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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

HYDRODYNAMIC QUALITIES OF A $\frac{1}{10}$-SIZE POWERED DYNAMIC MODEL OF THE XP5Y-1 FLYING BOAT IN SMOOTH WATER - LANGLEY TANK MODEL 246

TED NO. NACA DE320

By David R. Woodward, Irving Weinstein, and
Walter E. Whitaker, Jr.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

The hydrodynamic characteristics of a $\frac{1}{10}$-size powered dynamic model of the XP5Y-1 flying boat were determined in Langley tank no. 1. Stable take-offs were possible at all practicable positions of the center of gravity and flap deflections. An increase in gross load from 123.5 to 150.0 pounds (21.5 percent) had only a slight effect on the stable range for take-off. A decrease in forward acceleration from 3.0 to 1.0 feet per second per second had only a very small effect on the stable range for take-off.

In general, the landings were free from skipping except at trims below 6° where one skip was encountered at an aft position of the center of gravity. The model porpoised during the landing runout at all positions of the center of gravity when landed at trims above 10°.

Spray in the propellers was light at the design gross load, and was not considered excessive at a gross load of 136.0 pounds.

INTRODUCTION

A hydrodynamic investigation of several hull configurations of the Consolidated Vultee Aircraft Corporation's XP5Y-1 flying boat has been made in Langley tank no. 1 and is described in reference 1. The results of these and other tests were used by the Bureau of Aeronautics and the manufacturer in arriving at the final configuration of the production design.

Detailed hydrodynamic qualities in smooth water of a $\frac{1}{10}$-size powered dynamic model of this final configuration were determined at the request of the Bureau of Aeronautics, Department of the Navy. The principal changes incorporated in the model of the final configuration included a decrease in power loading, a decrease in angle of afterbody keel, and a modification of the wing and tail surfaces to make them correspond to those of the production airplane. The hull of the revised model corresponds to that of model 228G-1 described in reference 1.

SYMBOLS

C_{Δ_o} gross load coefficient (Δ_o/wb^3)

b maximum beam of hull, feet

Δ_o gross load, pounds

w specific weight of water (63.4 for these tests), pounds per cubic foot

C_L aerodynamic lift coefficient $\left(\frac{\text{Lift}}{\frac{1}{2}\rho S V^2}\right)$

C_m aerodynamic pitching-moment coefficient $\left(\frac{M}{\frac{1}{2}\rho S V^2 \bar{c}}\right)$

$\bar{c}$ mean aerodynamic chord (M.A.C.), feet

δ_e elevator deflection, degrees

δ_f flap deflection, degrees

M aerodynamic pitching moment, pound-feet

ρ density of air, slugs per cubic foot

S area of wing, square feet

τ trim (angle between base line of hull and water plane), degrees

τ_L landing trim at contact with water, degrees

V carriage speed (approx. 95 percent of airspeed), feet per second

DESCRIPTION OF MODEL

The XP5Y-1 is a 123,500-pound long-range flying boat having a wing loading of 59.5 pounds per square foot (full size), a power loading of 5.6 pounds per horsepower (full size), and a gross load coefficient (C_{Δ_o}) of 1.95. The model was designed by the Consolidated Vultee Aircraft Corporation and was constructed at the David Taylor Model Basin. Photographs of the model, designated Langley tank model 246, are shown as figure 1. A three-view drawing of the model is shown in figure 2 and pertinent dimensions are given in table I.

The model has a forebody length-beam ratio of 5.8 and an afterbody length-beam ratio of 4.2, making an over-all hydrodynamic length-beam ratio of 10.0. The forebody had a constant angle of dead rise of 22.5° for approximately $\frac{2}{3}$ beam forward of the step centroid and the dead rise increased rapidly at forward stations to the bow. The step had a 30° vee plan form, the centroid being located at 31.3 percent of the projected mean aerodynamic chord. The depth of step was 14.2 percent beam at the centroid and 16.2-percent beam at the keel. The angle between the forebody and afterbody keels was 5.5°. The horizontal stabilizer was fixed at 0° relative to the base line of the model.

The model was powered by four two-horsepower, three-phase alternating-current induction motors. Each motor turned a four-blade propeller of the paddle-wheel square-tip type.

The moments of inertia of the ballasted model were as follows:

Center of gravity (percent M.A.C.)	Moment of inertia (slug-ft^2)
20	16.6
37	15.7

APPARATUS AND PROCEDURE

A general description of Langley tank no. 1 is included in reference 2. The apparatus and procedures were the same as those used for the tests described in reference 1.

Take-off thrust was obtained at a propeller speed of 5800 rpm. The effective thrust was measured at 0° trim, 0° flaps, 0° elevators, and with the step of the model 8 inches above the water surface. The effective thrust is plotted against speed in figure 3.

In order to provide data from which the load on the water can be approximated, the aerodynamic lift and pitching moments were obtained with the model in the same position as that used for determining the effective thrust. The aerodynamic data for the model with power off and with take-off power are shown in figures 4 and 5, respectively. Figure 6 shows the effect of flap deflection on the aerodynamic lift and pitching-moment coefficients. All aerodynamic tests were referred to a center-of-gravity position of 25 percent mean aerodynamic chord.

The center-of-gravity limits of stability were based on the behavior during accelerated runs to take-off with fixed elevators, full thrust, and a constant acceleration of 3 feet per second per second. A sufficient range of flap and elevator deflection, center-of-gravity position, and gross load was investigated to cover the normal operating range and to define the center-of-gravity limits of stability. The trim limits of stability were obtained at constant speeds for a gross load of 123.5 pounds and with the flaps deflected 20°.

The landing stability was determined by flying the model at the desired landing trim and then decelerating the towing carriage at the rate of approximately 2 feet per second per second to simulate the landing maneuver. The model was held at the desired landing trim by a brake which was released electrically upon contact with the water. This procedure eliminated the tendency for the trim to decrease as the model approached the water. The elevators were set at a constant deflection such that the aerodynamic pitching moment about the center of gravity was approximately zero at the instant of first contact with the water. The sinking speeds of the model ranged from 0.69 to 1.00 fps. The landings were made with the model free to move fore and aft and with the power adjusted so that the model was self-propelled during the high-speed part of the landing runout. Approximately one-half take-off thrust (4600 rpm) was used. All landings were made with the flaps deflected 50° (gaps on top surface taped) and at the design gross load of 123.5 pounds.

Spray characteristics were determined for gross loads of 110.0, 123.5, and 136.0 pounds. Simultaneous bow and side photographs were taken at low speeds to determine the coordinates of the peaks of the bow spray blisters with reference to the model. Spray tests were made with take-off power, 20° flap deflection, 0° elevators, and with the center of gravity at 30 percent mean aerodynamic chord.

RESULTS AND DISCUSSION

Take-off stability.- The trim limits of stability are presented in figure 7. These trim limits are approximately the same as those estimated for model 228G-1, reference 1. The variation of trim during take-off at a gross load of 123.5 pounds is presented in figures 8, 9, and 10 for deflections of the flaps of 0°, 20°, and 40°, respectively. The trim limits from figure 7 have been included in figure 9 to show the relation between the trim limits (obtained at constant speed) and trim during take-off (obtained at constant acceleration). Hatched lines within the porpoising boundaries are shown in figures 8, 9, and 10 to indicate the porpoising range and amplitude.

A small amplitude oscillation $\left(\frac{1}{2}^\circ \text{ to } 1^\circ\right)$ was frequently encountered at trims between the trim limits, particularly at high trims in the range of speed from 25 to 35 feet per second. This oscillation, which is indicated on the trim tracks by vertical crosshatching, occurred when spray from under the forebody intermittently struck the leading edge of the horizontal tail. A similar oscillation was observed during the investigation of the original model, reference 1.

The maximum amplitudes of porpoising, obtained from the trim tracks in figures 8 to 10, have been plotted against position of the center of gravity in figure 11(a). By assuming a maximum allowable amplitude of porpoising of 2°, the center-of-gravity limits, shown in figure 11(b), were obtained. These center-of-gravity limits are presented as a plot of flap deflection against center-of-gravity position for several constant deflections of the elevators. Elevator deflections at which lower- and upper-limit porpoising occurred are indicated. For a given elevator deflection, a range of position of the center of gravity for take-off of approximately 15 percent mean aerodynamic chord was available between the forward and the after limits.

Stable take-offs were possible for all deflections of the flaps for a range of position of the center of gravity from 22 to 36 percent mean aerodynamic chord. A change in flap deflection of 10° was approximately equivalent to a change in elevator deflection of 5° except for large elevator deflections where the effectiveness of the elevators appeared to be reduced. A comparison of these results with those for model 228G-1 (reference 1) indicates that the after limit for model 246 has been shifted aft approximately 4 percent mean aerodynamic chord. The forward limit was not obtained for model 228G-1, but comparison with data for other modifications in reference 1 indicates that the forward limit for model 246 was shifted aft approximately 2 percent mean aerodynamic chord. The after movement of these limits with increase in flap deflection was slightly greater for model 246 than was the movement found for model 228G-1 in reference 1.

Increasing the gross load from 123.5 pounds to 150.0 pounds (21.5 percent) slightly increased the trims (fig. 12) and shifted the limits for stable positions of the center of gravity forward approximately 1.5 percent mean aerodynamic chord (fig. 13). This shift in stable position of the center of gravity is consistent with that obtained in reference 1.

Trim tracks, obtained at rates of acceleration of 1.0 and 3.0 feet per second per second, are presented in figure 14. Within the accuracy of the test, acceleration did not change the stable trim tracks, which may be seen in figure 15. As would be expected, when porpoising occurred, a greater number of oscillations were encountered at the low acceleration. An increase in acceleration from 1.0 to 3.0 feet per second per second increased the range of stable position of the center of gravity approximately 1 percent mean aerodynamic chord. This increase is in agreement with that obtained for model 228, reference 1.

Landing stability.- The landing behavior of the model is presented as a landing record showing the variation of trim, rise, and forward speed with time for typical landings at trims from 3° to 14° (fig. 16). A summary of these data is presented in figure 17 as a plot of the number of skips (main step leaves the water) and maximum and minimum trim and rise of the model at the greatest amplitude of oscillation against trim at first contact. The maximum obtainable trim with full-up elevators was 8° at a center-of-gravity position of 22 percent mean aerodynamic chord and 11° at 30 percent mean aerodynamic chord; landings above these trim angles, however, were made by holding the trim at the desired angle by means of a trim brake. Some rotation resulted at impact because of the unbalanced aerodynamic moment, but the results did not appear to be materially affected.

In general, the landings were free from skipping except at trims below 6°, where one skip was encountered at an aft center-of-gravity position (34 percent M.A.C.). At contact trims above 10°, porpoising occurred during the landing runout at all center-of-gravity positions. The amplitude of oscillation in both trim and rise was at a minimum at a contact trim of about 8°.

The landing behavior was generally similar to that of model 228G-1 (reference 1), although at low trims the landings of model 246 were more stable than those of model 228G-1. This difference in behavior was principally attributed to the difference in landing technique used in the two investigations. A trim brake, which held a constant landing trim, enabled model 246 to be landed with approximately zero angular velocity at the instant of contact with the water. An appreciable angular velocity at the initial contact usually occurred for model 228G-1, as the model would change trim as it approached the water because of the inherent aerodynamic stability and the ground effect. The change in trim was too rapid to be corrected by use of the elevators. On landing at high trims, the behavior of the two models was similar since the trim brake was released when the sternpost contacted the water. It is believed that by use of the trim brake the landing maneuver more nearly simulates that of the full-size airplane.

Spray characteristics.- The range of speed over which spray entered the propellers and struck the flaps is shown in figure 18. Heavy spray from the bow blister entered the propellers and struck the flaps over a small speed range and did not appear to be excessive even at a gross load of 136.0 pounds when compared with that observed for other models of service aircraft at their design gross loads.

Spray photographs are presented in figure 19 for three values of gross load. At a gross load of 110.0 pounds it will be noted that the spray is clear of the propellers at all speeds. At a gross load of 123.5 pounds and above, considerable spray was drawn up into the propellers over a small speed range. In figure 20, envelopes of the peaks of the main spray blisters are shown relative to the model. These peaks cover a range of speed up to that at which the spray enters the propeller, after which the slipstream causes the spray blister to lose its identity as a solid sheet of water.

Observations of take-off runs showed that light spray from the forebody blister wetted the tail surface at speeds above 20 feet per second. During the landing runout, however, heavy spray struck the horizontal tail surfaces.

CONCLUSIONS

The results of the tank investigation of the powered dynamic model of the XP5Y-1 flying boat indicated that:

1. Stable take-offs were possible at all practicable positions of the center of gravity and flap deflections. An increase in gross load from 123.5 pounds to 150.0 pounds (21.5 percent) had only a slight effect on the stable range for take-off. A decrease in forward acceleration from 3.0 to 1.0 feet per second per second had only a very small effect on the stable range for take-off.

2. In general, the landings were free from skipping except at trims below 6° where one skip was encountered at an aft position of the center of gravity. When landed at trims above 10°, the model porpoised during the landing runout at all positions of the center of gravity.

3. Spray in the propellers was light at the design gross load, and was not considered excessive at a gross load of 136.0 pounds.

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1. Olson, Roland E., Haar, Marvin I., and Woodward, David R.: Hydrodynamic Characteristics of a $\frac{1}{10}$-Size Powered Dynamic Model of the XP5Y-1 Flying Boat in Smooth Water - Langley Tank Model 228C-1 - TED No. NACA DE309. NACA RM L7E28, Bur. Aero., 1947.

2. Truscott, Starr: The Enlarged N.A.C.A. Tank and Some of Its Work. NACA TM 918, 1939.

TABLE I

DIMENSIONS OF BASIC MODEL 246

Hull:	
Maximum beam, in.	12.0
Length:	
Forebody, bow to centroid of main step, in.	69.60
Length–beam ratio	5.80
Afterbody, centroid of main step to sternpost, in.	50.40
Length–beam ratio	4.20
Tail extension, sternpost to aft perpendicular, in.	33.5
Over–all, bow to aft perpendicular, in.	153.5
Forebody flat, beams from centroid	$\frac{2}{3}$
Depth of step, (30°–vee):	
At keel, in.	1.95
At keel, percent beam	16.2
At centroid, in.	1.7
At centroid, percent beam	14.2
Step location at centroid, percent M.A.C.	31.3
Angle of forebody keel to base line, deg	0
Angle of afterbody keel to base line, deg	5.5
Angle of dead rise of forebody, at step (excluding chine flare), deg	22.5
Angle of dead rise of afterbody, deg	22.5
Height of center of gravity above base line, in.	17.6
Wing:	
Area, sq ft	21.0
Span, ft	14.5
Root chord, in.	26.1
Tip chord, in.	8.7
Angle of wing incidence to base line, deg	5.0
Mean aerodynamic chord (M.A.C.), in.	18.9
Leading edge aft of bow, in.	60.8
Leading edge M.A.C., aft of bow, in.	63.7
Leading edge M.A.C., above base line, in.	22.5
Aspect ratio	10.0
Flaps:	
Deflection for take–off, deg	20
Deflection for landing, deg	50 (taped)

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TABLE I – Concluded

DIMENSIONS OF BASIC MODEL 246 – Concluded

Horizontal tail:	
Span, ft	5.5
Chord, in.	17.2
Area, stabilizer, sq ft	3.56
Area, elevator, sq ft	1.53
Total area, sq ft	5.1
Angle of stabilizer setting to base line, deg	0
Dihedral, deg	10
Vertical tail:	
Total area, (with dorsal), sq ft	5.0
Propeller:	
Blades	4
Diameter, in.	18.1
Blade angle (3/4 radius), deg	10
Rpm at full power	5800
Angle of thrust line to base line, deg	2.0
Normal gross load, lb	123.5

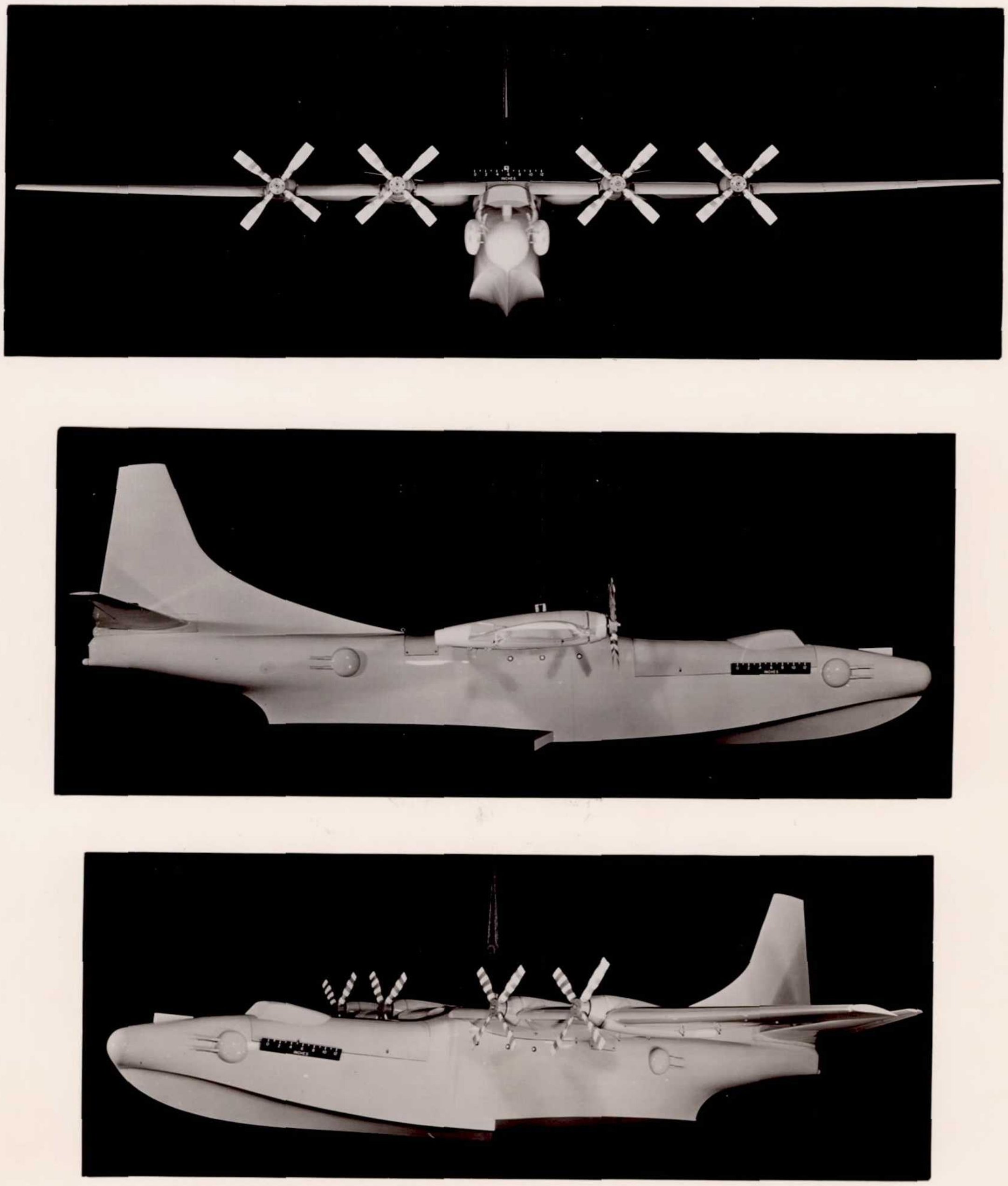

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Figure 1.- Langley tank model 246.

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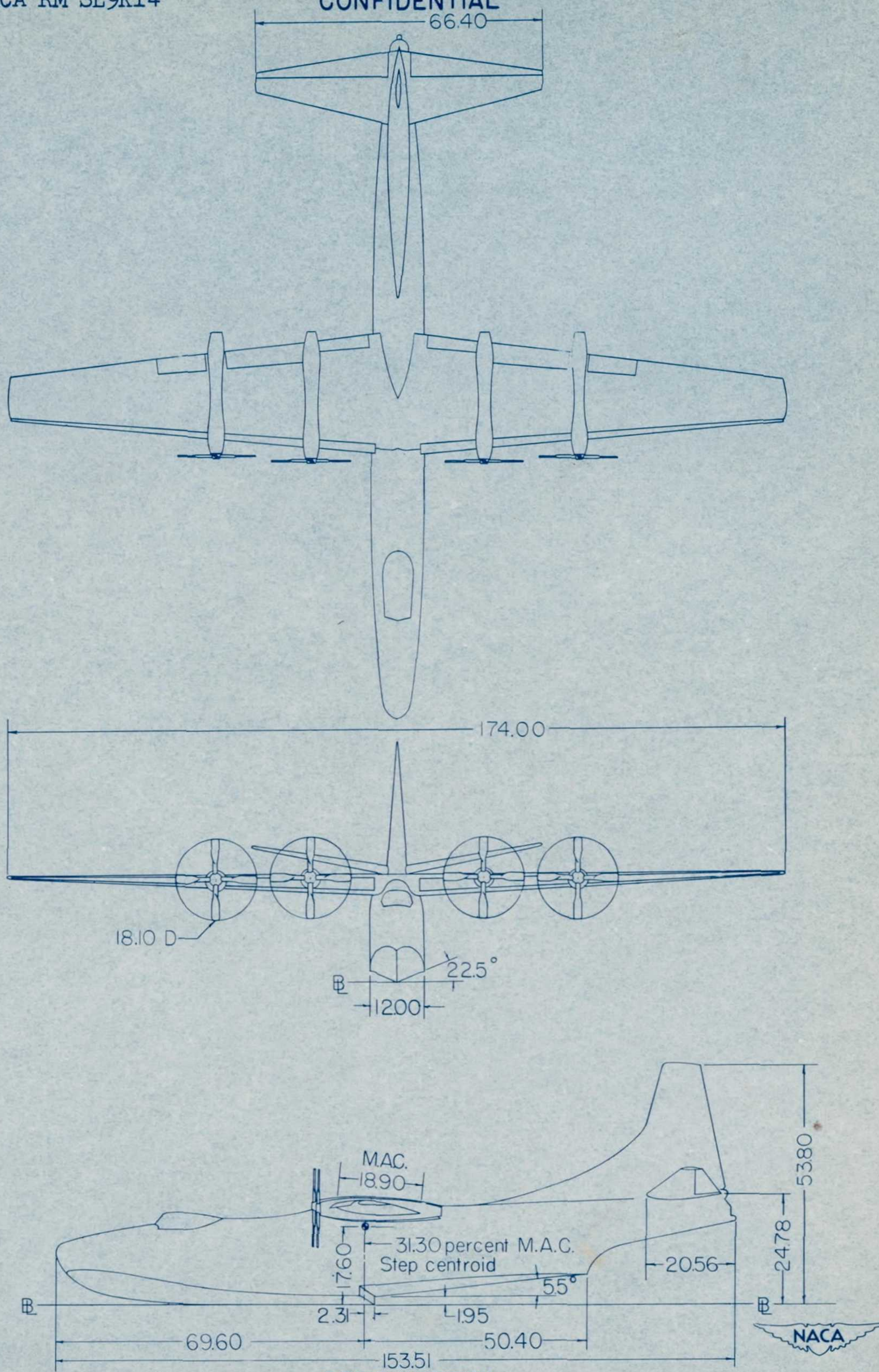

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Figure 2.- General arrangement of Langley tank model 246. (Dimensions are in inches.)

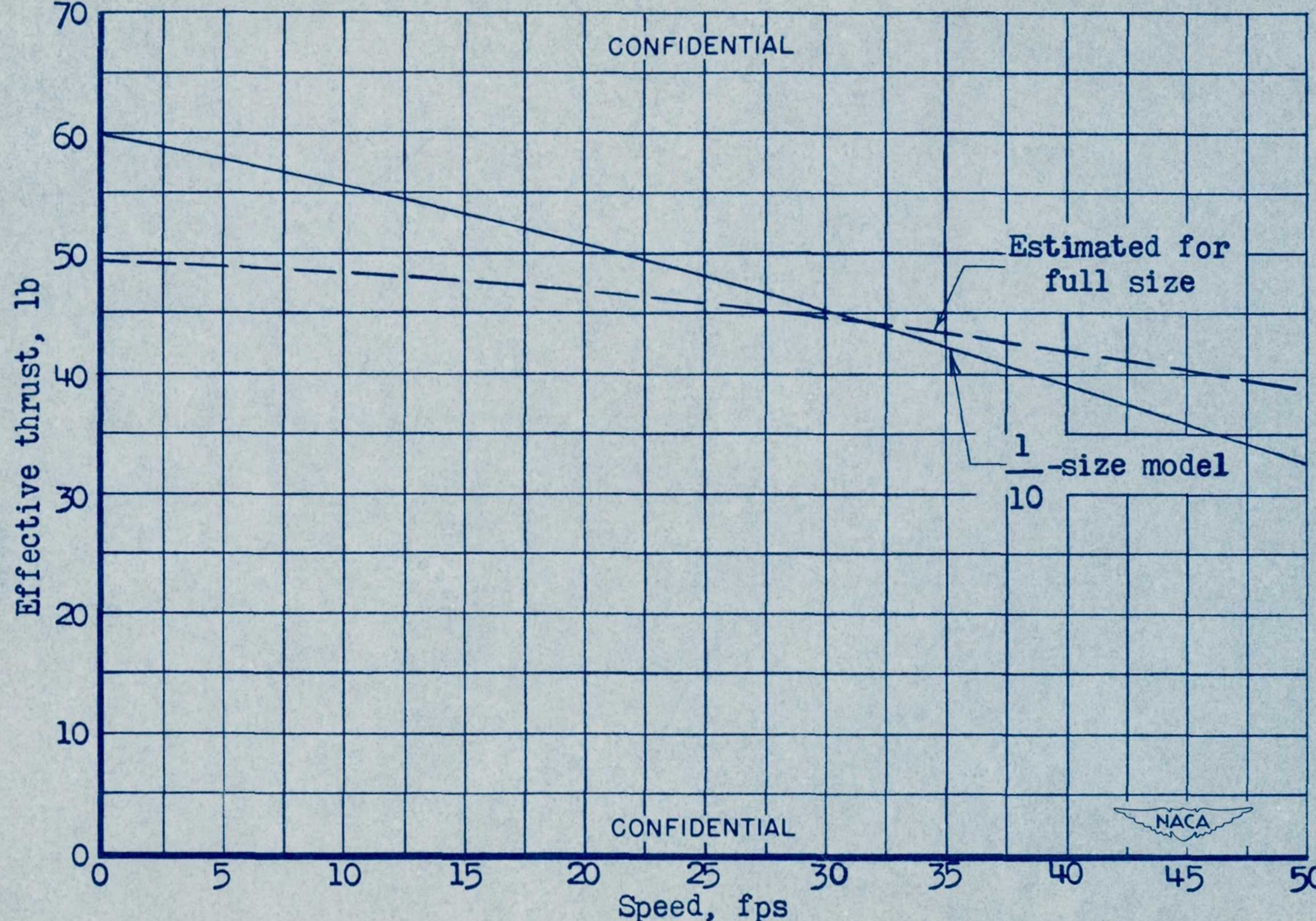


Figure 3.- Variation of effective thrust with speed. Trim, 0°; $\delta_f = 0^{\circ}$; $\delta_e = 0^{\circ}$.

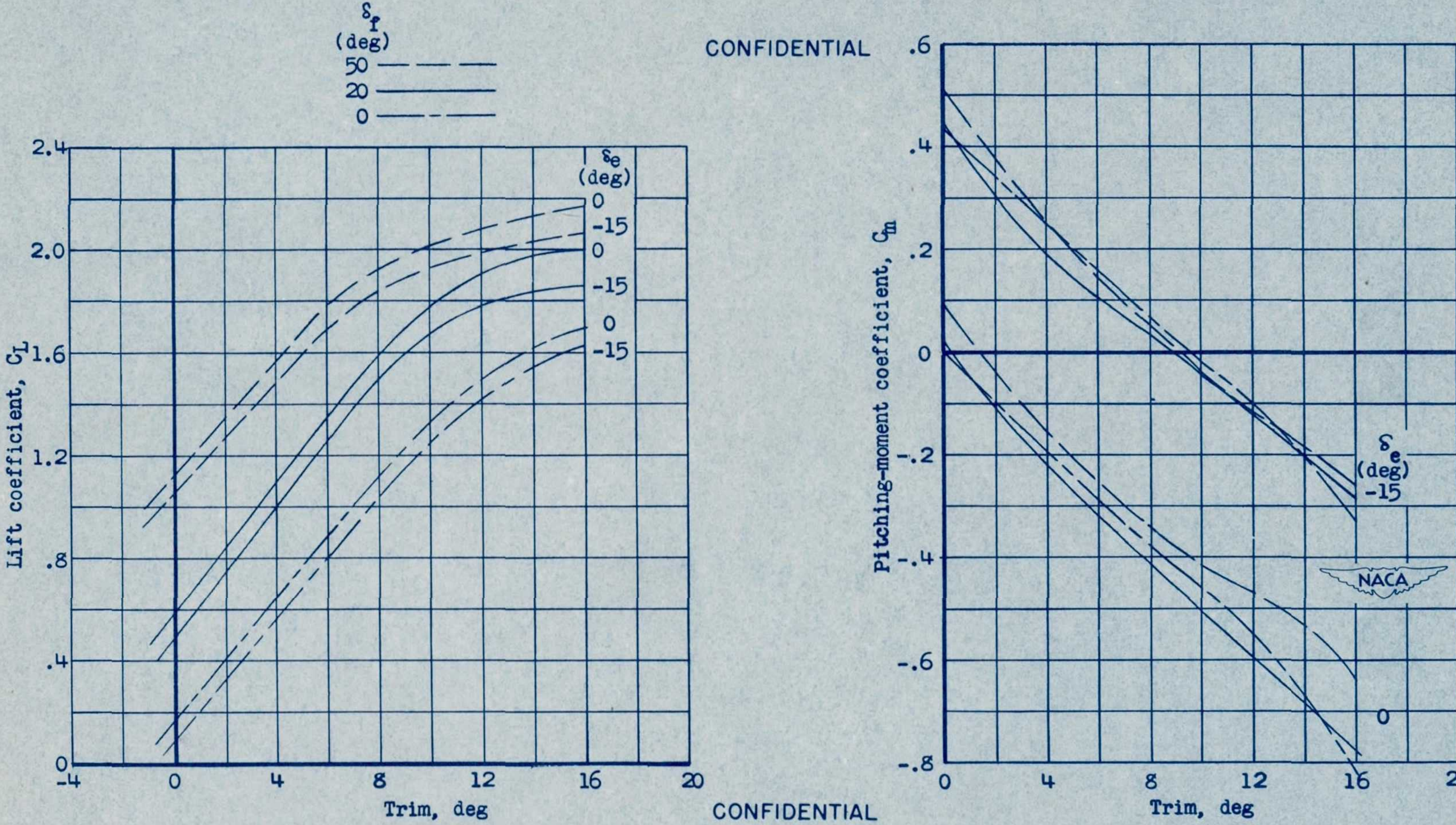
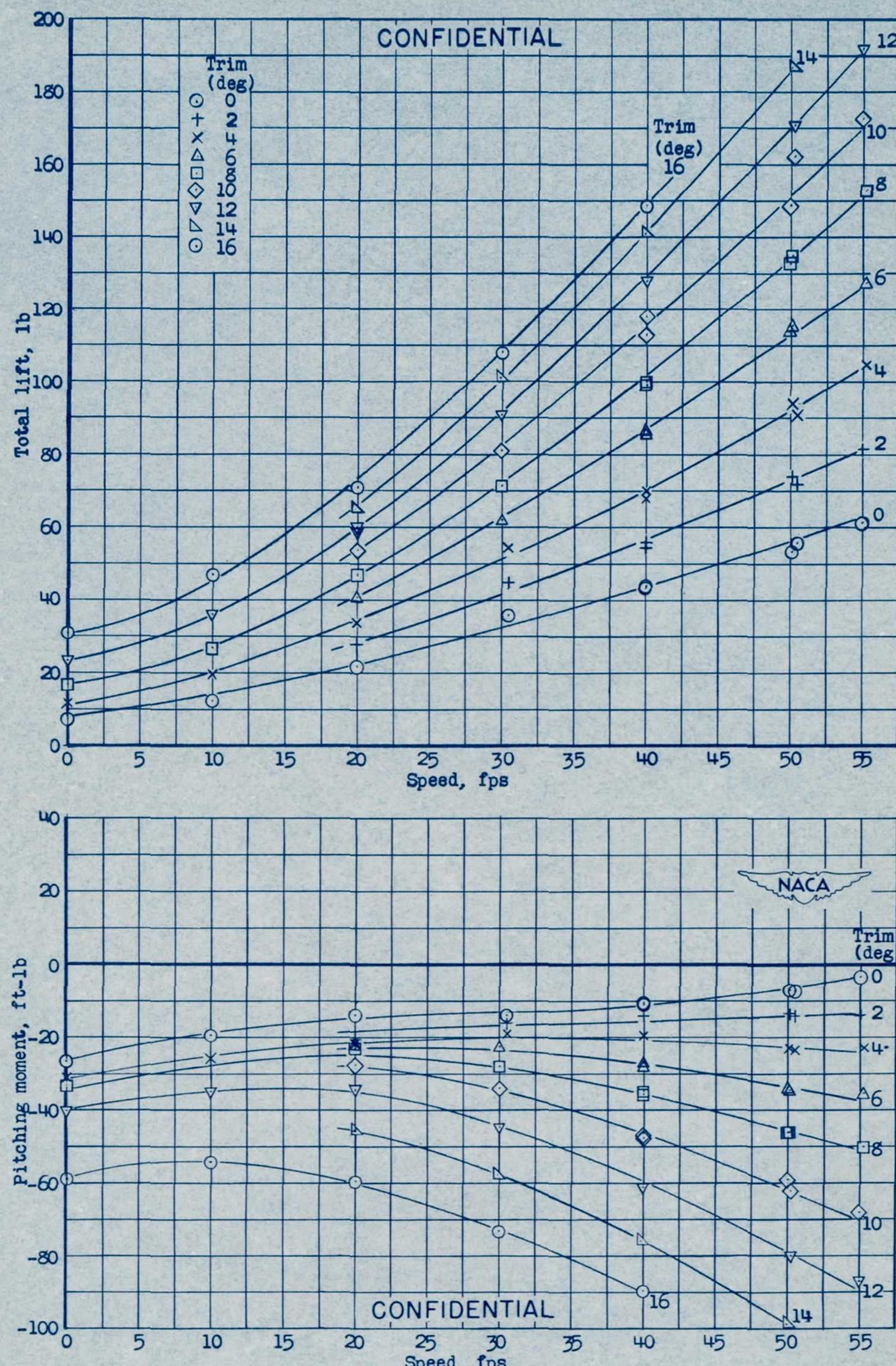
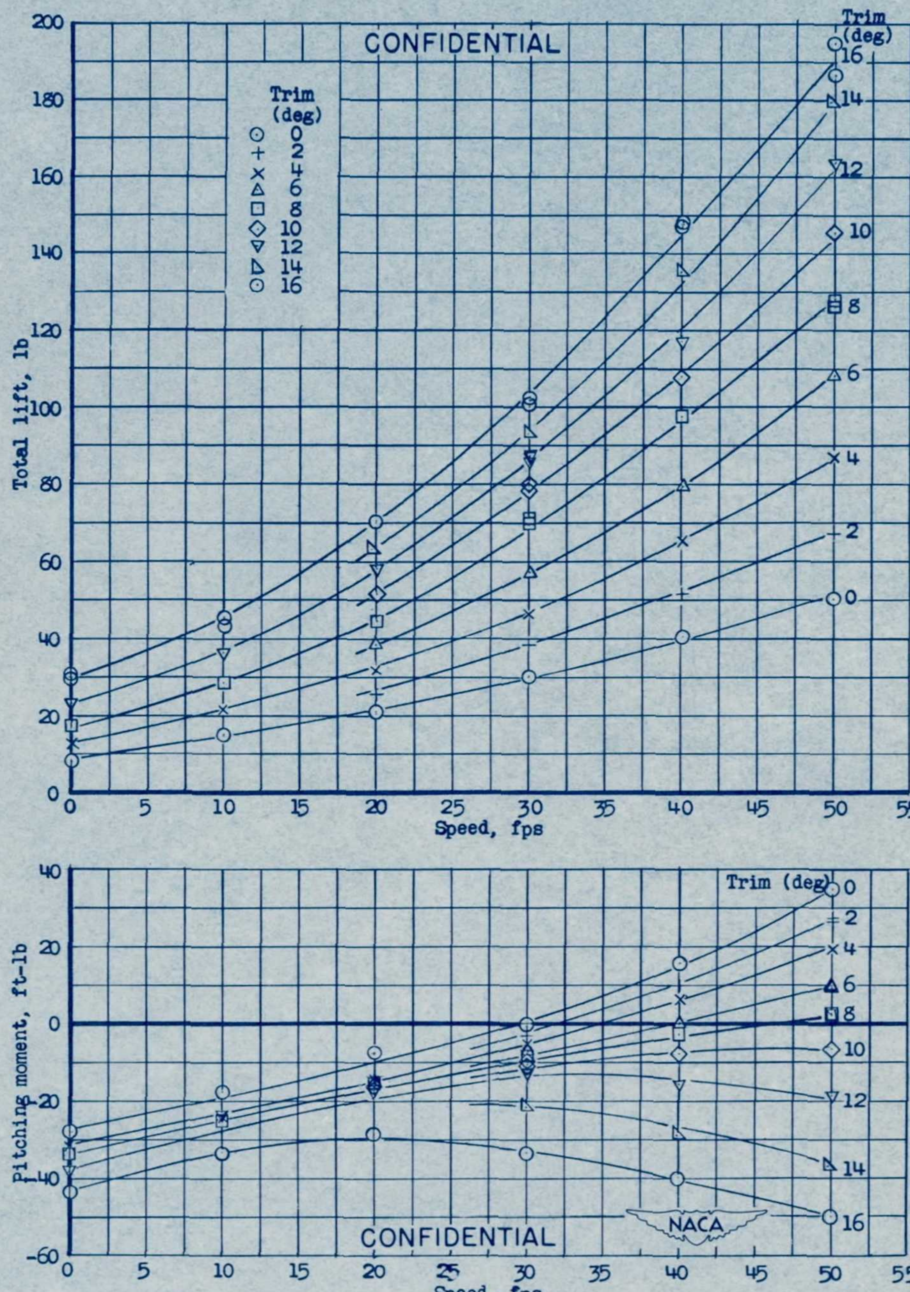


Figure 4.- Aerodynamic lift and pitching-moment coefficients, power off.



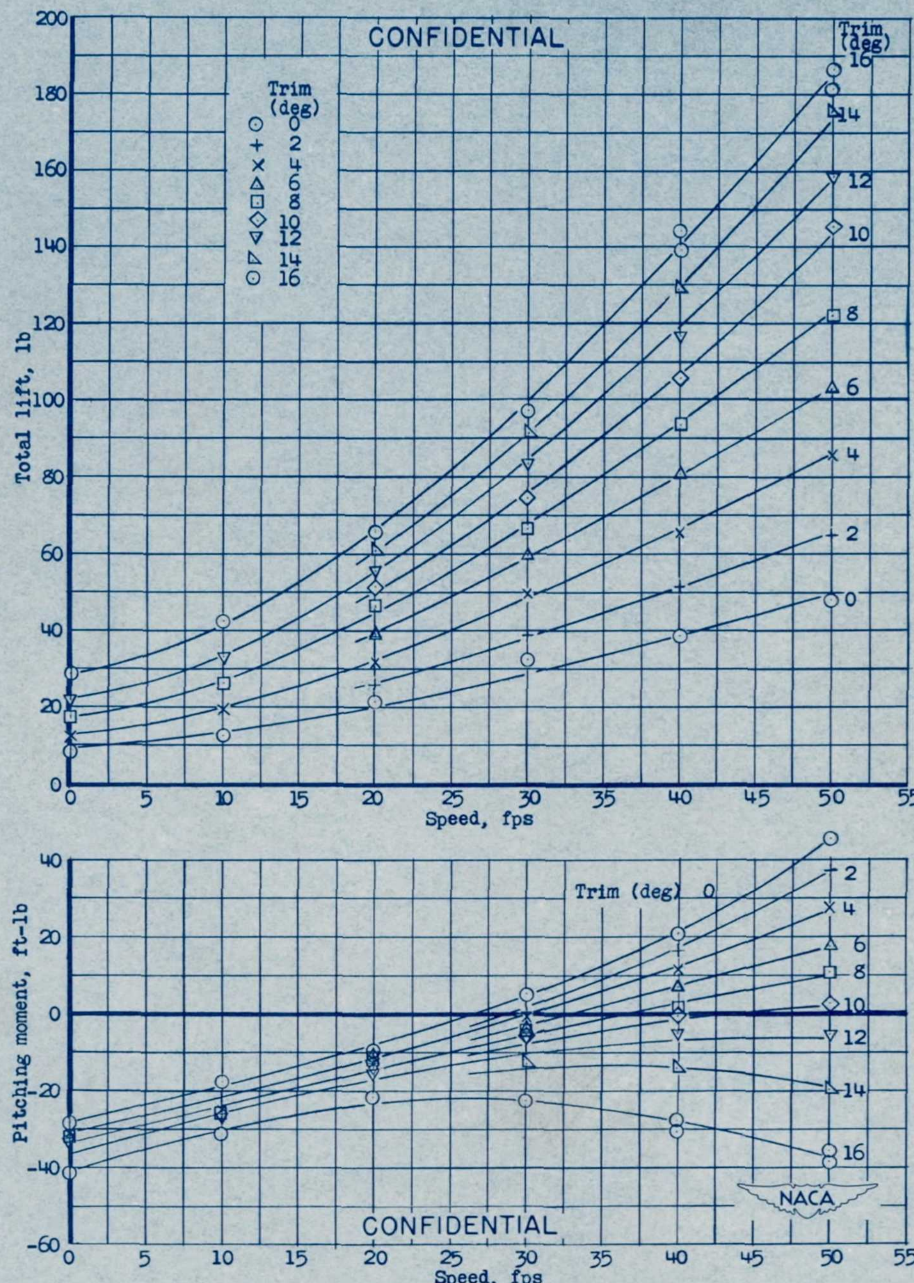
(a) Elevator deflection, 0°.

Figure 5.- Aerodynamic lift and pitching moment. Take-off power; flap deflection, 20°.



(b) Elevator deflection, -15°.

Figure 5.- Continued.



(c) Elevator deflection, -20°.

Figure 5.- Concluded.

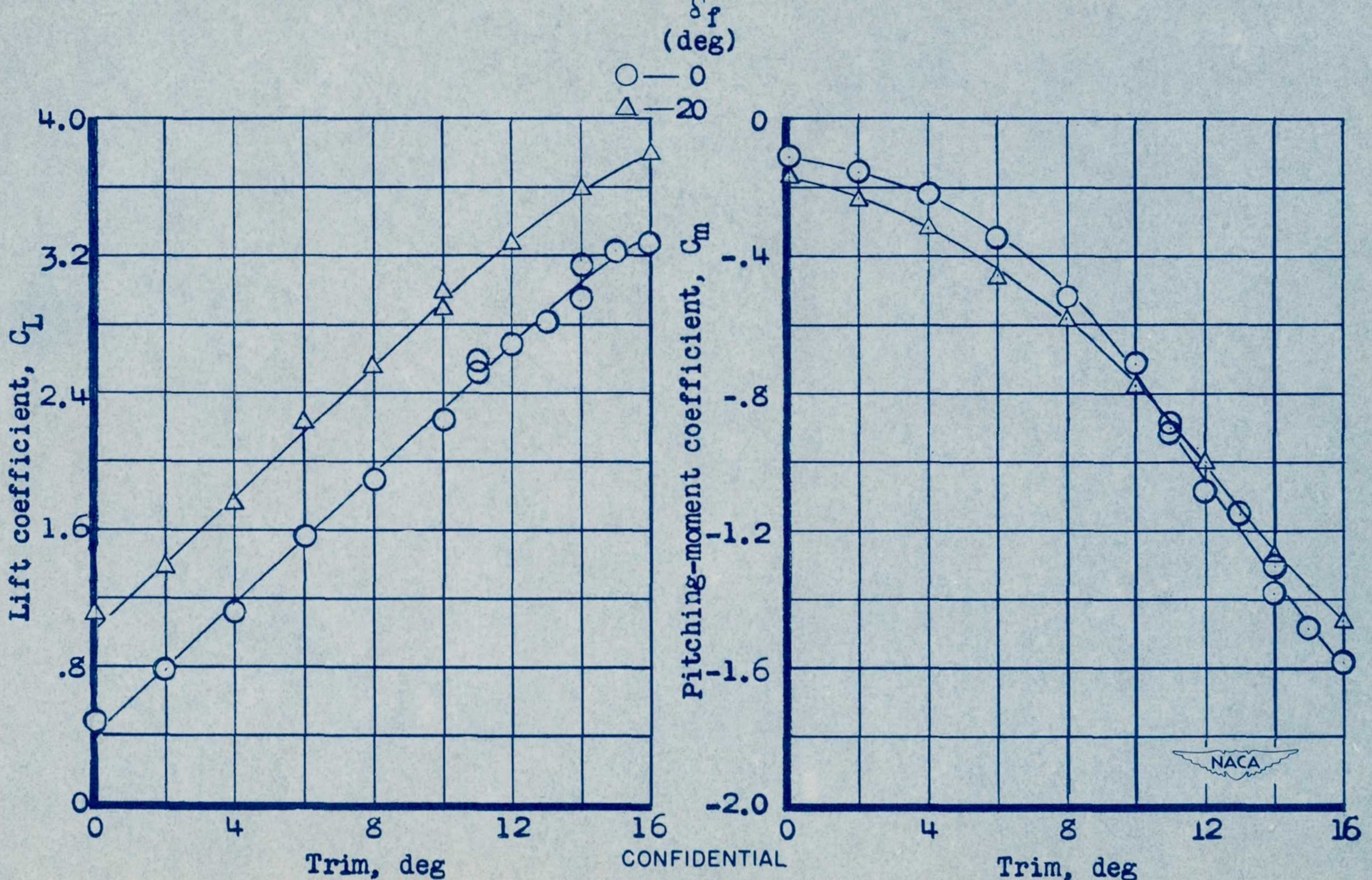


Figure 6.- Aerodynamic lift and pitching-moment coefficients, take-off power. V = 40 fps; $\delta_e = 0^{\circ}$.

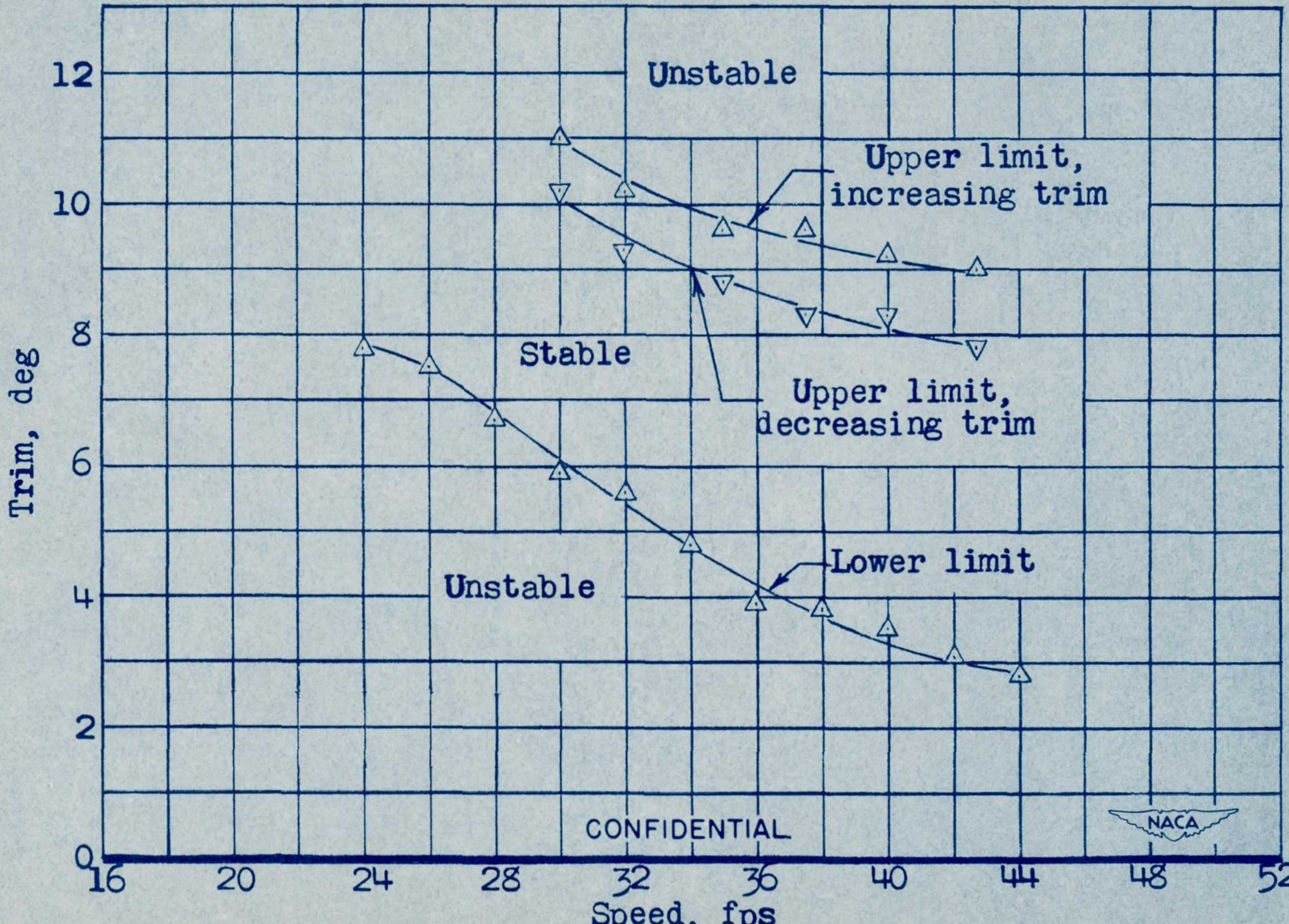
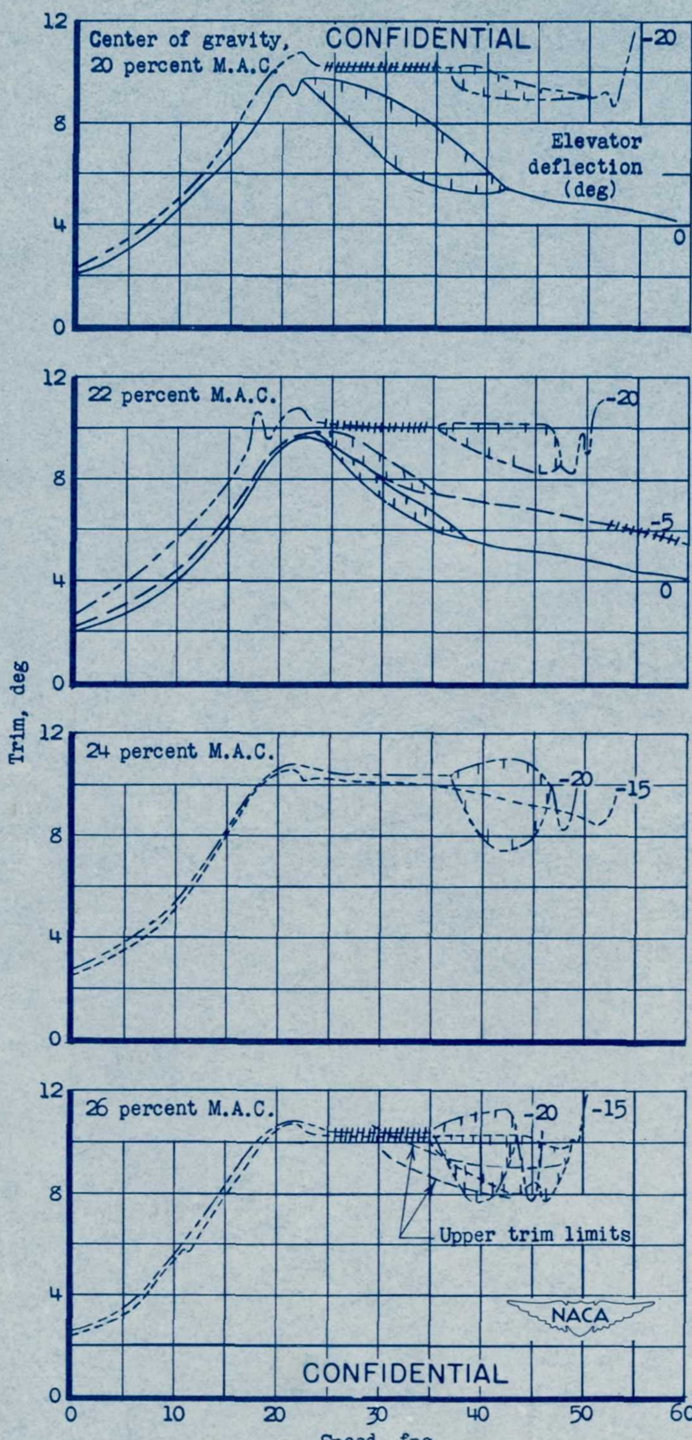
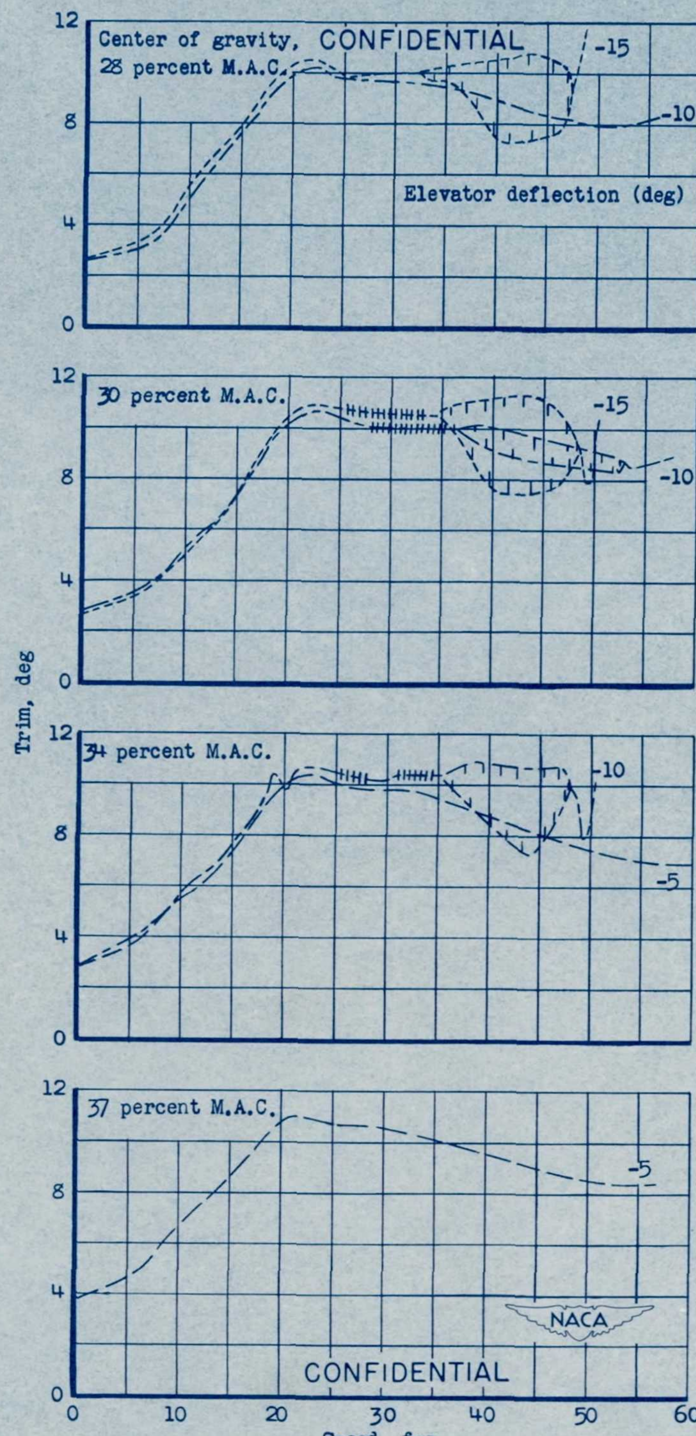


Figure 7.- Trim limits of stability. Gross load, 123.5 pounds; $\delta_f = 20^\circ$.



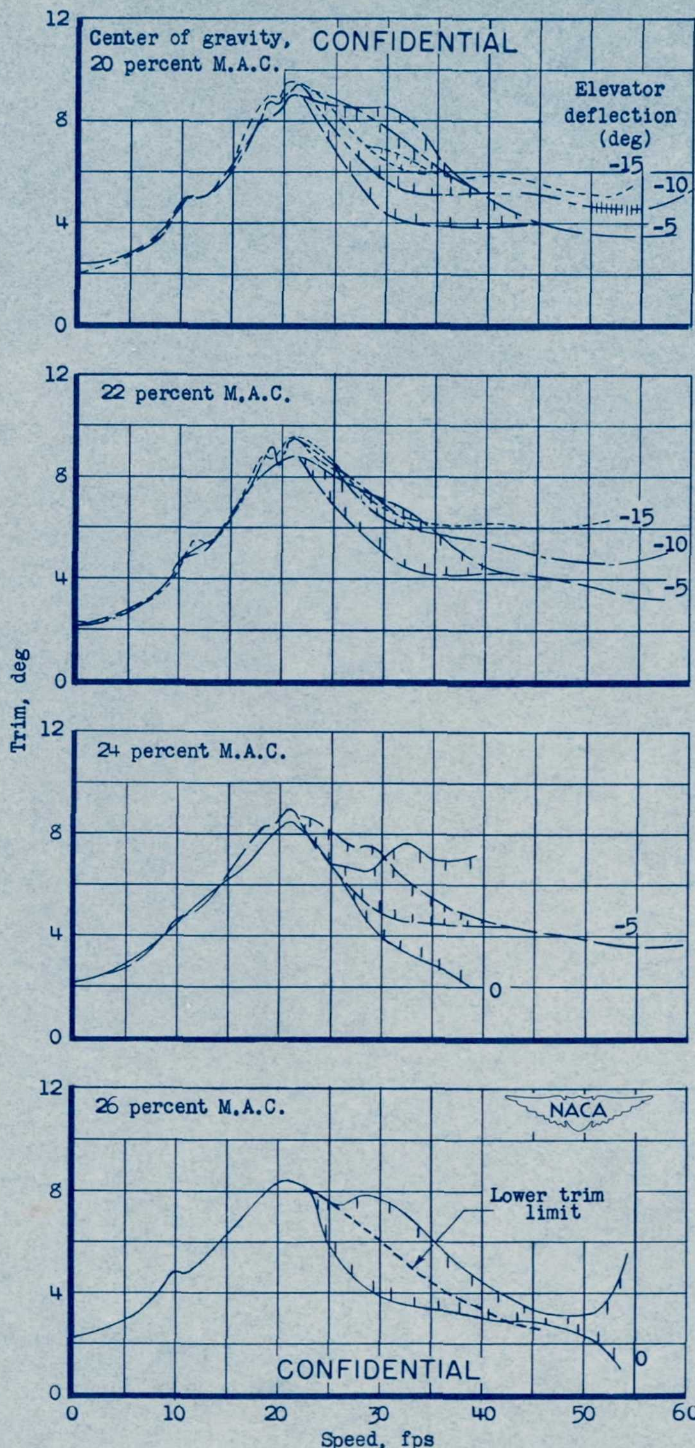
(a) Flap deflection, 0°.

Figure 8.- Variation of trim with speed. Gross load, 123.5 pounds; acceleration, 3.0 feet per second per second.



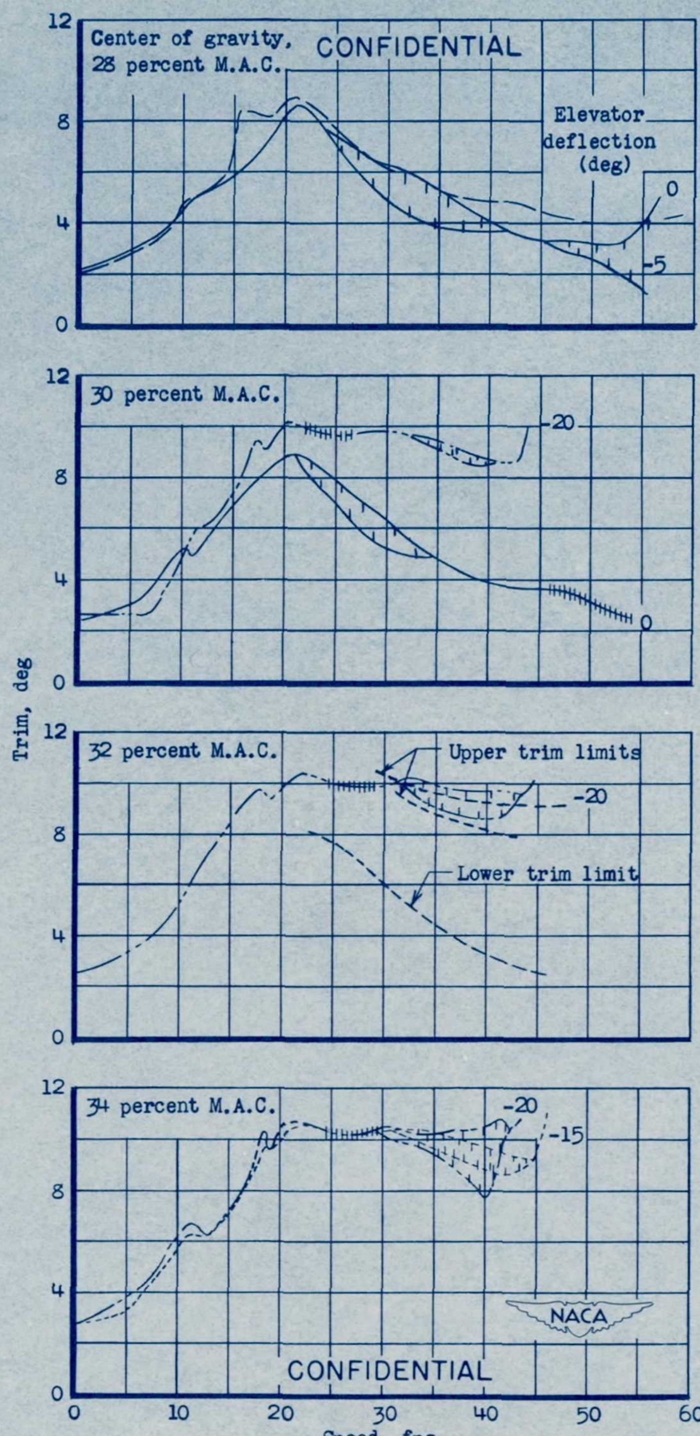
(b) Flap deflection, 0°.

Figure 8.- Concluded.



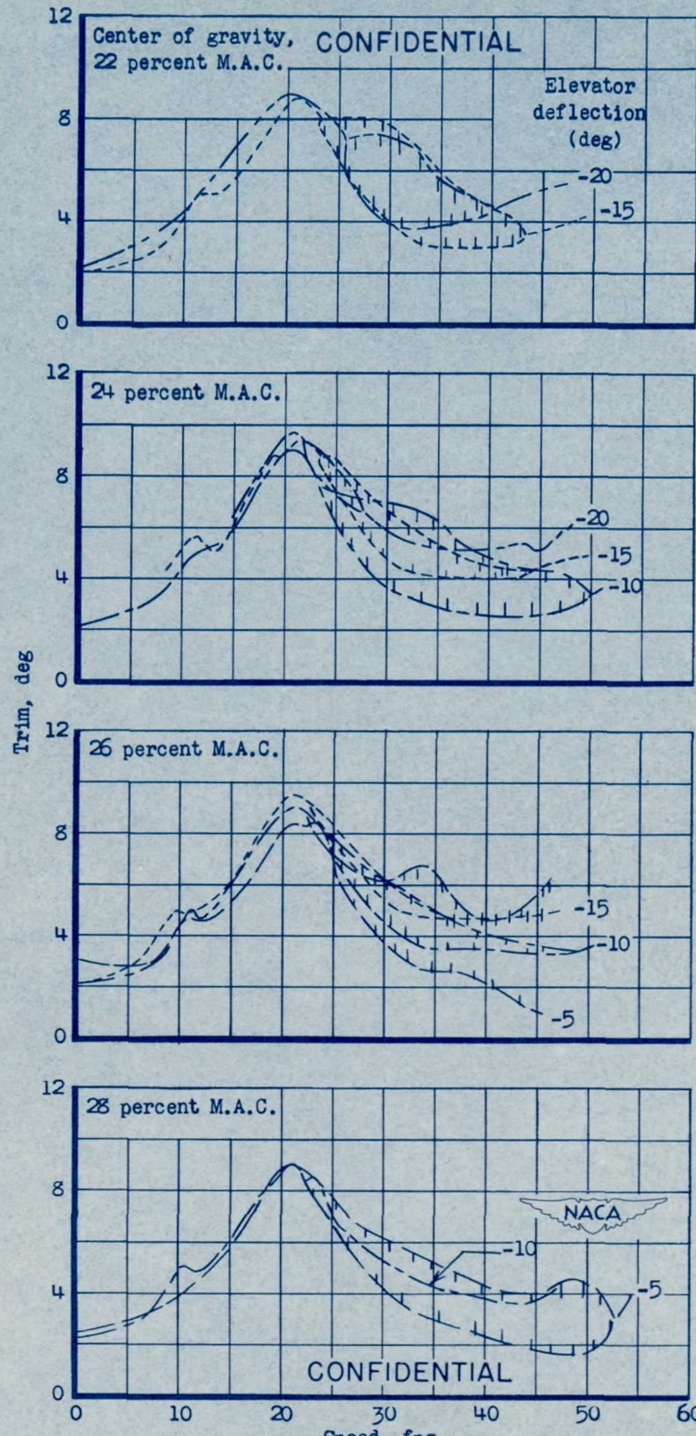
(a) Flap deflection, 20°.

Figure 9.- Variation of trim with speed. Gross load, 123.5 pounds; acceleration, 3.0 feet per second per second.



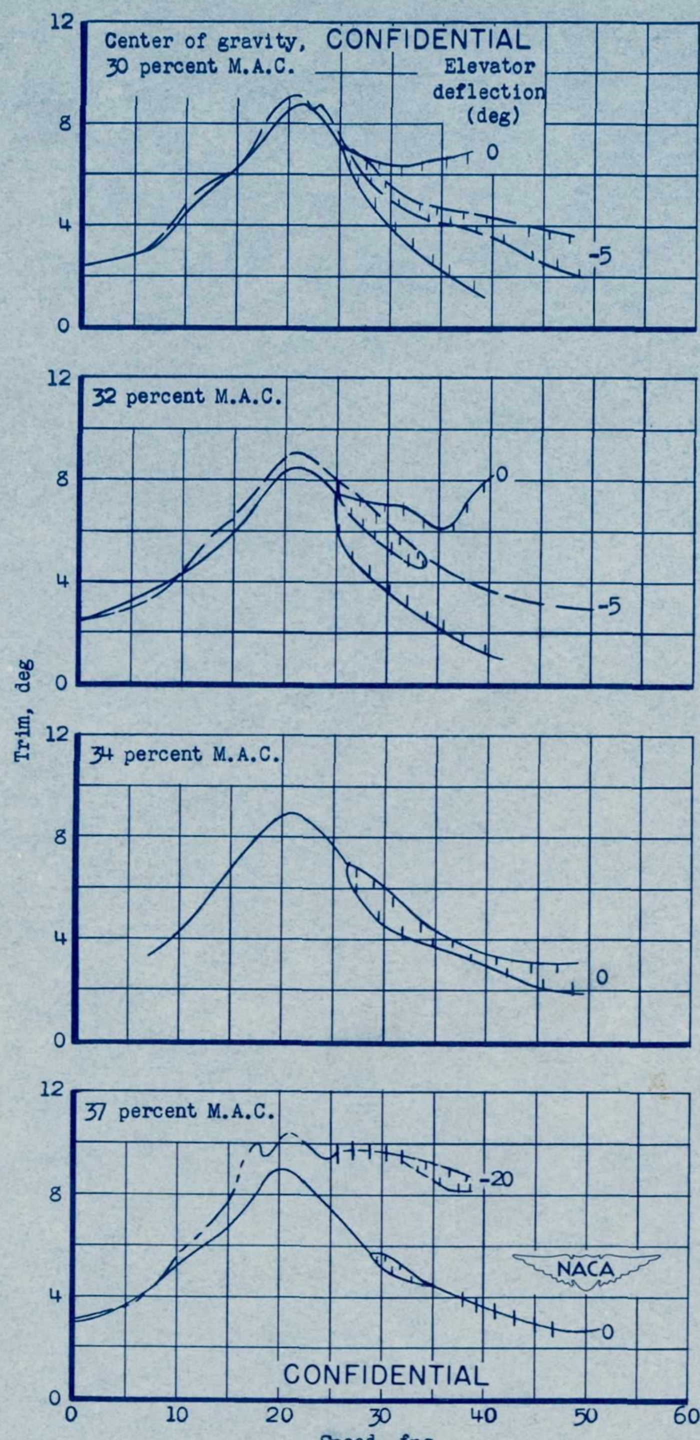
(b) Flap deflection, 20°.

Figure 9.- Concluded.



(a) Flap deflection, 40°.

Figure 10.- Variation of trim with speed. Gross load, 123.5 pounds; acceleration, 3.0 feet per second per second.



(b) Flap deflection, 40°.

Figure 10.- Concluded.

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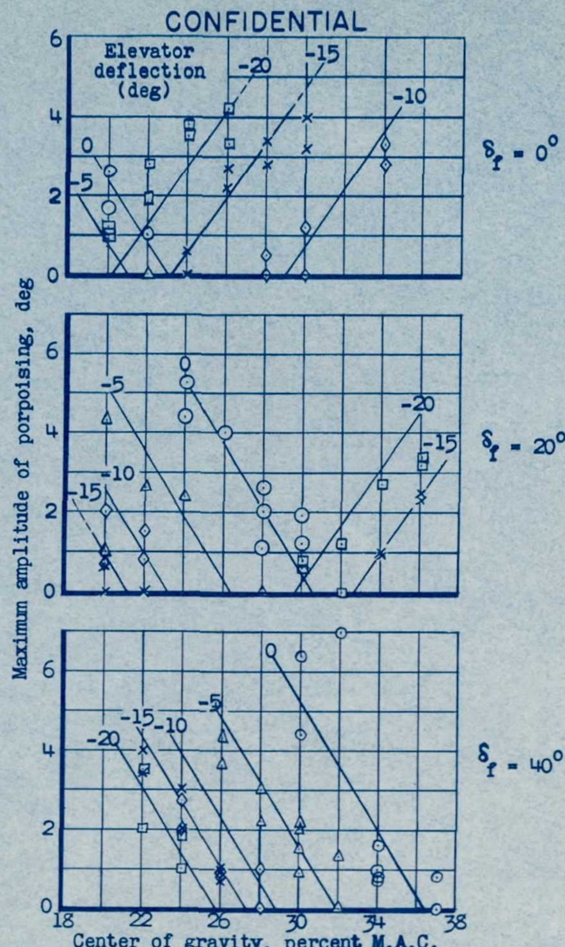
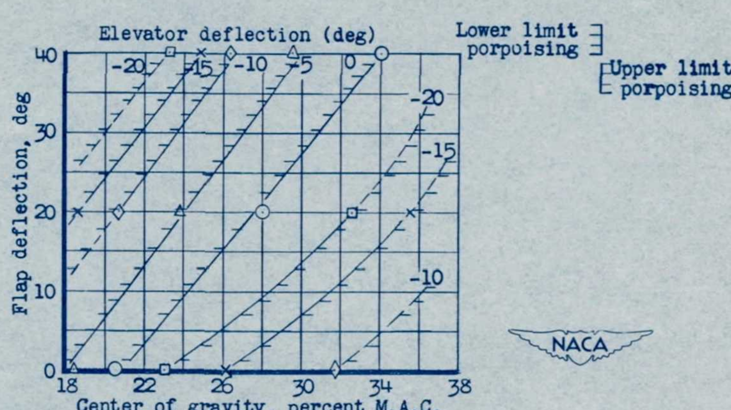


(a) Maximum amplitude of porpoising at different positions of the center of gravity.



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(b) Range of position of the center of gravity for stable take-off. Maximum allowable amplitude of porpoising, 2°.

Figure 11.- Effect of flap deflection on the take-off stability. Gross load, 123.5 pounds; acceleration, 3.0 feet per second per second.

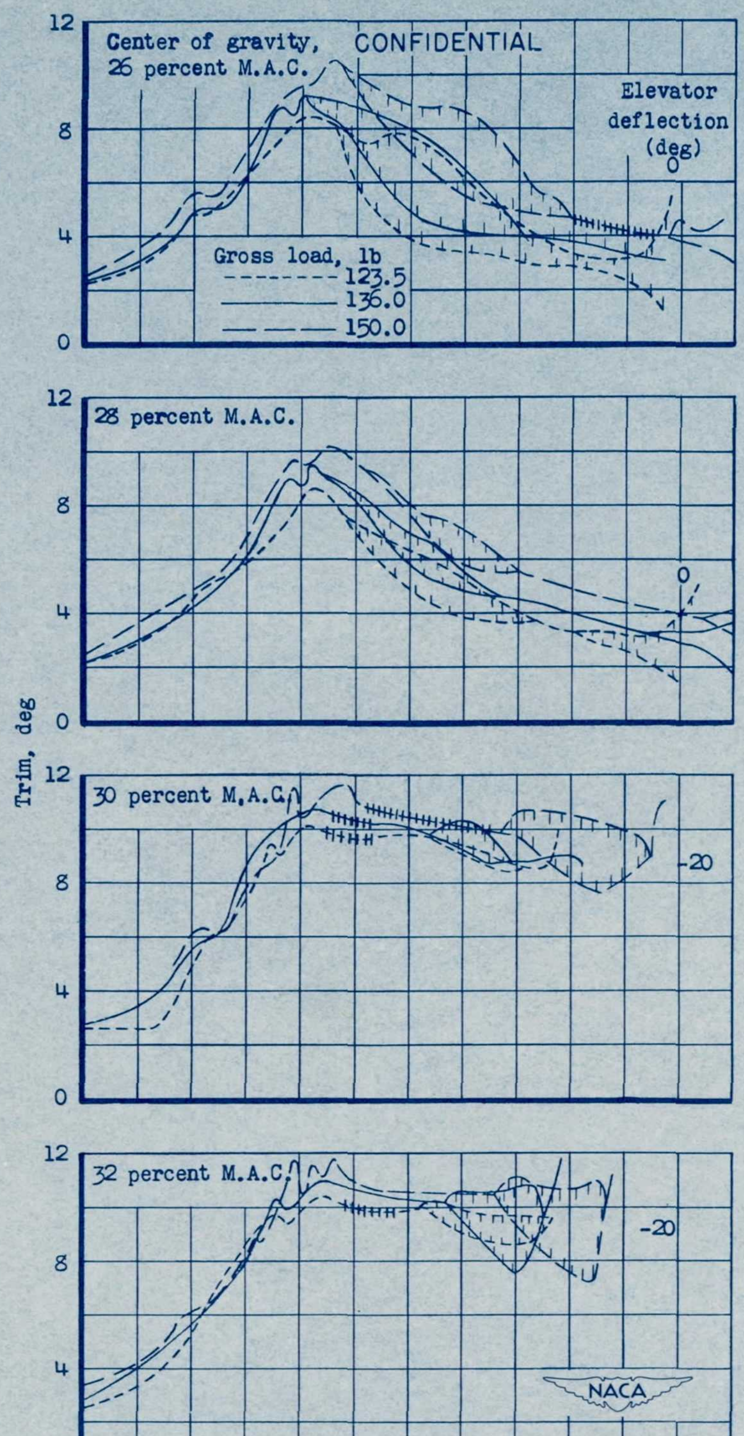

Figure 12.- Variation of trim with speed at three gross loads. $\delta_f = 20^{\circ}$; acceleration, 3.0 feet per second per second.

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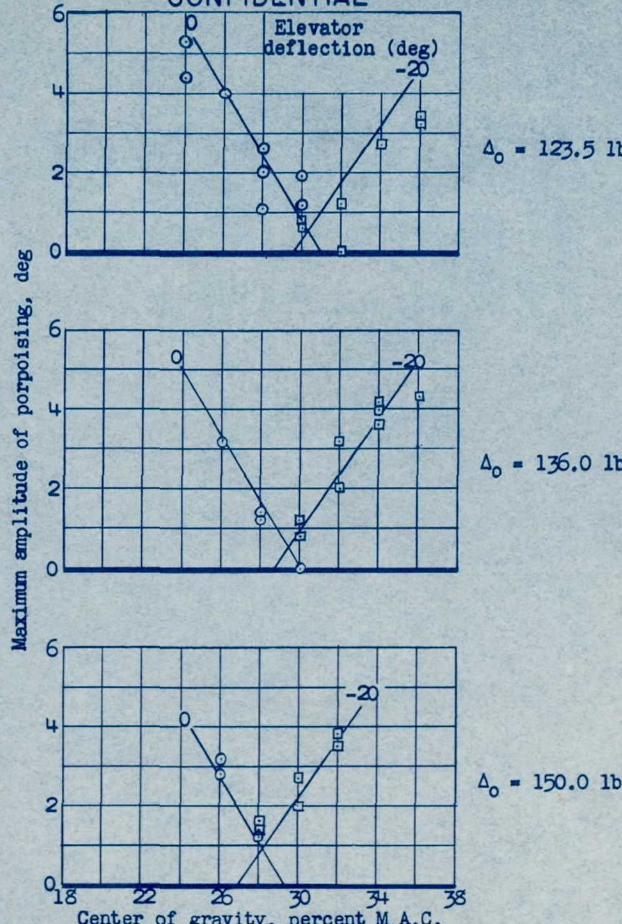
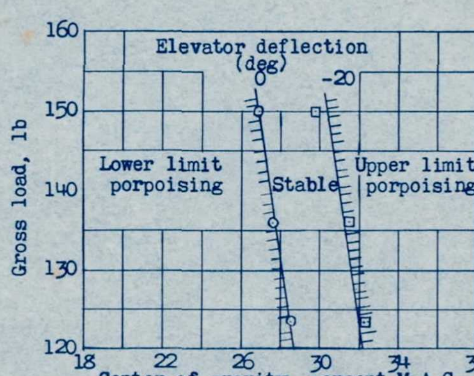


(a) Maximum amplitude of porpoising at different positions of the center of gravity.



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(b) Range of position of the center of gravity for stable take-off. Maximum allowable amplitude of porpoising, 2°.

Figure 13.- Effect of gross load on the take-off stability. $\delta_f = 20^{\circ}$; acceleration, 3.0 feet per second per second.

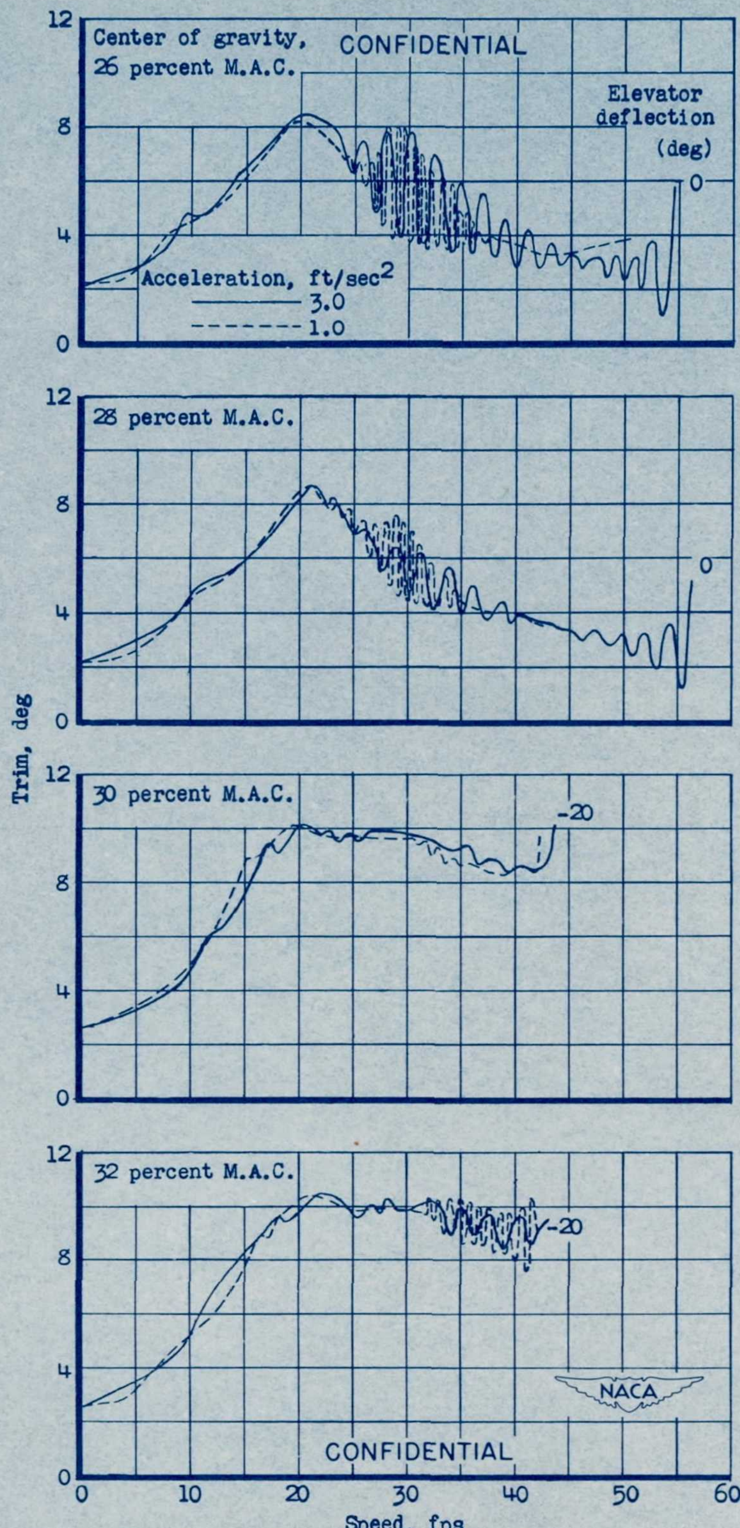

Figure 14.- Variation of trim with speed at two accelerations. Gross load, 123.5 pounds; $\delta_f = 20^\circ$.

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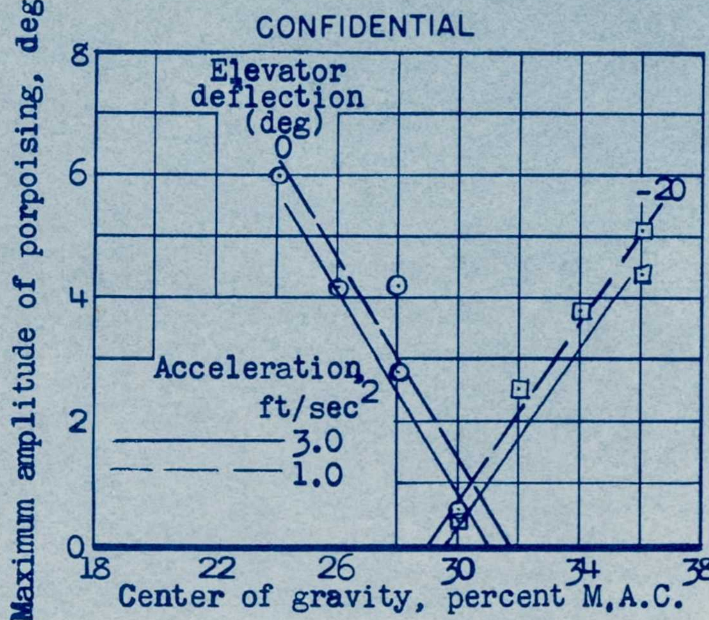
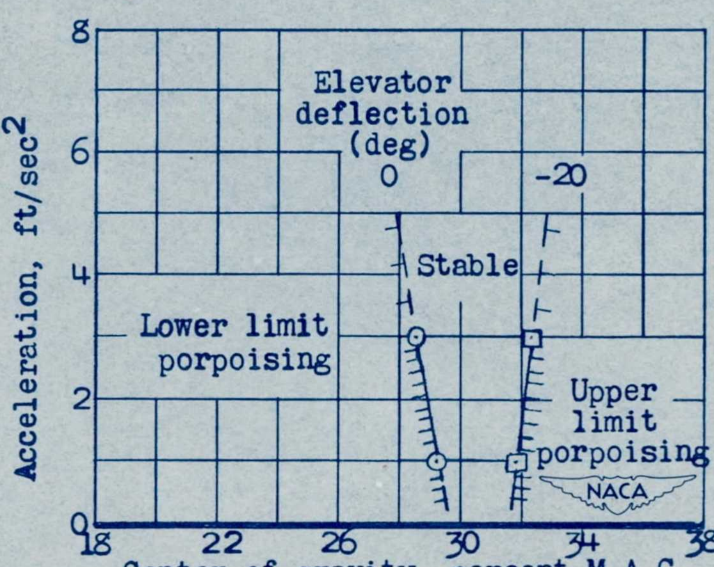


(a) Maximum amplitude of porpoising at different positions of the center of gravity.



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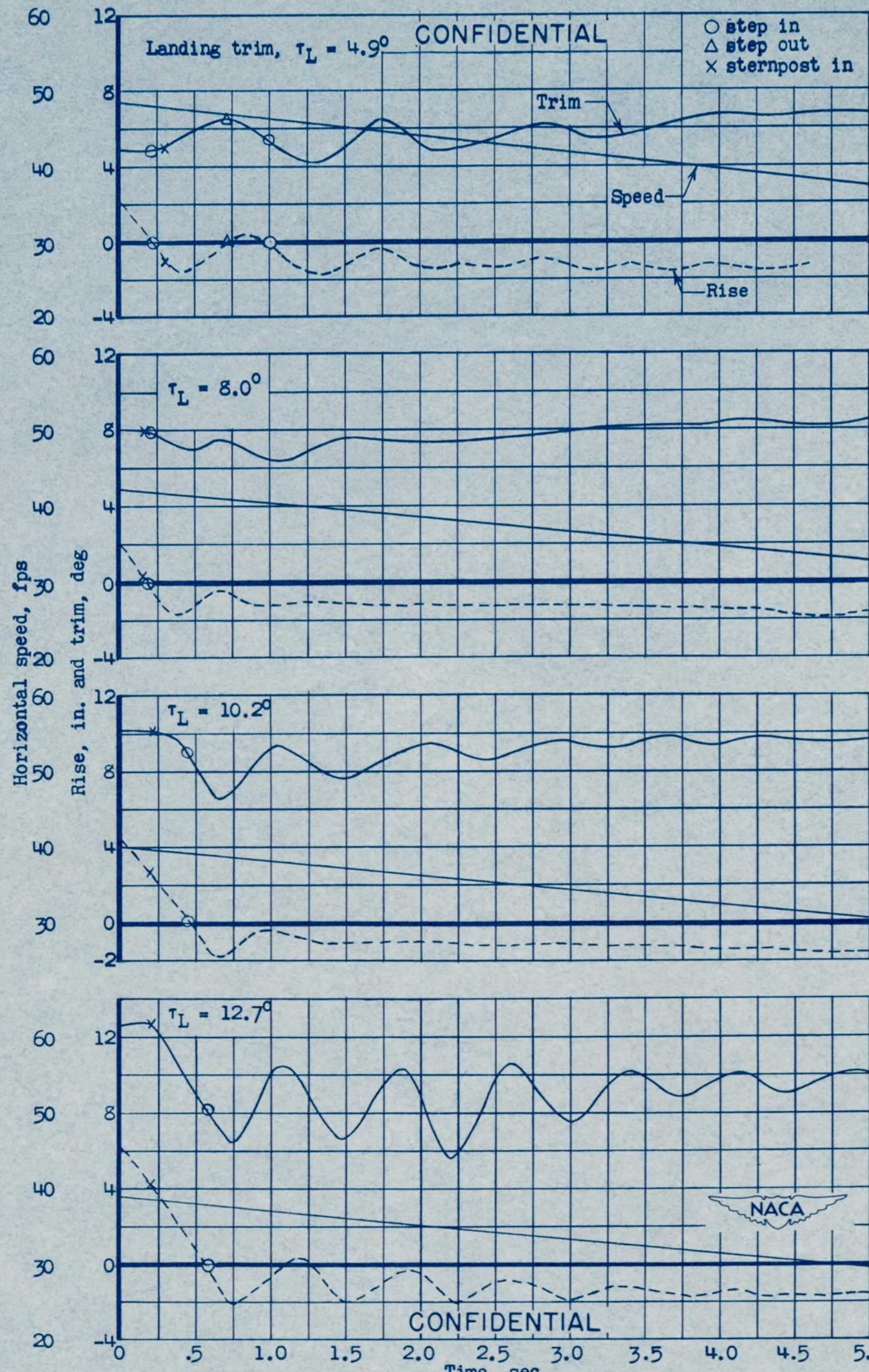
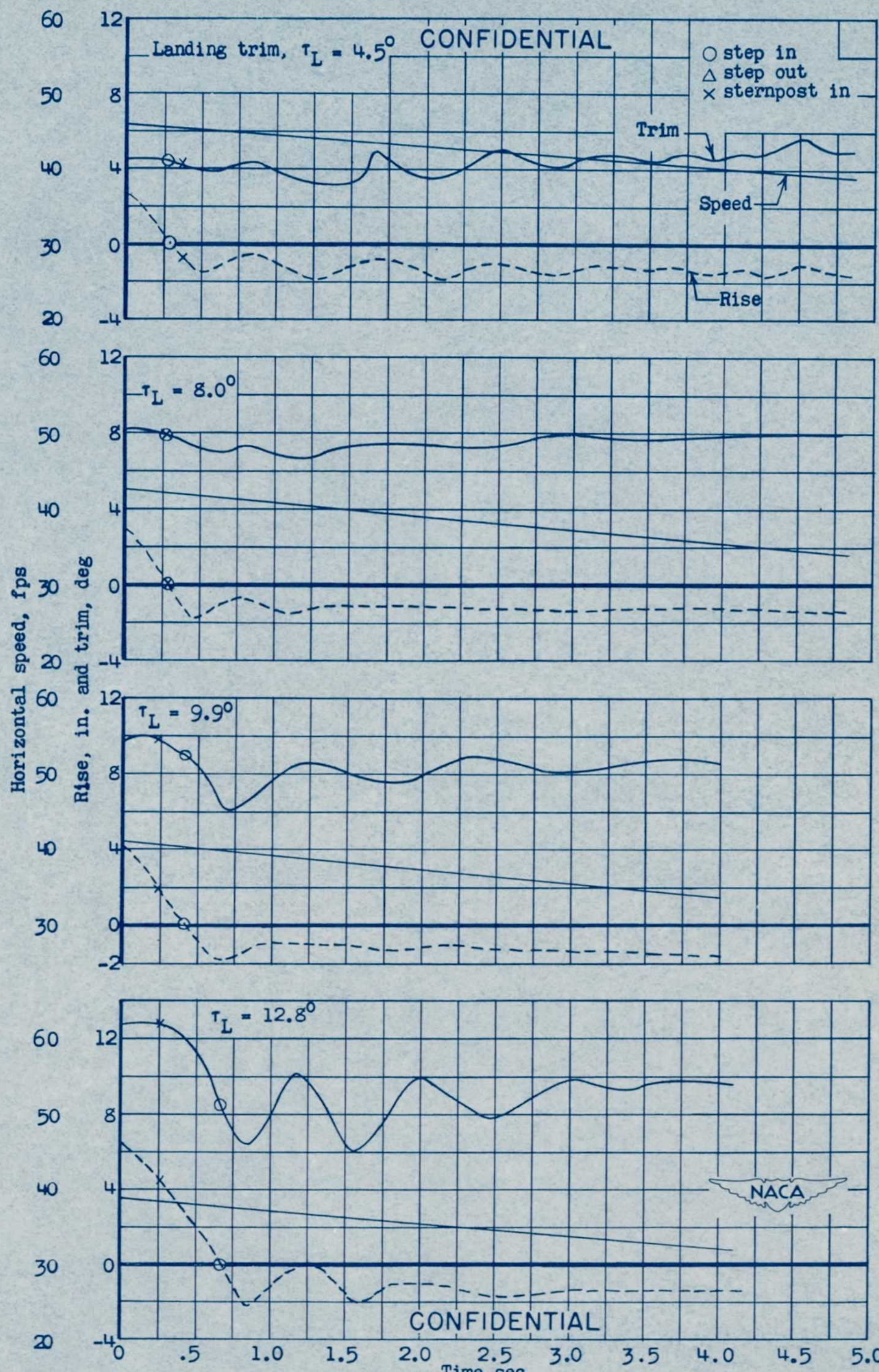
(b) Range of position of the center of gravity for stable take-off. Maximum allowable amplitude of porpoising, 2°.

Figure 15.- Effect of acceleration on the take-off stability. Gross load, 123.5 pounds; $\delta_f = 20^{\circ}$.



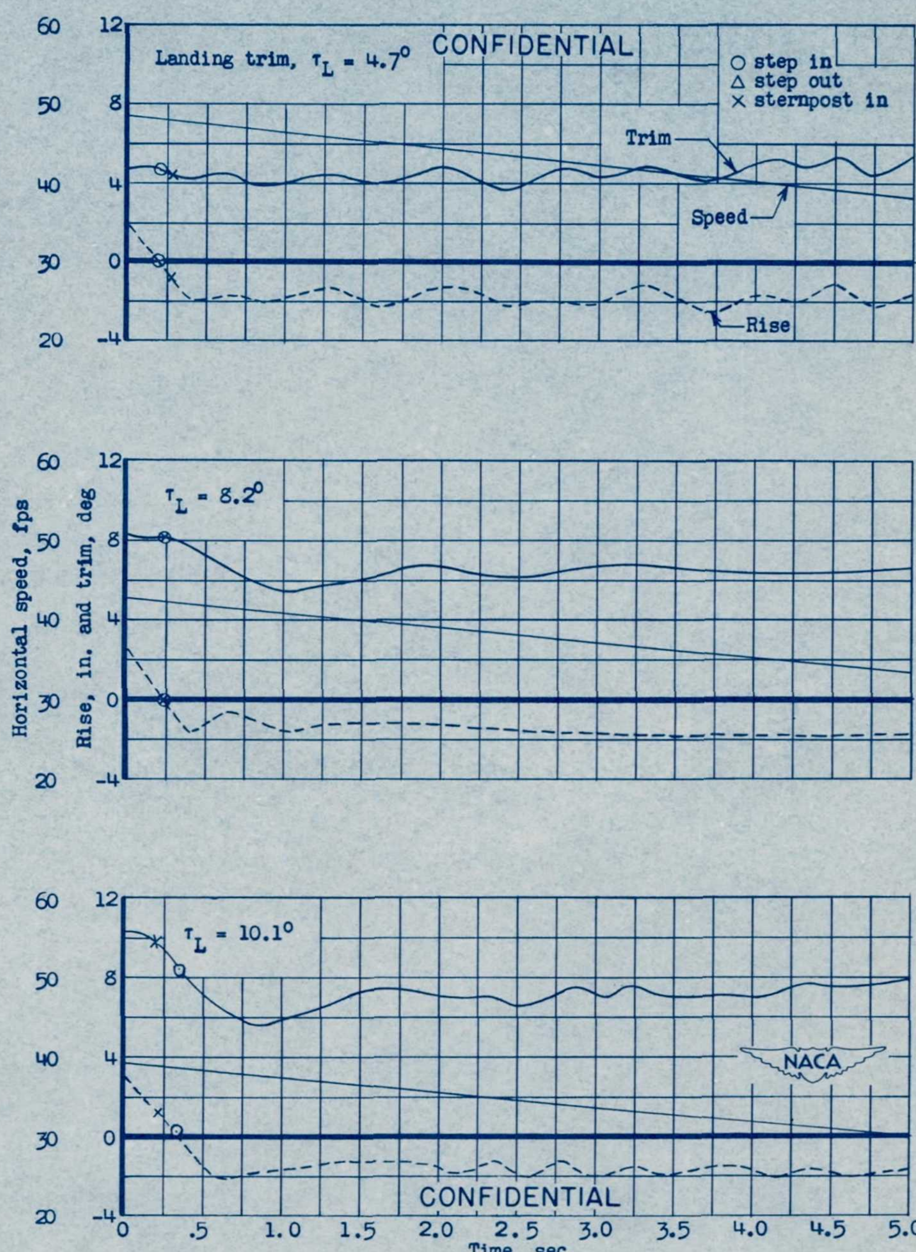
(a) Center of gravity, 34 percent M.A.C.

Figure 16.- Time histories of landings. Gross load, 123.5 pounds; $\delta_f = 50°$.



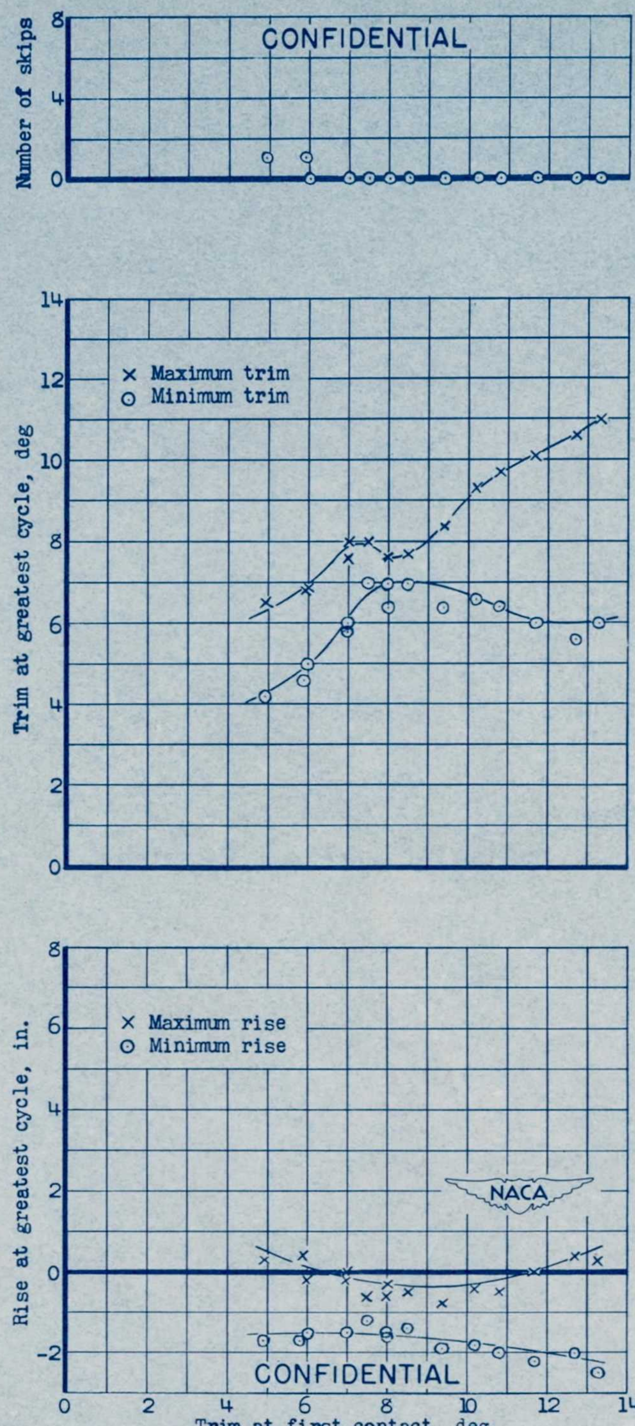
(b) Center of gravity, 30 percent M.A.C.

Figure 16.- Continued.



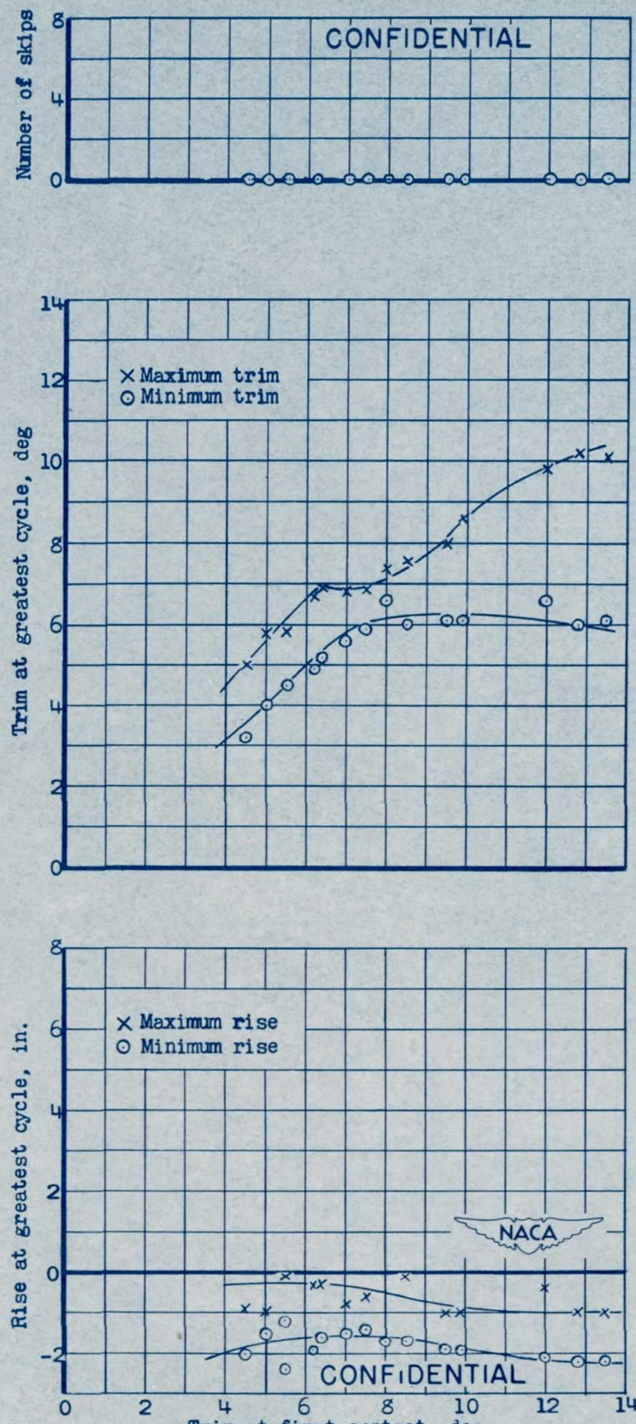
(c) Center of gravity, 22 percent M.A.C.

Figure 16.- Concluded.



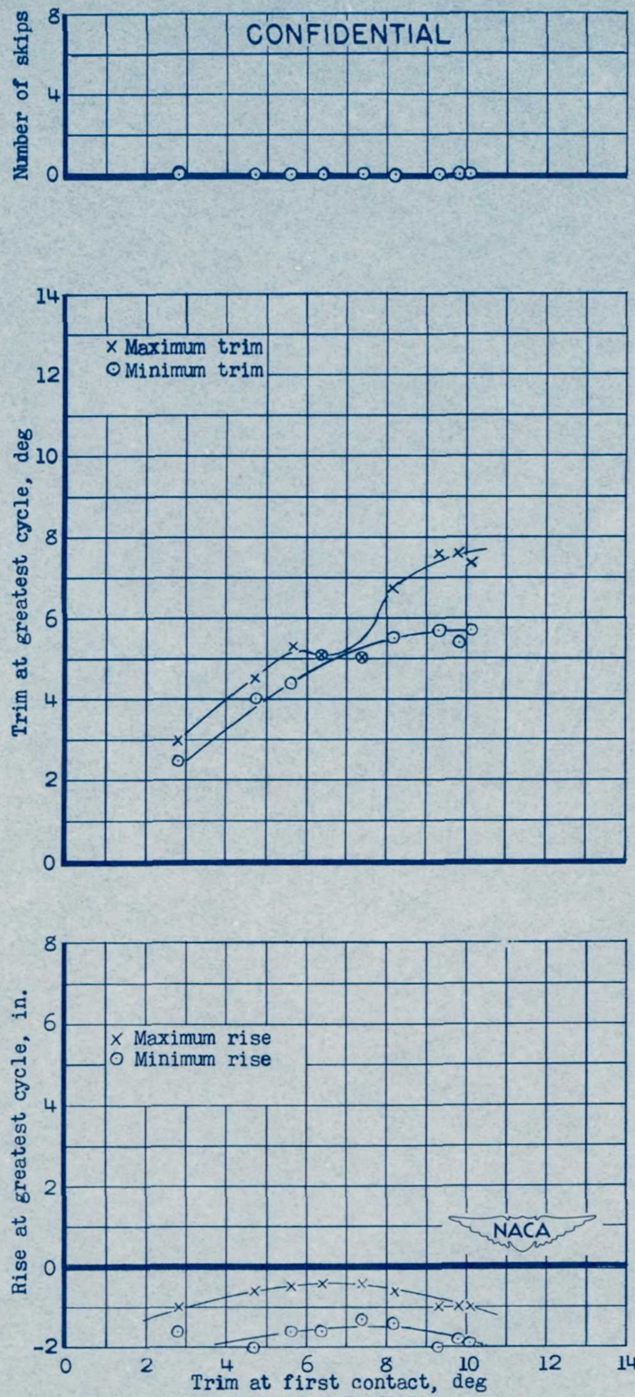
(a) Center of gravity, 34 percent M.A.C.

Figure 17.- Number of skips and maximum and minimum trim and rise during landing. Gross load, 123.5 pounds; $\delta_f = 50^{\circ}$.



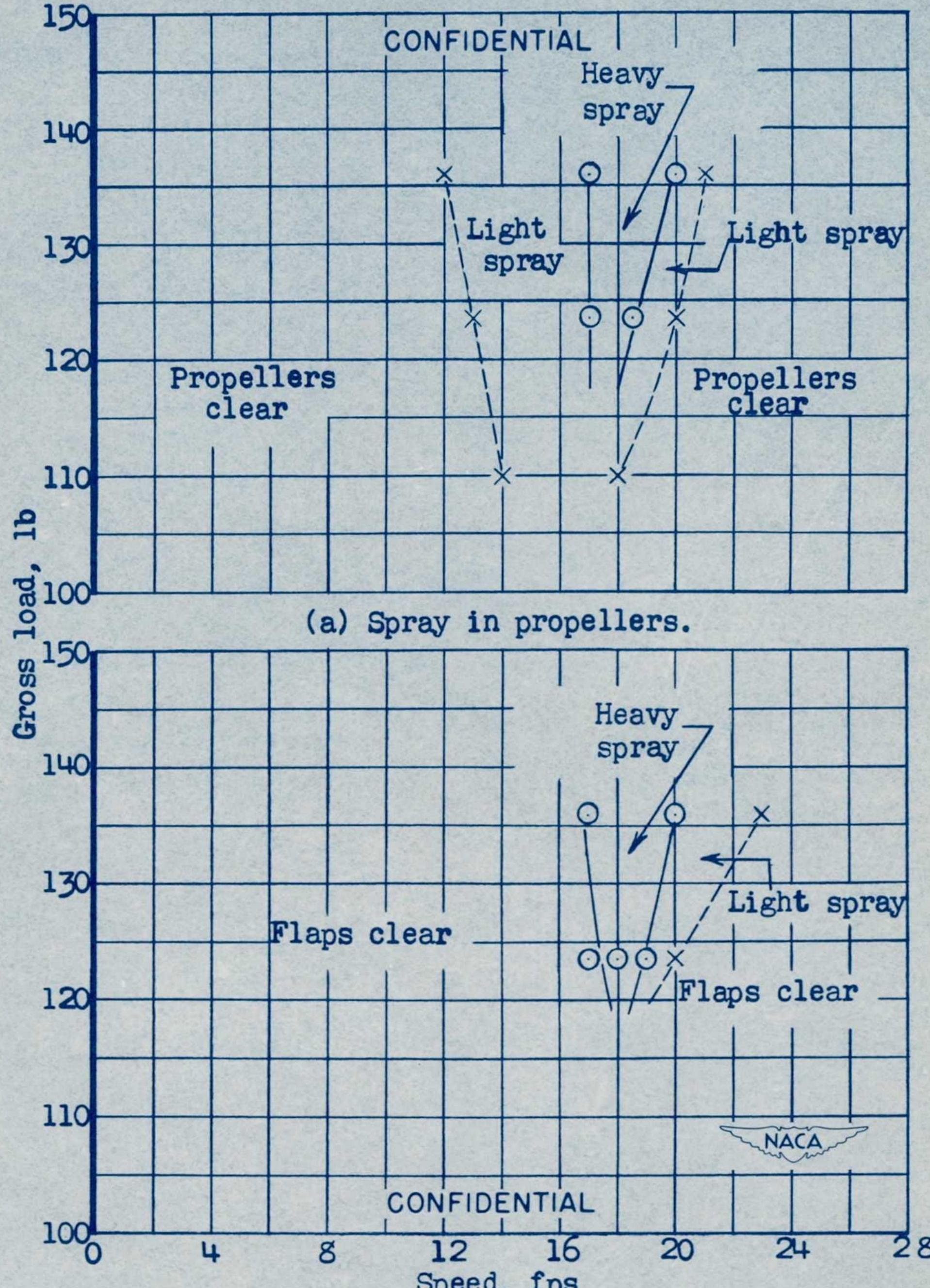
(b) Center of gravity, 30 percent M.A.C.

Figure 17.- Continued.



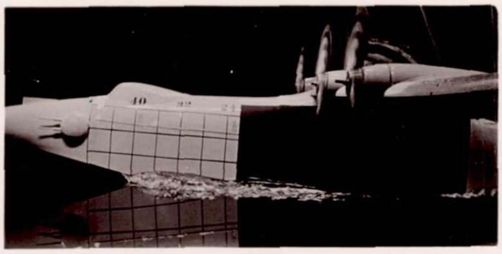
(c) Center of gravity, 22 percent M.A.C.

Figure 17.- Concluded.

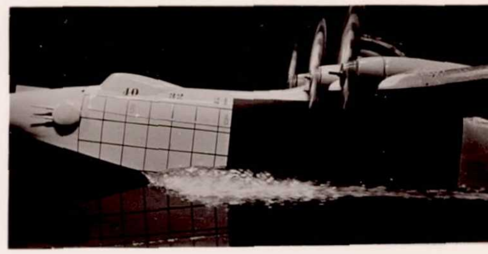


(b) Spray on flaps.

Figure 18.- Spray range over which spray strikes the propellers and the flaps. $\delta_f = 20^o$; $\delta_e = 0^o$; center of gravity, 30 percent M.A.C.; take-off power.

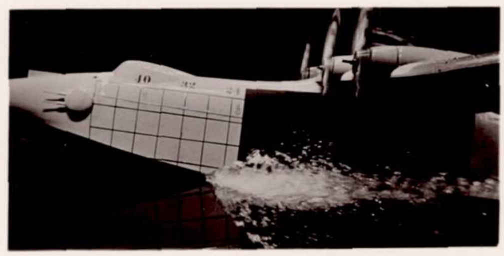


V = 8 fps; $\tau = 3.4^{\circ}$

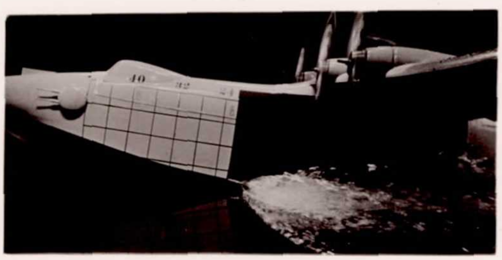


V = 12 fps; $\tau = 4.5^{\circ}$

V = 14 fps; $\tau = 5.2^{\circ}$

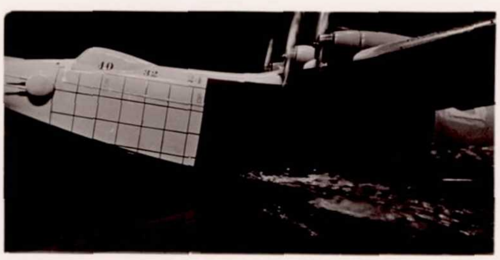


V = 16 fps; $\tau = 6.3^{\circ}$

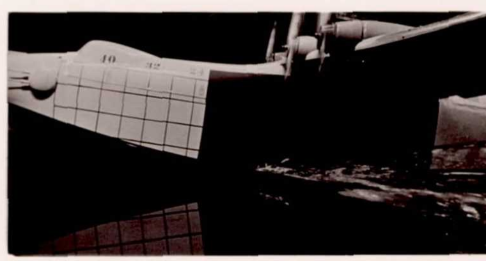


V = 18 fps; $\tau = 7.8^{\circ}$

V = 20 fps; $\tau = 8.5^{\circ}$



V = 22 fps; $\tau = 8.3^{\circ}$



V = 24 fps; $\tau = 7.4^{\circ}$

(a) Gross load, 110.0 pounds.

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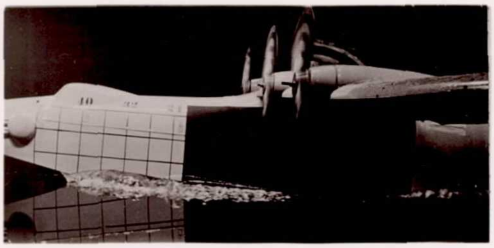
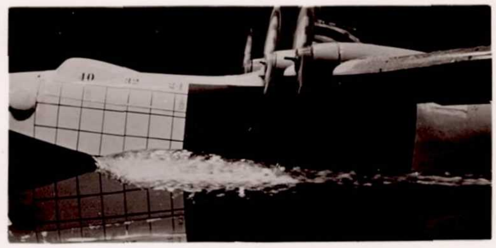
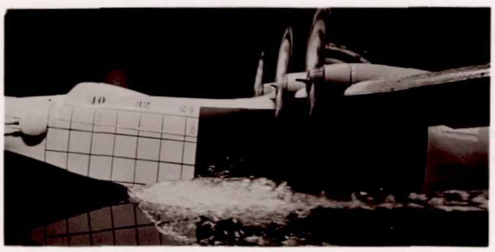
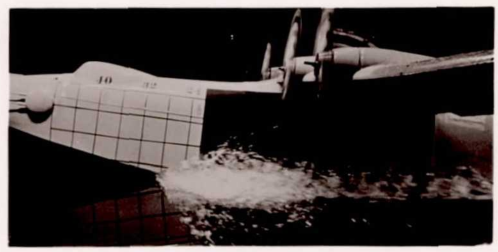
Figure 19.- Spray photographs at three gross loads. $\delta_f = 20^{\circ}$; $\delta_e = 0^{\circ}$; center of gravity, 30 percent M.A.C.; take-off power.

$V = 8$ fps; $\tau = 4.2^{\circ}$ $V = 12$ fps; $\tau = 5.4^{\circ}$

$V = 14$ fps; $\tau = 6.4^{\circ}$ $V = 16$ fps; $\tau = 7.3^{\circ}$


$V = 18$ fps; $\tau = 8.1^{\circ}$ $V = 20$ fps; $\tau = 8.7^{\circ}$


$V = 22$ fps; $\tau = 8.8^{\circ}$ $V = 24$ fps; $\tau = 8.2^{\circ}$

(b) Gross load, 123.5 pounds.

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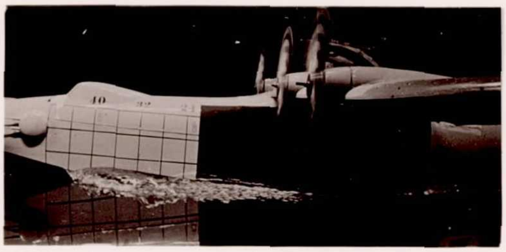
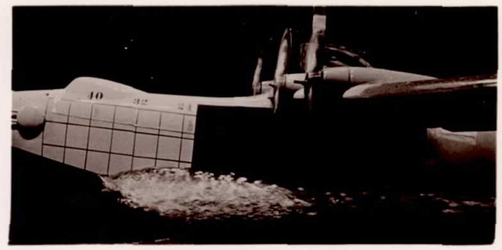
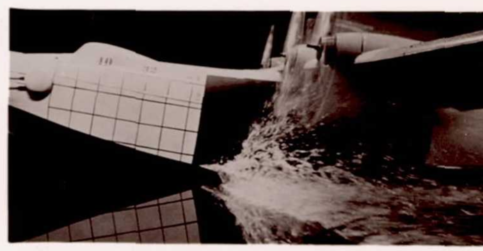
Figure 19.- Continued.



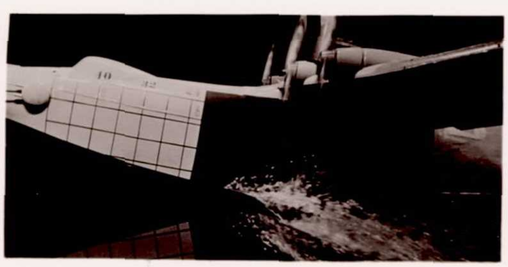


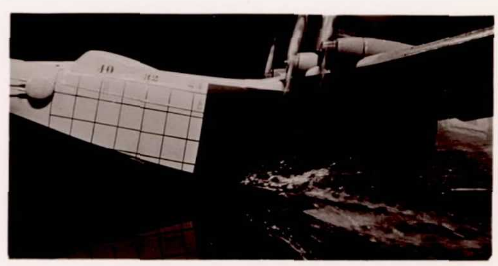
V = 8 fps; $\tau = 4.5^{\circ}$ V = 12 fps; $\tau = 5.6^{\circ}$

V = 14 fps; $\tau = 6.6^{\circ}$ V = 16 fps; $\tau = 7.5^{\circ}$



V = 18 fps; $\tau = 8.6^{\circ}$ V = 20 fps; $\tau = 9.4^{\circ}$





V = 22 fps; $\tau = 9.2^{\circ}$ V = 24 fps; $\tau = 8.7^{\circ}$

(c) Gross load, 136.0 pounds.

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Figure 19.- Concluded.

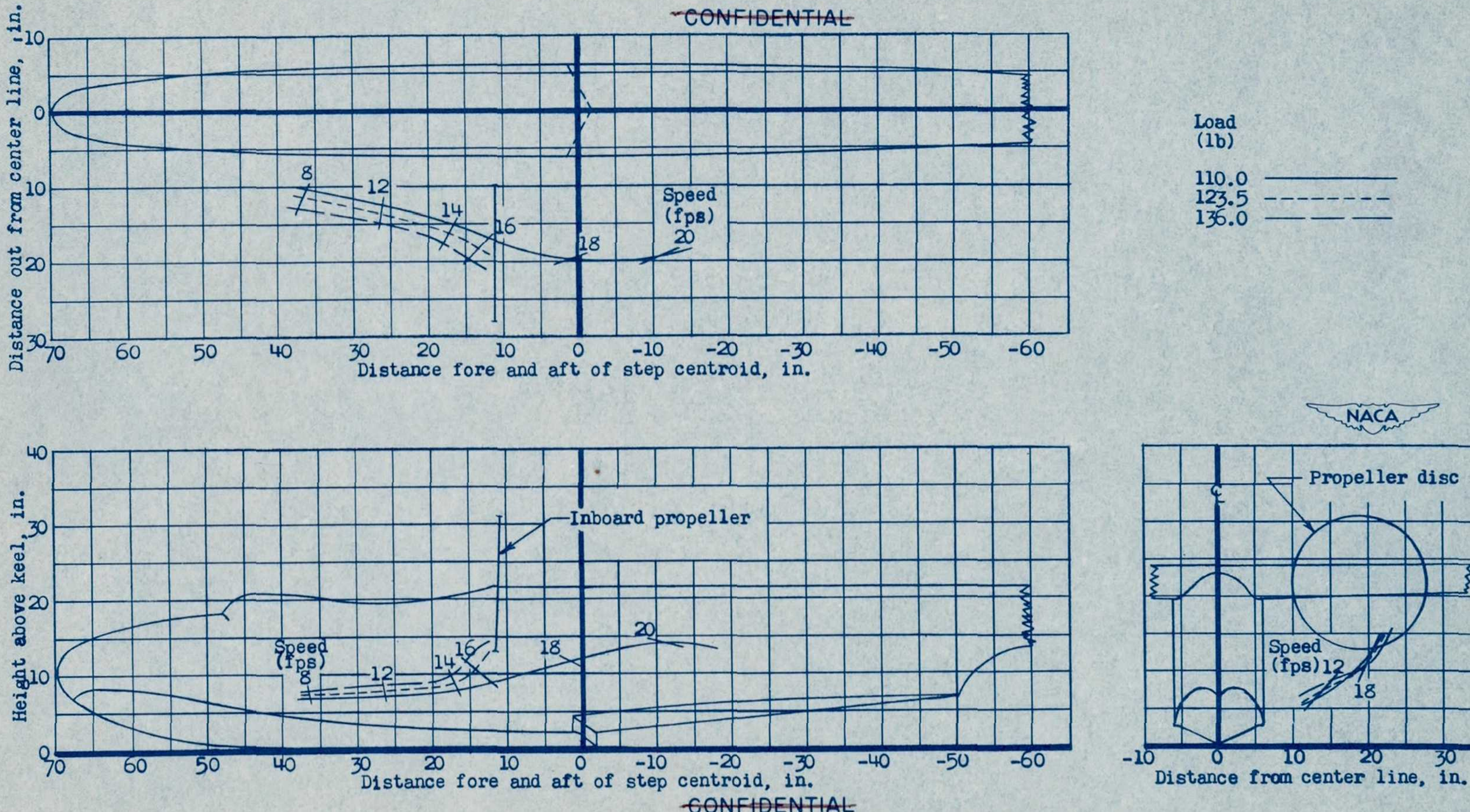

Figure 20.- Envelopes of peaks of main spray blisters. Center of gravity, 30 percent M.A.C.; $\delta_e = 0^\circ$; $\delta_f = 20^\circ$.