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RESEARCH MEMORANDUM

EFFECT OF AN INCREASE IN HULL LENGTH-BEAM RATIO FROM 15 TO 20 ON THE HYDRODYNAMIC CHARACTERISTICS OF FLYING BOATS

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EFFECT OF AN INCREASE IN HULL LENGTH-BEAM RATIO FROM 15 to 20 ON THE HYDRODYNAMIC CHARACTERISTICS OF FLYING BOATS

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SUMMARY

Investigations of the effect of hull length-beam ratio on the hydrodynamic characteristics of flying boats have been extended to include a length-beam ratio of 20. This hull of length-beam ratio of 20 was designed to meet advanced requirements for increased speed and increased range for flying-boat designs. The results obtained for the hull having a length-beam ratio of 20 are compared with those for the hull having a length-beam ratio of 15.

The range of stable center-of-gravity position of the hull having a length-beam ratio of 20 was less than that for the length-beam ratio of 15. The behavior of the model having the hull length-beam ratio of 20 was erratic and small disturbances of the water surface were likely to cause the model to porpoise. The landing stability was approximately the same as that for the length-beam ratio of 15. Extending length-beam ratio from 15 to 20 resulted in the elimination of heavy spray entering the propellers although the heavy spray striking the flaps did not differ greatly between the two length-beam ratios.

Extending length-beam ratio from 15 to 20 improved slightly the take-off behavior in waves. During landings in waves, the maximum vertical acceleration was 5.5g or 40 percent less than that obtained with the length-beam ratio of 15. The increase in length-beam ratio from 15 to 20 reduced the motions in trim and rise as well as the maximum trim and rise but had little effect on the maximum angular accelerations.

INTRODUCTION

The general program of aerodynamic and hydrodynamic research on hull length-beam ratio of flying boats has been extended to include the effect of an increase in length-beam ratio from 15 to 20. The hull of length-beam ratio of 20 is one of a related series with different length-beam ratios designed to have similar resistance and spray characteristics for the same gross weight and to be physically interchangeable on the seaplane design. All the hulls have the same length^2-beam product and, therefore, become longer and narrower as the length-beam ratio is increased. Increasing the length-beam ratio from 15 to 20 resulted in a 9-percent reduction in volume and a 16-percent reduction in frontal area.

The wind-tunnel investigation of this hull (reference 1) has shown that an increase in length-beam ratio from 15 to 20 resulted in only a small decrease in minimum drag coefficient. The minimum aerodynamic drag of the hull with a length-beam ratio of 15, on the other hand, was 29 percent less than the drag of the hull with the conventional length-beam ratio of 6 (reference 2).

The seaplane assumed for the evaluation of the hydrodynamic characteristics is a twin-engine propeller-driven flying boat having a design gross load of 75,000 pounds, a wing loading of 41.1 pounds per square foot, a power loading of 11.5 pounds per brake horsepower for take-off, and, for the length-beam ratio of 20, a gross load coefficient of 10.5. The hydrodynamic qualities (reference 3) determined in the investigation were longitudinal stability during take-off and landing, spray characteristics, and take-off performance in smooth water, and take-off and landing behavior in waves. These qualities were determined from tests of a $\frac{1}{10}$-size powered dynamic model in Langley tank no. 1 and are compared with the same qualities of the seaplane having a hull length-beam ratio of 15 as presented in references 4 and 5.

SYMBOLS

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

b maximum beam of hull, feet

g acceleration due to gravity (32.2), feet per second per second

n_v vertical acceleration, g units

V_h horizontal velocity (carriage speed), feet per second

V_v vertical velocity (sinking speed), feet per second

w specific weight of water (63.4 for these tests, usually taken as 64 for sea water), pounds per cubic foot

α angular acceleration, radians per second per second

γ flight-path angle, degrees

δ_e elevator deflection, degrees

Δ_o gross load, pounds

τ trim (angle between forebody keel at step and horizontal), degrees

τ_L landing trim, degrees

DESCRIPTION OF MODELS AND APPARATUS

The form, size, and relative locations of the aerodynamic surfaces were the same as those of the design having hull length-beam ratios of 6 and 15 (reference 4). The model having a hull length-beam ratio of 20 was designated Langley tank model 239. Photographs and hull lines of the model, and general arrangement of the flying boat are given in figures 1, 2, and 3, respectively. For comparison, photographs of the model and general arrangement of the flying boat having a hull length-beam ratio of 15 are shown in figures 1 and 3, respectively. Offsets of the hull are given in reference 1. Pertinent characteristics and dimensions of the flying boats with hull length-beam ratios of 15 and 20 are given in table I. Additional information regarding dimensions and characteristics may be found in references 1 and 2. The length used for determining the length-beam ratio is the distance from the forward perpendicular to the sternpost.

The hull had the same depth of step, position of the step relative to the mean aerodynamic chord, maximum height of hull, ratio of forebody to afterbody length, and length^2-beam product as that used for the hull with the length-beam ratio of 15. (See reference 4.) The fairing aft of the sternpost (reference 1) was omitted from the tank model and a slight modification was made to the sides of the afterbody above the chine. These changes would have a negligible effect on the hydrodynamic characteristics.

The model was powered with three-blade metal propellers driven by two variable-frequency motors. Slats were attached to the leading edge of the wing in order to delay the stall to an angle of attack more nearly equal to that of the full-size flying boat.

The investigation was made in Langley tank no. 1, which is described in reference 6. The setup of the model on the towing carriage and the testing apparatus are shown in figure 4. The apparatus was the same as that used for the tests of other models in this series (references 4 and 5). The model was free to trim about the pivot, which was located at the center of gravity and was free to move vertically but was restrained laterally and in roll and yaw. In order to measure excess thrust, the towing gear was connected to a spring balance which measured the longitudinal force. For the self-propelled tests in waves, the model had approximately 2 feet of fore-and-aft freedom with respect to the towing carriage in order to absorb the longitudinal accelerations introduced by the impacts.

An accelerometer mounted on the towing staff of the model measured the vertical accelerations. Two accelerometers were used to measure the angular accelerations.

PROCEDURES

Effective-thrust and aerodynamic lift and pitching-moment data for the model having a hull length-beam ratio of 15 are presented in reference 4 and are applicable to Langley tank model 239.

The hydrodynamic qualities in smooth water and in oncoming waves were determined at the design gross load corresponding to 75,000 pounds, except for the spray investigation in which the gross loads corresponded to loads from about 50,000 pounds to 95,000 pounds. The flaps were deflected 20° for all the hydrodynamic tests. All data are presented as full-size values with the exception of the data of table II which are pertinent model data taken directly from the records.

Trim limits of stability.- The trim limits of stability were determined at constant speeds by use of the methods described in reference 7. In order to obtain sufficient control moment to trim the model to the trim limits, the lower limit was determined at forward positions of the center of gravity and the upper trim limits were determined at after positions of the center of gravity.

Center-of-gravity limits of stability.- The center-of-gravity limits of stability were determined by making accelerated runs to take-off speed with fixed elevators, full thrust, and a constant rate of acceleration of 1 foot per second per second. Trim, rise of the center of gravity, and amplitude of porpoising were continuously recorded during the accelerated run. Zero rise was set with the step just touching the water surface at zero trim. A sufficient number of center-of-gravity positions and elevator deflections were investigated to cover the normal operating range and to define the center-of-gravity limits of stability.

Landing stability.- The landing stability was investigated by trimming the model in the air to the desired landing trim at a speed slightly above flying speed and then decelerating the towing carriage at a uniform rate of 2 feet per second per second; this technique allowed the model to glide onto the water and simulate an actual landing. The elevator deflection was not changed after the desired landing trim was attained. The distance between the center of gravity and the water surface was held constant at 20 inches in order to minimize the tendency of the trim to change caused by ground effect on the aerodynamic moments during the approach to the water surface. The contact trims and behavior on landing were observed visually, and trim and rise were continuously recorded throughout the landing run. The landings were made with one-half take-off thrust and with the center of gravity located at 32-percent mean aerodynamic chord.

Spray characteristics.- The speeds at which light loose spray and the speeds at which heavy blister spray entered the propellers or struck the flaps were determined for gross loads from a lightly loaded to a heavily overloaded condition.

Excess thrust.- The excess thrust (thrust available for acceleration) was determined at constant speeds for several fixed settings of the elevators. The center of gravity was located at 32-percent mean aerodynamic chord.

Taxying and take-off behavior in waves.- The taxying behavior in waves was investigated with full thrust up to hump speed at a forward rate of acceleration of 1 foot per second per second. The take-off behavior was investigated with full thrust up to take-off speed at a forward rate of acceleration of approximately 3.3 feet per second per second. Complete time histories of the taxi and take-off runs were recorded.

Landing behavior in waves.- The landing behavior in waves was investigated at the same deceleration used in the investigation of the smooth-water landing stability. Prior tests in rough water have shown that landing trim had little effect on either the variation of trim during the landing runout or the maximum accelerations. All landings were consequently made at a trim of approximately 8°. In order to provide sufficient clearance for landings in waves, the distance between the center of gravity and the water surface was approximately 40 inches. For all landings the model was held in trim by the electrically actuated trim brake during the initial landing approach, and the elevators were set to give the proper trimming moments upon contact with the water. This procedure was used to overcome the tendency of the trim to change caused by ground effect on the aerodynamic moments during the approach to the water surface. The landing behavior was observed visually, and a time history was continuously recorded throughout the landing run. The time history included recordings of trim, rise, fore-and-aft position, vertical accelerations, angular accelerations, wave profiles, and speed. The landings were made with the thrust adjusted so that the model was approximately a free body during the initial landing and the high-speed portion of the landing runout.

RESULTS AND DISCUSSION

Longitudinal Stability

Trim limits of stability.- The trim limits of stability are compared in figure 5 with those for the hull with a length-beam ratio of 15. The upper limit, increasing trim, and the upper limit, decreasing trim, were approximately the same for both length-beam ratios. The lower limit for the hull having a length-beam ratio of 20 was shifted to higher speeds in the intermediate planing-speed range. This shift decreased the range of stable trim between the lower limit and the upper limit, increasing trim, over the speed range where lower limit porpoising generally occurs during take-off. When even slight porpoising occurred, the trim was more likely to penetrate both the lower and upper trim limits because of the resultant narrow range of stable trim, and the tendency to porpoise, therefore, was more pronounced for the length-beam ratio of 20 than for the length-beam ratio of 15.

Center-of-gravity limits of stability.- Representative trim tracks for length-beam ratio of 20 are presented in figure 6(a) for several positions of the center of gravity and elevator deflections. Comparable trim tracks for length-beam ratio of 15 are presented in figure 6(b). The maximum amplitudes of porpoising that occurred during take-off are plotted against position of the center of gravity in figure 7. The maximum amplitude is defined as the difference between the maximum and minimum trims during the greatest porpoising cycle that occurred during the take-off.

The plot of maximum amplitude of porpoising against position of the center of gravity of the length-beam ratio of 20 is similar to that of the length-beam ratio of 15. With both length-beam ratios, the amplitude of lower-limit porpoising increased rapidly with forward movement of the center of gravity. At after positions of the center of gravity the amplitude of upper-limit porpoising never exceeded approximately 2.5° for either length-beam ratio.

For a given elevator deflection, the practical center-of-gravity limit is usually defined as that position of the center of gravity at which the amplitude of porpoising becomes 2°. A plot of elevator deflection against center-of-gravity position at which the maximum amplitude of porpoising was 2° is presented in figure 8. With the length-beam ratio of 20, the range of stable center-of-gravity position was slightly less than that for the length-beam ratio of 15. The behavior of the model having the hull length-beam ratio of 20 was erratic, however, and small disturbances of the water surface were likely to cause the model to porpoise.

Landing stability.- Several typical time histories of landings with the two models are presented in figure 9. The maximum and minimum values of the trim and rise at the greatest cycle of oscillation during the landing run were obtained from these data and are plotted against trim at first contact in figure 10.

The hull having the length-beam ratio of 20 did not skip on contact at any landing trim (4° to 13°) and it may be concluded that the depth of step of 20.1 percent beam provided adequate ventilation. Porpoising during the landing runout was encountered at contact trims above 9.5°. The landing stability for the length-beam ratio of 20 was approximately the same as that for the length-beam ratio of 15.

Spray Characteristics

The range of speed over which spray entered the propellers and struck the flaps is plotted against gross load in figure 11 for both hulls. At the design gross load, only light spray entered the propellers for the hull with the length-beam ratio of 20. The gross load was increased approximately 20 percent (90,000 pounds) before the blister spray entering the propellers was equivalent to the spray from the hull with the length-beam ratio of 15 at the design gross load (75,000 pounds). Blister spray struck the flaps at a slightly lower gross load with the length-beam ratio of 20 than with the length-beam ratio of 15. At the design gross load, however, heavy spray striking the flaps did not differ greatly between the hulls having length-beam ratios of 20 and 15. The quantity of spray striking the tail surfaces during landings as well as the range over which this spray occurred was less for the higher length-beam ratio.

Take-Off Performance

Abbreviated tests of the model with the hull length-beam ratio of 20 indicated no appreciable change in excess thrust available for take-off when compared with the excess thrust obtained for the hull of length-beam ratio of 15. The over-all take-off performance of the two hulls, therefore, would not differ greatly.

Taxying and Take-Off Behavior in Waves

The results of the investigation of the taxying behavior in waves are qualitative, but several points are of interest. Although the trim cycles were large in 4-foot waves, the bow showed no tendency to dig in. Observations indicated, however, that a decrease in forebody length would not be advisable.

Tracings of typical records of take-offs in waves for both models are shown in figure 12. The oscillations in trim and rise at low speeds were large but did not appear to be dangerous. At higher speeds the oscillations became small as the hull planed over the wave crests and relatively stable take-offs were made. The maximum trim and the maximum oscillation in trim were reduced for the length-beam ratio of 20 when compared with those for the length-beam ratio of 15. The rise cycles for the higher length-beam ratio hull were also slightly smaller.

Landing Behavior in Waves

Pertinent data obtained from the records made during the landing investigation in waves are presented in table II. The sinking speeds for the initial landing approach ranged from 170 to 280 feet per minute (0.9 to 1.5 fps, model size) and were small compared with the sinking speeds at the maximum vertical accelerations. The sinking speeds associated with the maximum vertical accelerations for the hull of length-beam ratio of 20 ranged from 300 to 810 feet per minute (1.6 to 4.3 fps, model size). The sinking speeds associated with the maximum vertical accelerations for the hull with the length-beam ratio of 15 ranged from 195 to 1070 feet per minute (reference 5). With the reduction in the maximum sinking speed, a lower maximum vertical acceleration would be expected for the higher length-beam ratio hull.

Vertical accelerations.- The variations of maximum vertical acceleration with wave length are shown in figure 13. A peak was apparently reached in the maximum vertical accelerations at wave lengths near 185 feet. The peak maximum vertical acceleration of approximately 5.5g for the hull having a length-beam ratio of 20 was about 40 percent less than the peak maximum vertical acceleration for the hull having a length-beam ratio of 15. The peak accelerations occurred at approximately the same wave length for both hulls.

The position of landing on a wave for the initial impact, as well as subsequent impacts during the landing runout, was not under the control of the operator, and this lack of control accounts for the scatter of the test data. The envelopes of the data indicate the maximum probable accelerations that would be obtained for the range of wave lengths investigated.

Angular accelerations.- Maximum angular accelerations are plotted against wave length in figure 14. A peak apparently was reached in the maximum positive accelerations (bow rotated upward) at the shorter wave lengths. At the longest wave length investigated, the accelerations were reduced about 70 percent below the acceleration at the apparent peak.

The negative angular accelerations occurred when a bow-down rotation was induced during landing on the sternpost. The maximum negative accelerations also occurred at the shorter wave lengths.

An increase in length-beam ratio from 15 to 20 had little effect on the maximum angular accelerations.

Motions in trim and rise.- The maximum and minimum trim and rise at the cycle with greatest amplitude of oscillation that occurred during the high-speed portion of the landing runout are plotted against wave length in figure 15. The variation of maximum and minimum trim and rise over the entire range of wave lengths was small.

The increase in length-beam ratio from 15 to 20 resulted in an appreciable reduction in the maximum amplitude of oscillation in both trim and rise. The oscillation in trim was reduced approximately 15 percent and the oscillation in rise nearly 25 percent. The increase in length-beam ratio also reduced the maximum trim 2° and the maximum rise approximately 6 feet.

Summary Chart

The hydrodynamic qualities of a flying boat with a low-drag hull having a length-beam ratio of 20, as determined by powered-dynamic-model tests, are summarized in figure 16. This chart gives an over-all picture of the hydrodynamic characteristics in terms of full-scale operational parameters and is therefore useful for comparisons with similar data regarding other seaplanes for which operating experience is available.

CONCLUSIONS

The results of an investigation to determine the effect of an increase in hull length-beam ratio from 15 to 20 led to the following conclusions:

1. The range of stable center-of-gravity position was less than that for the length-beam ratio of 15. The behavior of the model having the hull length-beam ratio of 20 was erratic and small disturbances of the water surface were likely to cause the model to porpoise.

2. The landing stability was approximately the same as that for the length-beam ratio of 15.

3. Extending length-beam ratio from 15 to 20 resulted in the elimination of heavy spray entering the propellers although the heavy spray striking the flaps did not differ greatly between the two length-beam ratios.

4. Extending length-beam ratio from 15 to 20 improved slightly the take-off behavior in waves.

5. During landings in waves, the maximum vertical acceleration was 5.5g or 40 percent less than that obtained with the length-beam ratio of 15. The increase in length-beam ratio from 15 to 20 reduced the motions in trim and rise as well as the maximum trim and rise but had little effect on the maximum angular accelerations.

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TABLE I

PERTINENT CHARACTERISTICS AND DIMENSIONS OF FLYING BOATS

HAVING HULL LENGTH-BEAM RATIOS OF 20 AND 15

	$\frac{L}{b} = 20$	$\frac{L}{b} = 15$
General:		
Design gross load, lb	75,000	75,000
Gross load coefficient, C_{Δ_0}	10.5	5.88
Wing area, sq ft	1826	1826
Take-off horsepower	6500	6500
Wing loading, lb/sq ft	41.1	41.1
Power loading, lb/hp	11.5	11.5
Hull:		
Maximum beam, ft	4.82	5.84
Length:		
Forebody, bow to step, ft	55.5	50.4
Forebody length-beam ratio	11.5	8.6
Afterbody, step to sternpost, ft	40.9	37.2
Afterbody length-beam ratio	8.5	6.4
Tail extension, sternpost to aft perpendicular, ft	13.8	17.5
Over-all, bow to aft perpendicular, ft	110.2	105.1
Step:		
Type	Transverse	Transverse
Depth at keel, in.	11.6	11.6
Depth at keel, percent beam	20.1	16.5
Angle of forebody keel to base line, deg	0	0
Angle of afterbody keel to base line, deg	5.4	5.4
Angle of sternpost to base line, deg	6.7	6.9
Angle of dead rise of forebody:		
Excluding chine flare, deg	20	20
Including chine flare, deg	16.5	16.5
Angle of dead rise of afterbody, deg	20	20
Wing:		
Span, ft	139.7	139.7
Root chord, ft	16.0	16.0
Mean aerodynamic chord (M.A.C.):		
Length, projected, ft	13.7	13.7
Leading edge aft of bow, ft	48.7	43.7
Leading edge foward of step, ft	6.7	6.7
Leading edge above base line, ft	15.1	15.1
Angle of incidence, deg	4	4
Horizontal tail surfaces:		
Area, sq ft	333	333
Span, ft	43.0	43.0
Angle of stabilizer to wing chord, deg	-4	-4
Elevator root chord, ft	3.20	3.20
Elevator semispan, ft	16.7	16.7
Length from 25 percent M.A.C. of wing to hinge line of elevators, ft	49.5	49.5
Height above base line, ft	19.0	19.0
Propellers:		
Number of propellers	2	2
Number of blades	3	3
Diameter, ft	16.5	16.5
Angle of thrust line to base line, deg	2	2
Clearance above keel, ft	8.3	8.3

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TABLE II

DATA OBTAINED DURING LANDINGS IN WAVES
LENGTH-BEAM RATIO, 20

[All values are model size]

Landing	Wave height (ft)	Wave length (ft)	Initial impact τ_L (deg)	Initial impact V_v (fps)	Initial impact V_h (fps)	Initial impact γ (deg)	Initial impact n_v (g)	Initial impact α $\left(\frac{radians}{sec^2}\right)$	Maximum acceleration Impact	Maximum acceleration τ (deg)	Maximum acceleration V_v (fps)	Maximum acceleration V_h (fps)	Maximum acceleration γ (deg)	Maximum acceleration n_v (g)	Maximum acceleration α $\left(\frac{radians}{sec^2}\right)$
1	0.4	15.3	7.8	1.14	36.8	1.8	1.0	8	3	4.4	1.68	33.0	2.9	3.2	70
2	.4	16.5	7.8	1.00	37.5	1.5	.4	-6	2	3.7	2.35	35.2	3.8	3.1	78
3	.4	16.0	7.8	1.44	35.7	2.3	.5	0	3	5.5	3.29	30.0	6.3	5.8	74
4	.4	16.2	7.9	1.01	36.1	1.6	1.7	10	3	4.1	1.55	32.3	2.7	3.7	74
5	.4	15.8	8.5	.99	37.5	1.5	.4	0	5	4.1	2.45	30.0	4.7	3.9	106
6	.4	16.3	8.5	1.24	38.2	1.9	.8	0	4	5.0	2.75	31.9	4.9	4.9	90
7	.4	16.1	8.4	1.04	37.9	1.6	1.6	16	2	4.8	2.16	35.8	3.5	4.1	70
8	.4	16.4	8.3	1.30	38.1	2.0	2.2	20	2	5.4	2.09	35.8	3.3	4.0	50
9	.4	17.6	7.8	.89	36.7	1.4	1.0	4	6	4.5	1.79	33.2	3.1	3.4	67
									[a]9	3.4	2.78	28.5	5.6	1.9	84
10	.4	17.4	7.8	1.18	36.7	1.8	.8	0	7	3.9	2.33	31.0	4.3	3.3	95
11	.4	16.0	7.9	1.08	37.2	1.7	2.1	20	7	6.4	2.28	29.8	4.4	3.1	61
12	.4	16.1	7.9	.99	36.8	1.5	.3	-7	4	3.2	2.78	30.9	5.1	3.5	125
13	.4	17.5	8.2	1.04	37.1	1.6	1.3	11	4	5.0	2.76	30.2	5.2	4.9	90
14	.4	17.1	8.3	1.22	38.0	1.8	1.6	9	3	4.5	2.08	33.6	3.5	4.5	94
15	.4	17.2	8.3	1.02	38.0	1.5	1.8	12	4	3.6	2.44	31.3	4.5	4.2	107
16	.4	17.9	8.4	1.23	38.1	1.8	0	0	3	5.1	4.29	32.3	7.6	2.0	51
									[a]2	4.9	3.10	34.8	5.1	1.9	60
17	.4	16.9	8.4	1.07	37.2	1.6	1.3	8	5	3.9	3.87	28.0	7.9	3.5	100
18	.4	18.0	8.4	1.31	38.4	2.0	1.8	12	3	5.9	3.75	33.6	6.4	4.5	72
19	.4	20.3	7.7	.99	36.1	1.6	0	0	3	6.7	2.94	31.0	5.4	1.5	11
									[a]4	2.6	2.32	28.3	4.7	1.0	30
20	.4	20.6	7.7	1.06	36.9	1.6	0	0	2	5.1	1.60	34.9	2.6	2.2	40
									[a]5	1.9	3.14	27.5	6.5	1.0	42
21	.4	20.6	7.8	1.07	36.5	1.7	.3	0	4	4.8	4.10	28.9	8.1	5.0	85
22	.4	---	8.0	1.03	36.8	1.6	0	0	3	6.0	2.55	31.7	4.6	3.0	47
23	.4	19.9	7.9	.92	34.6	1.5	.6	0	2	4.8	1.74	32.4	3.1	3.2	40
24	.4	20.5	7.8	.97	35.3	1.6	2.4	19	4	7.0	3.30	28.9	6.5	2.6	36
									[a]3	4.7	2.59	31.3	4.7	2.4	58
25	.4	20.8	8.4	1.07	38.0	1.6	0	0	5	3.5	3.61	29.5	7.0	4.8	105
									[a]4	3.9	3.24	31.4	7.5	3.9	115
26	.4	19.4	8.4	1.30	38.2	1.9	.8	0	2	6.1	2.74	35.4	4.4	3.4	51
27	.4	19.6	8.4	1.04	37.9	1.6	.7	0	5	4.7	4.15	30.2	7.8	3.9	96
28	.4	22.5	8.3	1.18	38.3	1.8	0	0	4	6.2	3.93	30.0	7.5	4.2	95
29	.4	---	7.7	1.10	36.8	1.6	0	0	3	5.3	3.38	31.2	6.2	2.6	40
30	.4	---	7.7	1.08	37.0	1.7	.8	0	3	5.3	3.30	31.5	6.0	2.9	46
31	.4	23.0	7.7	.98	36.1	1.6	1.0	0	6	8.6	1.58	28.3	3.2	1.1	23
32	.4	23.8	7.8	1.03	37.1	1.6	1.0	11	3	8.0	3.38	31.4	6.1	1.5	0
									[a]2	4.2	2.07	34.0	3.5	1.0	22
33	.4	22.8	8.0	1.11	34.2	1.9	1.1	0	4	7.9	2.48	24.8	5.7	2.1	19
34	.4	24.2	7.9	1.07	35.7	1.7	1.9	50	3	6.5	3.69	29.1	7.2	3.4	39
									[a]1	5.4	1.48	35.0	2.4	1.9	50
35	.4	22.4	7.8	.94	34.5	1.6	1.1	0	5	5.8	2.02	28.0	4.1	1.2	26
36	.4	23.5	7.9	.94	35.6	1.5	1.8	28	2	6.0	3.04	32.1	5.4	2.0	26
									[a]1	5.4	1.35	34.9	2.2	1.8	28
37	.4	28.9	7.7	1.00	37.0	1.5	.9	0	10	7.0	2.90	26.2	6.3	1.7	22
38	.4	26.8	7.8	1.08	37.1	1.7	1.4	26	3	5.2	3.88	31.0	7.1	3.0	43
39	.4	28.1	7.7	1.15	36.9	1.8	.8	0	9	7.2	2.56	27.4	5.3	1.7	22
40	.4	27.7	7.8	1.14	37.2	1.8	1.2	26	5	6.4	3.60	27.1	7.6	2.0	39
41	.4	26.3	7.9	1.04	34.6	1.7	1.1	15	5	5.8	3.66	24.0	8.7	2.4	51
42	.4	27.2	7.9	1.05	35.8	1.7	1.3	10	3	6.3	3.92	29.7	7.5	3.3	45
43	.4	27.3	7.9	.97	34.5	1.6	.9	0	7	6.1	3.28	24.8	7.5	1.8	30
44	.4	26.3	7.9	1.01	35.7	1.6	1.8	29	3	5.9	3.59	29.1	7.0	2.4	30
45	.4	33.7	7.6	.91	37.5	1.4	0	0	4	6.2	3.32	28.2	6.7	1.7	20
									[a]5	6.3	3.29	26.6	7.0	1.4	22
46	.4	32.6	7.6	1.10	37.3	1.7	0	0	2	7.5	3.07	33.8	5.2	1.8	10
									[a]7	5.5	3.56	25.1	8.1	1.5	27
47	.4	32.9	7.7	.96	37.9	1.5	1.0	5	5	5.3	3.82	29.2	7.5	1.9	37
48	.4	31.5	7.7	.96	36.9	1.5	0	0	4	4.4	3.61	28.5	7.2	1.8	39
49	.4	33.4	7.9	1.46	35.0	2.9	1.2	0	7	6.2	3.40	24.3	9.4	1.9	29
50	.4	34.6	7.8	.90	36.5	1.7	1.1	20	5	5.5	3.44	25.8	9.0	1.9	27
51	.4	33.3	7.8	1.49	34.5	2.9	1.4	0	4	4.8	3.44	27.0	8.6	2.3	46

[a]Impact for maximum angular acceleration.

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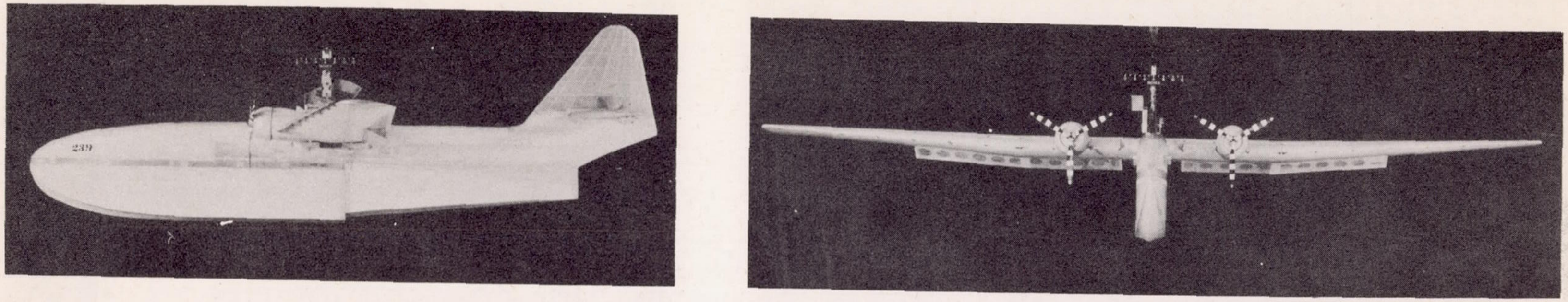
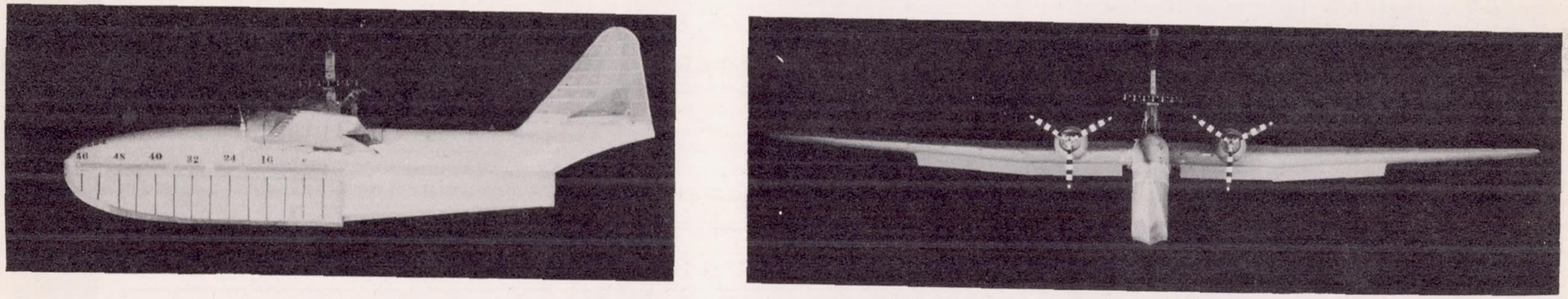


(a) Length—beam ratio, 20.



(b) Length—beam ratio, 15.

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Figure 1.— Models having hull length—beam ratios of 20 and 15.

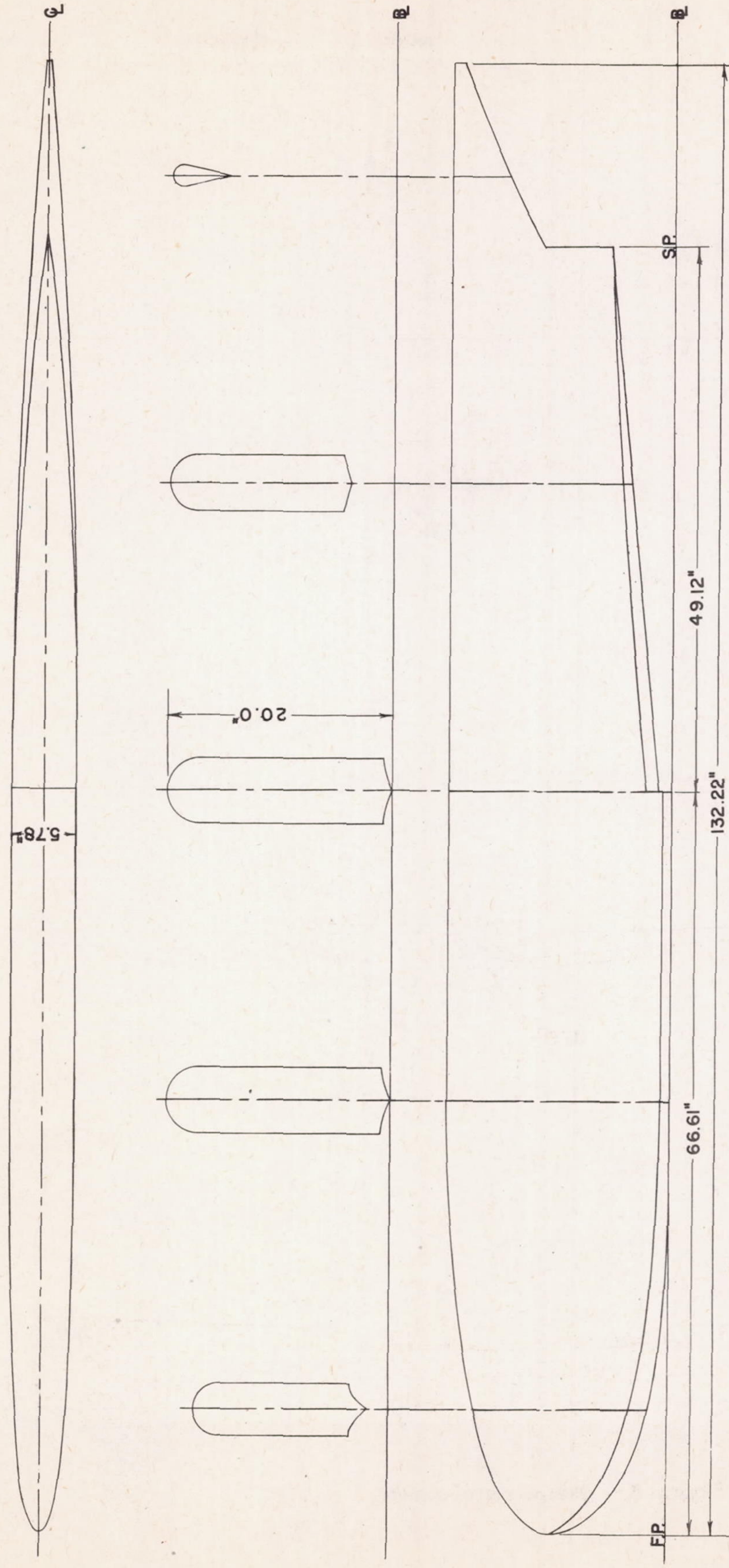


Figure 2.- Lines of Langley tank model 239.

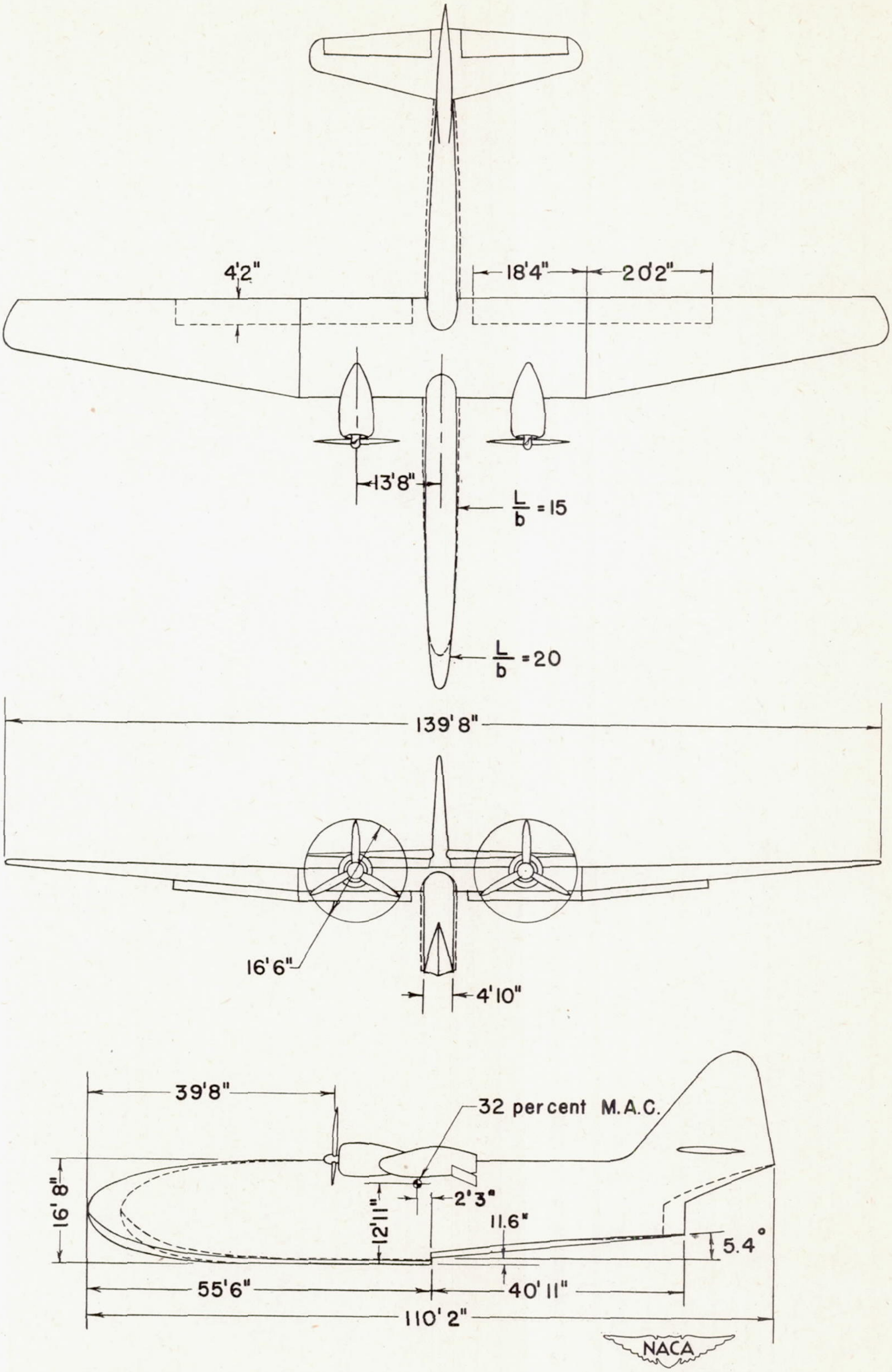
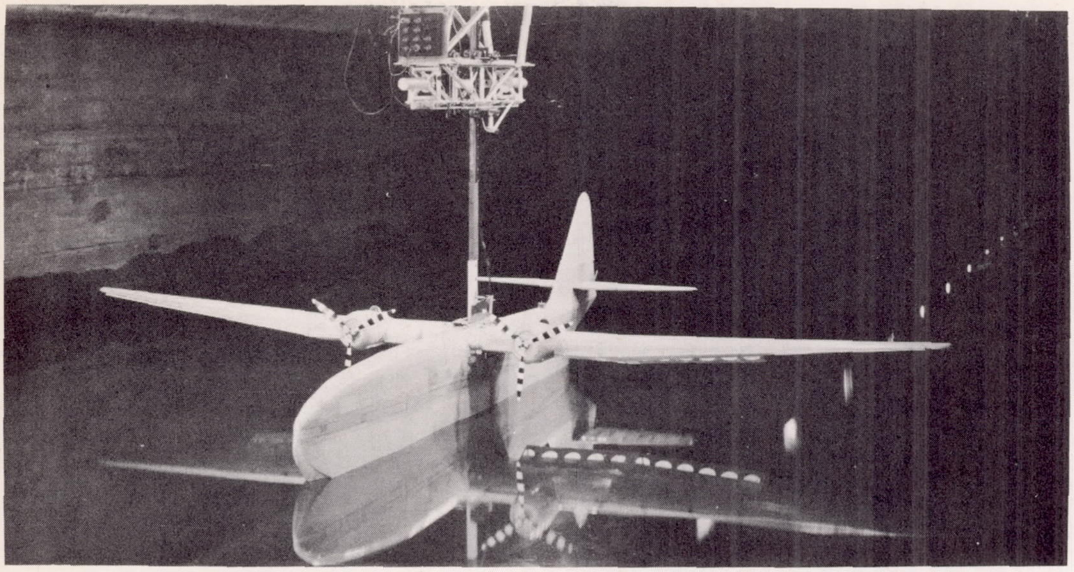
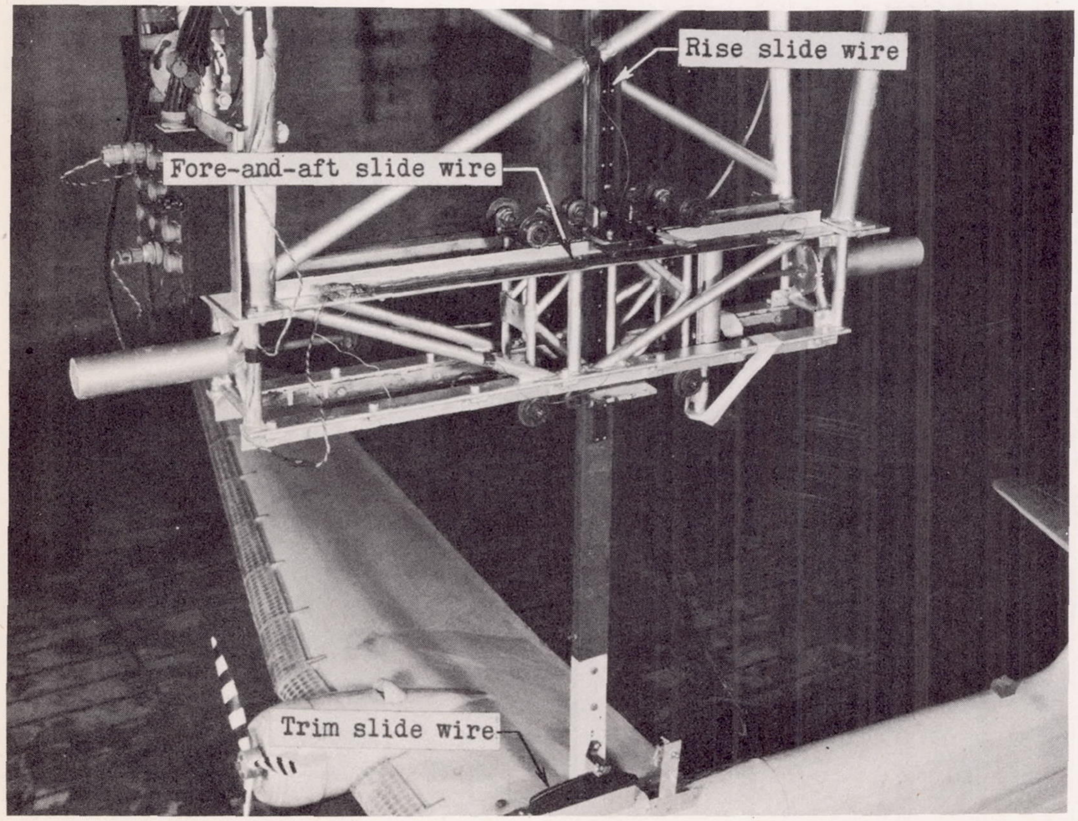


Figure 3.- General arrangement.



(a) Setup of model on towing apparatus.



(b) Details of fore-and-aft gear.

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Figure 4.- Model and towing apparatus.

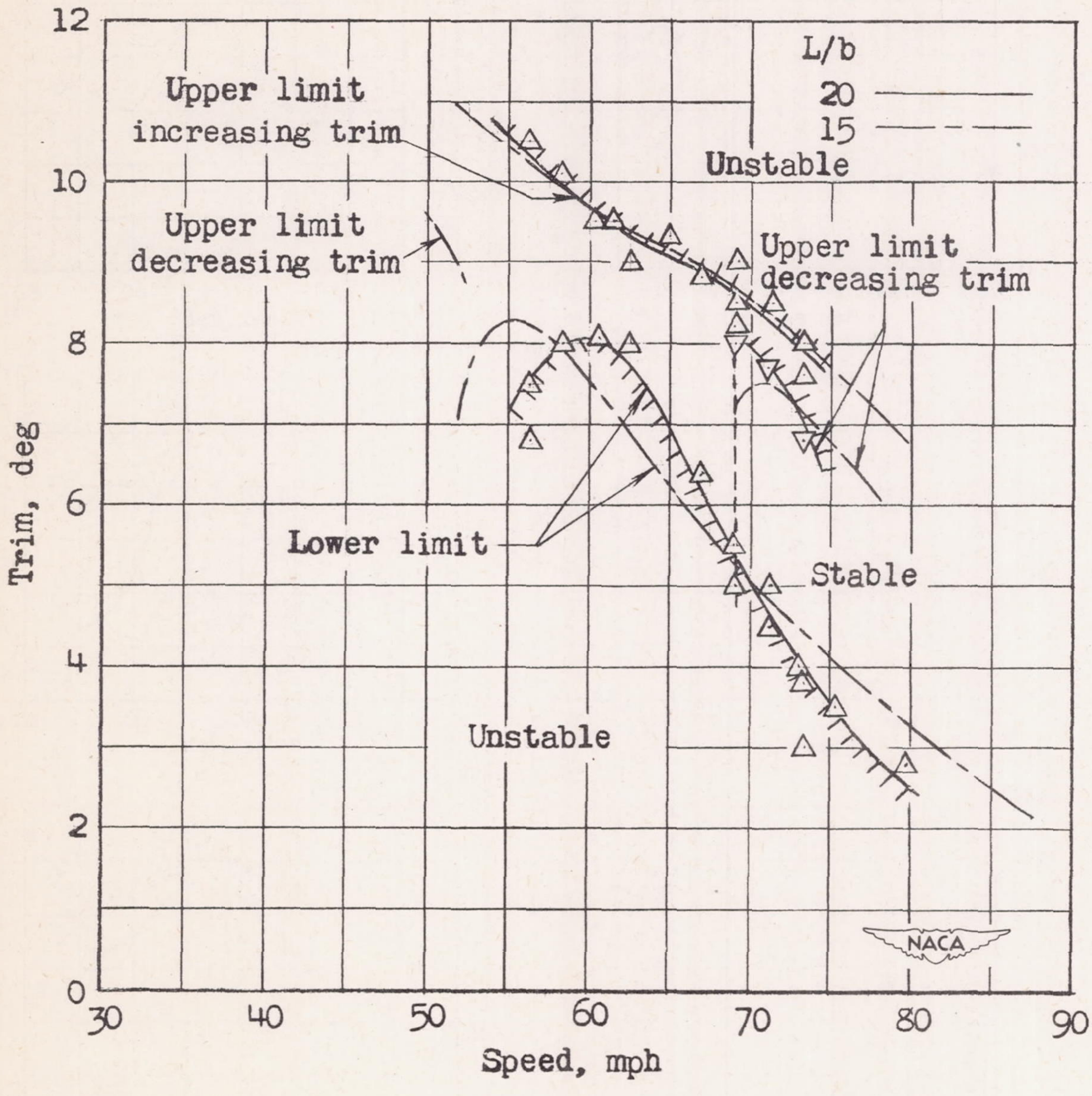
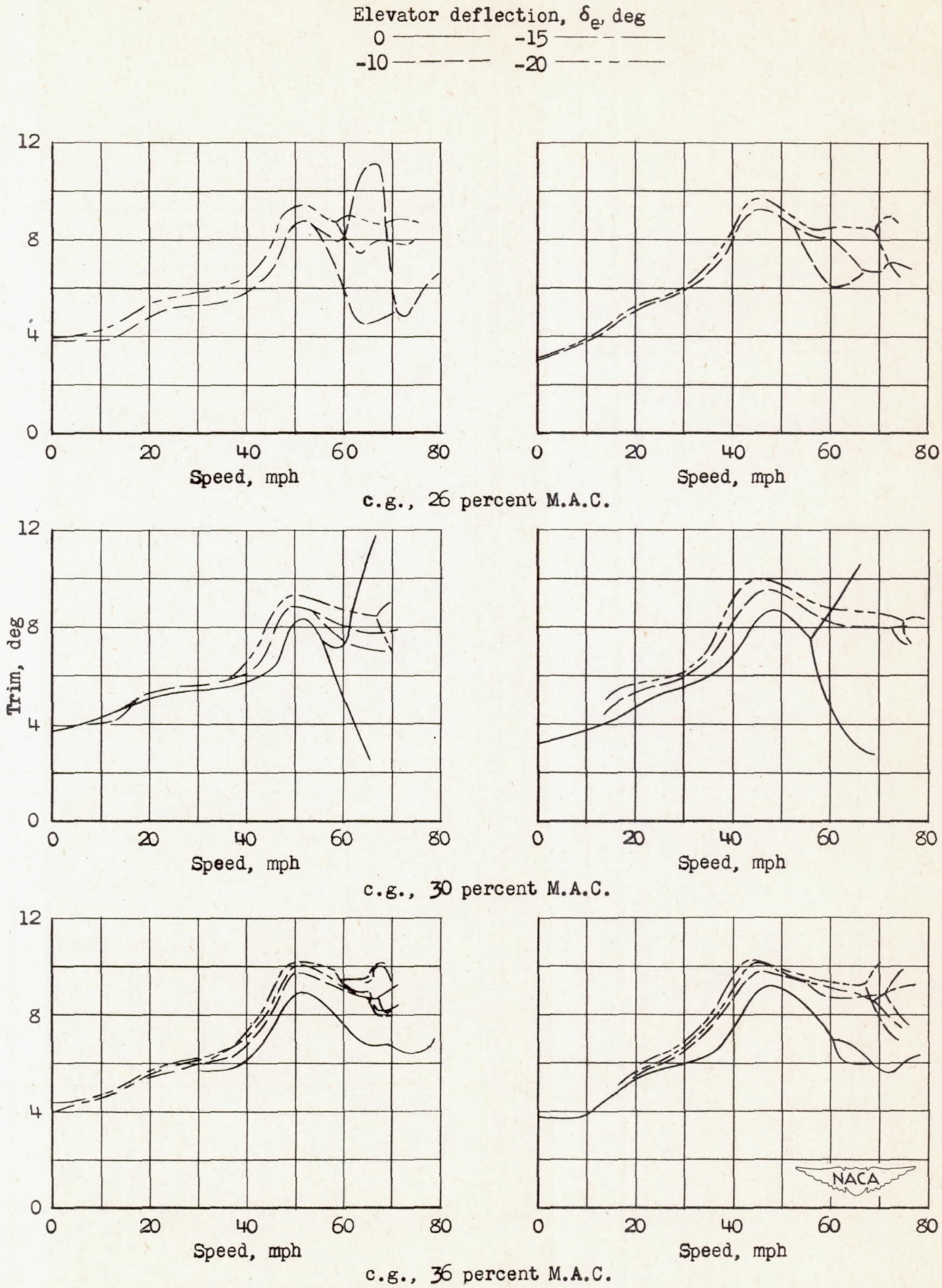


Figure 5.- Trim limits of stability.



(a) Hull of $\frac{L}{b}$ = 20.

(b) Hull of $\frac{L}{b}$ = 15.

Figure 6.- Variation of trim with speed.

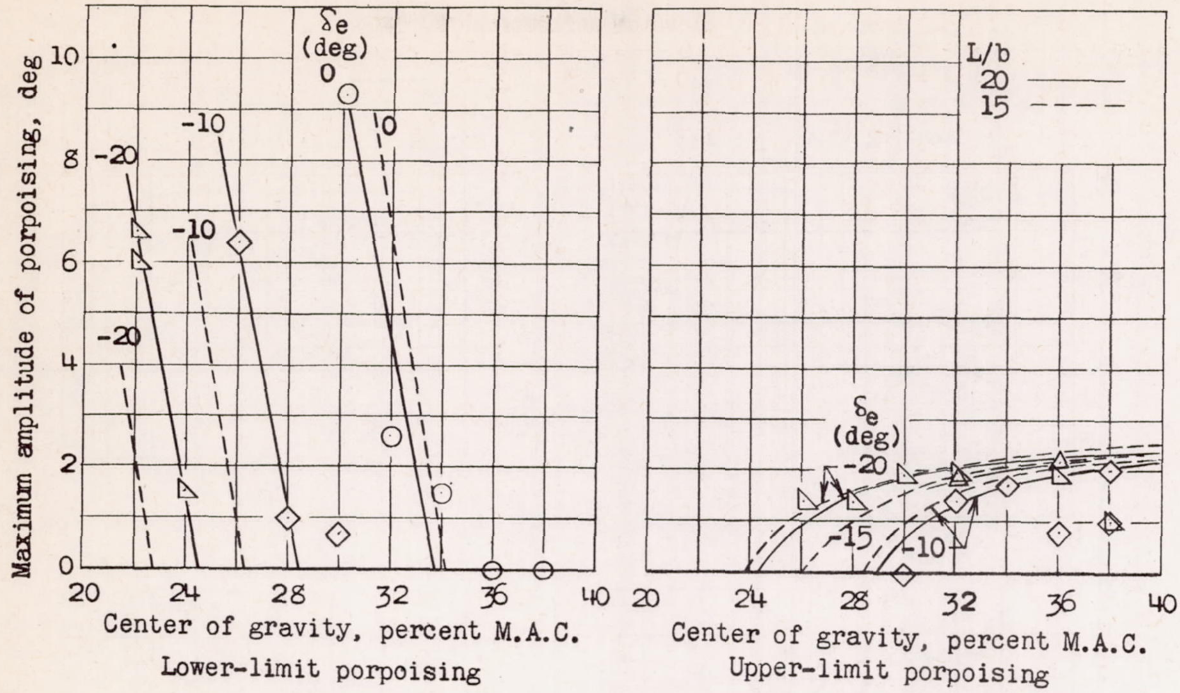


Figure 7.- Maximum amplitude of porpoising at different positions of the center of gravity.

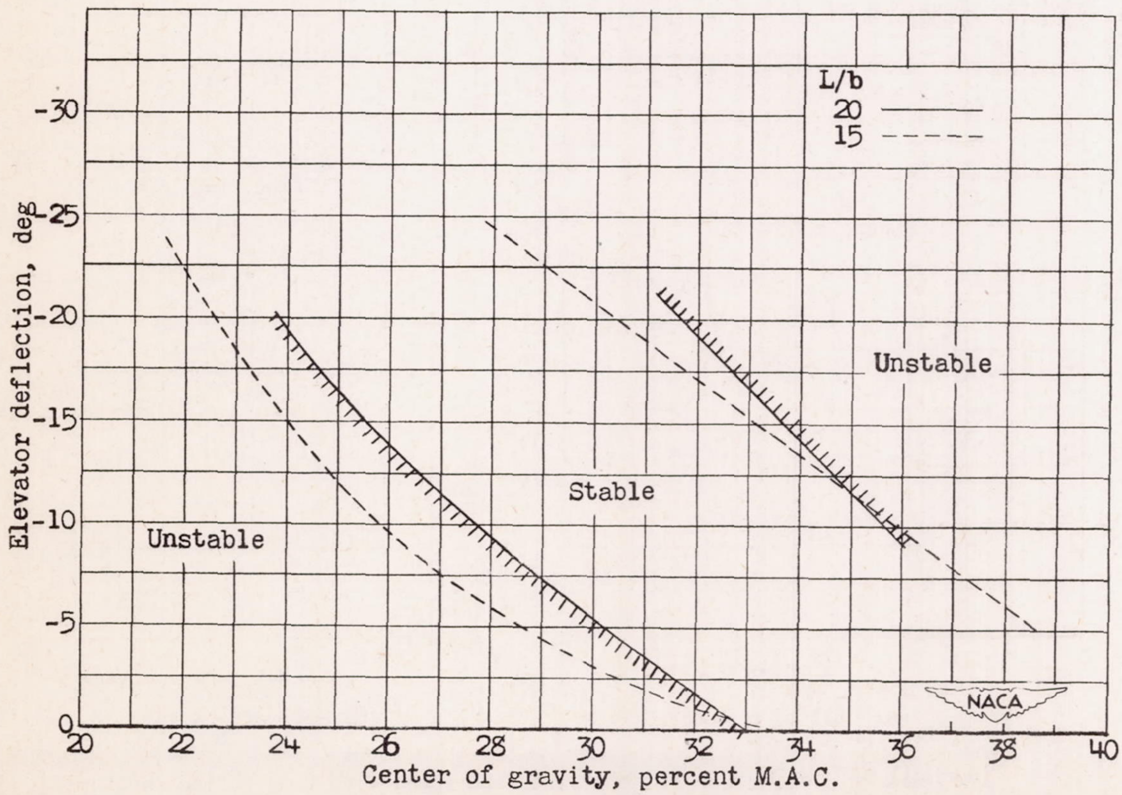
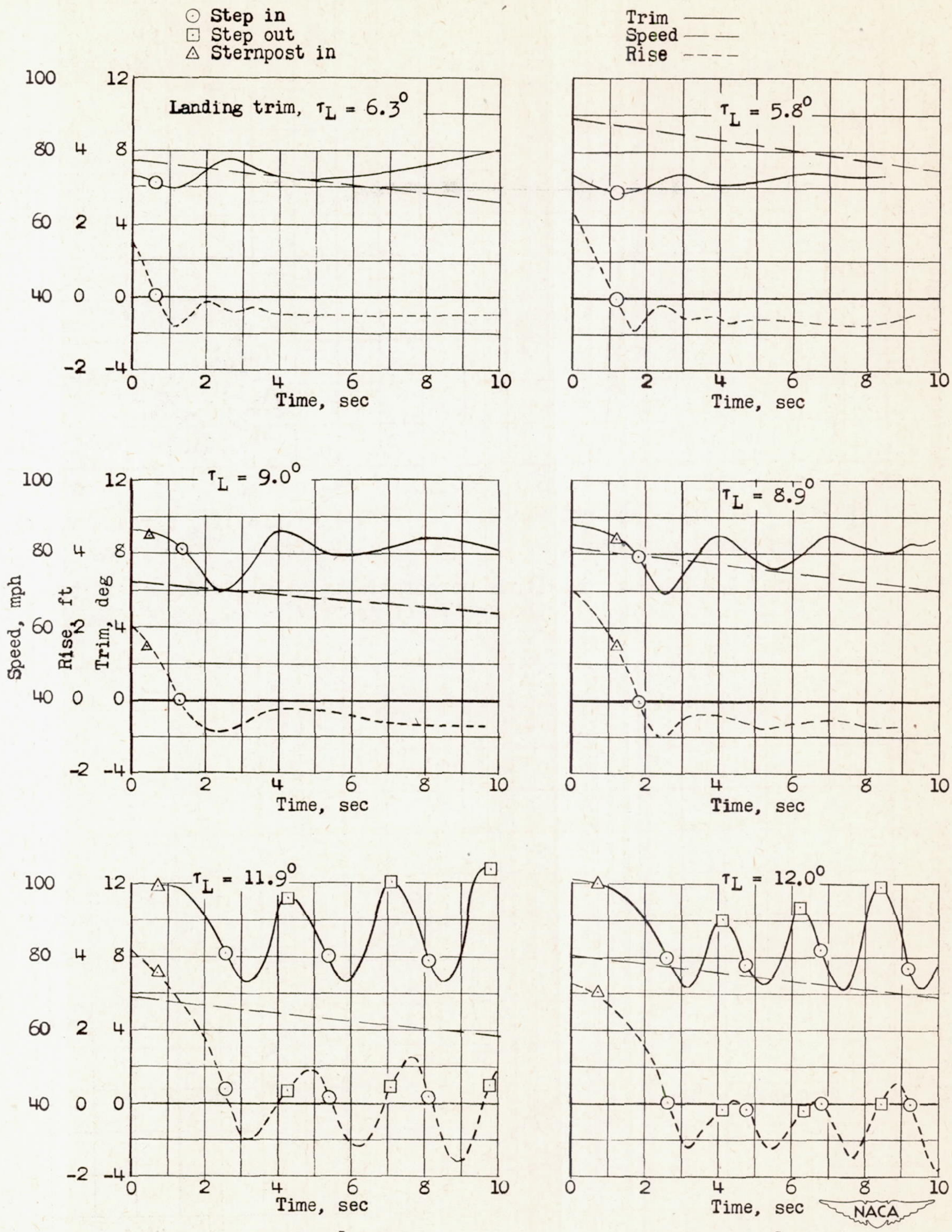


Figure 8.- Variation of center-of-gravity limits of stability with elevator deflection. 2^{0} amplitude of porpoising.



(a) Hull of $\frac{L}{b}$ = 20.

(b) Hull of $\frac{L}{b}$ = 15.

Figure 9.- Variation of trim, rise, and speed with time during landings.

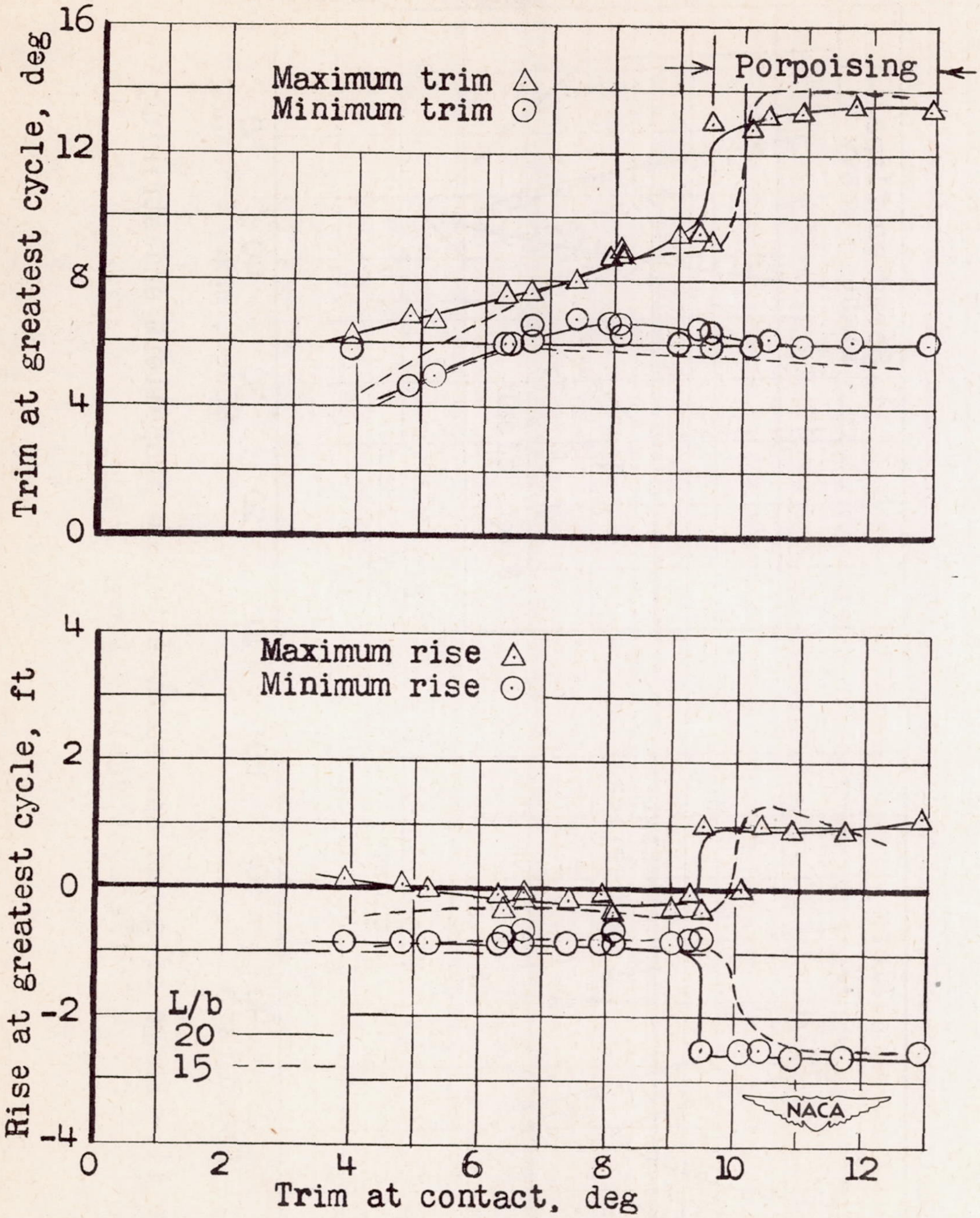


Figure 10.- Variation of maximum and minimum trim and rise with trim at contact during landings in smooth water.

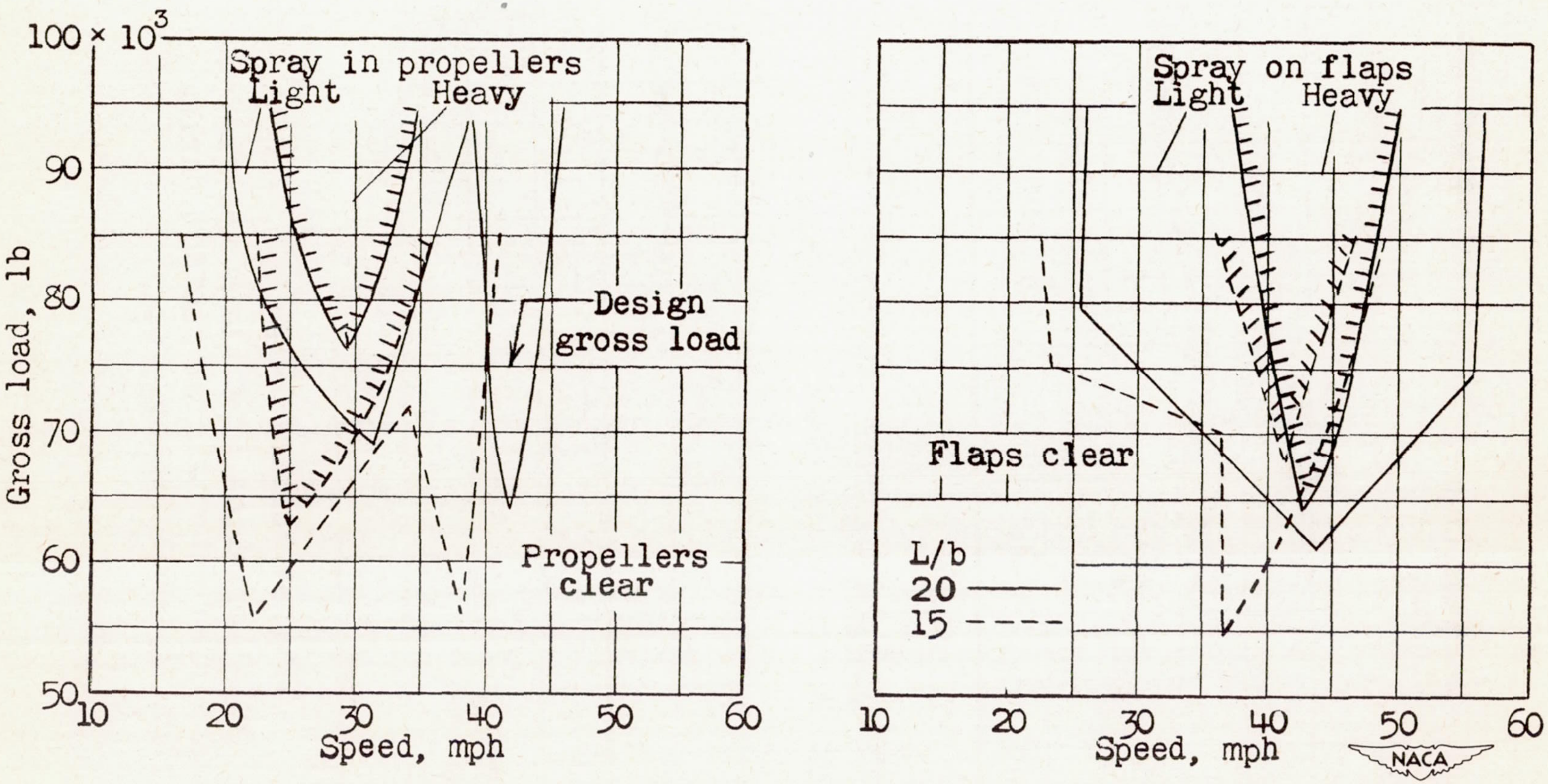
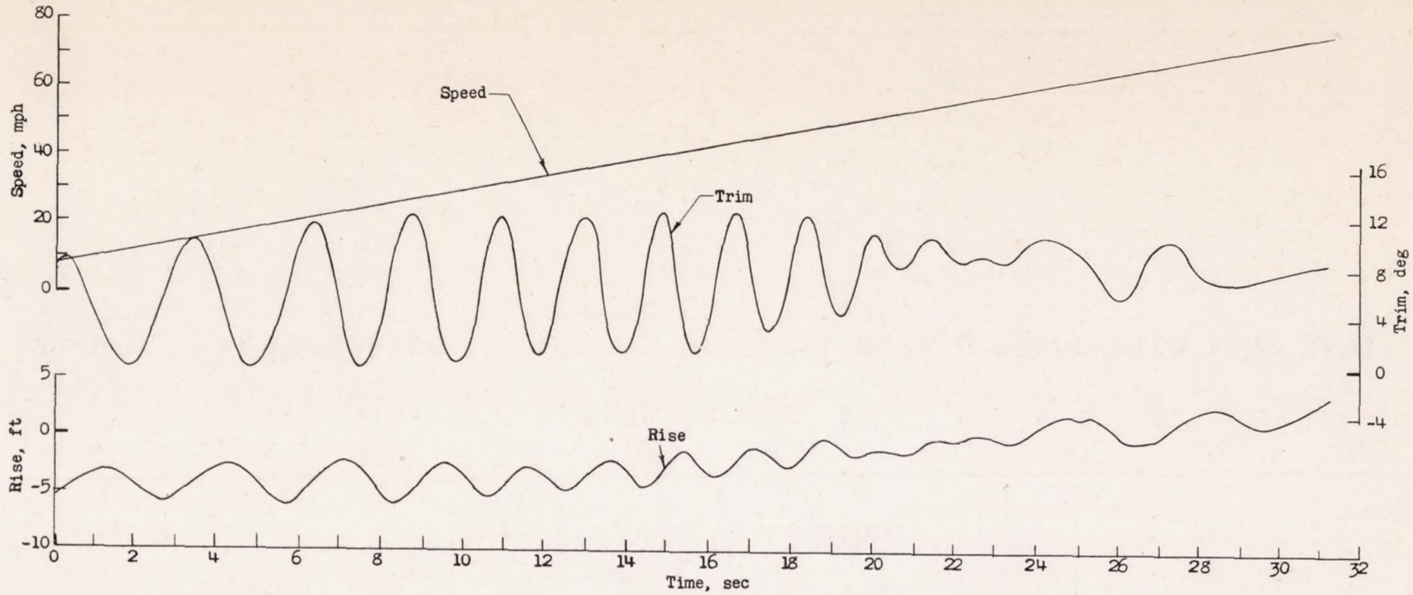
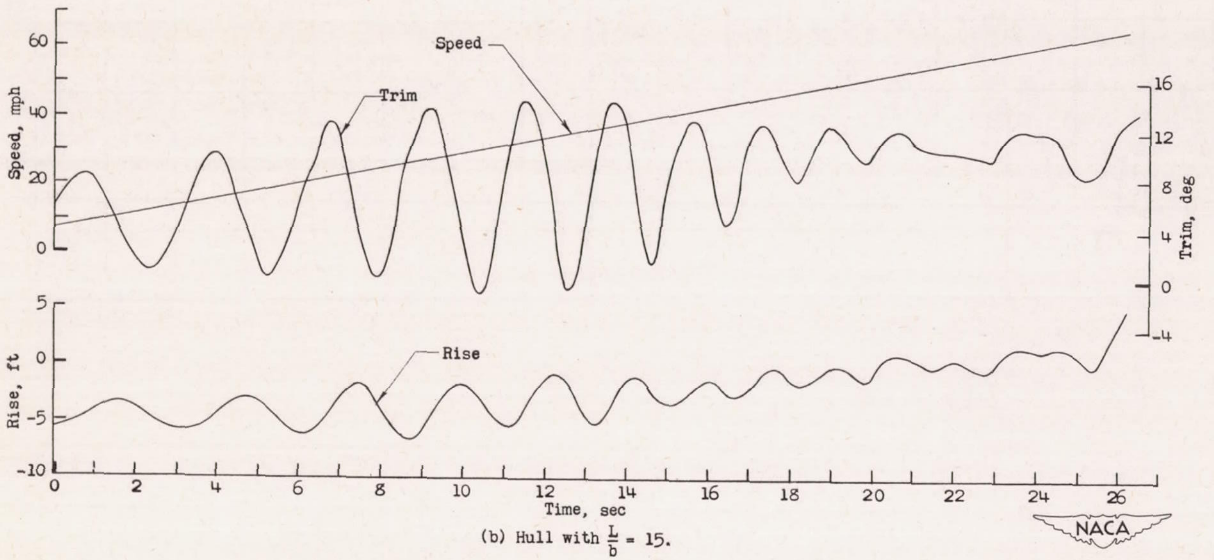


Figure 11.- Range of speed for spray entering propellers and striking flaps at various gross loads.



(a) Hull with $\frac{L}{b} = 20$.



(b) Hull with $\frac{L}{b} = 15$.

Figure 12.- Variation of trim and rise with speed during take-offs in waves 4 feet high and 150 feet long.

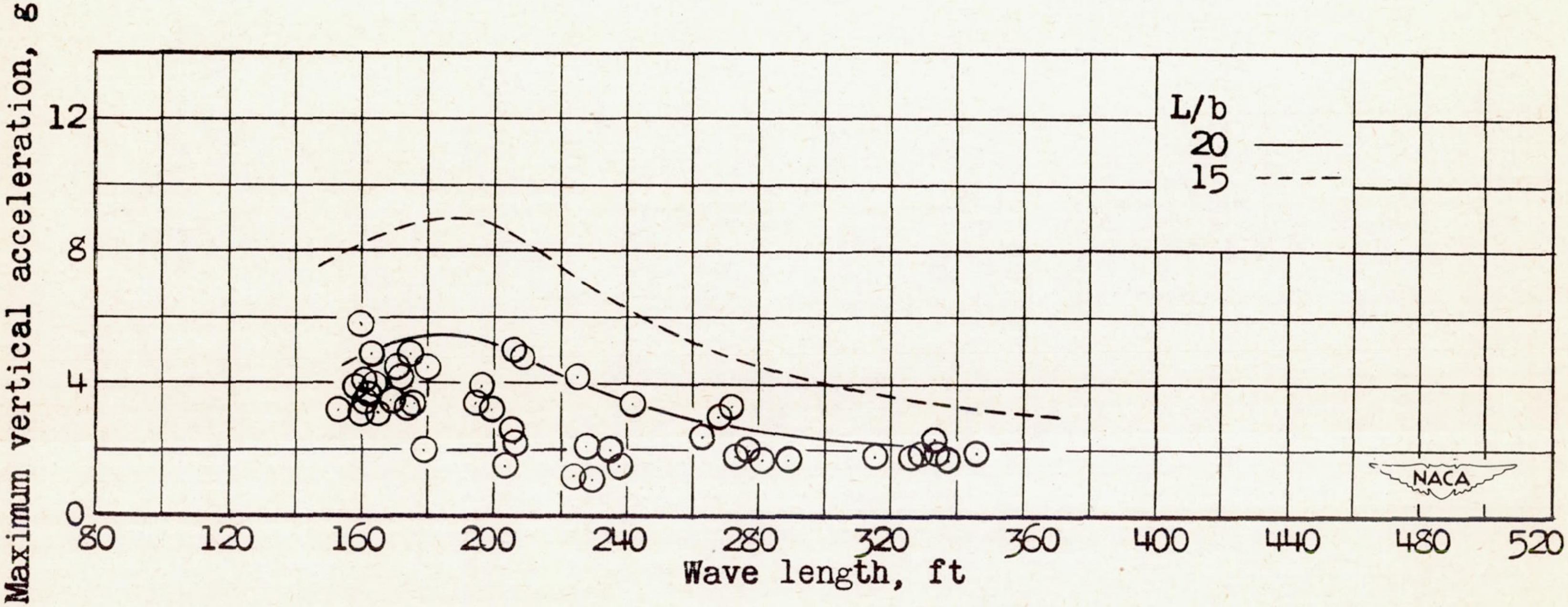


Figure 13.- Variation of maximum vertical acceleration with wave length. Wave height, 4 feet.

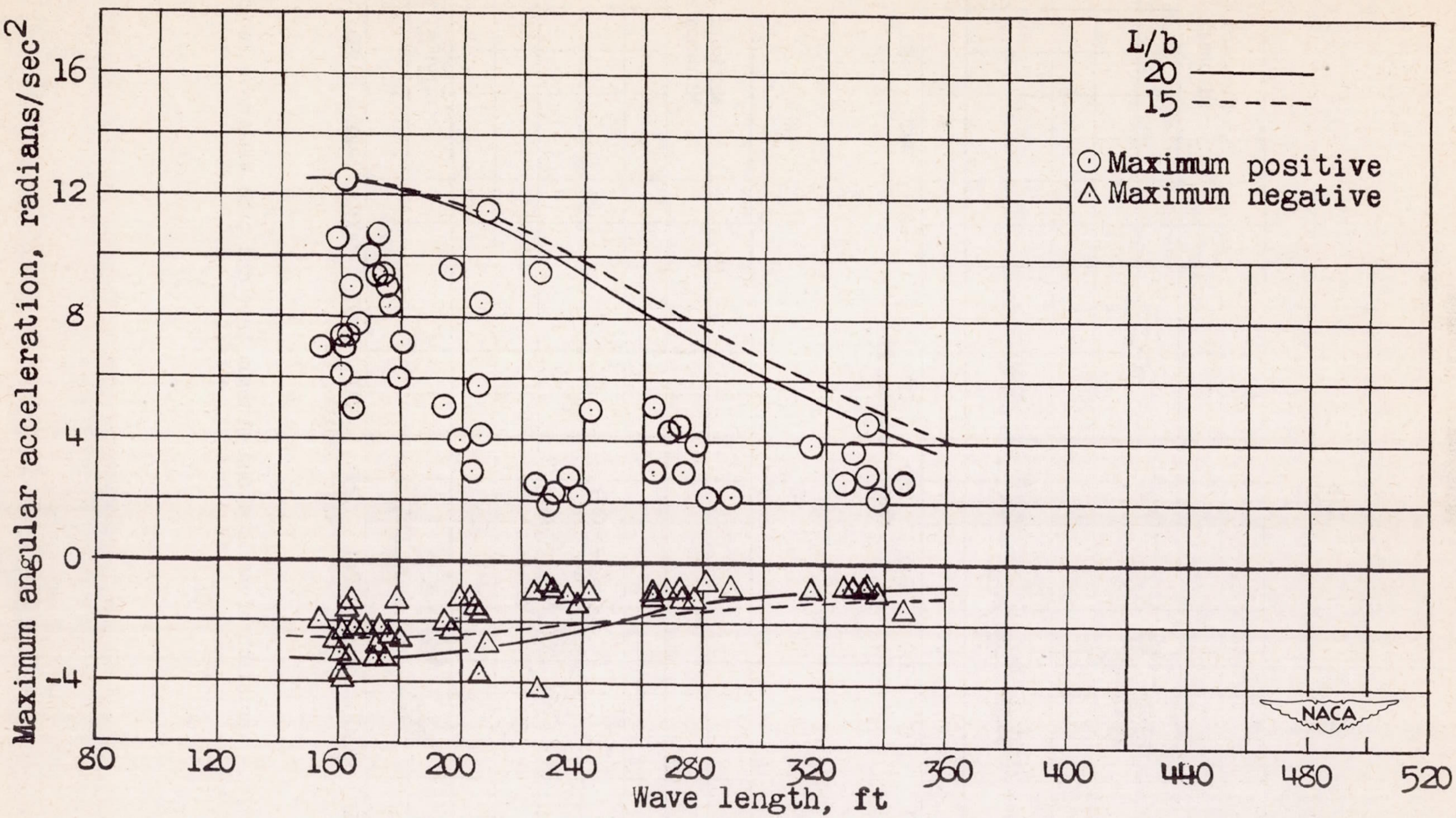


Figure 14.- Variation of maximum angular acceleration with wave length. Wave height, 4 feet.

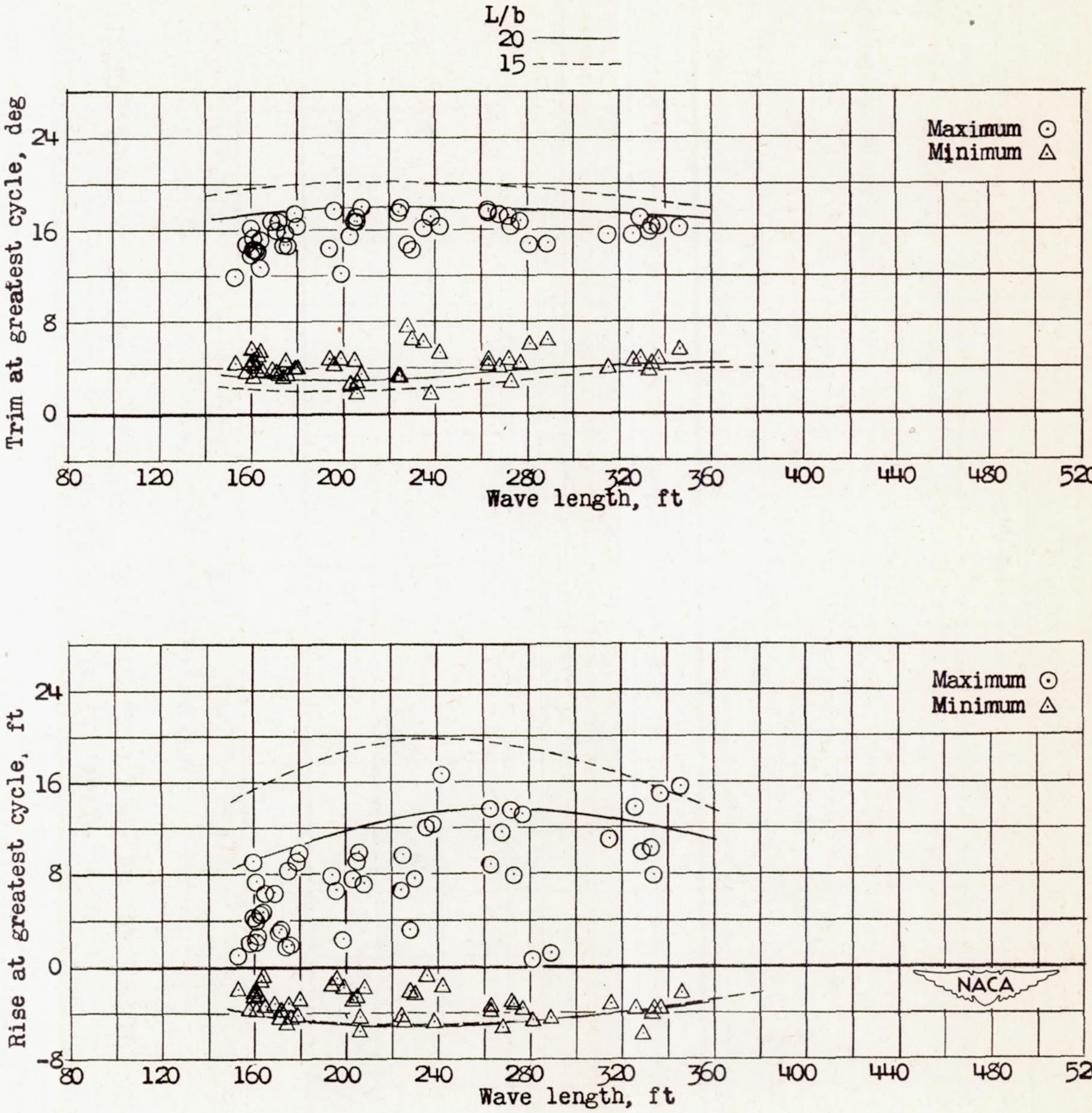
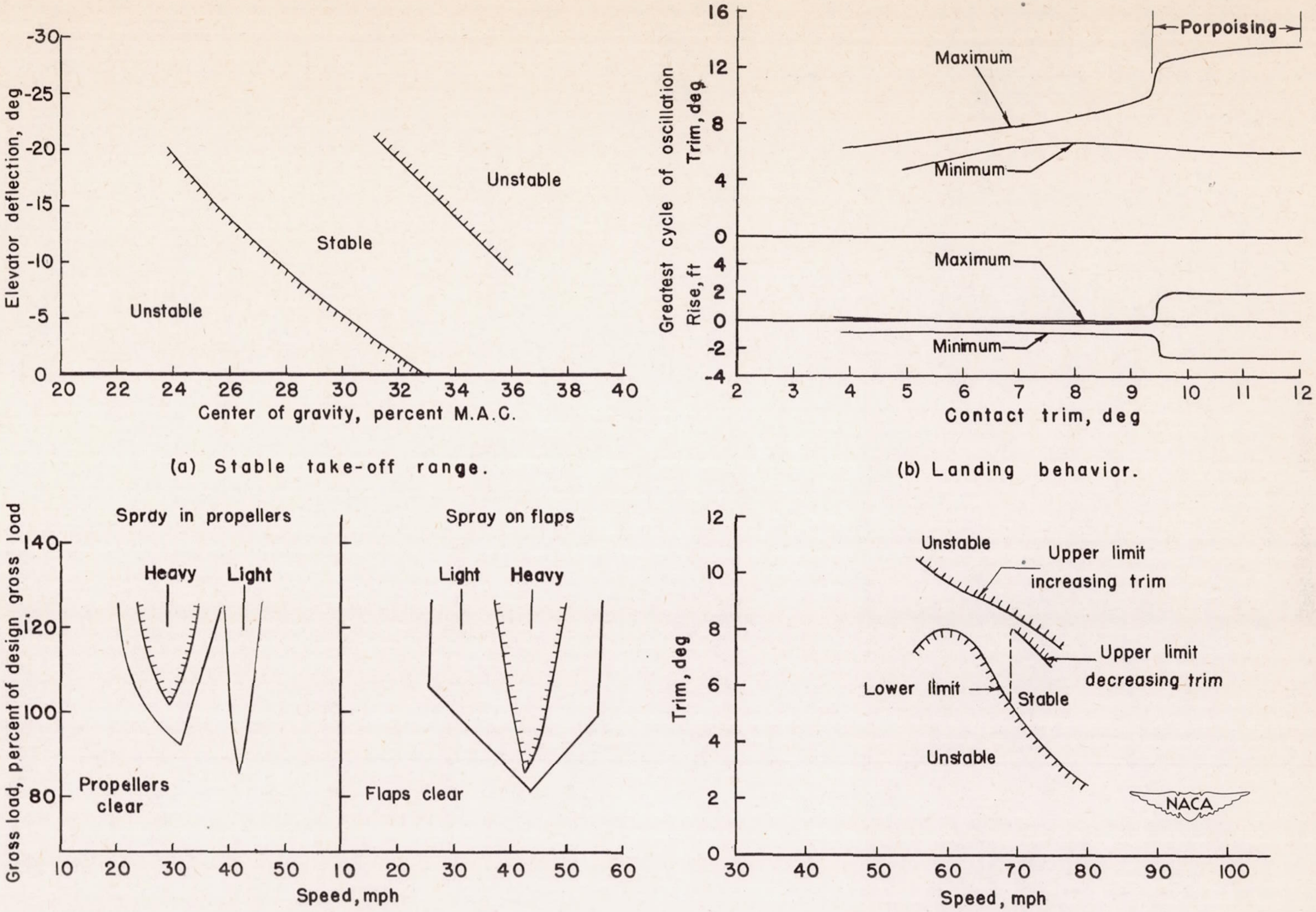


Figure 15.- Variation of maximum and minimum trim and rise with wave length. Wave height, 4 feet.



(a) Stable take-off range.

(b) Landing behavior.

(c) Effect of gross load on spray.

(d) Trim limits of stability.

Figure 16.- Summary chart of principal hydrodynamic qualities of a flying boat having a hull length-beam ratio of 20. Gross load, 75,000 pounds; power loading, 11.5 pounds per brake horsepower; wing loading, 41.1 pounds per square foot; flap deflection, 20°.