of load and speed corresponding to the ranges through which the 1/12-full-size model was tested, the ranges being increased in accordance with Froude's law of comparison for the increased size of the model. In order to facilitate direct comparisons, the load parameters that were tested were made to correspond with those used in the tests with the smaller model. (There was no change in the density of the water between the tests of the two models.)

In addition to the fixed-trim tests a general free-to-trim test, which did not include high speeds, was made. In the free-to-trim test the model was balanced to bring the center of gravity of the model to the position corresponding to the center of gravity of the full-size hull. The load parameters were the same as those used in the fixed-trim tests.

As is the usual practice in the NACA tank, the air drag of the towing gear was obtained by making runs without the model. The tare resistance was then deducted from the gross resistance to obtain the net air-plus-water resistance of the model.

In order to correlate the data from the present tests with the results from the R.A.E. tank, an approximate correction for the air drag of the model was obtained by towing the model in air close to the surface of the water. This procedure corresponds to the method used in deriving the results from the R.A.E. tank (reference 1). The correction thus obtained is given by the equation:

$$\Delta R = 0.095 V_F^2$$

where ΔR is the correction in pounds to be subtracted from the full-size resistance as derived from NACA tank tests in order to correspond to full-size resistance as derived from R.A.E. tank tests and V_F is the full-size speed in knots. This correction was applied only in the figures showing comparisons between the NACA and R.A.E. data.

No corrections were applied to the trimming moments obtained in the NACA tank tests, although in the R.A.E. tank the aerodynamic moment was eliminated in a manner similar to that for resistance described in the foregoing paragraph. At high speeds, at which the aerodynamic moment on the model is appreciable, the trimming moments from the two tanks should, therefore, show some differences because of this difference in procedure alone. The trims obtained in free-to-trim tests should differ for the same reason.

Drafts were measured at the main step as a convenient point of reference even though the afterbody sometimes was in the water deeper than the main step.

RESULTS

Test Data

The results from the fixed-trim tests are shown in figures 2 to 19. Each figure represents one value for trim and the load on the model is the parameter in all cases. The variations of resistance, trimming moment, and draft with speed are plotted in figures 2 to 7, figures 8 to 13, and figures 14 to 19, respectively. The free-to-trim results are shown in figures 20 and 21, in which resistance and trim are plotted against speed with the load as a parameter.

In order to obtain exact comparisons, the results for the 1/12-full-size model have been converted to 1/6 full size and are shown by dotted lines in figures 2 to 21.

Nondimensional Data

The trim for minimum resistance is determined by cross-plotting resistance against trim for selected speed parameters. The data thus determined for best trim are converted to the following nondimensional coefficients:

Speed coefficient, $C_V = \frac{V}{\sqrt{gb}}$

Load coefficient, $C_\Delta = \frac{\Delta}{wb^3}$

Resistance coefficient, $C_R = \frac{R}{wb^3}$

Trimming-moment coefficient, $C_M = \frac{M}{wb^4}$

where

V speed, feet per second

g acceleration of gravity, feet per second per second

b maximum beam of hull, feet

Δ load on water, pounds

w specific weight of water, pounds per cubic foot (w = 63.5 lb/cu ft for the water in the NACA tank during these tests)

R resistance, pounds

M trimming moment, pounds-feet

Any other consistent set of units may, of course, be used. The data, converted to these coefficients, are shown in figures 22 to 25. In figure 22, C_R is plotted against C_Δ with C_V as a parameter, and, in figure 23, C_R is plotted against C_V with C_Δ as a parameter. Figure 24 shows τ_o, the best trim, plotted against C_V with C_Δ as a parameter. Figure 25 shows C_M at τ_o plotted against C_V with C_Δ as a parameter.

COMPARISON WITH EARLIER TESTS

Compared With NACA 1/12-Full-Size Model

Scale effect.- The present tests were not undertaken for the purpose of establishing the order of the scale effect encountered in tank tests. The testing of only two models would be inadequate for such an investigation. Tests dealing with scale effect are reported in references 1, 5, and 6. The minimum-size model for satisfactorily accurate conversion of model data to full size, on the basis of Froude's law of comparison, is discussed in each of these references; and the size of the model normally tested in the NACA tank appears to be larger than the average of the minimum sizes recommended. The present 1/6-full-size model is slightly larger than the size normally tested in the NACA tank.

Resistance.- Examination of the curves of figures 2 to 7 shows, as might be expected, a general tendency for the converted resistance of the 1/12-full-size model to be greater than the resistance for the 1/6-full-size model. The smaller model consistently indicates a greater hump resistance, and the percentage differences generally increase with load and decrease with increasing trim. The maximum differences at the hump, which are of the order of 15 to 20 percent, occur at small trims and, as a result, would not be noted in a normal take-off. In the range of trims that would normally occur in take-offs the differences in the hump resistance are less than 8 percent. The differences in resistance just above the hump speed, when converted to the same size, are inconsistent for the two models but are, in general, less than the differences at the hump.

At the higher speeds, the converted resistances are, in general, larger for the smaller model than for the larger model. On a percentage basis the differences at high speeds are extremely large but, because a large part of the total air-plus-water resistance of a seaplane at high speeds is caused by air drag, the effect of the differences on take-off calculations is considerably less than it would first appear to be.

Trimming moment.- In figures 8 to 13 the curves for the small model are consistently above those for the large model, indicating that the center of pressure is relatively farther forward on the small model than on the large model. This fact is further demonstrated in figure 21, where it is seen that the trim is consistently greater for 1/12-full-size model than for the 1/6-full-size model. These results are in agreement with the results described in references 1 and 6.

Compared With R.A.E. 1/6-Full-Size Model

The results obtained in the NACA and R.A.E. tanks have been converted to correspond to a full-size gross load of 27,300 pounds. The wing lift was applied according to the lift-coefficient curve given in figure 16 of reference 2 for a wing area of 1760 square feet. The data for the R.A.E. tank were taken from figures 24, 26, and 27 of reference 1.

In the curves of trimming moment from the R.A.E. tests the aerodynamic moment of the model was deducted; in the NACA curves it is not deducted. The resistance values for the tests from both tanks were corrected for the air drag of the model. The curves representing the data from the NACA tank tests were obtained from figures 2 to 13, 20, and 21 by cross-plotting resistance, trimming moment, and trim against load at selected speeds and by determining the values of these variables for the computed loads.

A comparison of the results of the free-to-trim tests made in the two tanks should show differences in trims because, in the R.A.E. tests, aerodynamic moment on the model was eliminated. The resistance obtained in the NACA tank at the trims given in the results of the R.A.E. free-to-trim tests was determined from the NACA fixed-trim data. The resistance thus determined is compared with the free-to-trim resistance from the R.A.E. tank in figure 26. The agreement here is considered to be especially good.

A comparison of the resistances obtained in the two tanks for trims at three different speeds is shown in figure 27. The agreement here is, in general, considered to be satisfactory. An exception occurs at high trims for a speed of 53.2 knots. In this region the NACA model was riding on the afterbody with the main step clear of the water.

A comparison of the trimming moments, at the same three speeds mentioned previously, is shown in figure 28. The values of the trimming moments found in the NACA tests are consistently smaller than those obtained in the R.A.E. tests.

These comparisons indicate that the results of the NACA and R.A.E. tests of the 1/6-full-size model show about the same agreement as the results of previous tests made in the two tanks of a 1/12-full-size model. The differences in resistance and trimming moment observed in the tests of the 1/6-full-size and the 1/12-full-size models in the NACA tank might at first appear to be greater than those obtained in the R.A.E. tests of two models of the same scales, but a close inspection shows that the large discrepancies in the NACA data for the two models were obtained under conditions that were not tested in the R.A.E. tank, that is, at large loads, small trims, and very high speeds.

CONCLUSIONS

1. There is some scale effect indicated by the results from the tests with the 1/6- and 1/12-full-size models. The results are such that if the full-size resistance is computed in the usual manner, it will be larger when computed from the results of the tests of the smaller model than it would be if the results from the larger model were used. Because it has been established that the larger model will give more reliable results, it may be concluded that the full-size resistance would be overestimated by using the results from the tests with the smaller model.

2. A comparison of the data from the NACA tests of the 1/6-full-size model with the data from the R.A.E.

tests of a model of the same size shows that the results are in substantial agreement.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 9, 1942.

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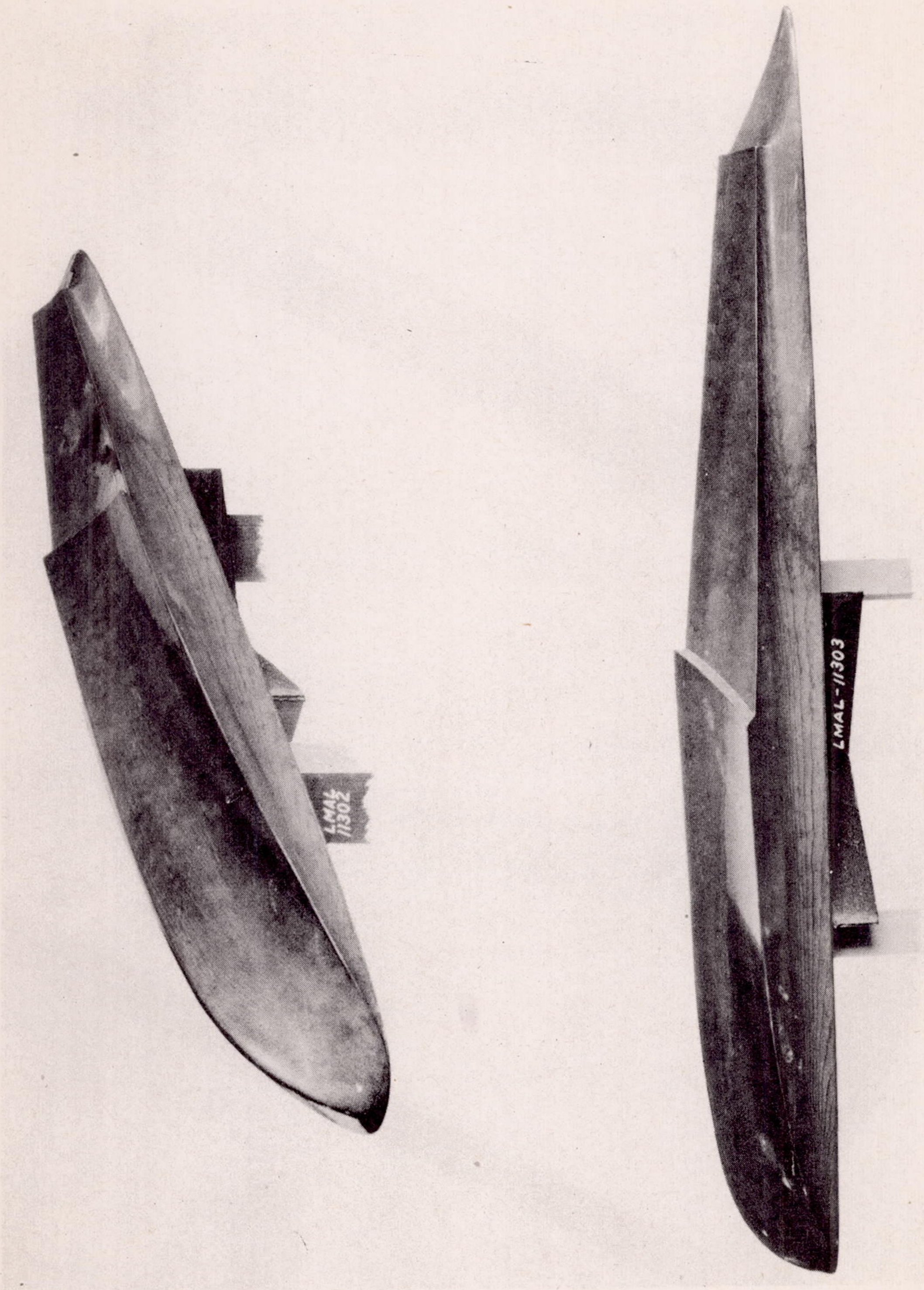

Figure 1.- Photographs of model 58.

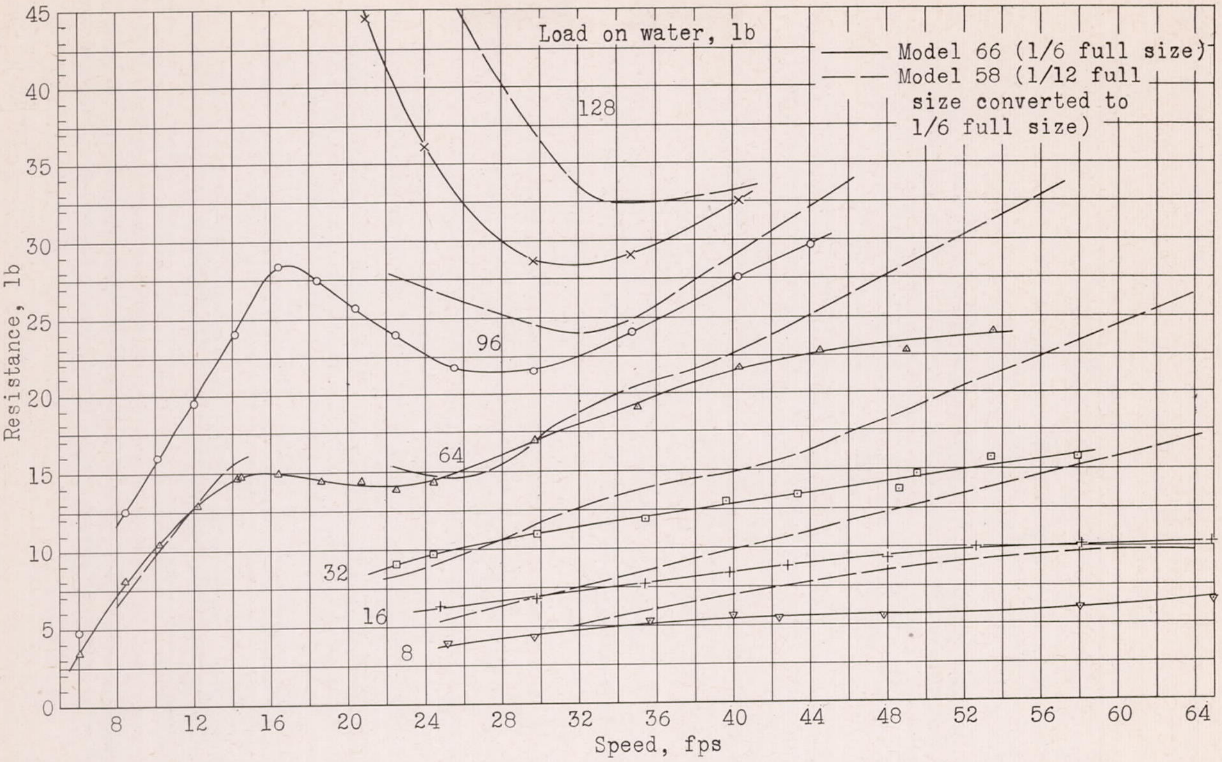

Figure 2.- Models 66 and 58. Variation of resistance with speed, $\tau = 3^{\circ}$.

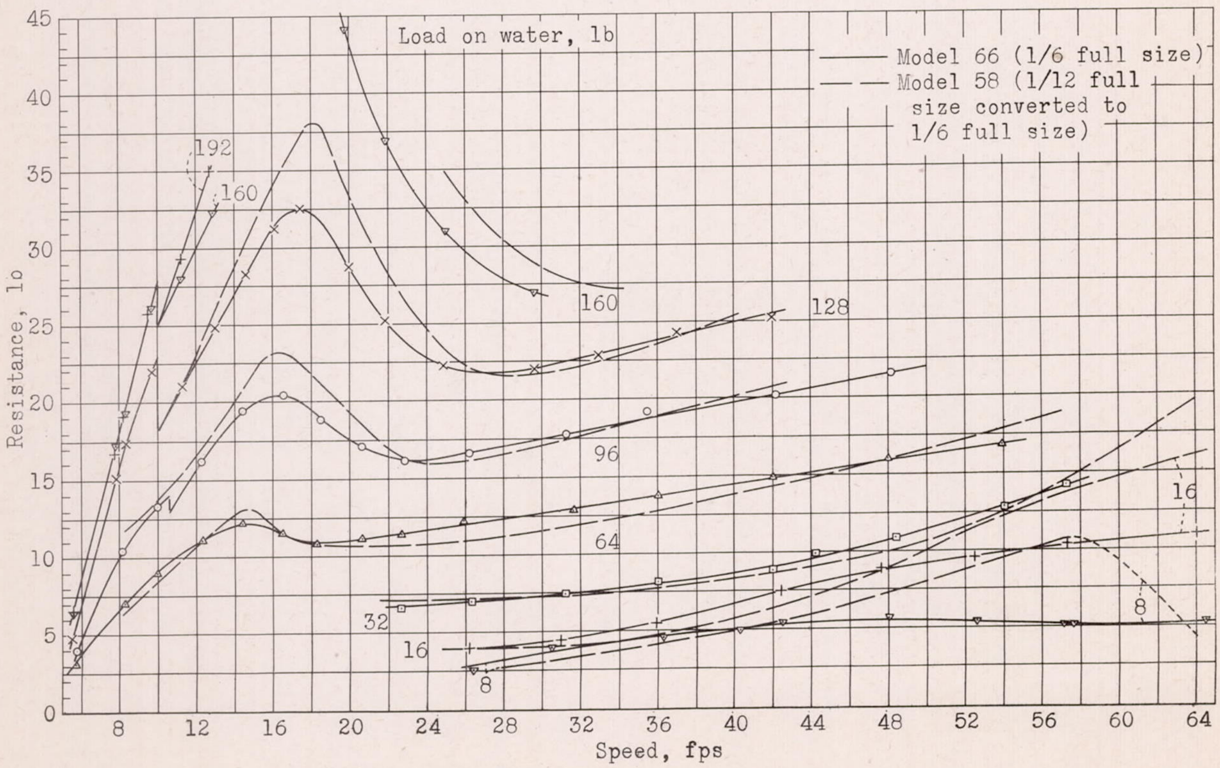

Figure 3.- Models 66 and 58. Variation of resistance with speed, $\tau = 5^{\circ}$.

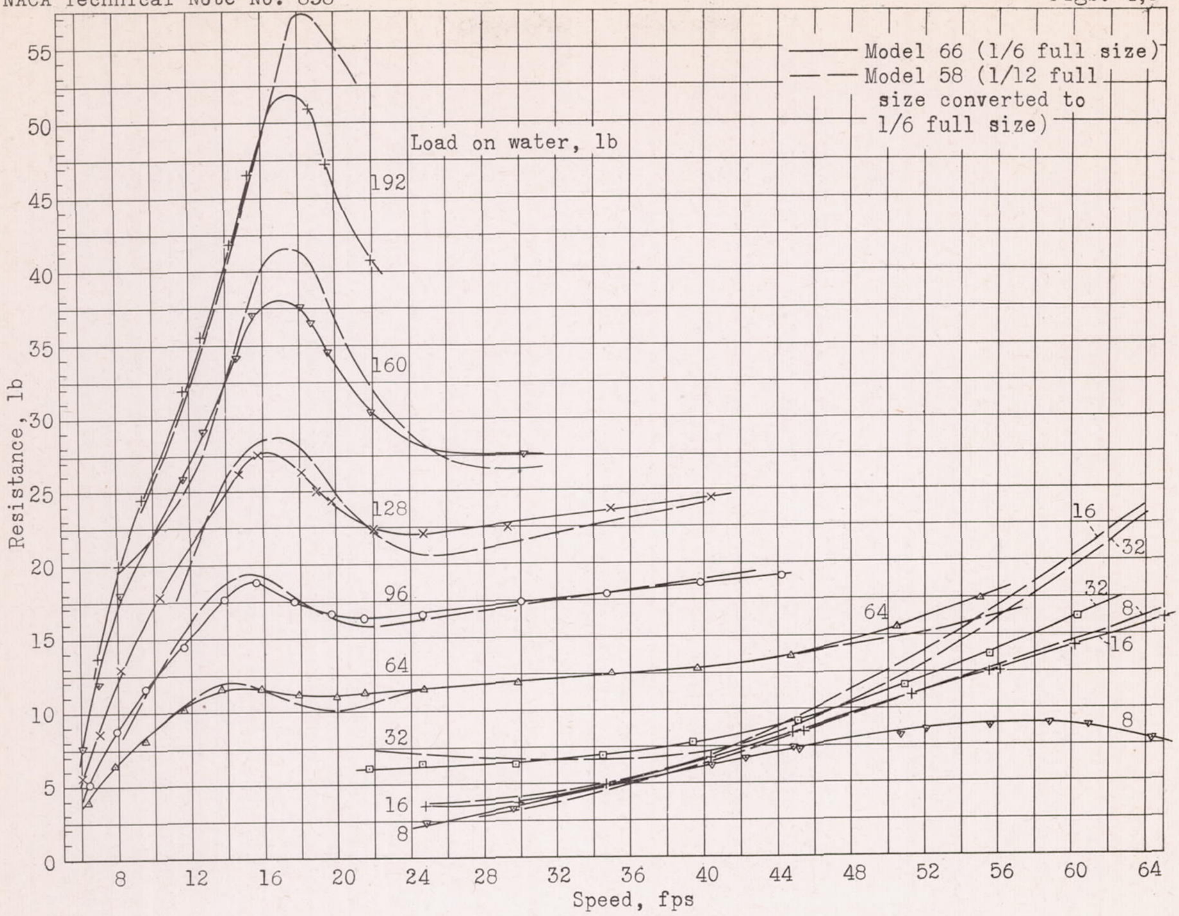

Figure 4.- Models 66 and 58. Variation of resistance with speed, $\tau = 7^{o}$.

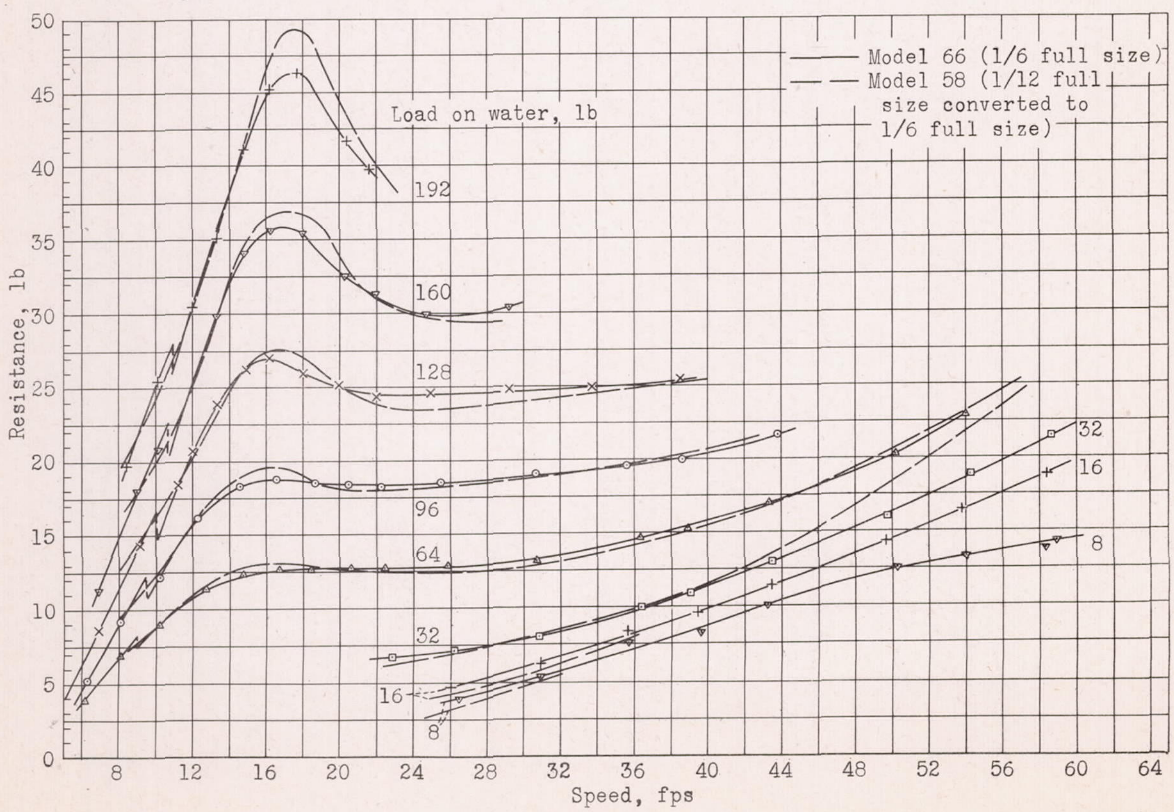

Figure 5.- Models 66 and 58. Variation of resistance with speed, $\tau = 9^{o}$.

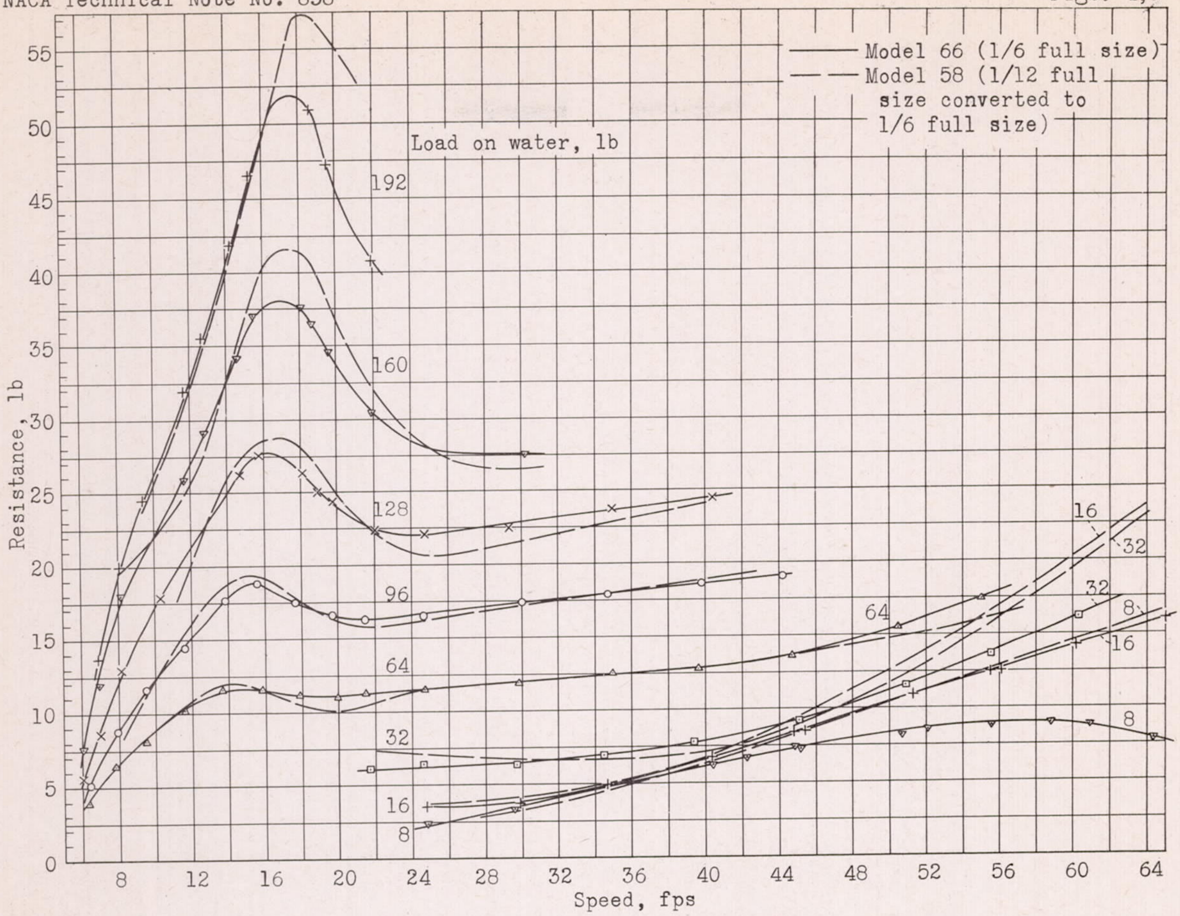

Figure 4.- Models 66 and 58. Variation of resistance with speed, $\tau = 7^{\circ}$.

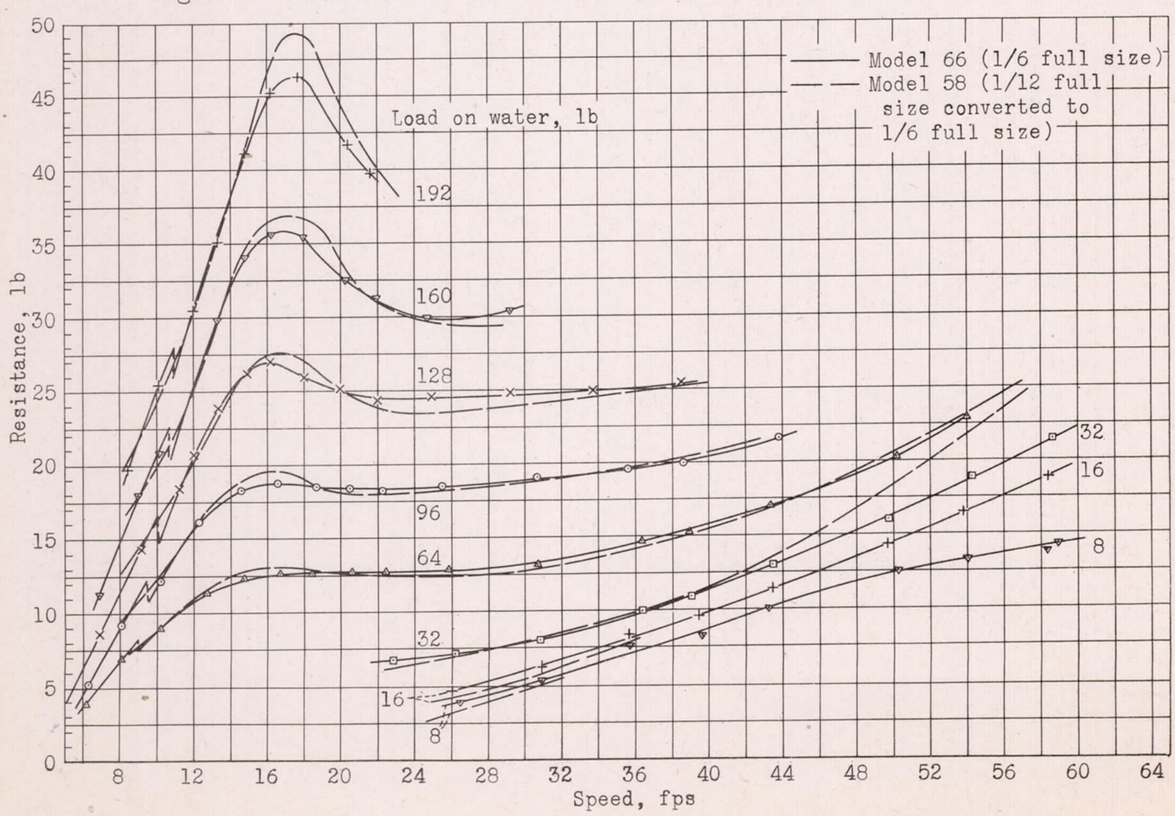

Figure 5.- Models 66 and 58. Variation of resistance with speed, $\tau = 9^{\circ}$.

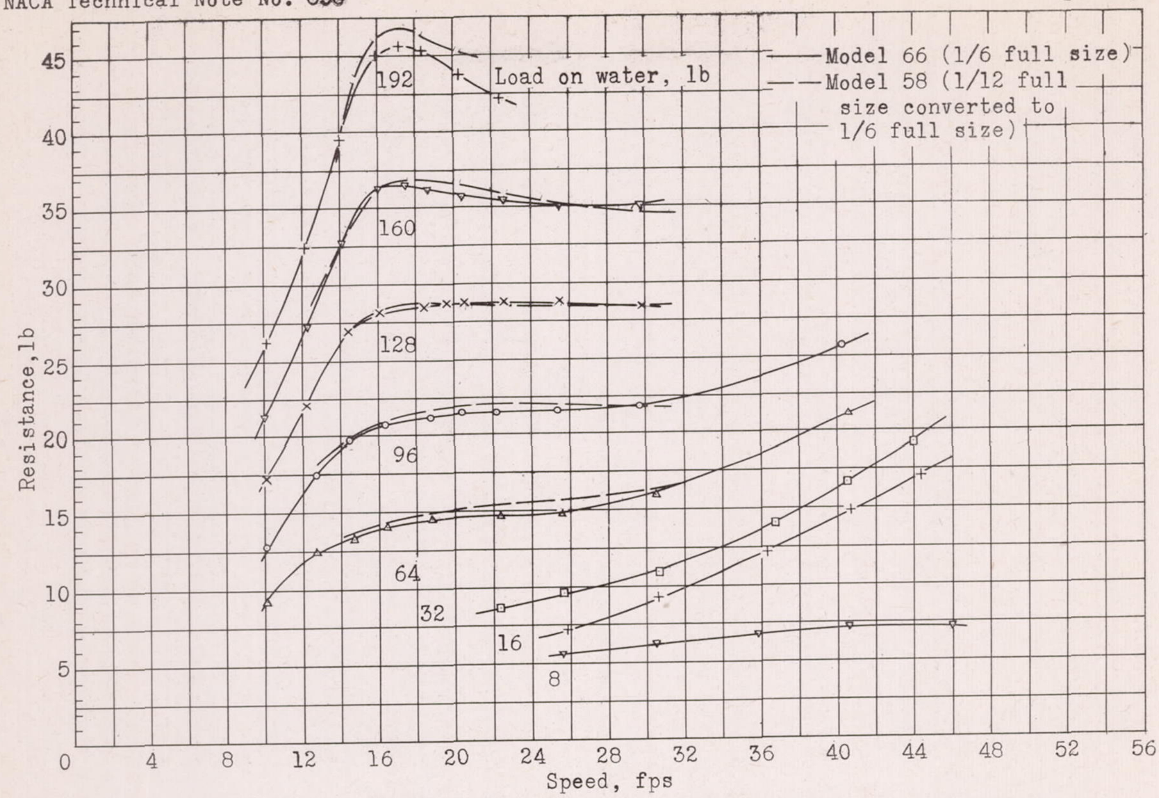

Figure 6.- Models 66 and 58. Variation of resistance with speed, $\tau = 11^{\circ}$.

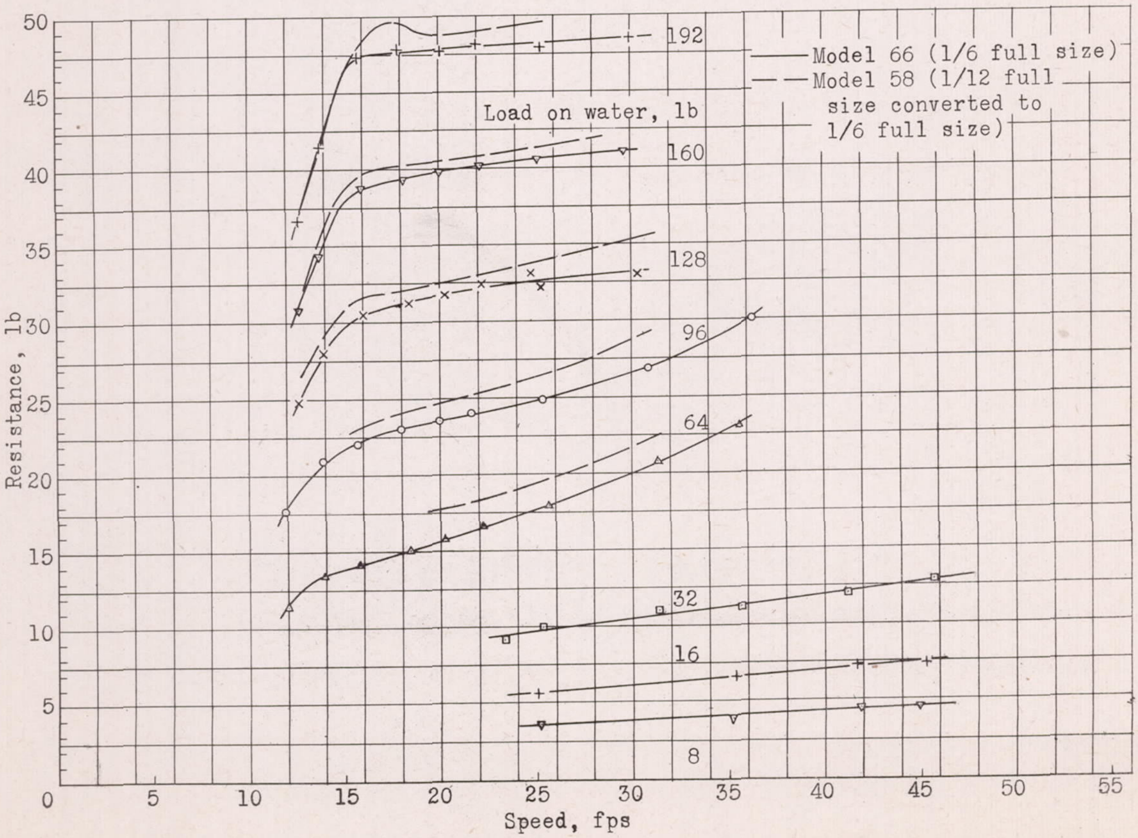

Figure 7.- Models 66 and 58. Variation of resistance with speed, $\tau = 13^{\circ}$.

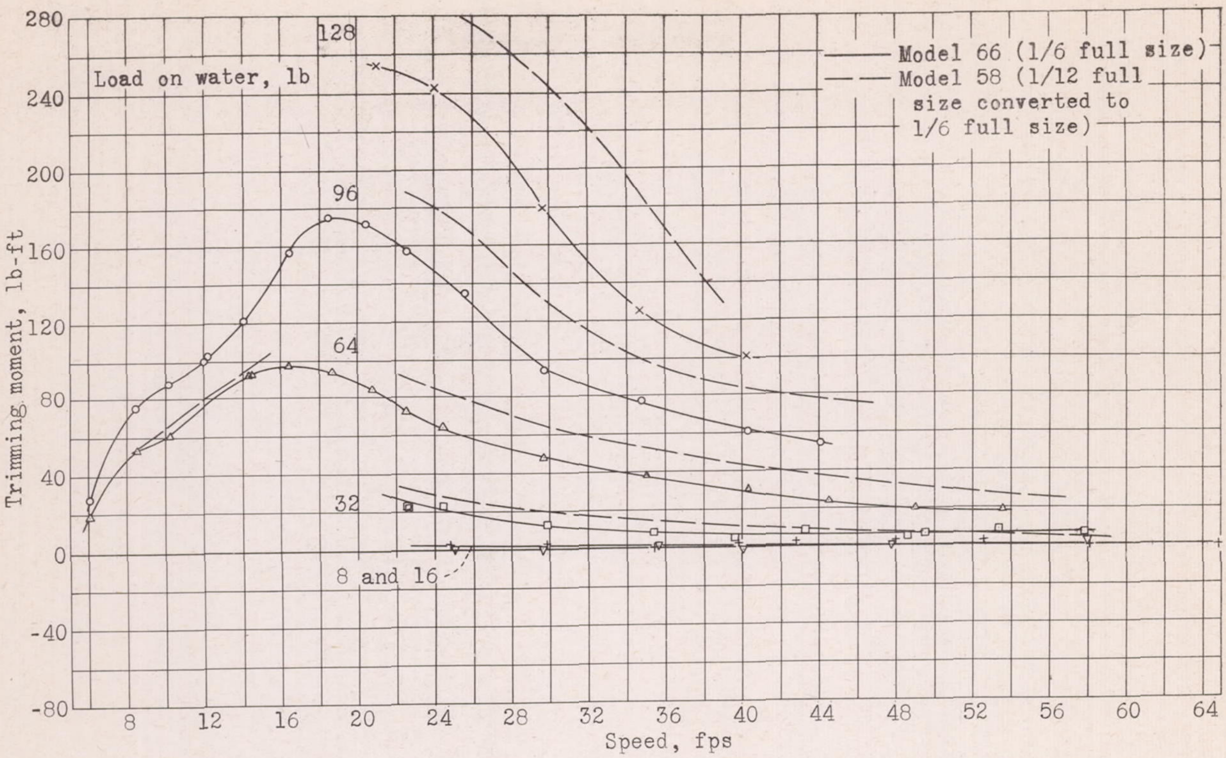

Figure 8.- Models 66 and 58. Variation of trimming moment with speed, $\tau = 3^{\circ}$.

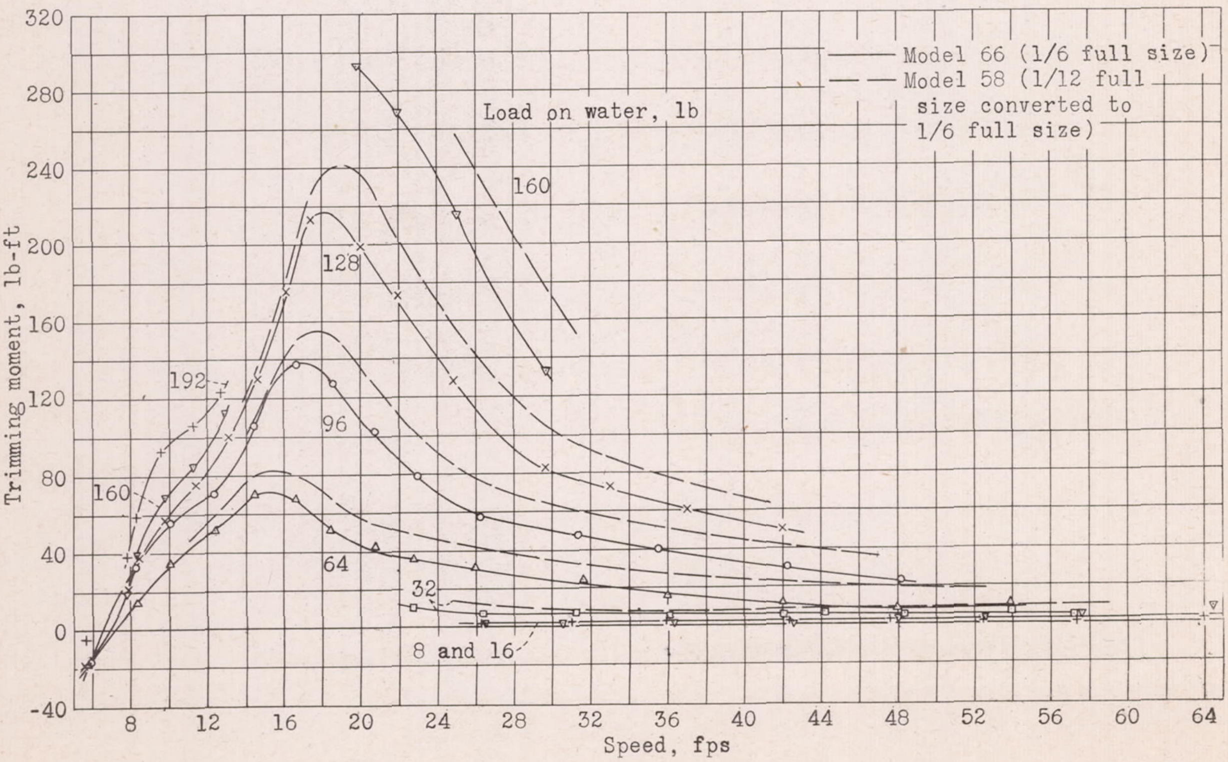

Figure 9.- Models 66 and 58. Variation of trimming moment with speed, $\tau = 5^{\circ}$.

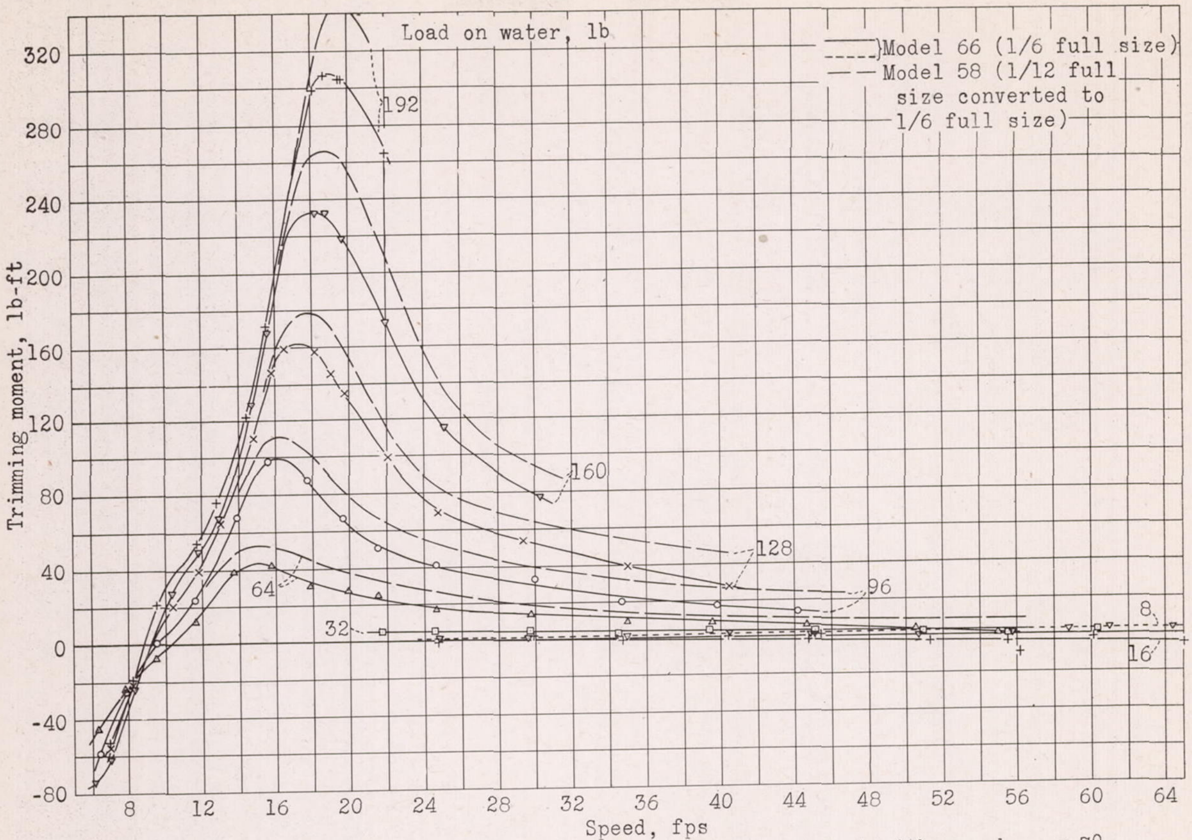

Figure 10.- Models 66 and 58. Variation of trimming moment with speed, τ = 7°.

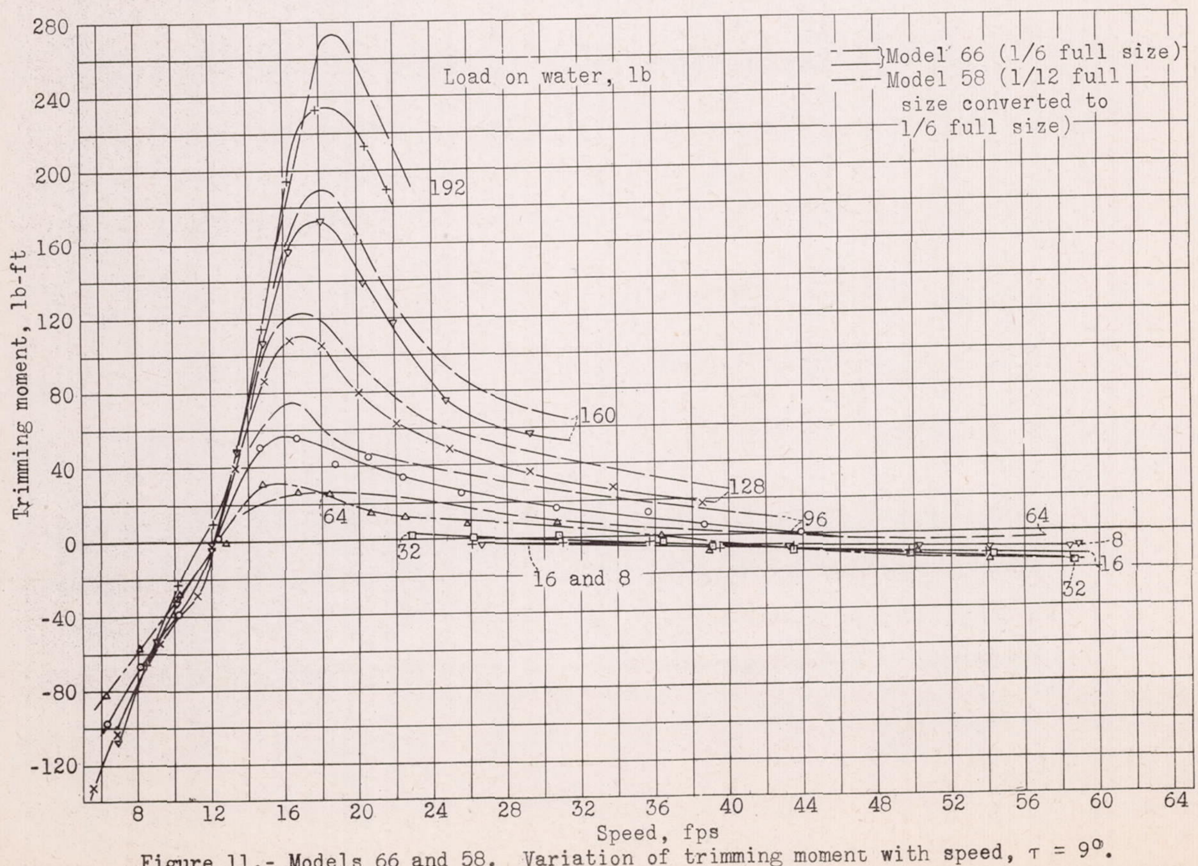

Figure 11.- Models 66 and 58. Variation of trimming moment with speed, τ = 9°.

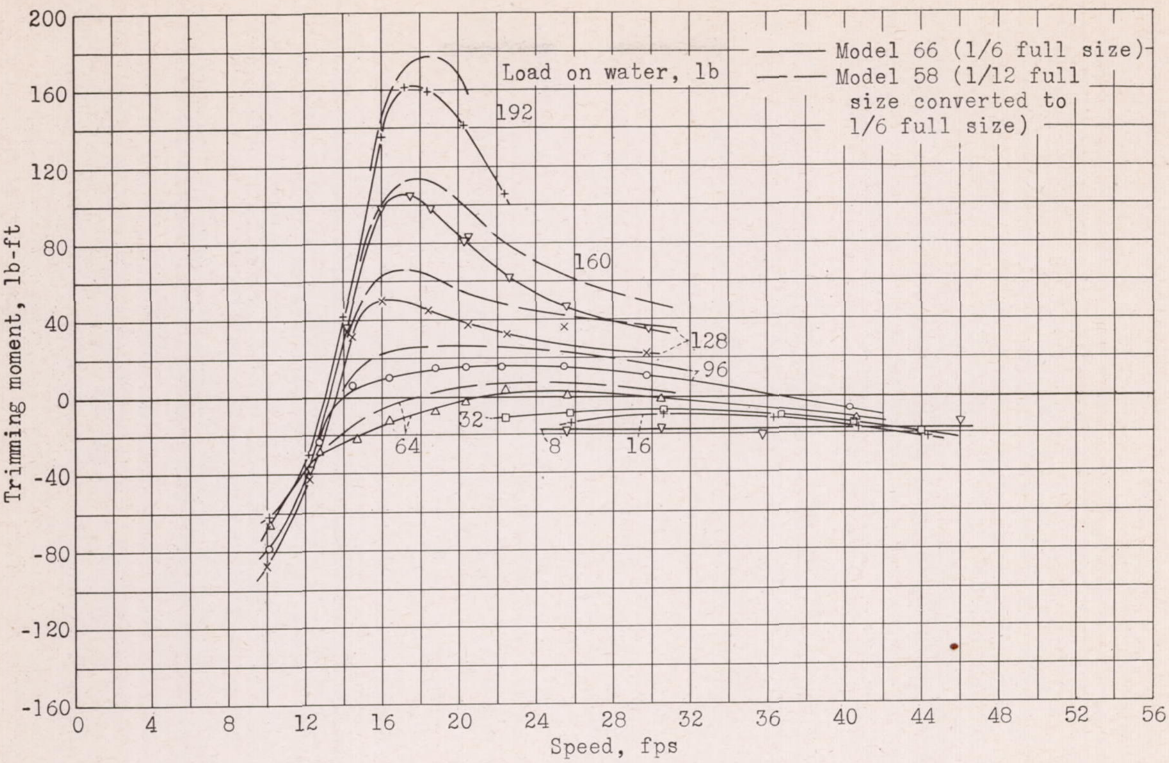

Figure 12.- Models 66 and 58. Variation of trimming moment with speed, τ = 11°.

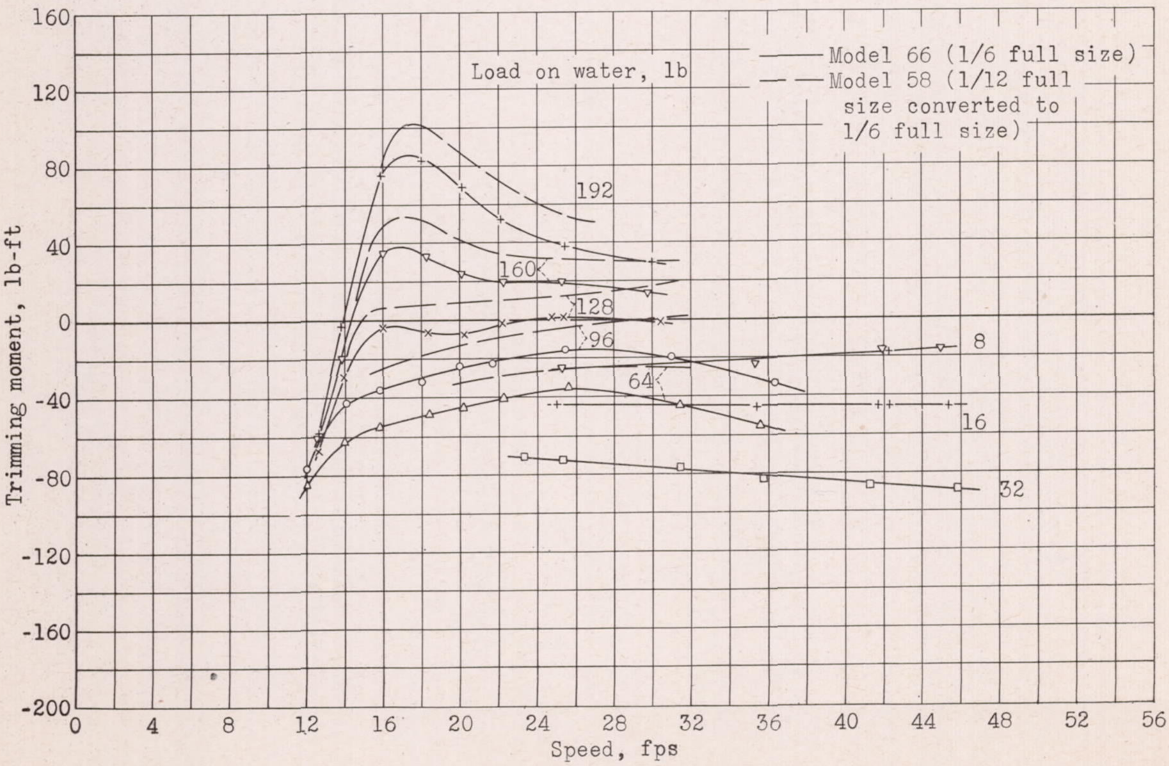

Figure 13.- Models 66 and 58. Variation of trimming moment with speed, τ = 13°.

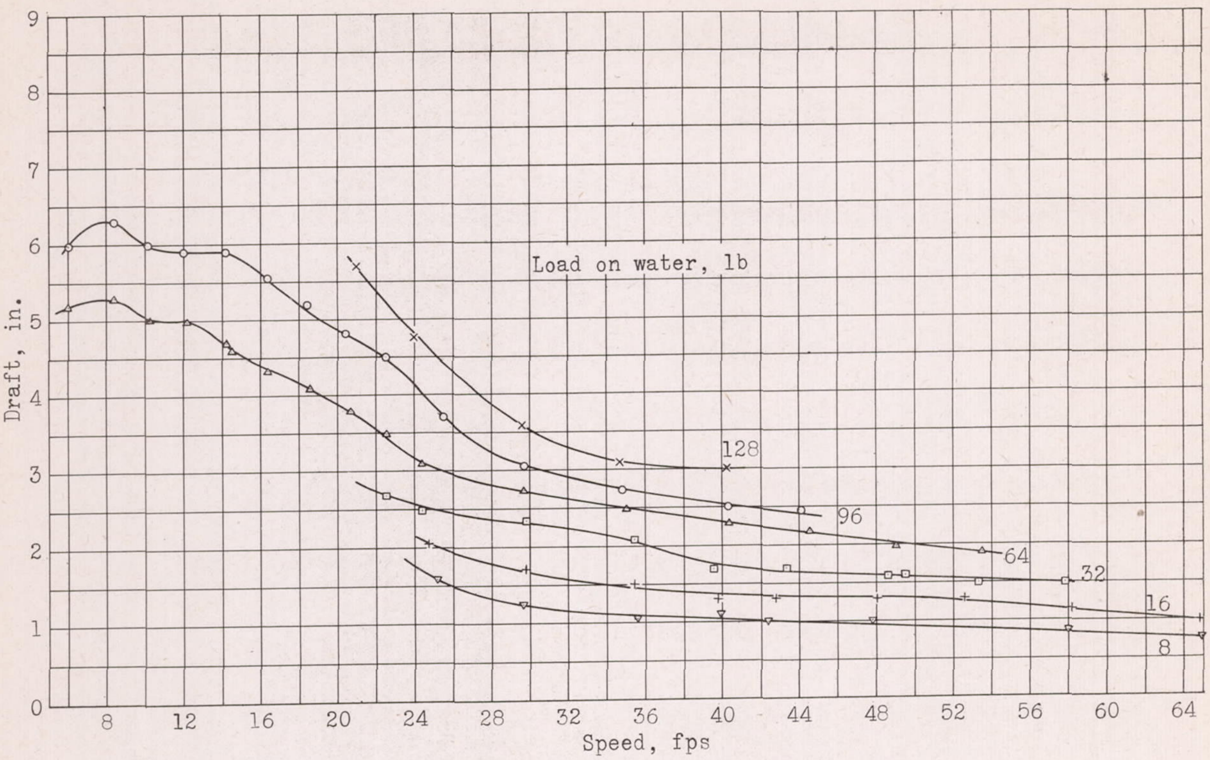

Figure 14.- Model 66. Variation of draft with speed, $\tau = 3^{\circ}$.

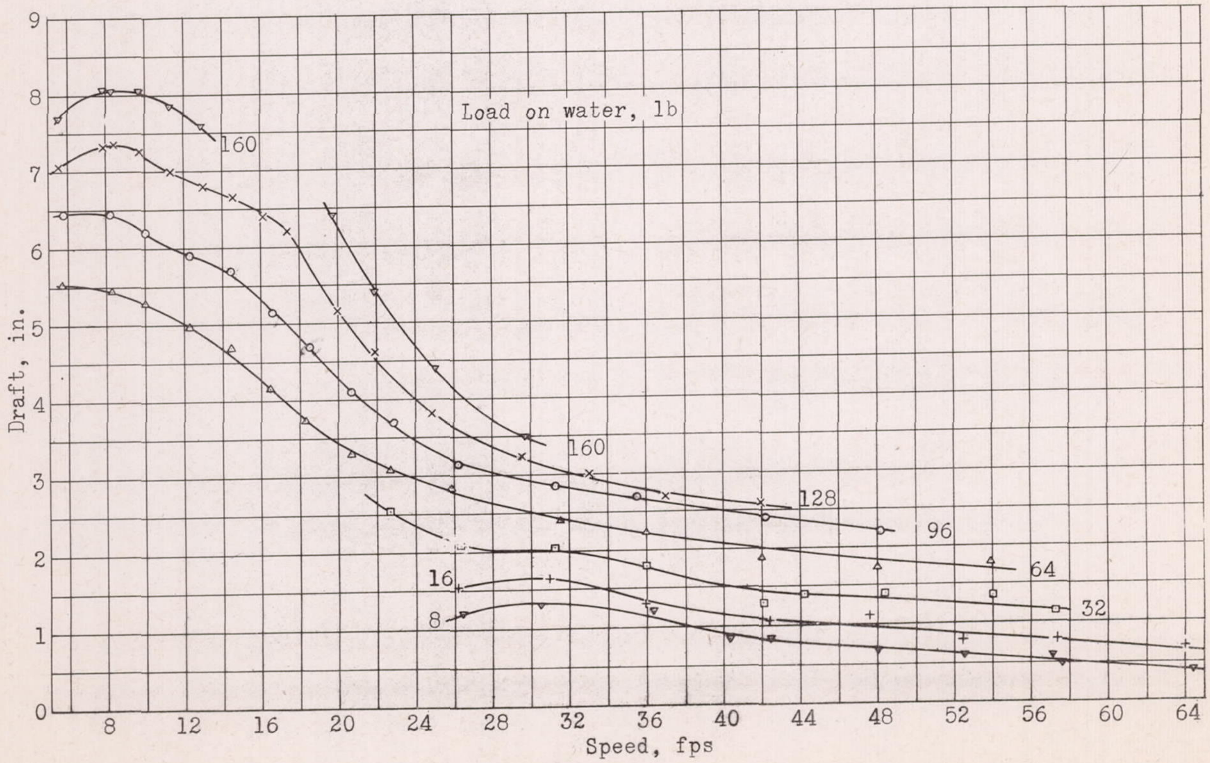

Figure 15.- Model 66. Variation of draft with speed, $\tau = 5^{\circ}$.

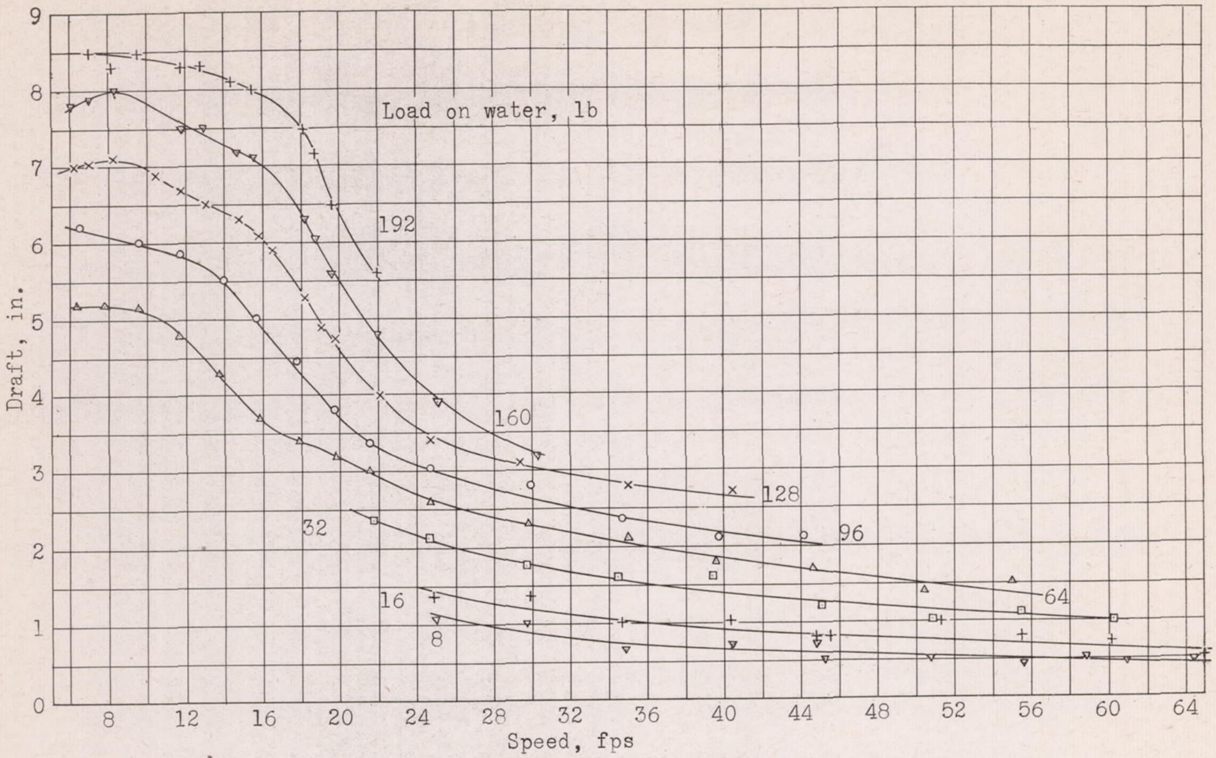

Figure 16.- Model 66. Variation of draft with speed, $\tau = 7^{\circ}$.

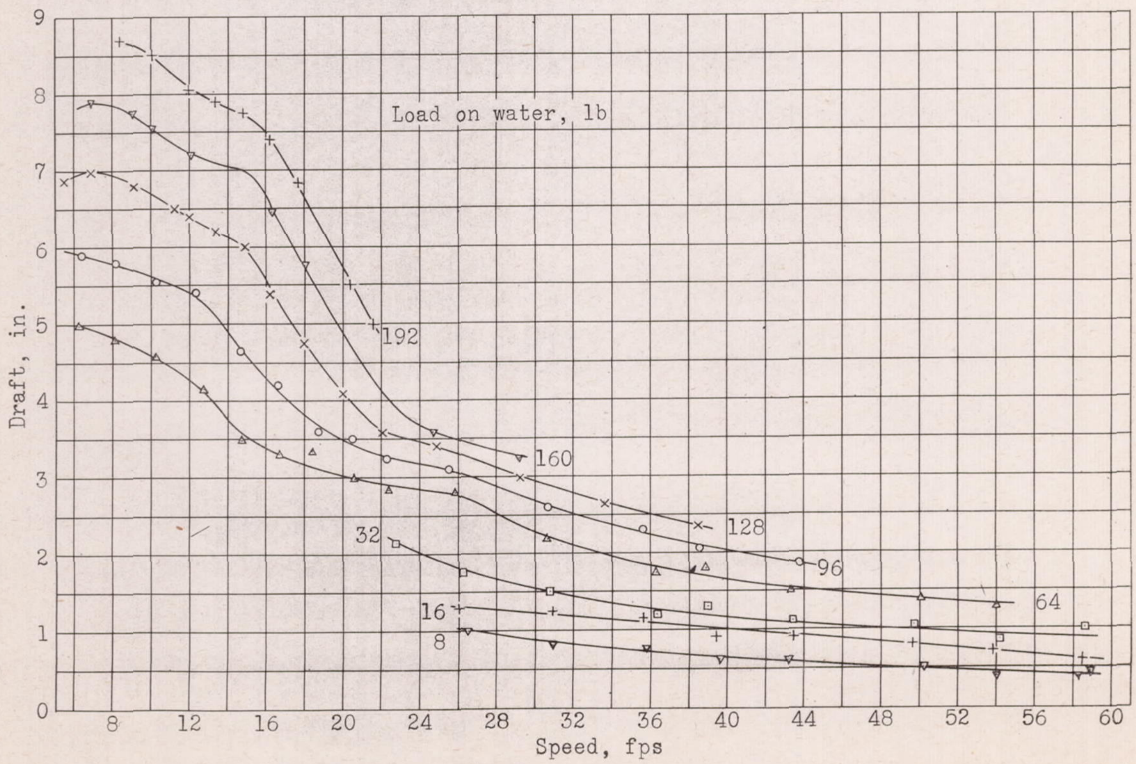

Figure 17.- Model 66. Variation of draft with speed, $\tau = 9^{\circ}$.

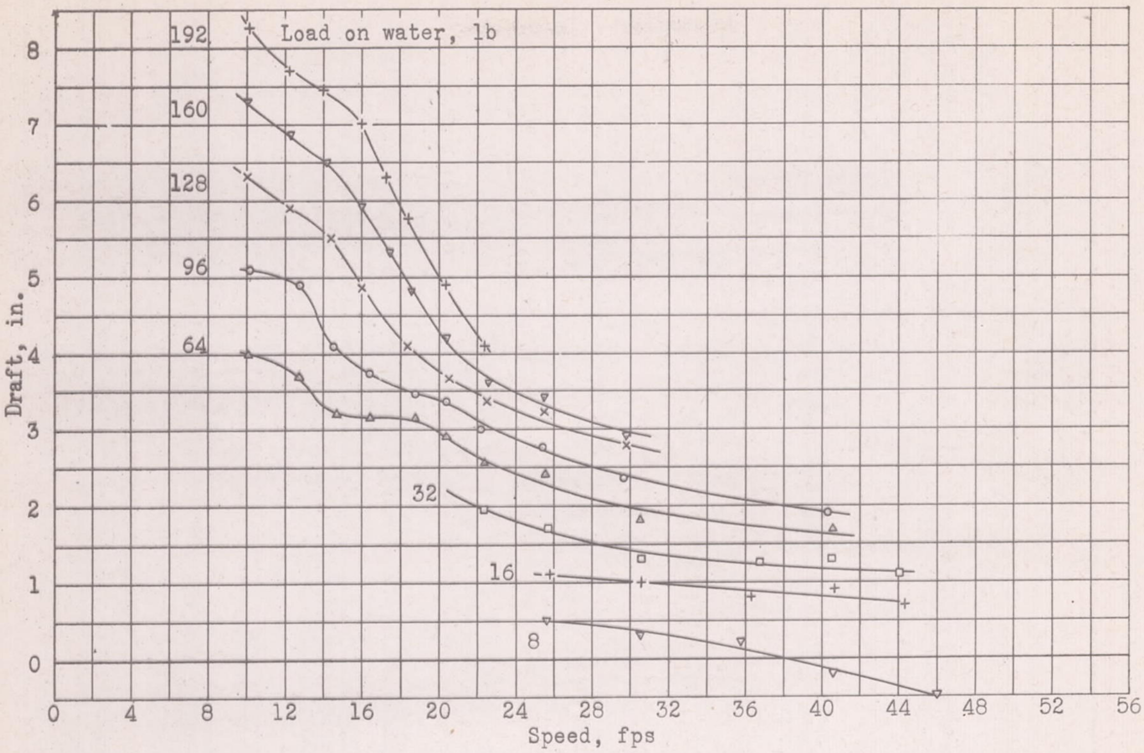

Figure 18.- Model 66. Variation of draft with speed. $\tau = 11^{\circ}$.

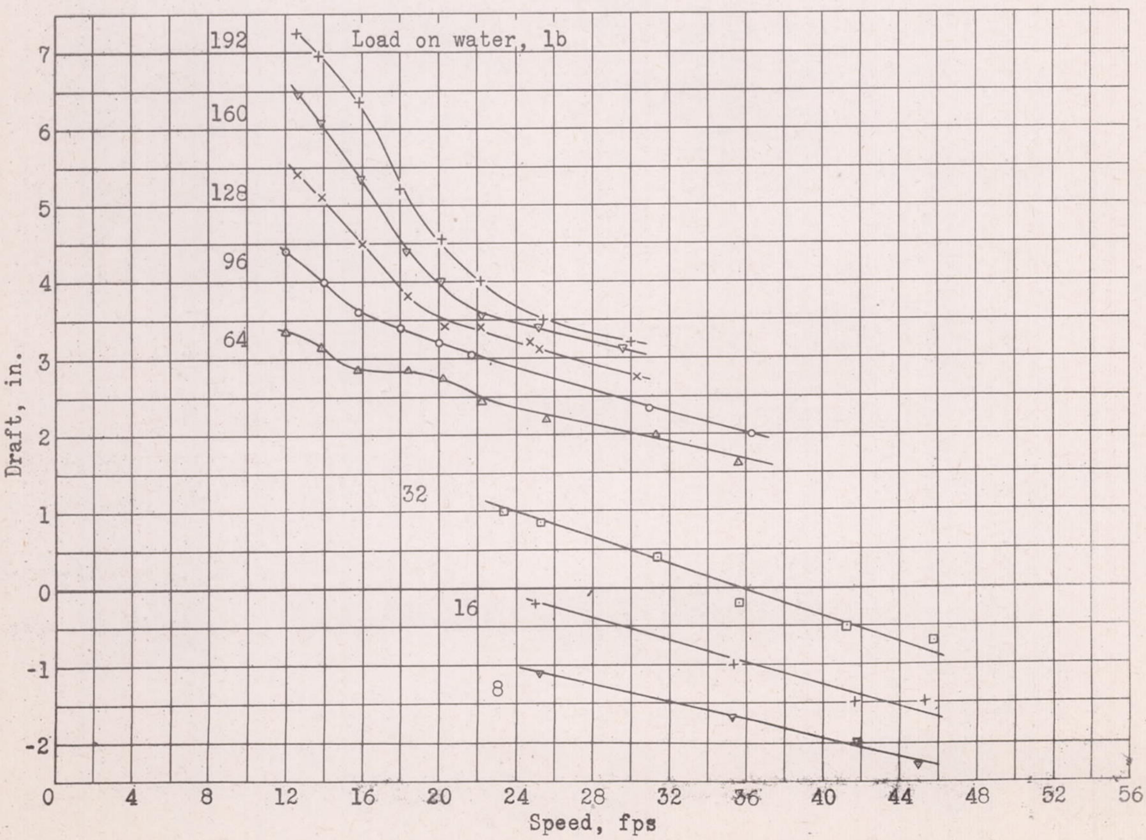

Figure 19.- Model 66. Variation of draft with speed. $\tau = 13^{\circ}$.

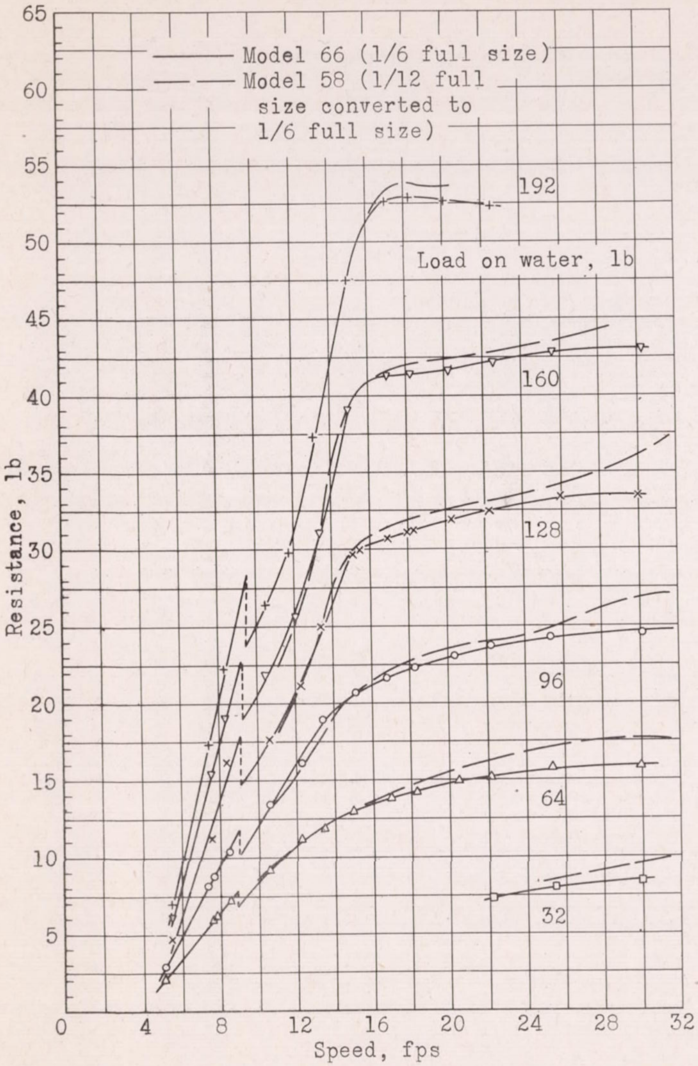

Figure 20.- Models 66 and 58. Variation of resistance with speed, free-to-trim.

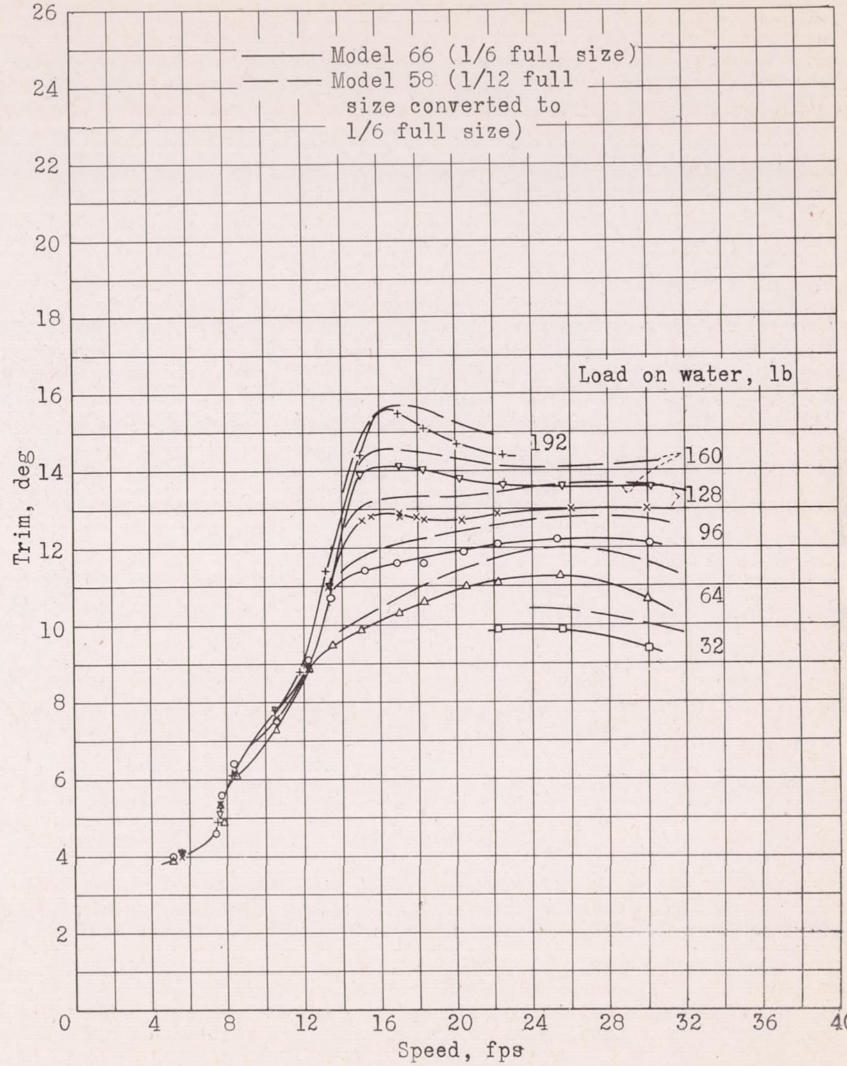

Figure 21.- Models 66 and 58. Variation of trim with speed, free-to-trim.

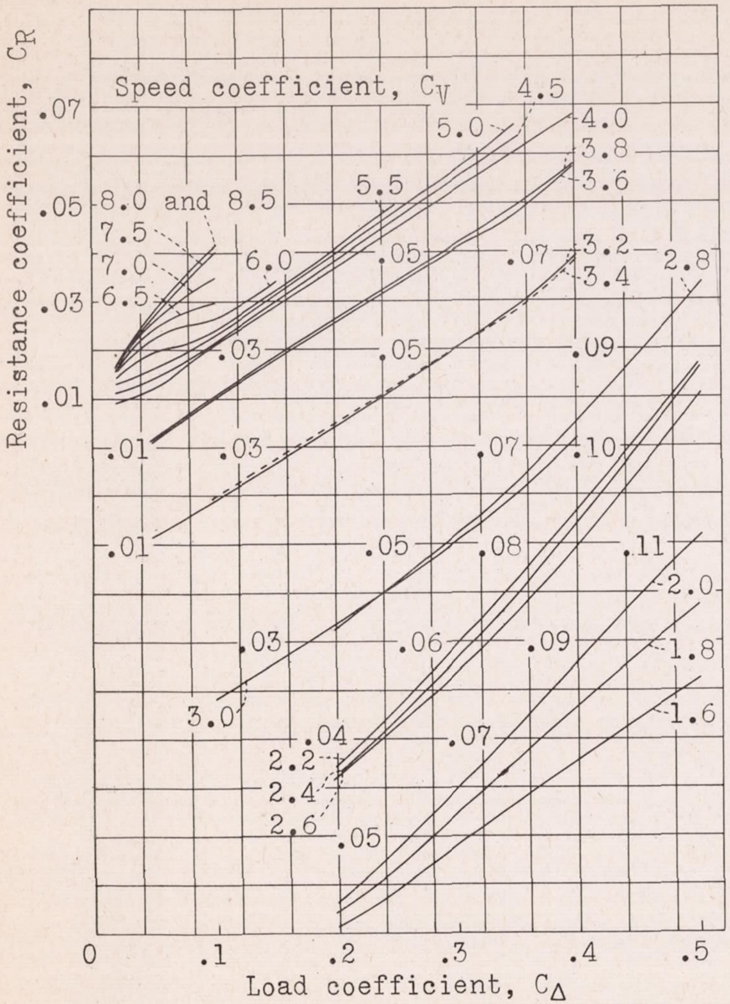

Figure 22.- Model 66. Variation of resis ance coefficient at best trim with load coeffici nt.

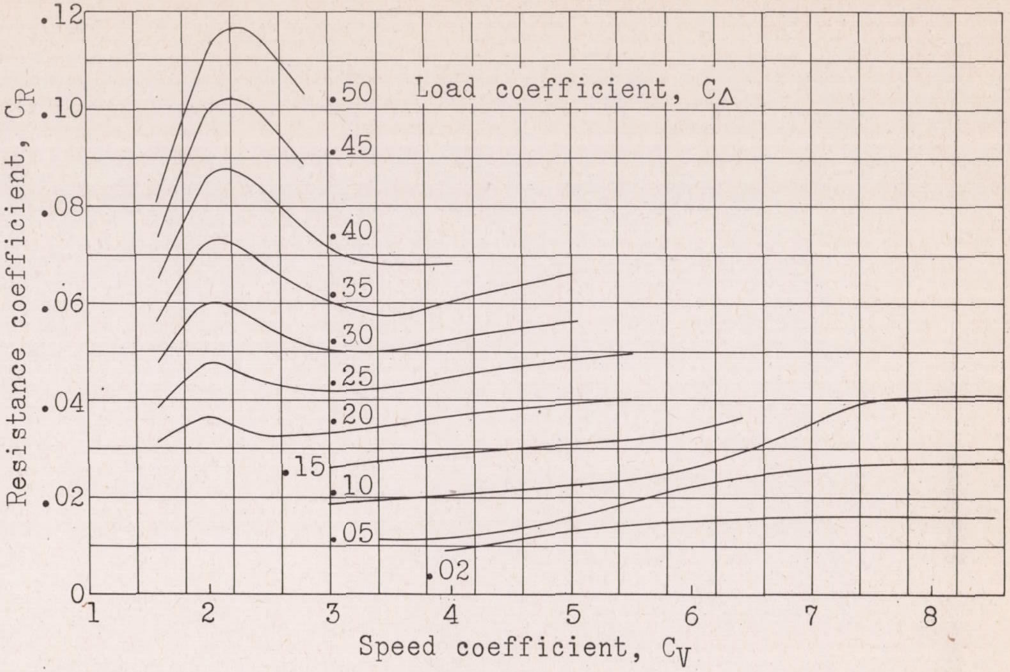

Figure 23.- Model 66. Variation of resistance coefficient at best trim with speed coefficient.

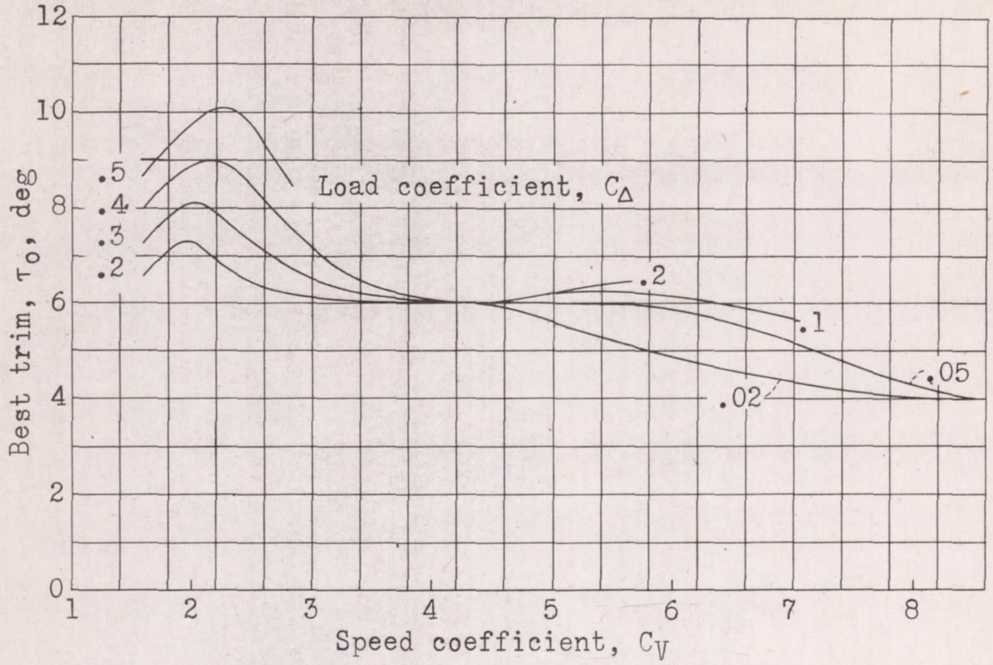

Figure 24.- Model 66. Variation of best trim with speed coefficient.

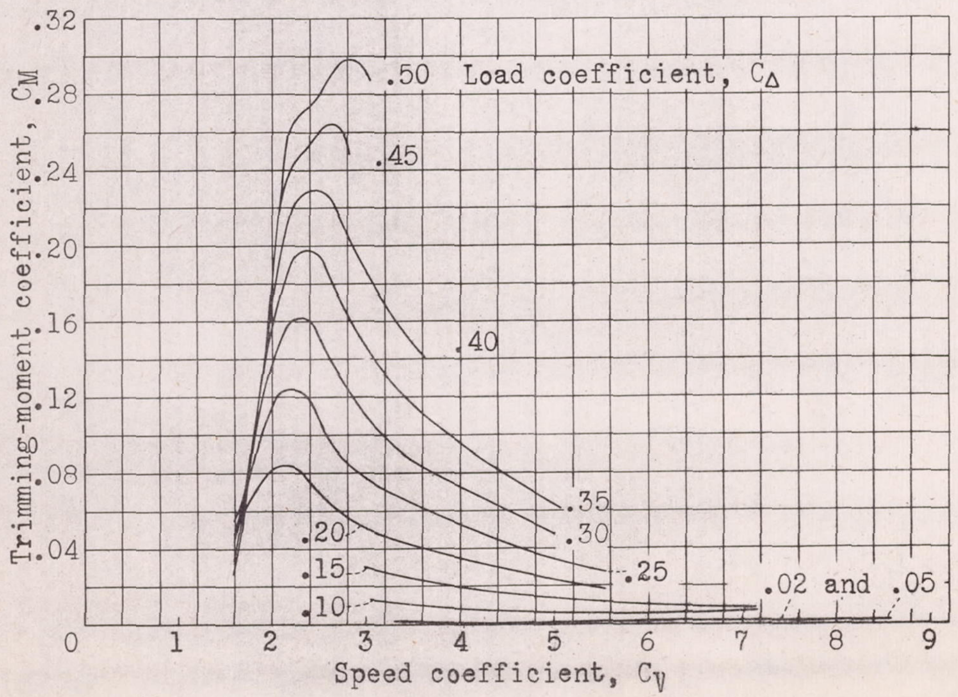

Figure 25.- Model 66. Variation of trimming-moment coefficient at best trim with speed coefficient.

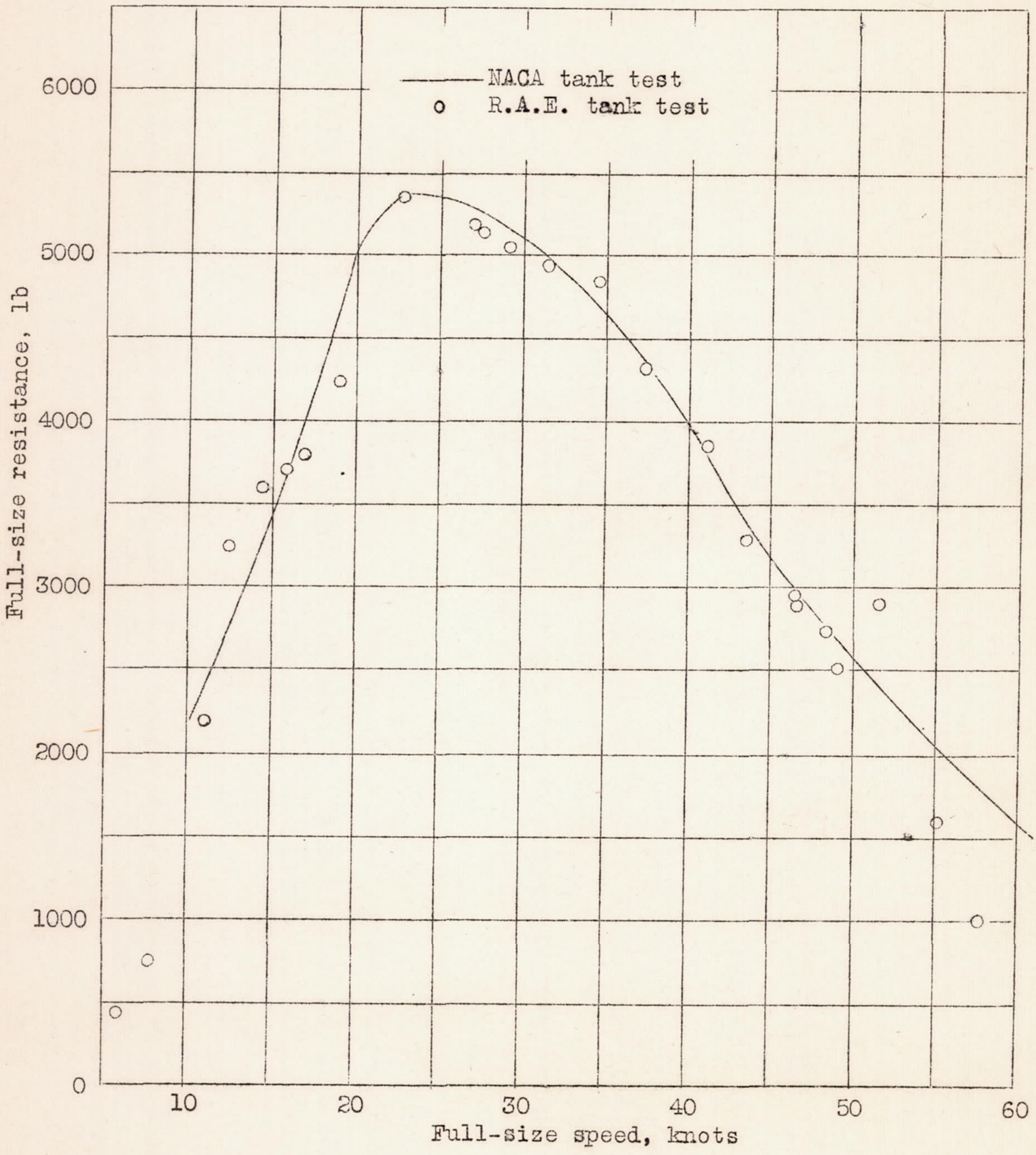

Figure 26.- Model 66. Comparison of free-to-trim resistance from R.A.E. tank with resistance obtained in NACA tank at same trims.

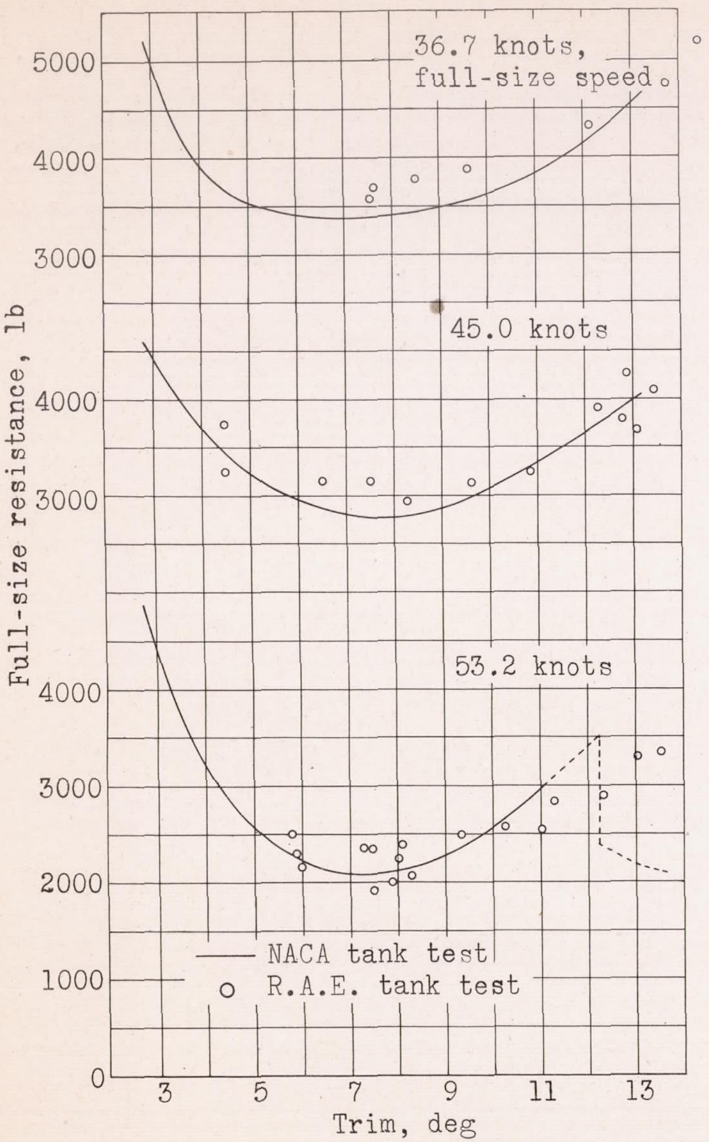

Figure 27.- Model 66. Comparison of resistance obtained in NACA and R.A.E. tanks.

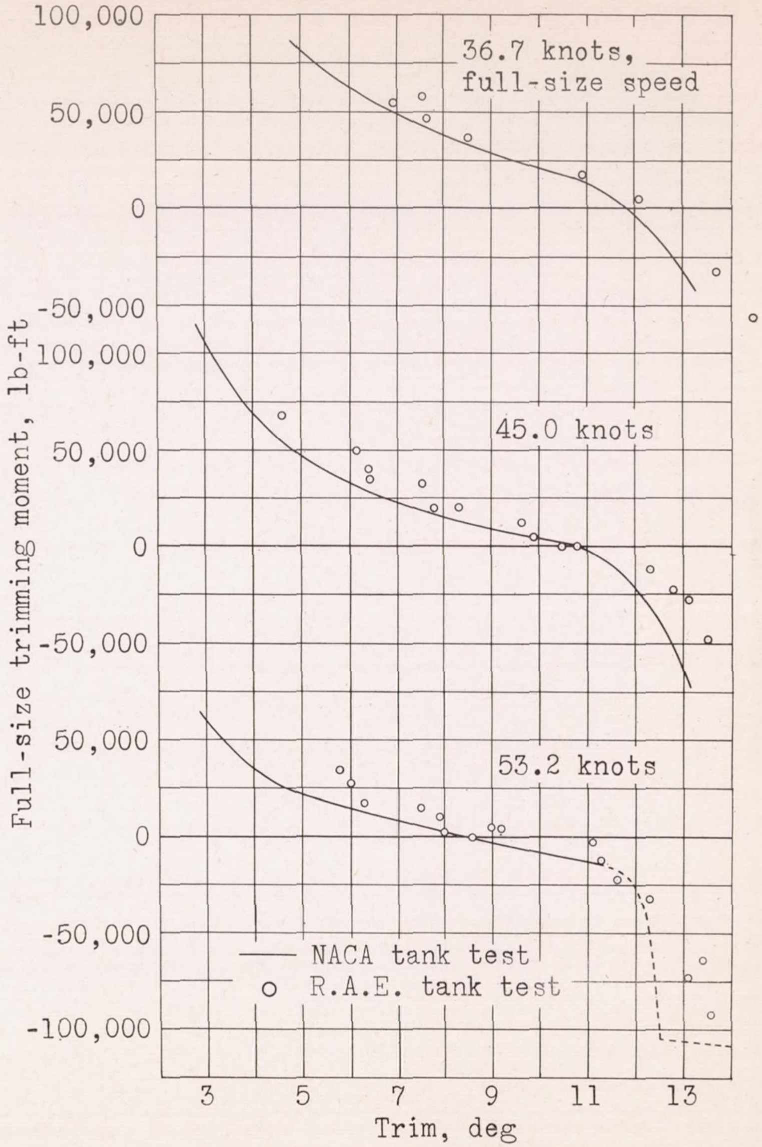

Figure 28.- Model 66. Comparison of trimming moments obtained in NACA and R.A.E. tanks.