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RESEARCH MEMORANDUM

CORRELATION OF THE TRIM LIMITS OF STABILITY OBTAINED FOR A PB2Y-3 FLYING BOAT AND A 1/8-SIZE POWERED DYNAMIC MODEL

By

Charlie C. Garrison, David M. Goldenbaum,
and Andrew Hacskaylo

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
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SUMMARY

Tests of a PB2Y-3 flying boat were made at the U. S. Naval Air Station, Patuxent River, Md., to determine its hydrodynamic trim limits of stability. Corresponding tests were also made of a 1/8-size powered dynamic model of the same flying boat in Langley tank no. 1. During the tank tests, the full-size testing procedure was reproduced as closely as possible in order to obtain data for a direct correlation of the results.

At a nominal gross load of 66,000 pounds, the lower trim limits of the full-size and model were in good agreement above a speed of 80 feet per second. As the speed decreased below 80 feet per second, the difference between the model trim limits and full-scale trim limits gradually became larger. The upper trim limit of the model with flaps deflected 0° was higher than that of the full-size, but the difference was small over the speed range compared. At flap deflections greater than 0°, it was not possible to trim either the model or the airplane to the upper limit with the center of gravity at 28 percent of the mean aerodynamic chord.

The decrease in the lower trim limits with increase in flap deflection showed good agreement for the airplane and model.

The lower trim limits obtained at different gross loads for the full-size airplane were reduced to approximately a single curve by plotting trim against $\sqrt{C_{\Delta_o}}/C_V$.

INTRODUCTION

The hydrodynamic trim limits of stability of a large number of flying boats have been determined in Langley tank no. 1 by the use of dynamically similar models. In order to investigate the validity of the model procedures, the trim limits of a PB2Y-3 flying boat were determined at the U. S. Naval Air Station, Patuxent River, Md. After the full-size data had been obtained, a 1/8-size powered dynamic model was tested in the tank under corresponding conditions to provide data for a direct correlation.

The full-size tests were made in the Patuxent River by Navy and NACA personnel in April, May, and June 1944, and January 1945. The model tests were made in Langley tank no. 1 in June 1945.

SYMBOLS

C_{Δ_o} gross load coefficient $\left(\Delta_o / wb^3\right)$

C_{Δ} load coefficient $\left(\Delta / wb^3\right)$

C_V speed coefficient $\left(V / \sqrt{gb}\right)$

where

Δ_o gross load, pounds

Δ load on water, pounds

w specific weight of water, pounds per cubic foot (63.0 for full-size tests, 63.5 for model tests)

b beam of hull, feet

V water speed, feet per second

g acceleration of gravity, feet per second per second $\left(32.2 \text{ ft/sec}^2\right)$

δ_e elevator deflection, degrees

δ_f flap deflection, degrees

M.A.C. mean aerodynamic chord

FULL-SIZE TESTS

Description of Flying Boat

The general arrangement of the four-engine PB2Y-3 flying boat for which the trim limits of stability were obtained is shown in figure 1, and pertinent data are listed in table I. The airplane had been fitted by the manufacturer with a center-line skeg aft of the second step to improve the directional stability characteristics, and with a ventilation duct on each side of the keel and just aft of the main step to improve take-off and landing stability.

Apparatus and Procedure

An NACA visual trim indicator was used to observe the trim during the tests; it was located so that the pilot and an observer could read the indicated trims. An NACA events recorder was used to record the water speed and to indicate the instant that porpoising started. The recorded trim from the gyro unit of the events recorder was not used for the final analysis as it was known to be affected by acceleration. The accuracy of the readings from the visual trim indicator was considered to be ±0.5°.

The trim limits of stability were obtained at nominal gross loads of 56,000, 61,000, and 66,000 pounds and with the center of gravity at 28 percent mean aerodynamic chord. The flaps were set at 0°, 20°, and 40°. The test runs were made at constant speeds, beginning at about 35 knots and continuing at 5-knot increments until the maximum permissible speed was attained. For each run, the flying boat was accelerated to speed and the engines were throttled until the speed was constant.

To determine the lower trim limits of stability, the elevators were moved down slowly from a position at which the airplane was at a stable trim until a lower trim was reached at which porpoising was encountered; the elevators were then moved up until porpoising ceased. In attempts to determine the upper trim limits, the elevators were moved up slowly until porpoising was encountered or the maximum available trim was reached. If porpoising started, the elevators were lowered until a stable trim was again reached. Because of the danger involved, the amplitude of the porpoising was not allowed to build up; consequently, fully developed upper limit porpoising did not occur, and the upper limit, decreasing trim, was not determined.

MODEL TESTS

Description of Model

The powered dynamic model, designated Langley tank model 165, is a 1/8-size model of the PB2Y-3 flying boat whose general arrangement is shown in figure 1. The model was constructed by the Consolidated-Vultee Aircraft Corporation; detailed data regarding the model are given in table I. Wing-tip floats, such as were used on the full-size flying boat, were not reproduced on the model, inasmuch as the model was restrained in roll and yaw during the tank tests. Ventilation ducts were installed in the afterbody just aft of the step, but the center-line skeg was not fitted aft of the second step as it was on the full-size flying boat. Four variable-frequency electric motors turned the three-blade metal propellers. Leading-edge slats were installed on the wing to delay the stall and make the stall occur at angles more nearly equal to those expected for the full-size flying boat.

Apparatus and Procedure

The tests were made in Langley tank no. 1, which is described in reference 1. The towing gear is described in reference 2. The trim was determined from the relative position of a pointer fixed to the vertical towing staff and a scale that rotated with the model.

The propellers of the model were adjusted to a blade angle of 8° at 0.75 radius. The propeller thrust was measured with the model at 0° trim and with the propellers rotating at 5600 rpm. The effective thrust approximated the scale value corresponding to the full-size thrust available with 1200 brake-horsepower engines (fig. 2).

Trim limits of stability were obtained at a gross load of 128 pounds (66,000 pounds full size) for flap deflections of 0°, 20°, and 40°. The center of gravity was at 28 percent mean aerodynamic chord. The model weight could not be reduced below a gross load corresponding to 66,000 pounds, full size; consequently, tank tests were limited to this load.

The trim limits were obtained by the methods described in reference 3. To simulate conditions under which full-size data were obtained, most of the runs were made with the rpm required for a net horizontal force of zero, (thrust = total drag). A few runs were made, however, with full power (5600 rpm with 8° blade angle). The accuracy of the trim readings was considered to be ±0.25°.

RESULTS AND DISCUSSION

The lower trim limits of stability obtained for the full-size flying boat at the nominal gross load of 66,000 pounds and for flap deflections of 0°, 20°, and 40° are shown in figure 3. Upper limit porpoising was encountered only when the flaps were at 0°. The upper limit, increasing trim, for this deflection is shown in figure 3(a). With the flaps deflected to 20° and 40° and with the center of gravity located at 28 percent mean aerodynamic chord, the available moment from the elevators was insufficient to increase the trim to the upper limit. The maximum available trims attained with flaps deflected 20° and 40° are shown as stable points in figures 3(b) and 3(c). In order to obtain the upper limit, it would have been necessary to move the center of gravity aft of 28 percent mean aerodynamic chord which was not feasible for these tests.

For the model, the lower trim limits of stability are presented in figure 4 for flap deflections of 0°, 20°, and 40°. A small amount of upper limit porpoising was obtained with the center of gravity at 28 percent mean aerodynamic chord for a flap deflection of 0°, as shown in figure 4(a). At flap deflections of 20° and 40°, however, the aerodynamic moments obtained with full-up elevators (as with the full-size flying boat) were insufficient to trim the model to the upper limit and an aft movement of the center of gravity would have been necessary to obtain the upper limits for these flap deflections.

The faired trim limits of the full-size airplane at the 66,000-pound load and those of the model at the corresponding load and speeds are compared in figure 5. The limits for the model lie above those of the airplane. Above 80 feet per second, however, the differences are within the accuracy of determination, and a good correlation is obtained. As the speed decreased below 80 feet per second, the difference between the model trim limits and the full-scale trim limits gradually became larger.

The upper limit for the model is higher than that for the airplane and was not obtained over as wide a speed range. If the difficulties of determining this limit in both tests are considered, however, the agreement is satisfactory over the speed range compared.

For the full-size flying boat at nominal gross loads of 56,000, 61,000, and 66,000 pounds, figure 6 shows that increasing the flap deflection reduces the lower trim limit. This trend has been noted in tank tests of several models and is attributed to the increase in lift of the wing (decrease in load on the water) that is obtained with increased flap deflection.

The faired lower limits of the airplane at the 66,000-pound load and those of the model at corresponding load and speeds are compared in figure 7. The decrease in the limits with increase in flap deflection for the airplane and model show good agreement.

In tests of dynamic models, it has been found that a plot of the lower trim limit against the criterion $\sqrt{C_\Delta}/C_V$ (which relates net waterborne load with speed) resulted in a single curve for all loads (reference 3). In an effort to determine if a similar plot for the full-size PB2Y-3 flying boat would result in a similar reduction of the load parameters to a single curve, the full-size lower trim limits were plotted against $\sqrt{C_{\Delta_0}}/C_V$ rather than against $\sqrt{C_\Delta}/C_V$, inasmuch as aerodynamic data to determine the net waterborne load coefficient C_Δ were not available. This procedure is justified because the same aerodynamic lift characteristics apply for all loads. The resultant plot is shown in figure 8. In this figure, for each of the three flap conditions, 0°, 20°, and 40°, the load parameters are sufficiently close to each other as to approximate a single curve, and indicate that the trim limits of the full size may be reduced to a single curve by the same methods that apply to the model results.

CONCLUSIONS

From the investigation of the trim limits of stability of a PB2Y-3 flying boat and a 1/8-size powered dynamic model, it is concluded that:

1. At a nominal gross load of 66,000 pounds, the lower trim limits of the full size and model were in good agreement above a full-size speed of 80 feet per second. As the speed decreased below 80 feet per second, the difference between the model trim limits and full-scale trim limits gradually became larger.

2. At the 66,000-pound load and 0° flap deflection, the upper trim limits of the model were higher than those of the full size but the difference was small over the speed range compared. At

flap deflections greater than 0°, it was not possible to trim either the model or the airplane to the upper limit with the center of gravity at 28 percent of the mean aerodynamic chord.

3. The decrease in tho lower trim limits with increase in flap deflection showed good agreement for the airplane and model.

4. The lower trim limits obtained at different gross loads for the full-size airplane were reduced to approximately a single curve by plotting trim against $\sqrt{C_{\Delta_o}/C_V}$.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

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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.

3. Davidson, Kenneth S. M., and Locke, F. W. S., Jr.: Some Analyses of Systematic Experiments on the Resistance and Porpoising Characteristics of Flying-Boat Hulls. NACA ARR No. 3I06, 1943.

TABLE I.- GENERAL DATA FOR FULL-SIZE PB2Y-3 FLYING

BOAT AND LANGLEY TANK MODEL 165

	Full size	Model
Hull:		
Length over-all, ft	79.0	9.9
Length of forebody, bow to point of step, ft	33.21	4.15
Length of afterbody, point of step to sternpost, ft	21.16	2.64
Beam, ft	10.5	1.31
Depth of step, in.	6.96	0.87
Type of step	30° Vee	30° Vee
Angle of forebody keel, deg	1.0	1.0
Angle of afterbody keel, deg	6.25	6.25
Dead rise, deg	22.5	22.5
Wing:		
Span, ft (floats retracted)	115.0	14.4
Area, sq ft	1779	27.8
Angle of wing setting to base line, deg	3.0	3.0
Mean aerodynamic chord, ft	16.19	2.02
Leading edge M.A.C. aft of bow, ft	23.3	2.91
Tail surface:		
Horizontal		
Area, sq ft	323.1	5.05
Span, ft	38.1	4.75
Root chord, ft	9.5	1.19
Tip chord, ft	8.0	1.0
Root incidence to base line, deg	2.0	-3.0
Vertical		
Area, sq ft	217.88	3.40
Chord, ft	10.2	1.28
Height, ft	12.75	1.59
Propellers:		
Number of propellers	4	4
Number of blades per propeller		
Inboard	4	3
Outboard	3	3
Diameter of propellers		
Inboard, ft	12.17	1.63
Outboard, ft	12.5	1.63
Thrust line, angle to base line, deg	0	0

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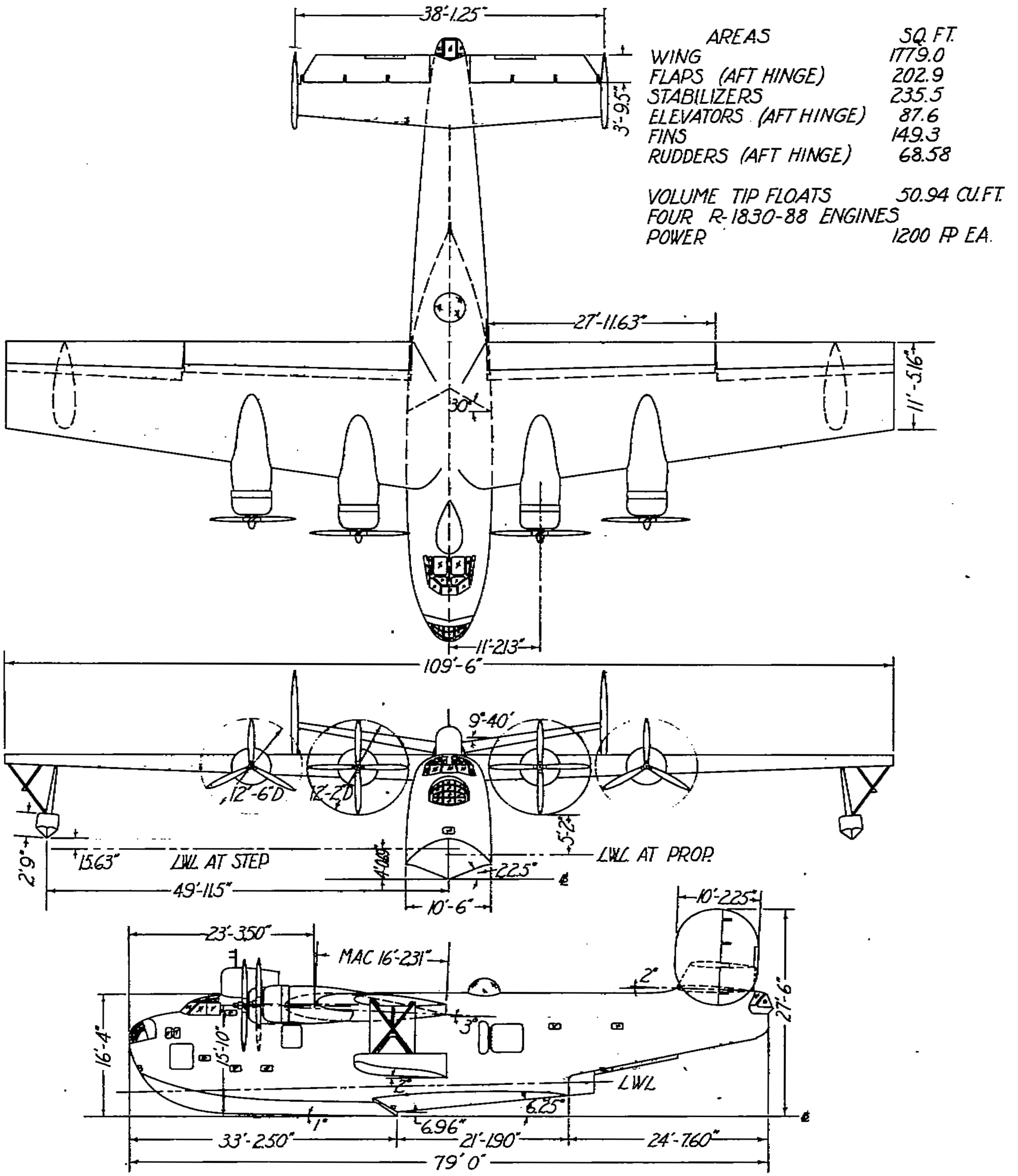

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FIGURE 1.- GENERAL ARRANGEMENT OF THE NAVY PB2Y-3 FLYING BOAT.

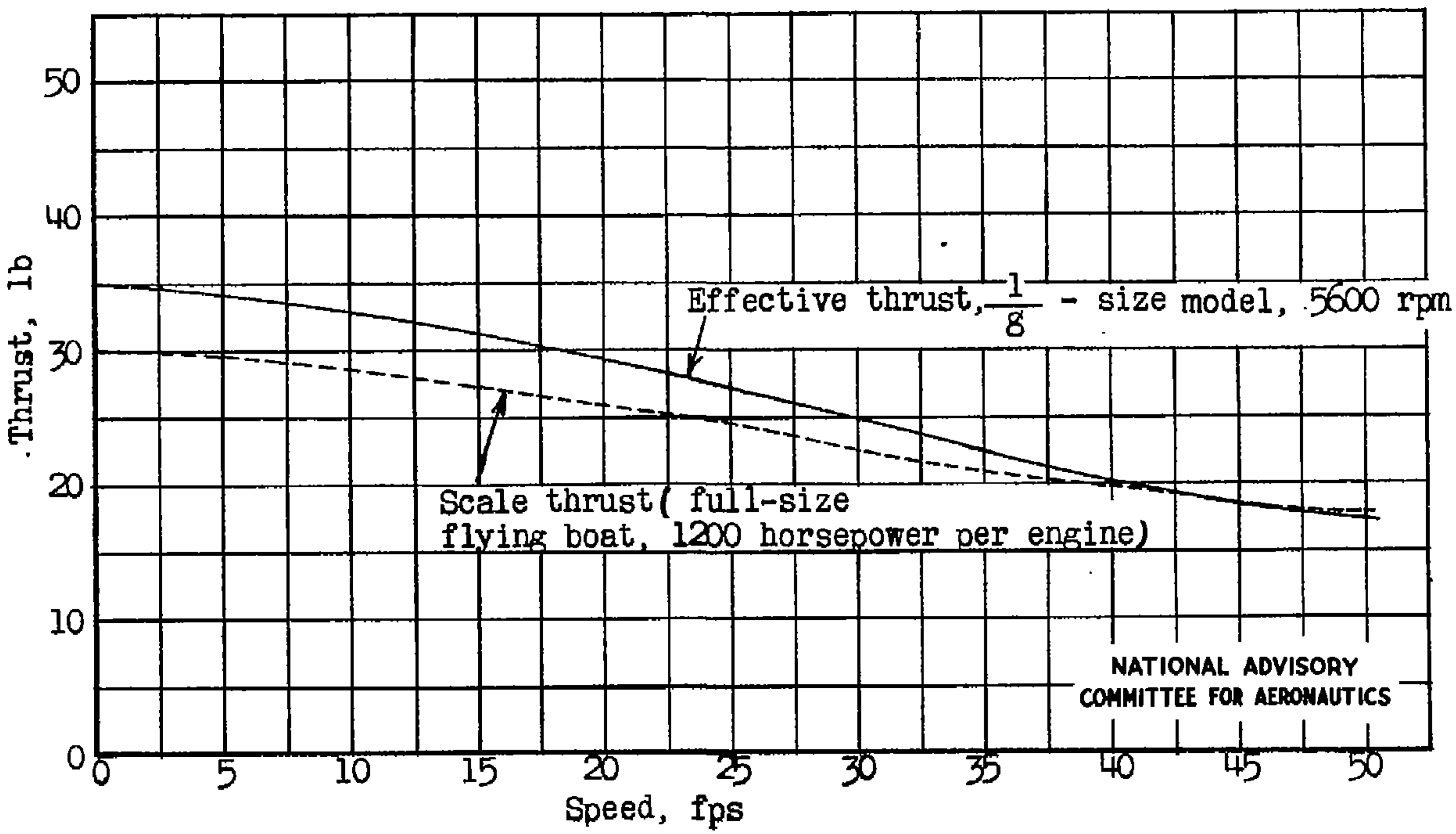

Figure 2.- Effective thrust of the $\frac{1}{8}$-size powered dynamic model and corresponding scale thrust of the full-size PB2Y-3 flying boat.

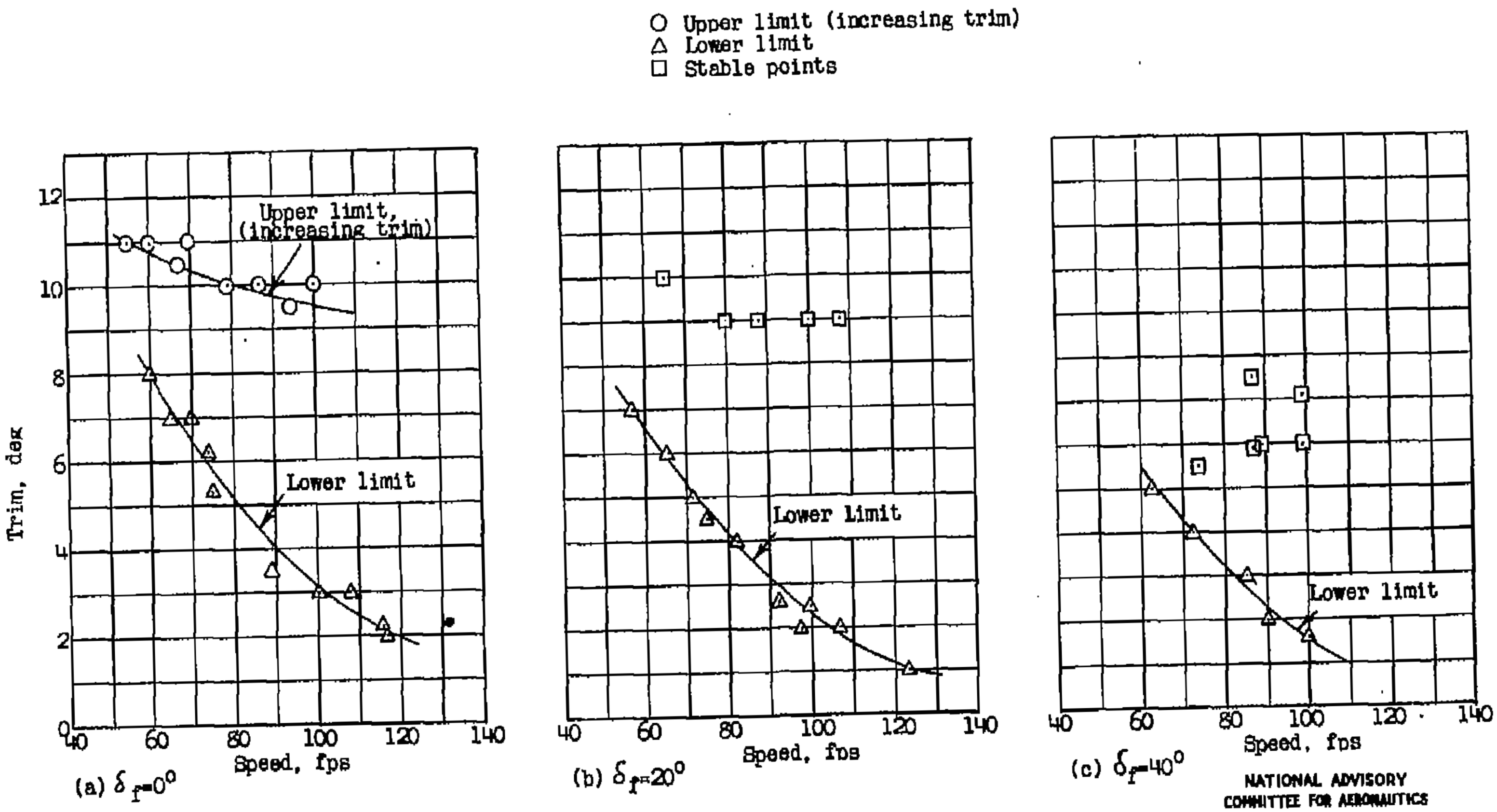

Figure 3.- Full-size PB2Y-3 flying boat. Trim limits of stability; nominal gross load, 66,000 pounds; center of gravity, 28-percent M.A.C.

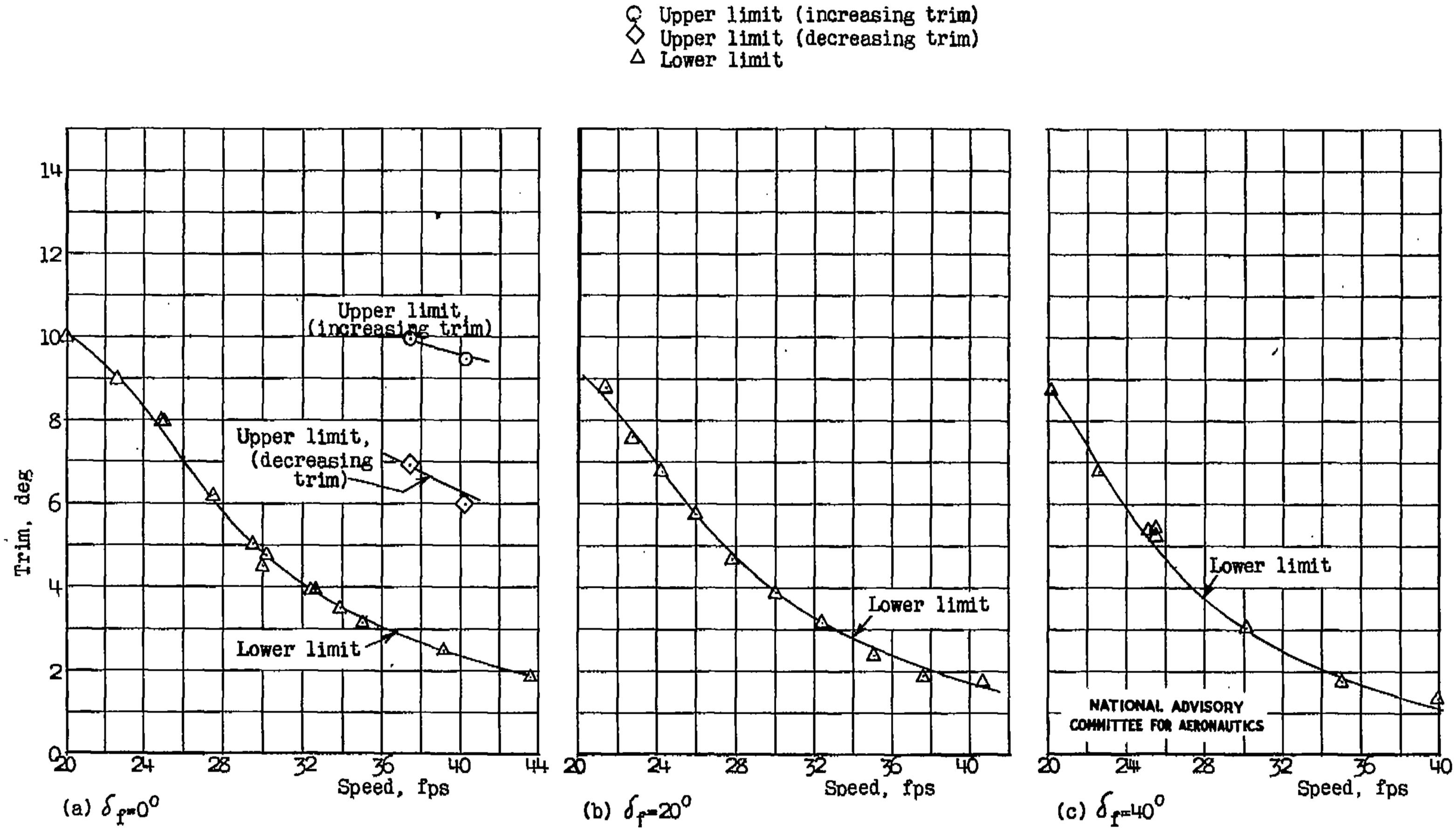

Figure 4.- Langley tank model 165. Trim limits of stability; gross load, 128.0 pounds (66,000 lb full size); center of gravity, 28-percent M.A.C.

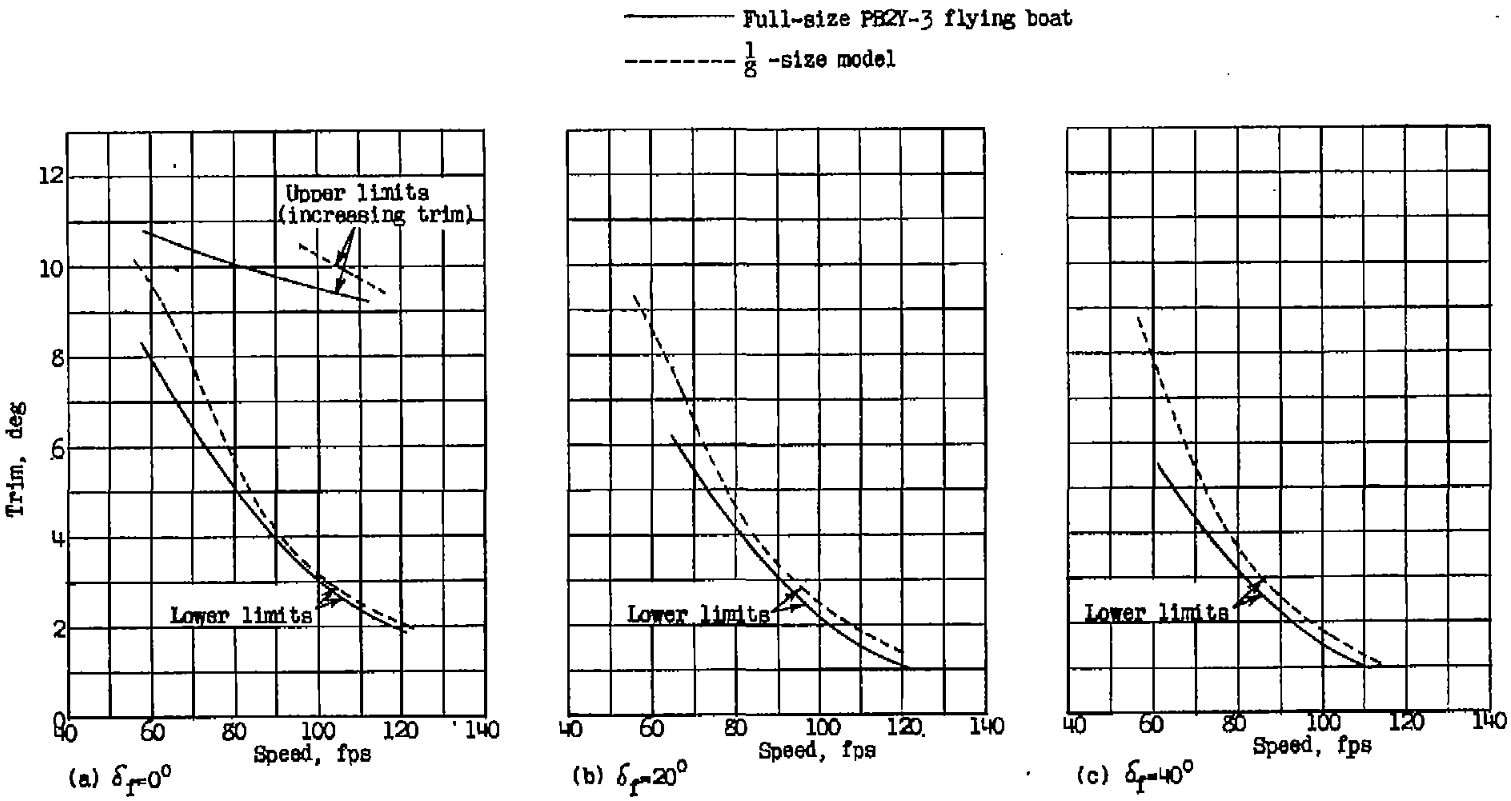

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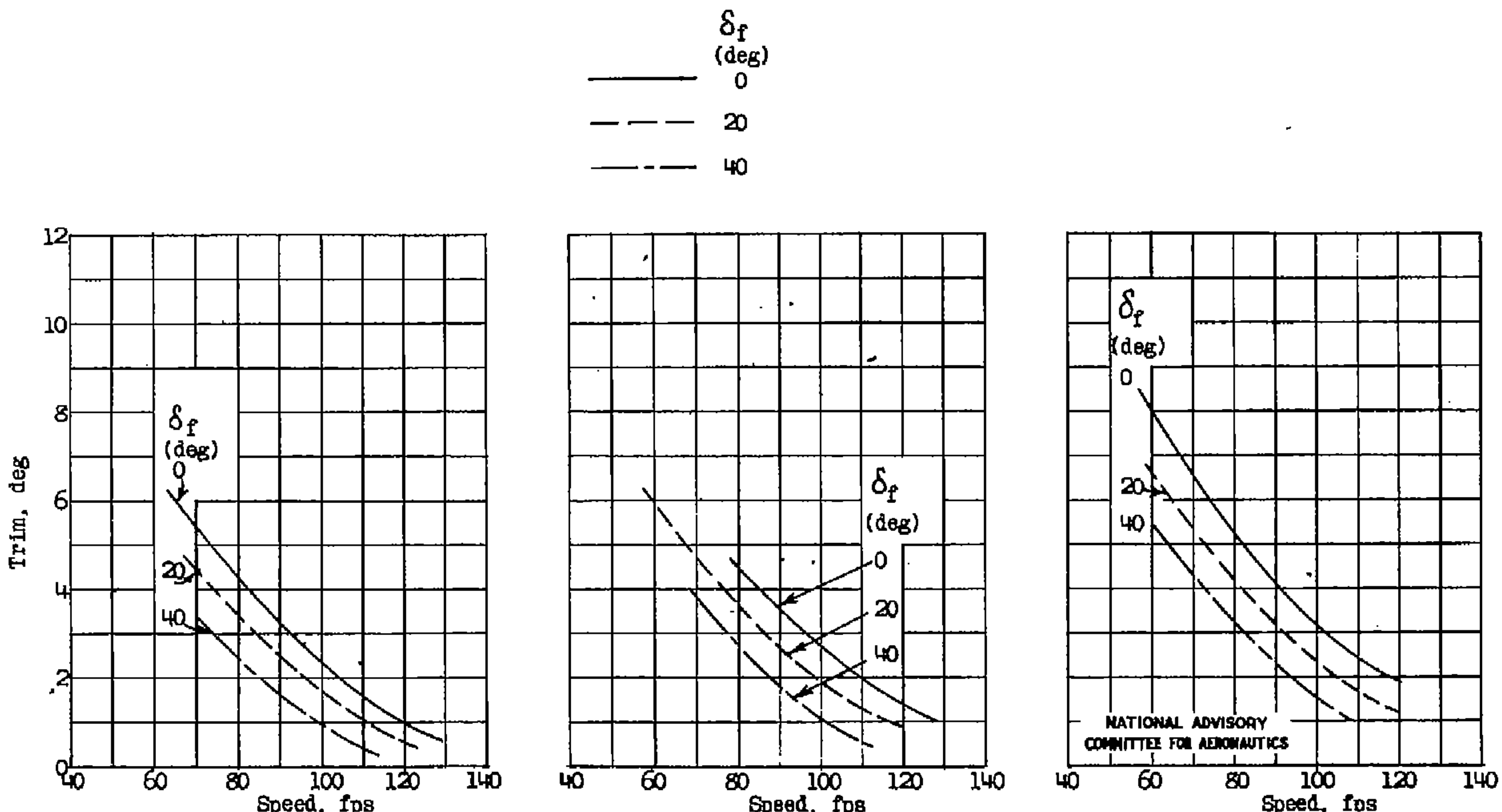
Figure 5.- Comparison of the trim limits of stability of the full-size PB2Y-3 flying boat and the $\frac{1}{8}$ -size model at corresponding full-size speeds. Nominal gross load, 66,000 pounds full size (128.0 lb model size). Center of gravity, 28-percent M.A.C.



(a) Nominal gross load, 56,000 pounds. (b) Nominal gross load, 61,000 pounds. (c) Nominal gross load, 66,000 pounds.

Figure 6.- Full-size PB2Y-3 flying boat. Effect of flap deflection on the lower trim limit of stability. Center of gravity, 28-percent M.A.C.

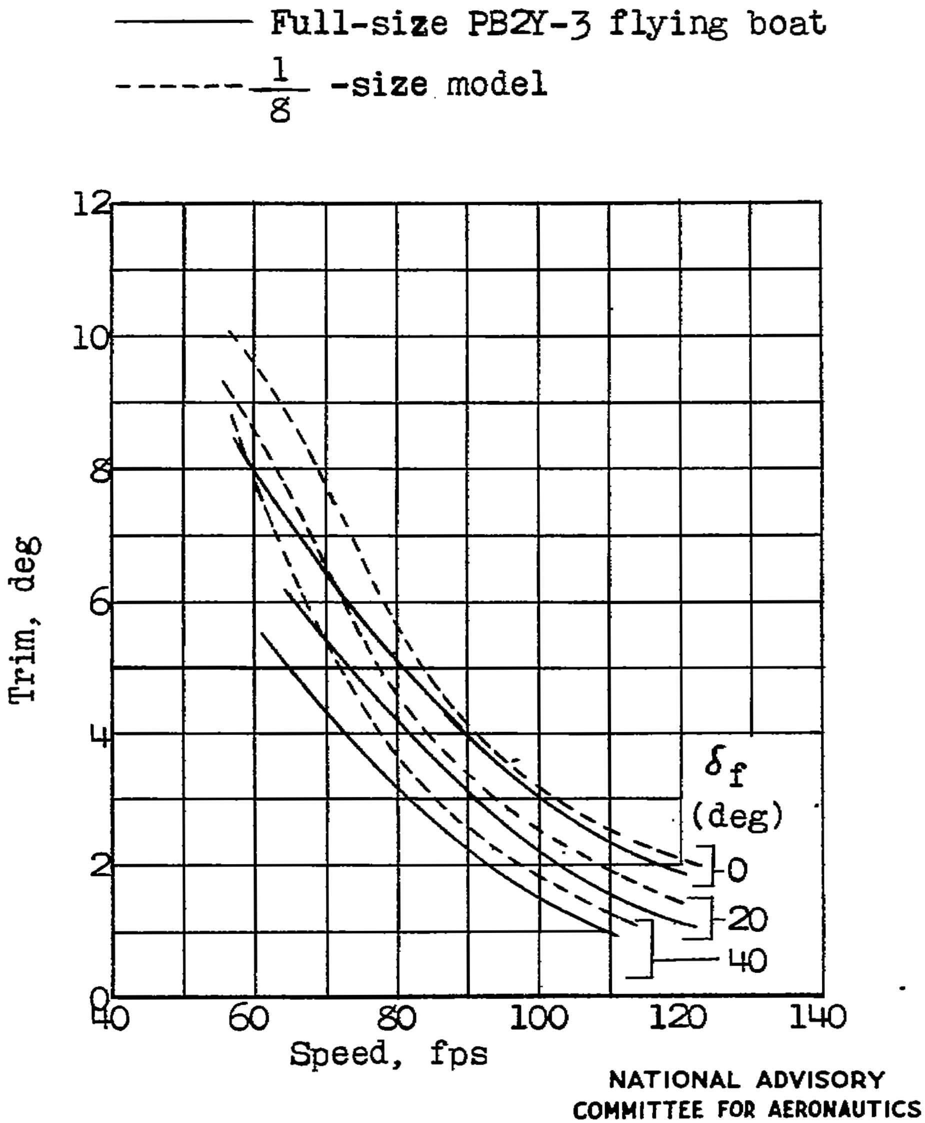


Figure 7.- Comparison of the effect of flap deflection on the lower trim limit of stability for the full-size PB2Y-3 flying boat and the $\frac{1}{8}$-size model at corresponding full-size speeds. Nominal gross load, 66,000 pounds full size (128.0 lb model size). Center of gravity, 28-percent M.A.C.

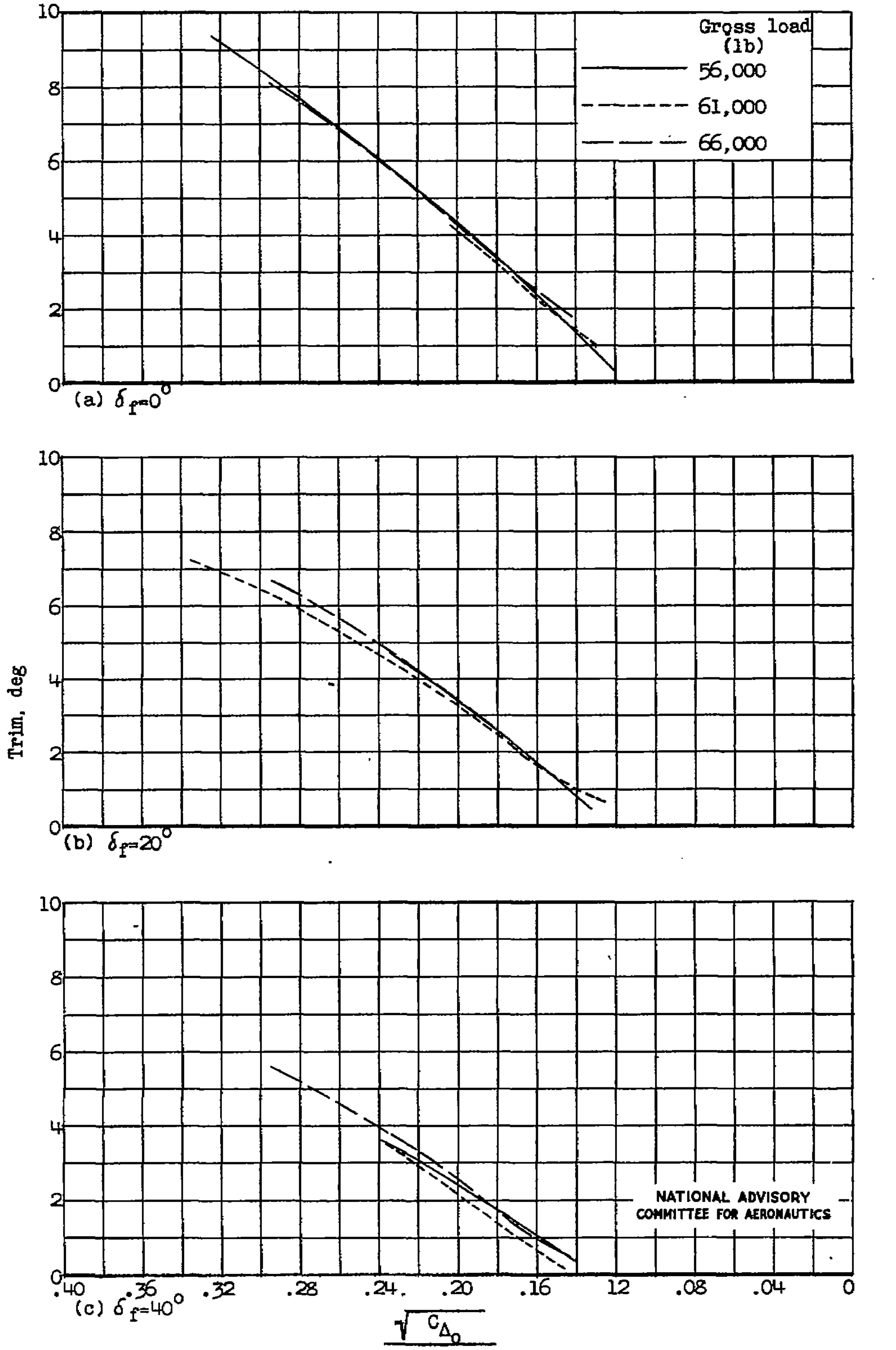


Figure 8.- Full-size PB2Y-3 flying boat. Variation of lower trim limit with $\frac{\sqrt{C_{\Delta_0}}}{C_V}$.
Center of gravity, 28-percent M.A.C.