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RESEARCH MEMORANDUM

INVESTIGATION OF THE HYDRODYNAMIC STABILITY AND RESISTANCE OF TWO STREAMLINE FUSELAGES

By Bernard Weinflash and Charles L. Shuford, Jr.

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Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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INVESTIGATION OF THE HYDRODYNAMIC STABILITY AND RESISTANCE OF TWO STREAMLINE FUSELAGES

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SUMMARY

An investigation of a dynamic model was made to determine the effects of hull form, gross load, and aerodynamic trimming moments on the trim limits, trim, hydrodynamic moment, hydrodynamic resistance, total resistance, and rise of two streamline fuselages modified by chine strips. The rear part of the first hull was approximately elliptical in cross section with the major axis vertical and the end squared off as for jet exhaust. The rear part of the second hull had circular cross sections and a pointed aft end. Both the longitudinal and transverse curvatures of the rear part of the second hull were more pronounced than for the first.

Lower-limit porpoising only was found to exist. Hull II trimmed higher and was stable for a larger range of speeds than hull I. Moments required to obtain stable trims were larger than aerodynamic trimming moments obtained with all-movable stabilizers. Under free-to-trim conditions, the maximum total resistance of hull II was less than that of hull I. However, at equal fixed trims, the total resistance of hull I was less. An increase in gross load generally raised the trim limit and total resistance of hull II more than those of hull I and decreased the stable portion of the speed range of both configurations. An increase in gross load resulted in a higher ratio of load to total resistance for both configurations.

INTRODUCTION

A streamline body having circular or elliptical cross sections unbroken by steps or chines is the ultimate goal of the flying-boat-hull designer with regard to aerodynamic performance. However the poor hydrodynamic performance caused by the suction forces associated with the flow over such a curved body has made its use impractical. These suction forces tend to increase rapidly with speed and to keep the body deeply immersed.

Force tests in Langley tank no. 2 have shown that the hydrodynamic characteristics of such a streamline fuselage can be greatly improved by the use of narrow breaker strips simulating chines. The primary purpose of the present investigation was to study the hydrodynamic longitudinal stability characteristics of the same fuselage form tested in reference 1 (hull I). This fuselage had a pointed nose and the rear end was squared off for jet exhaust. This hull shape was also tested reversed, so that it simulated a streamline fuselage having a pointed rear end (hull II). Comparative resistance and rise data were also determined for the two configurations.

DESCRIPTION OF MODEL

The model with hull I (fig. 1) was similar to the $\frac{1}{12}$-size dynamic model (fig. 2) described in reference 2 in that it had the same aerodynamic surfaces and the same fuselage bottom. However, it was necessary to raise the wing and tail 3 inches in order to eliminate water forces on the aerodynamic surfaces. The upper half of the fuselage was eliminated to facilitate testing. Fuselage offsets are shown in table I and details in figure 3. End plates were placed on the inboard edges of the semiwings to simulate the fuselage and retain approximately the same aerodynamic lift. To provide for a larger aerodynamic trimming moment than that available from elevators, the elevators were fixed at an angle of 0° to the stabilizer and the entire stabilizer made adjustable to angles of incidence between $\pm 30^{\circ}$.

The appearance of the model with the fuselage reversed (hull II) is shown in figure 4. A pointed fairing was glued to the flat forward end. In both configurations, the center of gravity was located on the center line at approximately midlength and the location of the aerodynamic surfaces with respect to the center of gravity was the same. Comparison of the rear halves of hulls I and II is made in figure 5. The forward halves were usually above the water surface during the tests.

APPARATUS AND PROCEDURE

Tests were conducted with the small model towing gear in Langley tank no. 2 (figs. 1 and 4). External trimming moments were applied to the models by the apparatus shown in figure 6. Weights were shifted from one weight pan to the other to keep constant the total weight moving vertically. The moment of inertia of the models with the moment applicator attached was 0.122 slug-foot^2 and was increased by 0.031 slug-foot^2 for each pound-foot of moment applied. It was necessary to use this device because the moments produced by the all-movable tail were insufficient to cover the trim range desired.

The model was supported at its center of gravity and statically balanced with the moment applicator attached. The model was towed free to rise and was free to trim about the pivot which was located at the center of gravity.

The trim limits of stability were determined for a range of trims from 4° to 16° and over a range of speeds from 17 to 75 feet per second. Several runs were made at each speed using different applied moments. If the model did not porpoise spontaneously after being lowered into the water it was manually trimmed down approximately 3° then released. The lower trim limit is defined as the lowest trim at which the resulting porpoising damped out. Where the lower limit of stability was double-valued, as in figure 7(a), the secondary limit was defined as the highest trim in the secondary limit region at which the resulting porpoising died out. The type and reproducibility of the data obtained by this method are shown in figure 7.

Trim, resistance, and rise were measured for zero applied moment at constant speeds varying from 17 to 75 feet per second. When the model tended to be unstable, the motions were damped manually before readings were taken. Trim was measured as the angle between the reference line and the horizontal. Rise was taken as the distance of the center of gravity above the undisturbed water level.

Aerodynamic drag, lift, and pitching moment were measured with the models 1 inch off the water surface at fixed trims for a range of stabilizer settings. The air drag of the model shown in figure 2 was also measured in this manner. The total resistance $R + D$ of hull I or hull II was obtained by subtracting their air drag from the total resistance actually measured to obtain the hydrodynamic resistance R and adding to this instead the more appropriate air drag D of the model shown in figure 2. The load on the water was obtained by subtracting the aerodynamic lift from the gross load.

Tests were made for 3.8-, 5.7-, and 7.6-pound gross loads with the stabilizers at 0°. To determine the effect of aerodynamic tail moments, hull I, which trimmed down with speed, was also tested with stabilizers set at -30° (bow-up applied moment) and hull II, which trimmed up with speed, was tested with 20° stabilizer (bow-down applied moment).

RESULTS AND DISCUSSION

Characteristics of Hull I

Stability and trim.- The trim limits of longitudinal stability and the trim tracks for 0° and -30° stabilizer settings are given in figure 8 for the three gross loads on hull I. The hydrodynamic moment at the trim limit and the hydrodynamic moment resulting from the -30° stabilizer deflection are also shown.

Only lower-limit porpoising was encountered. With increasing speed, trim decreased slightly and became constant at a value of 4° or 5° depending on the stabilizer deflection. With the stabilizer set at 0°, the trim track was below the lower trim limit for part of the speed range for all gross loads. For the 7.6-pound gross load the trim track was below the lower trim limit for almost the entire speed range. The small additional trim obtained with the -30° stabilizer was sufficient to stabilize the model for the 3.8-pound gross load (fig. 8(a)) and to reduce appreciably the unstable portion of the speed range for the other two gross loads. The shaded portion of the moment curve for the two higher gross loads (figs. 8(b) and 8(c)) shows the additional bow-up applied moment needed to achieve stability.

Total resistance and rise.- The total resistance, load on the water, and rise are given in figure 8 for 0° and -30° stabilizer settings. The air drag component of the total resistance is the air drag of the model shown in figure 2. The total resistance generally increased with speed and was approximately the same for both 0° and -30° stabilizer settings. For the 3.8-pound gross load, however, the use of -30° stabilizer resulted in a large reduction in total resistance at high speeds in spite of the increased aerodynamic drag due to the higher trim.

The load on the water was higher with the -30° stabilizer because the downward force on the stabilizer was greater than the increase in wing lift due to the slightly higher trim. The negative values of load near take-off speed for the 3.8-pound gross load, 0° stabilizer condition shows how much the hydrodynamic suction forces acting on the fuselage exceeded the hydrodynamic lift forces. The rise increased with speed at low speeds and then remained fairly constant. The use of -30° stabilizers caused a slight increase in rise at the higher speeds.

Characteristics of Hull II

Stability and trim.- The trim limits of stability and the trim tracks for 0° stabilizer setting are given in figure 9 for the three gross loads on hull II. The effects of setting the stabilizer at 20° are shown for the gross load of 3.8 pounds. The hydrodynamic moment at the trim limit and the hydrodynamic moment resulting from the use of the 20° stabilizer are given also.

Only lower-limit porpoising was found to exist. At all gross loads the model trimmed up rapidly with speed. As a result the model was unstable at low speeds only and quickly became stable as the model trimmed above the lower limit. As shown in figure 9(a) for a 3.8-pound gross load, the 20° stabilizer deflection decreased the trim a maximum of $1\frac{1}{2}^{\circ}$ while decreasing the stable speed range only slightly. A similar effect would be expected at the higher gross loads.

Total resistance and rise.- The total resistance, load on the water, and rise are given in figure 9 for the 0° stabilizer settings. The effect of setting the stabilizer at 20° is shown for the gross load of 3.8 pounds only. The air drag component of this total resistance is the air drag of the model in figure 2. The total resistance generally increased with speed but most of the increase was due to the increase in air drag. The use of 20° stabilizer resulted in slightly higher resistance.

As in the case of hull I, negative values of load on the water for the 3.8-pound gross load indicate the predominance of suction forces near take-off. The rise increased rapidly with speed at a fairly constant rate throughout the speed range.

Effects of Hull Form

Comparisons are made in figure 10 between hulls I and II with 0° stabilizer for the three gross loads. Hull II ran at much higher trims. Also the trims of hull II increased rapidly with speed while those of hull I decreased slightly. Thus, even though the trim limits were somewhat higher for hull II, it had a greater stable speed range.

The maximum total resistance of hull II was less than that of hull I. The rise of hull II was much greater than that of hull I and the difference increased with speed. For hull II, the greater rise was largely due to the higher trim.

The ratios of the load on the water to the total resistance $\frac{\Delta}{R + D}$ of the two configurations free to trim are compared in figure 11 for each of the three gross loads with the stabilizer set at 0°. The $\frac{\Delta}{R + D}$ ratio was greater for hull I, indicating its greater efficiency as would be expected from its lesser curvature.

The total resistances of the two configurations for trims fixed at 5°, 7°, 10°, and 13° are compared in figure 12 for a gross load of 7.6 pounds.

For the same trim, the total resistance of hull I was generally much lower than that of hull II. The total resistance of hull II decreased only slightly with increase in trim. The total resistance of hull I decreased rapidly with increase in trim up to about 10° even though the air drag was increasing. Its total resistance at 13° was approximately the same as at 10°. The total resistance as well as the stability characteristics of hull I could therefore be greatly improved by some auxiliary method of attaining higher trims.

The photographs in figure 13 show the spray characteristics of the two configurations at a gross load of 7.6 pounds for various speeds. The spray of hull I appears to be somewhat less than the spray of hull II. However, the wetted area of hull II appears to be the smaller of the two.

Effects of Gross Load

The effects of gross load are shown in figure 14 for each of the two configurations with 0° stabilizers. Changes in gross load appear to have a greater effect on the trim, trim limits, total resistance, and rise of hull II than upon those of hull I.

For hull I (fig. 14(a)) higher gross loads caused higher trims at low speeds; but at high speeds, the trim became 4° for all gross loads. The trim limits, however, were raised over the whole range of speeds by increasing the gross load. As a result, the stable portion of the speed range decreased with increase in gross load (fig. 8). The total resistance was about the same for all three gross loads except at very low speeds where the total resistance increased slightly with gross load. Except at low speeds, the rise was unaffected by the gross load.

For hull II (fig. 14(b)) higher gross loads resulted in lower trims and correspondingly lower rise values above 30 feet per second. The trim limits became higher with increase in gross load, resulting in a decrease in the stable range. Raising the gross load in this case increased the total resistance.

The effect of gross load on the ratio of load to total resistance $\frac{\Delta}{R + D}$ free to trim is shown in figure 15. The ratio $\frac{\Delta}{R + D}$ became increasingly higher with greater gross loads, showing that the total resistance did not increase in proportion to the gross load.

The photographs in figure 16 compare the spray of 3.8- and 7.6-pound gross loads for each of the two hulls. Comparisons are made at 20 and 50 feet per second. Doubling the gross loads had little effect on the spray of hull I but it increased the spray of hull II.

CONCLUSIONS

The results of an investigation of two streamline fuselages to determine the hydrodynamic stability and resistance indicate the following conclusions:

1. Lower-limit porpoising only was found to exist for both hulls.

2. Hull II trimmed higher and was stable for a larger range of speeds than hull I.

3. Moments required to obtain stable trims were larger than aerodynamic trimming moments available from the all-movable stabilizers.

4. Under free-to-trim conditions, the maximum total resistance of hull II was less than that of hull I. However, at equal fixed trims, the total resistance of hull I was less.

5. An increase in gross load generally raised the lower trim limits and the total resistance of hull II more than those of hull I and decreased the stable portion of the speed range of both configurations.

6. An increase in gross load resulted in a higher ratio of load to total resistance for both configurations.

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REFERENCES

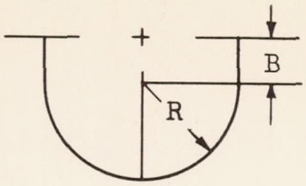
1. Weinflash, Bernard, Shuford, Charles L., Jr., and Christopher, Kenneth W.: Hydrodynamic Force Characteristics of a Streamline Fuselage Modified by either Breaker Strips or Rows of Air Jets Simulating Chines. NACA RM L9L21a, 1950.

2. King, Douglas A.: Tests of the Landing on Water of a Model of a High-Speed Airplane - Langley Tank Model 229. NACA RM L7I05, 1947.

TABLE I

OFFSETS FOR HULL I

[All dimensions are in inches]



Distance from nose (station)	Distance from reference line to center of circle, B	Half-breadth or radius, R
0	0	0
.42	0	.16
.83	0	.33
1.25	0	.48
2.08	0	.77
4.17	0	1.39
6.25	0	1.88
8.33	0	2.20
10.42	0	2.39
12.50	0	2.48
14.58	0	2.50
20.83	0	2.50
21.67	0	2.50
22.92	0	2.49
25.00	0	2.45
27.08	0	2.37
29.17	.05	2.25
31.25	.13	2.08
33.33	.22	1.88
35.42	.34	1.65
37.50	.47	1.40
39.58	.60	1.14
42.22	.75	.83

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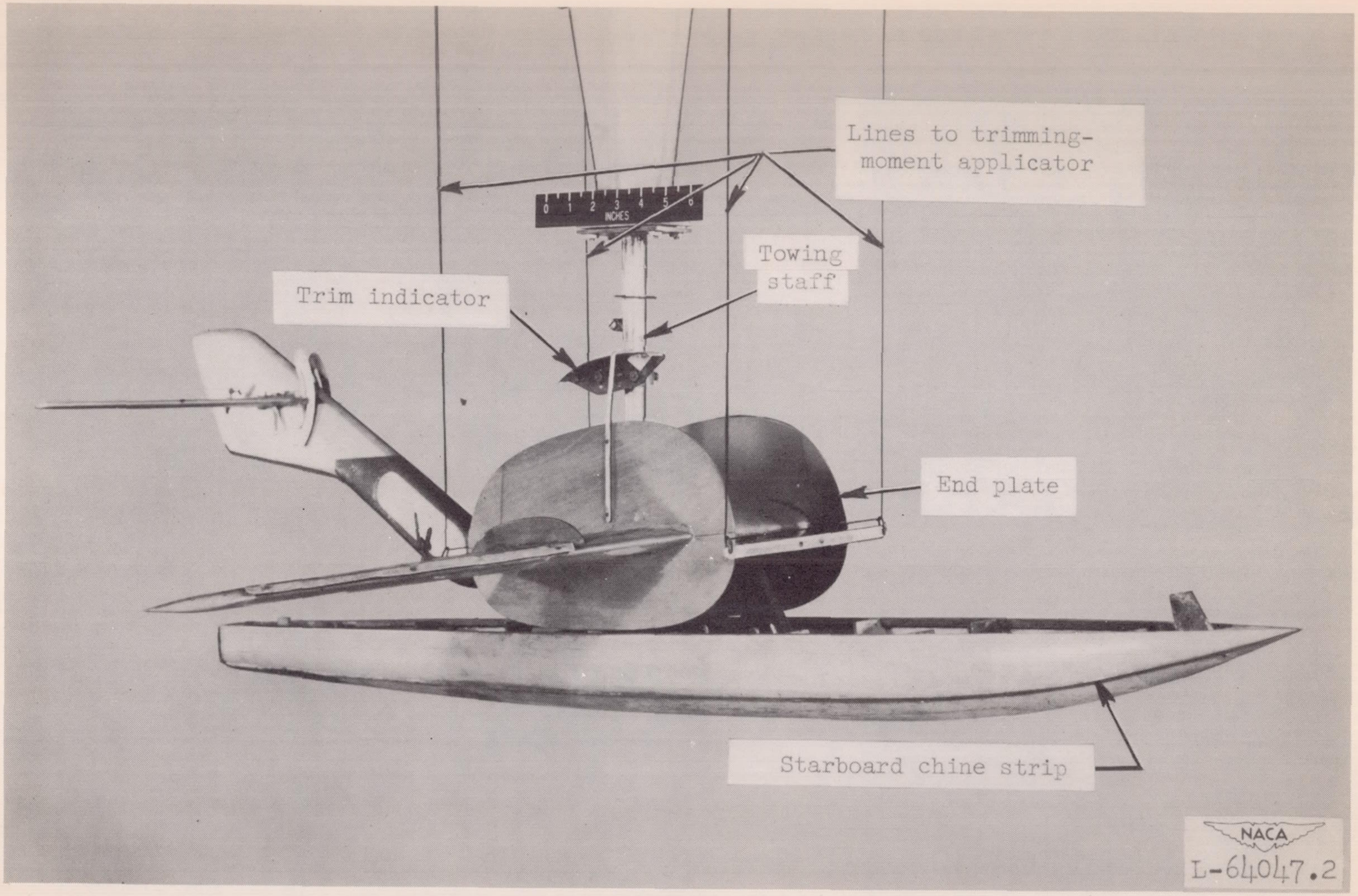
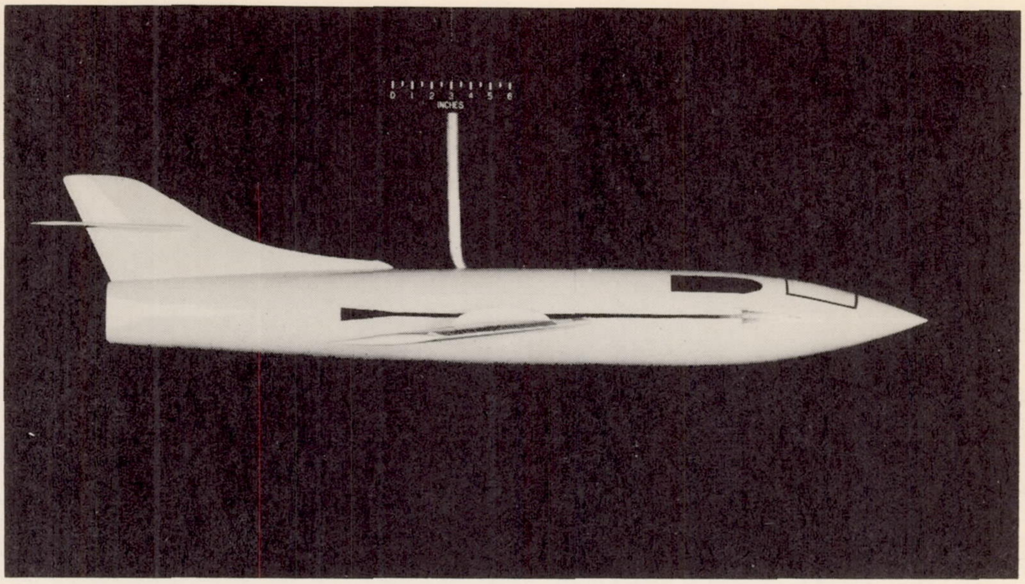


Figure 1.- Model used for hydrodynamic tests. Hull I.



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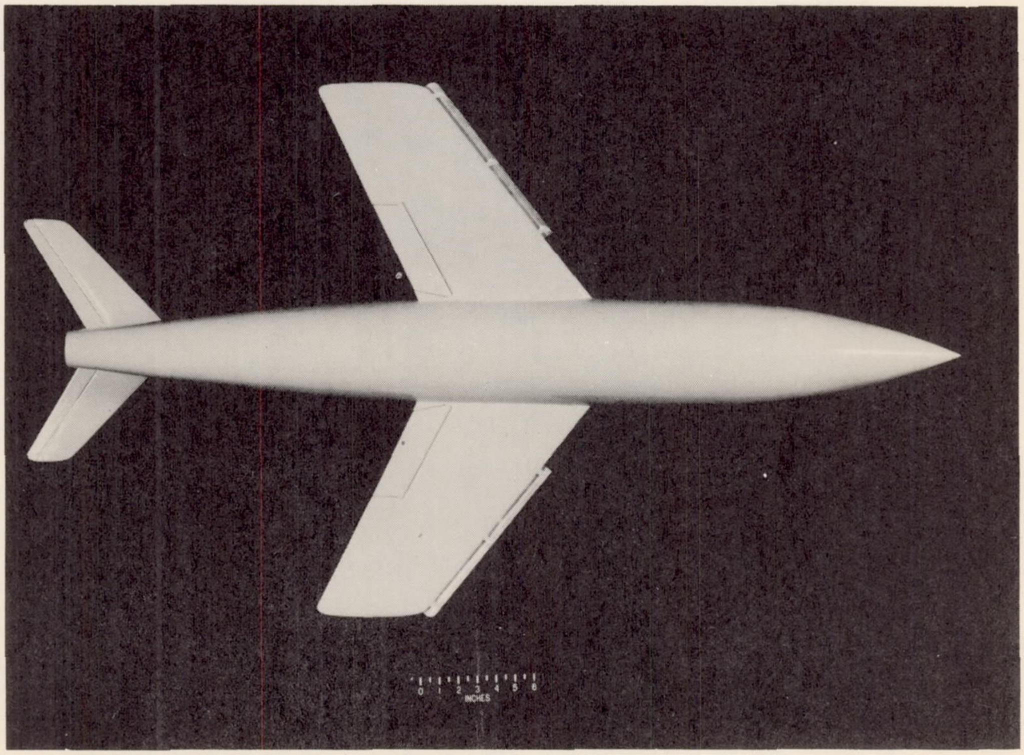

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Figure 2.- Model used for aerodynamic tests.

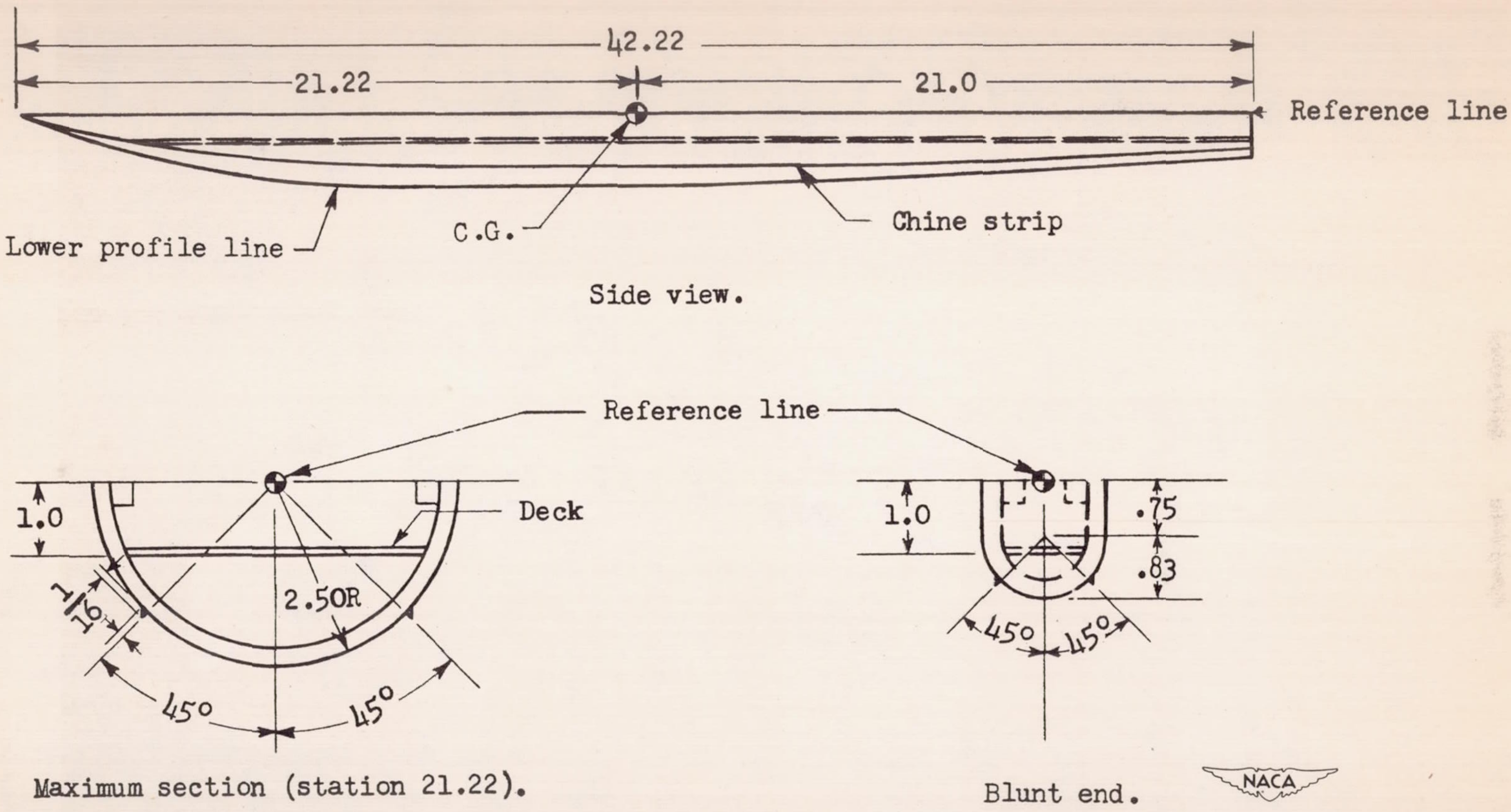


Figure 3.- Details of the hull used for hydrodynamic tests.
(Dimensions are in inches.)

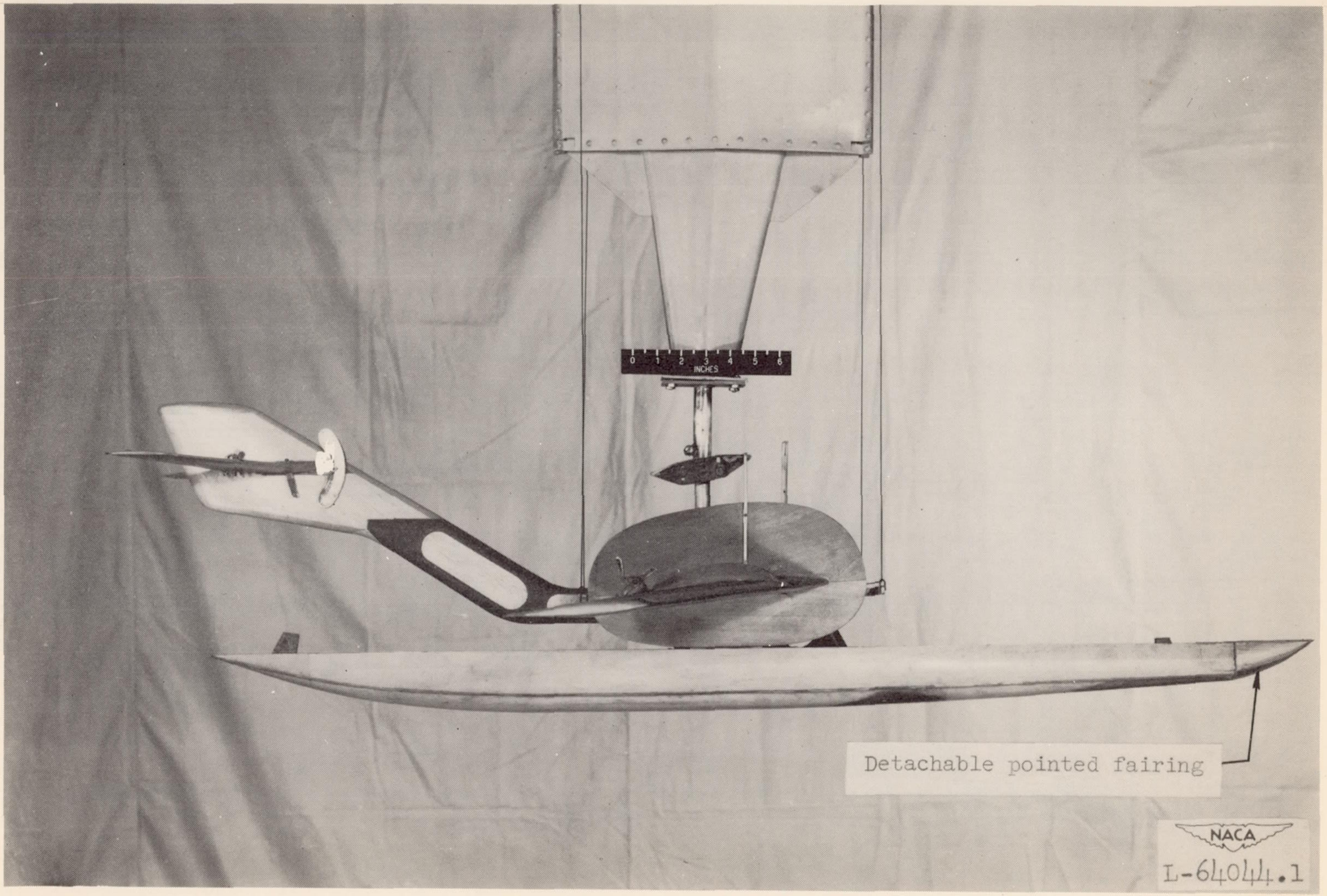


Figure 4.- Model used for hydrodynamic tests. Hull II.

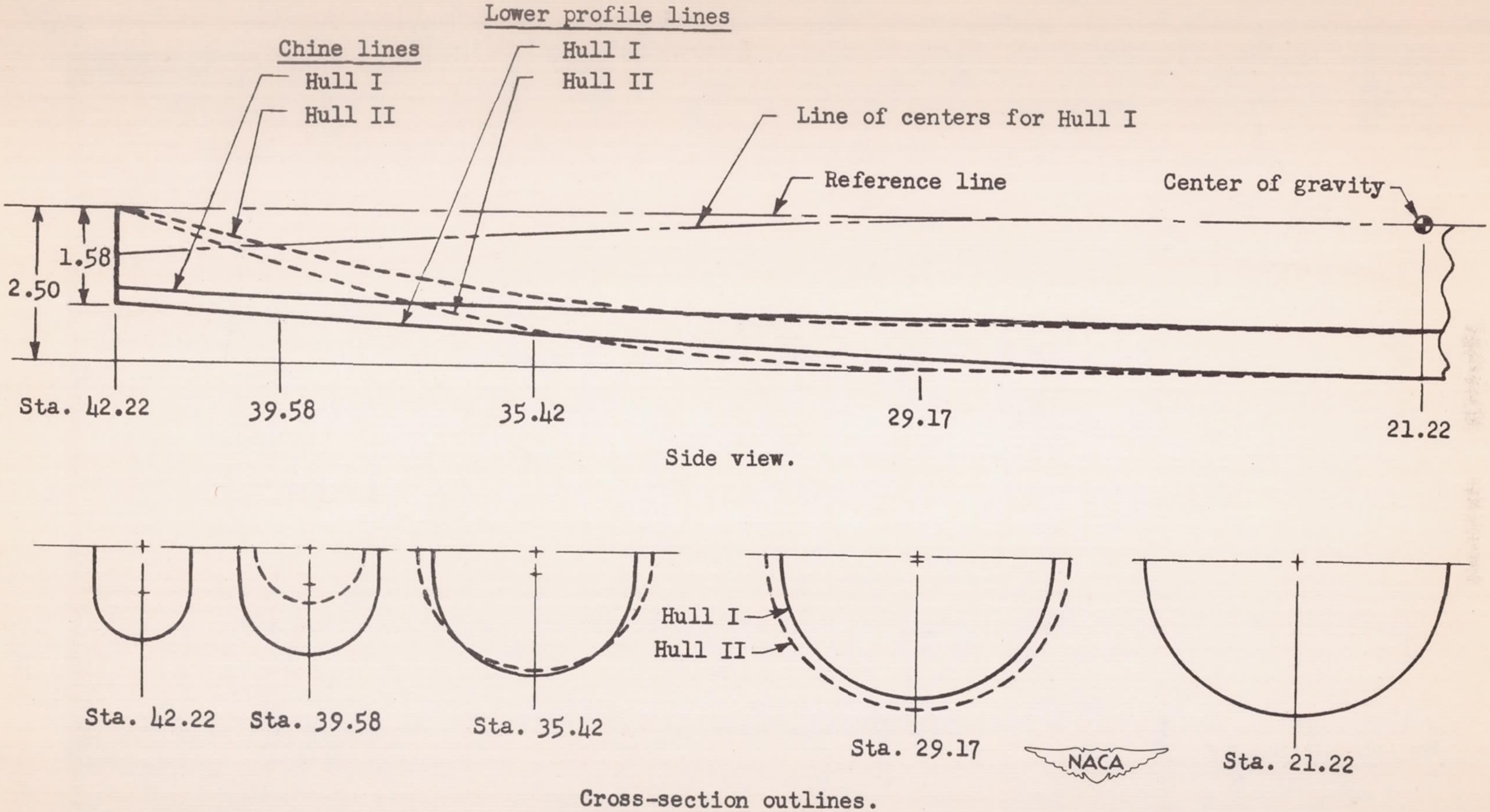


Figure 5.- Comparison of the form of the after halves of hulls I and II.

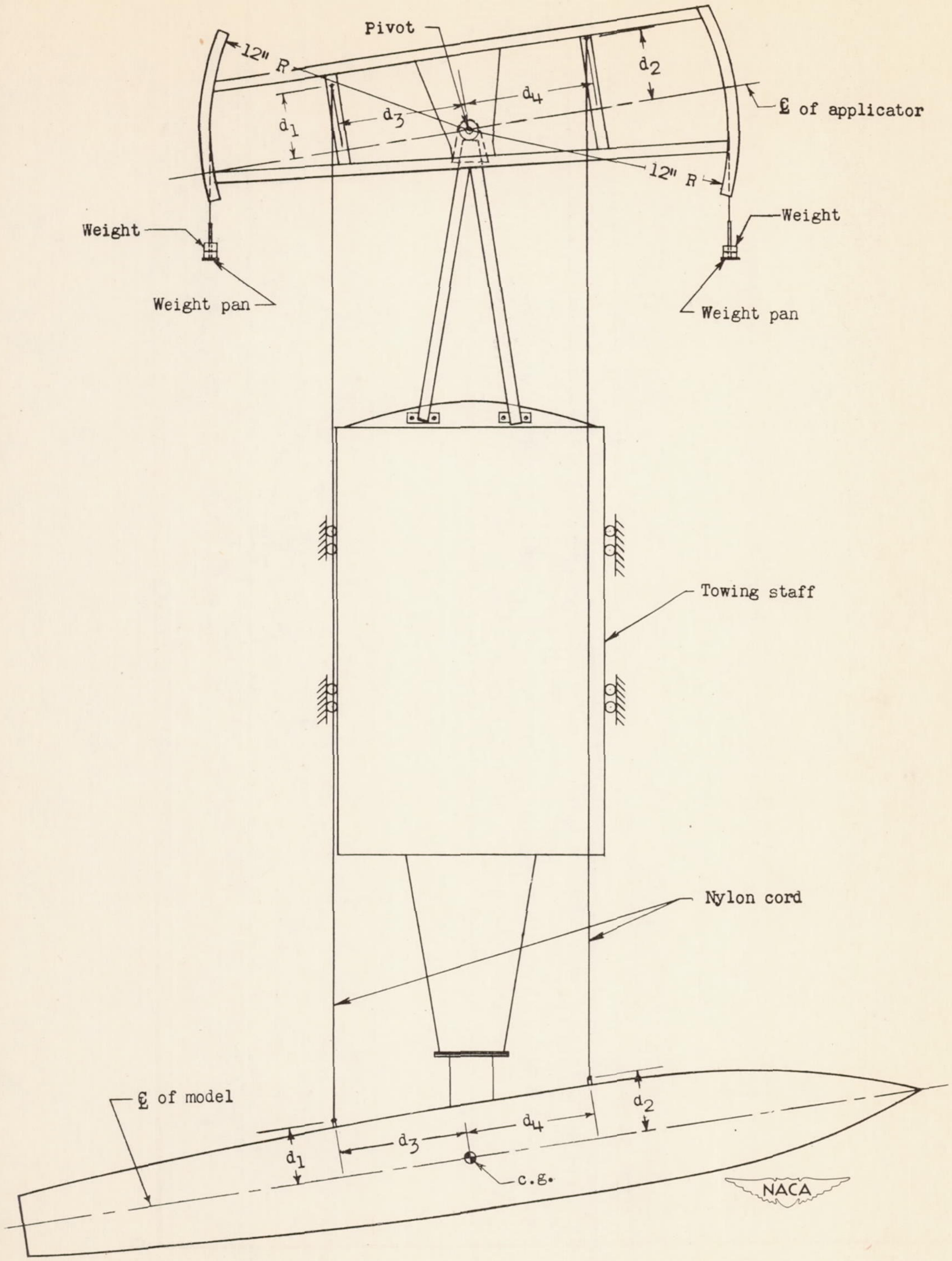
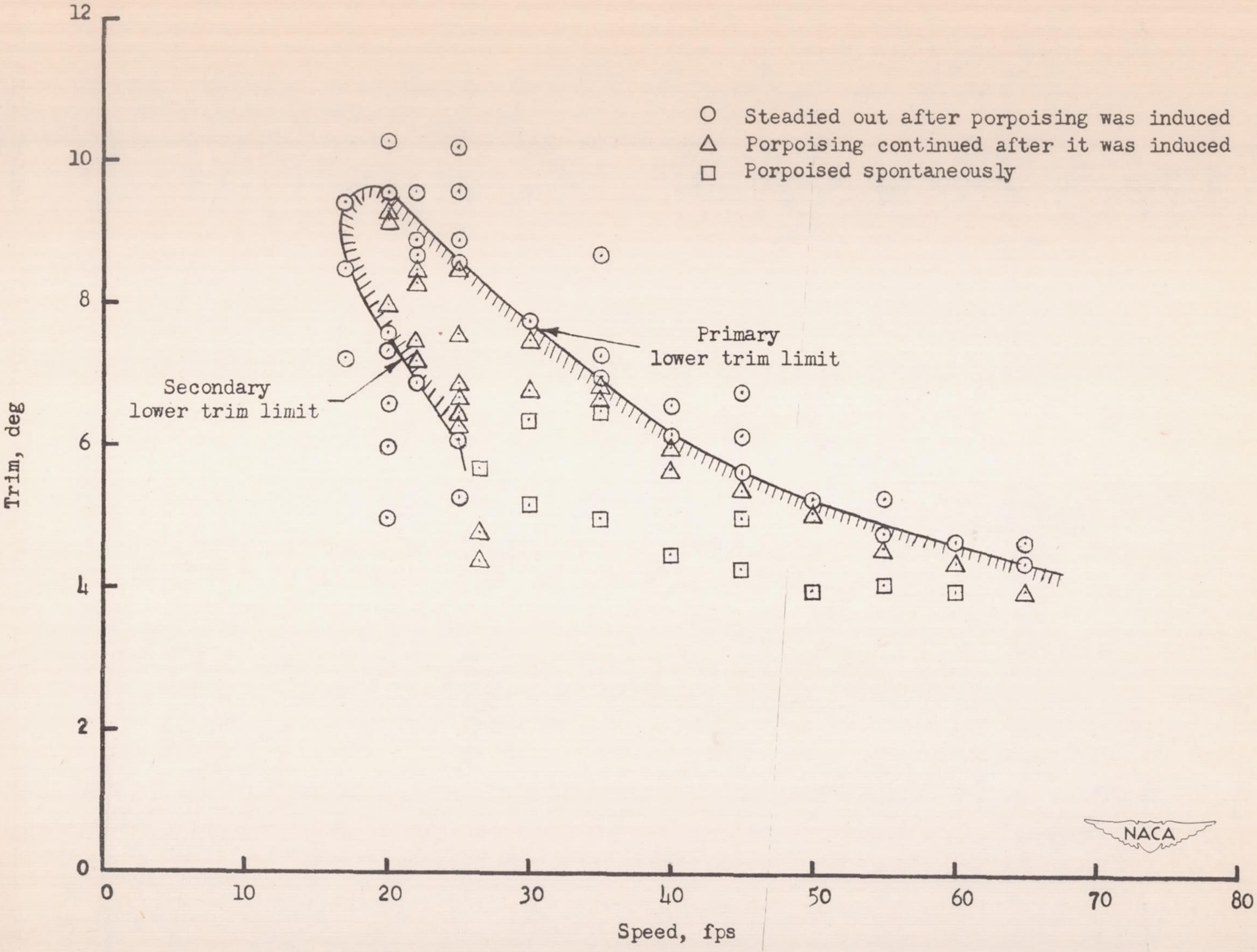
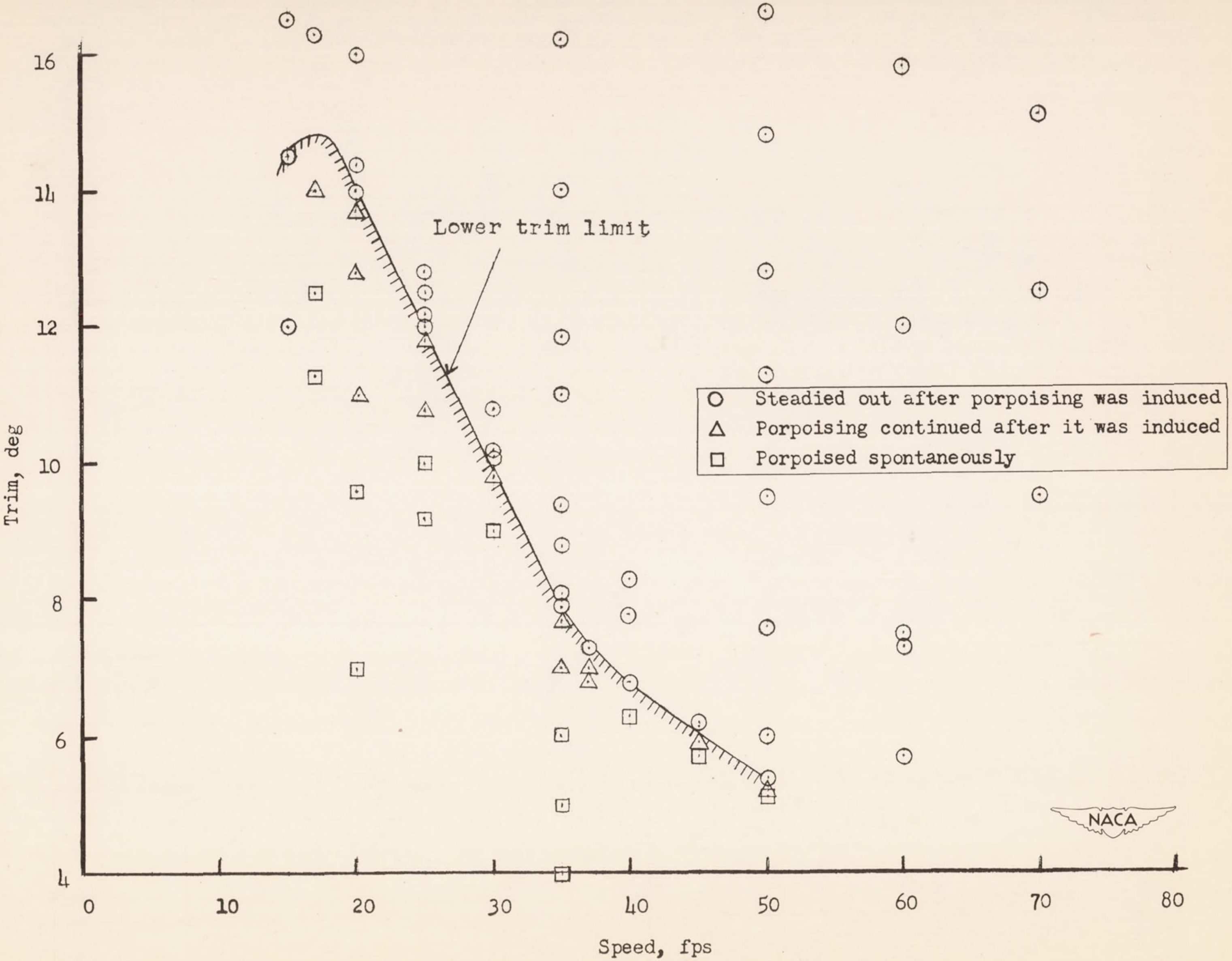


Figure 6.- Diagrammatic sketch of moment applicator. Note: Center line of applicator, center line of model, and the cords connecting them form a parallelogram.



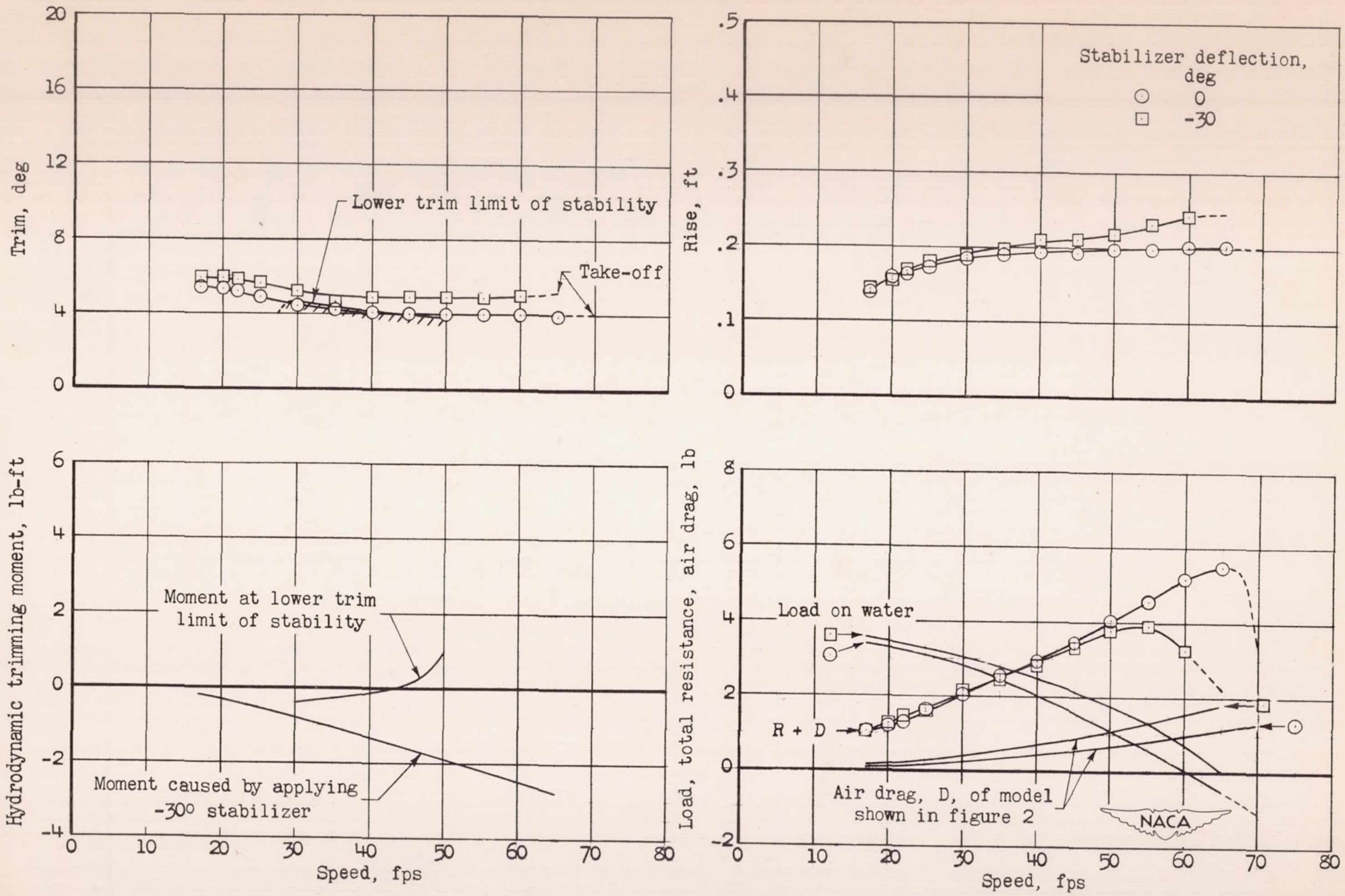
(a) Hull I; load, 7.6 pounds.

Figure 7.- Typical test data for trim limits.



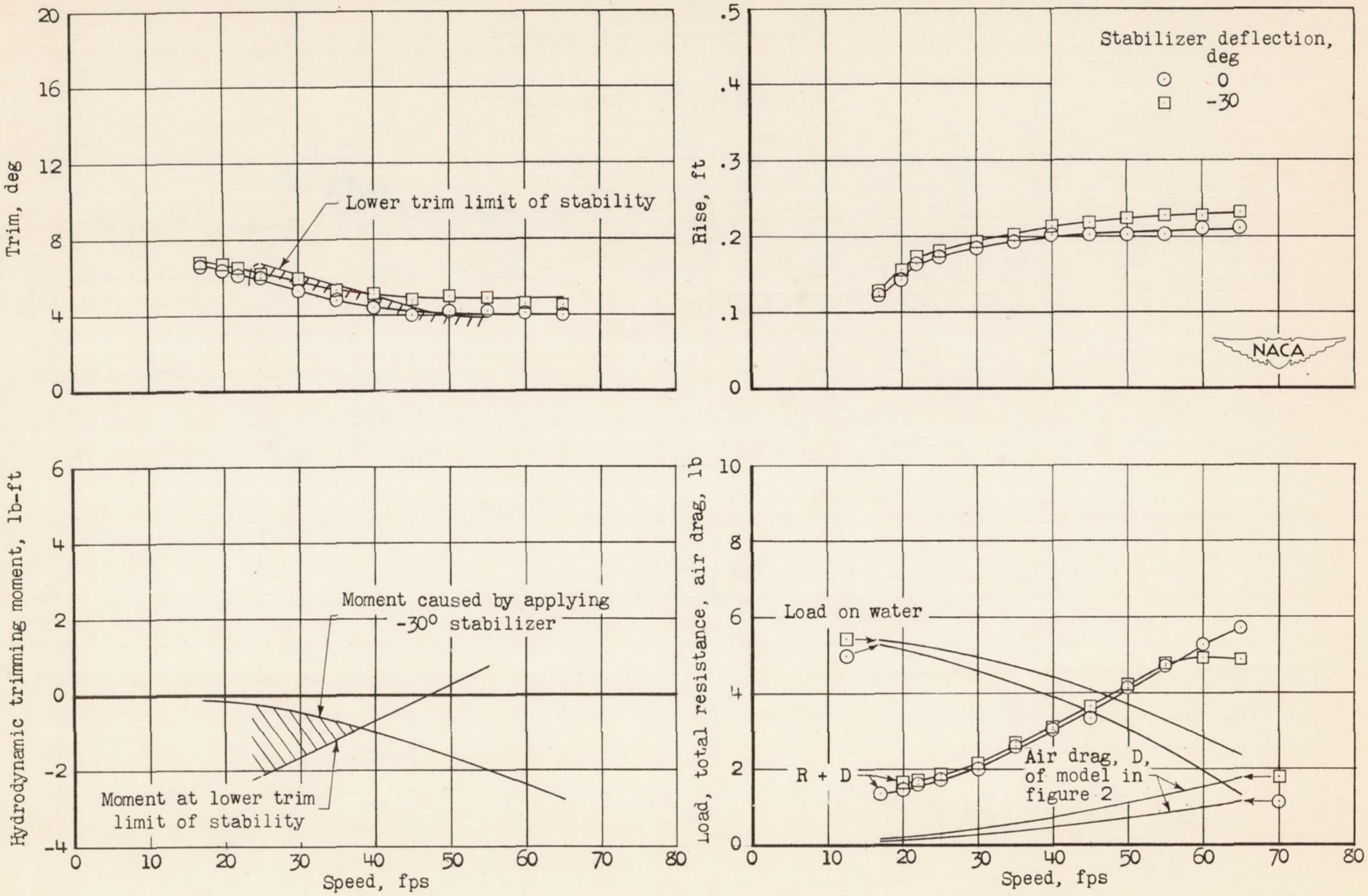
(b) Hull II; load, 7.6 pounds.

Figure 7.- Concluded.



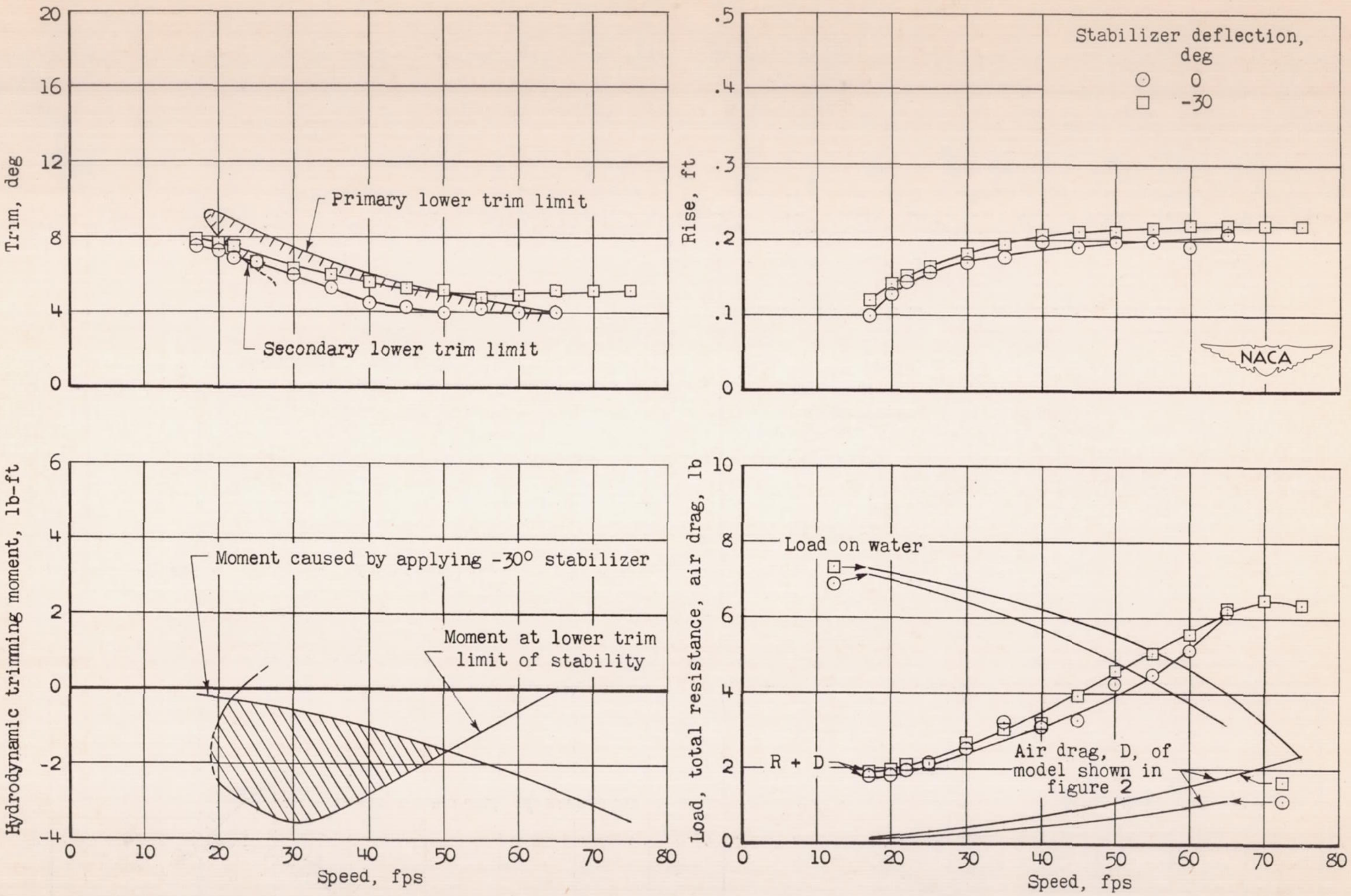
(a) Gross load, 3.8 pounds.

Figure 8.- Hydrodynamic characteristics. Hull I.



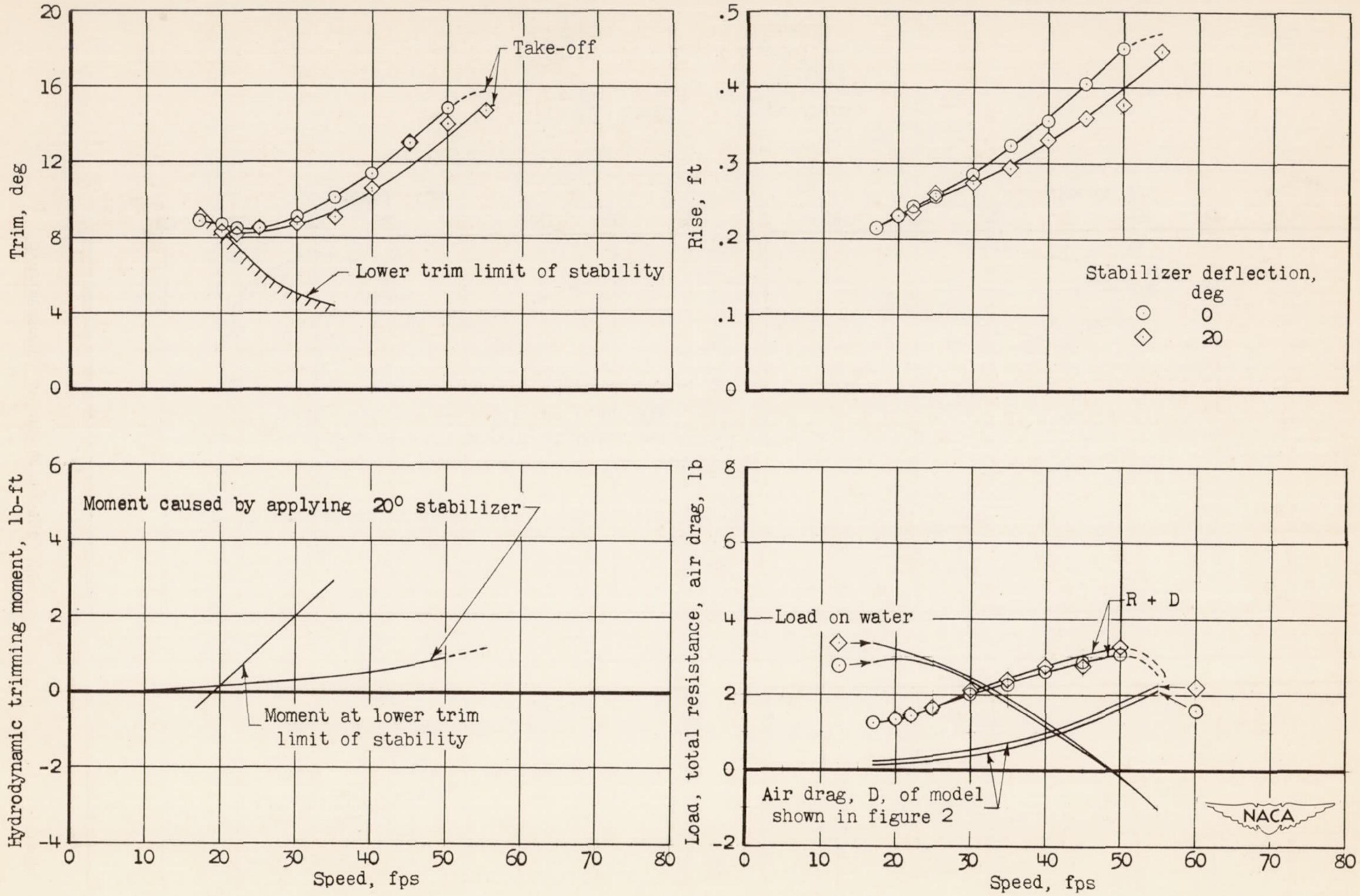
(b) Gross load, 5.7 pounds.

Figure 8.- Continued.



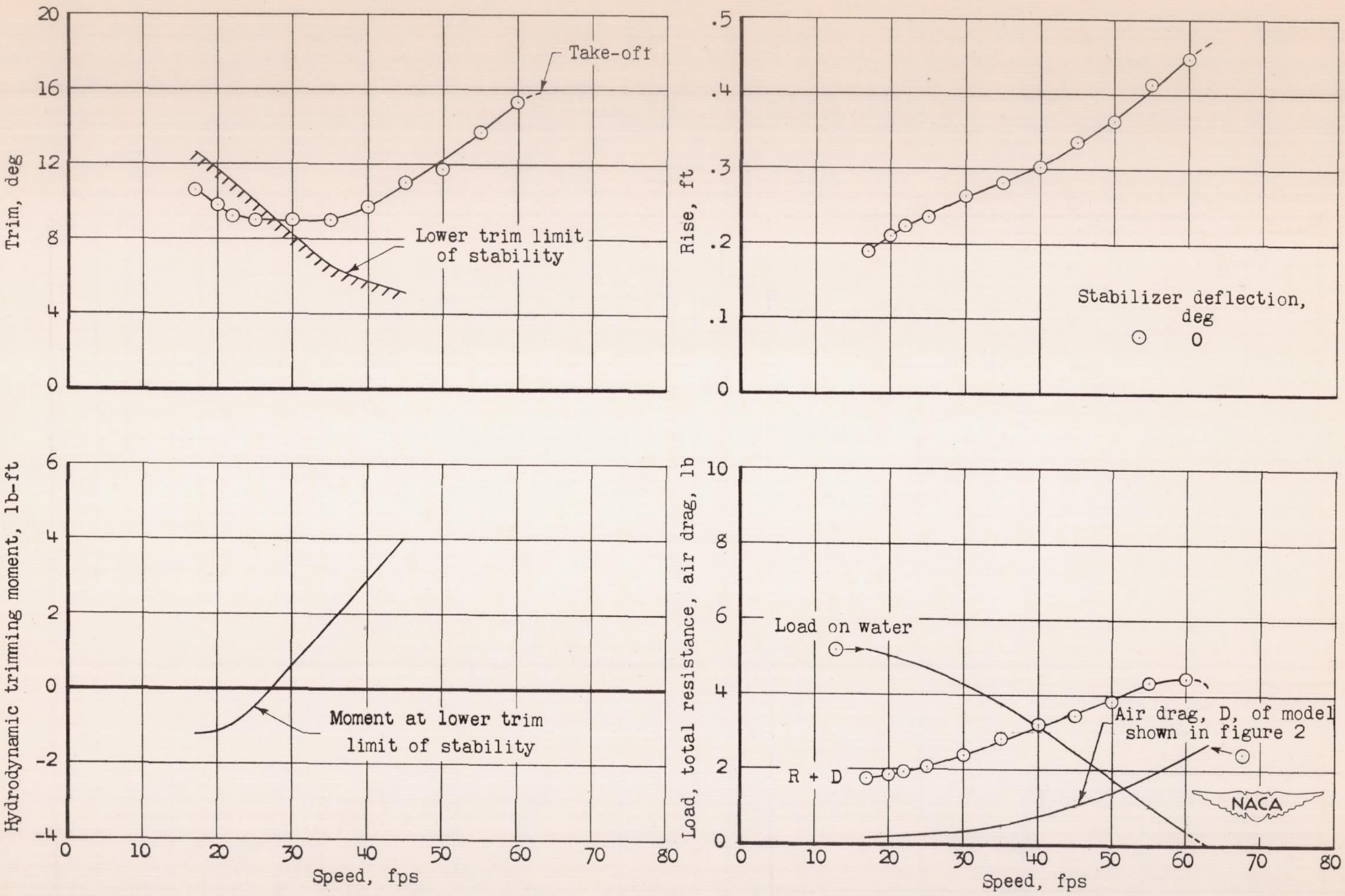
(c) Gross load, 7.6 pounds.

Figure 8.- Concluded.



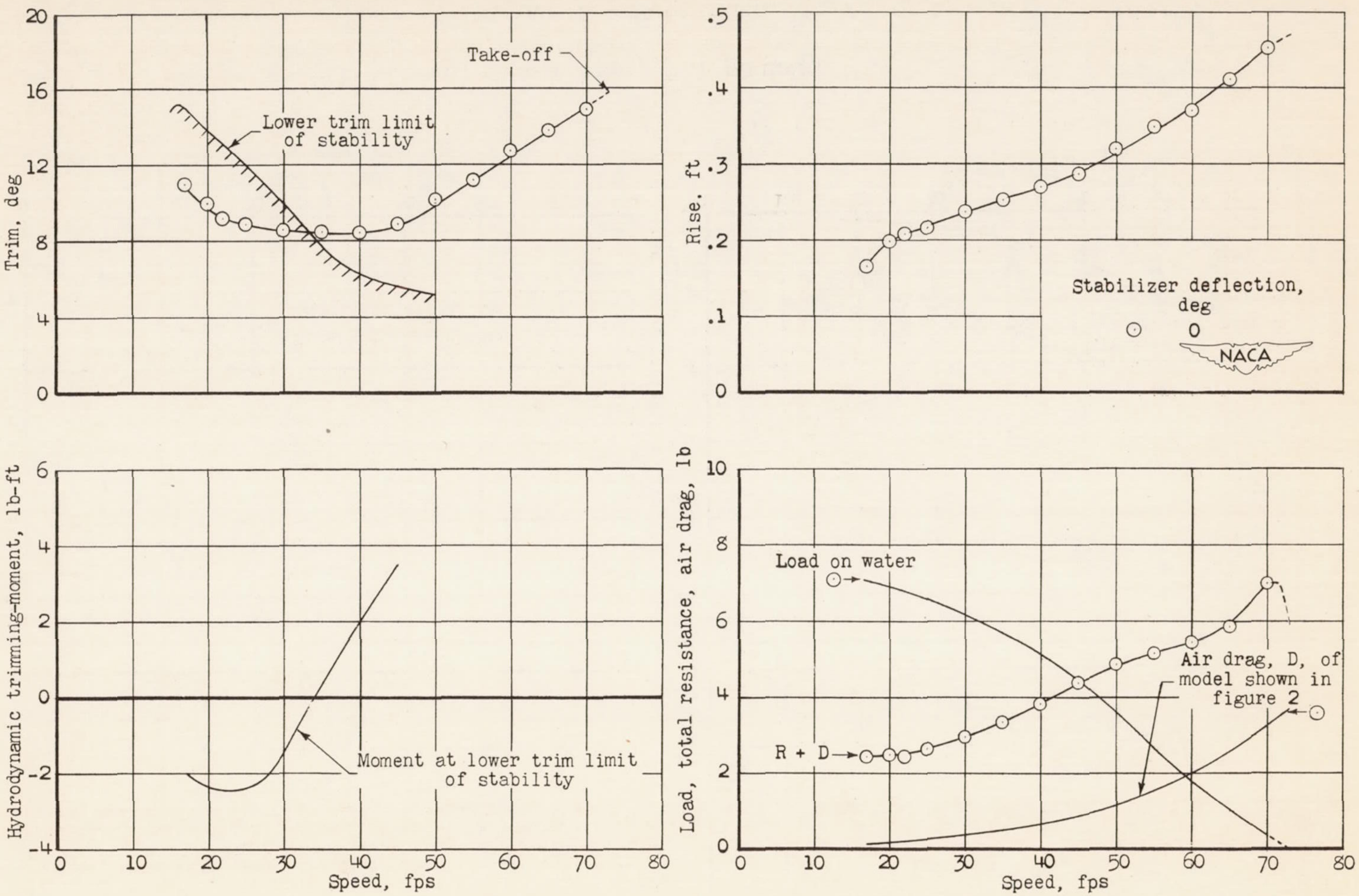
(a) Gross load, 3.8 pounds.

Figure 9.- Hydrodynamic characteristics. Hull II.



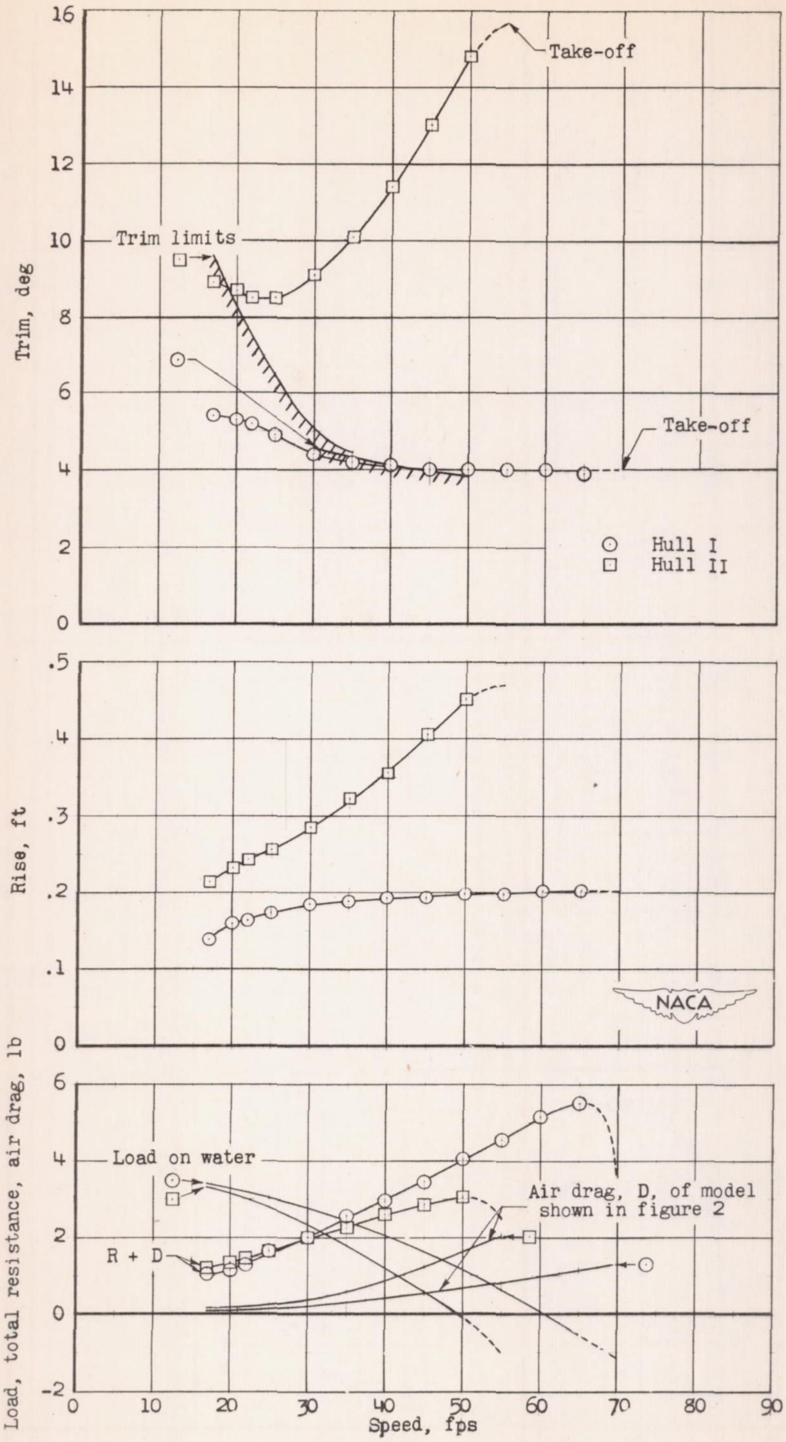
(b) Gross load, 5.7 pounds.

Figure 9.- Continued.



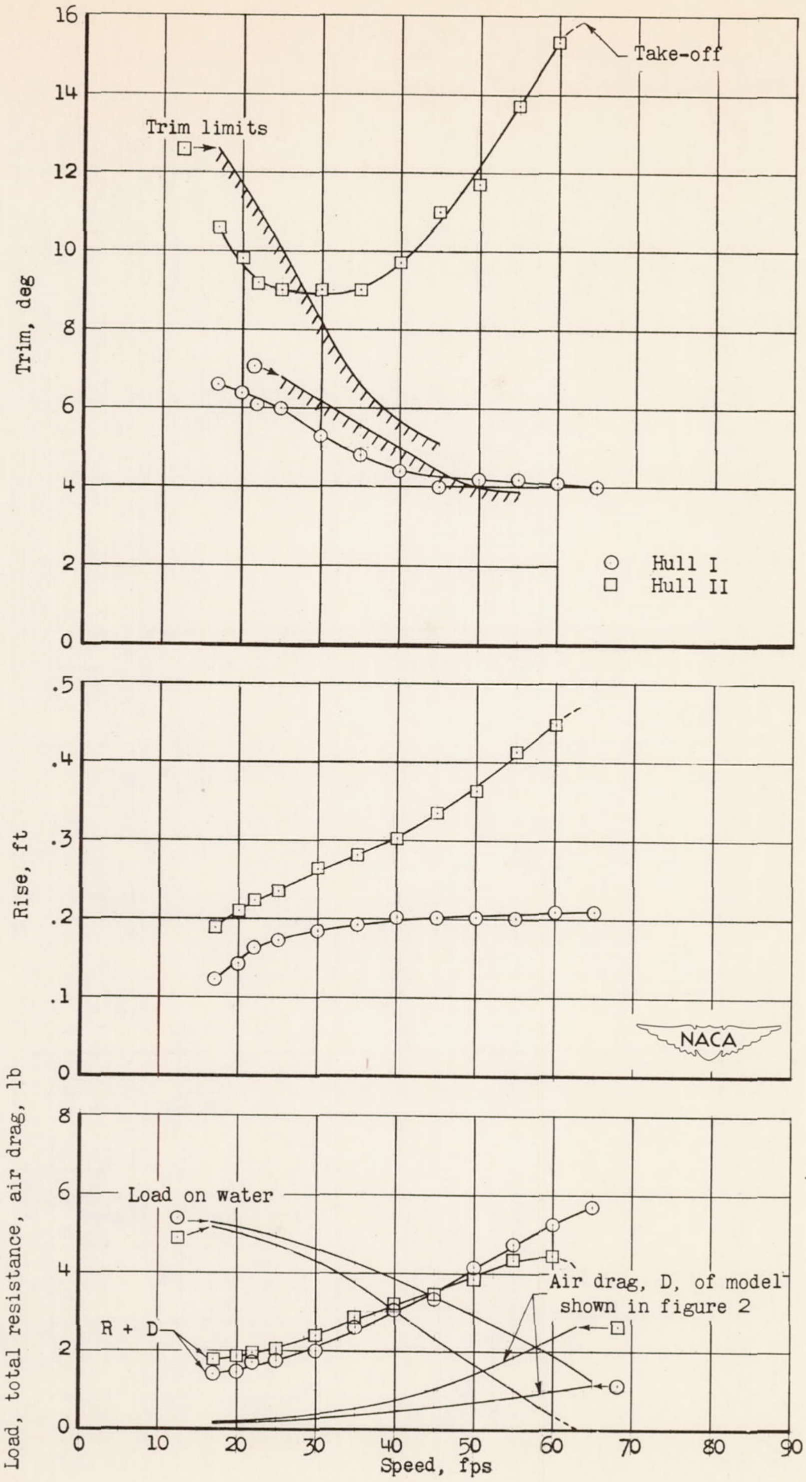
(c) Gross load, 7.6 pounds.

Figure 9.- Concluded.



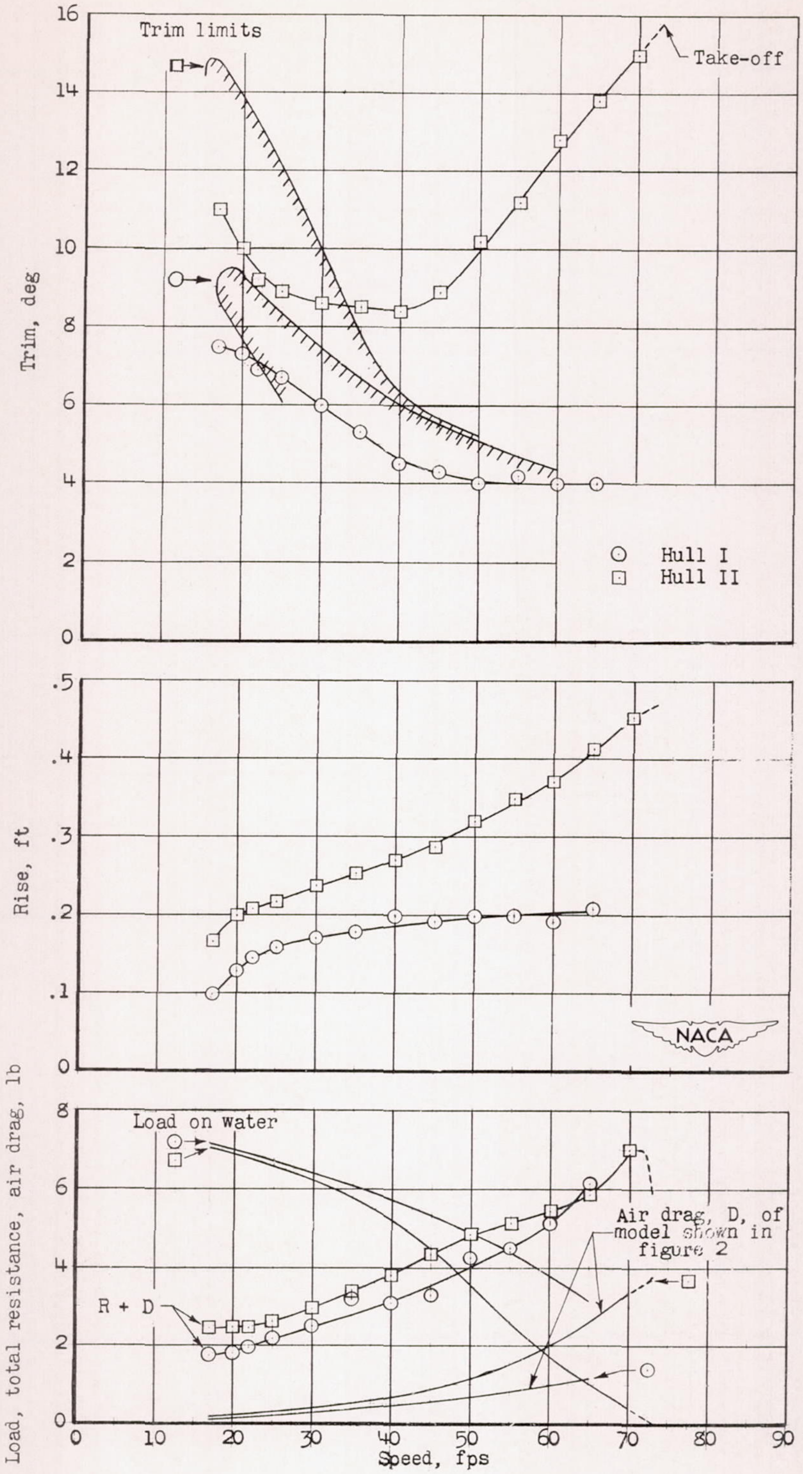
(a) Gross load, 3.8 pounds.

Figure 10.- Comparison of the hydrodynamic characteristics of hulls I and II. Stabilizer, 0°.



(b) Gross load, 5.7 pounds.

Figure 10.- Continued.



(c) Gross load, 7.6 pounds.

Figure 10.- Concluded.

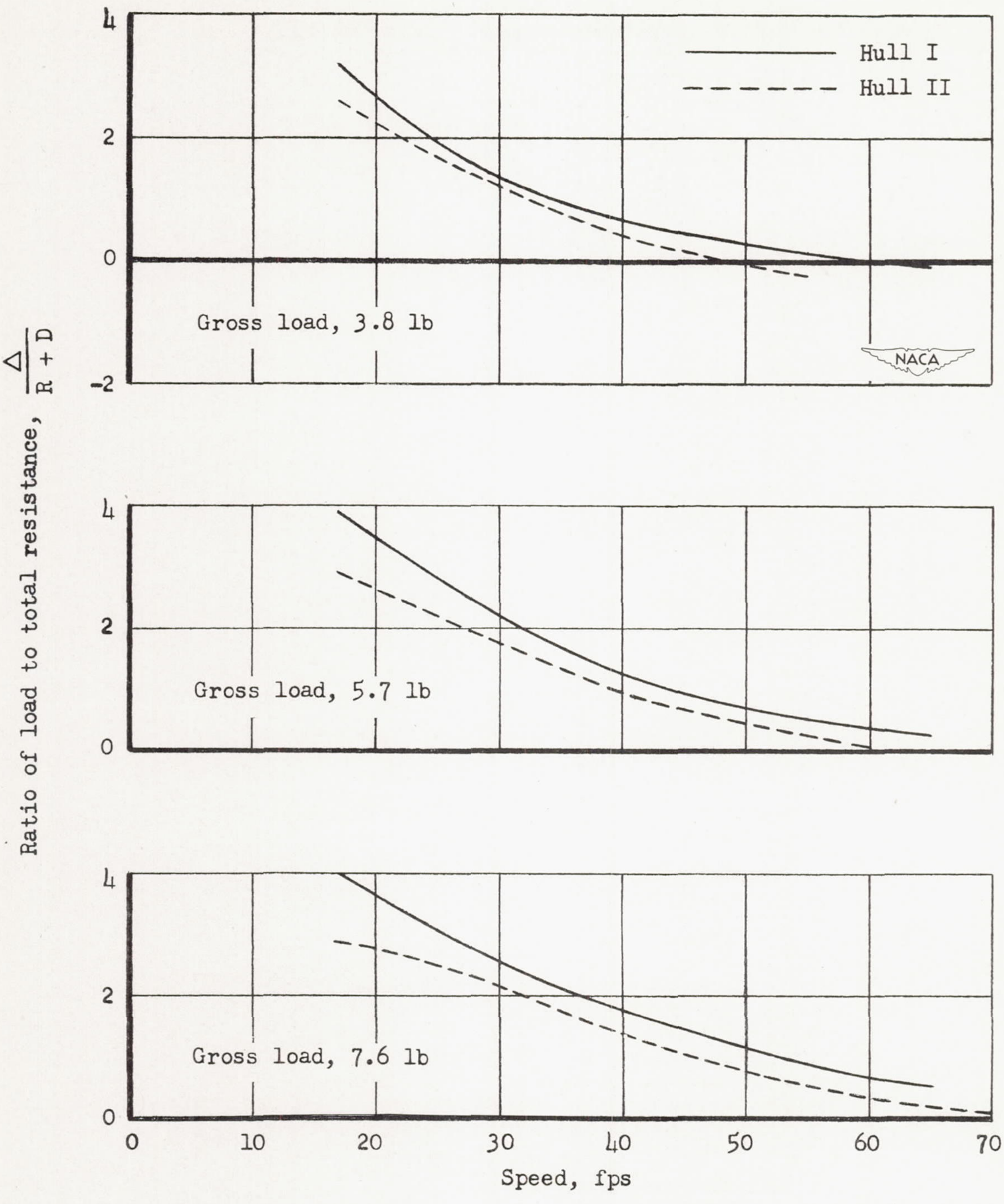


Figure 11.- Comparison of ratios of load to total resistance for hulls I and II. Stabilizer, 0°.

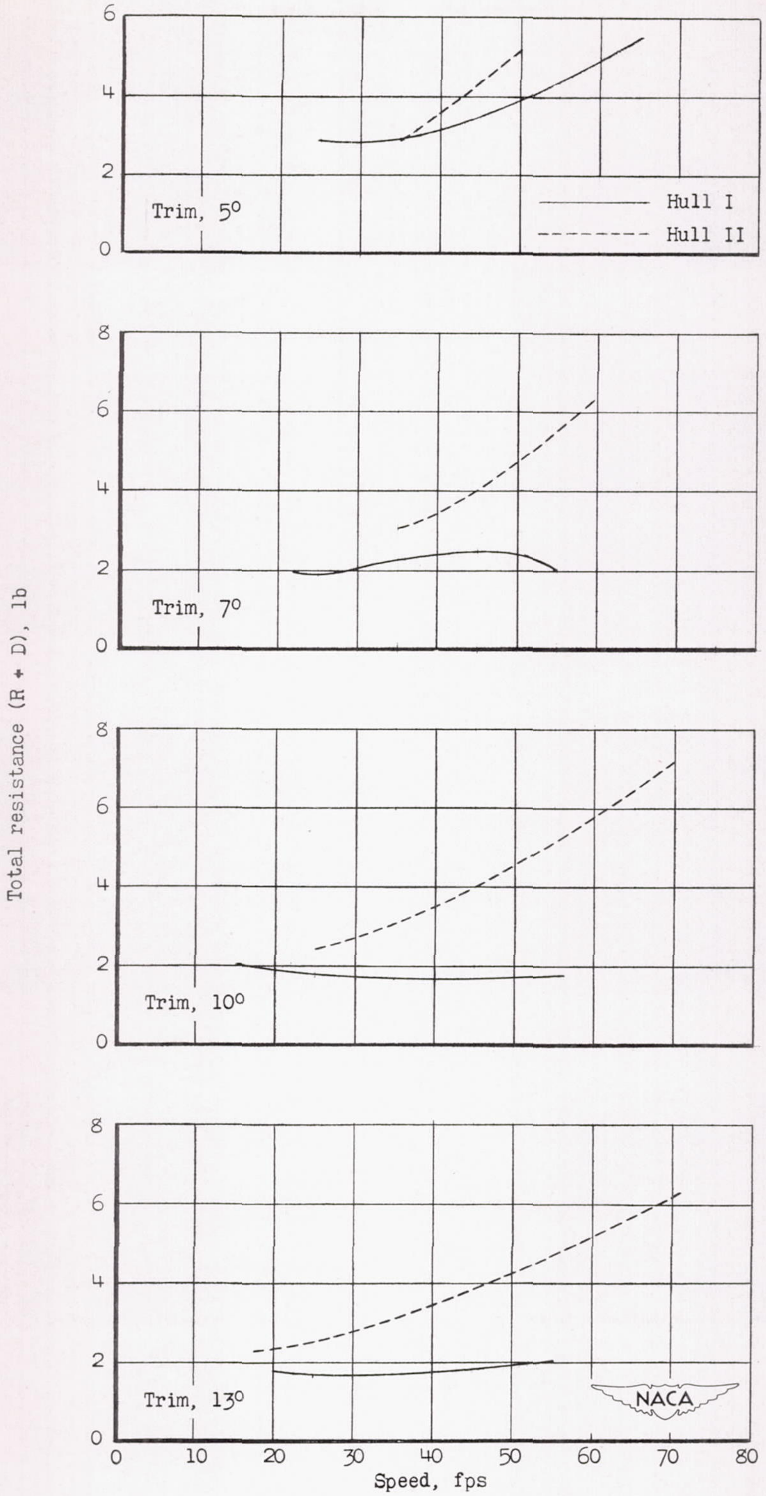
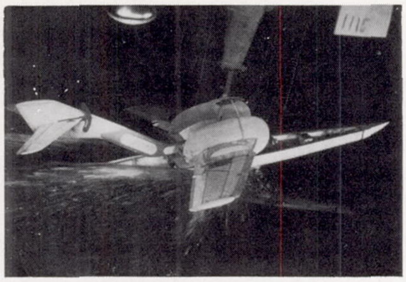
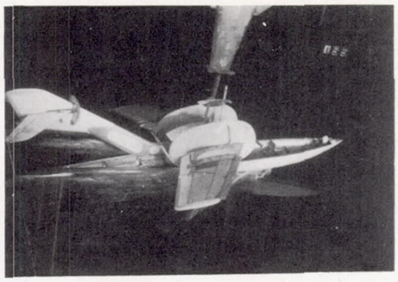
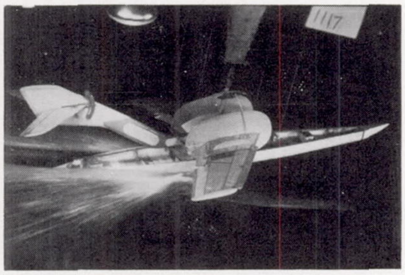


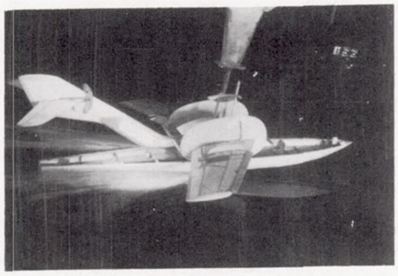
Figure 12.- Comparison of total resistance between hulls I and II at constant trims. Gross load, 7.6 pounds; stabilizer, 0°.



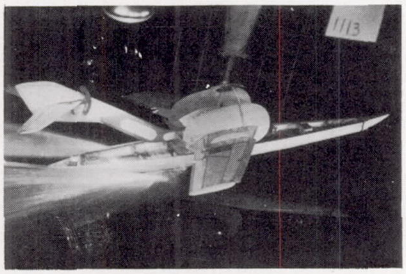


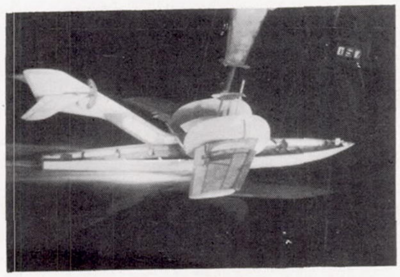
Trim, 9.6° 20 fps Trim, 7.3°



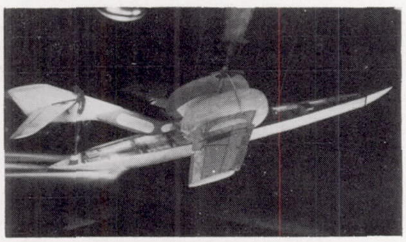


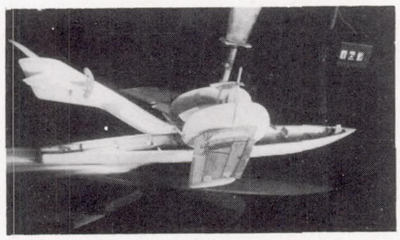
Trim, 8.5° 35 fps Trim, 5.3°





Trim, 9.5° 50 fps Trim, 4.0°





Speed, 70 fps; trim, 15.8°

Hull II.

Speed, 75 fps; trim, 5.2°; stabilizer, -30°

Hull I.

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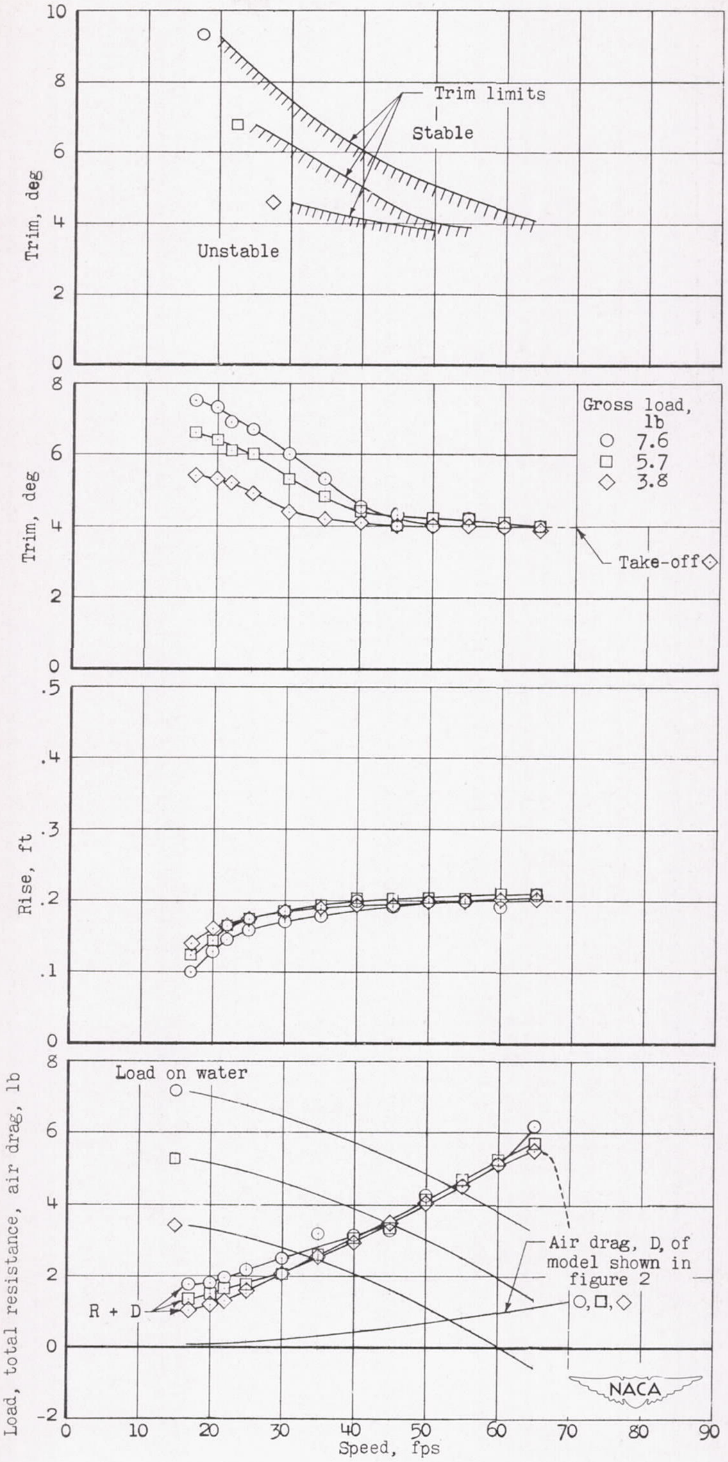
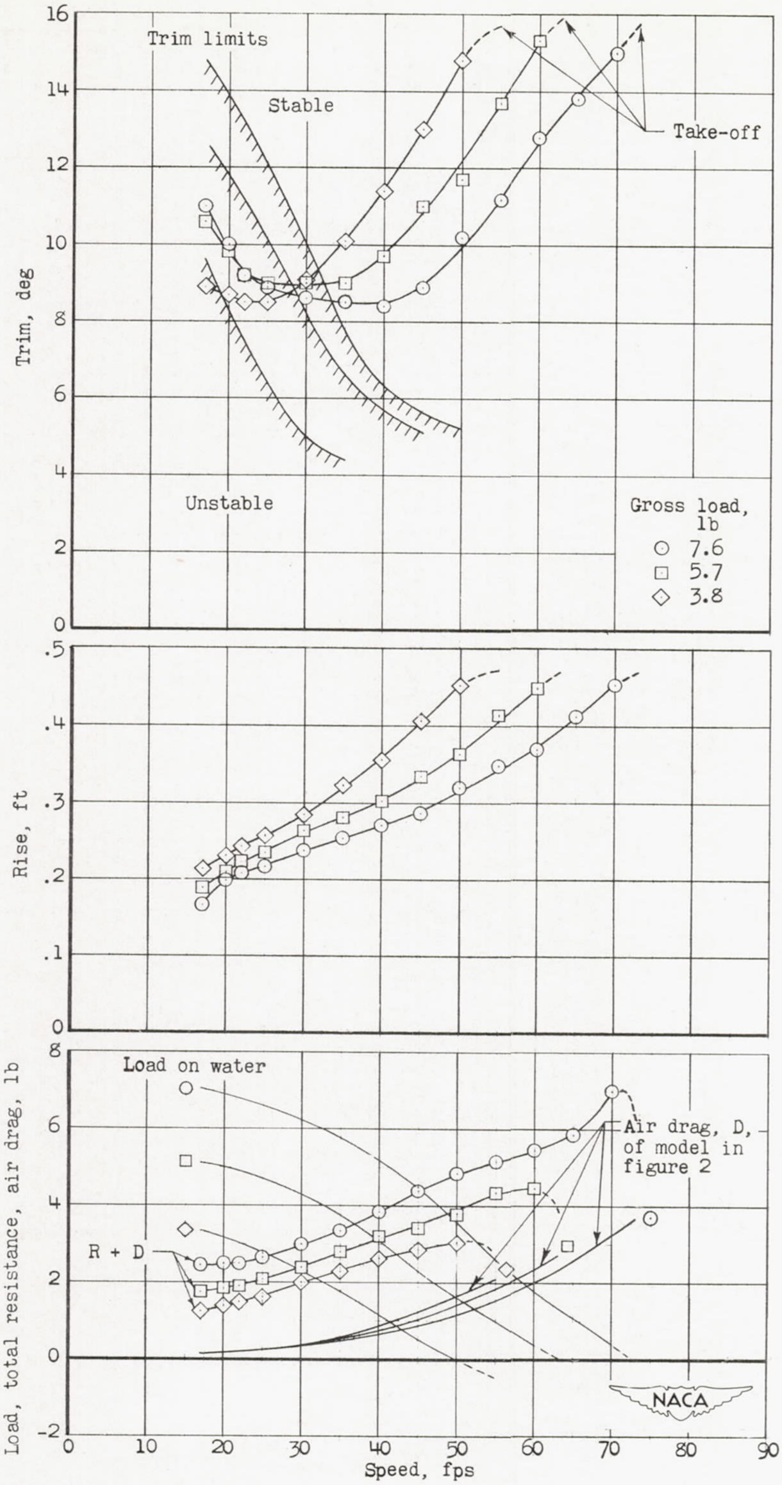
Figure 13.- Spray comparison of hulls I and II for a gross load of 7.6 pounds. Stabilizer, 0° except where noted.



(a) Hull I.

Figure 14.- Effect of gross load. Stabilizer, 0°.



(b) Hull II.

Figure 14.- Concluded.

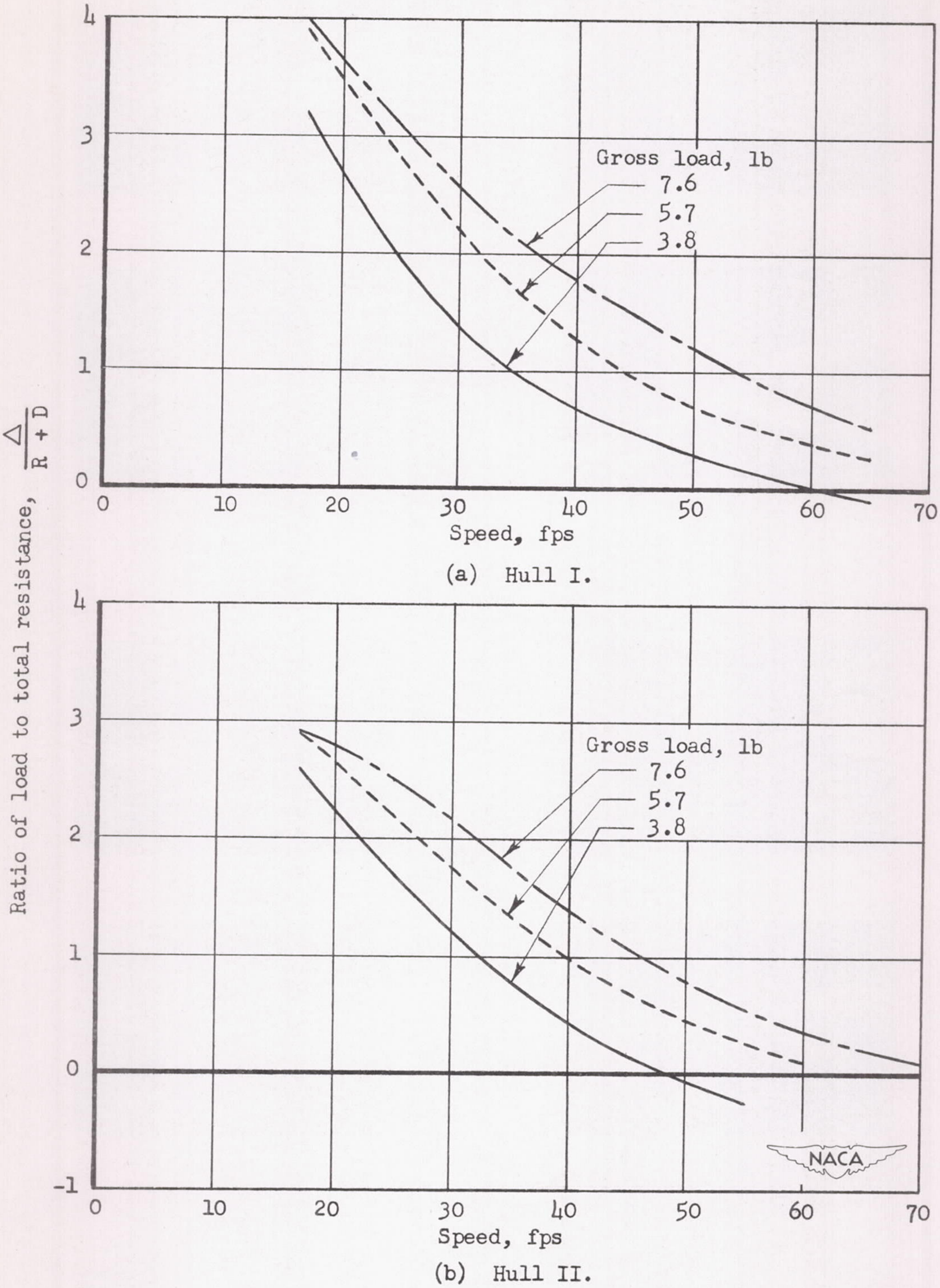
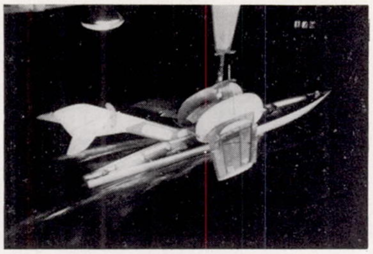
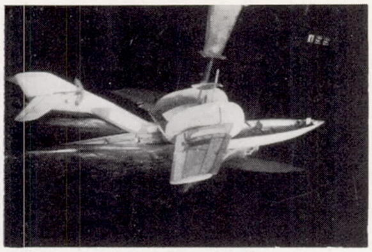


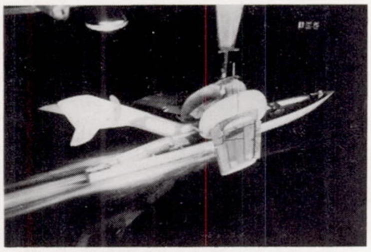
Figure 15.- Effect of gross load on ratio of load to total resistance. Stabilizer, 0°.

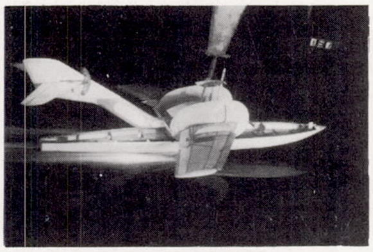




20 fps

Trim, 5.3° | Trim, 7.3°

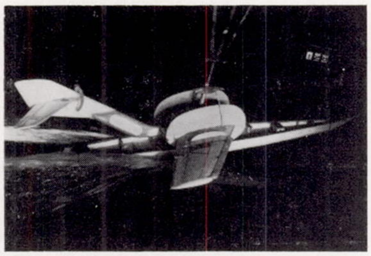


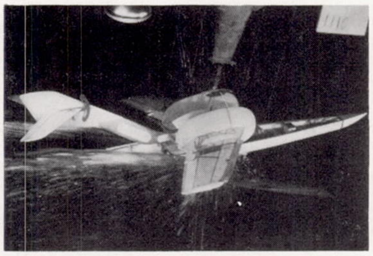


50 fps

Trim, 4.0° | Trim, 4.0°

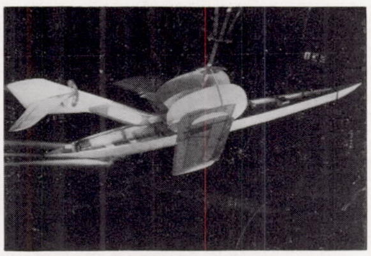
(a) Hull I.

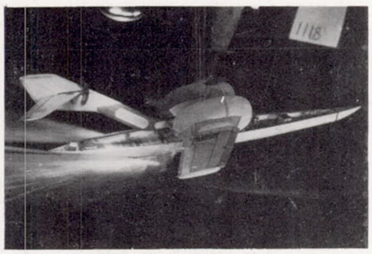




20 fps

Trim, 8.7° | Trim, 9.6°





50 fps

Trim, 14.8° | Trim, 9.5°

Gross load, 3.8 lb | Gross load, 7.6 lb

(b) Hull II.

NACA

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Figure 16.- Spray comparison between 3.8- and 7.6-pound gross loads. Stabilizer, 0°.