TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 563

TANK TESTS OF MODELS OF FLOATS FOR SINGLE-FLOAT SEAPLANES - FIRST SERIES

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SUMMARY

Large models of the Mark V and Mark VI floats used by the Bureau of Aeronautics, Navy Department, for single-float seaplanes (N.A.C.A. models 41-A and 41-B, respectively) were tested in the N.A.C.A. tank to provide general test data for typical single floats and a basis for possible improvements of their form. The tests were made at fixed trim angles over a wide range of possible loadings and also free to trim at the design load. N.A.C.A. model 35-B, a pointed-step hull that might be suitable for the same service, was tested free to trim with the same load and position of the center of gravity as used in the tests of the Mark V and Mark VI floats.

The resistance of model 41-B was greater than that of model 41-A either when free to trim or at the best trim angle for each. The resistance of model 35-B was less than either of the other models at the hump speed, greater at intermediate planing speeds, and less at the speeds and loads near get-away, although the spray was generally worse owing to the absence of transverse flare.

The results of the fixed-trim tests of model 41-A were cross-plotted to obtain data at the angle for zero trimming moment and at the best trim angle. These data are presented in nondimensional form for use in take-off calculations involving various float sizes and loadings.

The trims assumed by models 41-A and 41-B, when tested free to trim, were found to be excessive at the hump speed. The corresponding trim of model 35-B was found to be approximately 3° lower because of the lower angle of afterbody keel used in this model, and the maximum hump resistance was 15 percent lower. A small hydrofoil fitted at the second step of model 41-A reduced the maximum trim about 2° and the maximum resistance 9 percent.

INTRODUCTION

A combination of a conventional fuselage and a separate flotation system is widely used for small seaplanes. This arrangement provides sufficient water clearance for the wings and propeller without the departures from conventional landplane design found in small flying boats and makes possible the ready conversion of landplanes into seaplanes, or vice versa. In the United States, commercial and private operators generally prefer to use twin floats, replacing the two wheels; the Navy appears to favor the single float under the fuselage, with wing-tip floats providing lateral stability.

Although the twin-float system is preferable in many cases in which such factors as ease of access, when the seaplane is moored out or alongside a floating dock, and counteraction of engine torque are of prime importance, the single-float system has inherent advantages, particularly when the seaplane must operate in rough water. The structure connecting the central float and the fuselage is lighter and stronger. In single-engine seaplanes the central position of the float affords more protection for the propeller. The single-float arrangement is obviously easier to catapult and has been considered (reference 1) to be more maneuverable on the water. Practice has shown that for the same service a single-float system may have a smaller total buoyancy and the floats a smaller length-beam ratio, resulting in a further saving in weight and air drag.

In accordance with a request of the Bureau of Aeronautics, the investigation of possible improvements in the forms of single floats has been included in the research program of the Committee. As a part of this investigation, N.A.C.A. models 41-A and 41-B, representing respectively the Mark V and Mark VI floats developed by the Bureau of Aeronautics, Navy Department, and used successfully in service, have been tested in the N.A.C.A. tank to determine their water performance. The results of these tests provide data for estimating the take-off performance of similar floats over a wide range of loadings and for comparisons with future designs.

Because the thrust moment of float seaplanes around the center of gravity is usually small, free-to-trim tank tests of float models are more truly indicative of performance at low speeds than similar tests of flying-boat hulls, which are subjected to high thrust moments. Free-to-trim tests showed that both 41-A and 41-B models assumed excessive trims at low speeds, which resulted in high resistance and an undesirable flow over the afterdeck during take-off.

For the purpose of obtaining a lower trim angle at the hump speed, a small hydrofoil was fitted on model 41-A just abaft the second step and the model was tested free to trim with several small variations of the position of the hydrofoil. A comparison has also been made with the results of free-to-trim tests of N.A.C.A. model 35-B, which has a deep pointed step, zero angle of afterbody keel, and a relatively low angle of trim at the hump speed.

DESCRIPTION OF FLOATS AND MODELS

The afterbodies of models 41-A and 41-B are identical. The essential differences in the forebodies are shown in figures 1 and 2. In model 41-B, the forebody keel and buttock lines of the planing bottom rise more sharply, the bow is extended forward, and the plan form of the chine is slightly fuller. The sections at the step are almost the same in both models, model 41-B being slightly lower at the chine. Forward of the step, the bottom sections of model 41-A consist of straight lines at the keel and circular arcs at the chine to give a transverse flare. The corresponding sections of model 41-B are finer, except at the bow, and consist of curved lines faired to a narrow horizontal flat at the chine. The sections above the chines are radii in both models.

The hydrofoil placed at the second step of model 41-A in an attempt to improve the free-to-trim characteristics is shown in figure 3. Its dimensions are as follows:

	Model	Full size
Chord, in.	3/4	2-5/8
Thickness, in.	1/16	7/32
Span, in.	3-3/16	11-5/32
Dihedral, deg.	26.0	26.0
Section:		
Upper surface, circular arc		
Lower surface, straight line		

The full-size dimensions and particulars of the floats corresponding to the models tested are as follows:

N.A.C.A. model	41-A	41-B	35-B
Bur. Aero. float designation	Mark V	Mark VI	--
Length over-all	22 ft. 2-3/4 in.	23 ft. 2-1/8 in.	22 ft. 4 in.
Beam	3 ft. 6 in.	3 ft. 6 in.	3 ft. 7-1/2 in.
Depth	3 ft. 0 in.	3 ft. 0 in.	
Dead-rise angle, at keel	26°	26°	25°
Dead-rise angle, including flare	$22\text{-}1/2^{\circ}$	$21\text{-}1/2^{\circ}$	no flare
Center-of-gravity location, above keel	7 ft. 1-31/64 in.	7 ft. 1-31/64 in.	7 ft. 1-31/64 in.
Center-of-gravity location, forward of step	1 ft. 6-5/8 in.	1 ft. 6-5/8 in.	3 ft. 5-5/16 in.
Submerged displacement (sea water, 64 lb./cu.ft.)	7,050 lb.	7,300 lb.	--
Design load	3,800 lb.	3,800 lb.	3,800 lb.
Design get-away speed	89.5 f.p.s.	89.5 f.p.s.	89.5 f.p.s.
Trim at rest	3° 30'	2° 56'	5° 48'
Linear ratio, full size to model	3.50	3.50	3.35

Model 35-B is one of a series of pointed-step hulls having high length-beam ratios and large angles of dead rise developed by the Committee for use with flying boats. It was used in the present tests to obtain an indication of the application of the pointed-step form to the design of single floats. Its form is shown in figure 4 and a general test of it is described in reference 2.

The scale for the enlargement of model 35-B to full size was chosen to make the model represent a full-size float of approximately the same size and structural weight as the Navy floats. The full-scale height of the center of gravity above the keel was also made the same. The longitudinal position of the center of gravity was about the optimum for free trim at low speeds found by preliminary runs in the tank. The resulting trim at rest is high because the form was not designed for the high position of the center of gravity found in floats.

The three models were made of mahogany and smoothly finished in the usual manner with grey pigmented varnish. The offsets from which model 41-A was constructed are given in table I and those of model 35-B are given in reference 2. In view of the inferiority of model 41-B, its offsets have been omitted.

APPARATUS AND PROCEDURE

The N.A.C.A. tank is described in detail in reference 3. This tank is particularly suitable for testing large-scale models of seaplane floats because of the high speed of the towing carriage.

The towing gear, shown diagrammatically in reference 4, consists of a rigid frame suspended by steel tapes fore and aft and free to move vertically. The model is attached at a pivot point corresponding to the center of gravity of the complete seaplane and may be set free to pivot about this point or be locked to measure trimming moments at any desired angle. The load on the model is adjusted by counterweighting the suspension or by applying lift from a hydrofoil device running in the water at some distance from the model. The linkage transmitting the resistance force to the dynamometer is so arranged that the reading is unaffected by the vertical position of the frame.

General tests.- Models 41-A and 41-B were tested by the general method at several fixed trim angles to determine their resistance and trimming moments over all loadings thought to be applicable. For these models the range of trim angle was extended to include not only the best trim angle for each speed and load but also the angle for zero trimming moment at the lower speeds.

The net resistance and trimming moments obtained from the general tests were cross-plotted against trim angle for a large number of selected speeds. From these cross plots minimum resistance, best trim angle (trim angle corresponding to minimum resistance), trimming moment at best angle, angle for zero trimming moment, and resistance at zero trimming moment were obtained for each load and speed.

With the carriage at rest the static trimming moments and drafts were obtained over a range of loadings corresponding to that used in the tests. For wide departures from the design load, however, the upper part of the floats would be altered to maintain the proper surplus buoyancy.

Free-to-trim tests.- Force measurements were made with the models free to trim at constant speed up to 60 percent of the get-away speed and accelerated runs were made over the entire speed range to observe general behavior and stability. In these tests, the models were counterbalanced so that their centers of gravity coincided with the pivot point. During the runs the load was automatically adjusted by the hydrofoil device to correspond to the designed load and get-away speed with constant angle of attack of the wings. Frequent photographs were made during runs at constant speed and the behavior during accelerated runs was recorded by a motion-picture camera.

During the test of model 41-A the tail hydrofoil shown in figure 3 was attached and its effects on resistance, trim, and flow were found for several angles of attack and for two vertical positions of the hydrofoil.

RESULTS AND DISCUSSION

General Tests

Original data.- The resistance and trimming moment for model 41-A at all speeds, loads, and trim angles thought to apply are plotted against speed in figures 5 to 11. In these figures the trim angle τ is the inclination of the model base line to the horizontal. The resistance includes the air drag of the model. The trimming moments are referred to the center of gravity shown in figure 1 and include any aerodynamic moment on the float. Moments tending to raise the bow are considered positive.

A comparison of the original data of models 41-A and 41-B shows the latter model to have greater resistance at practically all loads, speeds, and trim angles. The differences in maximum trimming moment at the hump are small. Because of the extensive duplication of data involved, the original and derived data from the tests of model 41-B have been omitted.

The discontinuities in the resistance curves indicate the points in the speed range where the water breaks cleanly from the chines and steps and the model begins to plane. The transition is more marked at low trim angles and the speed at which it occurs increases with increase in load.

The drafts plotted in figure 12 for various angles of trim are the distances from the free-water surface to the keel at the main step. These curves define the vertical position of the model throughout the speed and load range tested. They appear to be of minor importance, however, because at present there seems to be no practical application of them and the actual contour of the water around the model varies considerably from that corresponding to the free-water surface.

Derived data.- The characteristics at the trim angle for zero trimming moment and at the best trim angle obtained from cross plots of figures 5 to 11 are plotted in figures 13 to 15 in a convenient form for use in take-off calculations. The coefficients are nondimensional and are based on Froude's law of similitude. They are defined as follows:

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

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

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

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

where

V is speed, f.p.s.

R, resistance, lb.

Δ, load, lb.

M, trimming moment, lb.-ft.

b, maximum beam of float, ft.

g, acceleration of gravity, 32.2 ft./sec.^{2}

w, specific weight of water, lb./cu.ft., usually taken as 64 lb./cu.ft. for sea water.

Any consistent system of units may be employed in place of those given. The water in the N.A.C.A. tank had a specific weight of 63.5 during these tests.

The application of the data at best trim angle to calculate total resistance for the best take-off is as follows: A series of speeds are chosen corresponding to the C_V parameters in figure 14 and to the assumed size (beam) of the float. The seaplane is assumed to be at the angle for minimum water resistance throughout the run and an approximate value of this best trim angle is read from figure 15 for each value of C_V. The angle of attack of the wing is then the sum of this angle and the angle of wing setting; the lift coefficient is obtained from curves of the aerodynamic characteristics of the seaplane modified to include the "ground effect" caused by the proximity of the water. The air drag of the float should be deducted as it is included in C_R. From the calculated wing lift, the load on the water and C_Δ are found. With this value of C_Δ, a more accurate value of the best trim angle can be read from figure 15 and the procedure repeated. The value of C_Δ from the second approximation is usually sufficiently accurate for use in obtaining the corresponding C_R from figure 14. From C_R and the drag coefficient excluding the hull the total resistance is then calculated. The trimming moment at best trim angle is obtained from figure 15.

For the calculation of total resistance at zero trimming moment the trim angle and C_R are read from figure

13 in place of the data at best trim angle. The original data of figures 5 to 11 may be used to obtain performance at any constant trim angle, say 5° or 7°.

The curve of trimming moments at rest against trim angle may be obtained from figure 16 for any displacement within the load range tested. This curve may be corrected for other positions of the center of gravity. The trim at rest, which is the trim giving zero trimming moment, and the draft at the main step, from the lower curves of figure 16, define the position of the load water line.

Comparison of resistance at best trim angle.- The resistances of models 41-A, 41-B, and 35-B at best trim angle and for various loads and speeds are compared in figure 17. (The curves for model 35-B are taken from reference 2.) It is seen that the differences in resistance coefficient between models 41-A and 41-B are negligible at very low speeds as well as at high speeds and light loads, where the wetted portions of the forebodies are practically the same. At the hump speed the resistance coefficient of model 41-B is from 4 to 6 percent higher than that of model 41-A. The general superiority of model 41-A is attributed to the fact that the forebody keel and buttock lines in way of the planing bottom are generally lower than those of model 41-B, as indicated in figure 1.

The hump resistance of model 35-B is less than that of the other models and occurs at a slightly lower speed coefficient. The resistance coefficient at lower planing speeds is slightly greater. At the light loads near get-away speeds, however, it is markedly smaller, presumably because of the increased afterbody clearance obtained in this form.

Free-to-Trim Tests

Comparison of forms tested.- The free-to-trim characteristics of the models at the designed load are shown in figure 18. In this figure the test results have been converted to the corresponding full-scale values to make them directly comparable. The rise is the vertical distance of the center of gravity above its position at rest.

Here again, the resistance of model 41-B is greater than that of model 41-A, the increase at the hump speed being about 6 percent. The maximum free-to-trim angle of model 41-A is about 5° higher than its corresponding best trim angle from figure 15. The hump resistance of model 35-B is approximately 15 percent less than that of model 41-A principally because the free-trim angle given by the pointed-step form with low angle of afterbody keel is nearer to the best trim angle.

Effect of tail hydrofoil.- The effect of the tail hydrofoil at the second step in reducing the excessive free-trim angle of model 41-A is shown in figure 19. As the angle of attack of the hydrofoil is increased, the trim and resistance at the hump speed are decreased but just before the discontinuity where planing begins the resistance is increased. Hence, from the standpoint of resistance, the best hydrofoil setting appeared to be about 16° up from the model base line. Increasing the vertical distance below the float produced no further improvement. From the curves it is concluded that a hydrofoil of the size tested will reduce the maximum trim about 2° and the hump resistance about 9 percent.

General behavior and spray.- During runs at constant speed, the afterdecks of models 41-A and 41-B were immersed at speeds slightly below the point where the chines became dry. The flow over the rounded decks during this condition gave rise to an undesirable yawing and skidding tendency that persisted, however, over only a very narrow range of speed and was only slightly apparent during accelerated runs. At constant speed, the reduction in trim given by the tail hydrofoil was not sufficient to correct this condition. It is not believed to be serious, however, as no mention of it was made in the reports of service trials of seaplanes fitted with the Mark V floats. The afterdeck of model 35-B remained dry at low speeds and it is believed that because of the lower free-trim angle it would not be submerged even if rounded like that of models 41-A and 41-B.

A very high roach, which would wet tail surfaces in the usual position, formed aft of all the models just before the hump speed. In the accelerated runs, this column of water appeared, reached its maximum, and disappeared in a very short time but nevertheless was clearly present.

Model 35-B was directionally unstable at the speed just before its chines became dry, a characteristic of this model that was noted in reference 2. The tendency to swerve was more pronounced during accelerated runs than the similar tendency caused by the flow over the after-decks of models 41-A and 41-B. This tendency has been partly controlled by spray strips and it is believed that a transverse flare incorporated in this form will reduce the magnitude of the side force by making the curved sides of the pointed step run dry earlier and that the tendency would be almost unnoticed in practice because of the very narrow speed range over which it acts.

It was quite evident during the tests that transverse flare at the chine is very desirable for floats. At the lower speeds there is, of course, a large amount of spray from the forebodies because of the heavy loading compared with the beam and over-all size of the floats. This spray was greatest in the case of model 35-B, principally because of the absence of transverse flare in its sections over the planing bottom. At high speeds, the spray rapidly thinned and all the models ran cleanly in the smooth-water conditions reproduced in the tank.

Photographs of the spray from model 41-A, with and without the tail vane, model 41-B, and model 35-B are shown in figures 20 to 22. The bow pictures show very little difference between models 41-A and 41-B but indicate that the reduction in trim effected by the tail hydrofoil might reduce the height of the spray slightly. When the difference in scale of the models is taken into account, model 35-B appears definitely worse as tested, but it is believed that transverse flare would effect a considerable improvement in its spray characteristics. The stern pictures show the roach formed aft of the models but the comparisons are complicated by the fact that it forms at slightly different speeds for each model.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 2, 1936.

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2. Dawson, John R.: Tank Tests of Three Models of Flying-Boat Hulls of the Pointed-Step Type with Different Angles of Dead Rise - N.A.C.A. Model 35 Series. T.N. No. 551, N.A.C.A., 1936.

3. Truscott, Starr: The N.A.C.A. Tank - A High-Speed Towing Basin for Testing Models of Seaplane Floats. T.R. No. 470, N.A.C.A., 1933.

4. Shoemaker, James M.: Tank Tests of Flat and V-Bottom Planing Surfaces. T.N. No. 509, N.A.C.A., 1934.

TABLE I

Offsets for N.A.C.A. Model 41-A Single Float (Inches)

Station	Distance from F.P.	Distance from base line: Keel	Chine	Deck	Tangent of flare	Half-breadths: Chine	Tangent of flare	Radius of flare	Radius of deck
F.P.	0.00	2.43	2.43	2.43		Tangent to F.P.			2.96
1	1.00	5.72	2.79	1.50	3.75	2.46	1.13	1.92	2.96
2	2.13	7.06	3.25	1.00	4.43	3.36	1.72	2.78	3.63
3	3.25	7.86	3.63	.74	4.86	3.93	2.06	2.98	4.12
4	5.50	8.79	4.29	.47	5.57	4.64	2.57	3.65	4.74
5	10.00	9.68	5.32	.22	6.54	5.32	3.15	4.71	5.31
6	14.46	10.00	6.14	.11	7.14	5.61	3.43	4.62	5.61
7	19.03	10.16	6.74	.03	7.61	5.78	3.61	5.16	5.78
7-1/2	23.52	10.25	7.15	.00	7.91	5.88	3.73	5.59	5.88
8	28.00	10.29	7.40	↑	8.13	5.93	3.80	6.02	5.93
8-1/2	32.50	↑	7.55		8.27	5.98	3.84	7.29	5.98
9	37.00	↓	7.68		8.36	5.99	3.86	7.34	5.99
10,F.	42.68	10.29	7.81		8.43	6.00	3.86	6.97	6.00
10,A.	42.68	9.36	6.44	↓					
11	46.00	↑	6.04	.00		5.90			5.90
12	53.68		5.35	.02		5.25			5.25
13	61.36	↓	4.93	.15		4.05			4.05
14	69.04	5.90	4.73	.54		2.39			2.39
15,F.	71.75	5.73	4.91	.72		1.68			1.68
15,A.	71.75	4.88	4.06						
16	74.29	↕	3.85	.97		1.00			1.00
A.P.	76.21	3.93	3.93						

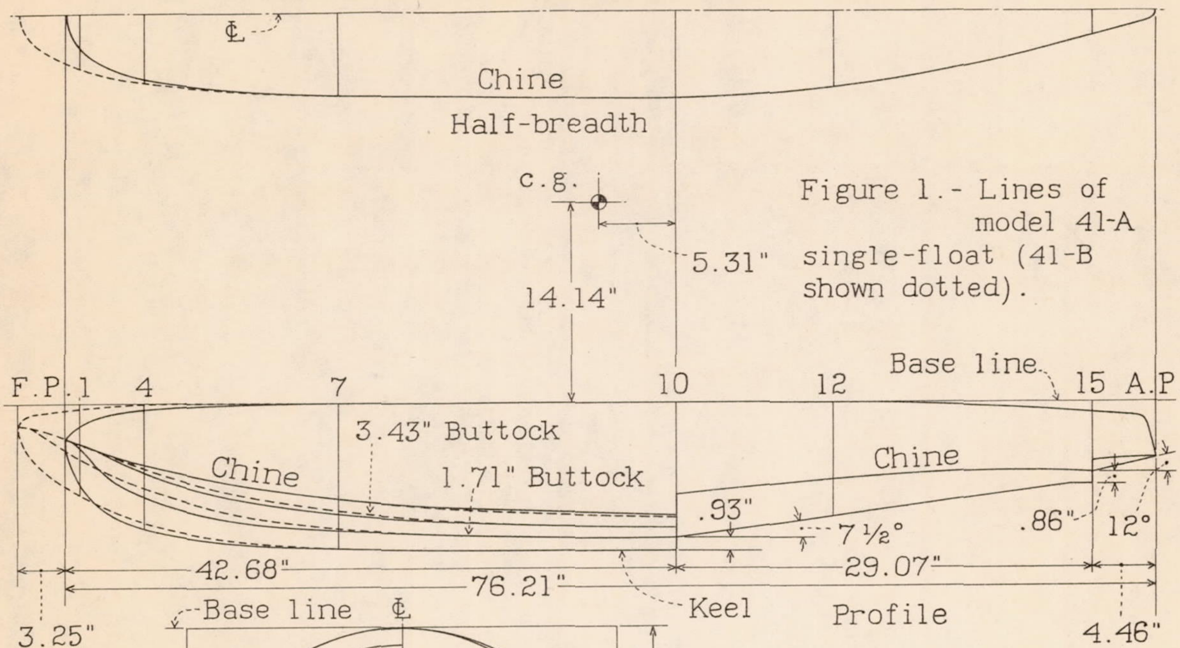
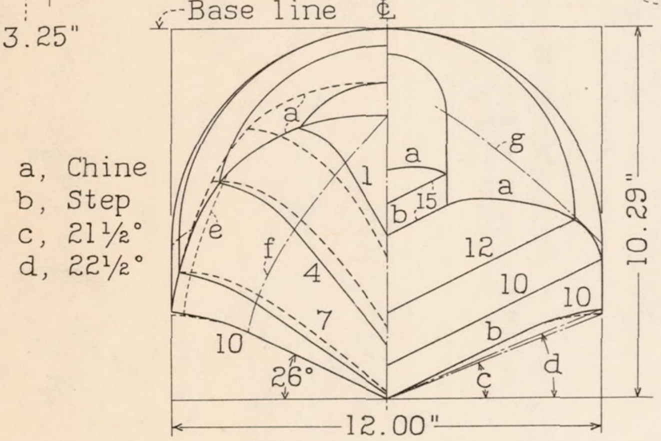


Figure 1.- Lines of model 41-A single-float (41-B shown dotted).



e, Tangency of flat (41-B).
f, " " flare (41-A).
g, " " deck radius.

Figure 2.- Body plan of model 41-A single float (41-B shown dotted).

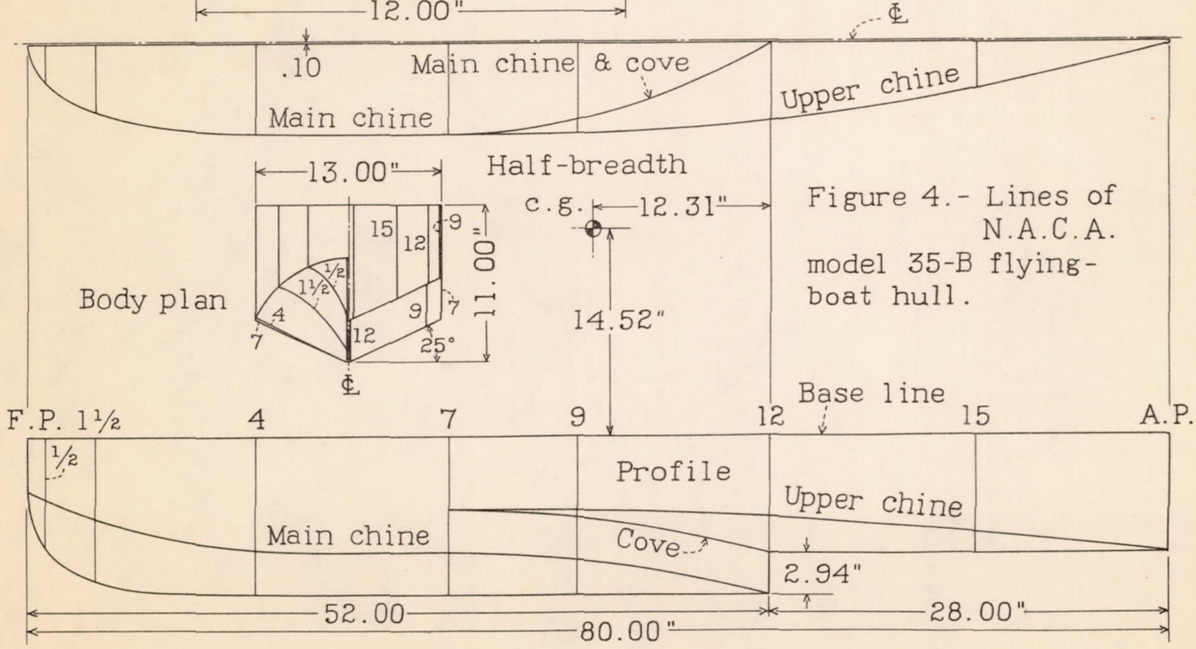


Figure 4.- Lines of N.A.C.A. model 35-B flying-boat hull.

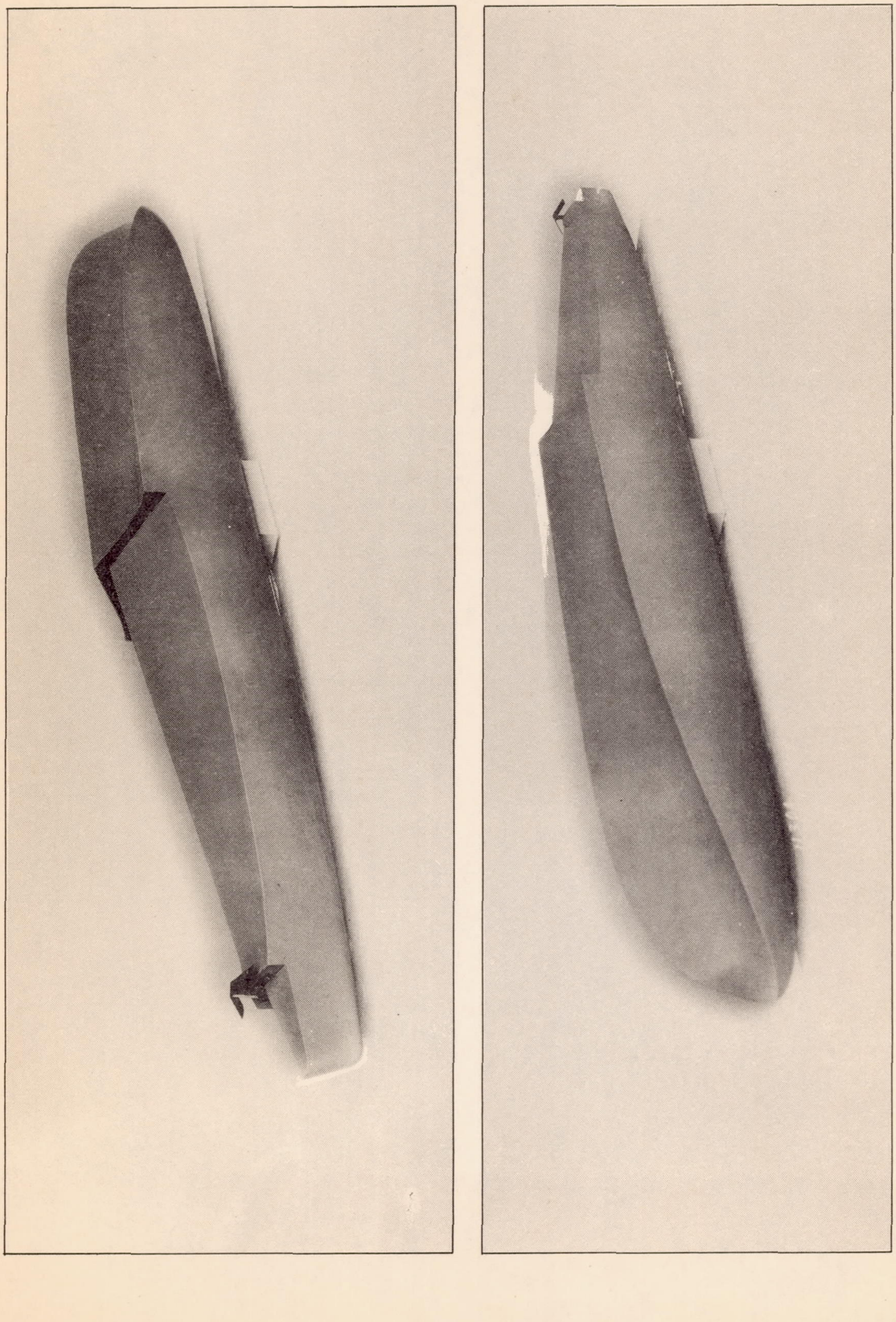


Figure 3.- Model 41 - A showing hydrofoil at second step.

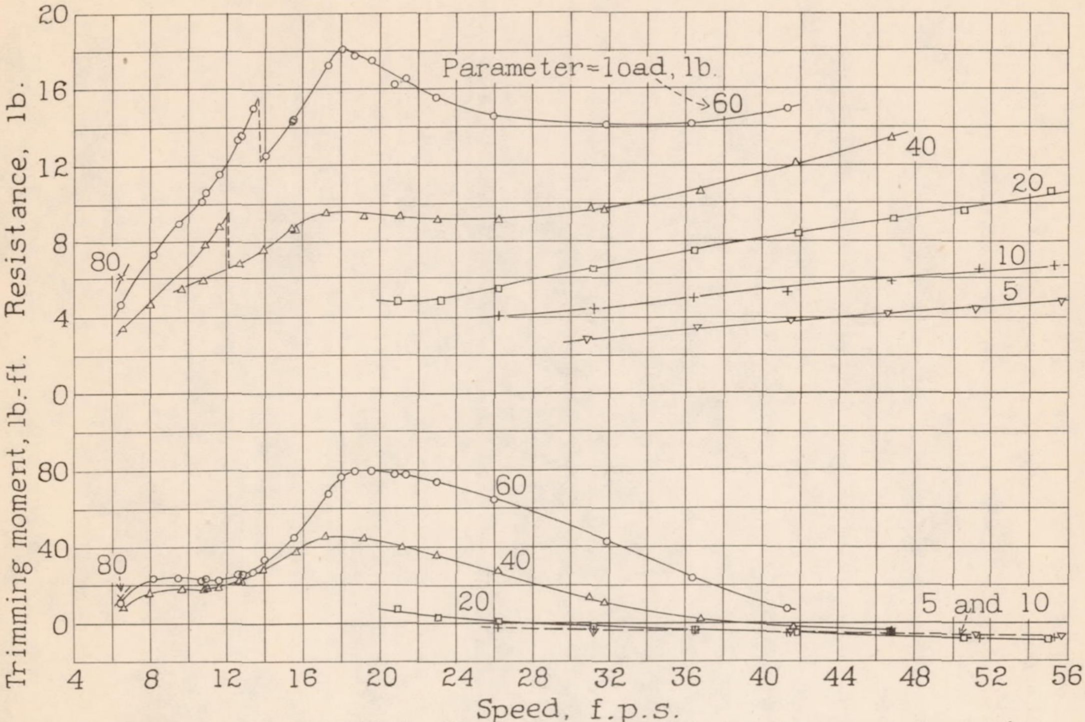


Figure 5.- Model 41-A. Resistance and trimming moment. $\tau = 3°$

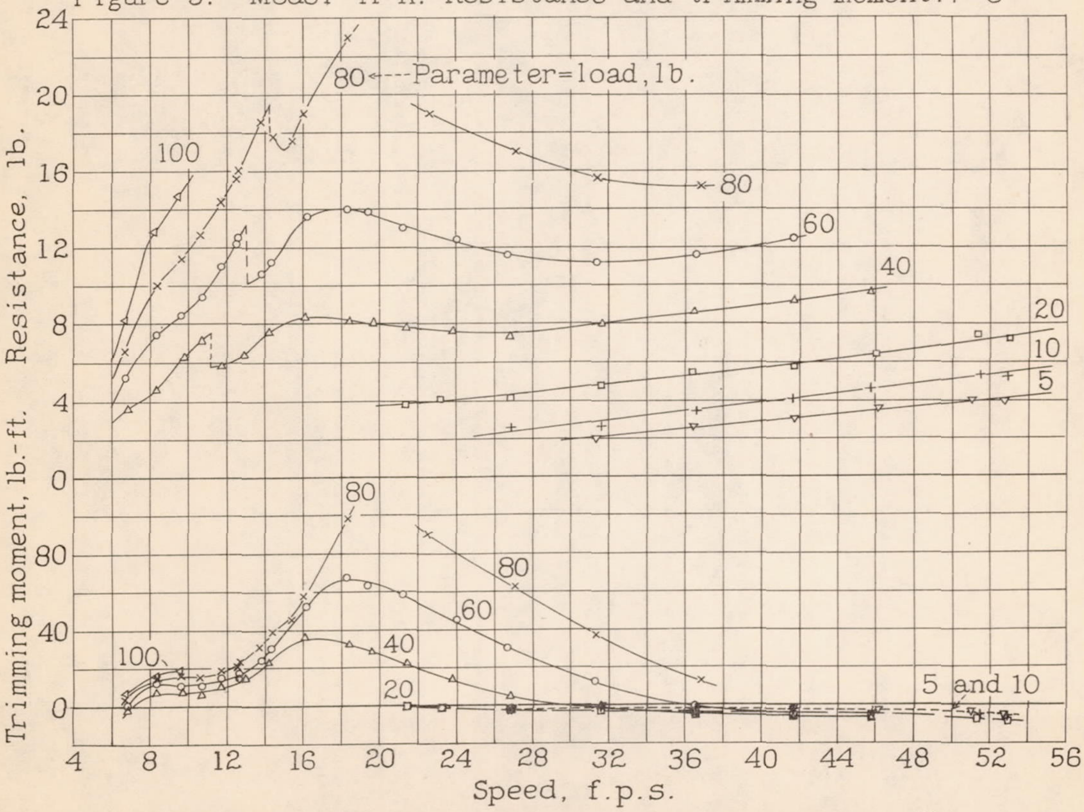


Figure 6.-Model 41-A. Resistance and trimming moment. τ - 5°

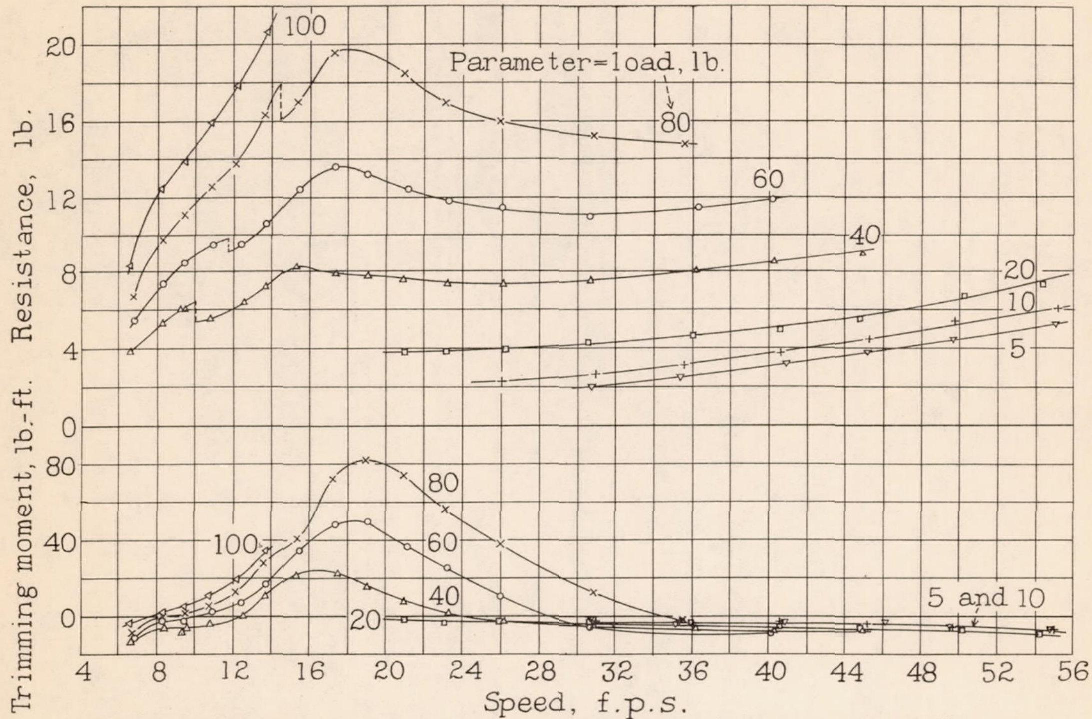


Figure 7.-Model 41-A. Resistance and trimming moment. $\tau = 7°$

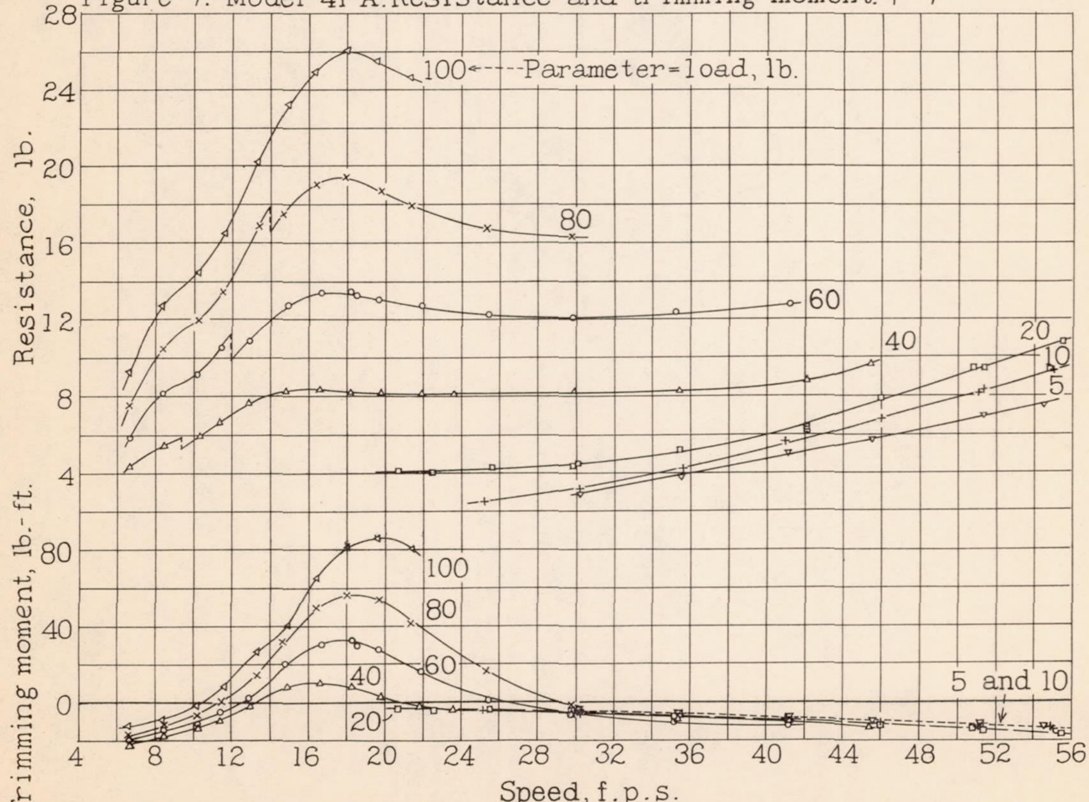


Figure 8.-Model 41-A. Resistance and trimming moment. $\tau = 9°$

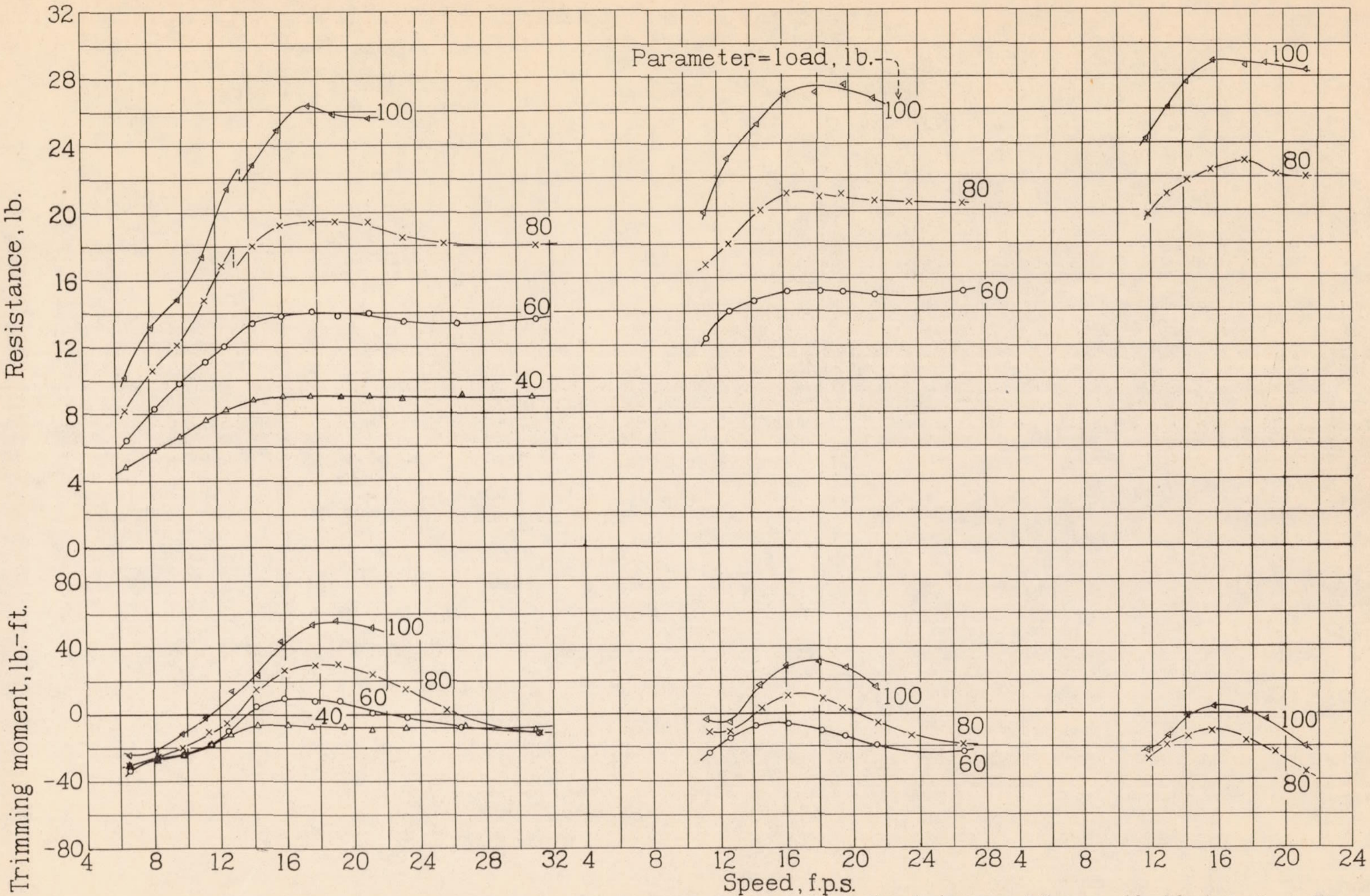


Figure 9.-Model 41-A. Resistance and trimming moment. τ = 11°

Figure 10.-Model 41-A. Resistance and trimming moment. τ = 13°

Figure 11.-Model 41-A. Res. and trim. moment. τ = 15°

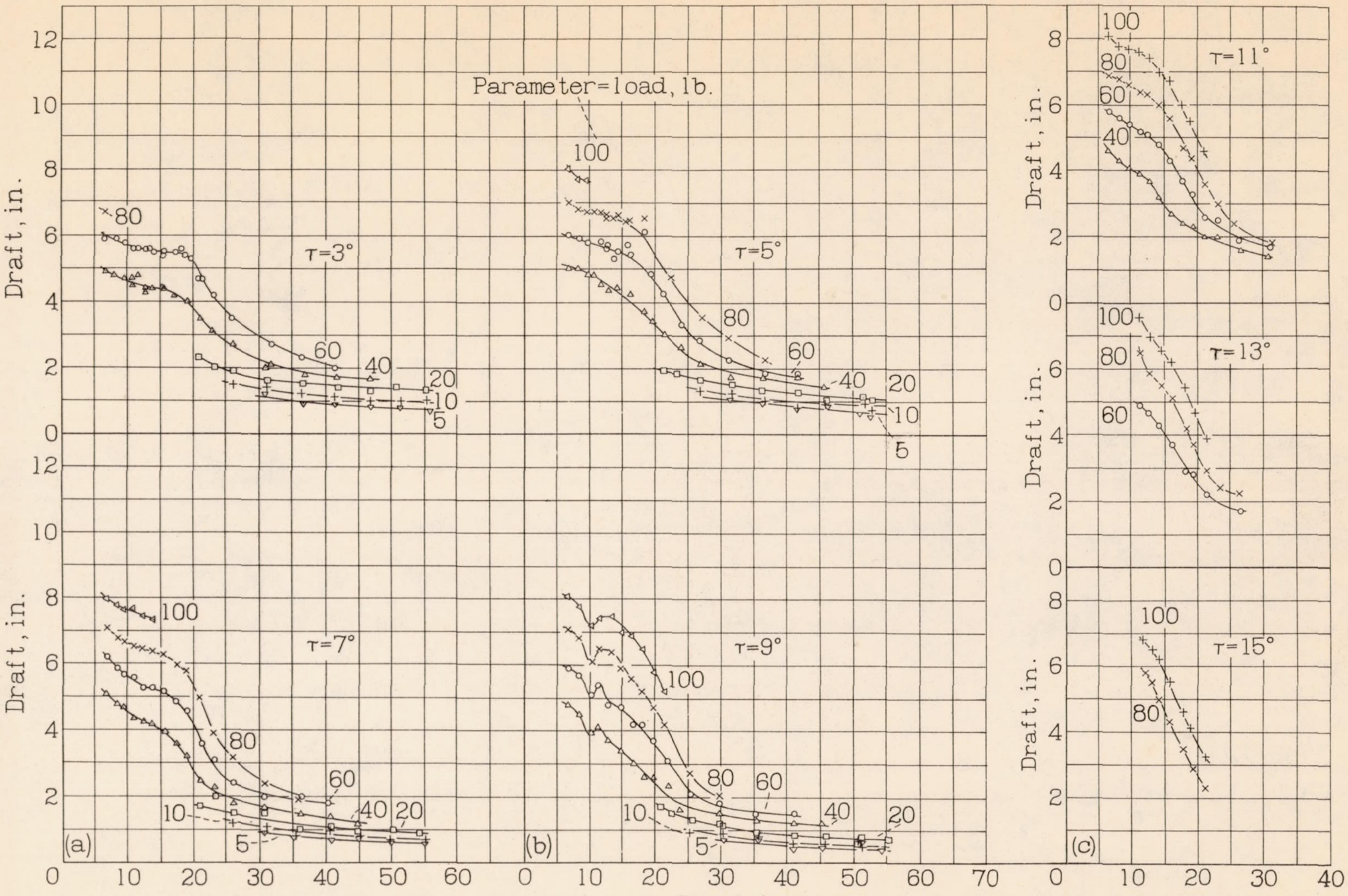


Figure 12.-Model 41-A. Drafts at main step.

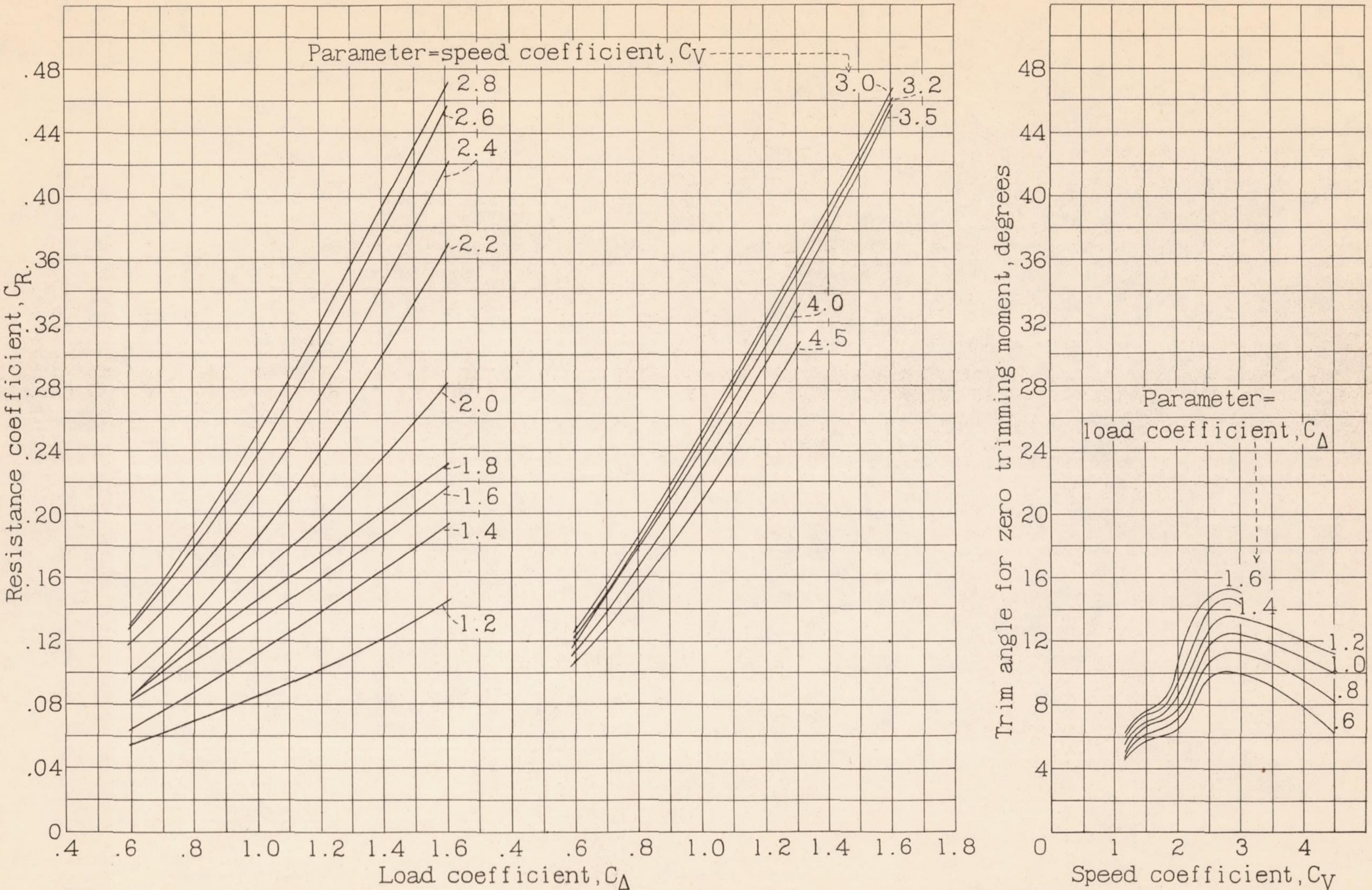


Figure 13.-Model 41-A. Chart for determination of resistance and trim angle at zero trimming moment.

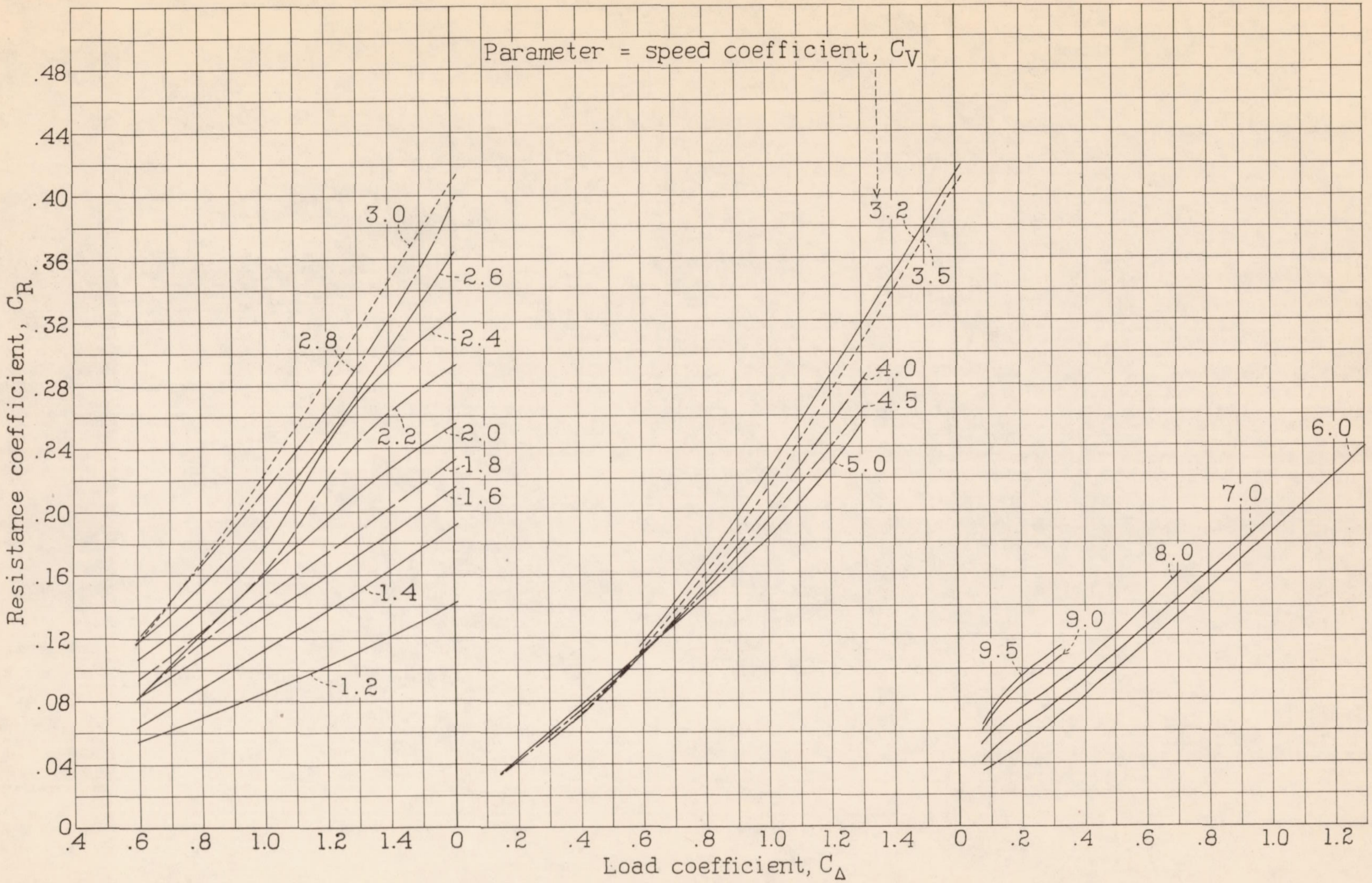


Figure 14.- Model 41-A. Chart for determination of resistance at best trim angle.

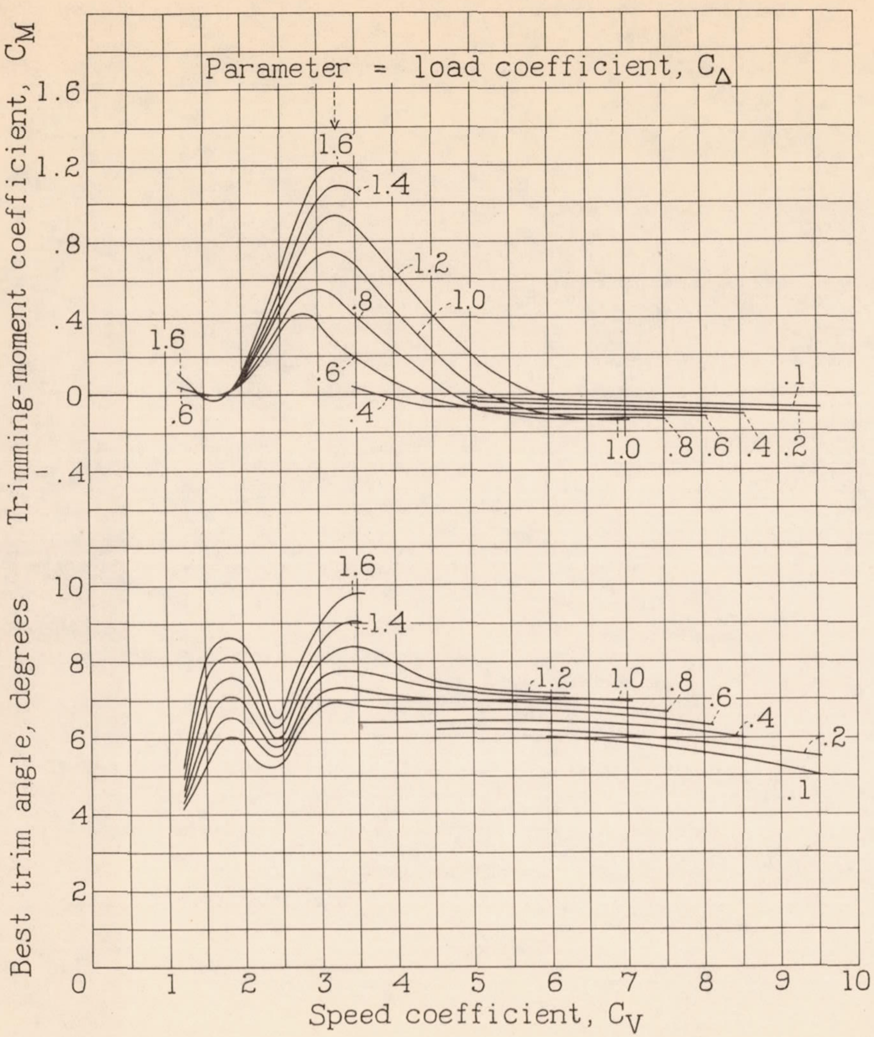


Figure 15.- Model 41-A. Chart for determination of best trim angle and trimming moment at best trim angle.

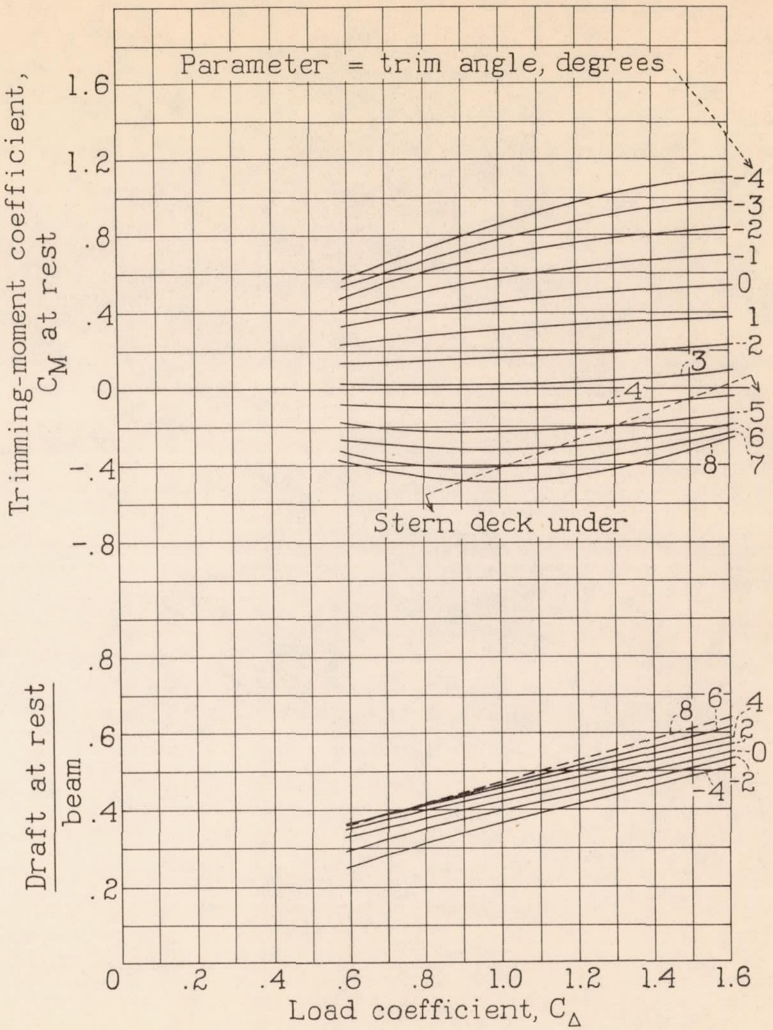
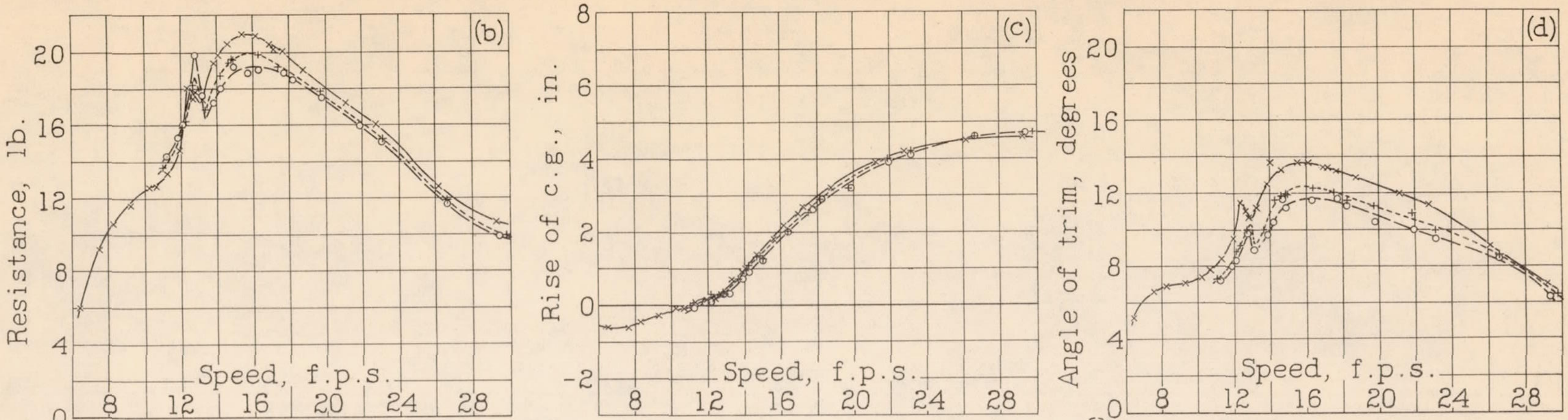
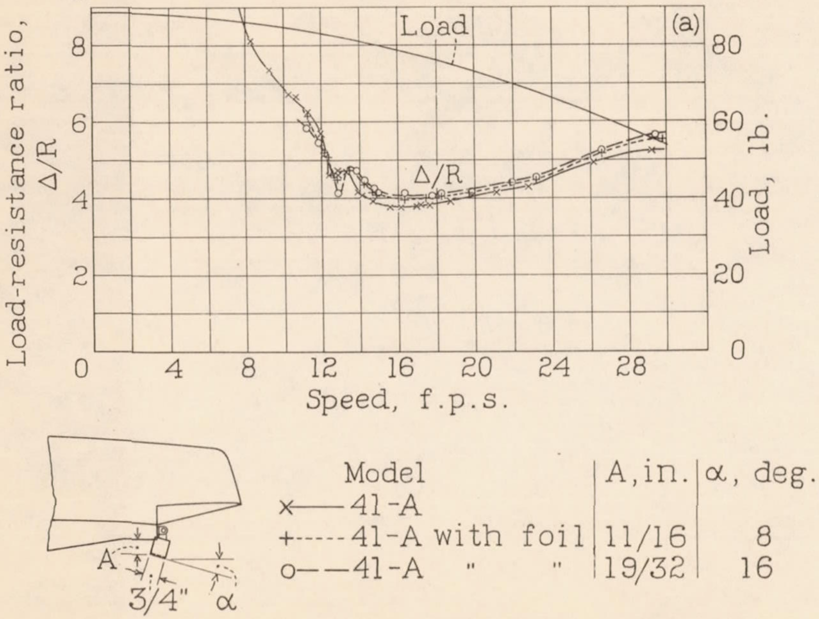


Figure 16.- Model 41-A. Chart for determination of trimming moments and drafts at rest.





Model	A, in.	α, deg.
×——41-A		
+-----41-A with foil	11/16	8
o——41-A " "	19/32	16

Figure 19.- Model 41-A. Effect of hydrofoil at second step on free-to-trim characteristics.
(a,b,c,d)

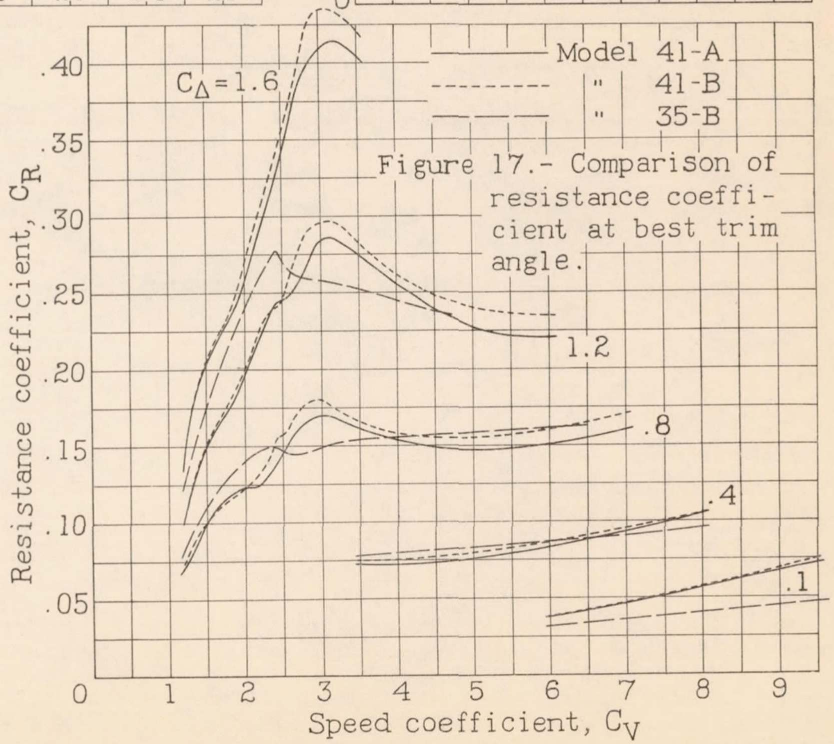


Figure 17.- Comparison of resistance coefficient at best trim angle.

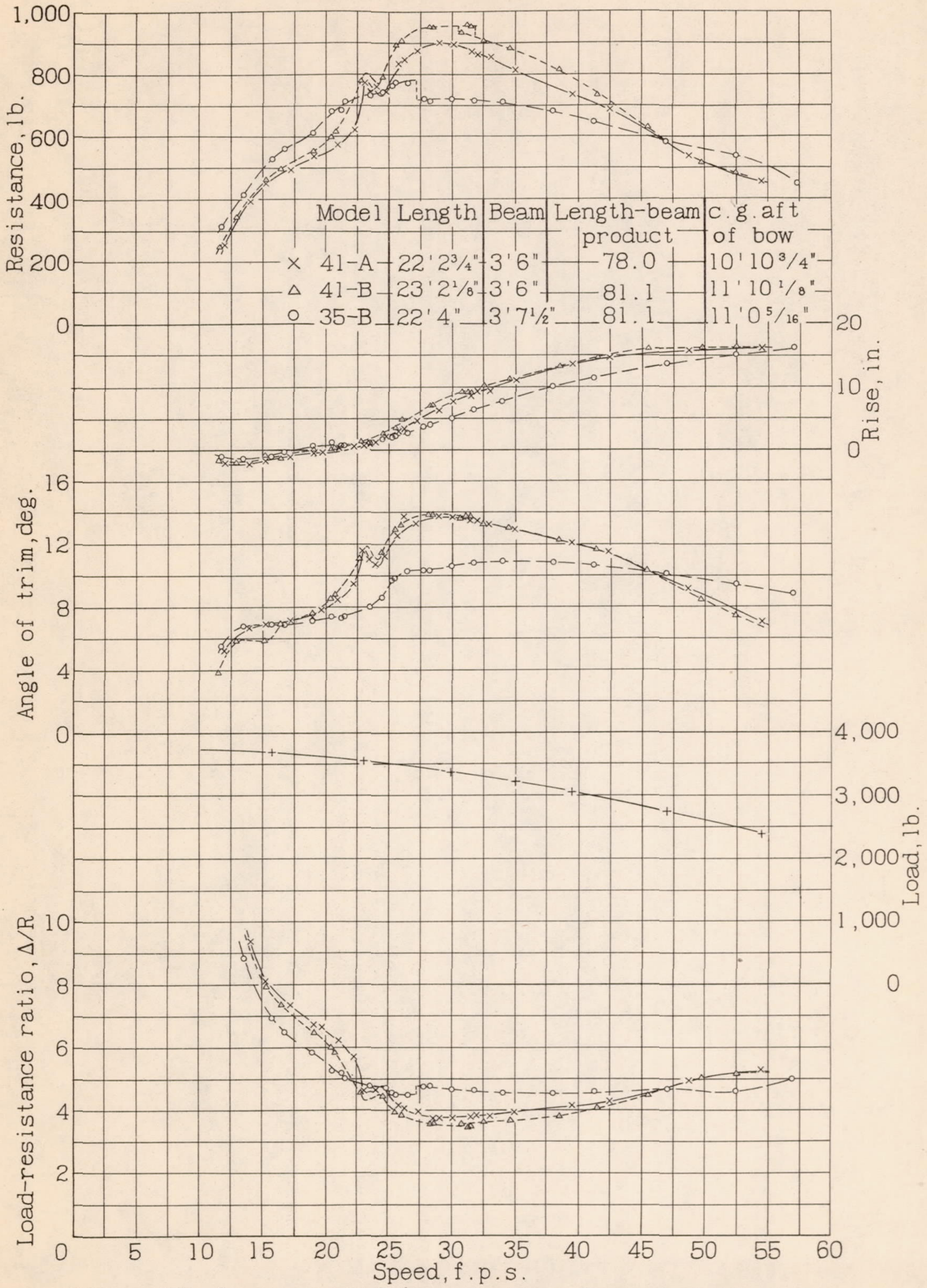
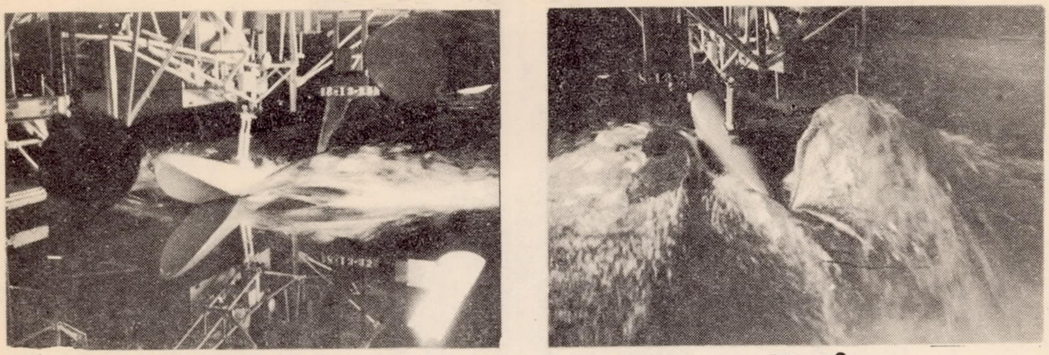
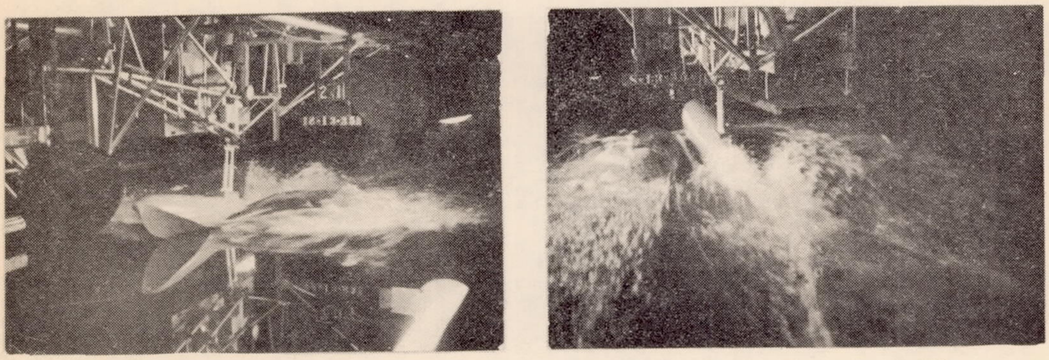


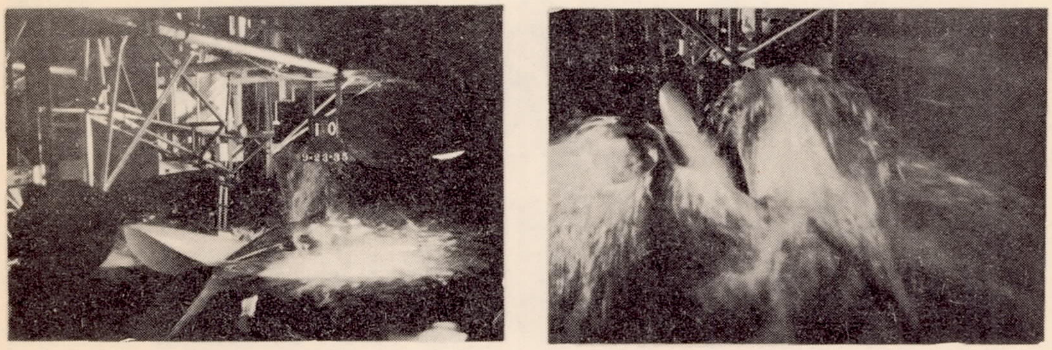
Figure 18.-Comparison of free-to-trim characteristics at 3,800 lb. gross load. c.g. above keel, 7'1 31/64".



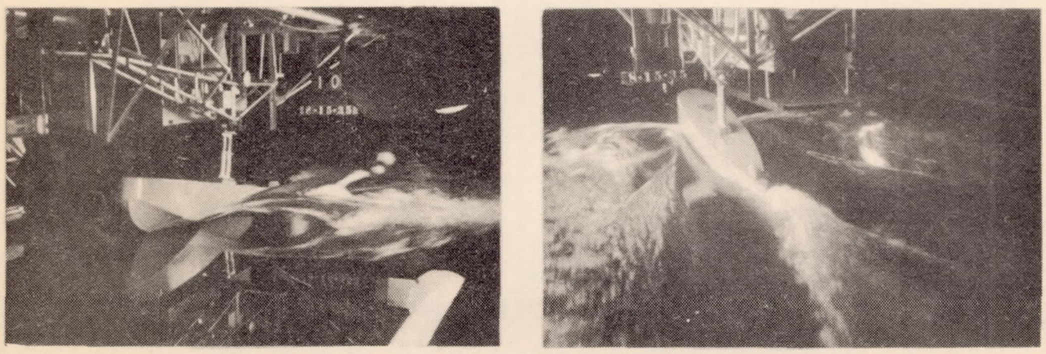
Model 41 - A; V = 13.8 f.p.s.; $\tau = 12.5^{\circ}$



Model 41 - A with hydrofoil; V = 13.8 f.p.s.; $\tau = 9.7^{\circ}$

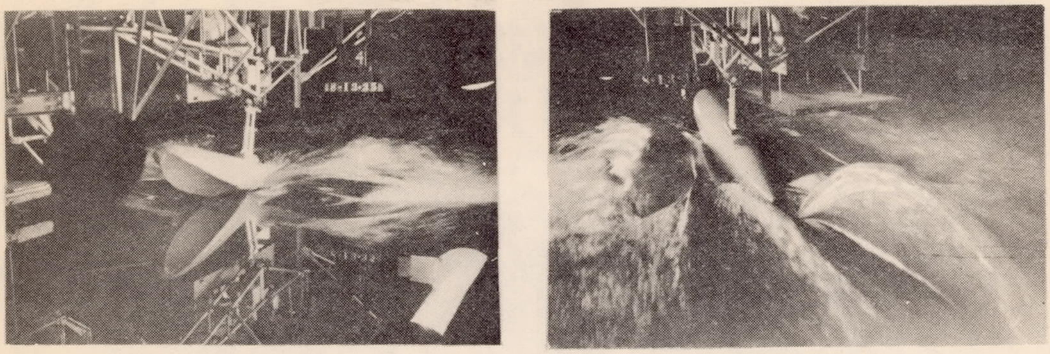


Model 41 - B; V = 13.6 f.p.s.; $\tau = 12.8^{\circ}$

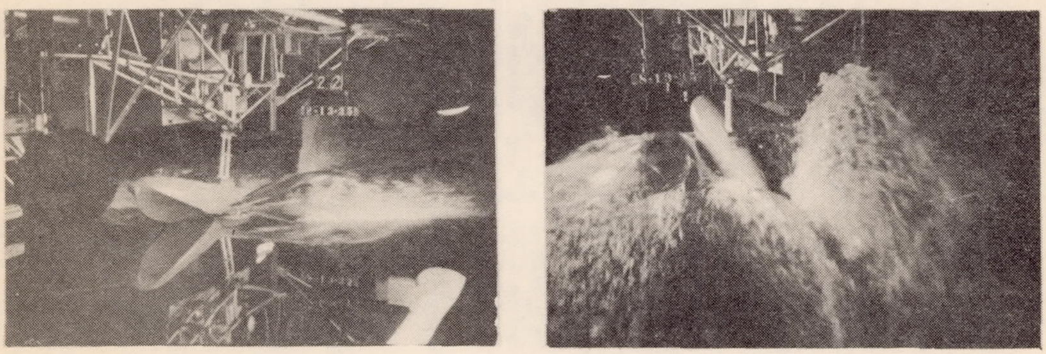


Model 35 - B; V = 14.0 f.p.s.; $\tau = 9.8^{\circ}$

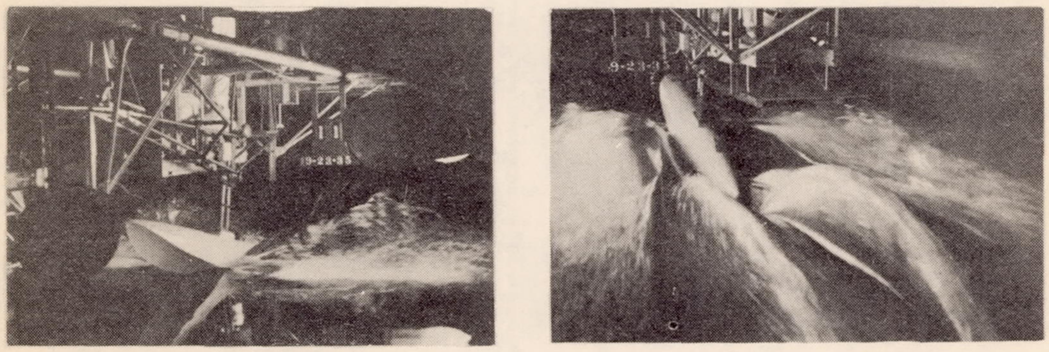
Figure 20.- Photographs of spray with models free-to-trim.



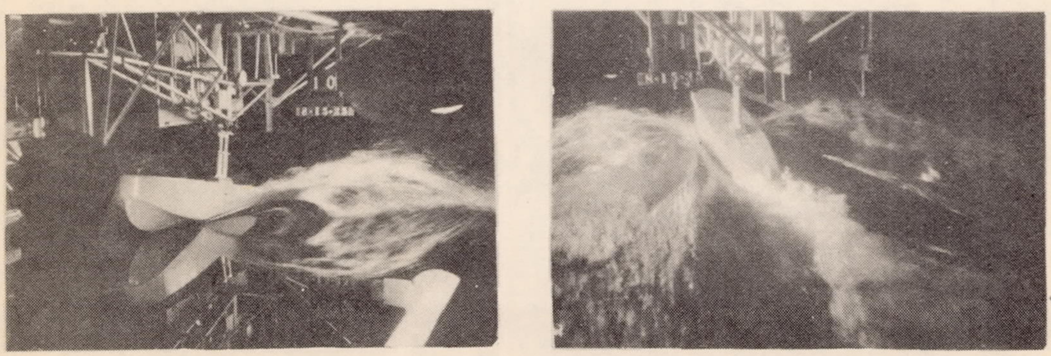
Model 41 - A; $V = 15.5$ f.p.s.; $\tau = 13.7^{\circ}$



Model 41 - A with hydrofoil; $V = 14.9$ f.p.s.; $\tau = 11.2^{\circ}$

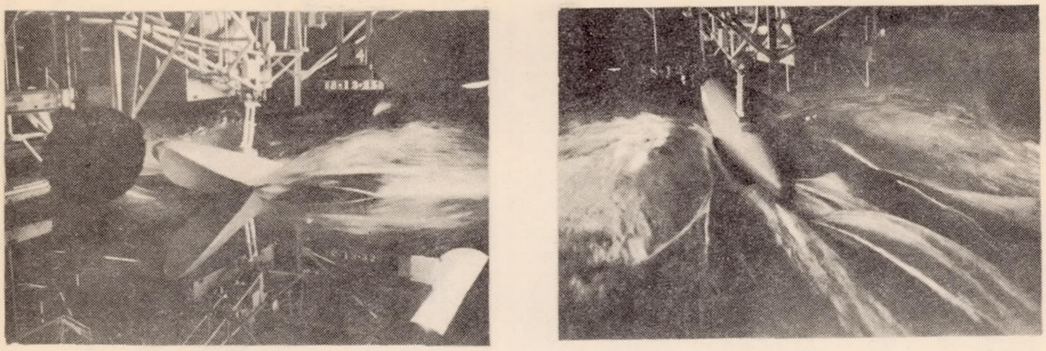


Model 41 - B; $V = 15.0$ f.p.s.; $\tau = 13.6^{\circ}$

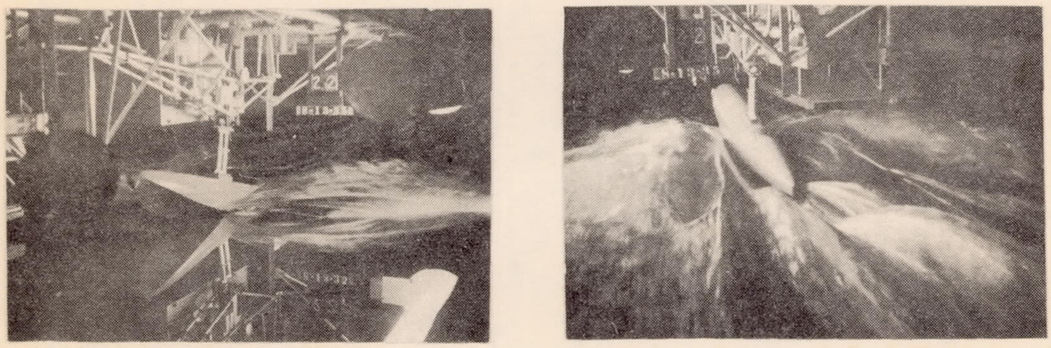


Model 35 - B; $V = 15.2$ f.p.s.; $\tau = 10.3^{\circ}$

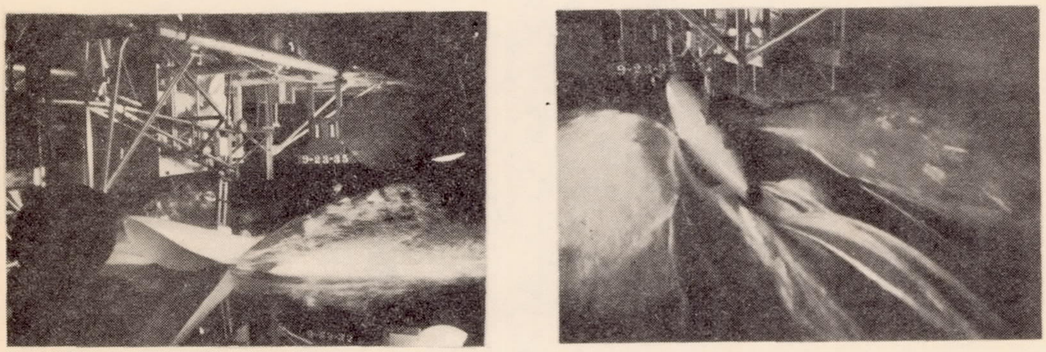
Figure 21.- Photographs of spray with models free-to-trim.



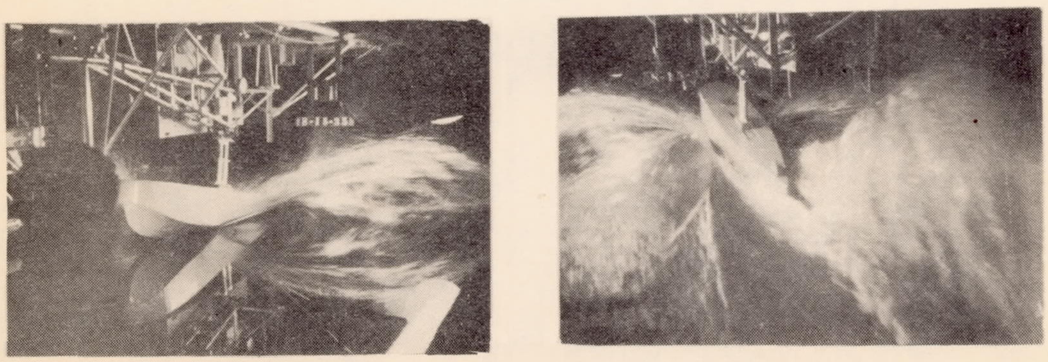
Model 41 - A; V = 17.6 f.p.s.; τ = 13.2°



Model 41 - A with hydrofoil; V = 17.7 f.p.s.; τ = 11.7°



Model 41 - B; V = 17.3 f.p.s.; τ = 13.3°



Model 35 - B; V = 17.4 f.p.s.; τ = 10.8°

Figure 22.- Photographs of spray with models free-to-trim.