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EFFECT OF FOREBODY WARP AND INCREASE IN AFTERBODY LENGTH
ON THE HYDRODYNAMIC QUALITIES OF A FLYING-BOAT
HULL OF HIGH LENGTH-BEAM RATIO

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SUMMARY

In an attempt to achieve improved hydrodynamic qualities for flying boats, an investigation was made to determine the combined effect of a warped forebody and extended afterbody on the hydrodynamic characteristics of a hull having a basic length-beam ratio of 15. Each of these modifications has been found to result in improvements in hydrodynamic qualities and their combined effect is therefore of interest.

The stable range of trims available for take-off was increased by warping the forebody and extending the afterbody. For take-off at constant elevator deflection, the range of center-of-gravity positions for satisfactory take-off stability was increased. The smooth-water landing stability remained satisfactory. Spray characteristics were improved, no spray entering the propellers or striking the flaps at the design gross load. Definite improvements in rough-water landing behavior were obtained with the combination of warped forebody and extended afterbody. For landings in waves 4 feet high, the impact accelerations were reduced more than 50 percent. The maximum amplitudes of oscillation in trim and rise occurring during the landing run-out were also substantially decreased. In general, the changes in hydrodynamic characteristics effected by combining these modifications were in the direction that would be predicted on the basis of results obtained for the individual modifications. Although the effects were not directly additive, they were cumulative and changes in opposite directions were compensating.

INTRODUCTION

Recent towing-tank investigations of flying-boat hulls having high length-beam ratios included the effect of forebody warp and the effect of afterbody length on hydrodynamic characteristics. These

modifications produced improvements in the over-all hydrodynamic characteristics of a hull having a basic length-beam ratio of 15. Warping the forebody reduced the bow spray and reduced the vertical accelerations encountered during landings in waves. See reference 1. Extending the afterbody increased the spray in the propellers but reduced the spray at the horizontal tail and reduced the vertical and angular accelerations during landings in waves. See reference 2. These results indicated that further improvement might be achieved in a single configuration incorporating both the warped forebody and the extended afterbody. The hydrodynamic characteristics of such a hull configuration were accordingly investigated to determine the extent of the improvement to be expected as a result of the combination. These characteristics were determined by the same procedures used in the investigations described in references 1 and 2 and are compared with those of the basic hull (references 3 and 4).

The model was assumed to be a $\frac{1}{10}$ -size powered dynamic model of a twin-engine propeller-driven flying boat having a design gross weight of 75,000 pounds, a gross load coefficient of 5.88, a wing loading of 41 pounds per square foot, and a power loading for take-off of 11.5 pounds per brake horsepower. The hull, which was one of the length-beam-ratio series under investigation at Langley tank no. 1, had a basic ratio of 15. The hydrodynamic characteristics of the basic hull are described in references 3 and 4, and its aerodynamic characteristics are described in reference 5.

SYMBOLS

g	acceleration due to gravity (32.2) feet per second per second
n_v	vertical acceleration, g units
α	angular acceleration, radians per second per second
V	carriage speed (approx. 95 percent of airspeed), feet per second
V_v	sinking speed, feet per second
γ	flight-path angle, degrees
δ_e	elevator deflection, degrees
τ	trim (angle between forebody keel at step and horizontal), degrees
τ_L	landing trim, degrees

DESCRIPTION OF MODEL

The model with the basic length-beam ratio of 15 was described in references 3 and 5. The general arrangement of the flying boat with the warped forebody and extended afterbody (Langley tank model 224J) is shown in figure 1. Hull lines of the model are presented in figure 2. The forebody of this model was modified by progressively increasing the dead rise from the step forward in the manner described in reference 1, thereby eliminating the customary straight buttocks on the forebody planing bottom just forward of the step. The afterbody length was increased from 6.37 to 9.24 beams as described in reference 2, the angle of afterbody keel remaining the same. The depth of step of 24 percent of the beam was the same as that used for tests of the basic model with the extended afterbody. The wing and tail were the same as those used in the tests of the hull having a basic length-beam ratio of 15.

APPARATUS AND PROCEDURES

The description of Langley tank no. 1 is presented in reference 6. The setup of the model and towing gear is shown in figure 3. The apparatus and procedures were identical to those described in reference 2. In all tests the model was free in trim and rise but restrained in roll and yaw.

The hydrodynamic qualities determined were the trim limits of stability, the range of center-of-gravity positions for satisfactory take-off stability, smooth-water landing stability, bow-spray characteristics during take-off, tail-spray characteristics during landings, propeller-spray characteristics while taxiing in waves, and impact accelerations and landing behavior in rough water.

The hydrodynamic qualities were all determined at a design gross load corresponding to 75,000 pounds except for the spray investigation in which gross loads from 75,000 to 95,000 pounds were included. The flaps were deflected 20° for all the hydrodynamic tests. With the exception of the landing tests, the hydrodynamic qualities were determined with full thrust. The landings in smooth water were made with approximately half thrust. In rough water the thrust was set so that the model was self-propelled during most of the landing run-out. Landing and spray tests were made with the center of gravity at 32 percent mean aerodynamic chord. The results have been converted to full-size units and all data with the exception of table I are presented as full-size values.

RESULTS AND DISCUSSION

Longitudinal Stability

Trim limits of stability.- The trim limits of stability for the configuration with the warped forebody and extended afterbody are presented in figure 4, together with those for the basic hull. The differences in the trim limits for the modified and basic hulls are consistent with those expected on the basis of previous investigations of forebody and afterbody modifications as described in references 1 and 2, respectively. The peak of the lower limit for the modified hull was lower than that of the basic hull. This change is similar to that obtained for the model with an extended afterbody and is in agreement with trends noted in investigations of other models (reference 7). Warping the forebody resulted in a shift of the entire lower trim limit to lower speeds so that, for most speeds beyond the hump, the lower limit was about 2° below that of the basic hull. Since lower-limit porpoising is principally a forebody phenomenon, extending the afterbody would not be expected to affect this limit except near hump speeds. Both branches of the upper trim limit were lowered approximately 1° at high speeds. The upper-limit porpoising, being affected principally by the afterbody, is not greatly influenced by the presence of the warped forebody and, consequently, the behavior of the model with the warped forebody and the extended afterbody was similar to that of the model with the extended afterbody alone. The available aerodynamic trimming moment was not great enough to trim the model to the upper limit at speeds below 64 miles per hour, principally because of the presence of the long afterbody. The stable range of trims was therefore substantially increased throughout the entire speed range up to take-off by combining the warped forebody with the extended afterbody.

Center-of-gravity limits of stability.- Representative trim tracks for take-off at several positions of the center of gravity and elevator deflections are presented in figure 5 for the modified and basic hulls. From such trim tracks, a plot of maximum amplitude of porpoising against center-of-gravity position was obtained. The maximum amplitude of porpoising is defined as the difference between the maximum and minimum trims that occurred during the greatest trim cycle. The maximum amplitudes of porpoising for the modified hull are plotted in figure 6 and compared in figure 7 with those for the basic hull. The position of the center of gravity at which lower-limit porpoising first appeared was shifted slightly aft for the modified hull. (See fig. 7(a).) Once lower-limit porpoising was encountered, the increase in amplitude with forward movement of the center of gravity was less for the modified hull than for the basic hull. This behavior is similar to that noted for the model with the extended afterbody, reference 2, and is

attributed to the increased damping of the oscillations in trim with the extended afterbody. At after positions of the center of gravity, the maximum amplitude of upper-limit porpoising for the modified hull was less than 2° . This reduction in the maximum amplitude was also attributed to the effectiveness of the extended afterbody in damping the oscillation in trim.

The practical center-of-gravity limit for a given elevator deflection is usually defined as that position of the center of gravity at which the amplitude of porpoising becomes 2° . Such a plot is presented in figure 8. Since the amplitude of upper-limit porpoising of the modified hull did not reach 2° , there is no after limit for this hull. Absence of the after limit is consistent with the results obtained with the extended afterbody (reference 2). This similarity of results would be expected inasmuch as the afterbody has a major influence on upper-limit porpoising which occurs at the after center-of-gravity limit. The forward limit of the modified hull was substantially the same as that of the basic hull, since the shift of the lower trim limit of stability to lower trims was accompanied by a compensating shift of the free-to-trim tracks to lower trims. Because of the elimination of the after limit, the take-off stability characteristics were improved by warping the forebody and extending the afterbody.

Landing Stability

Typical time histories of smooth-water landings made with the modified and basic hulls are presented in figure 9. These and similar time histories were used to determine the maximum amplitudes of oscillation in trim and rise of the center of gravity, which are plotted in figure 10.

The step was sufficiently deep to prevent skipping of both models at all the contact trims investigated, skipping being defined as the complete emergence of the hull from the water. The maximum trim amplitudes were comparable up to landing trims of 10° , except that the cycles of oscillation of the modified hull occurred at lower trims. Above 10° , the basic hull encountered greater oscillations. During some landings the modified hull encountered lower-limit porpoising during the run-out after being initially stable, see figure 9(c). This porpoising, which is similar to that noted in reference 2 for the model with the extended afterbody, did not start until the speed decreased to approximately 75 percent of landing speed and would be avoidable through proper control of the elevators. The maximum rise amplitudes were comparable to those of the basic model. The increased amplitudes of trim and rise and the lower-limit porpoising for the model with the extended afterbody (reference 2) apparently were partly compensated by the beneficial effect of warped forebody (reference 1). In general,

the smooth-water landing characteristics of the modified hull were considered satisfactory.

Spray Characteristics

A plot of gross load against the speed range over which spray entered the propellers and struck the flaps is presented in figure 11. The modified hull encountered no propeller spray at the design gross load of 75,000 pounds. (See fig. 12.) Observations indicate that propeller spray comparable to that of the basic hull at design gross load was approximated at a gross load of 85,000 pounds (fig. 13) which represents an overload of approximately 11 percent. No flap spray was encountered at design gross load and no heavy flap spray was encountered by the modified hull at any load investigated. This improvement in spray characteristics was attributed to the effectiveness of the warped forebody in reducing the height of the bow blister even though the trims were lower. Photographs showing the maximum flap spray at design gross load for both models are presented in figure 14.

Photographs of heaviest spray striking the horizontal tail surfaces during landings are shown in figure 15. Spray on the horizontal tail was considerably lessened with the extended afterbody.

The spray diagram obtained during taxiing tests in waves 2 feet high and 110 feet long is presented in figure 16. This spray was fairly heavy but occurred over a smaller range of speed and load than for the basic hull. The net effect of combining the warped forebody with the extended afterbody was a definite improvement in all spray characteristics.

Landings in Waves

The rough-water landings were made in oncoming waves 4 feet high varying in length from 130 to 360 feet. Pertinent data obtained from records of these landings are presented in table I.

The maximum vertical and angular accelerations are plotted against wave length in figure 17. The maximum vertical acceleration of $4g$ encountered by the modified hull was approximately 55 percent lower than the maximum encountered by the basic hull and approximately 30 percent lower than the maximum obtained during tests of configurations incorporating either the warped forebody or extended afterbody modifications alone (references 1 and 2). The maximum positive angular accelerations for the modified hull were 59 percent less than those of the basic hull, 19 percent less than those of the warped forebody alone,

and 39 percent less than those of the extended afterbody alone. The maximum negative angular accelerations remained relatively unchanged.

The maximum and minimum values of trim and rise at the greatest cycle of oscillation during each landing are plotted against wave length in figure 18. The maximum amplitudes of oscillation in trim of the modified hull were approximately 25 percent lower than those of the basic hull and of the warped-forebody configuration, and were substantially the same as those of the extended-afterbody configuration. The modified hull reduced the maximum amplitudes of oscillation in rise of the basic hull and of the warped-forebody configuration by approximately 20 percent, and increased those of the extended-afterbody configuration by approximately the same percentage.

Summary Chart

The hydrodynamic qualities in smooth water of the flying boat with a high-length-beam-ratio hull having a warped forebody and an extended afterbody are summarized in figure 19. This chart gives an over-all picture of the hydrodynamic characteristics in terms of full-scale operational parameters. It is therefore useful for comparisons with similar data regarding other seaplanes for which operating experience is available.

CONCLUSIONS

The effects of combining a warped forebody and an extended afterbody on a hull having a high length-beam ratio are as follows:

1. The stable range of trims available for take-off was substantially increased throughout the entire speed range to take-off.
2. The center-of-gravity limits of stability were improved, chiefly by the elimination of a practical after limit.
3. The smooth-water landing stability characteristics were approximately the same as those for the basic hull.
4. Spray characteristics were considerably improved; there was no propeller or flap spray at design gross load. Tail spray encountered during landings was considerably reduced.

5. Rough-water landing behavior was improved; reductions in the maximum impact acceleration of greater than 50 percent and in the maximum angular acceleration of approximately 60 percent were obtained as compared with those for the basic model.

6. During landings in waves the maximum amplitudes of oscillation in trim and rise attained during the high-speed portion of the run-out were reduced.

7. In general, the effect of the combination of the hull modifications (warped forebody and extended afterbody) on hydrodynamic characteristics was in the direction expected on the basis of the cumulative effect of the separate modifications.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Air Force Base, Va., March 9, 1949

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TABLE I

DATA OBTAINED DURING LANDINGS IN WAVES OF LANGLEY TANK MODEL 224J

[All values are model size;

wave height = 0.4 foot for all landings]

Landing	Wave length (ft)	Initial impact						Maximum acceleration						
		τ_L (deg)	V_v (fps)	V (fps)	γ (deg)	n_v (g)	$\frac{a}{\text{radians}} \text{sec}^2$	Impact	τ (deg)	V_v (fps)	V (fps)	γ (deg)	n_v (g)	$\frac{a}{\text{radians}} \text{sec}^2$
1	13.4	7.4	1.08	35.6	1.7	2.6	9	4	5.0	2.10	30.6	3.9	2.9	21
2	13.6	7.6	1.04	35.1	1.7	1.5	5	4	6.5	1.62	28.8	3.2	3.0	18
3	13.7	7.5	1.19	34.0	2.0	1.8	10	4	5.0	2.10	28.8	4.2	2.8	26
4	14.0	7.2	1.05	35.0	1.7	1.7	10	3	4.8	2.51	31.2	4.6	4.0	28
5	14.2	7.6	1.04	35.1	1.7	2.2	11	3	4.3	2.68	27.6	5.5	3.7	38
6	14.7	7.4	1.30	34.0	2.2	2.1	16	2	4.4	2.10	31.8	3.8	3.4	32
7	15.6	7.2	1.17	36.1	1.9	1.5	0	5	4.4	3.06	28.7	6.1	3.7	39
8	15.6	7.3	1.43	34.9	2.1	.9	0	4	3.9	2.62	28.5	3.3	2.9	40
9	15.8	7.5	1.42	36.0	2.3	2.1	13	2	5.6	2.98	33.6	5.1	2.7	28
10	16.0	7.4	1.53	36.1	2.4	.9	5	4	4.1	2.77	29.7	5.3	3.3	32
11	16.1	7.7	1.10	34.0	1.9	2.9	22	1	4.6	1.71	33.6	2.9	2.9	22
12	16.4	7.6	.81	37.5	1.2	.9	0	a3	2.8	3.49	28.6	7.0	2.0	41
13	16.4	7.4	1.30	36.1	2.1	1.9	9	a5	3.2	2.52	30.5	4.7	2.1	31
14	16.5	7.3	.79	37.4	1.2	1.8	10	a6	2.9	3.65	29.2	7.1	2.0	44
15	16.5	7.6	1.41	35.9	2.2	.7	-10	a6	5.0	2.04	29.5	4.0	2.8	20
16	16.6	7.3	1.49	36.0	2.4	2.1	16	(b)	5.2	2.49	27.9	5.1	2.3	25
17	16.9	7.4	.82	37.1	1.3	1.2	0	4	6.5	2.56	32.8	4.5	1.9	12
18	17.1	7.6	1.03	36.3	1.6	0	3	4	6.7	2.16	27.2	4.5	1.9	16
19	17.4	7.3	.74	38.2	1.1	0	0	a5	4.7	2.23	29.0	4.6	2.6	30
20	18.2	7.4	1.29	36.0	2.0	2.0	20	a4	1.3	2.92	31.5	5.3	2.9	28
21	18.7	---	.89	35.5	1.4	0	0	4	4.2	2.48	30.0	4.7	2.8	31
22	18.9	7.7	1.09	35.2	1.8	.8	0	a6	3.7	2.63	30.5	4.9	2.4	30
23	19.2	7.7	1.26	35.4	2.0	1.2	0	a5	3.4	2.71	29.5	5.2	2.1	41
24	19.4	---	1.06	36.0	1.7	1.0	0	a4	6.0	2.78	27.3	5.8	1.9	25
25	19.7	7.4	.81	37.0	1.2	1.4	7	4	4.3	2.36	29.2	4.6	1.5	30
26	20.1	7.8	.99	37.4	1.5	1.6	15	a6	3.1	3.25	32.9	5.6	2.8	30
27	20.3	7.8	1.05	37.1	1.6	.7	-10	3	4.2	4.21	29.0	8.2	1.9	40
28	21.7	7.5	1.34	36.5	2.1	.8	0	2	---	2.47	31.7	4.5	3.2	30
29	22.7	8.0	1.06	36.0	1.4	1.2	-10	a4	---	3.58	27.6	7.4	2.0	32
30	23.0	7.5	---	36.8	---	.9	0	4	3.6	3.61	28.5	7.2	2.3	36
31	23.0	7.7	1.00	35.8	1.8	1.2	9	3	5.2	2.68	31.4	4.9	2.3	30
32	23.1	8.0	1.40	36.0	2.2	1.6	17	a4	---	2.76	24.3	6.5	2.5	30
33	23.2	7.7	1.06	36.3	1.7	0	-10	a4	---	3.29	29.2	6.4	1.6	32
34	23.3	7.5	1.32	36.6	2.0	1.9	19	2	4.9	1.93	35.0	3.2	2.1	12
35	23.4	7.3	1.48	35.8	2.4	1.3	10	a6	2.9	3.15	28.9	6.2	1.1	27
36	23.4	7.6	1.01	36.1	1.6	1.4	8	3	4.6	4.25	31.4	7.7	3.0	55
37	23.6	8.5	.87	35.3	1.4	0	0	5	4.0	4.39	27.9	8.9	2.2	40
38	23.6	7.5	1.22	36.9	1.9	1.0	0	a3	6.3	1.09	36.0	1.7	2.6	19
39	24.1	8.0	.97	35.9	1.5	1.1	0	2	4.9	4.39	28.7	8.7	2.2	40
40	24.8	8.4	.86	36.8	1.3	1.8	18	a4	8.5	3.20	32.5	5.6	2.3	-10
41	25.9	7.8	1.01	36.1	1.6	1.0	0	5	4.9	4.28	28.4	8.6	2.1	29
42	26.0	8.2	1.12	36.6	1.8	1.3	16	4	---	9.5	---	---	2.1	12
43	26.8	7.9	1.13	38.0	1.7	1.0	0	5	5.3	---	27.3	---	1.2	20
44	27.1	7.9	1.61	38.2	2.4	1.3	13	3	10.0	3.30	30.0	6.3	2.2	44
45	27.2	7.8	.96	36.6	1.5	.6	0	a2	3.1	3.12	32.6	5.5	1.6	25
46	27.7	7.9	.97	38.0	1.5	.9	0	a2	3.1	3.75	29.3	7.3	2.2	19
47	28.1	7.9	.89	37.3	1.4	1.2	18	a2	1.8	2.43	31.9	4.4	1.7	21
48	32.5	7.8	.98	37.8	1.5	1.1	0	4	8.8	4.47	29.1	8.7	2.9	21
49	32.6	7.9	.97	39.0	1.5	1.0	0	3	9.6	3.21	30.3	6.1	2.4	-35
50	32.7	7.9	1.26	37.8	1.9	1.1	0	a2	3.9	3.29	32.4	5.8	1.9	31
51	34.0	7.8	.98	38.8	1.5	1.0	0	4	4.8	3.12	30.3	5.9	2.1	29
52	34.1	7.8	1.41	38.9	2.1	1.3	0	a2	3.1	3.30	30.6	6.1	2.0	10
53	34.8	7.9	.79	37.5	1.2	.6	0	4	4.1	2.28	32.6	4.0	1.1	17
54	35.3	7.7	1.00	36.3	1.6	0	0	2	8.3	3.02	31.8	5.4	2.4	4
55	36.1	7.7	1.06	36.0	1.6	1.2	0	a2	3.6	4.18	28.3	8.4	2.0	30
								5	4.6	3.84	29.0	7.5	2.1	31
								4	4.6	3.59	30.4	6.7	2.0	29
								3	4.4	3.09	30.8	5.7	2.1	29
								6	8.0	2.74	26.0	6.0	2.0	-14
								4	5.5	4.04	30.1	7.6	1.9	25
								4	9.1	2.66	27.0	5.6	2.1	-11
								a6	2.1	3.41	23.8	8.2	1.5	31
								a8	8.2	3.05	28.4	6.1	2.2	-22
								4	4.10	23.6	9.8	1.4	34	
								7	8	4.16	24.0	9.8	1.8	41
								3	7.4	4.14	30.2	7.8	2.6	19
								4	4.0	4.67	31.1	8.5	2.2	31
								3	8.7	4.17	31.2	7.6	3.1	-37
								a7	3.9	3.62	24.5	8.4	1.9	30
								5	5.4	4.08	28.0	8.3	1.6	18
								5	5.6	3.74	30.3	7.0	2.0	25
								3	8.0	4.10	32.8	7.1	2.2	20
								3	5.2	3.95	34.2	6.6	2.1	28
								5	6.1	3.86	30.0	7.3	2.0	21
								4	6.6	3.63	29.7	7.0	1.8	13
								4	6.9	3.00	26.9	6.4	1.9	13
								4	9.3	3.15	28.9	6.2	2.1	-30
								a3	5.3	2.67	30.8	5.0	1.1	16

^aImpact for maximum angular acceleration.^bMaximum angular acceleration resulted from model planing on waves rather than directly from an impact.

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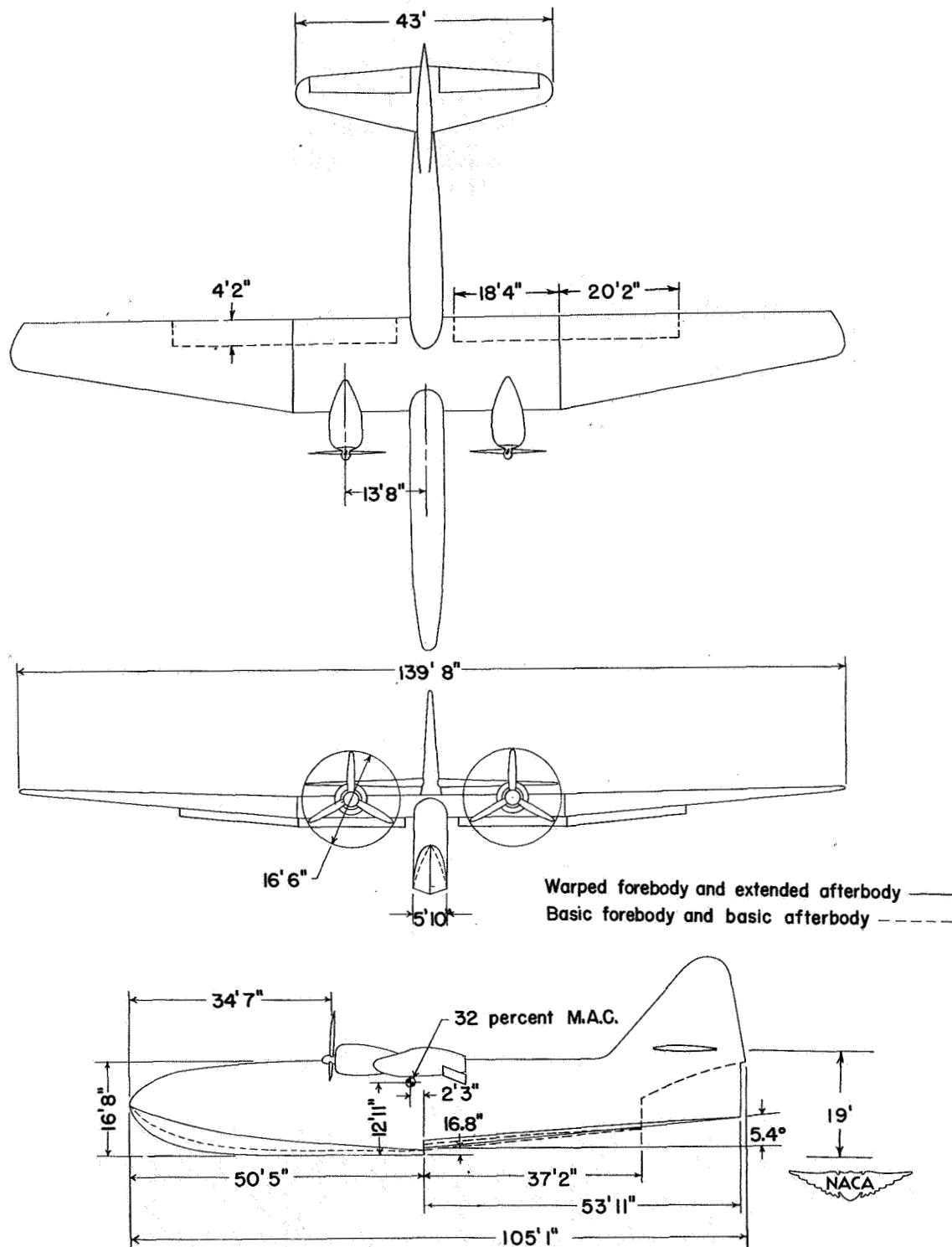
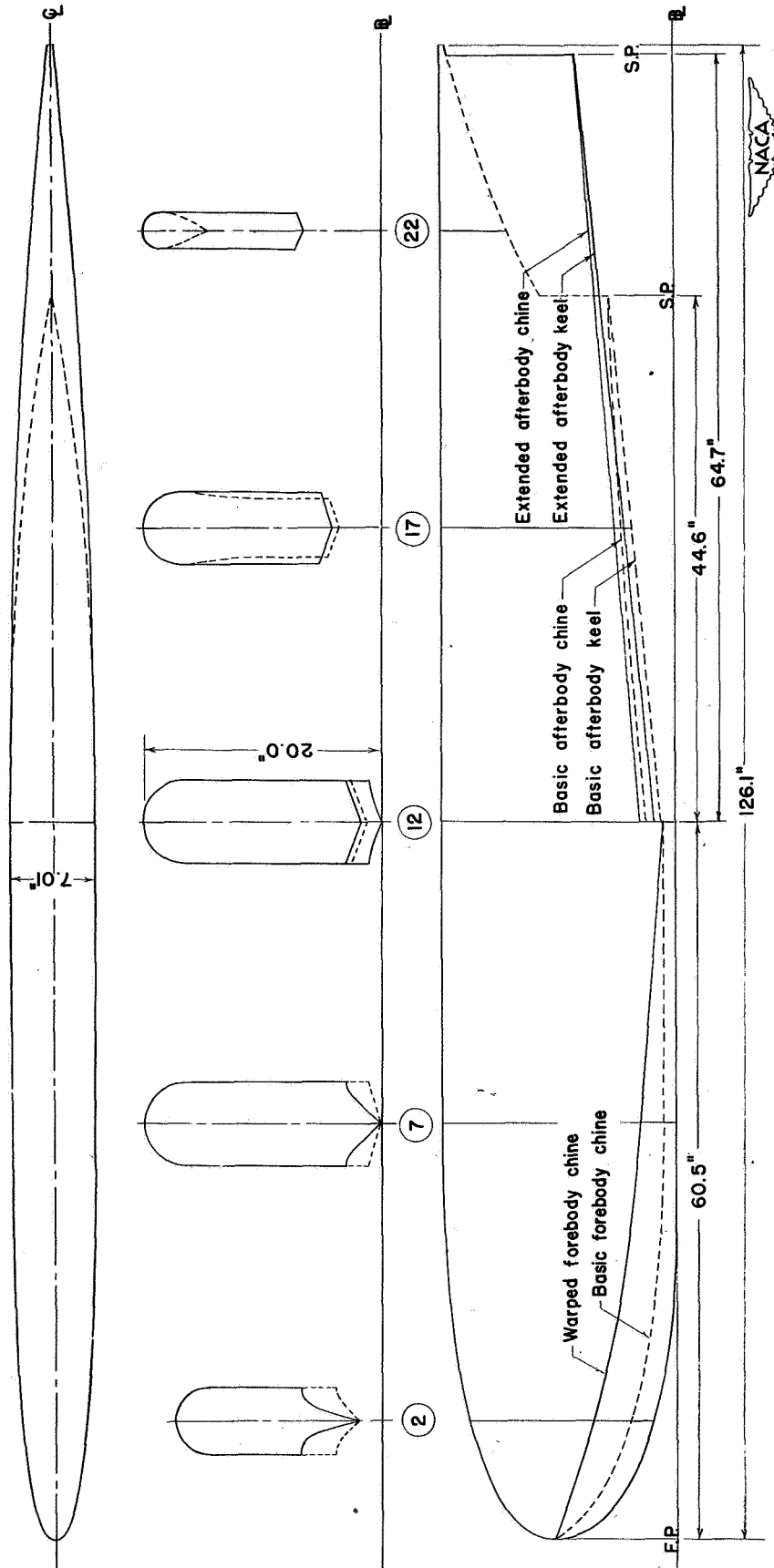
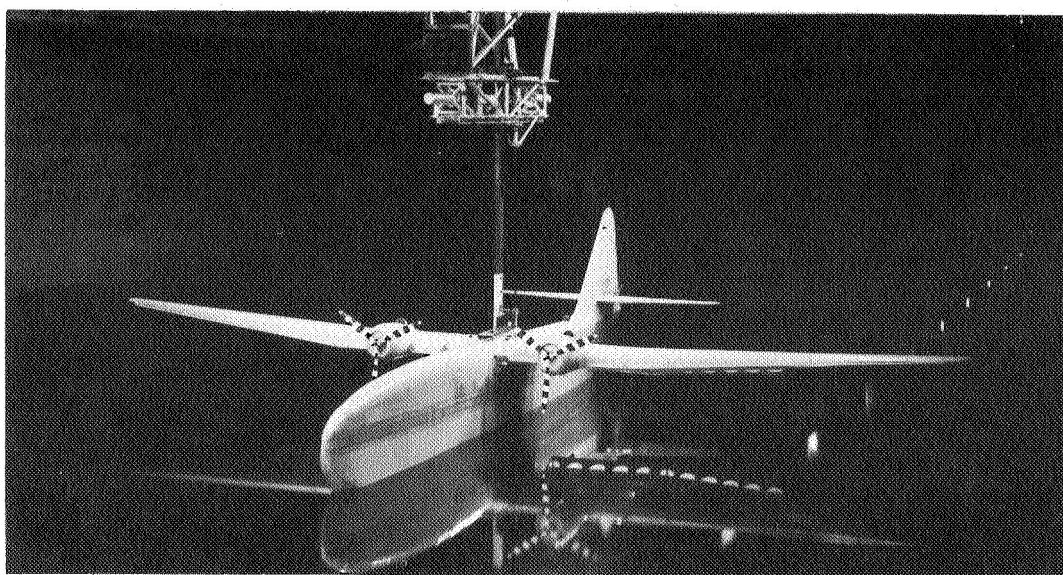
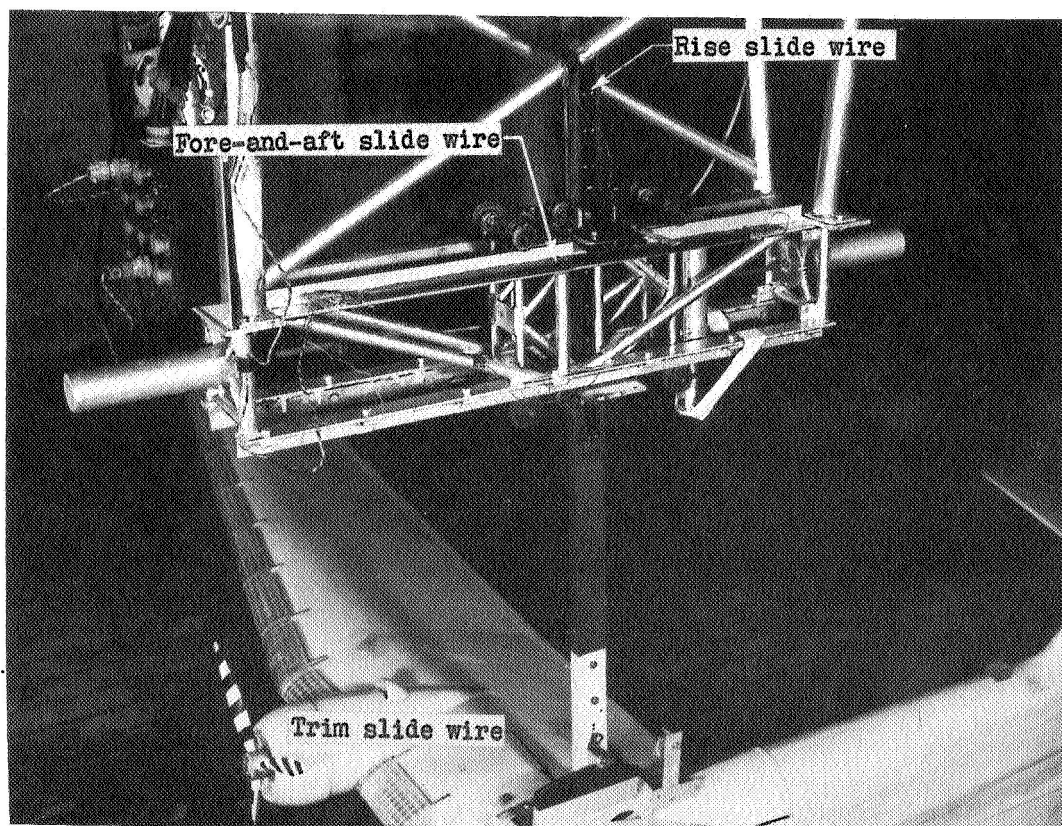


Figure 1.- General arrangement.





(a) Setup of model on towing apparatus.



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

Figure 3.- Model and towing apparatus.

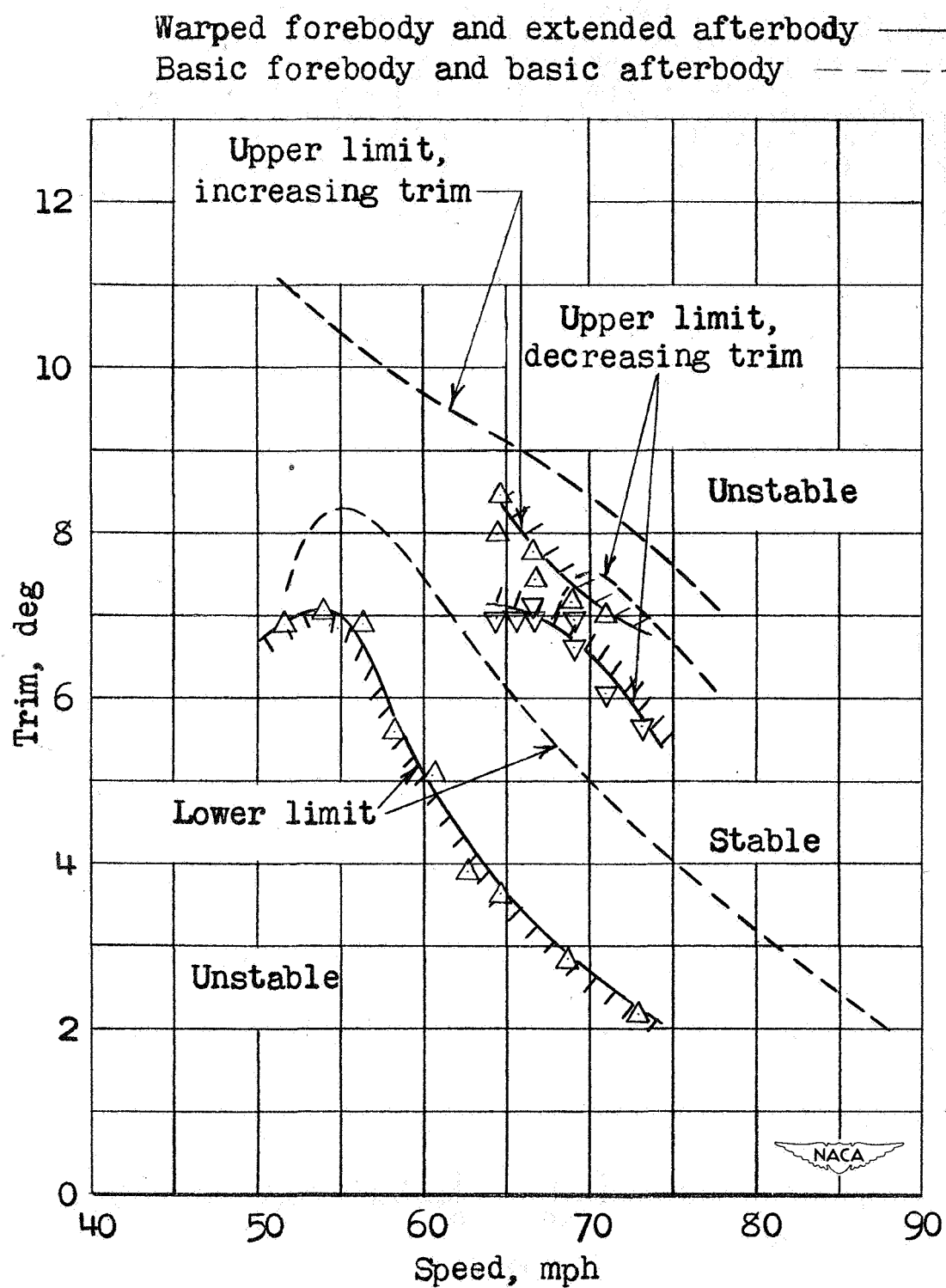


Figure 4.- Trim limits of stability.

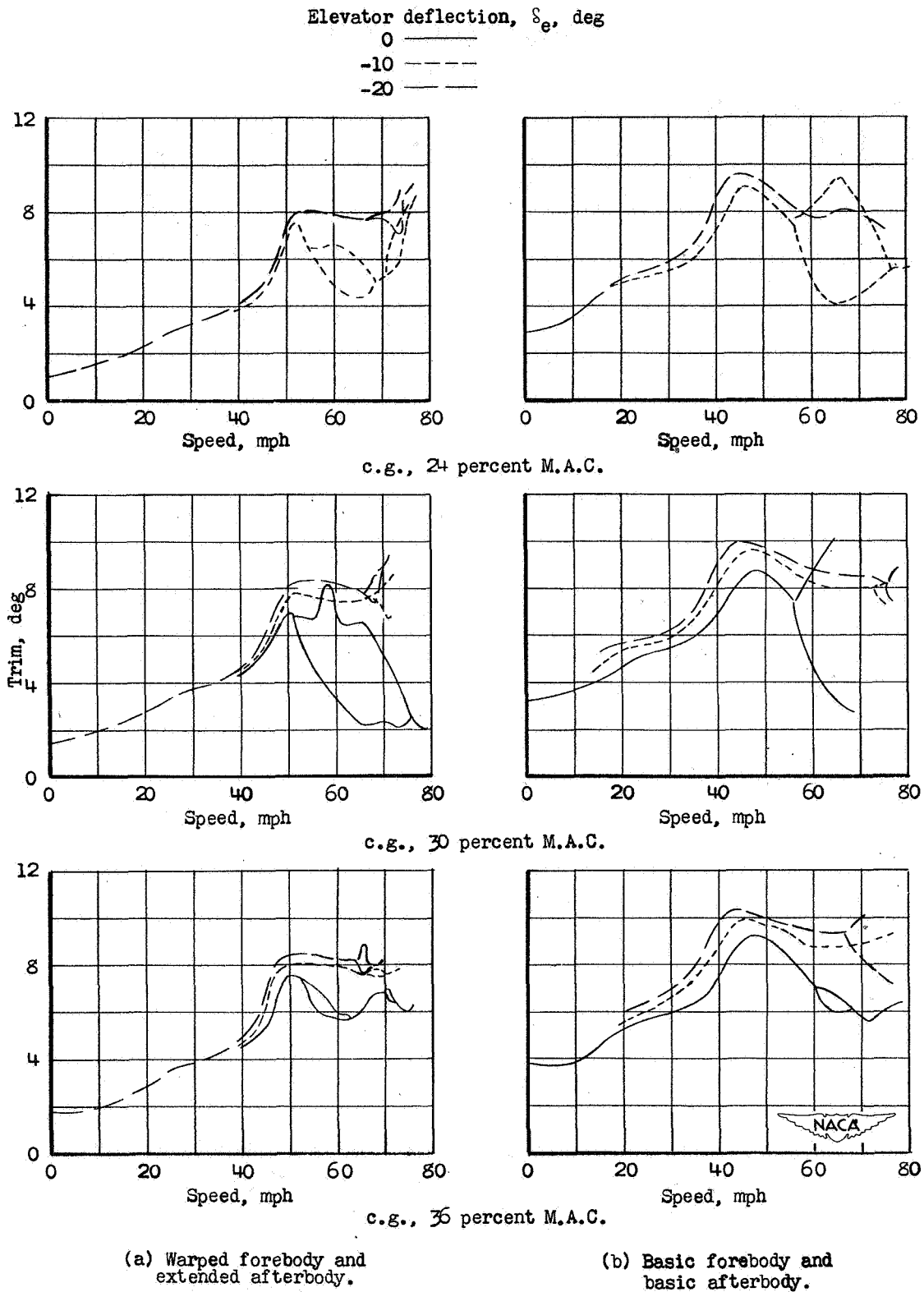
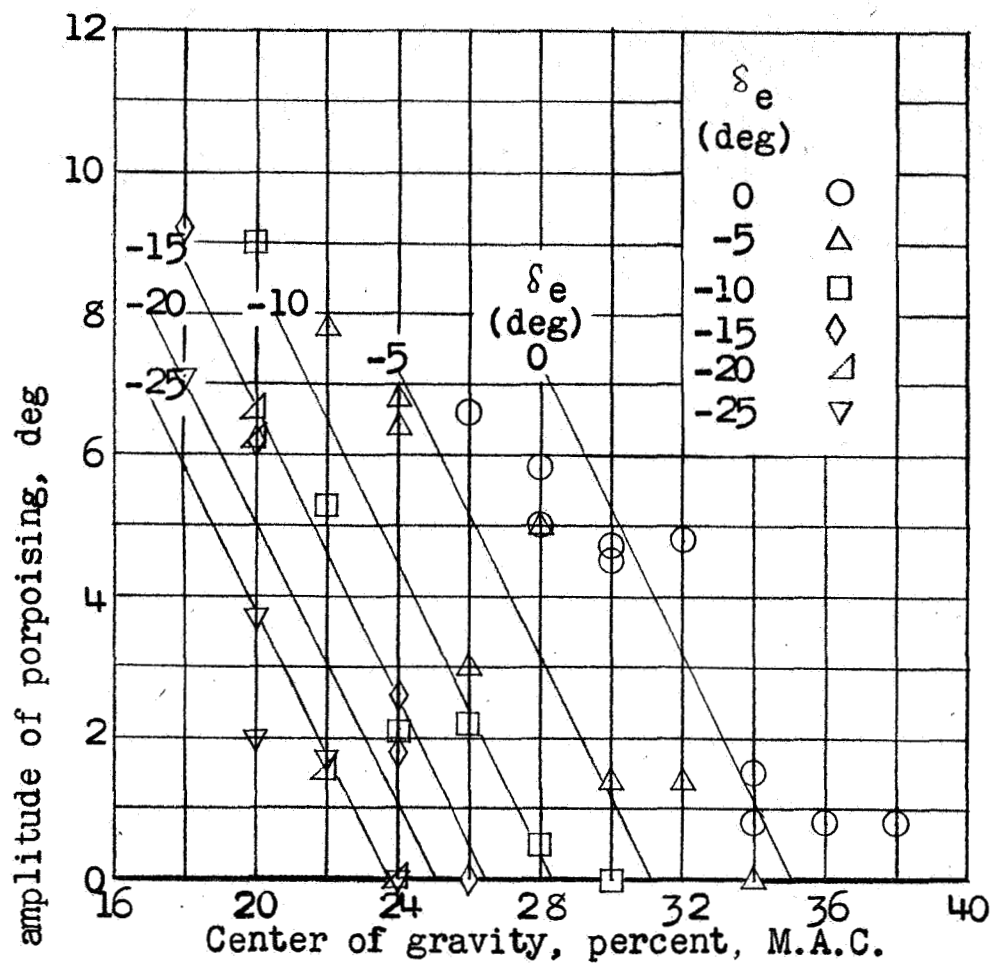
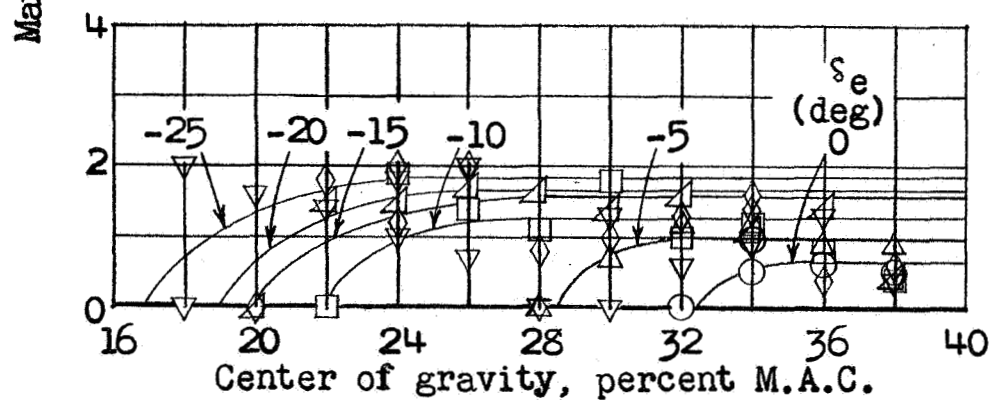


Figure 5.- Variation of trim with speed during take-off.



(a) Lower-limit porpoising.

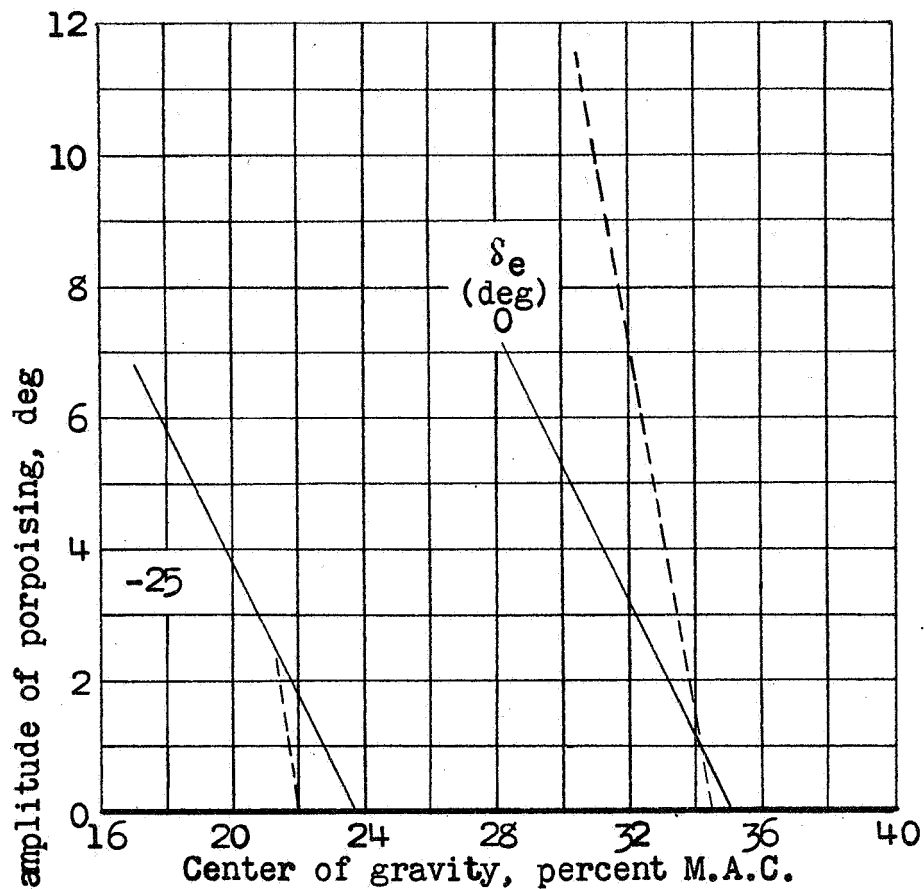


(b) Upper-limit porpoising.

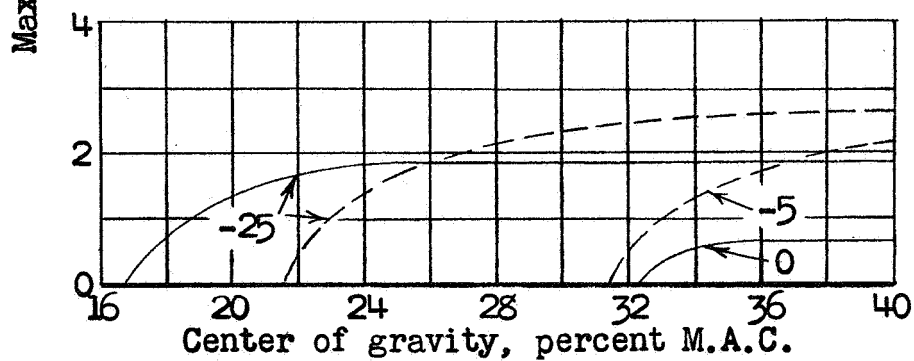


Figure 6.- Maximum amplitude of porpoising at different positions of center of gravity.

Warped forebody and extended afterbody ———
 Basic forebody and basic afterbody - - - - -



(a) Lower-limit porpoising.



(b) Upper-limit porpoising.

Figure 7.- Comparison of maximum amplitude of porpoising between basic and modified hulls.



Warped forebody and extended afterbody ———
 Basic forebody and basic afterbody - - - - -

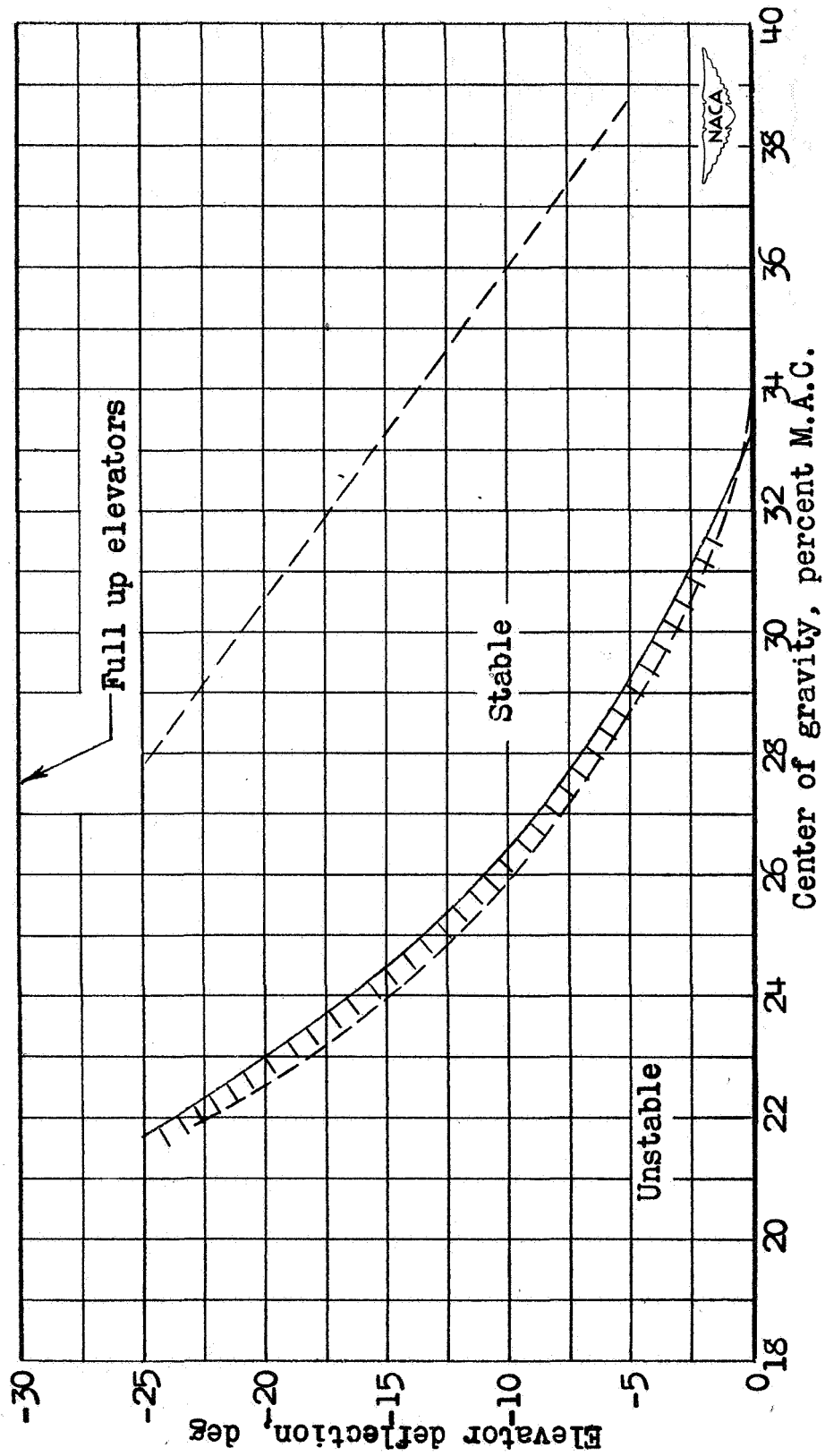


Figure g.- Variation of center-of-gravity limits of stability, with elevator deflection, for 2° amplitude of porpoising.

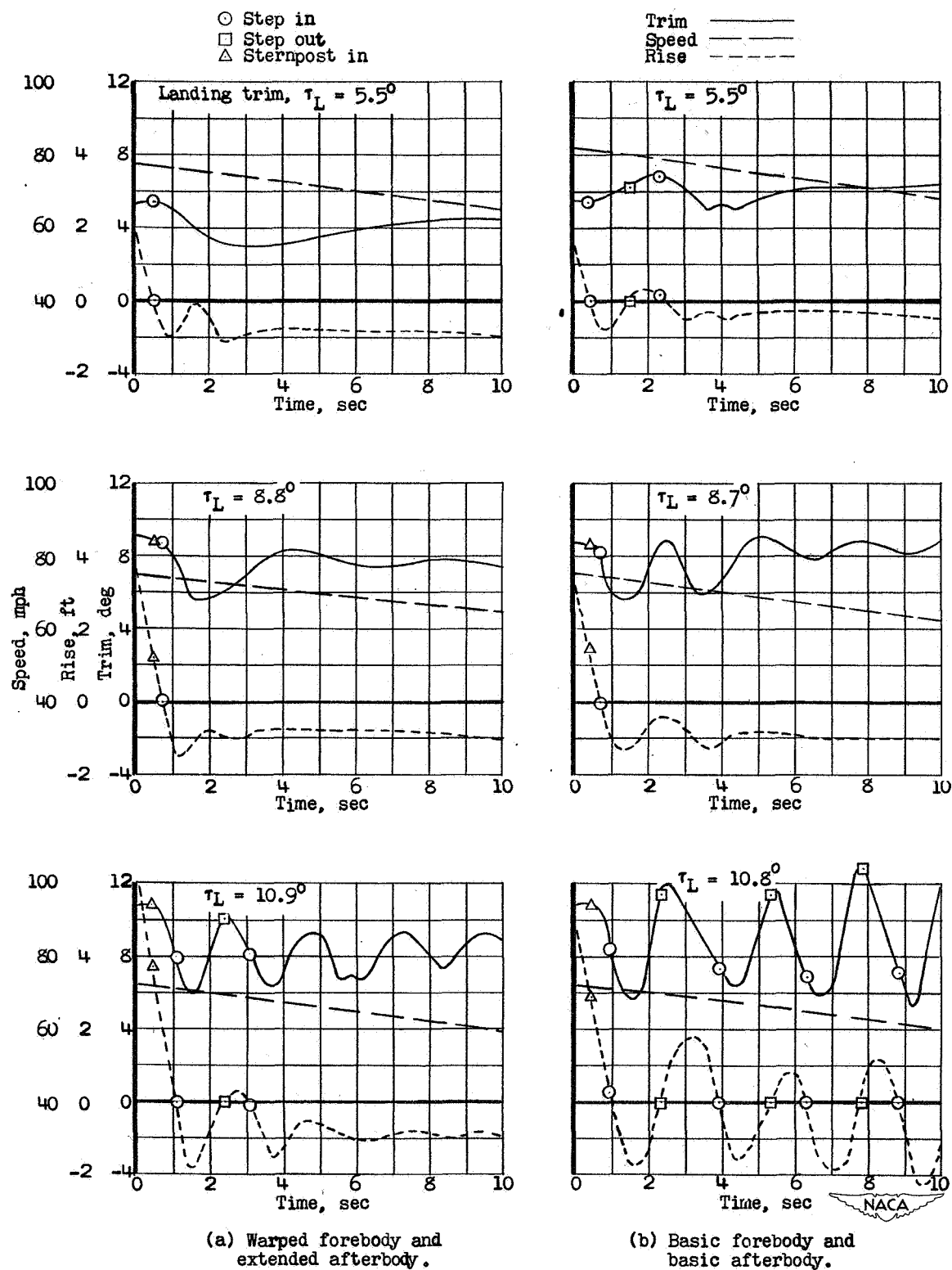
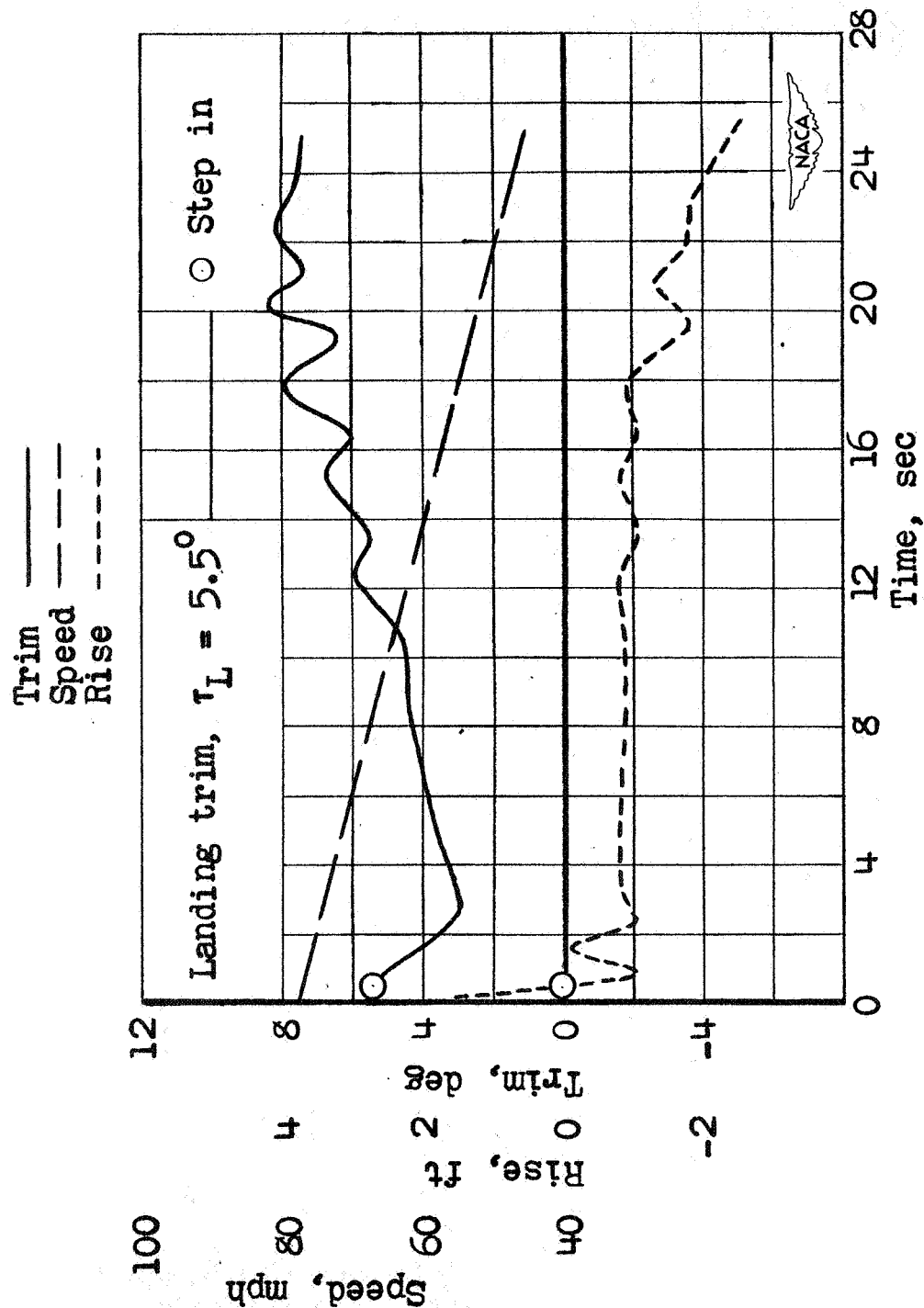
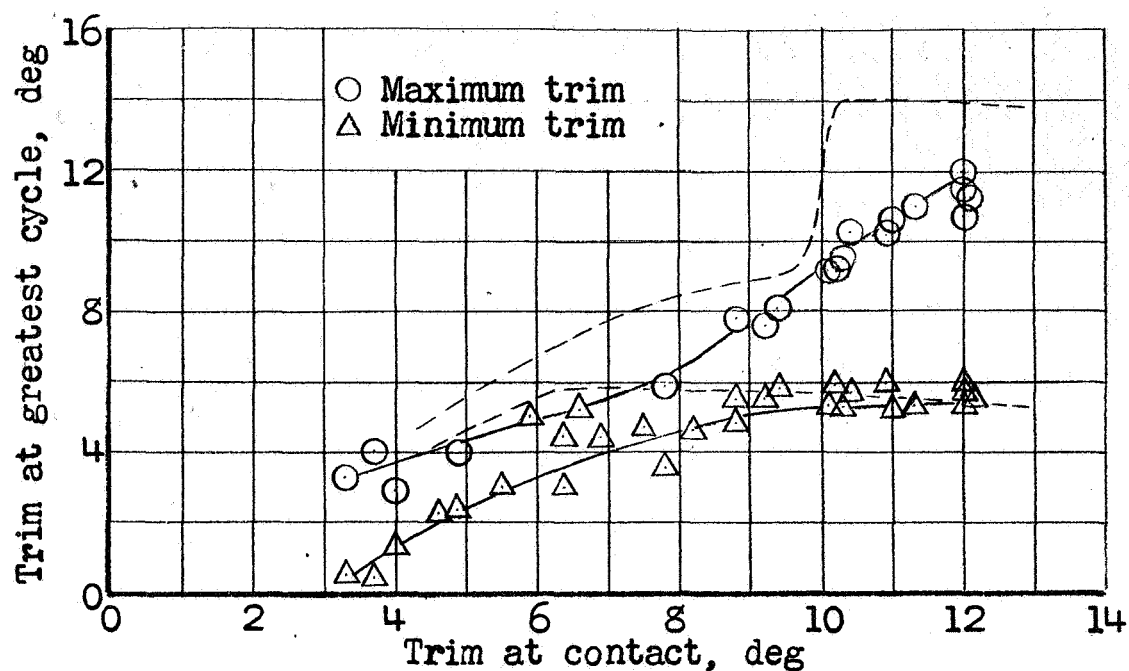


Figure 9.- Variation of trim, rise, and speed with time during landings in smooth water.



(c) Extended time history for a typical landing of the modified hull.

Figure 9.- Concluded.



Warped forebody and extended afterbody ———
 Basic forebody and basic afterbody - - - - -

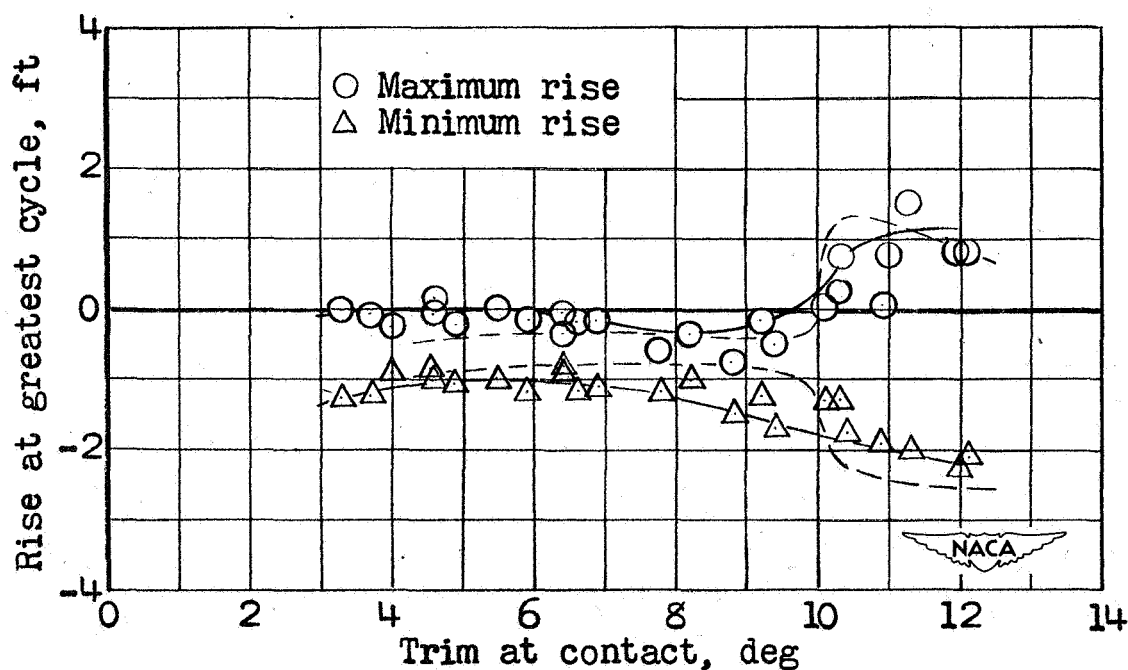


Figure 10.- Variation in maximum and minimum trim and rise with trim at contact, for landings in smooth water.

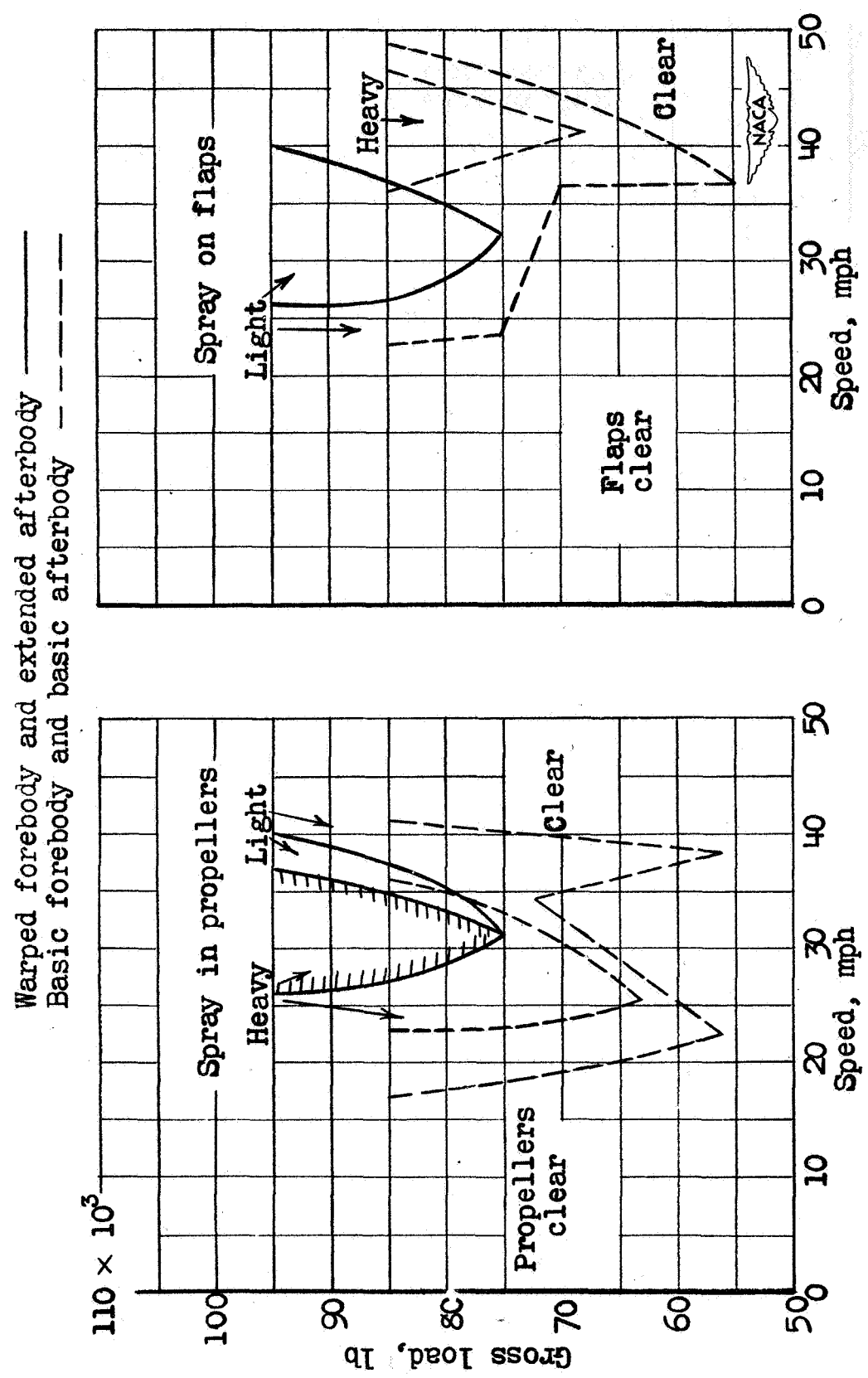
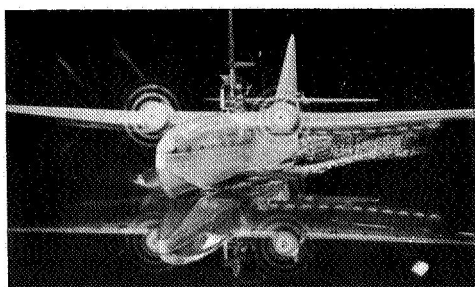
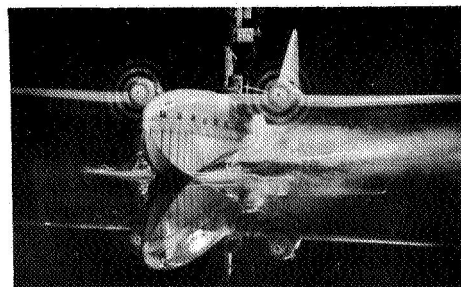
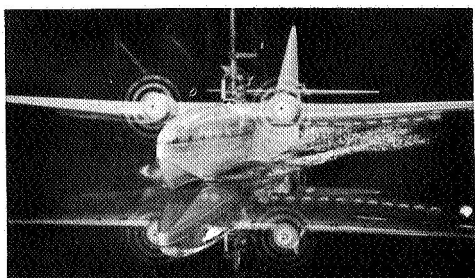
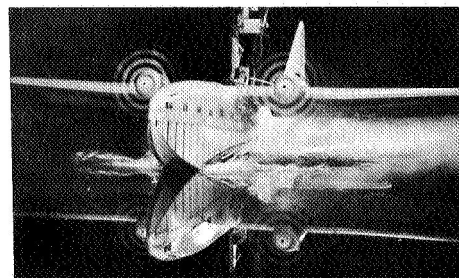
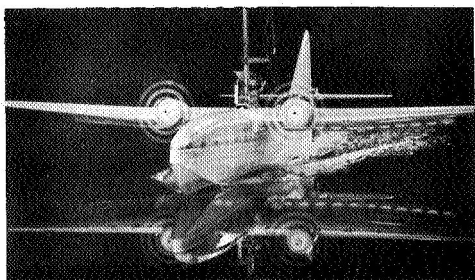
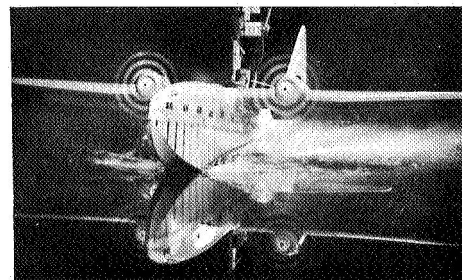
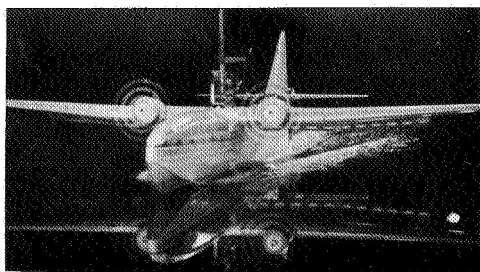
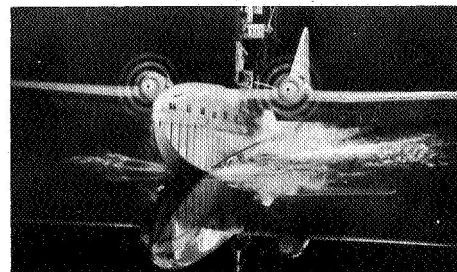


Figure 11.- Variation of range of speed for spray in propellers and on flaps with gross load.

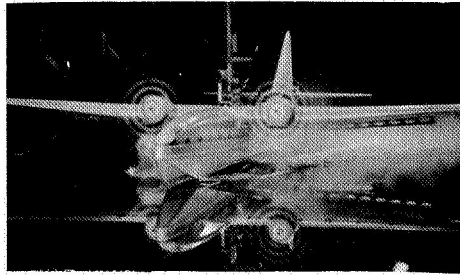

 $\tau = 3.1^\circ$
 $V = 25.9 \text{ mph}$

 $\tau = 6.1^\circ$

 $\tau = 3.2^\circ$
 $V = 28.0 \text{ mph}$

 $\tau = 6.0^\circ$

 $\tau = 3.2^\circ$
 $V = 30.2 \text{ mph}$

 $\tau = 6.4^\circ$

 $\tau = 3.3^\circ$
 $V = 32.3 \text{ mph}$

 $\tau = 6.7^\circ$

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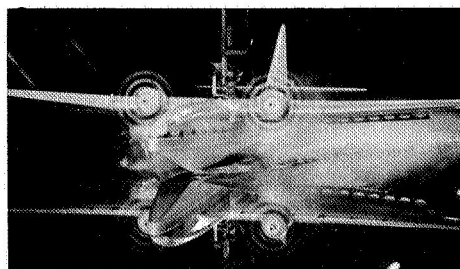
(a) Warped forebody and
extended afterbody.

(b) Basic forebody and
basic afterbody.

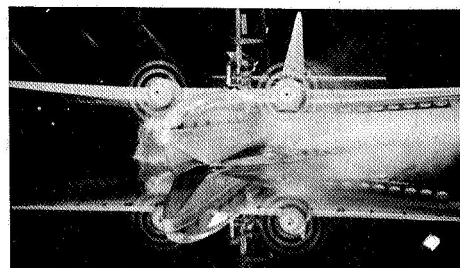
Figure 12.- Spray in propellers during take-off at design gross load.
 $\delta_e = -10^\circ$.



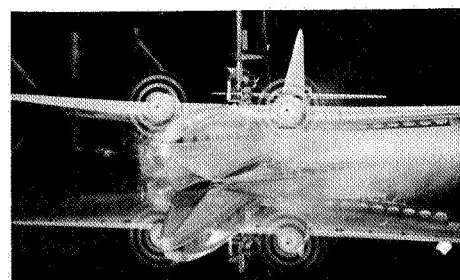
$\tau = 3.2^\circ$ $V = 28$ mph



$\tau = 3.2^\circ$ $V = 30.2$ mph



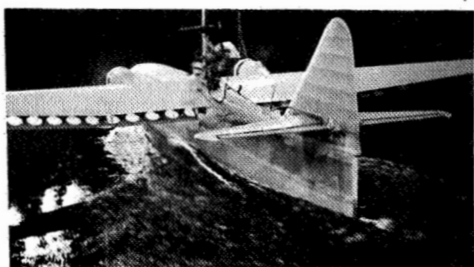
$\tau = 3.4^\circ$ $V = 32.3$ mph



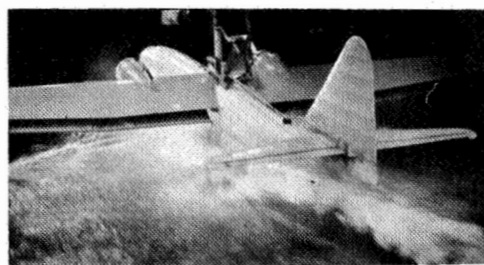
$\tau = 3.6^\circ$ $V = 34.5$ mph

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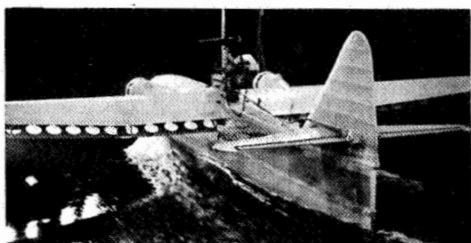
Figure 13.- Spray in propellers during take-off at gross load of 85,000 pounds (modified hull). $\delta_e = -10^\circ$.



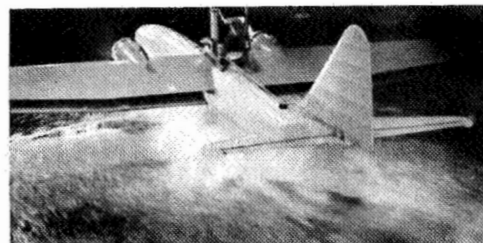
$V = 23.7 \text{ mph}; \tau = 3.1^\circ$



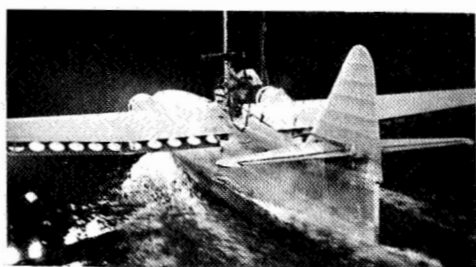
$V = 38.8 \text{ mph}; \tau = 8.7^\circ$



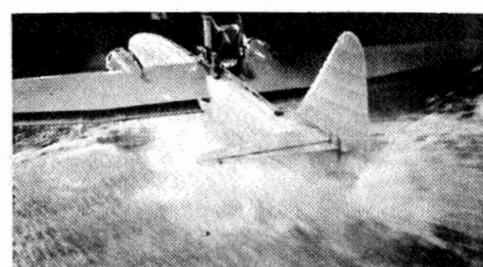
$V = 28.0 \text{ mph}; \tau = 3.2^\circ$



$V = 41.0 \text{ mph}; \tau = 9.4^\circ$



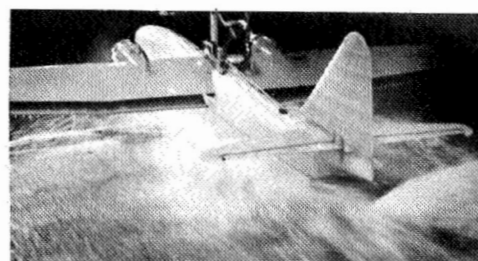
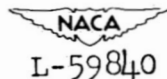
$V = 32.2 \text{ mph}; \tau = 3.3^\circ$



$V = 43.1 \text{ mph}; \tau = 9.9^\circ$



$V = 36.6 \text{ mph}; \tau = 4.0^\circ$

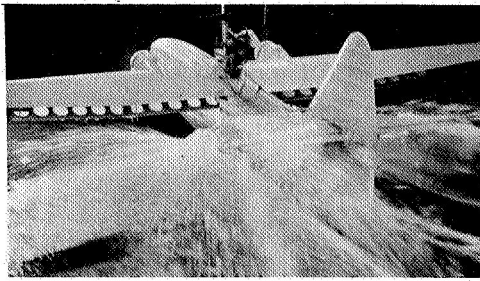


$V = 45.3 \text{ mph}; \tau = 10.5^\circ$

(a) Warped forebody and extended afterbody.

(b) Basic forebody and basic afterbody.

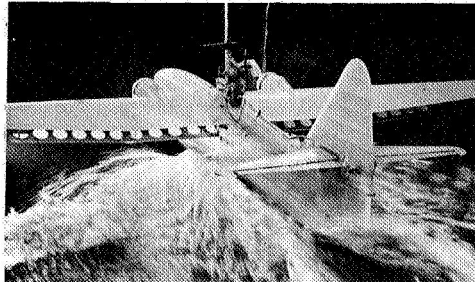
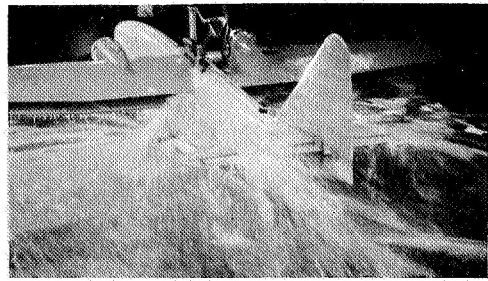
Figure 14.— Spray on flaps during take-off at design gross load.
 $\delta_e = -10^\circ$.



$$\tau = 9.4^\circ$$

$$V = 53.9 \text{ mph}$$

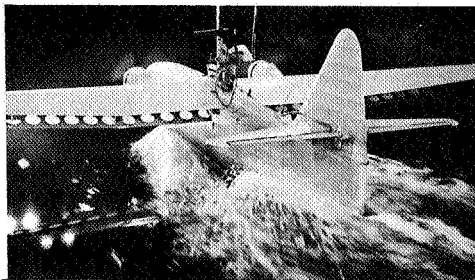
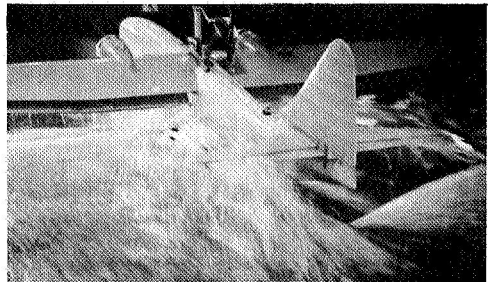
$$\tau = 11.9^\circ$$



$$\tau = 7.8^\circ$$

$$V = 47.4 \text{ mph}$$

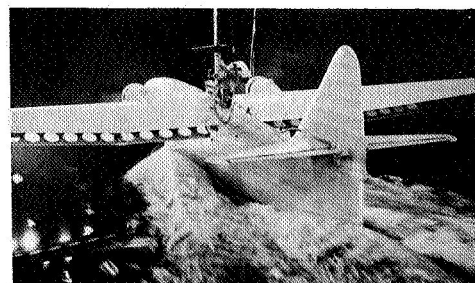
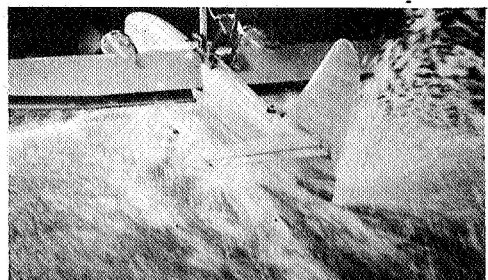
$$\tau = 12.5^\circ$$



$$\tau = 5.5^\circ$$

$$V = 43.1 \text{ mph}$$

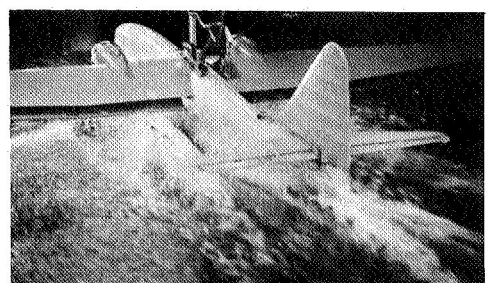
$$\tau = 12.4^\circ$$



$$\tau = 5.0^\circ$$

$$V = 38.8 \text{ mph}$$

$$\tau = 11.8^\circ$$



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(a) Warped forebody and
extended afterbody.

(b) Basic forebody and
basic afterbody.

Figure 15.— Spray on tail surfaces during landing at design gross load.
 $\delta_e = -10^\circ$.

Warped forebody and extended afterbody —————
 Basic forebody and basic afterbody - - - - -

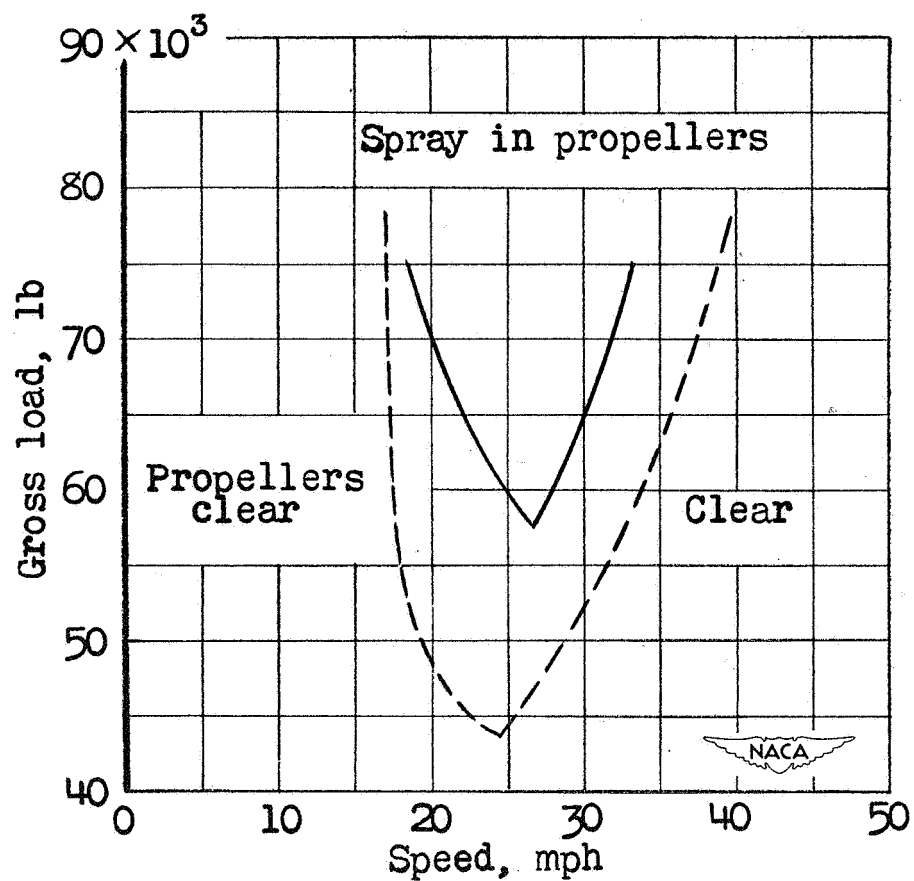


Figure 16.- Variation of range of speed with gross load for spray in propellers during taxiing in waves.

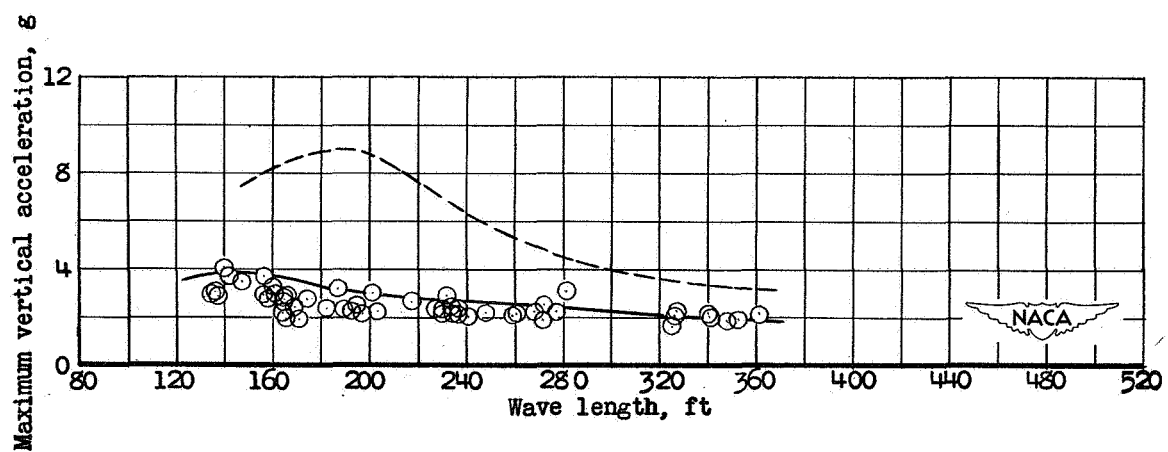
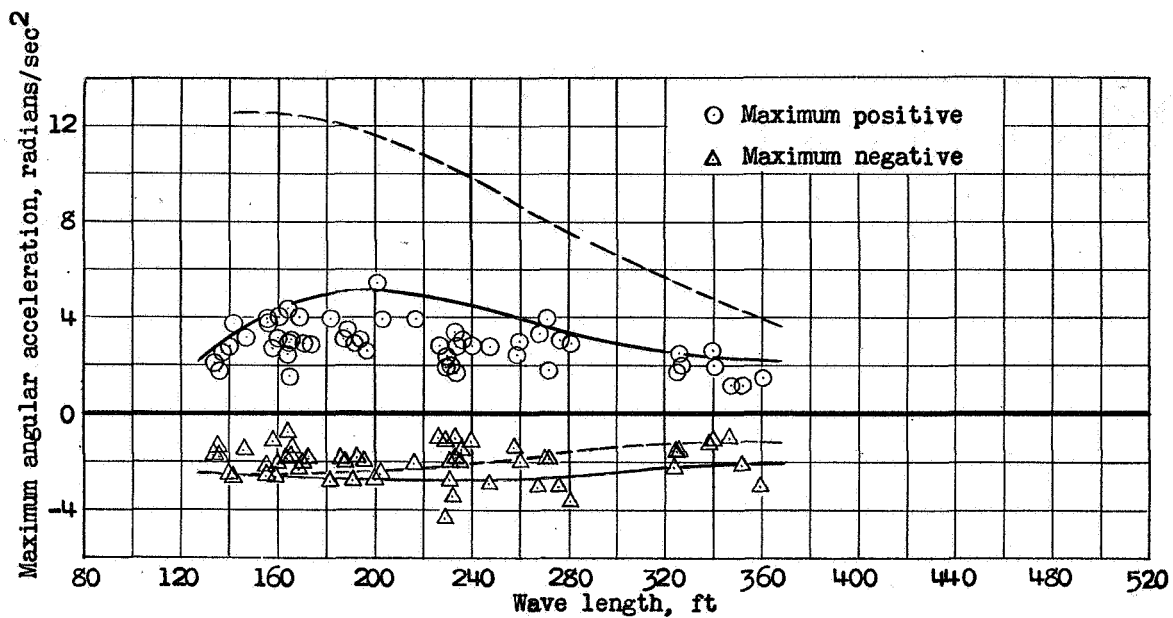


Figure 17.- Variation of maximum positive and negative angular and maximum vertical accelerations with wave length, for landings in waves 4 feet high.

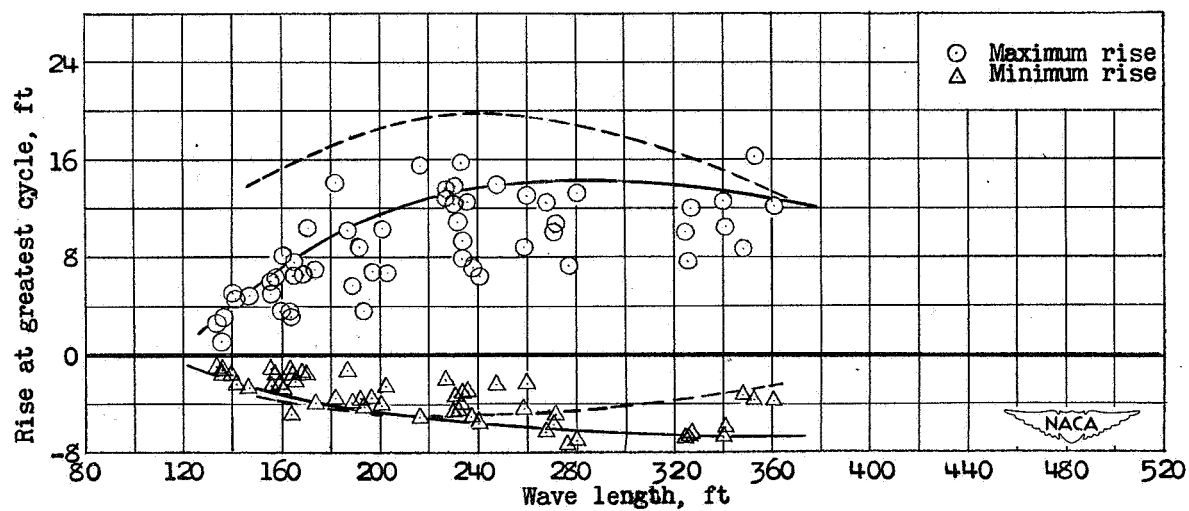
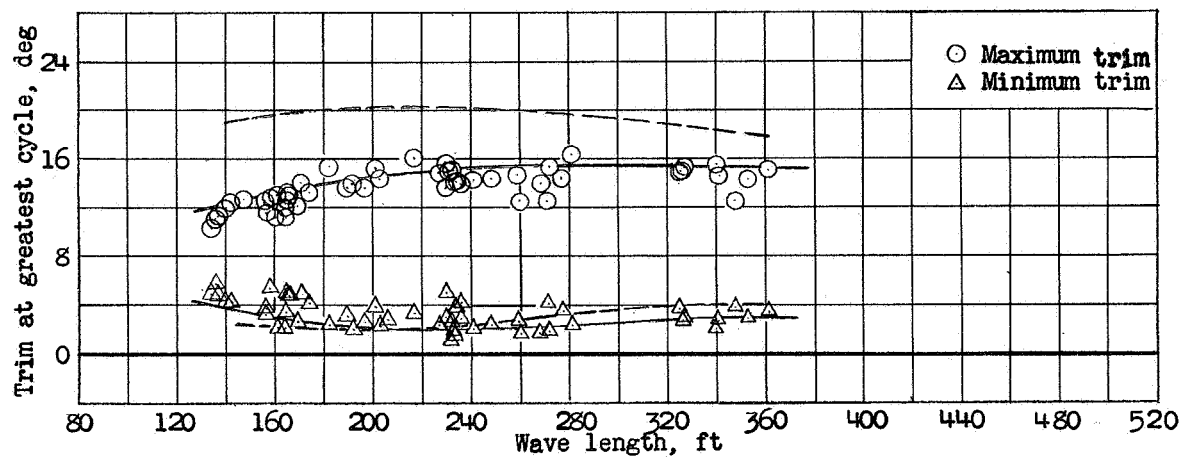


Figure 18.- Variation of maximum and minimum trim and rise with wave length, for landings in waves 4 feet high.

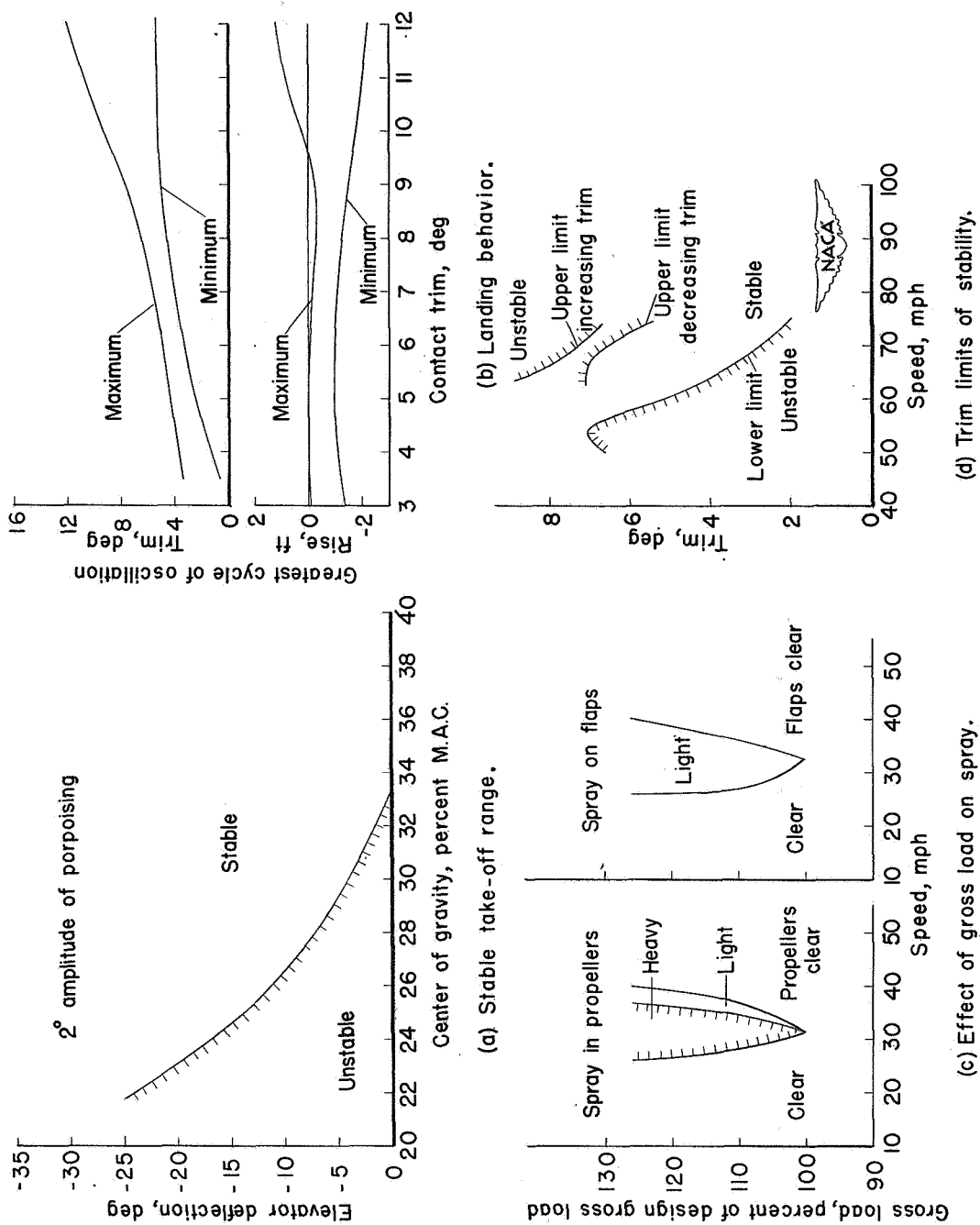


Figure 19. - Summary chart of principal hydrodynamic qualities of a flying boat having a hull of high length-beam ratio, a warped forebody, and an extended afterbody. Gross load, 75,000 pounds; power loading, 11.5 pounds per brake horsepower; wing loading, 41.1 pounds per square foot; flap deflection, 20°.