TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 490

TANK TESTS OF AUXILIARY VANES AS A SUBSTITUTE FOR PLANING AREA

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SUMMARY

The results of towing tests made on two models at the request of the Bureau of Aeronautics, Navy Department, are presented. The first model represents the hull of the U.S. Navy PN-8 flying boat. The second represents a proposed alteration of the PN-8, in which the sponsons of the original hull are removed and auxiliary lifting vanes are fitted at the chines immediately forward of the main step. The tests showed that the altered form gave a large increase in hump resistance and a very undesirable spray formation through a large part of the speed range.

INTRODUCTION

The hull of the U. S. Navy PN-8 flying boat has a wide planing bottom, formed by lateral extensions of the sides below the narrower central part that houses personnel and equipment. These extensions, or "sponsons" extend from the bow to a point aft of the second step. It was proposed by the Bureau of Aeronautics, Navy Department, to investigate the water performance of a modification of this hull in which the sponsons are removed and small auxiliary lifting vanes substituted. The vanes were intended to act as double-surface hydrofoils at the lower speeds where planing begins and to come clear at the higher speeds, where the narrower planing bottom that results from the removal of the sponsons would be more efficient. It was hoped that the modified hull would have less water resistance besides being more desirable from considerations of weight, strength, and air drag.

Model-basin tests of both the original and the modified hulls were made by the Committee at the N.A.C.A. tank, Langley Field, Va., at the request of the Bureau of

Aeronautics. It was planned to modify an existing PN-8 flying-boat for full-scale trials should these tests indicate the desirability of such an arrangement.

Two models were furnished by the Bureau for the investigation. The first, designated "Model 9", was a one-fifth full-size reproduction of the standard PN-8 hull as used in service. The second, designated "Model 10", was like Model 9 except that the sponsons were omitted and the auxiliary vanes substituted. The models were towed at the tank in March 1932.

Although the tests were made primarily for the Navy Department, permission has been granted to publish the results. It is believed that the manner in which the vanes behaved will be of interest in spite of the fact that the arrangement as tested proved to be undesirable.

DESCRIPTION OF MODELS

Photographs of the models as tested are shown in figures 1 and 2. They were constructed carefully to scale and made hollow to reduce the weight. The exterior surfaces were smoothly finished with enamel.

The models are 9 feet long, corresponding to a full-scale length of 45 feet. This large size of model, made possible by the high speed of the towing carriage at the N.A.C.A. tank, enables a more accurate reproduction of full-scale phenomena, particularly that of spray formation, which was an important consideration in this investigation.

The sheer line of the full-size hull is not reproduced in the models. The vertical sides are carried up to a straight sheer line 13.8 inches above the keel at step. The open tops are closed in with light plywood decking to keep spray out of the interiors.

The form of the original hull, Model 9, is shown in figure 1. The altered form of Model 10 and the type of vanes employed are shown in figure 2. It can be seen that the cross-sectional area of the modified hull is considerably reduced by the elimination of the sponsons; the beam of Model 9 is 24.48 inches and that of Model 10 is 12.38 inches.

In figure 2, it is seen that the auxiliary vanes are attached at the chines immediately forward of the main step so that their under surfaces form a continuation of the planing bottom. The plan form of the vanes is trapezoidal and their longitudinal sections are similar to sharp-nosed propeller profiles. The significant dimensions are as follows:

Root chord	11.00 in.
Tip chord	7.40 in.
Root thickness	1.00 in.
Tip thickness	.67 in.
Area each vane (projected on a horizontal plane)	38.8 sq.in.
Beam over vanes	20.30 in.

APPARATUS AND PROCEDURE

The N.A.C.A. tank and its equipment for testing models of seaplane hulls are described in reference 1. The larger towing gear was used for testing Models 9 and 10.

The center of gravity of the complete seaplane was taken as the towing point and the center of the trimming moments. For both models this point is 8.75 inches forward of the main step and 20.1 inches above the base line (line through the keel at the main step and parallel to the sheer). The models were balanced longitudinally so that the designed trim at rest, 0°, was obtained, but they were not balanced vertically. At angles other than 0°, then, the attitude of the models when run free-to-trim was influenced slightly by the moment about the towing point, owing to the displacement of the model center of gravity. The effect of this gravity moment is not thought to be detrimental, however, since the net aerodynamic moment of the actual airplane due to the wings, tail surfaces, and propeller acts in the same direction.

The load on the water at rest for each model was 112 pounds, and the get-away speed was 39.4 feet per second, corresponding to a full-scale gross load of 14,000 pounds and a get-away speed of 60 miles per hour. The hydrovane lift device described in reference 1 was adjusted to lift the model just clear at the get-away speed and its lift was assumed to vary as the square of the speed, scale effect on the lift of the vane being neglected. This procedure is equivalent to assuming a constant lift coefficient for the wings throughout the take-off.

The models were towed free-to-trim and at fixed trims of 10°, 8°, 6°, 5°, and 4°. This range of angles insured finding the trim for minimum resistance for each part of the speed range. In a succession of constant-speed runs of the towing carriage, data were obtained for curves of resistance, Δ/R, rise of center of gravity, trim angle, and trimming moment against speed. Several photographs of Model 10 were obtained in that part of the speed range where the vanes were in contact with the water.

TEST RESULTS

The net values of the quantities measured, obtained by deducting the usual towing-gear tares (see reference 1) from the observed values, are plotted in figures 3 and 4. These curves show the data plotted against speed, both for the free-to-trim condition and for the various fixed trims. The interpretations of the quantities are as follows:

1. The resistance is equal to water resistance plus air drag of the model.

2. The symbol Δ/R is the ratio of load on the water to resistance. The load, Δ, at any speed, V, is defined by the relation

$$\Delta = \Delta_0 \left[1 - \left(\frac{V}{V_G}\right)^2\right]$$

where Δ_0 is the initial load, 112 pounds.

V_G, the get-away speed, 39.4 feet per second.

3. The rise of the center of gravity is measured from the position obtained at rest with the model at 0° trim.

4. The trim angle is measured between the base line (or sheer) of the model and the horizontal.

5. The trimming moments are given with reference to the towing point. Moments which tend to raise the bow are considered positive. The moment curve shown for the free-to-trim condition in each case is that of the water moment equal and opposite to the gravity moment, the existence of which was explained in the preceding section.

PRECISION

The test results as given by the faired curves are estimated to be correct within the following limits:

Speed	±0.1 f.p.s.
Resistance	±0.1 lb.
Trim angle	±0.1°
Trimming moment	±1.0 lb.-ft.
Rise of center of gravity	±0.2 in.

DISCUSSION OF RESULTS

The characteristics of Model 9, as shown by the curves of figure 3, are representative for the type. The resistance and trim angle rise to a maximum at about 38 percent of the get-away speed, then drop off as the progressively unloaded hull continues through the planing region to the get-away speed. Its performance, in general, is satisfactory, although the value of Δ/R at the hump speed is rather low as compared with that of more recent designs.

The curves of figure 4 show marked differences in the characteristics of Model 10. In the region of the hump speed, particularly, the trim angle jumps from 5.4° at 15 feet per second to 10° at 17 feet per second, accompanied by a sharp peak in the resistance curve between these speeds. It is uncertain just how the hull would behave at this point under full-scale conditions and accelerated motion.

The Δ/R curves for the two models are compared in figure 5. These curves were constructed by fairing the upper envelope of the Δ/R curves in figures 3 and 4, hence they show the resistance characteristics of the models while running at the most favorable trim angle for each part of the speed range. From the curves of this figure it appears that the vanes acted as expected at speeds below the hump and at speeds above 60 percent of the get-away. The alteration, however, resulted in a considerably lower value of Δ/R at the hump, which decrease might seriously threaten the reserve propeller thrust available at this point.

The spray characteristics of Model 10 were very poor throughout the greater portion of the speed range. Figure 6 illustrates the extreme "dirtiness" of the arrangement. These photographs were taken while the model was running, free-to-trim, at the speeds noted in the figure. At speeds below 11 feet per second, the vanes ran submerged and were presumably furnishing lift, but the forebody blister was objectionable, as shown in (a). At speeds from 12 to 15 feet per second, the vanes began to take air over their upper surfaces, causing a secondary blister which, in combination with that of the forebody entrance, gave the very confused spray patterns shown in (b) and (c). From 15 to 17 feet per second (fig. 6(d)), the trim angle rose sharply, causing the spray to increase in quantity and height until the blister from the vanes rose about 12 inches above the sheer line and wetted the entire afterbody. At 20 feet per second, the chines became dry and the blisters thinned down, although considerable water was raised because of the interference of the leading edge of the vanes with the blister coming from the hull. The appearance of the model at this point is seen in (e). Shortly beyond this condition, the model was planing more cleanly on the vanes and main step, as shown in (f).

The spray thrown from Model 9 was normal for the type. Model 10 was so decidedly inferior in this respect that it was not thought necessary to include spray photographs of Model 9 for comparison.

Neither model showed a tendency toward longitudinal instability while under way. The model tests described herein, however, are not sufficient to give definite assurance that "porpoising" would not occur during an actual take-off.

CONCLUDING REMARKS

As the points of extreme blister interference from the vanes of Model 10 coincide reasonably well with the region of lower Δ/R on figure 5, the poorer performance of the altered hull at the hump speed is probably due, in part, to the extreme "dirtiness" of the vanes as they emerge. After the vanes break the surface, much of the objectionable water is caused by their leading edges, which deflect the blister from the main hull up over the afterbody. Some means of controlling this condition would have to be found before the alterations could be successfully applied to the PN-8 hull.

The photographs of figure 6 give some evidence that insufficient planing area was furnished by the narrow hull and the under surfaces of the vanes. More general tests at the N.A.C.A. tank on hulls of conventional form have invariably shown that as hull size, and consequently the planing area, is increased the Δ/R ratio at the hump speed becomes higher.

The undesirable features resulting from the alteration of the PN-8 point to the possibility of improvement of the vanes by increasing their area and raising their leading edges. When this is done, the vanes approach the more familiar form of stub-wing stabilizers as used on the Dornier hulls and others. These stabilizers are primarily intended to furnish lateral stability at rest in place of side or wing-tip floats. If properly designed, they may also materially improve the take-off performance of highly loaded hulls. Further development along this line is now being studied by the Committee.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., January 26, 1934.

REFERENCE

1. Truscott, Starr: The N.A.C.A. Tank - a High-Speed Towing Basin for Testing Models of Seaplane Floats. T.R. 470, N.A.C.A., 1933.

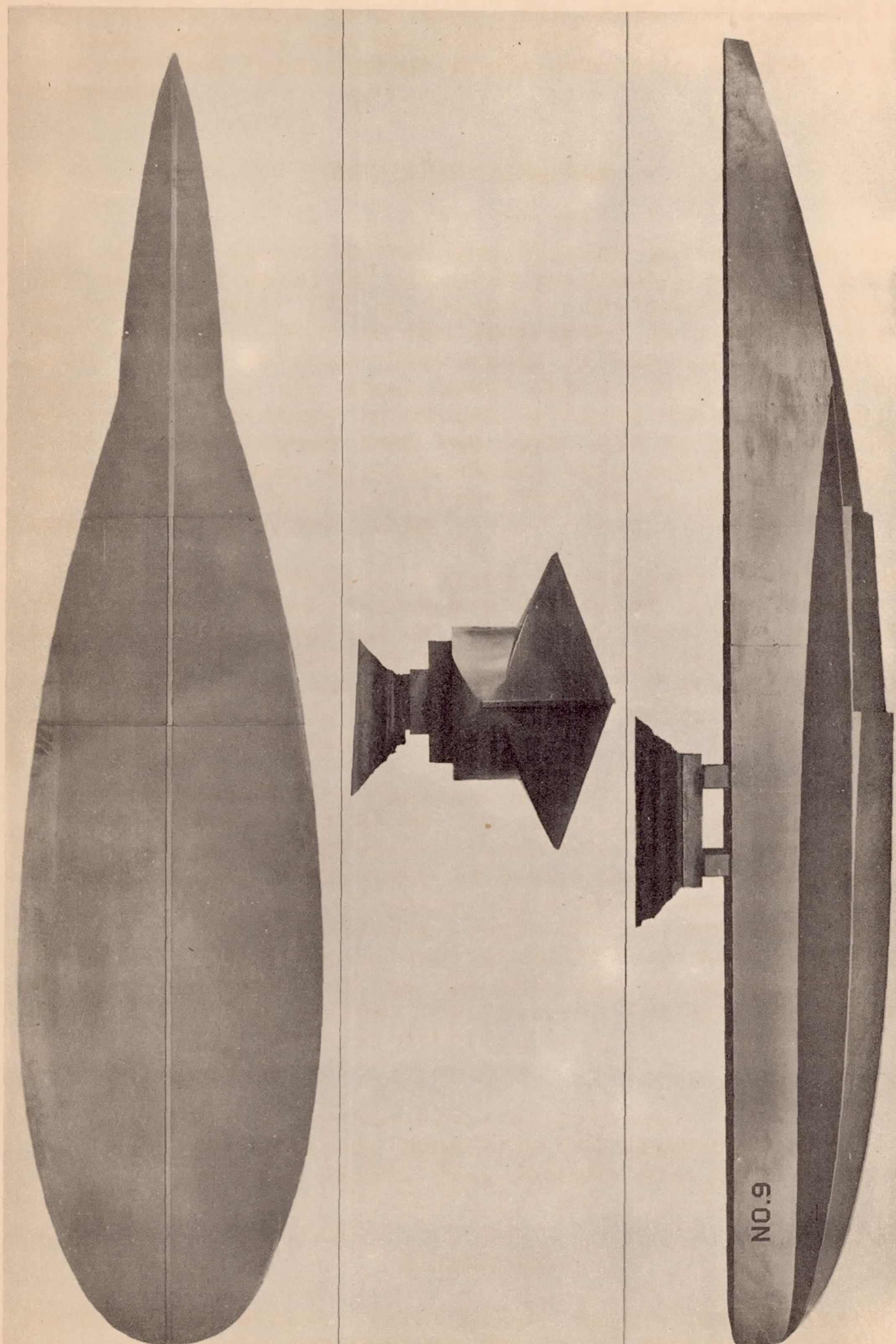


Figure 1.-Model 9. Hull of U.S. Navy PN-8 flying boat.

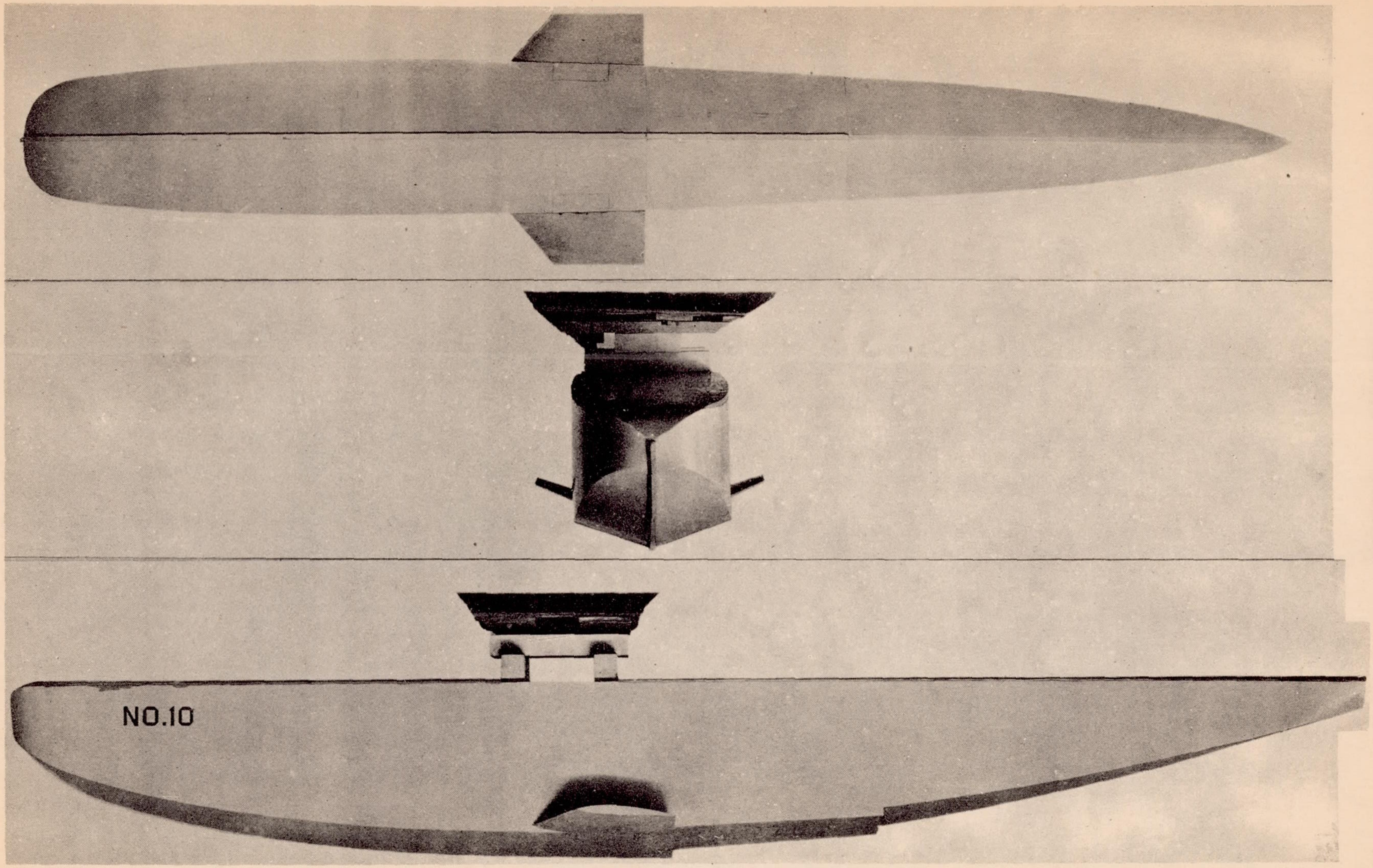


Figure 2.-Model 10, showing the substitution of auxiliary vanes for the original sponsons of the PN-8.

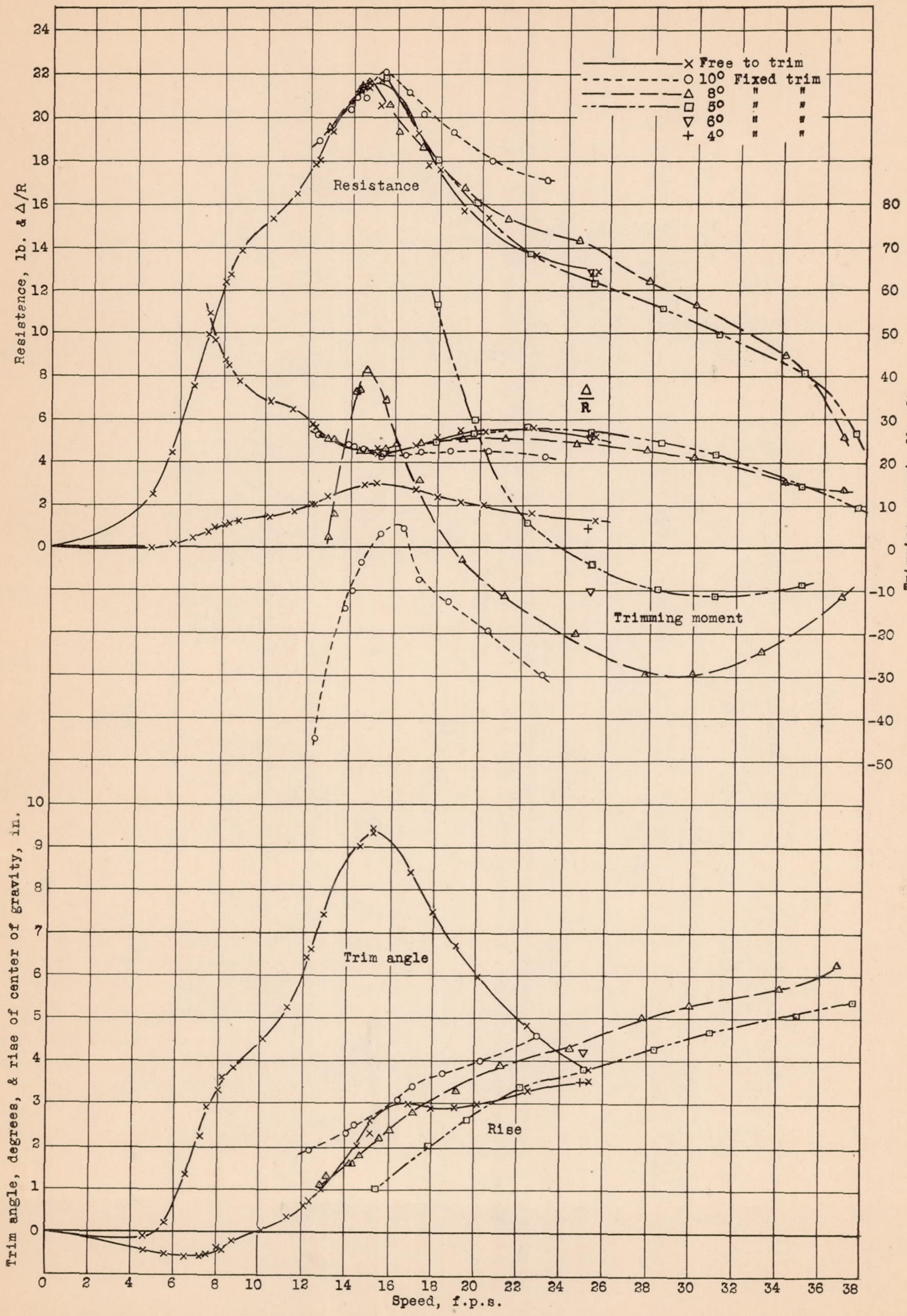


Figure 3.- Curves of resistance, Δ/R, rise of center of gravity, trim angle, and trimming moment for Model 9. Model initial load, 112 lb. Model get-away speed, 39.4 feet per second.

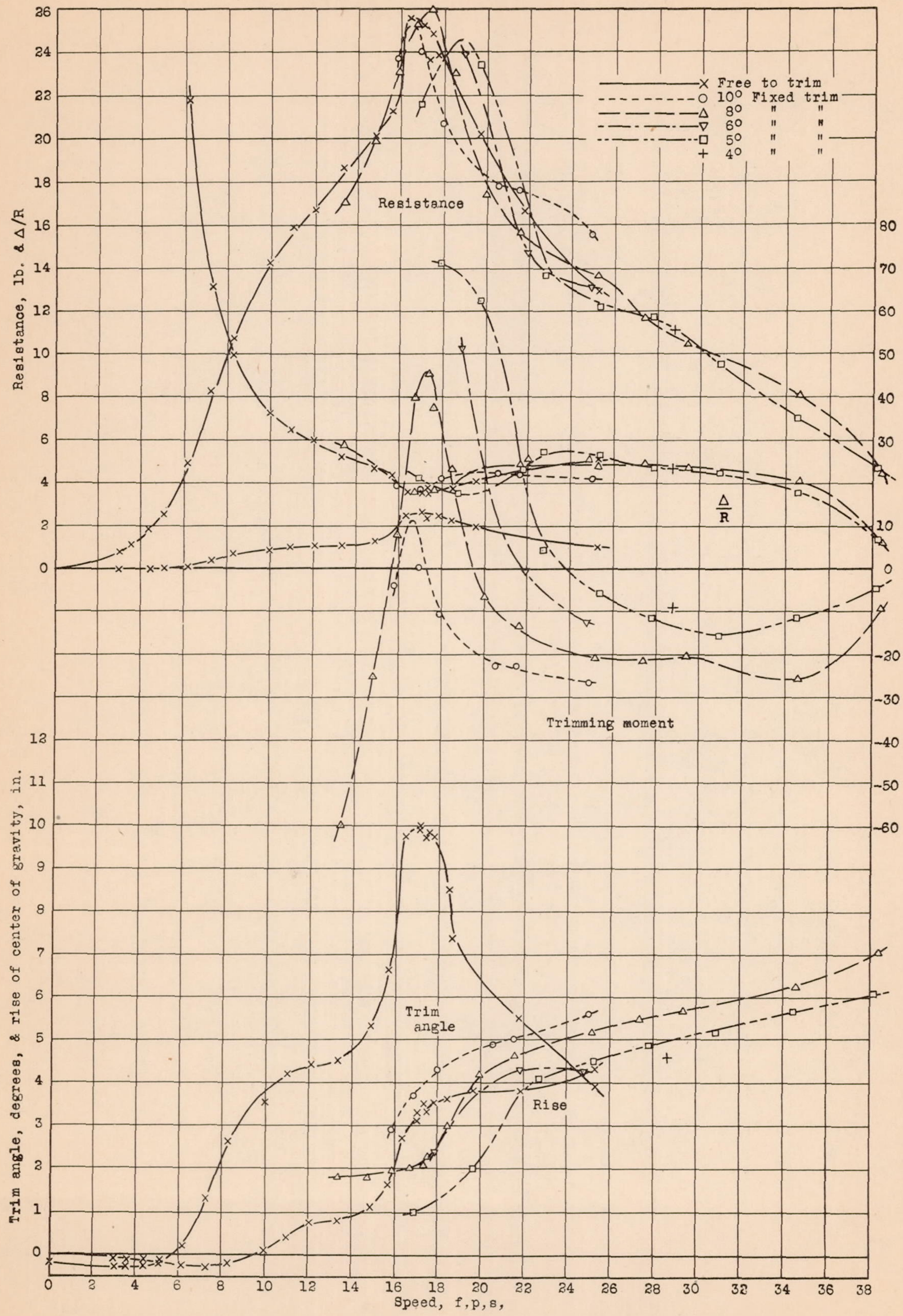


Figure 4.- Curves of resistance, Δ/R, rise of center of gravity, trim angle, and trimming moment for Model 10. Model initial load, 112 lb. Model get-away speed, 39.4 feet per second.

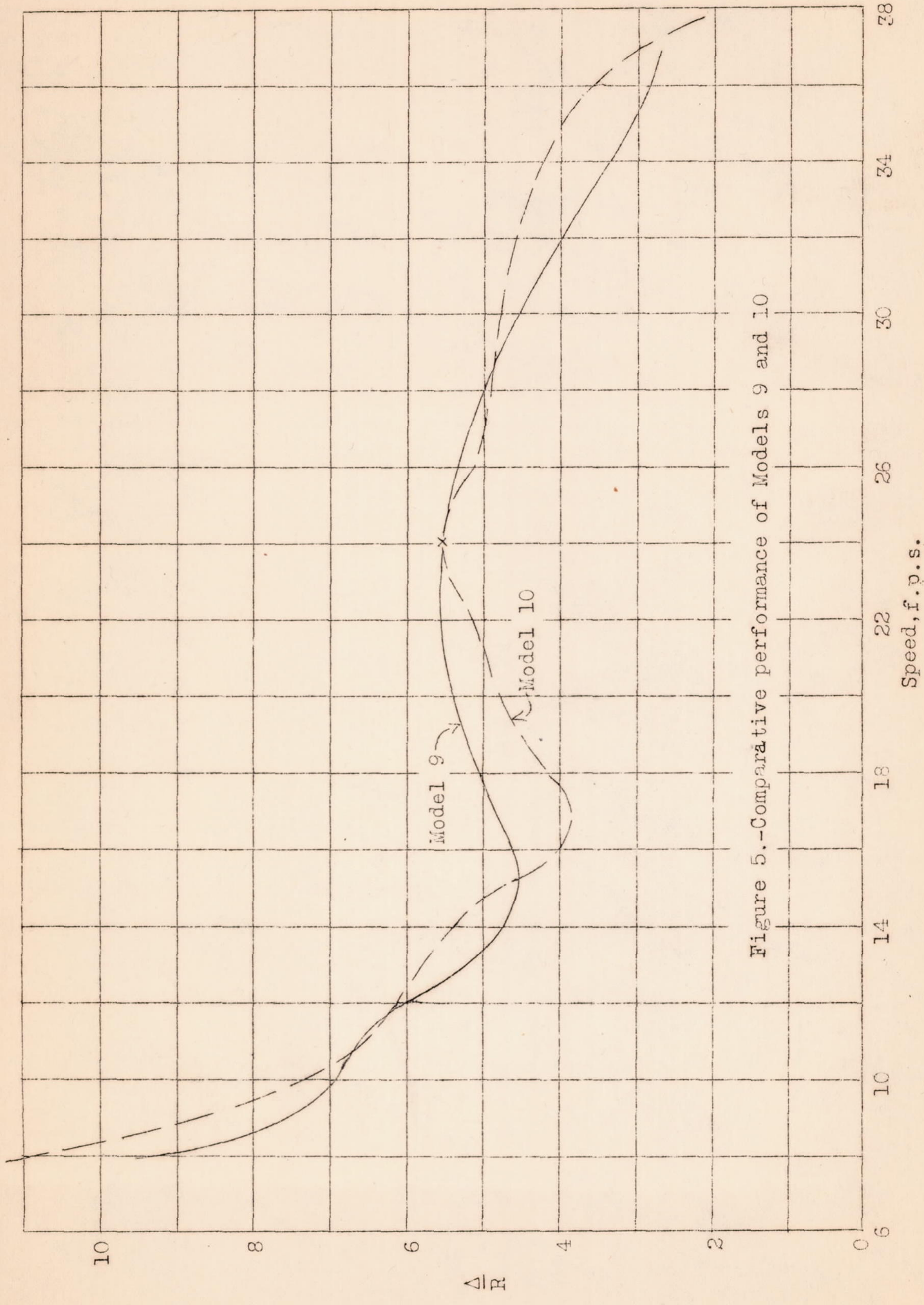
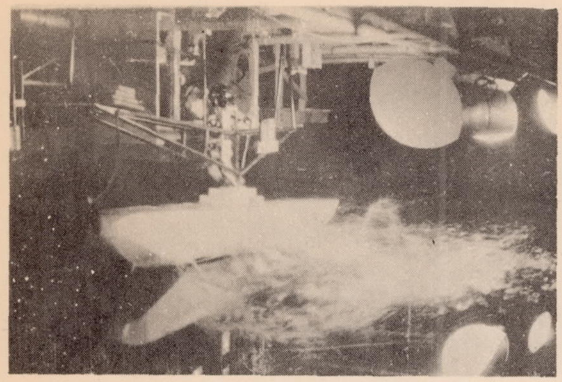
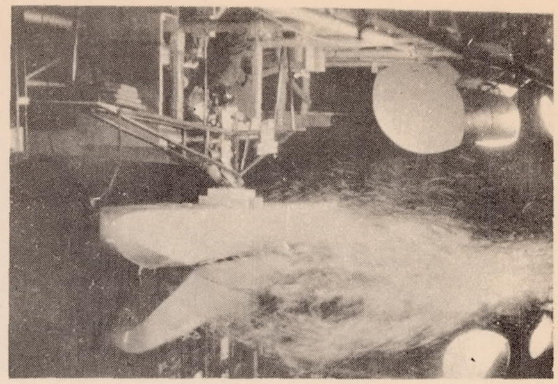


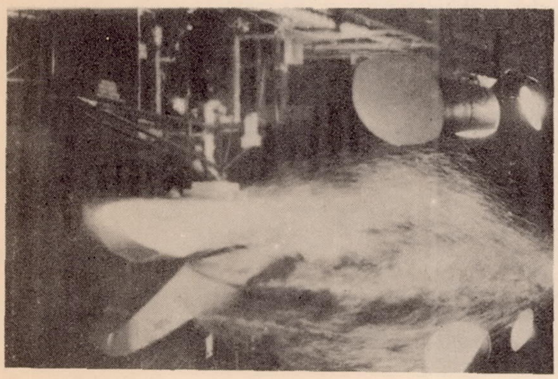
Figure 5.-Comparative performance of Models 9 and 10



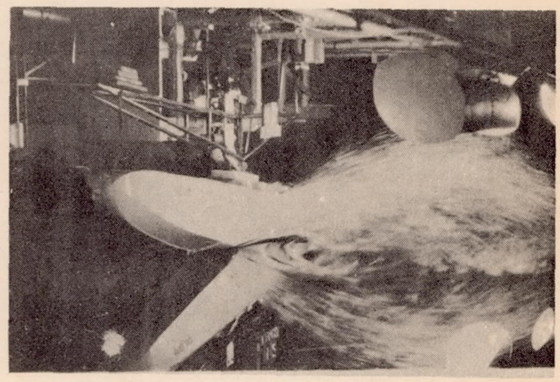
(a) 10.8 f.p.s.



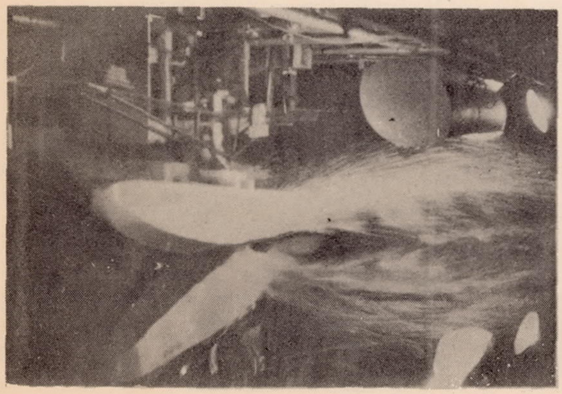
(b) 12.4 f.p.s.



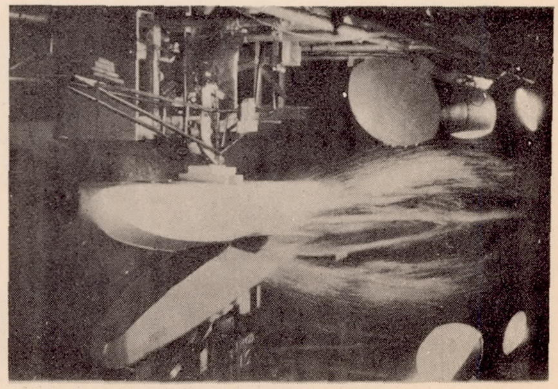
(c) 14.7 f.p.s.



(d) 16.8 f.p.s.



(e) 20.1 f.p.s.



(f) 24.5 f.p.s.

Figure 6.-Spray photographs of Model 10