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INVESTIGATION OF THE EFFECT OF SPRAY STRIPS ON THE LOW-SPEED SPRAY CHARACTERISTICS OF A 1/8-SIZE MODEL OF THE CONSOLIDATED PB2Y-3 FLYING BOAT - NACA MODEL 116E-3

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NACA

WASHINGTON

MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

INVESTIGATION OF THE EFFECT OF SPRAY STRIPS ON THE LOW-SPEED SPRAY CHARACTERISTICS OF A 1/8-SIZE MODEL OF THE CONSOLIDATED PB2Y-3 FLYING BOAT - NACA MODEL 116E-3

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INTRODUCTION

When the Consolidated Aircraft Corporation PB2Y-3 flying boat is operated at gross weights very much in excess of the original gross weight of 56,000 pounds, the spray from the bow becomes excessive and causes serious damage to the propellers. Spray entering the carburetor intakes of the inboard engines reduces the power output of these engines. This loss in power prolongs the time during which the spray enters the propeller disks and may even prevent take-off.

One measure for at least alleviating the difficulties caused by the spray was thought to be the fitting of suitable spray strips around the bow and extending aft. The tests described in this report have been made for the purpose of investigating the effect of such spray strips on the spray and determining in what form they should be fitted to give the most practicable answer to the problem of controlling the spray at heavy loads.

The gross weight of this flying boat has been increased from 56,000 pounds to 66,000 pounds and a further increase to 72,500 pounds is required. The present tests were therefore made at the latter values of the gross weight. Spray strips of two different widths and three different angles to the horizontal were investigated. In order to simulate the full-size flying boat more accurately, powered propellers driven by electric motors were installed.

These tests were requested by the Bureau of Aeronautics, Navy Department.

APPARATUS

NACA tank no. 1 and its equipment are described in reference 1. The apparatus and procedure which are used for tests of dynamically similar models are described in reference 2. A spring dynamometer was installed on the roller cage which guides the towing staff of the model, and the total resistance was estimated by measuring the deflections of the spring.

DESCRIPTION OF THE MODEL

The model used in these tests corresponds to the PB2Y-3 airplane. Four 0.9-horsepower, 110-volt, high-speed series-wound, direct-current motors were installed in the nacelles on the wing. Each motor drove a three-blade, metal propeller at approximately 3800 rpm. The scale propellers, 19.5 inches in diameter, that were intended for use on this model, were not available; and in order to avoid delay in testing, propellers that were immediately available were substituted. These propellers were three-blade, 21.6 inches in diameter, and had a blade angle of 12°.

The particulars of the model are given in table I. The lines of the basic hull and of the subsequent modifications are shown in figure 1. A description of the modifications with reference to model designations and spray photographs is presented in the following table:

Model no.	Description	Spray photographs, figure no.
116E-3	Basic model	2
116E-3f	Horizontal spray strips, 1.5 inches (1.0 foot, full size) wide, added to chines. Strips carried around bow and extended aft 59.2 inches (39.3 feet, full size). Strips faired into afterbody.	3
116E-3g	Horizontal spray strips of model 116E-3f shortened. Strips extended 30.0 inches (20.0 feet, full size) from the bow and not faired into the hull at after end.	4
116E-3h	Spray strips of model 116E-3g turned down 20°, starting 8.0 inches (5.3 feet, full size) from bow.	5
116E-3i	Spray strips of model 116E-3h reduced in width to 1.0 inch (0.67 foot, full size).	6

Model no.	Description	Spray photographs, figure no.
116E-3j	Spray strips of model 116E-3i turned down 30° starting 8.0 inches (5.3 feet, full size) from bow. Full width of strip extended 22.5 inches (15.0 feet, full size) from bow and faired into hull 30.0 inches (20.0 feet, full size) from bow.	7
116E-3k	Spray strips of model 116E-3j turned down 30° starting 2.5 inches (1.7 feet, full size) from bow.	8

The aerodynamic surfaces differ from the full size in several respects. The area of the wings was increased by 15 percent, the elevator chord was increased by 20 percent, leading-edge slats and full-span flaps were installed, and the stabilizer was set at -6° with respect to the wing chord. The changes were based on the results of aerodynamic tests made without power. These changes were made to compensate for scale effect and low airspeed under the towing carriage. Although the application of power has a large effect on the aerodynamic characteristics (reference 3), no further modifications of the aerodynamic surfaces were made. At the low speeds at which the spray was being investigated, the effect of power on the aerodynamic surfaces was believed to be of secondary importance. The model as it was tested appeared to reproduce the undesirable spray characteristics of the full size.

TEST PROCEDURE

The spray characteristics at gross loads of 128.0 pounds (66,000 pounds, full size) and 140.5 pounds (72,500 pounds, full size) were investigated. The model was towed free to rise and free to pitch about the center of gravity which was located at 28 percent of the mean aerodynamic chord. Tests were made at a slow rate of acceleration, 1/4 foot per second per second, and Leica photographs of the bow spray were obtained at speed intervals of 1 foot per second. A continuous motion picture at 16 frames per second was obtained during the same test run. Motion pictures were also taken at a camera speed of 64 frames per second and a carriage acceleration of 1 foot per second per second. The appearance of the spray in these latter motion pictures should approximate that of the full size.

The forward limit for stable positions of the center of gravity was determined for the final modification by making accelerated runs at several positions of the center of gravity and observing the behavior of the model. The procedure is described in reference 2.

Only the forward limit was investigated because, at the high trims encountered at after positions of the center of gravity, the parts of the hull affected by the modifications were out of the water.

The landing stability of the model with the final modification was also investigated. These landings were all made with the center of gravity at 28 percent mean aerodynamic chord and without power.

RESULTS AND DISCUSSION

With a gross load of 140.5 pounds (72,500 pounds, full size) the spray rose vertically at the nose of the basic model at very low speeds, which indicates that either the forebody is not long enough at this increased gross weight or the trims at which the bow enters the water are too low. As the speed increased the bow wave appeared as a blister (fig. 2) which was formed about 6 inches (4 feet, full size) aft of the forward perpendicular. Spray from this blister was picked up by the propellers and the amount of spray entering the propeller disk increased as the bow blister moved aft. At approximately 13 feet per second (22 knots, full size) the spray struck the propeller hubs. This water was broken up by impact with the propeller blades and was thrown back over the wing and engine nacelles. At a higher speed, when the peak of the blister had moved aft of the propeller disk, water was drawn up from behind the propeller and was thrown against the under surface of the wing and the flaps. The propellers were not clear of the spray until the bow blister had moved several inches aft of the propeller disks.

The height of the bow spray was very definitely increased when power was applied. Although the spray was clear of the propeller disk with idling propellers, the change in air flow which was produced by the turning propellers caused the spray to enter the propeller disks. (See reference 3.) Conclusions as to the effects of modifications on bow spray are therefore subject to error if the effects of turning propellers are neglected.

The spray patterns were similar at both of the gross loads which were investigated. At the greater load, the spray was heavier and damage to the propellers from spray would be more likely.

The addition of horizontal spray strips, model 116E-3f, which increased the beam 1.5 inches (1.0 foot, full size) on each side of the model, did not cause an appreciable reduction in spray through the propellers (fig. 3). The water no longer tended to rise vertically at the nose at very low speeds due to the presence of the horizontal spray strip with the sharp chines. The resistance and trim at hump speeds were definitely decreased because of the increased planing area of the forebody. Reducing the length of the strips (model 116E-3g) produced no measurable change in the spray characteristics (fig. 4) and the resistance and trim at hump speed were approximately equal to that of the basic model.

When the strips were turned down 20° (model 116E-3h), the propellers were almost entirely clear of the spray (fig. 5). The spray from under the forebody was deflected down and appeared to be broken up. Smooth, high blisters did not form and the water was not picked up by the propellers. The spray, in being deflected downward, did not appear to strike the water surface and rebound into the propellers.

A reduction in the width of the spray strip from 1.5 inches (1.0 foot, full size, model 116E-3h) to 1.0 inch (8.0 inches, full size, model 116E-3i) allowed some spray again to enter the propeller (fig.6). The narrower strip, which was also turned down 20°, showed a large improvement when compared with the basic model but was not as satisfactory as the wider strip. Turning the strips down an additional 10° (a total of 30°) was not effective unless the 30° deflection started approximately 2.5 inches (1.7 feet, full size) aft of the bow. Model 116E-3j, with a 30° deflection of the strip starting 6.0 inches (4.0 feet, full size) aft of the bow (fig. 7), had spray entering the propellers from a blister which originated ahead of the portion of the strip which was turned down 30°. Model 116E-3k, with a 30° deflection of the strip starting 4.0 inches from the bow, showed satisfactory spray characteristics (fig. 8). The tendency of the spray to bounce on striking the surface of the water had no appreciable effect on spray in the propellers.

The after ends of the spray strips of model 116E-3j and model 116E-3k were faired into the hull just forward of the beaching gear. The full width of strip was continued aft as far as the propeller disk. Photographs showing the change in spray pattern as these strips clear the water are given in figure 8.

Measurements of the resistance of these latter modifications indicate that neither the resistance nor the trim are appreciably changed from that of the basic model.

The variations of trim with speed for model 116E-3K at gross weights of 128.0 pounds (66,000 pounds, full size) and 140.5 pounds (72,500 pounds, full size) and without power are presented in figures 9 and 10. Plots of maximum amplitude of porpoising are shown in figure 11(a). The curves that were obtained from tests of the basic model are also included. When the results of the basic model are compared with those of model

116E-3k, the differences in maximum amplitude at forward positions of the center of gravity are found to be negligible.

The limits for stable positions of the center of gravity of the basic model are shown in figure 11(b). Comparable data for model 116E-3k at the forward limit are also included. It will be noted that the addition of the spray strip had no appreciable effect on the forward limit for stable positions of the center of gravity.

The landing characteristics of model 116E-3k were similar to those of the basic model. No change would be expected inasmuch as the parts of the model affected by this modification are clear of the water at landing speeds.

CONCLUDING REMARKS

1. From experience with tests of dynamic models, with and without power, and from such correlations of the spray of the model with spray of the full size that have been possible, it is apparent that results from investigations of the spray characteristics with models are subject to an appreciable error if the effects of power on the spray pattern are not included.

2. The spray problem encountered during operation of the PB2Y-3 flying boat appeared to be reproduced by tests of the model.

3. The spray characteristics of the basic model definitely limit increases in gross weight much beyond 128.0 pounds (66,000 pounds, full size).

4. The addition of spray strips 1.5 inches wide (1.0 foot, full size), turned down 20°, carried around the bow, and extending aft 22.5 inches (15.0 feet, full size) prevented water from rising vertically at the bow at very low speeds, and the amount of spray that entered the propeller disks at a gross weight of 140.5 pounds (72,500 pounds, full size) was small.

5. The addition of spray strips, 1.0 inch (8.0 inches, full size), carried around the bow, turned down 30° aft of a point 2.5 inches (1.7 feet, full size) from the bow, and extending aft 22.5 inches, was also satisfactory. This modification, however, was not as effective as the former.

6. These modifications do not appreciably effect the range of stable positions of the center of gravity or the landing characteristics.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., January 27, 1943.

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1. Truscott, Starr: The Enlarged NACA Tank and Some of Its Work. T.M. No. 918, NACA, 1939.

2. Olson, Roland E., and Land, Norman S.: The Longitudinal Stability of Flying Boats as Determined by Tests of Models in the NACA Tank. I - Methods Used for the Investigation of Longitudinal-Stability Characteristics. NACA A.R.R., Nov. 1942.

3. Parkinson, John B., and Olson, Roland E.: Tank Tests of a 1/5 Full-Size Dynamically Similar Model of the Army OA-9 Amphibian with Motor-Driven Propellers - NACA Model 117. NACA A.R.R., Dec. 1941.

TABLE I

Dimensions of Basic Airplane (Model 116E-3)

	Model	Full size
Hull		
Beam at step, in.	15.75	126.0
Length, in.		
Bow to main step at keel	49.81	398.5
Main step at keel to 2nd step	31.75	253.9
Tail extension	36.94	295.6
Over all	118.50	948.0
Type of step	30° vee	30° vee
Depth of step, in.		
At keel	0.87	6.96
At mean	0.57	4.56
Angle of dead rise, deg		
Including chine flare	19.00	19.00
Excluding chine flare	22.50	22.50
Angle-of-forebody keel, deg	1	1
Angle-of-afterbody keel, deg	6.25	6.25
Angle between keels, deg	7.25	7.25
Center of gravity		
Percent M.A.C.	28.00	28.00
Forward of step, in.	7.95	64.06
Wing		
Area, ft^2	[a]27.80	17.80
Span, ft	[b]14.38	115.0
Angle of wing setting, deg	3.00	3.00
L.E. M.A.C. aft L.E.W. at root, in.	6.01	48.10
L.E. wing at root aft of nose, in.	28.93	231.4
Length M.A.C., in.	24.29	194.3

[a]Actually 15 percent greater to compensate for loss in airspeed under towing carriage.

[b]Actually 18 feet to give 15-percent increase in area.

NACA TANK NO. 1
National Advisory
Committee for Aeronautics

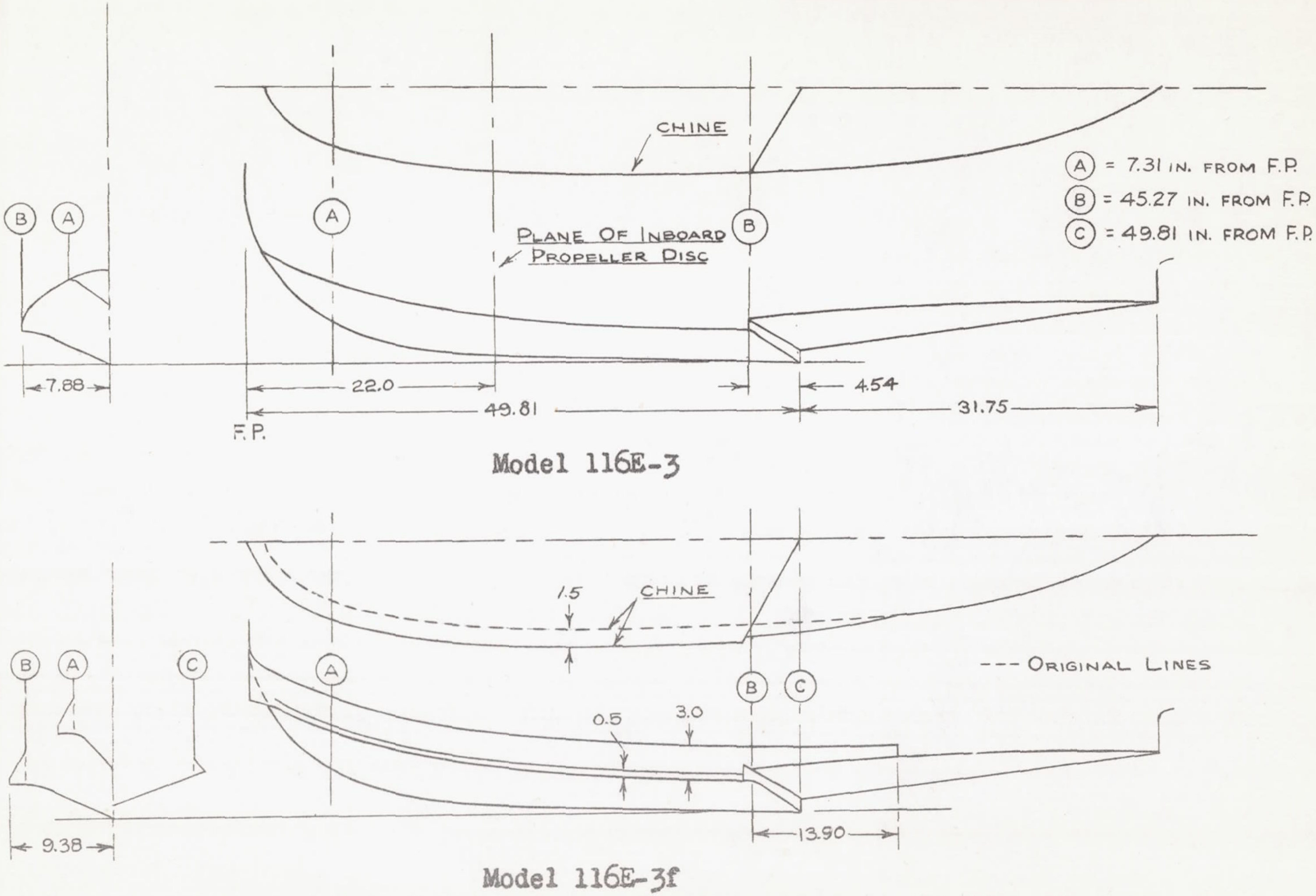

Figure 1 .- Lines of NACA Model 116E-3 and modifications. All dimensions are in inches.

NACA TANK NO. 1
National Advisory
Committee for Aeronautics

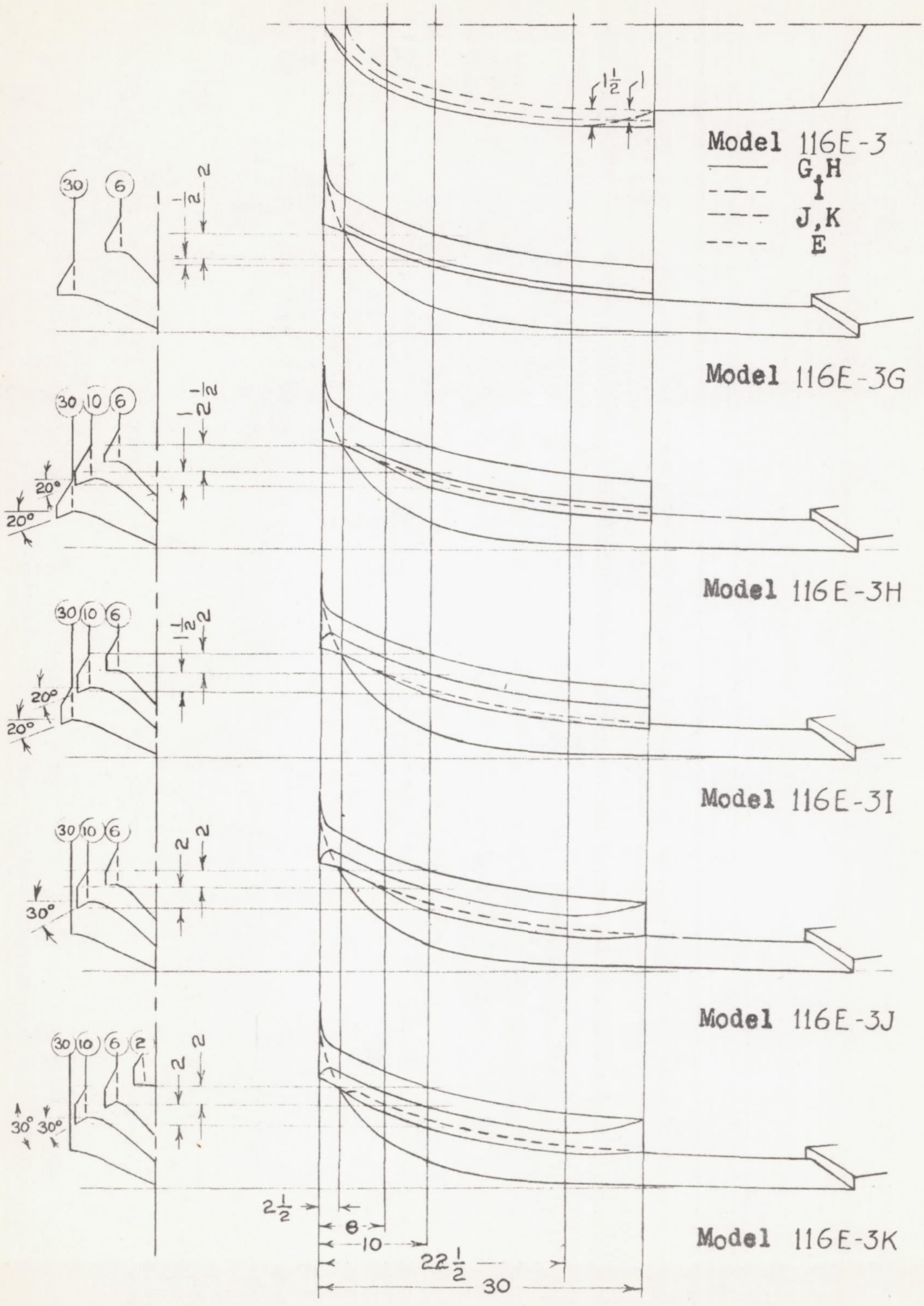

Figure 1 .- Concluded.

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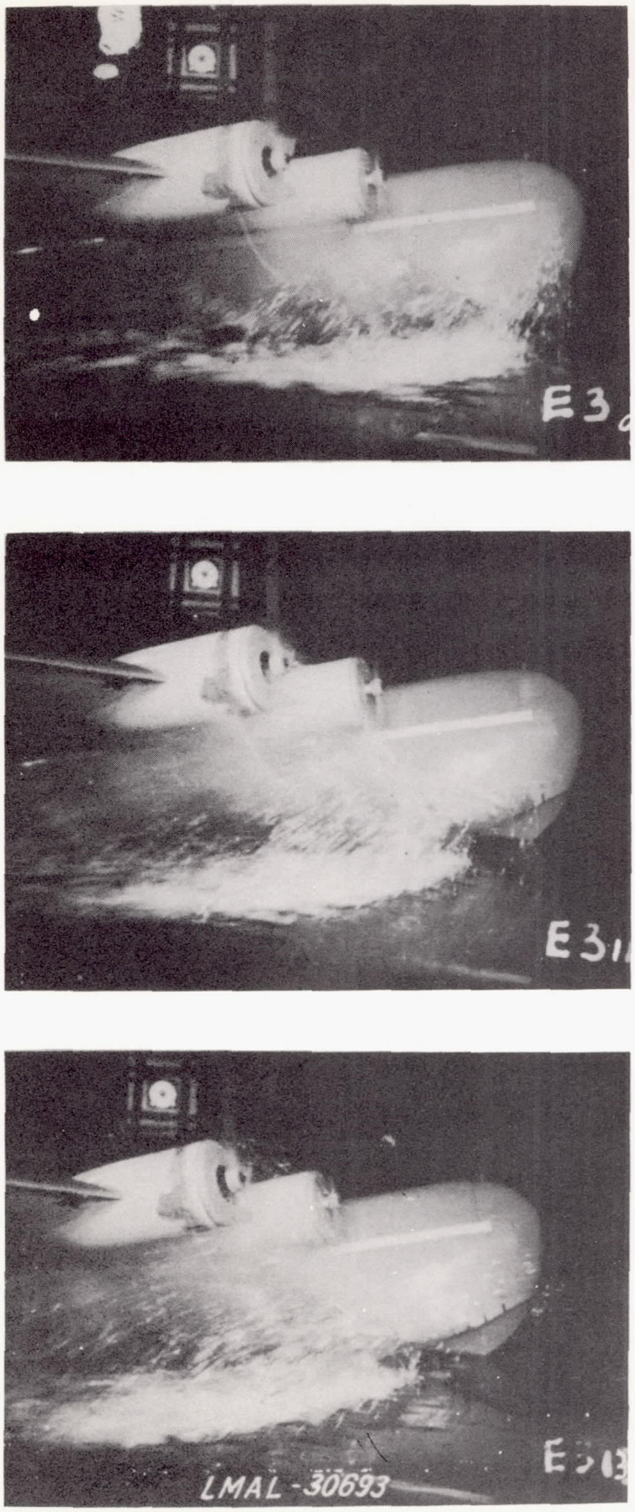

$V = 9.0$ fps

$\tau = 7.5^{\circ}$

$V = 11.0$ fps

$\tau = 9.2^{\circ}$

$V = 13.0$ fps

$\tau = 9.5^{\circ}$

Figure 2.- Model 116E-3. Basic model. Δ_o, 140.5 pounds; center of gravity, 28 percent M.A.C.; δ_e, -25°; δ_f, 0°, full power.

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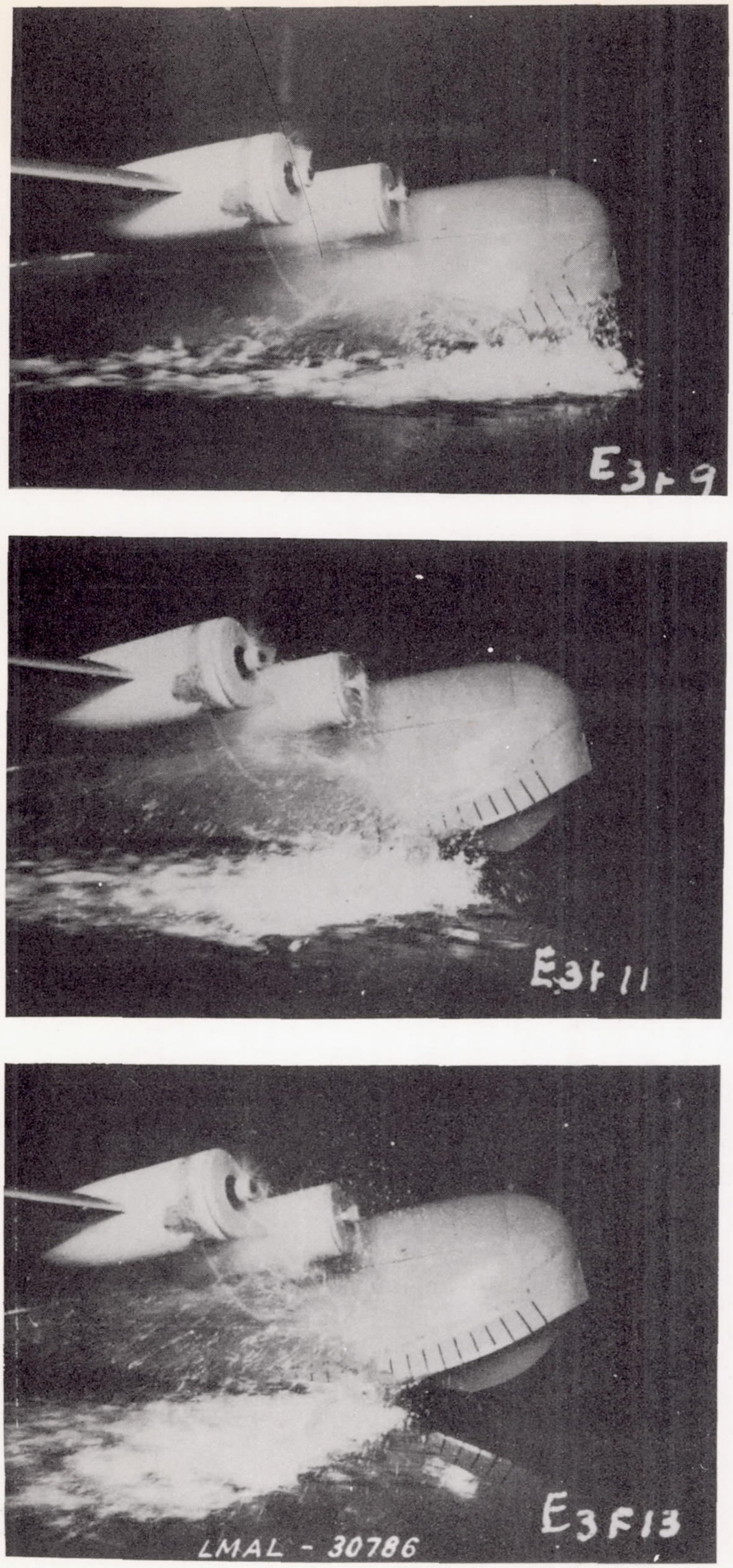

$V = 9.0$ fps

$\tau = 7.5^{\circ}$

$V = 11.0$ fps

$\tau = 9.2^{\circ}$

$V = 13.0$ fps

$\tau = 10.4^{\circ}$

Figure 3.- Model 116E-3f. Same as model 116E-3 with horizontal spray strip, 1-1/2 inches wide, extending 59.2 inches from original bow, Δ_o, 140.5 pounds; center of gravity, 28 percent M.A.C. δ_e, -25°; δ_f, 0°, full power.

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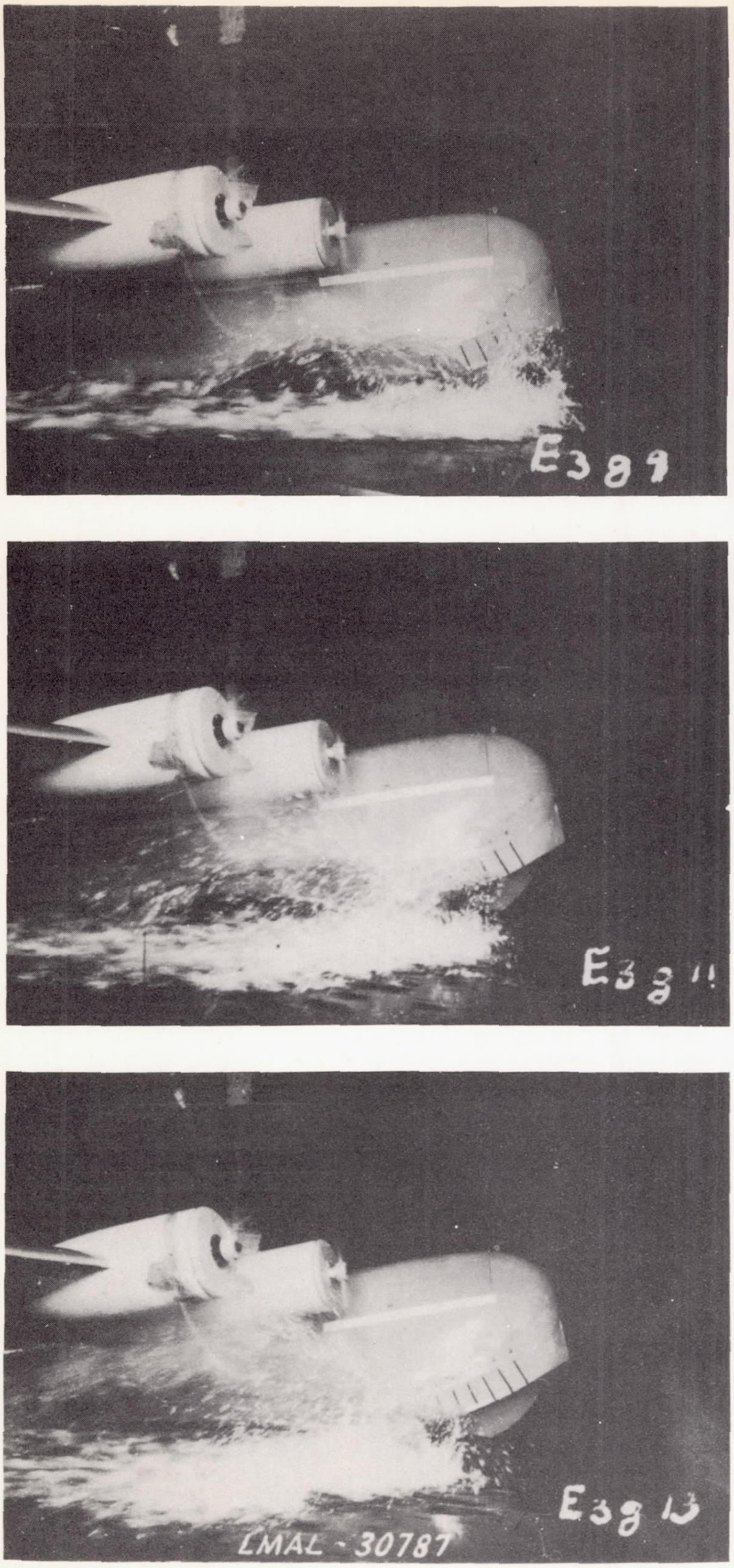

V = 9.0 fps

τ = 7.5°

V = 11.0 fps

τ = 9.2°

V = 13.0 fps

τ = 10.3°

Figure 4.- Model 116E-3g. Same as model 116E-3f with horizontal spray strips extending 30.0 inches from original bow. Δ_o, 140.5 pounds; center of gravity, 28 percent M.A.C.; δ_e, -25°; δ_f, 0°, full power.

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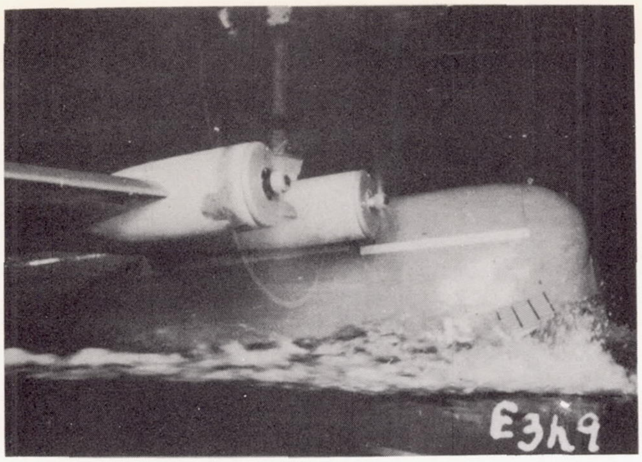
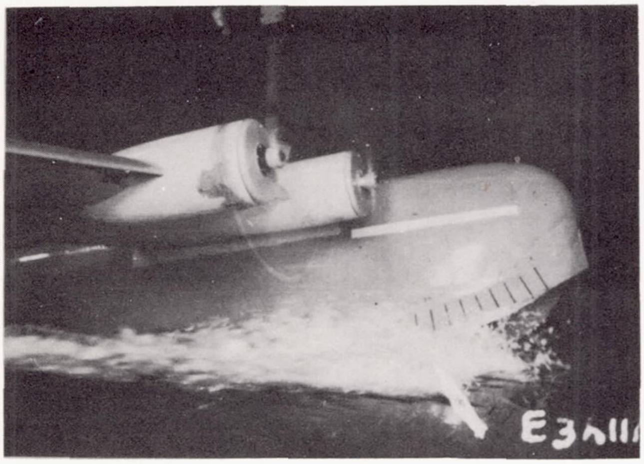


V = 9.0 fps

τ = 7.6°



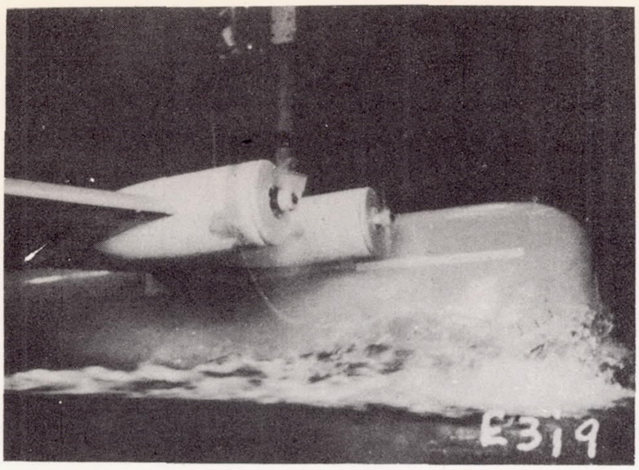
V = 11.0 fps

τ = 9.4°

V = 13.0 fps

τ = 10.4°

Figure 5.- Model 116E-3h. Same as model 116E-3g with spray strip turned down 20°, Δ_o = 140.5 pounds; center of gravity, 28 percent M.A.C.; δ_e, -25°; δ_f, 0°, full power.



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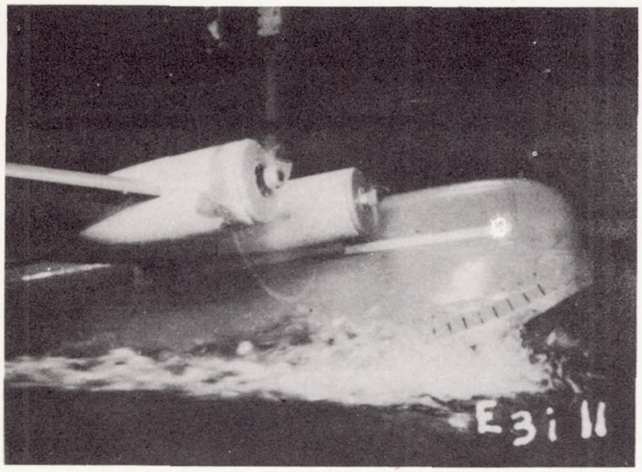
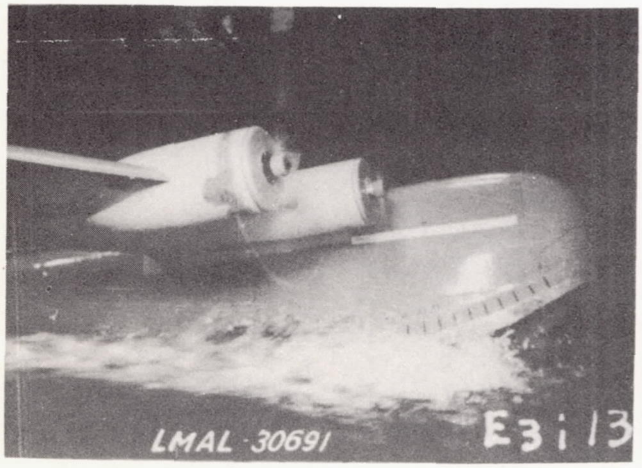


V = 11.0 fps

τ = 9.4°



V = 13.0 fps

τ = 10.4°

Figure 6.- Model 116E-3i. Same as model 116E-3h with spray strips 1 inch wide. Δ_o = 140.5 pounds; center of gravity, 28 percent M.A.C.; δ_e, -25°; δ_f, 0°, full power.

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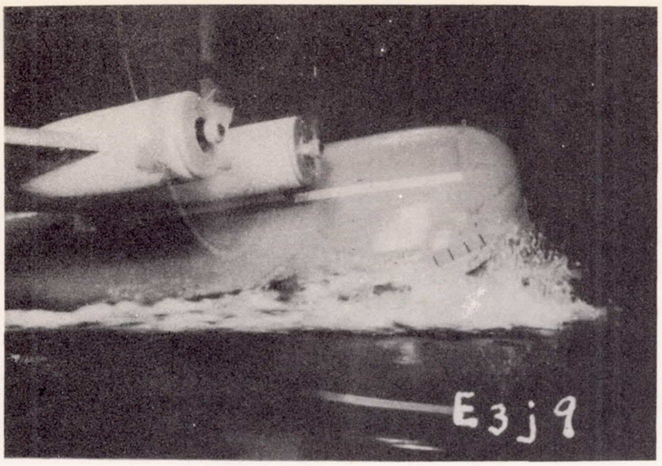

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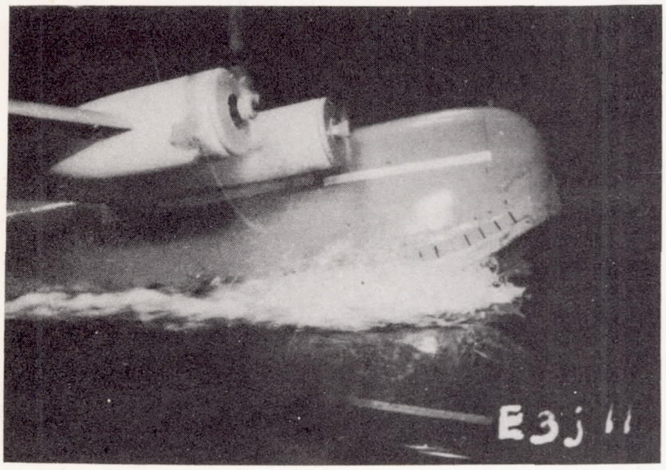
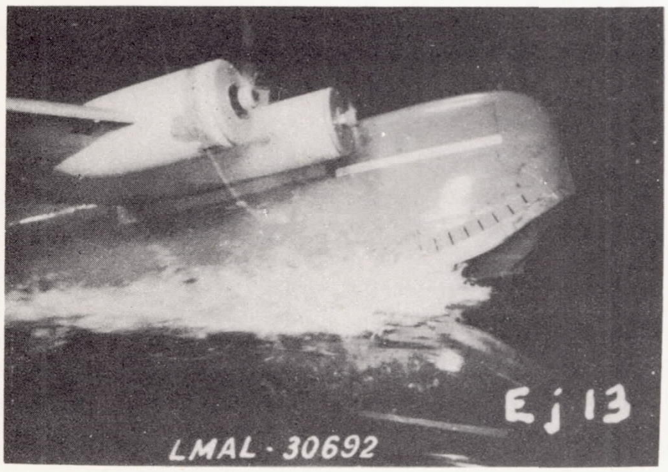
τ = 7.5°



V = 11.0 fps

τ = 9.4°



V = 13.0 fps

τ = 10.4°

Figure 7.- Model 116E-3j. Same as model 116E-3i with the same spray strips turned down 30°, starting at a point 6.0 inches from bow. After end of strips faired into hull starting at a point 22.0 inches from bow. Δ_o, 140.5 pounds; center of gravity, 28 percent M.A.C.; δ_e, -25°; δ_f, 0°; full power.

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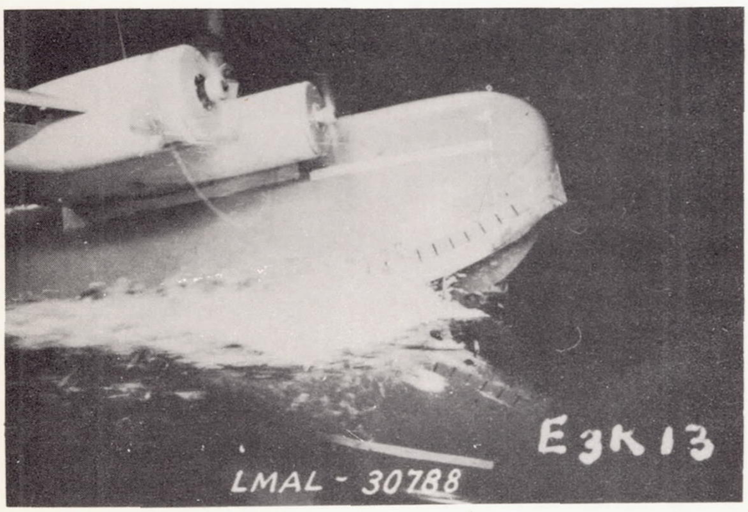
V = 9.0 fps

τ = 7.4°

V = 11.0 fps

τ = 9.3°



V = 13.0 fps

τ = 10.4°

Figure 8.- Model 116E-3k. Same as model 116E-3j with spray strips turned down 30°, starting at a point 2.5 inches from bow. Δ_o, 140.5 pounds; center of gravity, 28 percent M.A.C.; δ_e, -25°; δ_f, 0°; full power.

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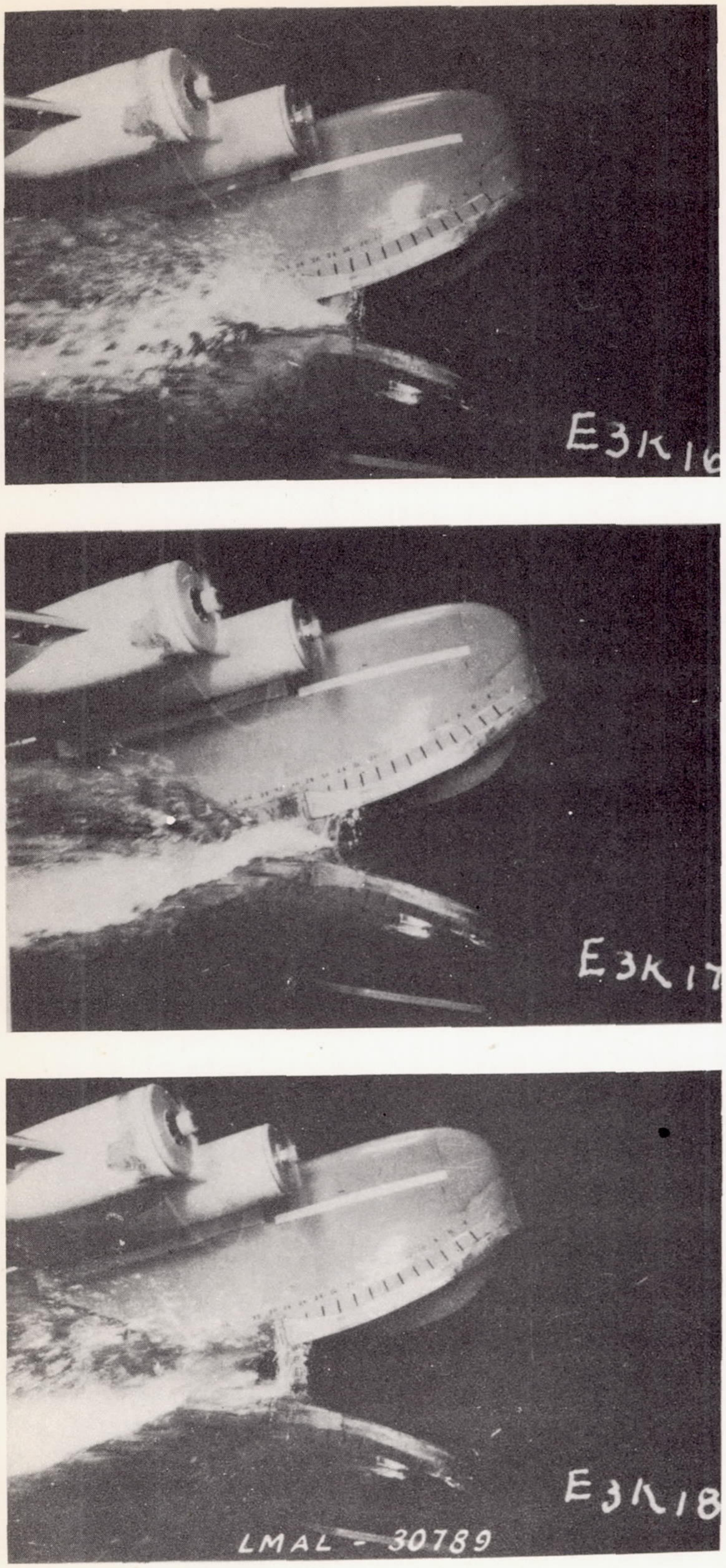

V = 16.0 fps

τ = 12.3°

V = 17.0 fps

τ = 13.0°

V = 18.0 fps

τ = 13.9°

Figure 8.- Model 116E-3k. Concluded.

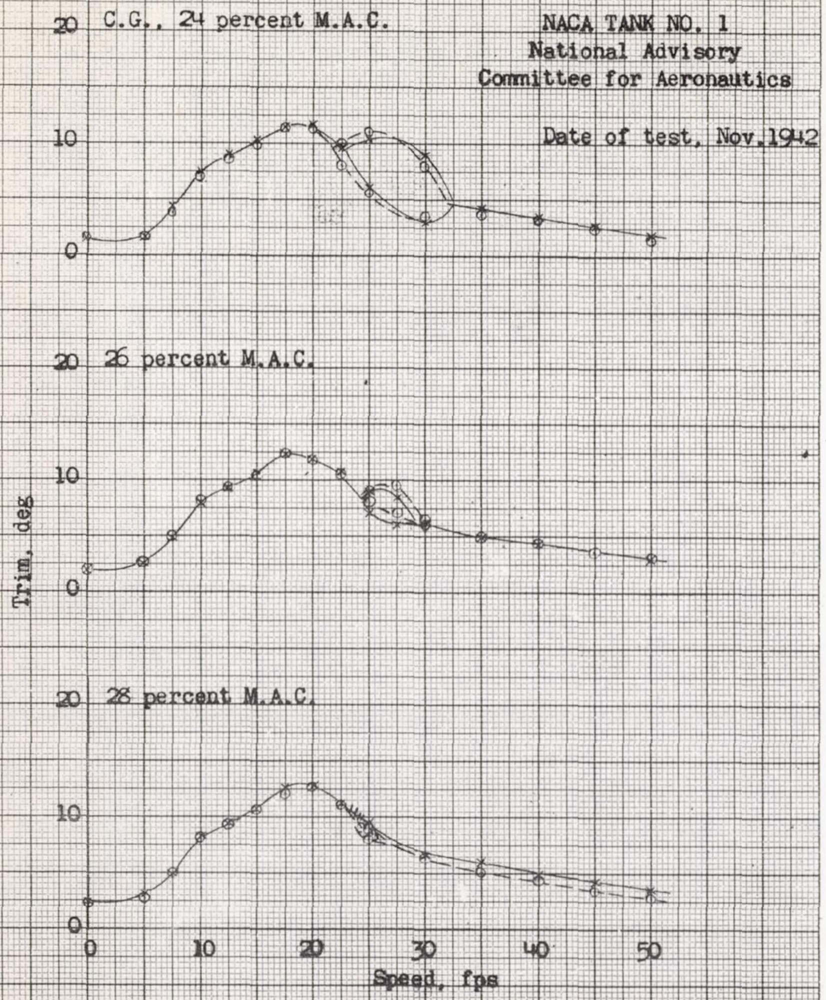

Figure 9 .- Model 116E-3k. Variation of trim with speed. Δ_0, 128.0 lb (66,000 lb, full size); δ_f, 40°; δ_e, 0°; zero power.

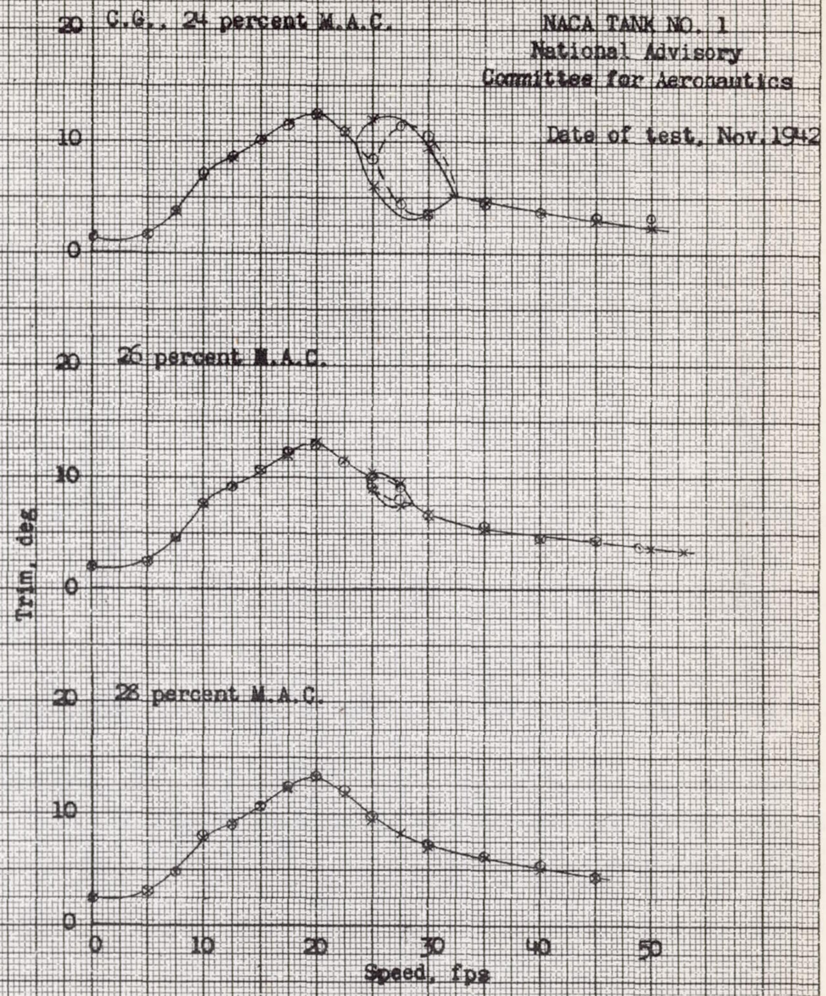

Figure 10 .- Model 116E-3k. Variation of trim with speed. Δ_0, 140.5 lb (72,500 lb, full size); δ_f, 40°; δ_e, 0°; zero power.

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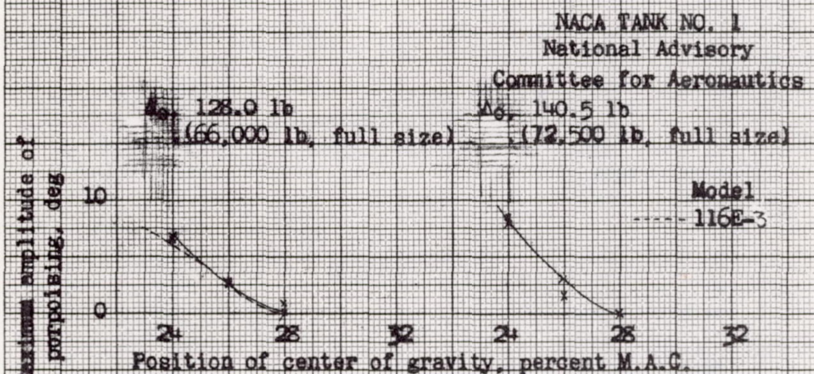
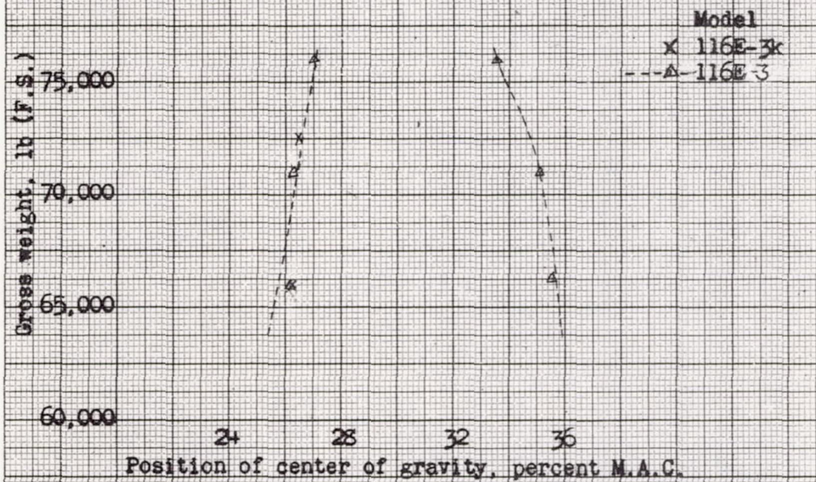


(a) Maximum amplitude of porpoising.



(b) Limits for stable positions of center of gravity.

Figure 11 .- Model 116E-3k. Effect of change in position of center of gravity on stability characteristics. δ_f, 40°; δ_e, 0°; power off.