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THE EFFECT OF AFTERBODY LENGTH OF THE HYDRODYNAMIC STABILITY OF A DYNAMIC MODEL OF A FLYING BOAT - LANGLEY TANK MODEL 134

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MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

THE EFFECT OF AFTERBODY LENGTH ON THE HYDRODYNAMIC STABILITY OF A DYNAMIC MODEL OF A FLYING BOAT - LANGLEY TANK MODEL 134

By Norman S. Land

SUMMARY

A program of model tests has been completed at Langley tank no. 1 which will furnish a qualitative guide as to the relation of length of afterbody and depth of step. The model used for the tests was a 1/12-size unpowered dynamic model of a hypothetical 160,000-pound airplane. The results showed that an increase in length of afterbody requires an accompanying increase in depth of step to maintain adequate landing stability. Changing the length of afterbody and depth of step in such a manner as to maintain a given landing stability will result in only small changes in take-off stability.

INTRODUCTION

Until recently little information has been available to guide designers toward a rational choice of dimensions for the afterbody of a flying boat. The tests described in this report were made in order to partially supply this need for design information by gathering data on the effects of length of afterbody on hydrodynamic stability. A model with four afterbodies ranging from 1.6 to 3.1 beams in length with a constant keel angle was tested. The test program was based on the premise that landing stability is of paramount importance. From previous experience, it was known that the depth of step is perhaps the major dimension controlling the landing stability of any conventional afterbody.

Therefore, each of the afterbodies was tested with several depths of step to determine the depth necessary for adequate landing stability. In addition, the trim limits of stability and the range of stable locations of the center of gravity were determined for each afterbody with its optimum depth of step. These data then indicate the proper relation between the depth of step and afterbody length and the variation in take-off stability resulting from any choice of afterbody dimensions satisfying the above relation.

DESCRIPTION OF MODEL

The model used for the tests was 1/12-size unpowered model of a hypothetical flying boat with a design gross load of 160,000 pounds and a span of 200 feet. A full-size flying boat comparable to the model tested would be generally similar to the Martin XPB2M-1. The wing and tail surfaces are similar to those of the XPB2M-1 in size and in location with respect to the step. A profile of the model is shown in figure 1 and photographs of it in figure 2. This model is described in greater detail in reference 1.

Profile and plan views of the four afterbodies tested are shown in figure 3. The four afterbodies tested had a constant keel angle and length-beam ratios of 1.6, 2.1, 2.6, and 3.1. These models are designated as follows:

Designation	Afterbody length-beam ratio
134E	3.1
134A	2.6
134F	2.1
134G	1.6

Where dash numbers follow the above designation, they indicate the depth of step in percent of the maximum beam.

APPARATUS AND PROCEDURE

The apparatus used and the methods of testing employed are, in general, as described in reference 2.

The first test made with each afterbody was with a depth of step of 7 percent of the beam. As indicated by the landing stability of the model, the step was then altered in depth in a direction which would approach marginal landing stability. Every test included the determination of the trim limits of stability data as well as the landing stability. When a depth of step was reached which was just sufficient to give adequate landing stability, the limits of stable locations of the center of gravity were determined as well.

All of the tests were made with a gross load of 91.8 pounds (160,000 pounds full size) and a flap setting of 20°. All landings were made with a carriage deceleration of 1.0 foot per second per second. Each model was tested over a range of landing trims from 4° to 14°. Records of the trim and the vertical location of the center of gravity were taken during each landing. The limits of stable locations of the center of gravity were determined from accelerated runs made at a rate of 1.0 foot per second per second with elevators neutral or full-up.

RESULTS AND DISCUSSION

Analysis of landings.- A landing of a flying boat is obviously undesirable if it results in either critically high structural loads or large uncontrollable motions or both. The present landing tests deal only with the motions involved. Each landing record was analyzed to determine: (1) the trim at contact, (2) the number of times the main step cleared the water (number of "skips"), (3) the largest change in rise in a skipping cycle, and (4) the largest change in trim in a skipping cycle. Since time was not recorded, the above analysis gives no indication of the rapidity of such motions but serves nevertheless to indicate the relative landing stability of a model. From such an analysis, the stability of a model may be judged by its motion in rise, its motion in pitch, the number of skips, or some combination of these factors.

The results of landing tests made with one afterbody and several depths of step were analyzed on the basis of: (1) average and maximum change in trim, (2) average and maximum change in rise, (3) average and maximum number of skips, (4) average product of change in trim and change in rise, (5) average product of the number of skips, change in trim and change in rise. In addition, these criteria were further extended by a consideration of the magnitude of the range of landing trims in which such motions were appreciable. A careful consideration of each criterion for landing stability led to approximately the same conclusion as to the proper depth of step associated with a given afterbody. The conclusion based on the analysis of the data alone was also borne out by the visual observations of the behavior during landings.

Effect of afterbody length on depth of step required for landing stability.- The results of the analysis of the landing tests with different afterbody lengths and depths of step are shown in figure 4. It is apparent that an increase in afterbody length is accompanied by a large increase in the minimum depth of step which will give adequate landing stability. The increase in depth of step required as the afterbody is lengthened is approximately that which results in a constant sternpost angle. In this case, the average sternpost angle for the four afterbodies is 8.2° to the forebody keel.

Effect of afterbody length on take-off stability.- The effects of afterbody length on the range of stable trims is shown in figure 5 and on the range of stable locations of the center of gravity is shown in figure 6. No data are given in figure 6 for the shortest afterbody as this was not obtained. As shown in figure 5, shortening the afterbody raises the upper trim limits. This increase in stable trim range is small, however, being approximately 1° at a speed just below take off. The effect of lengthening the afterbody on the range of stable locations of the center of gravity, (fig. 6) is also small and probably within the accuracy of determination.

CONCLUSIONS

Within the range of these tests, the following conclusions may be drawn:

1. An increase in length of afterbody requires an accompanying increase in depth of step in order to maintain adequate landing stability. The increase in depth of step required is approximately that which results in a constant sternpost angle.

2. Changing afterbody length and depth of step in such a manner as to maintain a given landing stability will result in little changes in the take-off stability.

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

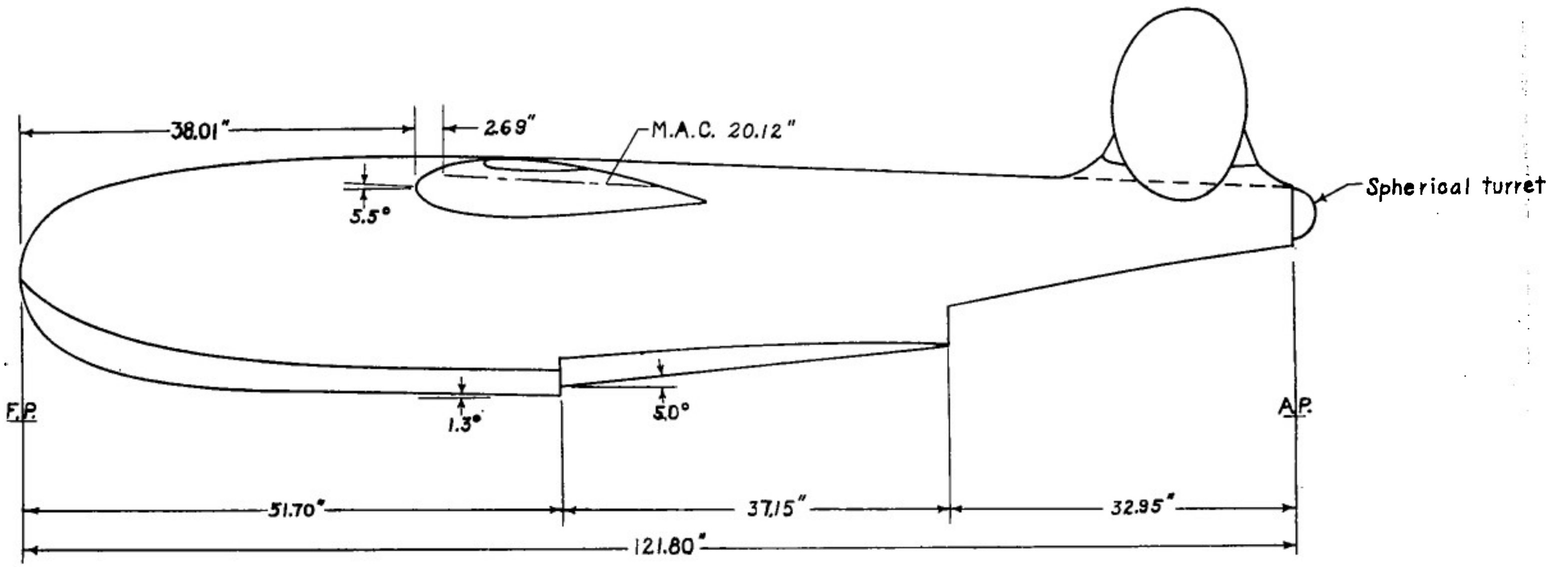
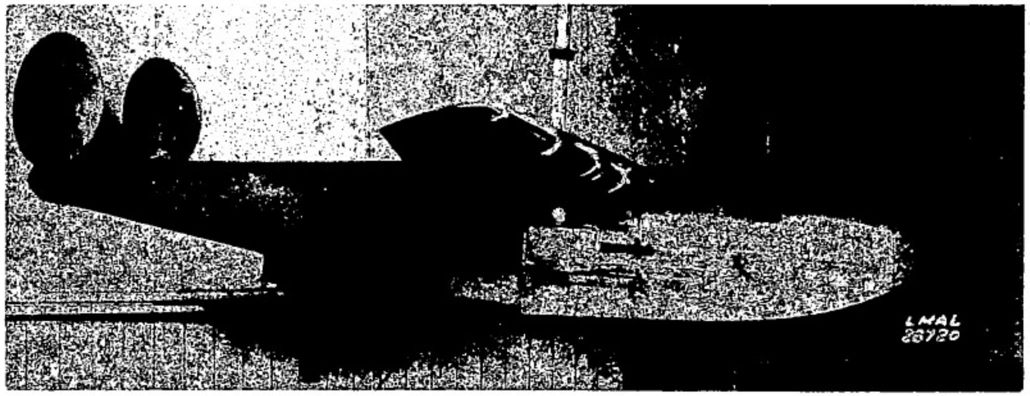
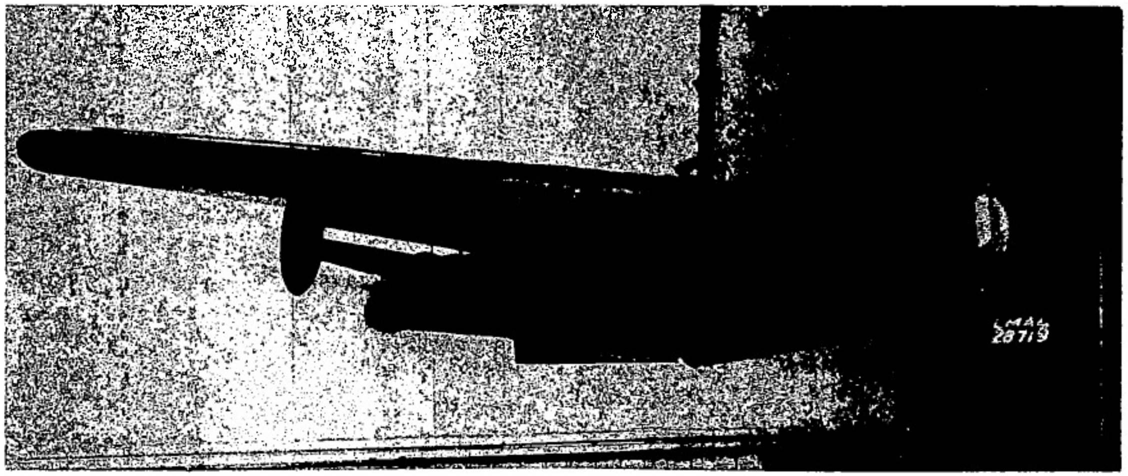


Figure 1.– Profile of Model 134A

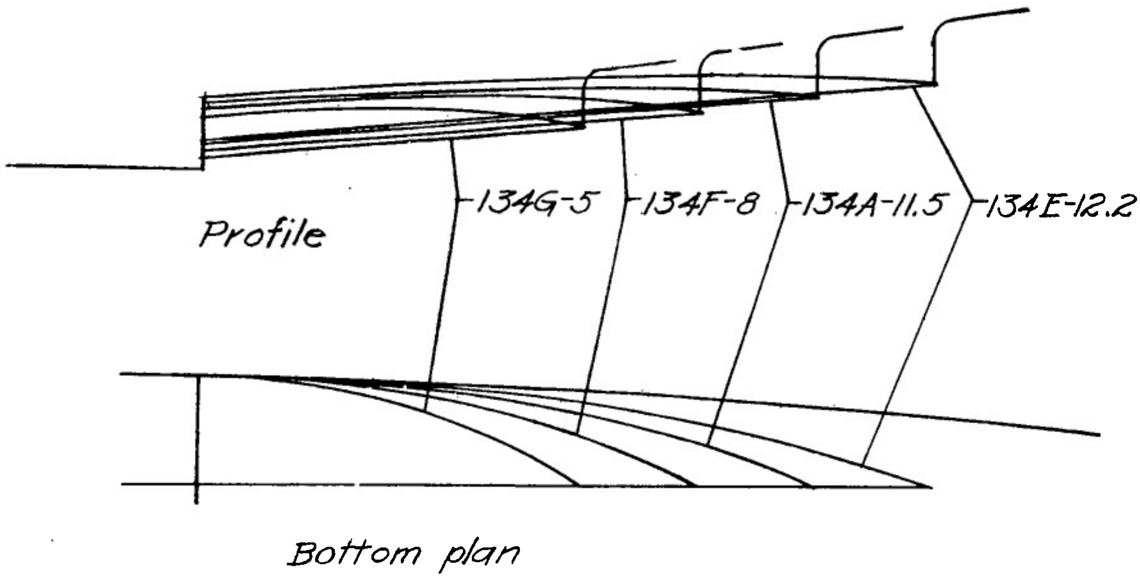


(a) Profile view.



(b) Three-quarter front view.

Figure 2.- Model 134A.



Model	Afterbody Length-beam ratio	Depth of step, percent beam
134E-12.2	3.1	12.2
134A-11.5	2.6	11.5
134F-8	2.1	8
134G-5	1.6	5
Max. beam = 14.24 in. (all models)		
Afterbody keel angle = 5.0° (all models)		

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Figure 3.- Model 134. Details of stable afterbodies

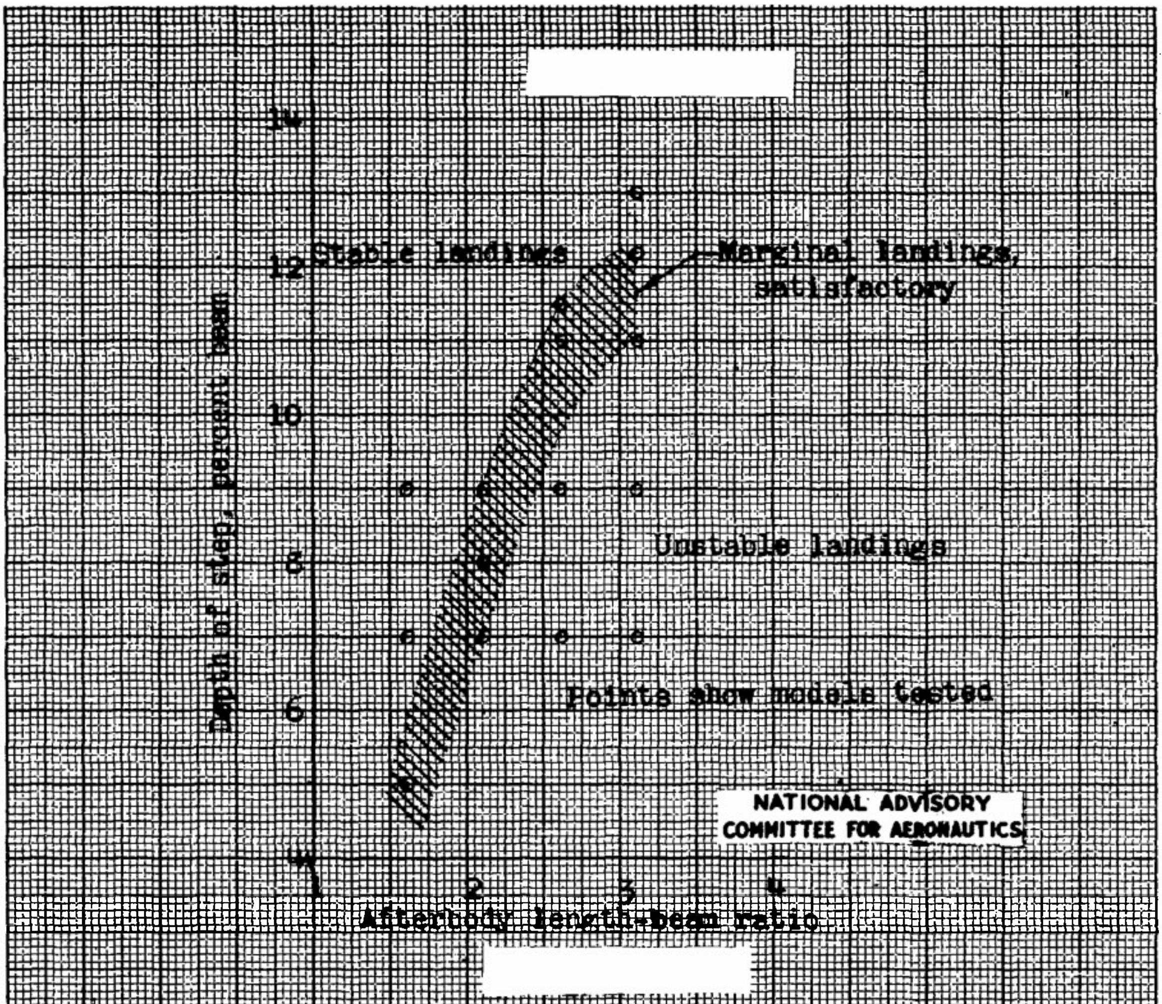

Figure 4.- Model 134. Variation of depth of step required for landing stability with afterbody length-beam ratio.

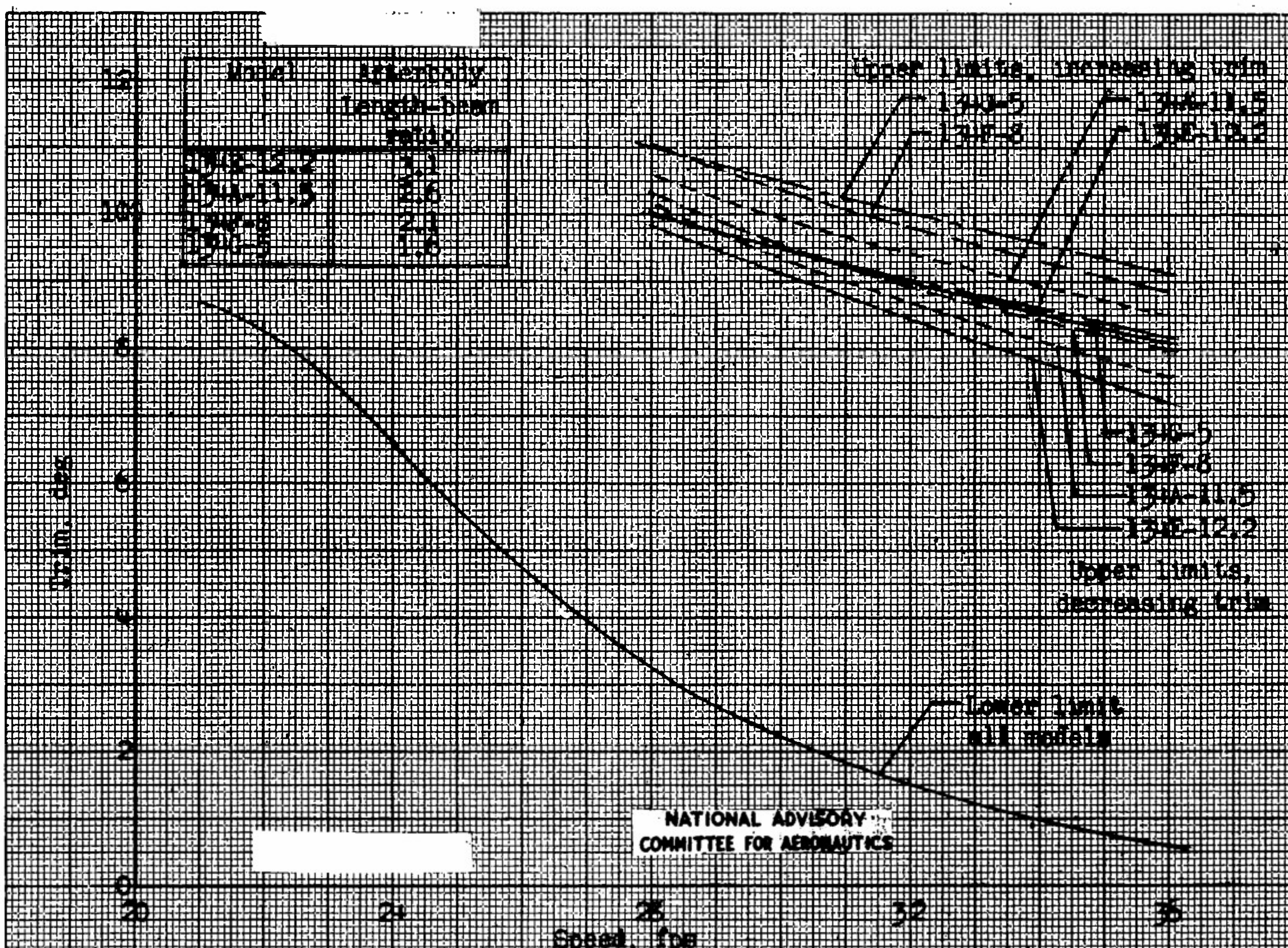

Figure 5.- Model 134. Comparison of trim limits showing the effect of changing the afterbody length-beam ratio. Each afterbody used with a depth of step which results in adequate landing stability.

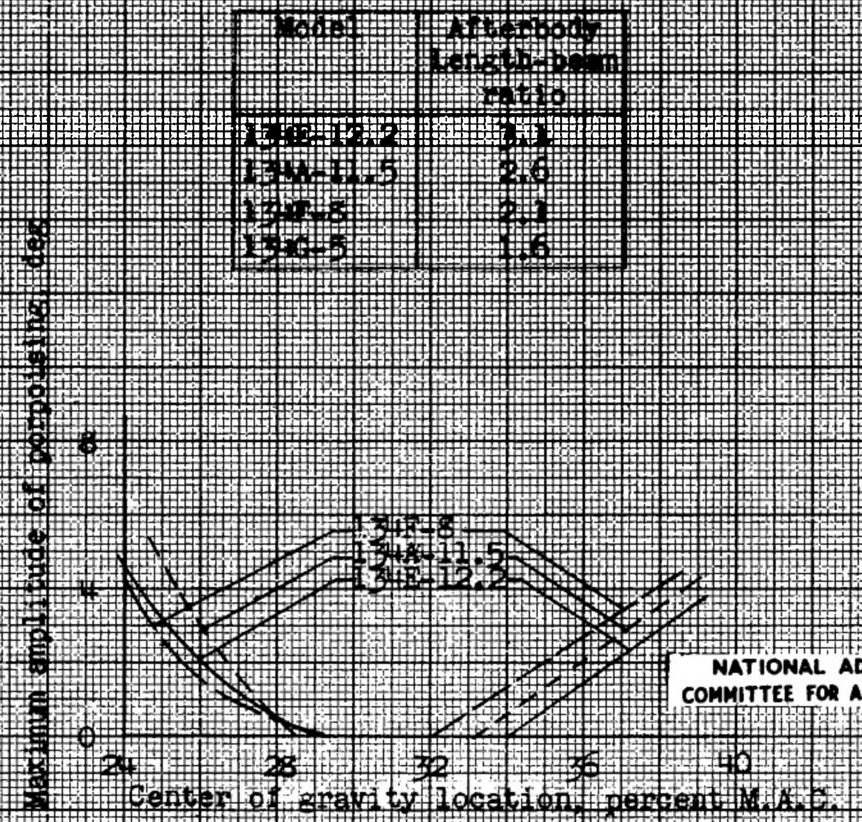

Figure 6 .- Comparison of maximum amplitude of porpoising at several center of gravity locations showing the effect of changing the afterbody length-beam ratio. Each afterbody used with a depth of step which results in adequate landing stability.

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ABSTRACT:

A 1/12-size unpowered model of a hypothetical 160,000-pound airplane was used to study the relation of afterbody length and depth of step. Results showed that an increase in afterbody length requires an accompanying increase in depth of step to maintain adequate landing stability. Only small changes in take-off stability will result from changing afterbody length and depth of step in such a manner as to maintain a given landing stability.

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