RESEARCH MEMORANDUM

TANK INVESTIGATION OF A SERIES OF RELATED HYDRO-SKIS AS LOAD-ALLEVIATION DEVICES FOR LANDING A SEAPLANE IN WAVES

By Arthur W. Carter, Archibald E. Morse, Jr.,
and David R. Woodward

Langley Aeronautical Laboratory
Langley Field, Va.

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SUMMARY

A tank investigation has been made to determine the effects of hydro-skis as load-alleviation devices for landing a seaplane in waves. Landings were made into oncoming waves with various hydro-ski configurations.

A nose-high attitude throughout the landing run was effective in reducing the impact accelerations and motions of the model equipped with relatively large hydro-skis. For small, more heavily loaded hydro-skis, unless placed in an extremely forward position, a nose-high attitude was a necessity to prevent diving. The vertical and angular accelerations decreased with increase in beam loading from 10 up to 100. An increase in beam loading above 200 caused a significant increase in the impact accelerations unless high incidence was used. The impact loads for beam loadings of 100 and 200 were approximately the same. With these hydro-skis, the maximum vertical acceleration was 16 percent and the maximum angular acceleration was 9 percent of those for the basic hull without hydro-ski. The maximum vertical and angular accelerations appeared to be a function of the product of the length and beam dimensions of the hydro-ski.

A decrease in landing speed resulted in an appreciable decrease in the maximum vertical accelerations but, in general, had little effect on the maximum angular accelerations. The maximum accelerations increased with increase in wave height, but in spite of the increase the maximum accelerations for the hydro-ski in 8-foot waves were considerably less than those for the basic hull in 4-foot waves.

INTRODUCTION

The overall motions and accelerations imposed on seaplanes during rough-water landings become more severe as the landing speeds are increased. At landing speeds of about 120 knots, the adverse effects induced by these high landing speeds appear large in moderately rough water even on configurations with high-length-beam-ratio hulls.

One solution to the problems imposed by the high landing speed is the use of hydro-skis for load alleviation. Model and full-scale experience with hydro-skis has indicated that these relatively highly loaded surfaces provide impact load alleviation due to greater penetration in waves as well as smoother operation, localization of the water loads, and additional vertical clearance by virtue of the support strut for the rest of the airplane.

An investigation has been made in Langley tank no. 1 to determine the load-alleviating effects of hydro-skis during landing of a model having wing loadings of 40, 80, and 120 pounds per square foot (full size) with landing speeds of 70, 100, and 120 knots, respectively. Landings were made into oncoming waves with various hydro-ski configurations. The investigation was made to determine the effects of variations in longitudinal and vertical locations, beam loading, length, plan form, and incidence of the hydro-ski in addition to landing trim, landing speed, aerodynamic stability, and wave height.

SYMBOLS

C_{Δ_o}	gross-load coefficient or beam loading, $\frac{\Delta_o}{wb^3}$
b	beam of hydro-ski or hull, ft
$\bar{c}$	mean aerodynamic chord, ft
g	acceleration due to gravity (32.2), ft/sec^2
h	height of wave, ft
L	overall length of hydro-ski, ft
V_L	landing speed, knots
w	specific weight of water (63.4 for these tests, usually taken as 64 for sea water), lb/cu ft

x	distance between center of pressure of hydro-ski and center of gravity of airplane, ft
z	vertical distance between keel of hydro-ski at trailing edge and forebody keel of hull at step, ft
Δ_o	gross load, lb
τ_L	landing trim (angle between forebody keel at step and horizontal), deg

DESCRIPTION OF MODEL

A $\frac{1}{12}$-size dynamic model (Langley tank model 279) was used as a test vehicle for the investigation of hydro-skis. The hull had a length-beam ratio of 15 and had the same lines as the $\frac{1}{10}$-size model described in reference 1. The form, size, and relative location of the tail surfaces corresponded to those of the model described in reference 1. In addition to the original wing which had a wing loading of 40 pounds per square foot (full size), two additional wings were constructed with reduced area so that the seaplane had wing loadings of 80 and 120 pounds per square foot, respectively. The quarter-chord point of the mean aerodynamic chord was the same for the three wings.

The general arrangement of the seaplane with a 120-pound wing loading and with a hydro-ski having a beam loading of 200 is shown in figure 1. Pertinent characteristics and dimensions of this configuration are given in table I.

Offsets and description of the hydro-skis are given in table II. The range of hydro-ski sizes and shapes is shown in figure 2 where the plan forms of the hydro-skis are superposed on that of the hull. The hydro-skis shown in figure 2(a) had geometrically similar pointed bows and 60° V trailing edges. The beam loading C_{Δ_o} varied from 5.9 (same as the hull) to 600. The length-beam ratio varied from 3.25 to 6.12.

As shown in figure 2(b), two of the hydro-skis were modified to incorporate a transverse trailing edge. When the trailing-edge plan form was changed, the projected area of the hydro-ski was held constant.

Chine strips were added to the hydro-skis as spray-control devices as shown in table II. These strips extended from station $2\frac{1}{2}$ to the trailing edge, had 5° down flare, and were one-quarter of a foot wide (full size) for all of the hydro-skis, irrespective of the beam of the hydro-ski.

All the hydro-skis were attached to the hull by two rigid struts as shown in figure 1 with the exception of the hydro-ski with a beam loading of 600, which had a single strut. For most of the investigation, the strut length was selected such that the keel of the hydro-ski was 6 feet (full size) below the forebody keel of the hull. Inasmuch as the present investigation was concerned primarily with alleviation of impact loads, and the maximum impacts, in general, occurred prior to wetting of the struts, the shape of the struts was of minor importance. For convenience a rectangular strut was used.

APPARATUS AND PROCEDURE

The investigation was made in Langley tank no. 1. A description of the tank and the apparatus used for testing dynamic models is presented in reference 2. For these tests, 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. The model had 5 feet of fore-and-aft freedom with respect to the towing carriage in order to absorb longitudinal accelerations introduced by the impacts and to permit the model to act as a free body in the longitudinal direction.

A strain-gage-type accelerometer mounted on the towing staff of the model measured the vertical accelerations. Two strain-gage-type accelerometers, electrically connected in such a manner that they measured the angular accelerations directly, were located within the model with their centers of gravity in line with the model center of gravity. In the static condition, the three accelerometers read zero. The frequency-response curve of the accelerometer and recording galvanometer system was flat within ±5 percent between 0 and 32 cycles per second.

Slide-wire pickups were used to measure the trim, the rise of the center of gravity, and the fore-and-aft position of the model. An electrically actuated trim brake, attached to the towing staff, locked the trim of the model in the air during the initial approach. The trim brake was automatically released when any of three contacts along the keel of the hull or the hydro-ski touched the water. These contacts were located at the sternpost and step of the hull and at the stern of the hydro-ski.

Waves were generated by the Langley tank no. 1 wave maker which is described in reference 2.

All data were obtained at a gross load corresponding to 75,000 lb, with a flap deflection of 20°, and with the center of gravity located 2.35 feet (full size) forward of the step. Angles of incidence of the keel of the hydro-ski relative to the keel of the hull of 0°, 4°, and 8° and distances between the keels of the hydro-ski and the hull of 3, 6, and 9 feet (full size) were investigated.

The model was trimmed in the air to the desired landing trim at a speed slightly above flying speed and the towing carriage was decelerated at a uniform rate; this technique allowed the model to glide onto the water and simulate an actual landing. The landings were made without power and the elevators were set so that the model was in trim at the instant of contact with the water. After initial contact with the water, the model was free to trim with the elevators remaining fixed for the remainder of the landing run. In order to maintain longitudinal freedom, the rates of deceleration of the towing carriage were approximately 7 and 8 feet per second per second for landing trims of 8° and 12°, respectively.

Landings were made in waves 4, 6, and 8 feet in height (full size). In general, landings were made in waves of four different lengths. With the small, heavily loaded hydro-skis, the variation of accelerations with wave length was small, and in some cases only two lengths of waves were used. The range of wave lengths which was used was believed to include the critical wave length (wave length at which the maximum acceleration occurred) for each configuration.

In general, eight landings were made in each wave inasmuch as the position of landing on a wave (for the initial contact as well as subsequent impacts during the landing runout) was not under the control of the operator. The behavior of the model on landing was observed visually, and a time history of the motions was continuously recorded throughout the landing run. The time history included recordings of trim, rise of the center of gravity, fore-and-aft position, vertical and angular accelerations, and speed.

RESULTS AND DISCUSSION

All test results have been converted to values corresponding to those of the full-size seaplane. Unless noted otherwise, the hydro-skis were geometrically similar with a length-beam ratio of 6.12, the angle of incidence of the keel of the hydro-ski relative to the forebody keel of the hull was zero, the distance between the keels of the hydro-ski and the hull was 6 feet (full size), the waves were 4 feet high, and the wing loading was 120 pounds per square foot.

Basic Model (Without Hydro-Ski)

In order to illustrate the magnitude of the accelerations and motions of the basic model (without a hydro-ski) and to provide a basis of comparison for the load-alleviation effects of hydro-skis, the landing characteristics of the basic model in waves are shown in figure 3. The maximum vertical and angular accelerations obtained during each landing are plotted against wave length in figure 3(a) and an oscillograph record of a typical landing showing the motions in trim and rise is presented in figure 3(b). The critical wave length at which the accelerations reached a maximum for the basic model was approximately 210 feet or a wave length-height ratio of about 50. At the critical wave length, maximum vertical accelerations as high as 13g and maximum angular accelerations as high as 26 radians per second per second were obtained. The associated oscillations in trim and rise also were very large.

Effect of Longitudinal Location of Hydro-Ski

Typical results, showing the effect of longitudinal position, are presented in figure 4 for hydro-skis having beam loadings of 10 and 100. With a beam loading of 10, data were not obtained at the most rearward position ($x = 12.75$ feet) because violent diving occurred during the landing. The optimum location appeared to be near the intermediate position ($x = 14.38$ feet). At this location, the vertical and angular accelerations and motions tended to reach a minimum. At the most forward position ($x = 17.65$ feet), the maximum angular accelerations were appreciably increased without a significant change in the maximum vertical accelerations. Similar trends were noted for beam loadings of 20 and 30.

With a high beam loading of 100, the trends were generally similar to those with the lower beam loadings but to a lesser degree. There was little difference in the accelerations and motions at the forward and intermediate positions. At the aft position ($x = 6.92$ feet), however, diving occurred, which, although not violent, caused a definite increase in both vertical and angular accelerations (fig. 4(a)) and in the trim motions at high speeds (fig. 4(b)), when compared with those for the more forward positions.

Results of the investigation of longitudinal position are summarized in figure 5, where the ratio x/L is plotted against hydro-ski length. In determining x, the center of pressure of the hydro-ski was assumed to be two-thirds of the length of the hydro-ski forward of the trailing edge. (See ref. 3.) The curve of figure 5 is faired through the optimum locations. At these locations, the resultant of the lift and drag forces of the hydro-ski acted through or near the center of gravity of the airplane and the accelerations and motions tended to reach a minimum. At locations aft of the optimum, the resultant vector was aft of the center of gravity and the model tended to dive. At locations forward of the optimum, the resultant vector was too far forward of the center of gravity and the model tended to balloon off the waves.

Effect of Landing Trim

Landing investigations of hull-type seaplanes (ref. 4) have shown that, for landing trims above 4°, there is little effect of trim on the rough-water behavior. This conclusion, however, does not hold for a hydro-ski type of airplane, where trim was found to have a large effect on the behavior of the model.

Typical results showing the effect of landing trim for beam loadings of 10 and 20 are presented in figure 6. An increase in landing trim from 8° to 12° decreased the maximum vertical and angular accelerations (fig. 6(a)) and the motions (fig. 6(b)). With a beam loading of 30, diving was encountered during landings at a trim of 8° even with the hydro-ski relatively far forward. Landings at a trim of 12°, however, eliminated this diving. These results indicate that a nose-high attitude throughout the landing run is effective in reducing the impact accelerations and motions for the larger hydro-skis having beam loadings less than 30. For the smaller, more heavily loaded hydro-skis, unless placed in an extremely forward position, a nose-high attitude is a necessity to prevent diving.

Effect of Hydro-Ski Dimensions

The effect of size of the hydro-ski is shown in figure 7, where the maximum vertical and angular accelerations and the motions are presented for typical, geometrically similar hydro-skis having beam loadings from 10 to 600. The vertical and angular accelerations (fig. 7(a)) and motions (fig. 7(b)) decreased with increase in beam loading (decrease in size) up to 100. In this range of loading, the hydro-ski tended to plane during the high-speed portion of the landing run and rebounding from the waves was likely to occur.

A further increase in loading to 200 had no appreciable effect on the accelerations. At this beam loading, however, rebound after initial impact was negligible, and there was a gradual increase in draft or penetration with little angular motion. In general, the impact on the hull, when it finally entered the water, was less than that on the hydro-skis.

It is interesting to note that the impact loads as shown in figure 7(a) for the planing hydro-ski (beam loading of 100) and the penetrating hydro-ski (beam loading of 200) were approximately the same, although the latter ski had 37 percent less area. For these hydro-skis, the maximum vertical acceleration was 16 percent and the maximum angular acceleration was 9 percent of those for the basic hull.

An increase in beam loading from 200 to 600 (smallest hydro-ski investigated) caused the accelerations to increase again. At 0° incidence, this hydro-ski had to be located at an extremely forward longitudinal position in order to prevent diving. Because of this forward position, the afterbody became involved in the impact along with the hydro-ski and this combination resulted in a significant increase in the maximum vertical and angular accelerations.

From the data presented in figure 7(a) and similar data for additional hydro-skis, including variations in hydro-ski length with beam constant, beam with area constant, and plan form of the trailing edge, the maximum vertical and angular accelerations for each hydro-ski were obtained and plotted against length-beam product of the various hydro-skis in figure 8.

The use of the product of the length and beam of the hydro-ski as a parameter resulted in a straight-line grouping of the vertical-acceleration data at length-beam products greater than 30. At length-beam products less than 30, the data varied from the straight line. The maximum angular accelerations also appeared to be a function of the length-beam product of the hydro-ski.

The maximum vertical and angular accelerations reached a minimum value at a length-beam product of approximately 30 for this particular series of related hydro-skis.

Effect of Landing Speed

The effect of landing speed on the maximum accelerations is shown in figure 9. The decrease in landing speed resulted in an appreciable decrease in the maximum vertical accelerations but had little effect on the maximum angular accelerations except for the hydro-ski with a beam loading of 600, where the angular accelerations were decreased appreciably. These data and a brief investigation of longitudinal location indicate that the same size of hydro-ski and the same longitudinal location may be used for impact load alleviation over a wide range of landing speed and wing loading.

Effect of Vertical Location of Hydro-Ski

The effect of the vertical location, which establishes the length of the supporting strut, was determined for the hydro-ski having a beam loading of 200 and the results are presented in figure 10. The maximum vertical and angular accelerations are plotted against z/h. These data indicate that the accelerations reached a minimum value when the vertical location of the hydro-ski below the hull approximated the height of the waves. The motions and accelerations increased slightly when the vertical spacing was greater than the wave height. Vertical spacings which were less than the wave height resulted in greatly increased vertical and angular accelerations.

These data were obtained with a hydro-ski which tended to penetrate the waves with negligible rebound after initial impact and the results are not necessarily applicable to hydro-skis having beam loadings such that the hydro-ski tended to plane and rebound at high speeds.

Effect of Wave Height

Typical results obtained for landings in 4-, 6-, and 8-foot waves are presented in figure 11 for hydro-skis having beam loadings of 30 and 200. A 6-foot spacing between the keels of the hull and ski was maintained with the exception of landings with the higher beam loading in 8-foot waves, where a 9-foot spacing was used.

The maximum accelerations increased with increase in wave height for both beam loadings. In spite of the increase in accelerations with wave height, the maximum accelerations in the 8-foot waves were considerably less than those for the basic hull in 4-foot waves.

The effect of wave height on the motions in trim and rise was more pronounced than the effect on the accelerations. As shown in figure 11(b), the motions increased rapidly with increase in wave height. In 6- and 8-foot waves, the hydro-ski having a beam loading of 200 rebounded from the waves with considerable angular motion instead of penetrating the waves as when landed in 4-foot waves.

Effect of Angle of Incidence

When the smallest hydro-ski $\left(C_{\Delta_0} = 600\right)$ was located such that the center of pressure was 12.75 feet forward of the center of gravity and landings were made at an angle of incidence of 0°, diving resulted as shown in figure 12(a). With 4° incidence, this diving tendency was reduced, although the accelerations (fig. 12(b)) and the motions (fig. 12(a)) were large. With 8° incidence, the hydro-ski penetrated the waves without rebounding and the accelerations and motions were appreciably reduced.

This hydro-ski was of particular interest because of its relatively small size (8 square feet of area for a 75,000-pound airplane). With this very small and heavily loaded hydro-ski at 8° incidence, the impact accelerations were slightly greater than those for the hydro-ski having a beam loading of 200, but the maximum vertical accelerations were only 21 percent and the maximum angular accelerations were only 11 percent of those obtained with the basic model.

Effect of Aerodynamic Stability

As stated previously, the horizontal tail surfaces were not decreased in area when the wing area was decreased. As may be noted in figure 1, the tail surfaces are relatively large compared with the size of the wing having a wing loading of 120 pounds per square foot. The aerodynamic pitching-moment coefficients for wing loadings of 40 and 120 pounds per square foot with this horizontal tail are plotted against trim in figure 13. It will be noted that the aerodynamic stability was considerably greater for the wing loading of 120 pounds per square foot than for the wing loading of 40 pounds per square foot, as indicated by the increase in slope of the moment curve. The slope of the moment curve for the wing loading of 120 pounds per square foot also was considerably greater than that for a typical transonic design having comparable landing speeds as shown in figure 13.

In order to determine the effect of reduced stability on the behavior of the model during rough-water landings, a brief preliminary investigation was made with the wing loading of 120 pounds per square foot and with a small tail, which resulted in a moment-curve slope similar to that shown for the transonic design. This preliminary investigation indicated that the behavior of the model during rough-water landings at speeds near 120 knots may be affected greatly by the degree of aerodynamic stability. On the other hand, the behavior of the model with a wing loading of 40 pounds per square foot and a landing speed of 70 knots had been very satisfactory with the stability shown in figure 13 for this lower wing loading.

In the case of the wing loading of 120 pounds per square foot with a small tail at a landing speed of 120 knots, the hydro-ski may dive after a rebound from a wave. As a result of the reduced stability and lack of tail damping, the model trimmed down to a very low attitude as it approached the water after a rebound. At this attitude, the hydro-ski did not have sufficient lift to support the load on the water and therefore submerged. This investigation, however, was made with fixed elevators throughout the landing run, and with pilot control this unfavorable trimming down with the resultant dive possibly could be prevented even with a design having low aerodynamic stability.

Consideration of Hydro-Skis as Ditching Aid

The small size of the hydro-ski having a beam loading of 600 has an obvious potential application as a ditching aid for landplanes. This hydro-ski had only 8 square feet of area for a 75,000-pound airplane. A hydro-ski of this size could feasibly be installed in the bottom of the fuselage of aircraft making long trips over water. The hydro-ski could be used to localize the impact loads and keep the high loads, normally encountered during the high-speed portion of a ditching, off the fuselage and, thus, would permit the ditching to be accomplished with the aircraft intact.

Further reductions in the size of the hydro-ski might be possible by use of greater incidence and lower length-beam ratio.

CONCLUSIONS

The results of the tank investigation of hydro-skis as load-alleviation devices for landing a seaplane in waves led to the following conclusions:

1. A nose-high attitude throughout the landing run was effective in reducing the impact accelerations and motions of the model equipped with relatively large hydro-skis. For the small, more heavily loaded hydro-skis, unless placed in an extremely forward position, a nose-high attitude was a necessity to prevent diving.

2. The vertical and angular accelerations decreased with increase in beam loading from 10 up to 100. An increase in beam loading above 200 caused a significant increase in the impact accelerations unless high incidence was used.

3. The impact loads for beam loadings of 100 and 200 were approximately the same. With these hydro-skis, the maximum vertical acceleration was 16 percent and the maximum angular acceleration 9 percent of those for the basic hull without a hydro-ski.

4. The maximum vertical and angular accelerations appeared to be a function of the product of the length and beam dimensions of the hydro-skis.

5. A decrease in landing speed resulted in an appreciable decrease in the maximum vertical accelerations but, in general, had little effect on the maximum angular accelerations. Apparently the same size hydro-ski and the same longitudinal location may be used for impact load alleviation over a wide range of landing speed and wing loading.

6. The maximum accelerations increased with increase in wave height, but in spite of the increase the maximum accelerations for the hydro-ski in 8-foot waves were considerably less than those for the basic hull in 4-foot waves. The effect on the motions in trim and rise was more pronounced than on the accelerations, and the motions increased rapidly with increase in wave height.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., September 7, 1956.

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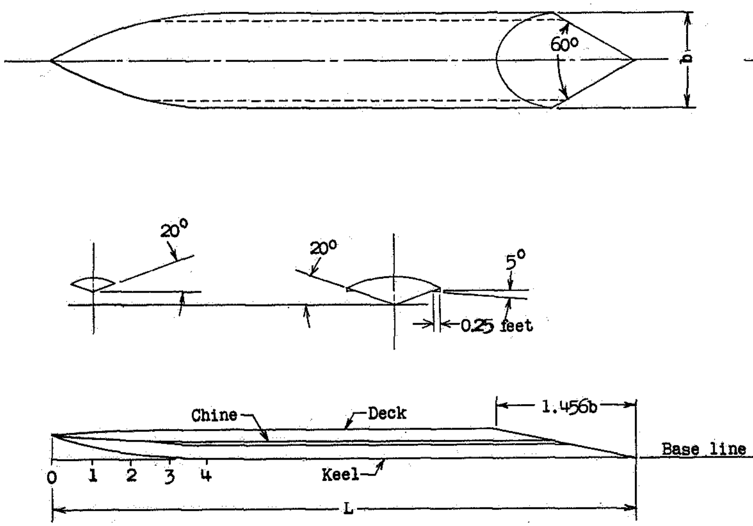
TABLE I

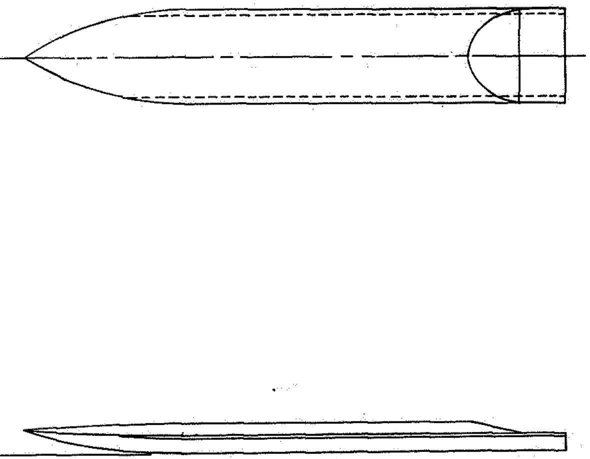
PERTINENT CHARACTERISTICS AND DIMENSIONS OF SEAPLANE HAVING HULL LENGTH-BEAM RATIO OF 15 AND WING LOADING OF 120 POUNDS PER SQUARE FOOT

General:	
Design gross load, lb	75,000
Gross load coefficient of hull, C_{Δ_0}	5.88
Wing area, sq ft	625
Wing loading, lb/sq ft	120
Hull:	
Maximum beam, ft	5.84
Length:	
Forebody, bow to step, ft	50.4
Forebody length-beam ratio	8.6
Afterbody, step to sternpost, ft	37.2
Afterbody length-beam ratio	6.4
Tail extension, sternpost to aft perpendicular, ft	17.5
Overall, bow to aft perpendicular, ft	105.1
Step:	
Type	Transverse
Depth at keel, in.	6.3
Depth at keel, percent beam	9
Angle of forebody keel to base line, deg	0
Angle of afterbody keel to base line, deg	5.4
Angle of sternpost to base line, deg	6.2
Angle of dead rise of forebody:	
Exculding chine flare, deg	20
Including chine flare, deg	16.5
Angle of dead rise of afterbody, deg	20
Wing:	
Span, ft	81.5
Root chord, ft	9.4
Mean aerodynamic chord:	
Length, projected, ft	8.0
Leading edge aft of bow, ft	45.2
Leading edge forward of step, ft	5.2
Leading edge above base line, ft	15.0
Angle of incidence, deg	4
Horizontal tail surfaces:	
Area, sq ft	333
Span, ft	43.0
Angle of stabilizer to wing chord, deg	-4
Elevator root chord, ft	3.2
Elevator semispan, ft	16.7
Length from 25 percent mean aerodynamic chord of wing to hinge line of elevators, ft	49.5
Height above base line, ft	19.0

TABLE II.- OFFSETS AND DESCRIPTION OF HYDRO-SKIS



60° V trailing edge



Transverse trailing edge

OFFSETS OF HYDRO-SKIS

(All dimensions are in beams of the hydro-ski)

Station	Distance from sta. 0	Distance above base line			Chine half-breadth	Deck radius
		Keel	Chine	Deck		
0	0	0.255	0.255	0.255	0	0
1	0.408	.137	.220	.288	0.231	0.424
2	.816	.063	.200	.302	.369	.710
3	1.224	.022	.186	.306	.453	.918
4	1.633	0	.182	.306	.500	1.037

DESCRIPTION OF HYDRO-SKIS

Beam loading C_{Δ_0}	L (ft)	b (ft)	L/b	L × b (ft^2)	Area (ft^2)	Hydro-ski loading (lb/sq ft)	Type of trailing edge
5.9	18.96	5.84	3.25	110.7	76.9	975	60° V
5.9	16.43	5.84	2.81	96.0	76.9	975	Transverse
10	30.00	4.90	6.12	147.0	123.0	610	60° V
10	25.10	4.90	5.12	123.0	98.9	760	60° V
10	20.71	4.90	4.23	101.5	76.9	975	60° V
20	23.81	3.89	6.12	92.6	76.9	975	60° V
30	20.82	3.40	6.12	70.8	59.2	1265	60° V
30	19.35	3.40	5.69	65.8	59.2	1265	Transverse
30	18.02	3.40	5.30	61.3	49.2	1565	60° V
40	18.86	3.08	6.12	58.1	49.2	1565	60° V
100	13.90	2.27	6.12	31.6	26.3	2850	60° V
200	11.00	1.80	6.12	19.8	16.6	4530	60° V
600	7.65	1.25	6.12	9.6	8.0	9375	60° V

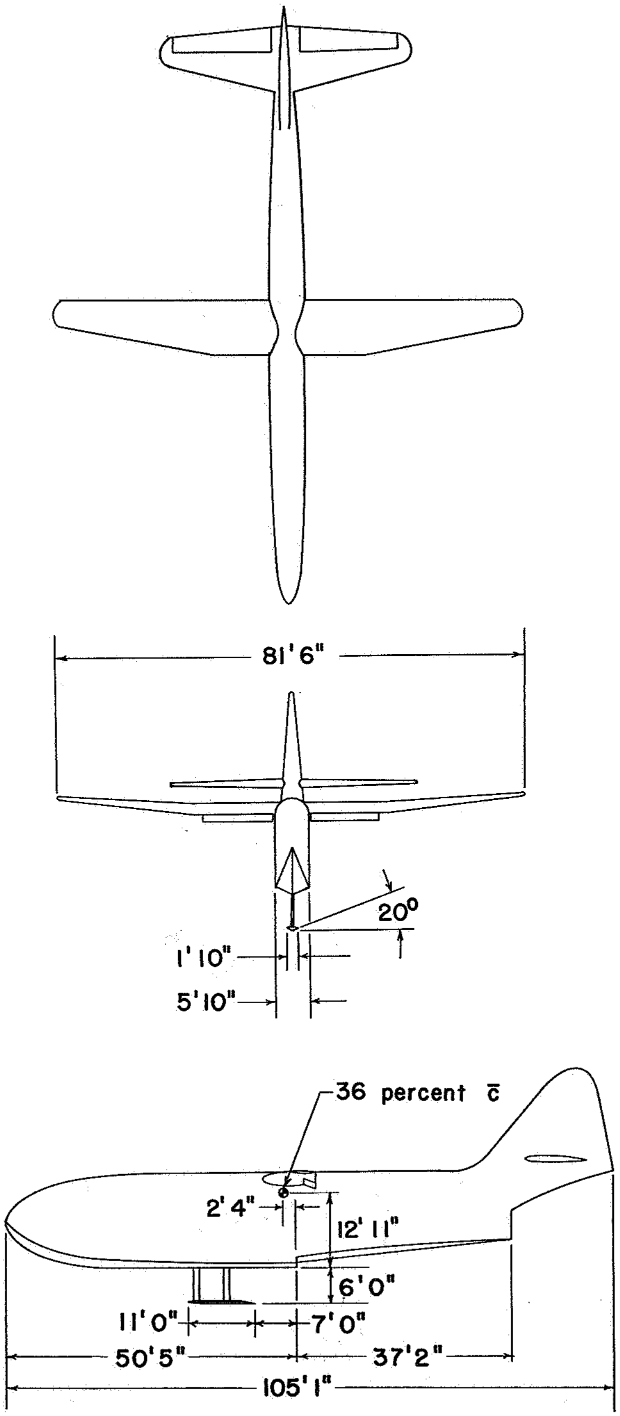
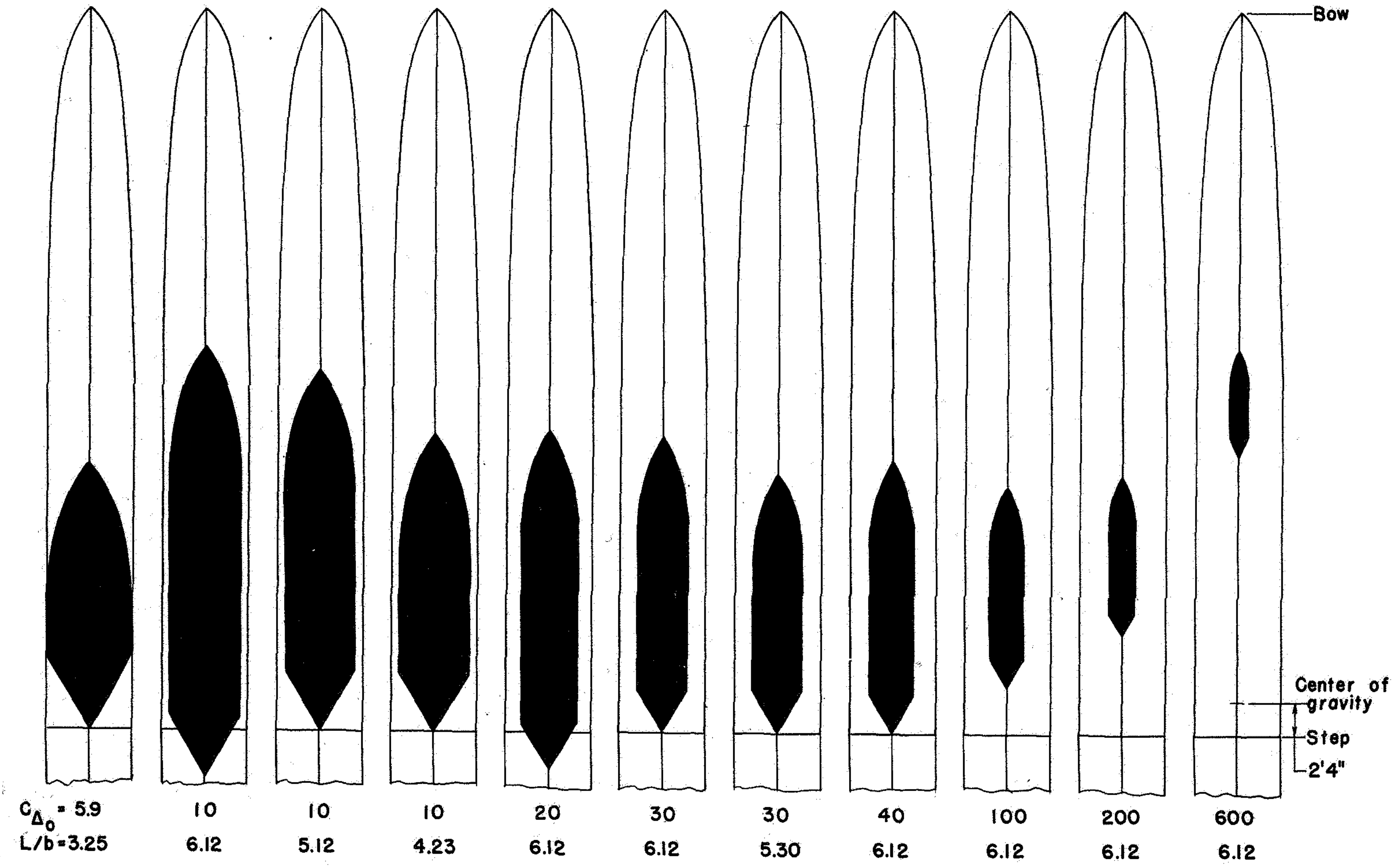
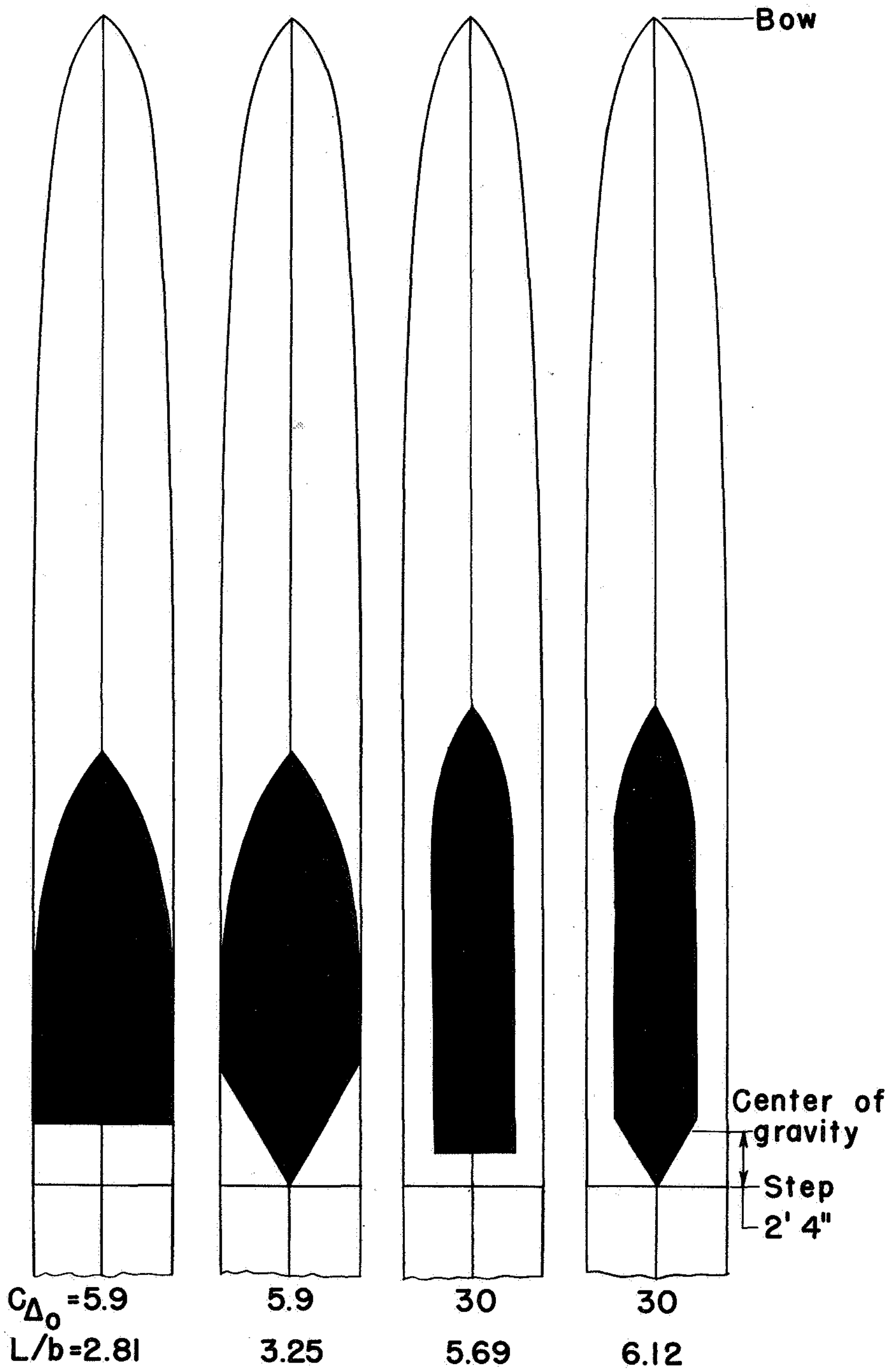


Figure 1.- General arrangement of the seaplane with a 120-pound wing loading and with a hydro-ski having a beam loading of 200.



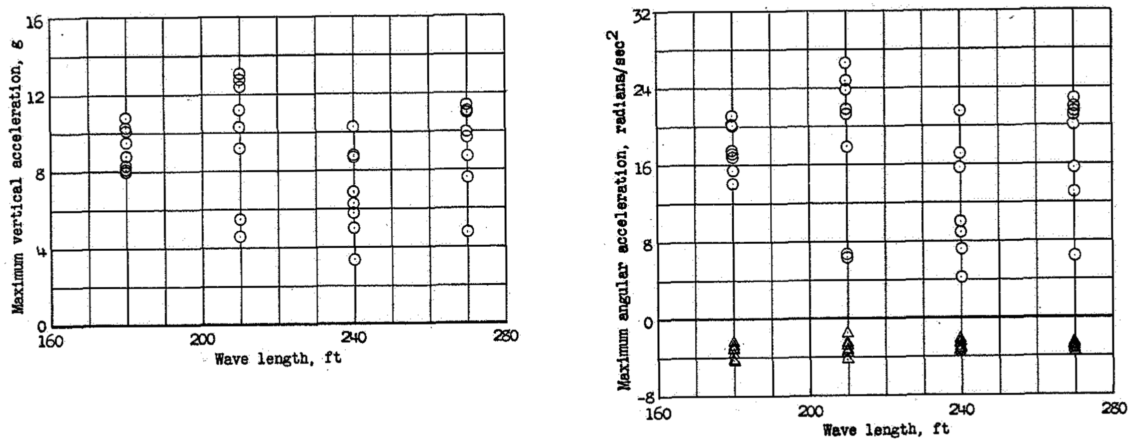
(a) 60° V trailing edge.

Figure 2.- Hydro-ski plan forms.

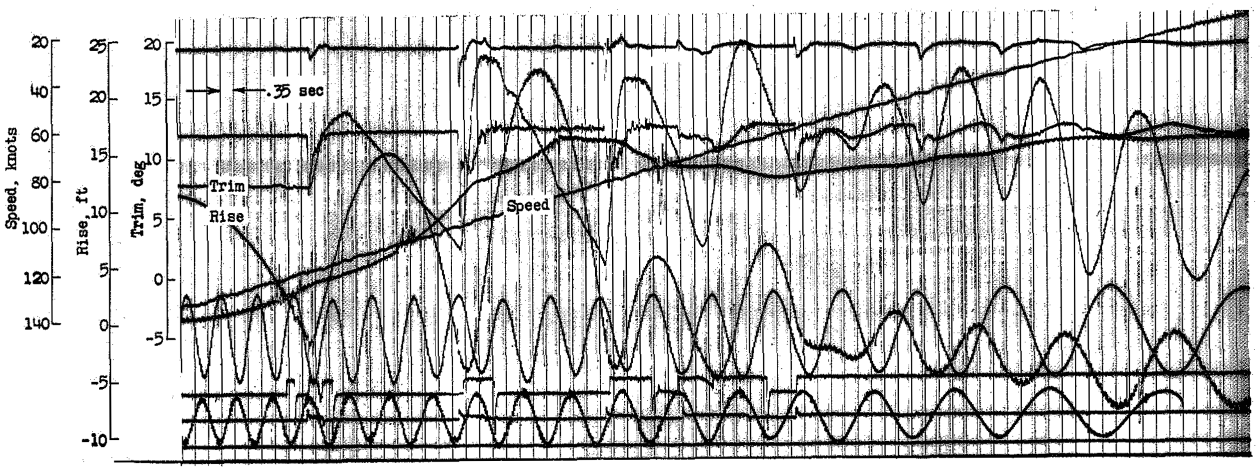


(b) 60° V and transverse trailing edge.

Figure 2.- Concluded.

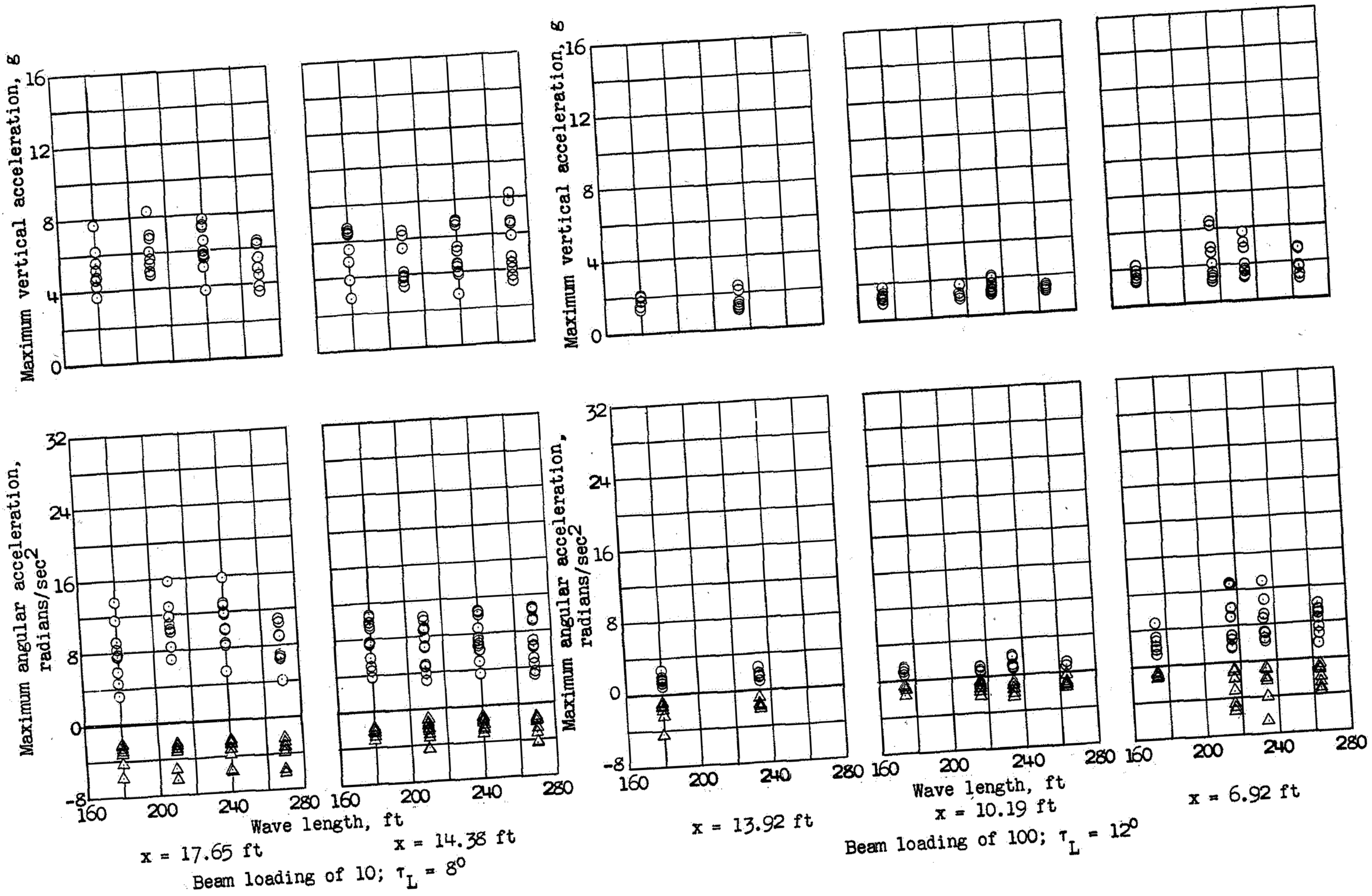


(a) Maximum vertical and angular accelerations.



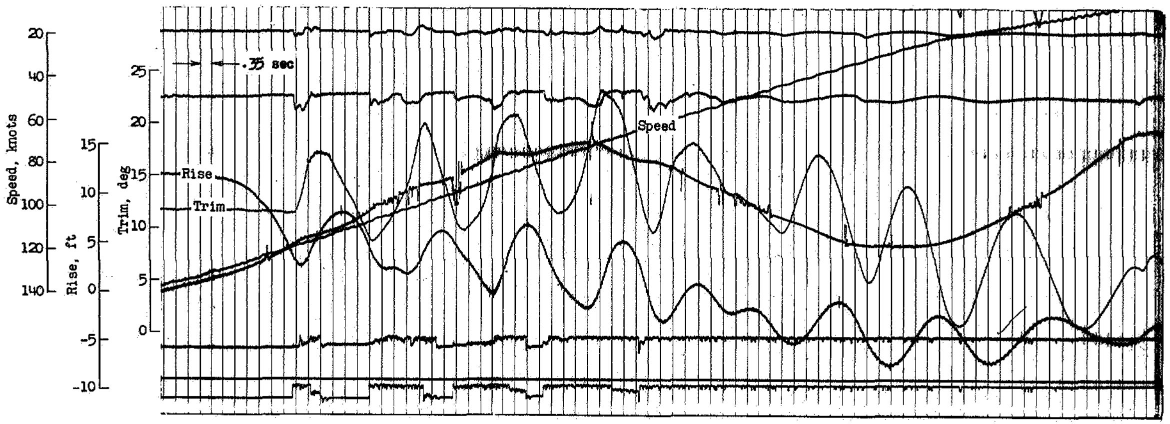
(b) Typical record showing motions in trim and rise.

Figure 3.- Landing characteristics in waves of basic model without hydro-ski.

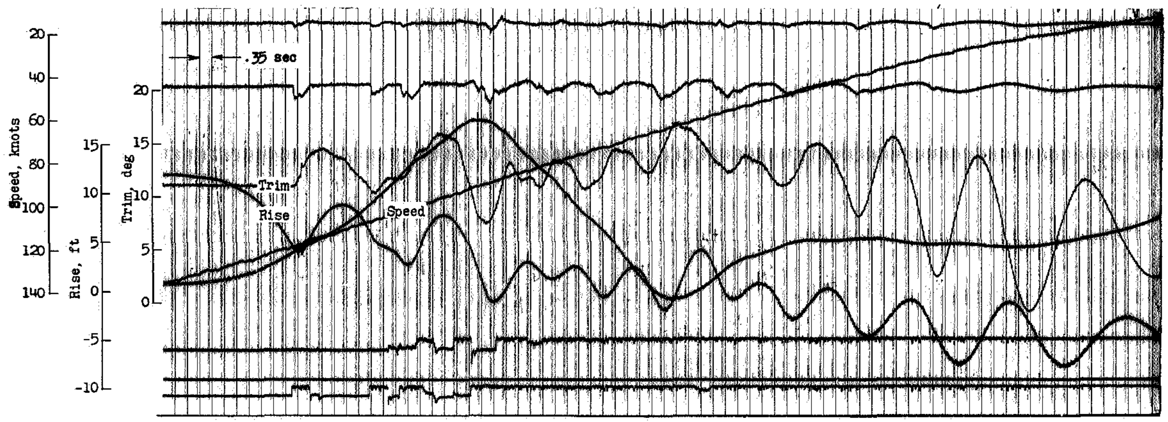


(a) Maximum vertical and angular accelerations.

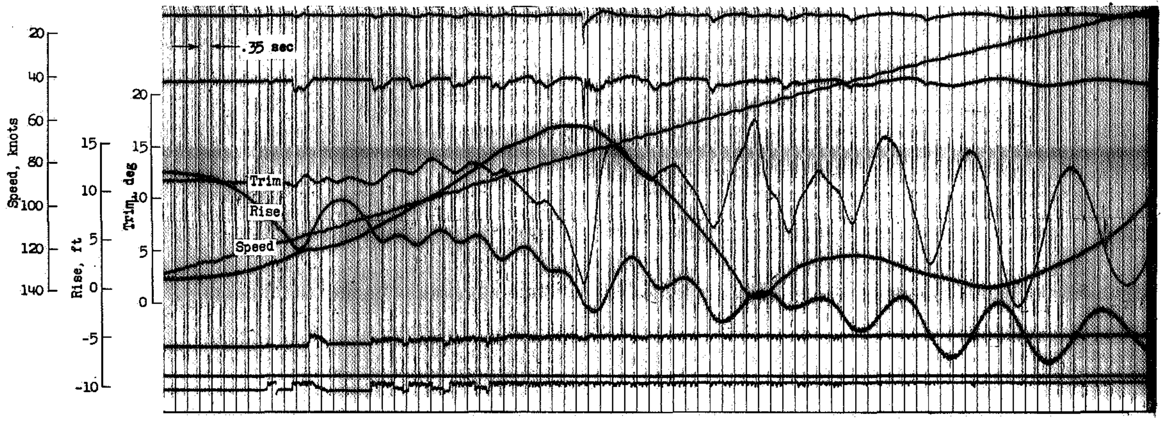
Figure 4.- Effect of longitudinal location of hydro-ski on landing characteristics in waves.



x = 13.92 ft



x = 10.19 ft



x = 6.92 ft

(b) Typical records showing motions in trim and rise. Beam loading of 100.

Figure 4.- Concluded.

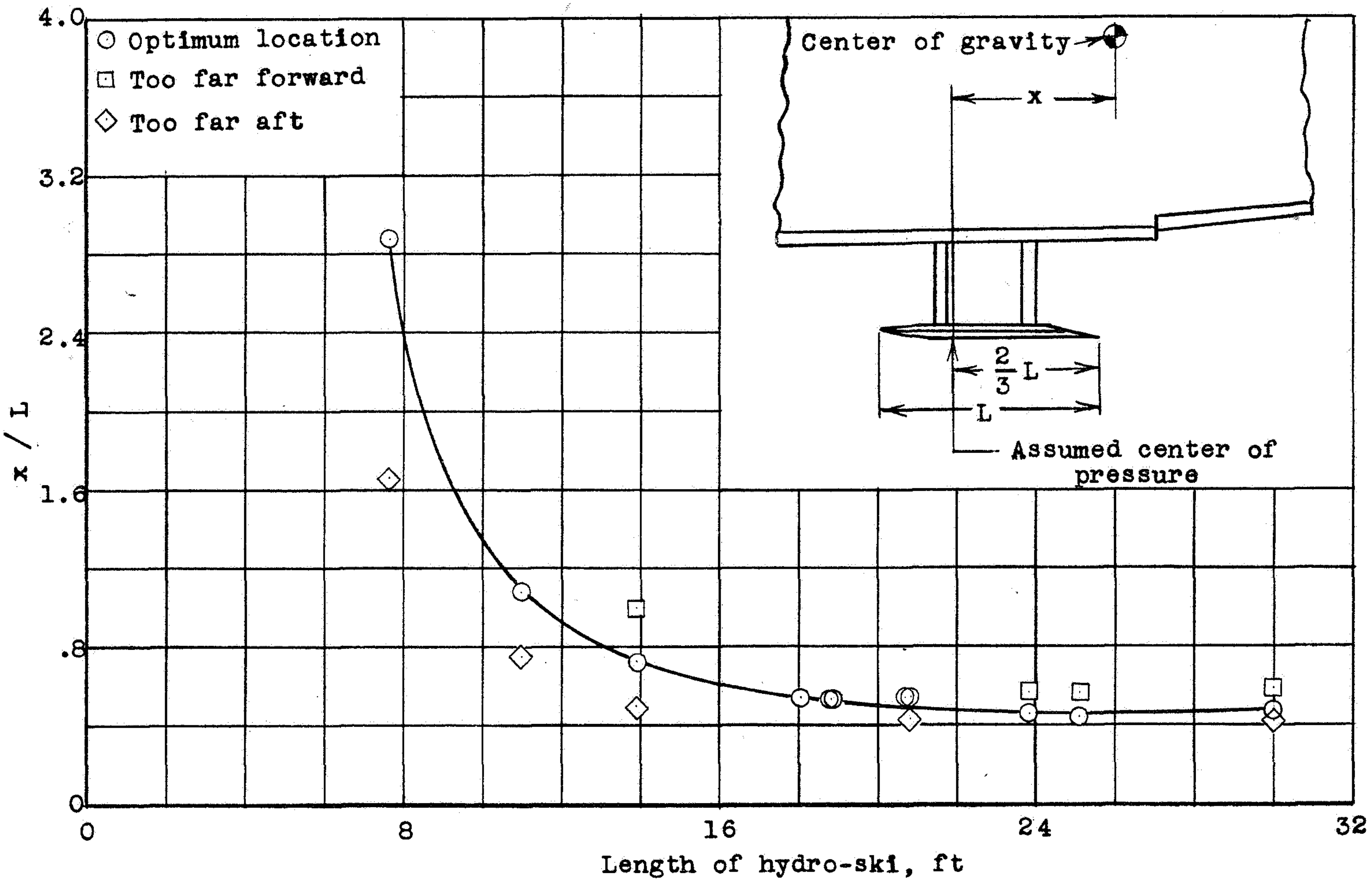
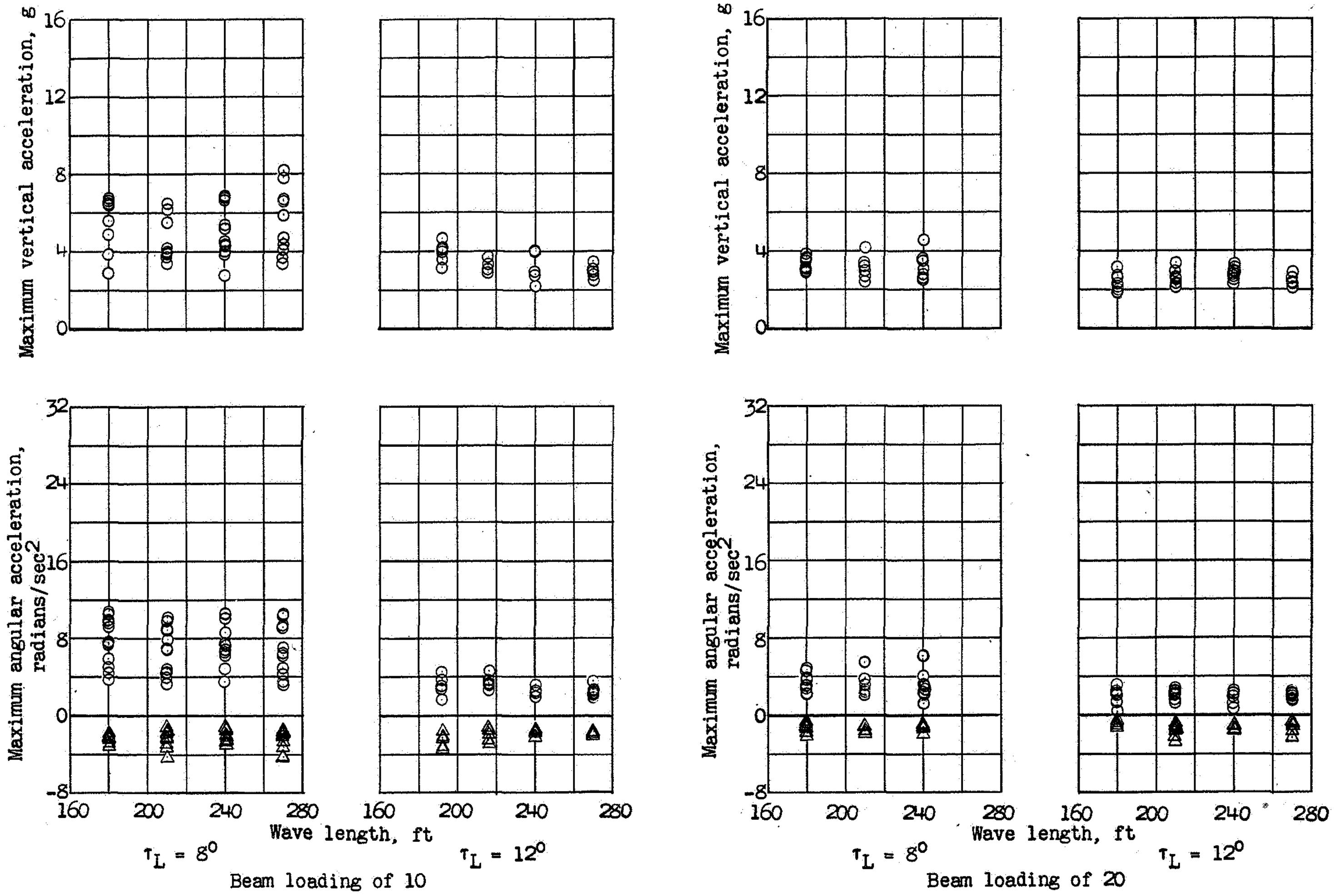
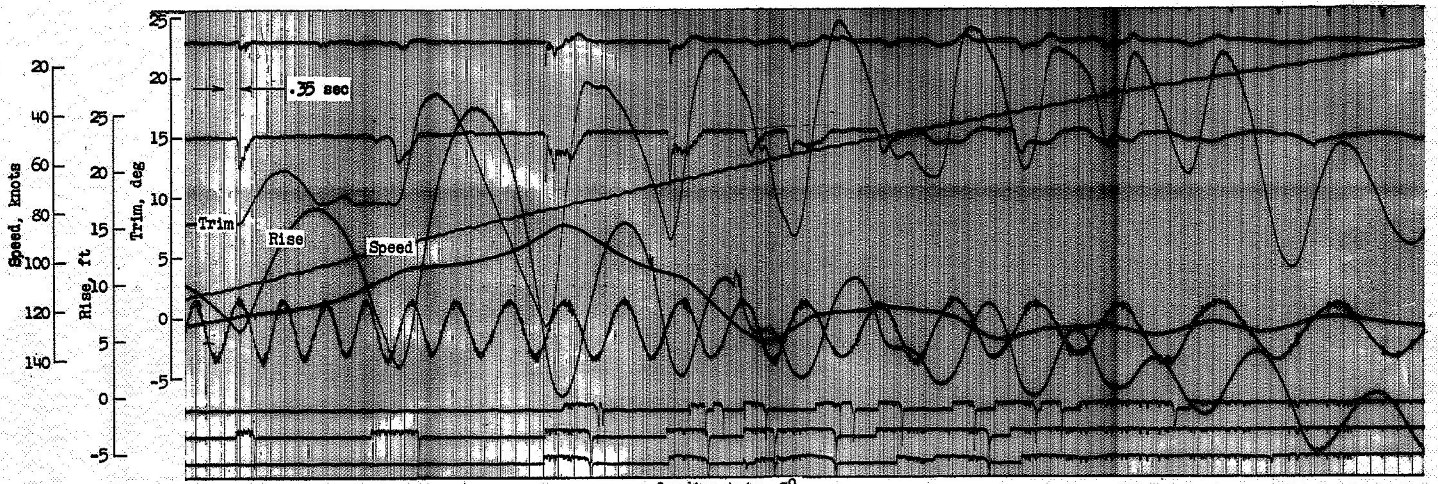


Figure 5.- Longitudinal location of various hydro-ski configurations.

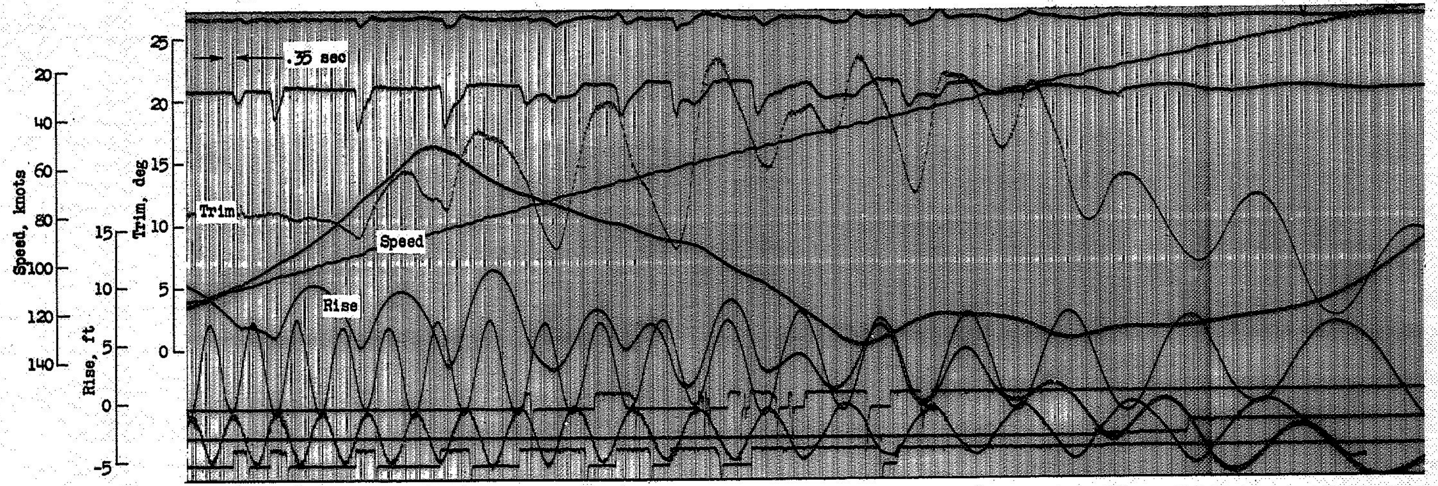


(a) Maximum vertical and angular accelerations.

Figure 6.- Effect of landing trim on landing characteristics of hydro-skis in waves.



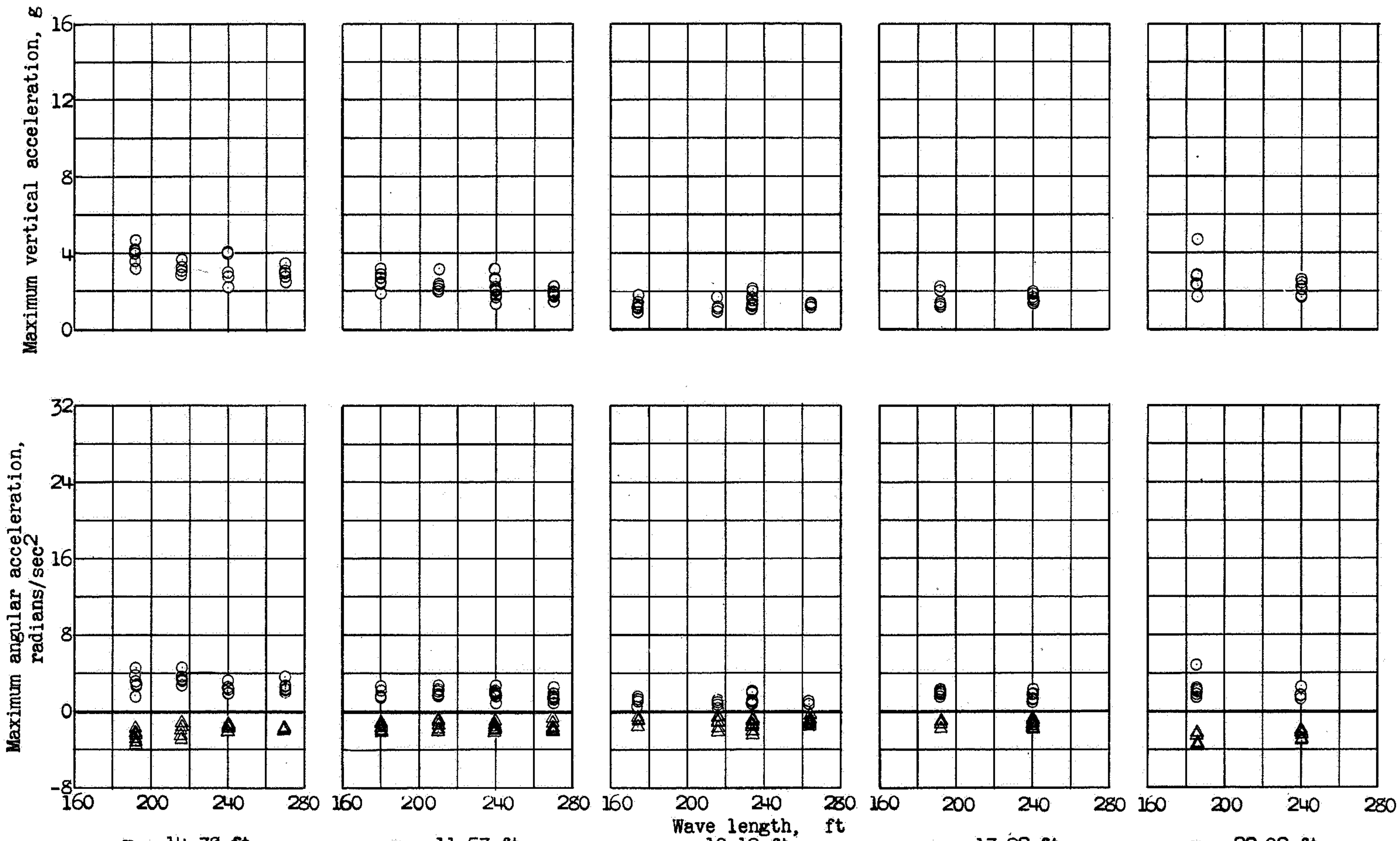
Landing trim, 8°



Landing trim, 12°

(b) Typical records showing motions in trim and rise. Beam loading of 10.

Figure 6.- Concluded.



x = 14.38 ft
Beam loading of 10

x = 11.53 ft
Beam loading of 30

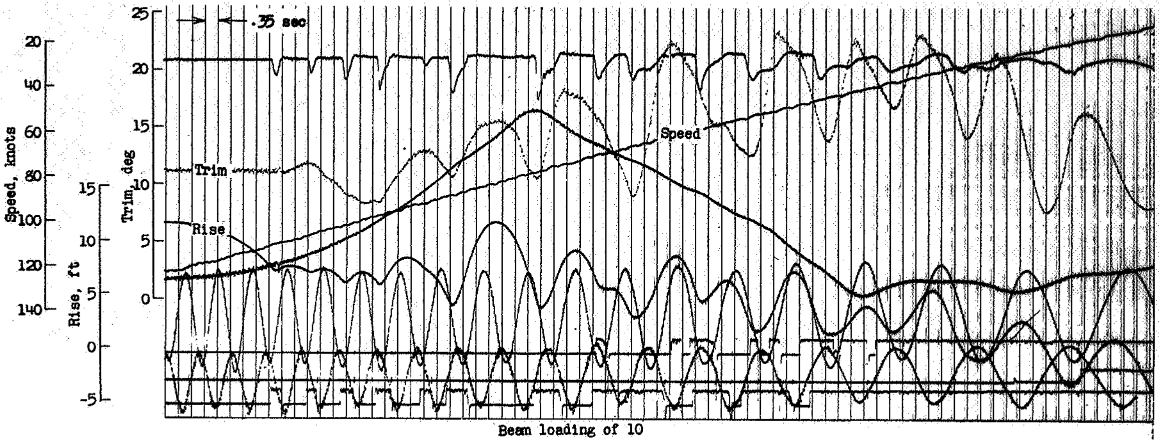
x = 10.19 ft
Beam loading of 100

x = 13.92 ft
Beam loading of 200

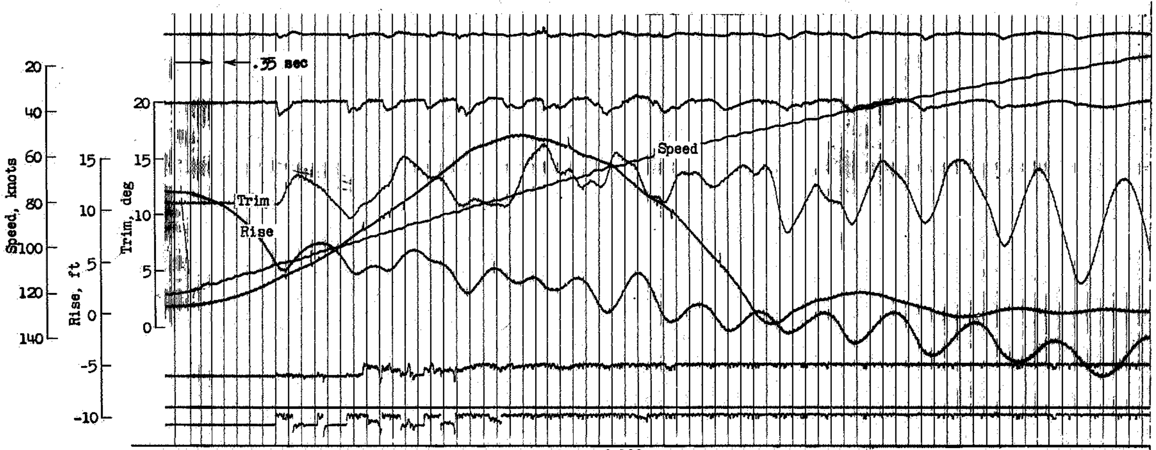
x = 22.02 ft
Beam loading of 600

(a) Maximum vertical and angular accelerations.

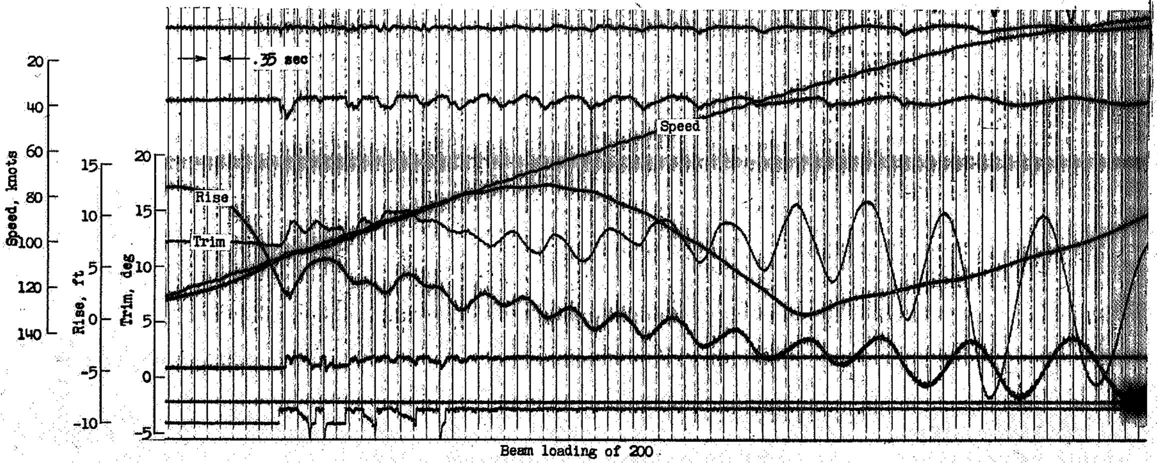
Figure 7.- Typical data obtained with hydro-skis during landings in waves. Landing trim, 12°.



Beam loading of 10



Beam loading of 100



Beam loading of 200

(b) Typical records showing motions in trim and rise.

Figure 7.- Concluded.

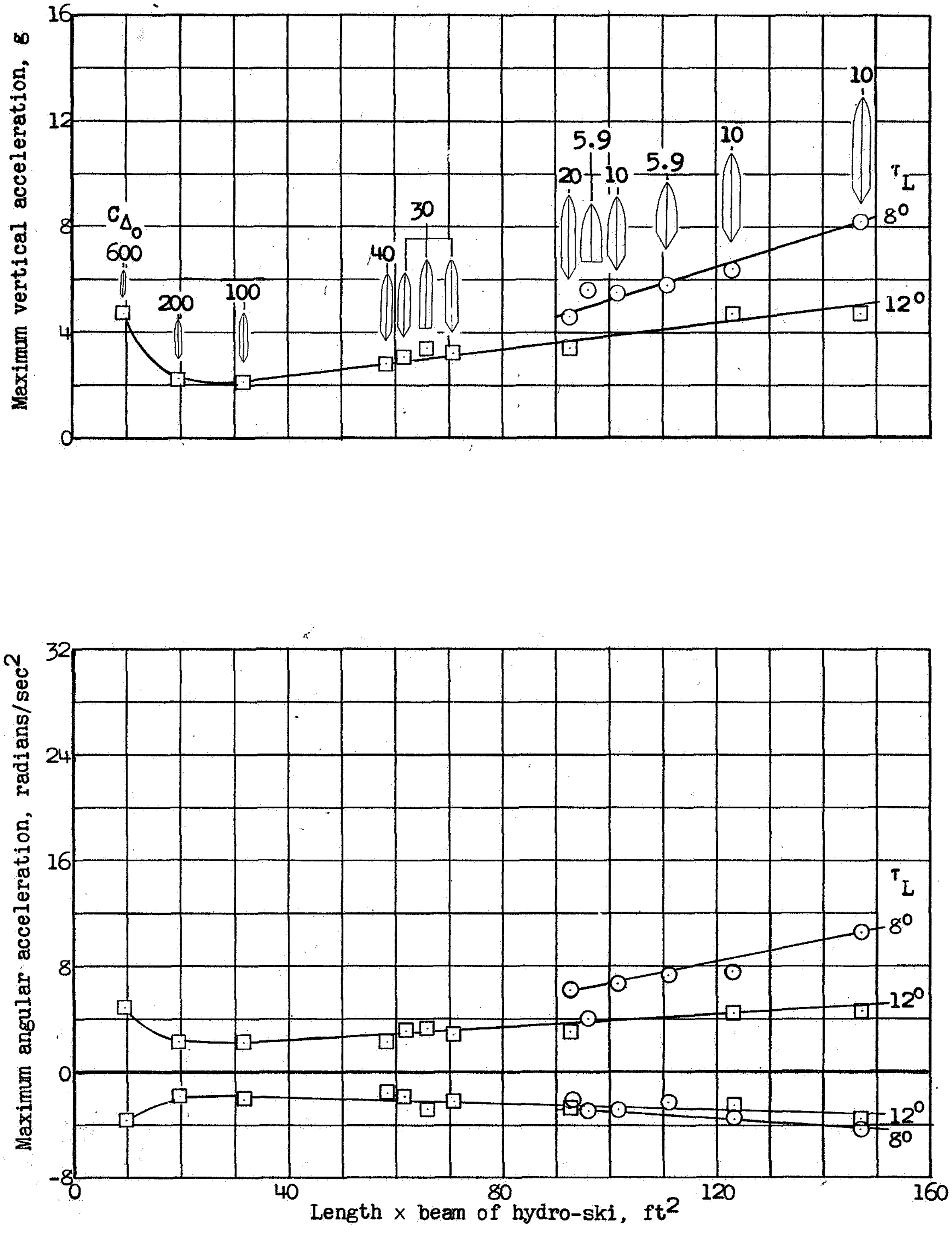


Figure 8.- Variation of maximum vertical and angular accelerations with length-beam product of the hydro-ski.

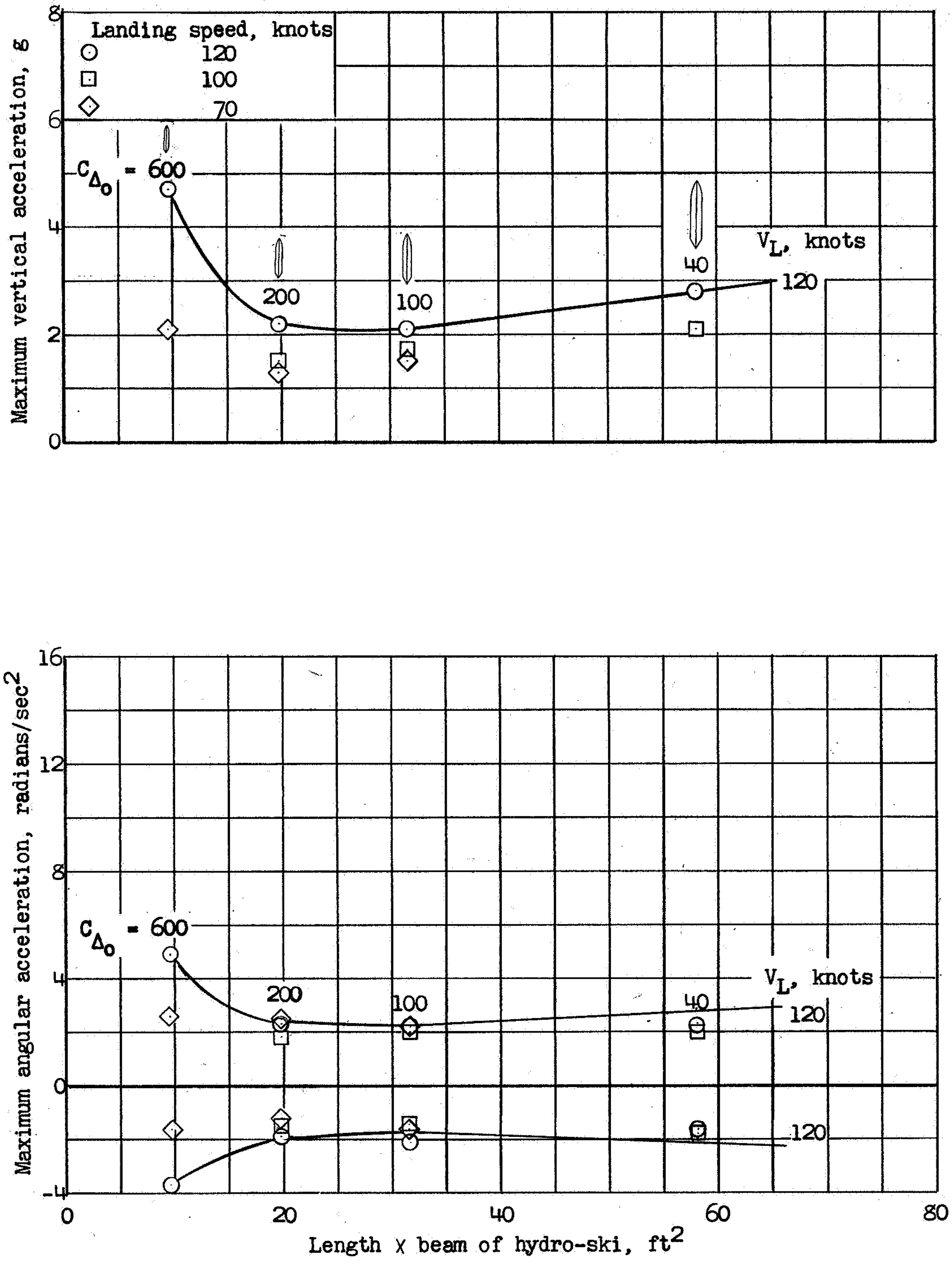


Figure 9.- Effect of landing speed on landing characteristics of hydro-skis in waves; landing trim, 12°.

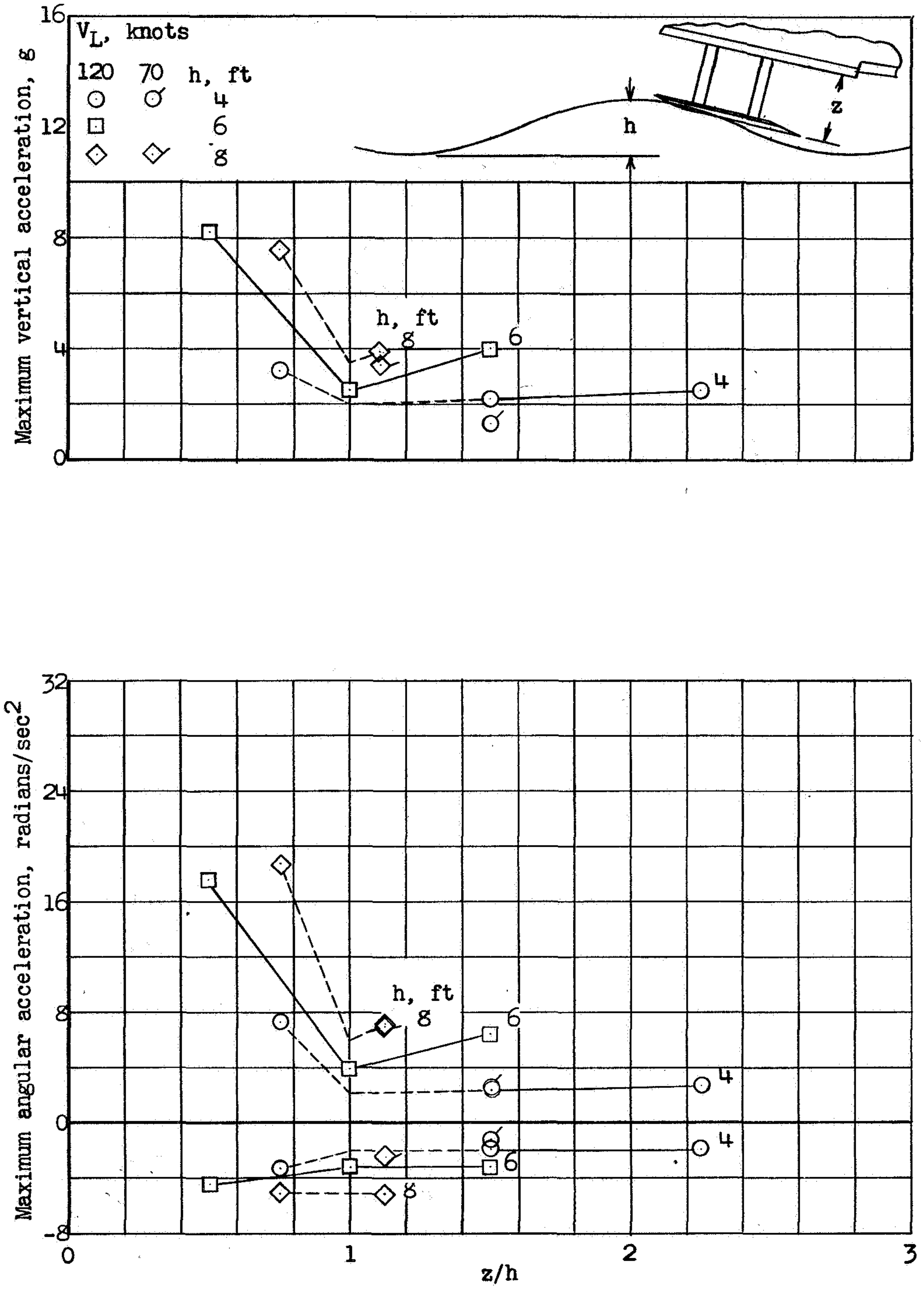
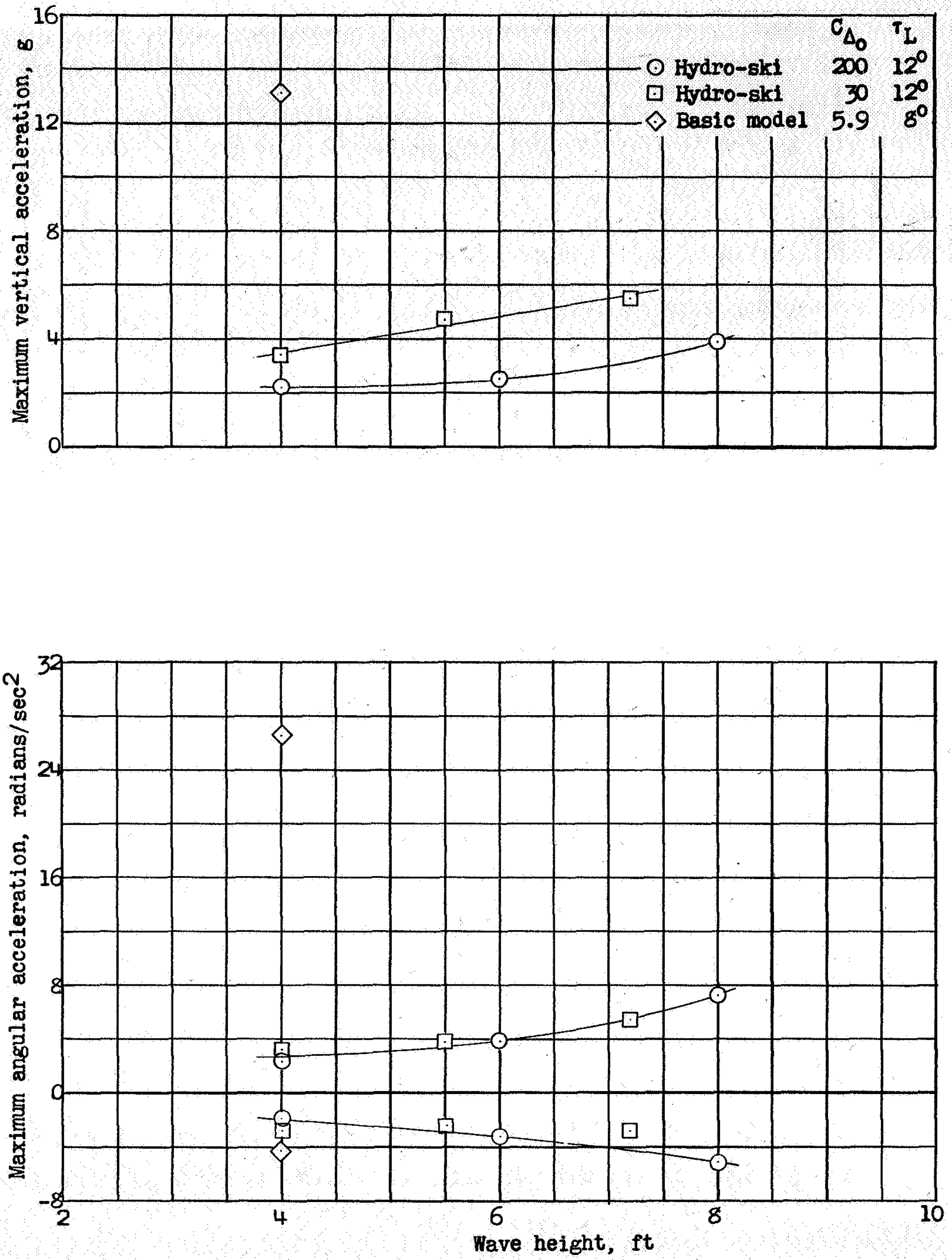
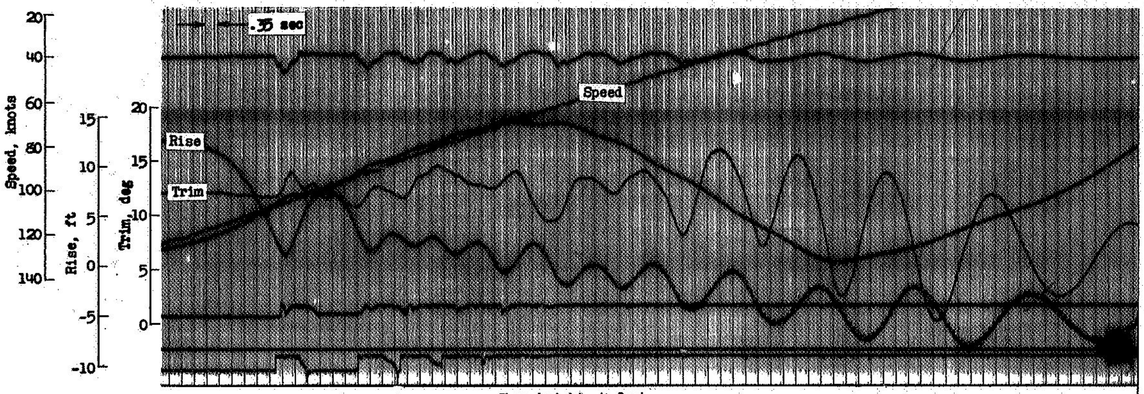


Figure 10.- Effect of vertical location of hydro-ski on landing characteristics in waves. Beam loading, 200; landing trim, 12°.

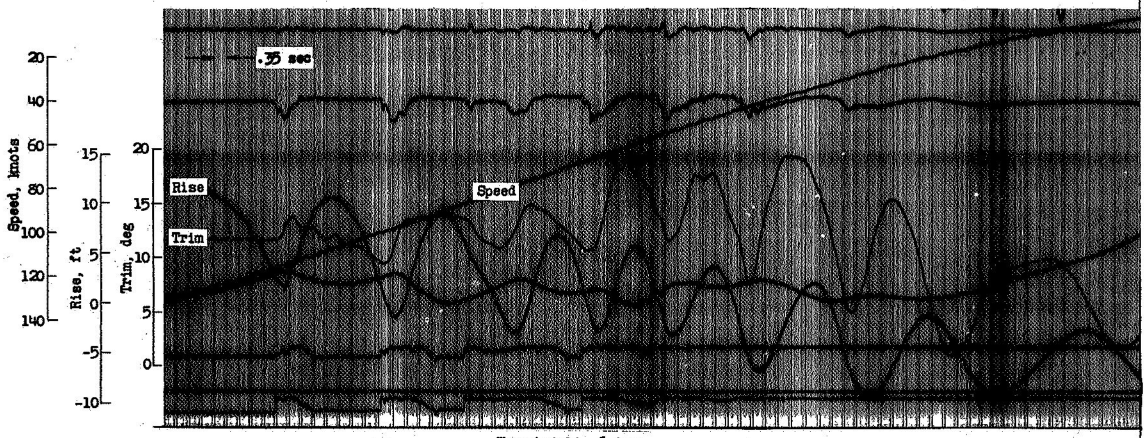


(a) Maximum vertical and angular accelerations.

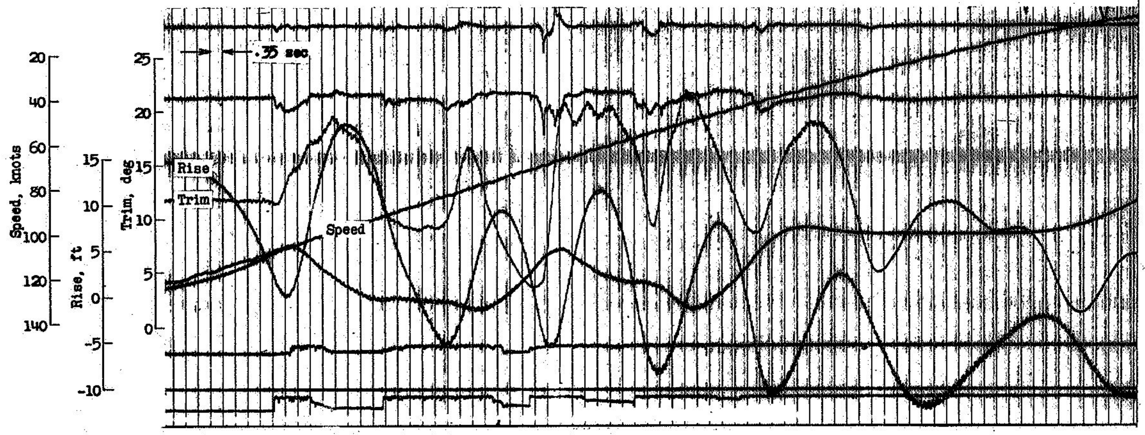
Figure 11.- Effect of wave height on landing characteristics of hydro-skis.



Wave height, 4 feet



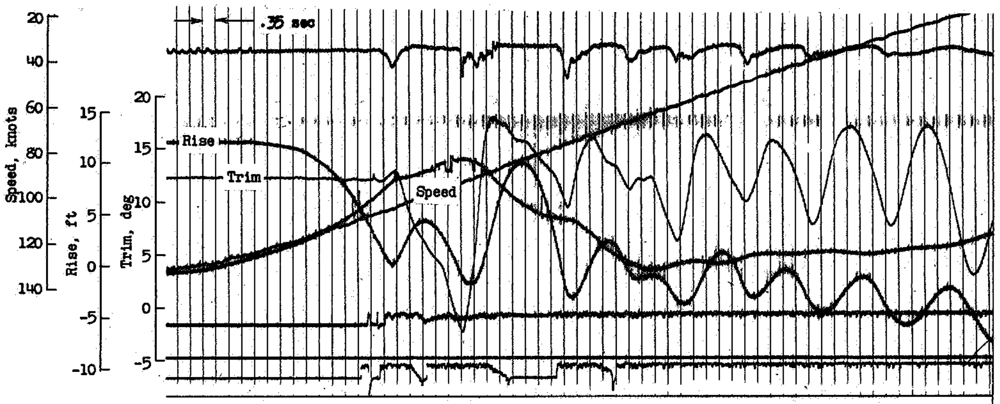
Wave height, 6 feet



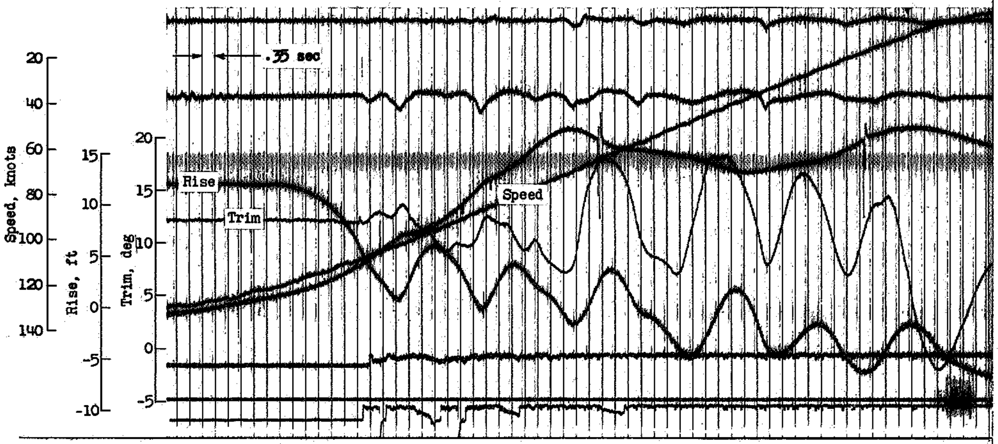
Wave height, 8 feet

(b) Typical records showing motions in trim and rise. Beam loading of 200.

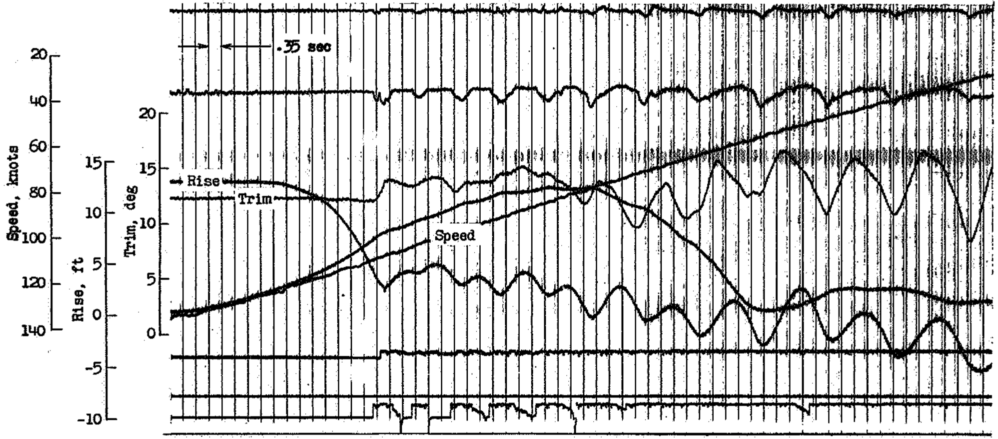
Figure 11.- Concluded.



0° incidence



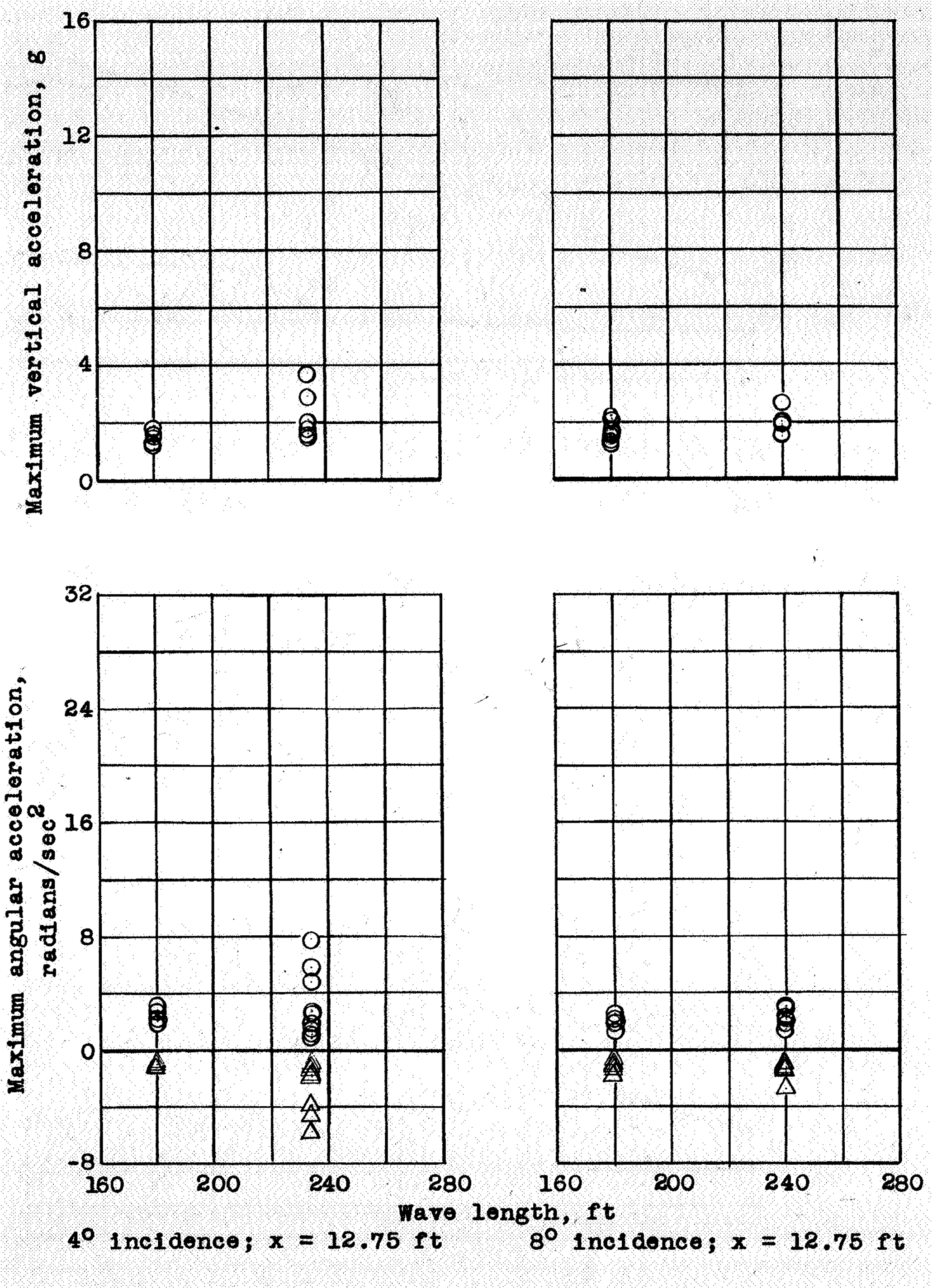
4° incidence



8° incidence

(a) Typical records showing motions in trim and rise. x = 12.75 feet.

Figure 12.- Effect of angle of incidence of hydro-ski on landing characteristics in waves. Beam loading of 600; landing trim, 12°.



(b) Maximum vertical and angular accelerations.

Figure 12.- Concluded.

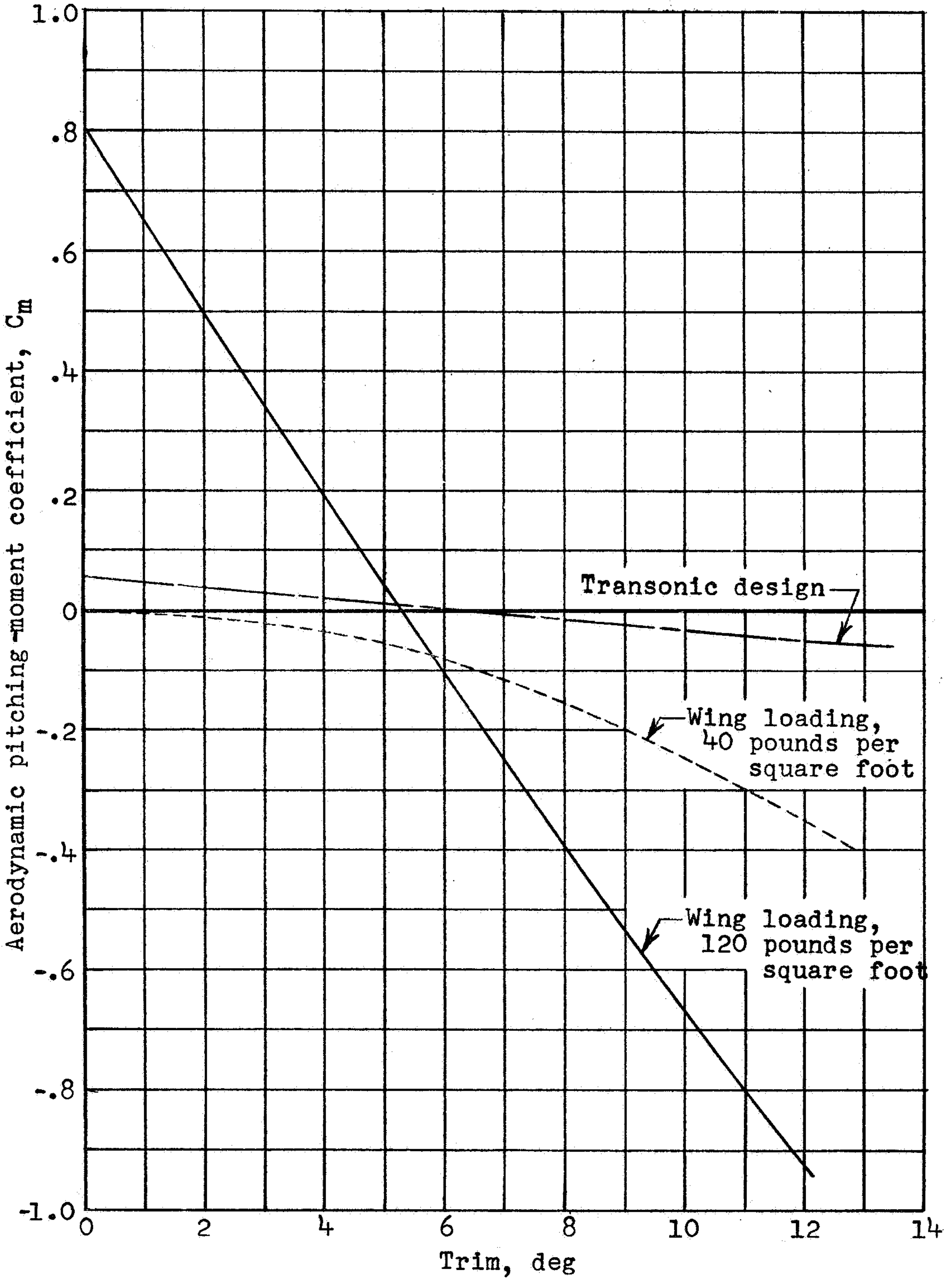


Figure 13.- Variation of aerodynamic pitching-moment coefficient with trim.

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