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FLIGHT TESTS OF AN SB2C-3 AIRPLANE WITH A PRODUCTION AND TILTED PROPELLER AXIS

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NACA

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MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

FLIGHT TESTS OF AN SB2C-3 AIRPLANE WITH A PRODUCTION AND TILTED PROPELLER AXIS

By R. Fabian Goranson

SUMMARY

Flight tests have been made to measure the changes in static longitudinal stability due to tilting the propeller axis of an SB2C-3 airplane downward $3\frac{1}{2}^{\circ}$. The results of these tests show that tilting the propeller axis downward was beneficial in that the stick-free neutral point moved aft 1 to 3 percent mean aerodynamic chord for the climb condition, 1 percent in the approach condition, and 2 to 5 percent in the wave-off condition; however, this increase in stability was appreciated by the pilot only at a forward center-of-gravity position where the airplane was unstable with the standard engine but became stable when the tilted engine was installed. With the tilted engine, trim forces due to power changes were reduced by 25 percent of the values obtained with the standard engine installation.

INTRODUCTION

Analytical investigations and wind-tunnel tests (reference 1) indicate that tilting the propeller axis downward can result in beneficial changes in the static longitudinal stability characteristics of an airplane. Flying-qualities measurements (reference 2) indicated that the SB2C-1 airplane was deficient in longitudinal stability. Interest in the potential use of tilted propeller axis to improve the longitudinal stability of this and other Naval combat aircraft prompted the

Bureau of Aeronautics, Navy Department, to authorize the modification of SB2C-3 airplane No. 19332 so as to tilt the propeller axis downward $3\frac{1}{2}^{\circ}$. Flight tests at the Patuxent Naval Air Station (reference 3) which were made for a rear center-of-gravity position indicated that no differences existed between the airplane with the tilted propeller axis and other SB2C-3 airplanes with standard engine installations, but no quantitative measurements were made. The Bureau of Aeronautics, therefore, requested that the Langley Laboratory instrument the airplane and make more complete tests. The tests were conducted between January 25, 1945 and March 16, 1945. In order to eliminate errors due to differences between production airplanes, only one airplane was used and the propeller axis tilt was altered by changing engine mounts.

DESCRIPTION OF AIRPLANE AND TESTS

The SB2C-3 airplane (No. 19332) used in these tests differs from earlier models of the SB2C airplane in that it is equipped with a Wright R-2600-20 engine and a four-blade Curtiss electric propeller (Curtiss Co. Drawing No. C271200). The engine installation was converted from the standard to the tilted installation by replacing the engine mount and a part of the cowling. A side view of the airplane with the tilted engine installed is shown in figure 1 and a close-up of the cowling for the tilted and standard installation is shown in figure 2. The tilted propeller axis was inclined downward 3.5° from the standard installation.

Static longitudinal stability characteristics were measured for five configurations tabulated in the following table:

Condition	Landing gear	Flaps	Front hood	Cowl flaps	RPM	Manifold pressure, in. Hg at 5000 ft	Trim speed (mph)
Climb	Up	Up	Closed	Open 1 in.	2400	38	200
Glide	Up	Up	Closed	Closed	Engine idling	Engine idling	200
Wave-off	Down	Down	Open	Full open	2400	38	100
Approach	Down	1/2 down	Open	Open 1 in.	2400	21	100
Landing	Down	Down	Open	Open 1 in.	Engine idling	Engine idling	100
Bomb-bay doors, vision doors, and rear hood closed for all conditions.							

For each condition, static longitudinal stability was measured at three center-of-gravity positions which are tabulated in the following table together with the corresponding gross weights:

The data obtained were measured by the following standard NACA instruments synchronized by a chronometric timer:

Airspeed recorder
Elevator-position recorder
Recording accelerometer (three-component)
Stick-force recorder
Yaw-angle recorder
Recording inclinometer (longitudinal axis)

Airspeed was measured by an NACA free-swiveling static head and a shielded total head mounted on a straight boom approximately 1 chord length ahead of the right wing tip (fig. 1). The installation was calibrated for position error by the trailing-bomb method. The term "airspeed" as used in this report is the service indicated airspeed defined by the equation:

$$V_i = 45.08 f_o \sqrt{q_c}$$

where

V_i service indicated airspeed in miles per hour; that is, the reading that would be given by a standard Army-Navy airspeed meter if it were connected to a pitot-static system free from position error

f_o standard sea-level compressibility correction factor

q_c pressure differential in inches of water between total and static head, corrected for position error

RESULTS AND DISCUSSION

The elevator stick forces due to friction in the control system was measured on the ground and these data (fig. 3) show that stick forces due to friction were approximately ±3.5 pounds throughout the deflection range. Static stability data for each of the five configurations with standard and tilted engine installation are presented in conventional form in figures 4 through 8. These data are replotted as a function of airplane normal-force coefficient in figres 9 and 10 and the graphical determination of neutral points from these replots is presented in figure 11. A summary plot showing the variation of neutral-point location with normal-force coefficient is presented in figure 12.

The data presented herein show that tilting the propeller axis down $3\frac{1}{2}^{\circ}$ increased the stability an amount corresponding to a rearward shift in the stick-free neutral point ranging from 1 to 3 percent mean aerodynamic chord in climb conditions, 1 percent in the approach condition, and 2 to 5 percent in the wave-off condition. The pilot, however, did not appreciate the improvement except at the extreme forward center-of-gravity position. Tests at this extreme forward center-of-gravity position, well forward of the normal service center-of-gravity range, were included in order that the airplane with tilted engine be tested at a center of gravity forward of the stick-free neutral point for all conditions. The data in figure 11 show that the airplane was unstable for some conditions with the standard engine but was stable for all conditions with the tilted engine. It appears, therefore, that the pilot could appreciate the improved stability when the change went from an unstable to a stable condition but that it was difficult, in cases where the airplane was unstable with both engine installations, to ascertain which of the two unsatisfactory conditions was more undesirable.

Trim-force changes with changes in power and flap setting were also measured and the results are presented in table I. Examination of these data indicates that tilting the propeller axis reduced the trim-force changes due to power by approximately 25 percent of the force changes that occurred with the standard engine installation.

The propeller axis inclination was measured in level flight at 230 miles per hour, service indicated airspeed. These measurements showed that the inclination of the propeller axis with respect to the flight path was 2.0° up for the standard engine and 0.7° down for the tilted engine. Because the change in engine tilt was 3.5°, these measurements indicate that the angle of attack of the airplane was 0.8° greater with the tilted engine installation than with the standard engine installation. The 0.8° change in airplane angle of attack may be accounted for approximately by the changes in resultant normal forces on the propeller and the horizontal tail.

CONCLUSIONS

1. Tilting the propeller axis improved the static longitudinal stability of the SB2C-3 airplane, but the change was not sufficiently large to make the airplane stable in all normal service flight condition. It was therefore difficult for the pilot to appreciate the improvement in longitudinal stability except at an extreme forward center-of-gravity position where the airplane with normal engine installation was unstable in some conditions but the airplane with tilted engine installation was stable in all flight conditions tested.

2. With the tilted engine, stick-force changes due to power changes were reduced by approximately 25 percent of the values with the standard engine installation.

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REFERENCES

1. Goett, Harry J., and Delany, Noel K.: Effect of Tilt of the Propeller Axis on the Longitudinal-Stability Characteristics of Single-Engine Airplanes. NACA ACR No. 4E29, 1944.

2. Phillips, W. H., Williams, W. C., and Hoover, H. H.: Measurements of Flying Qualities of a Curtiss SB2C-1 Airplane (No. 00014). NACA MR, March 14, 1944.

3. Booth, C. T.: Interim Report on Model SB2C-4 Airplanes - Production Inspection Trials - TED No. BIS 2160. U. S. Naval Air Station, Patuxent River, Md., Nov. 15, 1944.

TABLE I.- CHANGE IN ELEVATOR STICK FORCE WITH CHANGES IN AIRPLANE CONFIGURATION

Condition	Climb condition trim at 120 miles per hour			
	Pull force		Pull force	
	Tilted engine, Tab 4.3° n. up c.g. 0.238 M.A.C.	Standard engine, Tab 3.0° n. up c.g. 0.243 M.A.C.	Tilted engine, Tab 1.5° n. up c.g. 0.308 M.A.C.	Standard engine, Tab 1.3° n. down c.g. 0.317 M.A.C.
CLIMB	0	0	0	0
Power off, cowl flaps closed	10	13	4	6
Gear lowered	12	13	7	9
Hood open, cowl flaps open 1 in.	11	14	8	8
Flaps lowered	6	9	1	5
Rated power applied	-1.5	-.4	0	4
	Landing condition trim at 100 miles per hour			
	Tilted engine, Tab 14.9° n. up c.g. 0.238 M.A.C.	Standard engine, Tab 15.6° n. up c.g. 0.242 M.A.C.	Tilted engine, Tab 4.9° n. up c.g. 0.308 M.A.C.	Standard engine, Tab 5.1° n. up c.g. 0.315 M.A.C.
LANDING	0	0	0	0
Rated power applied	-24	-30	9.5	-13
Gear retracted	-27	[a]35+	-10	-15
Cowl opened	-25	[a]35+	-9	-15
Flaps retracted	-23.5	-29	-9	-17
Hood closed	-19	-28	-9	-15.5

[a]Record line went off scale, indicating that the force exceeded -35 pounds.

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Figure 1.- View from starboard side of SB2C-3 airplane with tilted engine installation.

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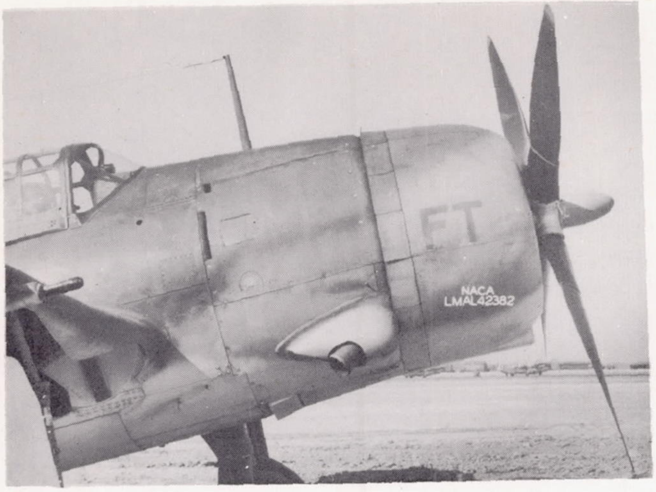
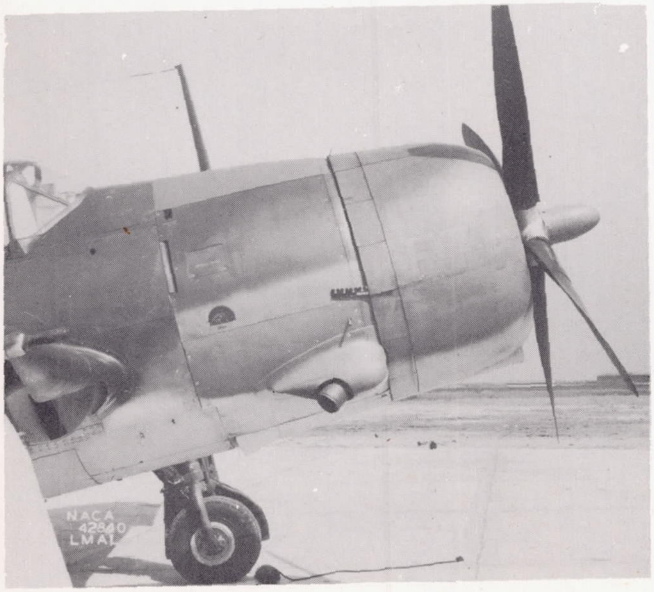


(a) Tilted engine installation.



(b) Standard engine installation.

Figure 2.- Closeup of engine cowl installation.

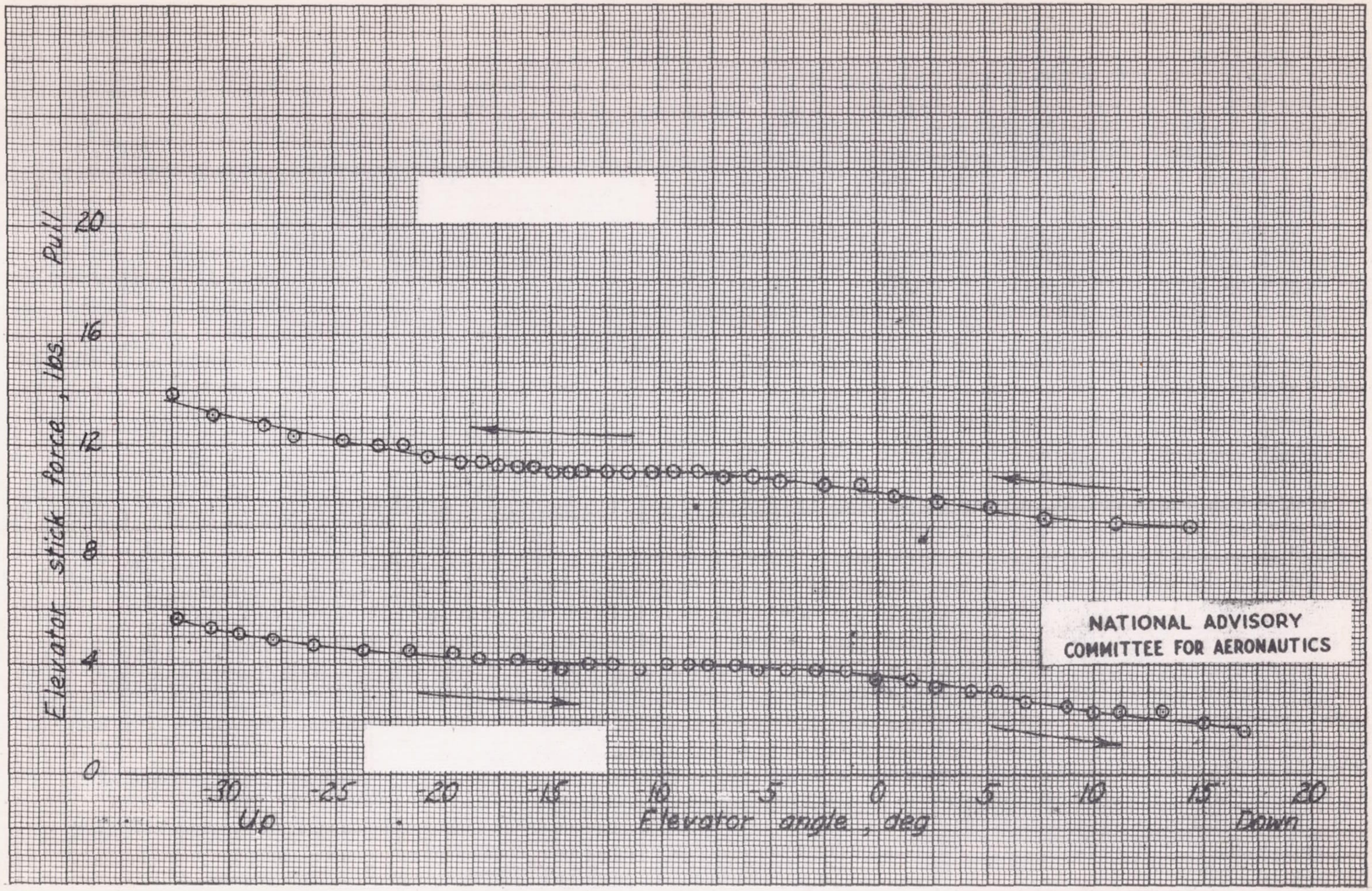
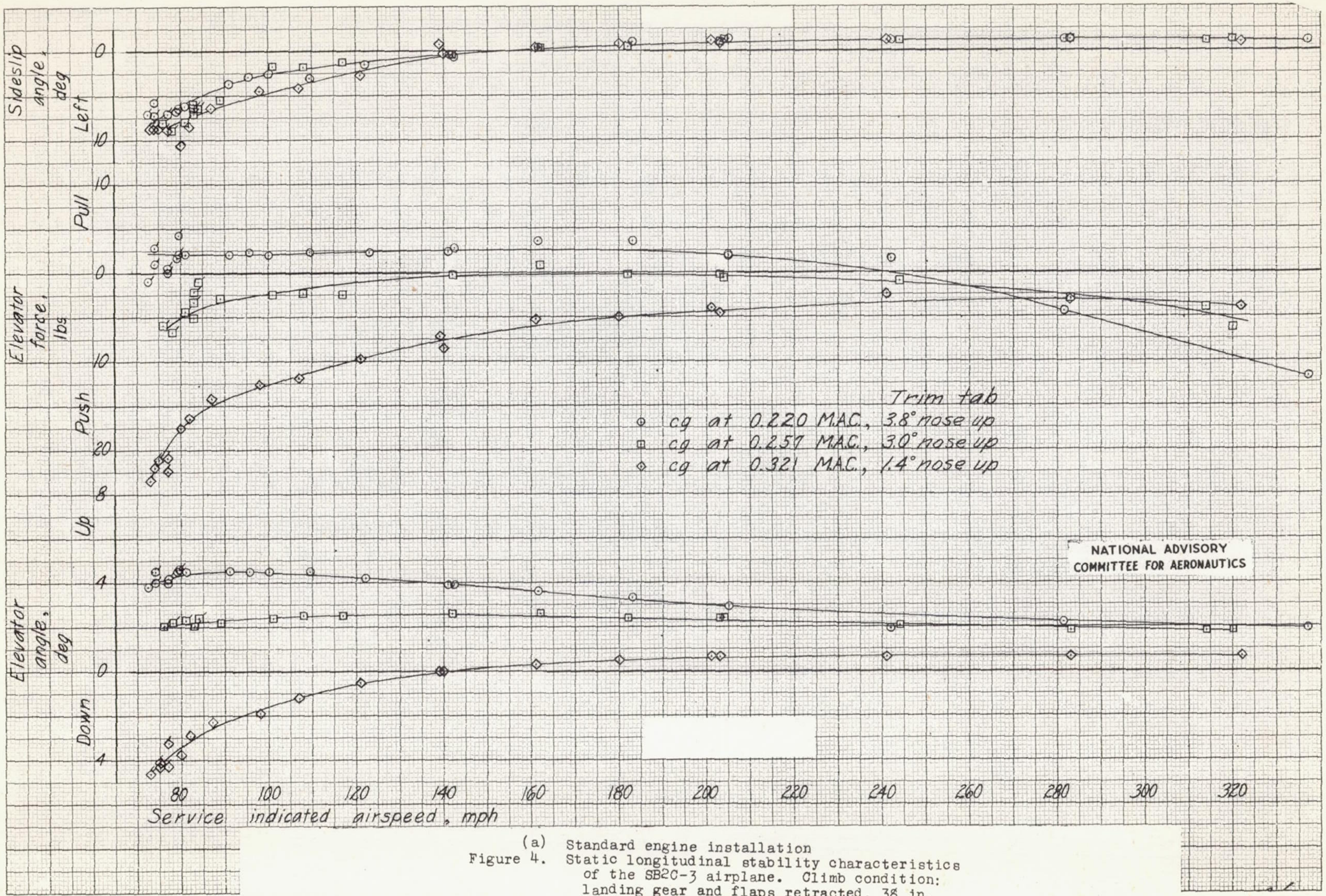


Figure 3. - Elevator stick force due to friction and weight moments as measured at three-point attitude on the ground with no load on the elevator. Production bobweight installed. Free air temperature 10 degrees C. SB2C-3 airplane.



(a) Standard engine installation

Figure 4. Static longitudinal stability characteristics of the SB2C-3 airplane. Climb condition: landing gear and flaps retracted, 38 in. Hg manifold pressure at 2400 rpm.

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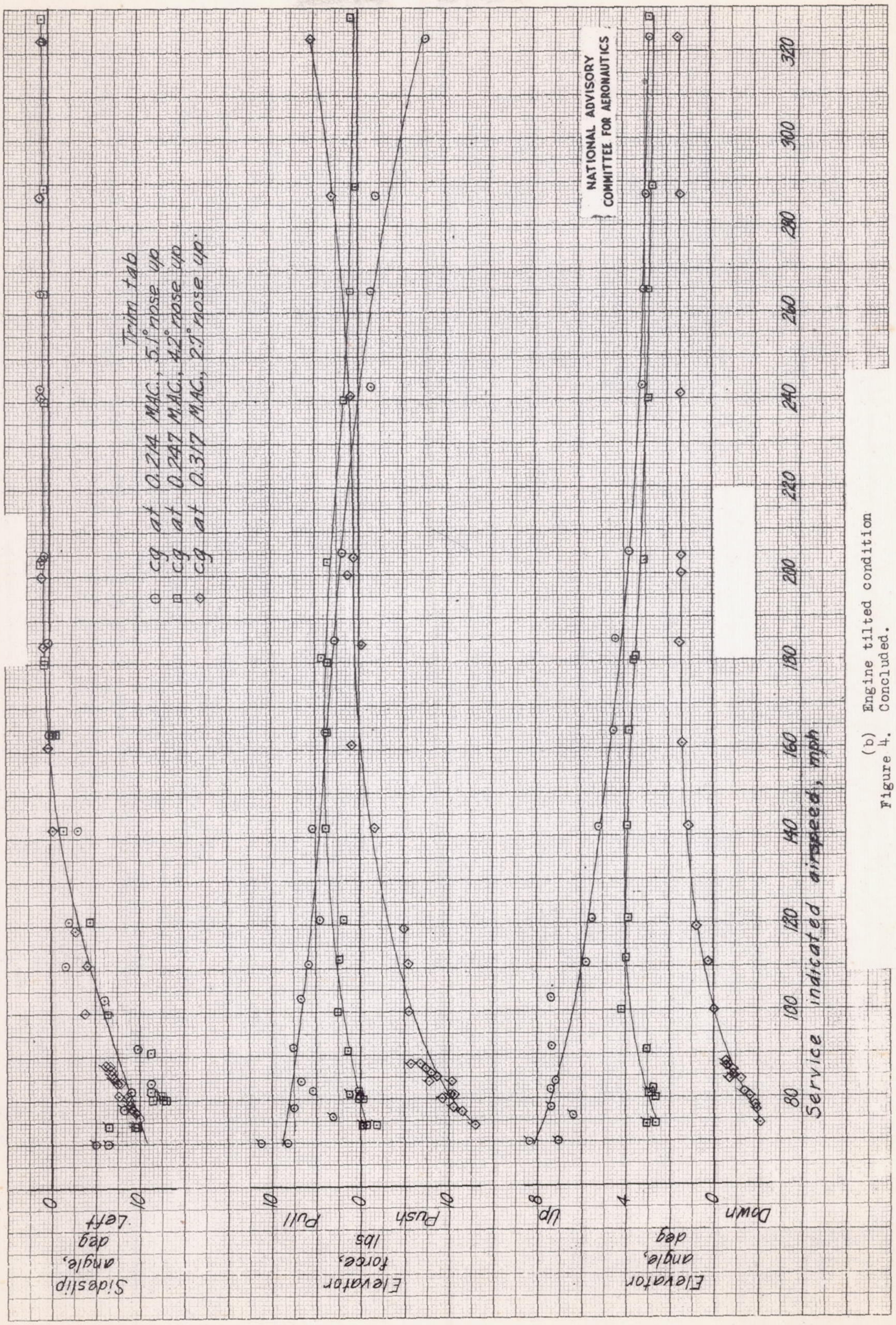
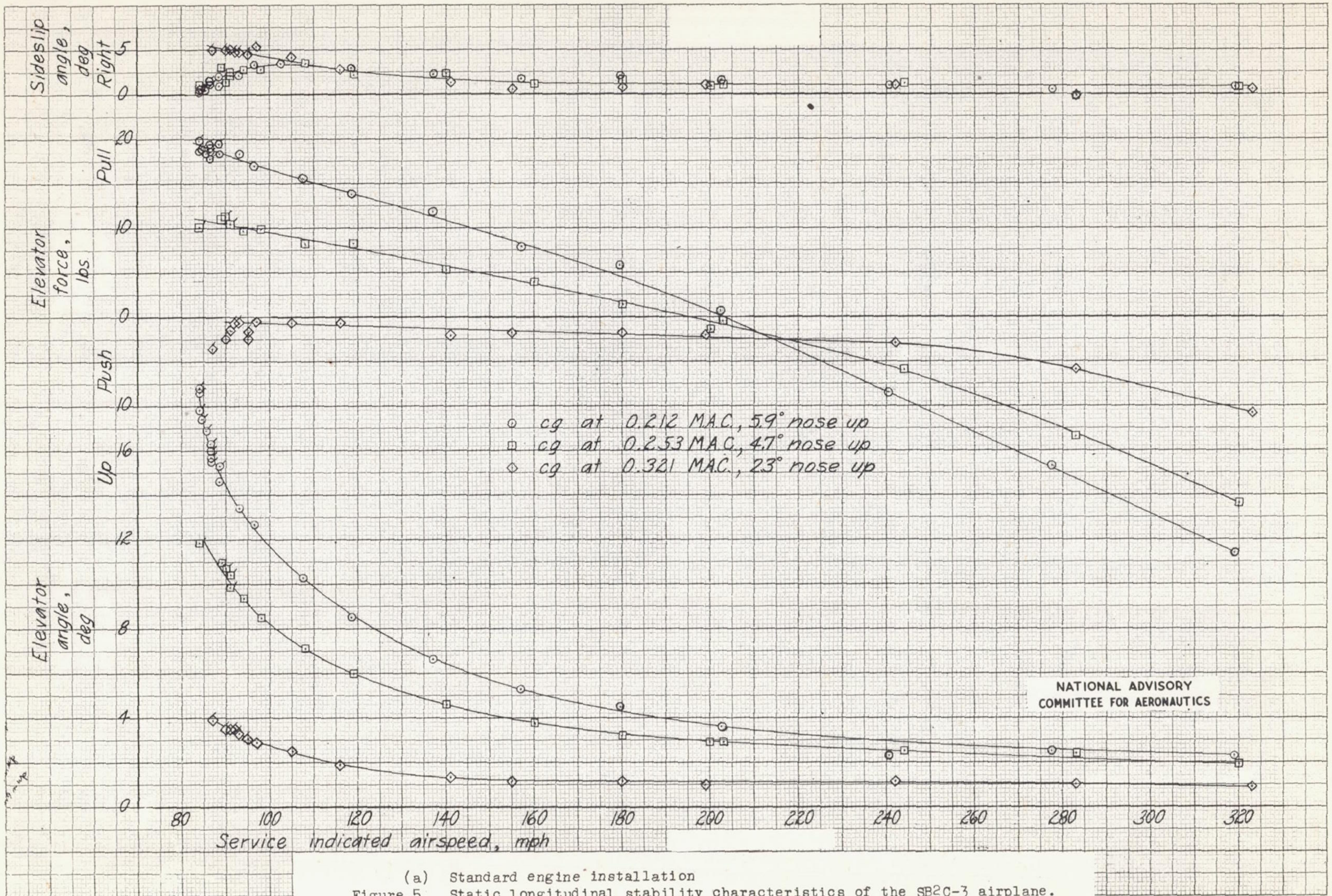


(b) Engine tilted condition
Figure 4. Concluded.



(a) Standard engine installation

Figure 5. Static longitudinal stability characteristics of the SB2C-3 airplane. Glide condition: landing flaps and gear retracted, engine idling.

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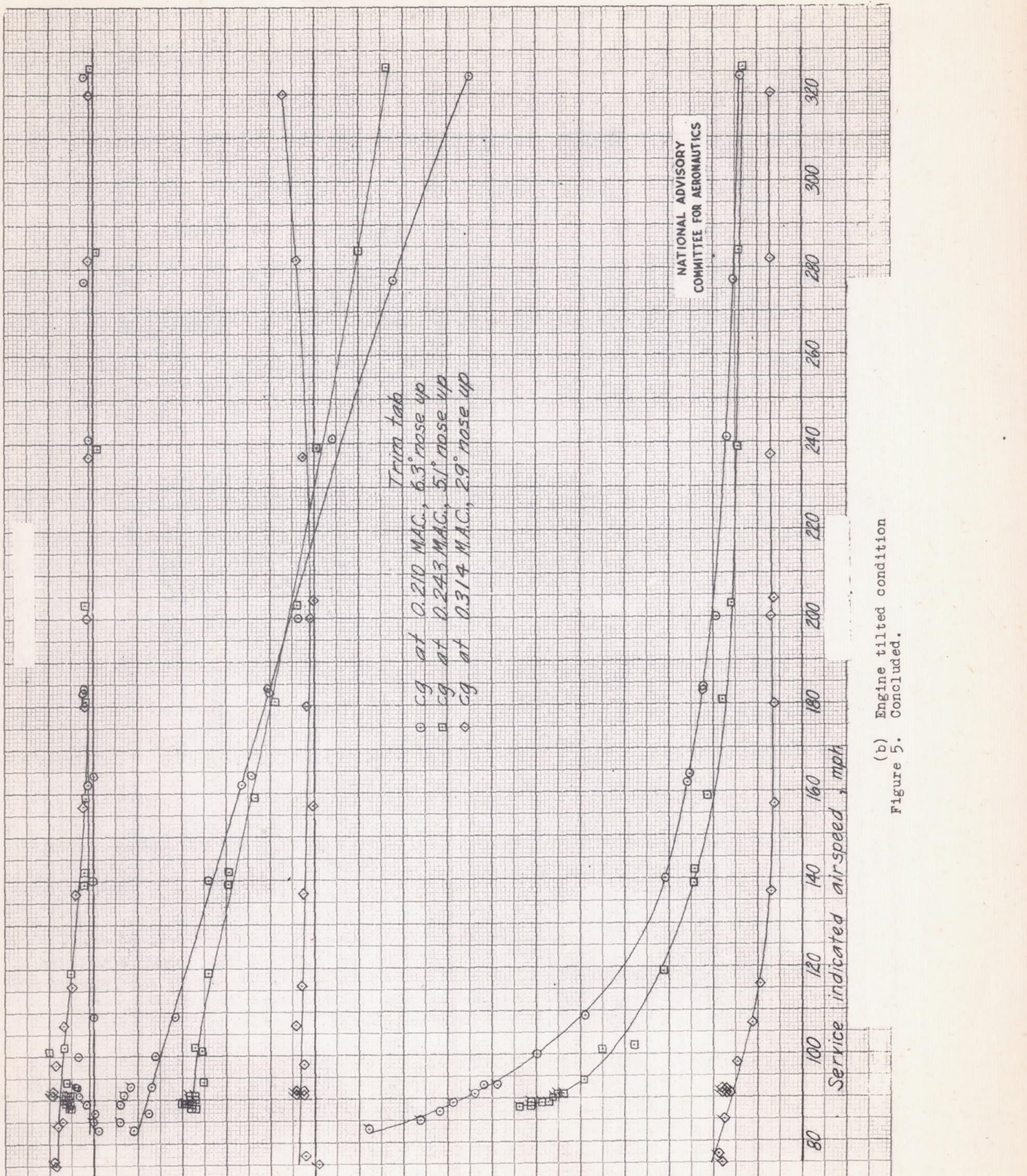
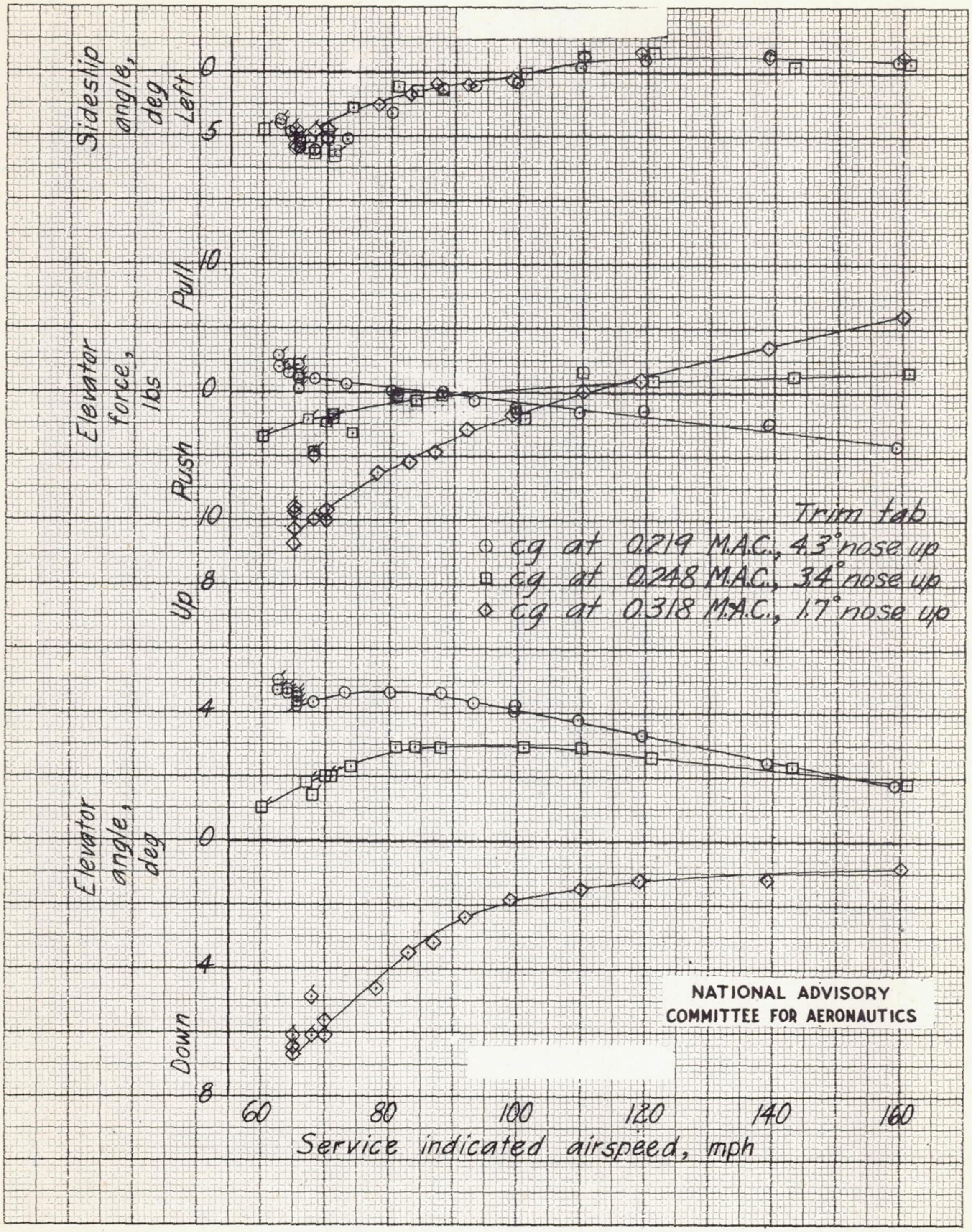


(b) Engine tilted condition
Figure 5. Concluded.



(a) Standard engine installation

Figure 6. Static longitudinal stability characteristics of the SB2C-3 airplane. Wave-off condition: landing flaps and gear down, 38 in. Hg manifold pressure at 2400 rpm.

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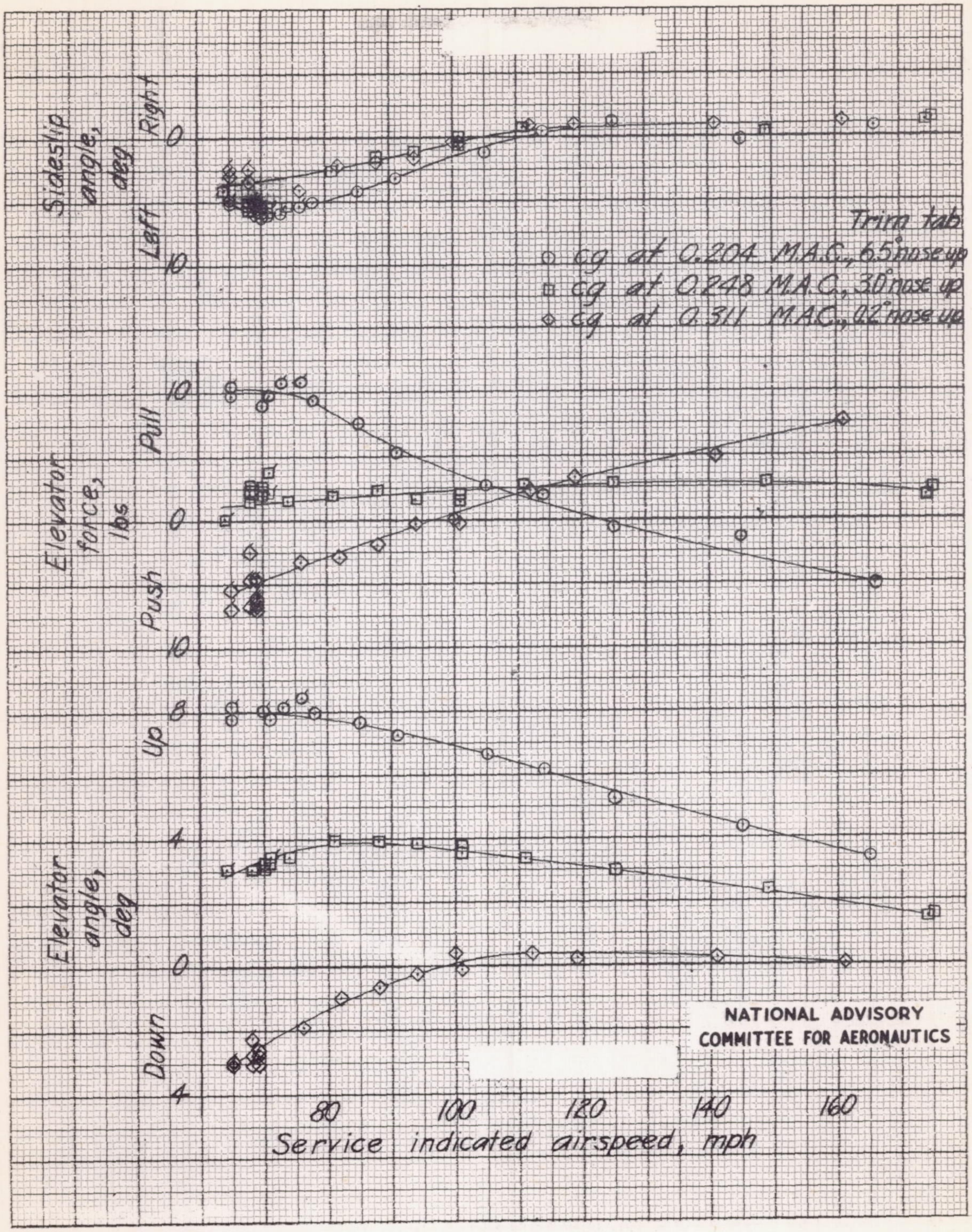
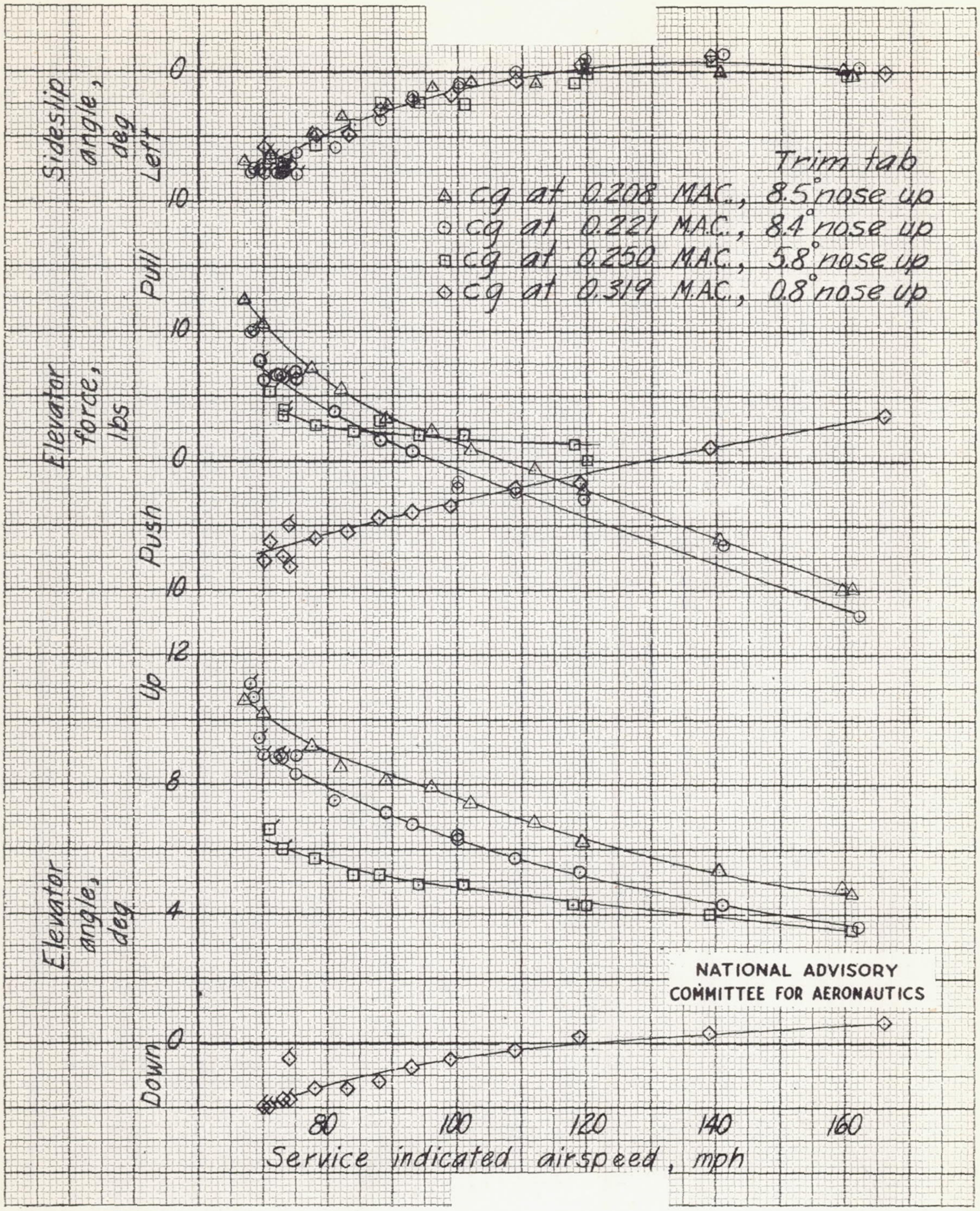


(b) Engine tilted condition
Figure 6. Concluded.



(a) Standard engine installation

Figure 7. Static longitudinal stability characteristics of the SB2C-3 airplane. Approach condition: landing gear down, flaps ½ down, 21 in. Hg manifold pressure at 2400 rpm.

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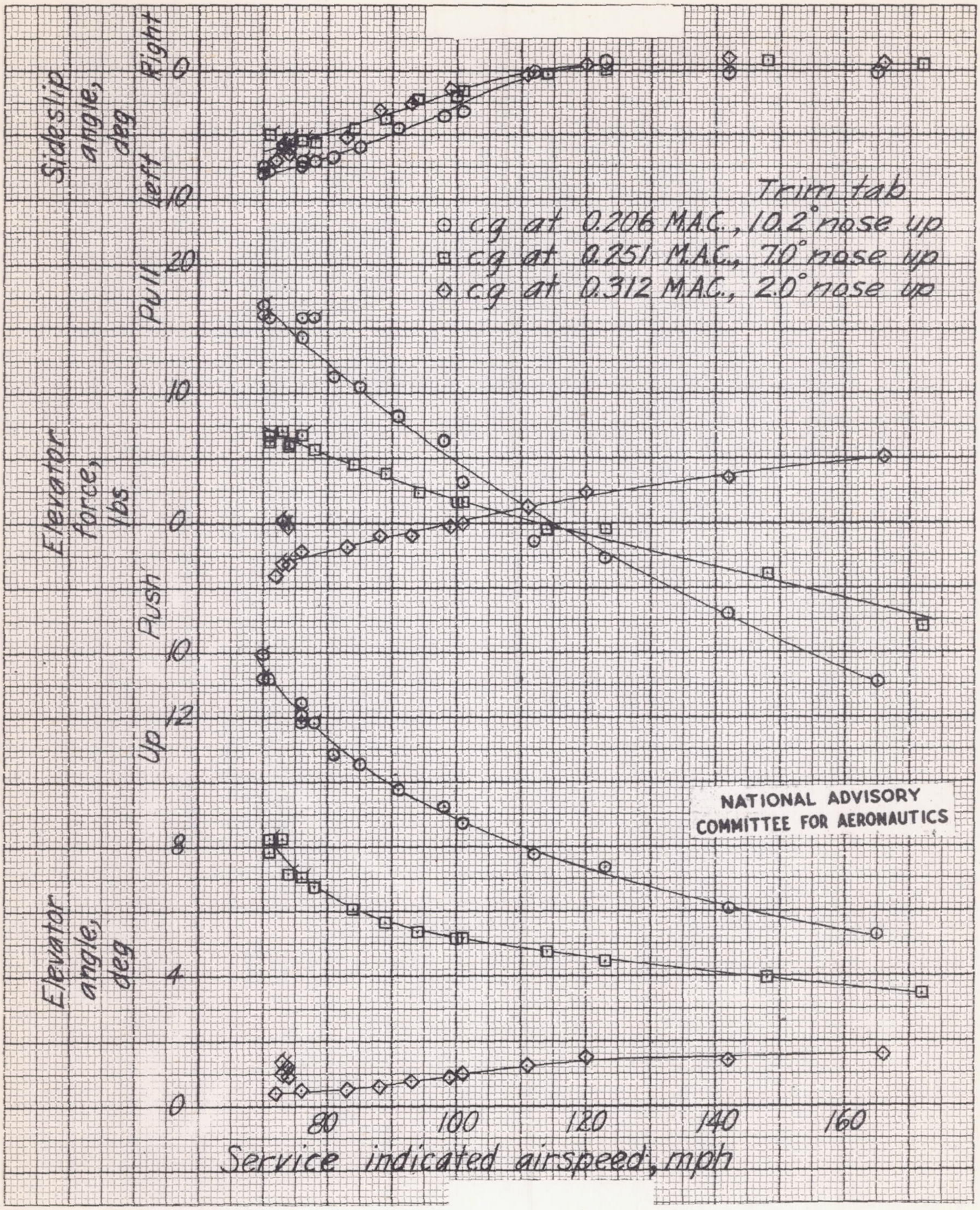
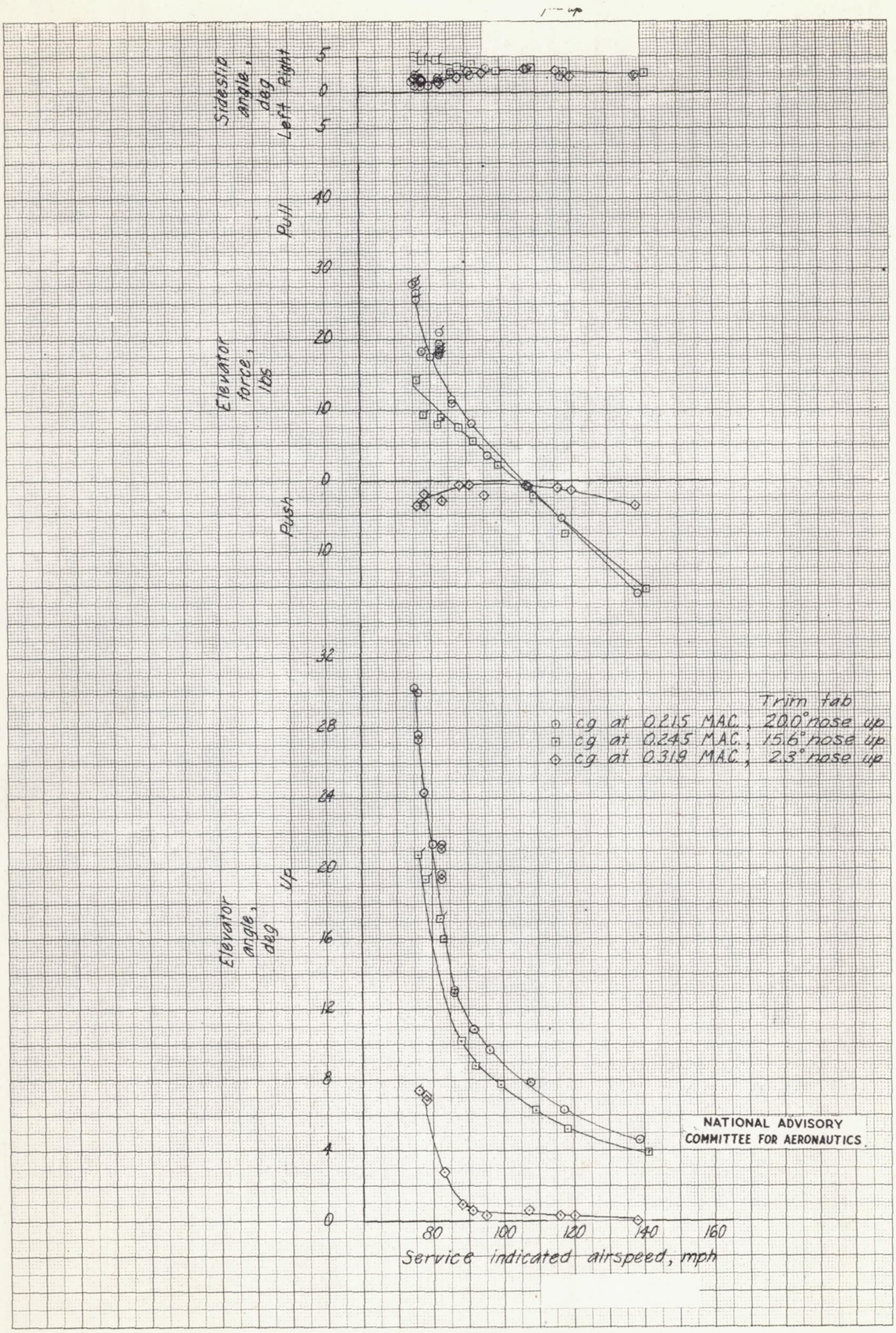


(b) Engine tilted condition
Figure 7. Concluded.



(a) Standard engine installation
Figure 8. Static longitudinal stability characteristics of the SB2C-3 airplane. Landing condition: landing gear and flaps down, engine idling.

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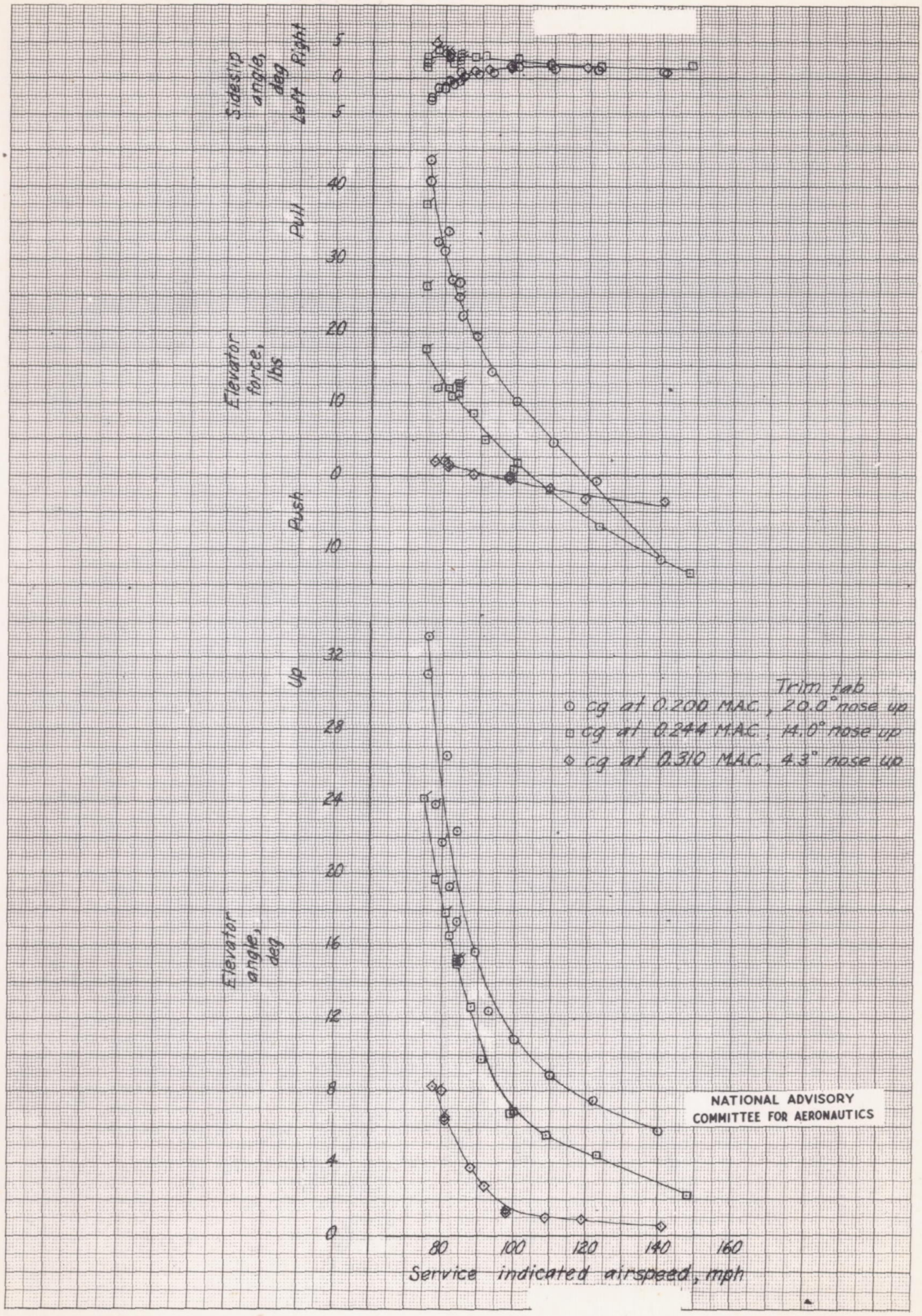
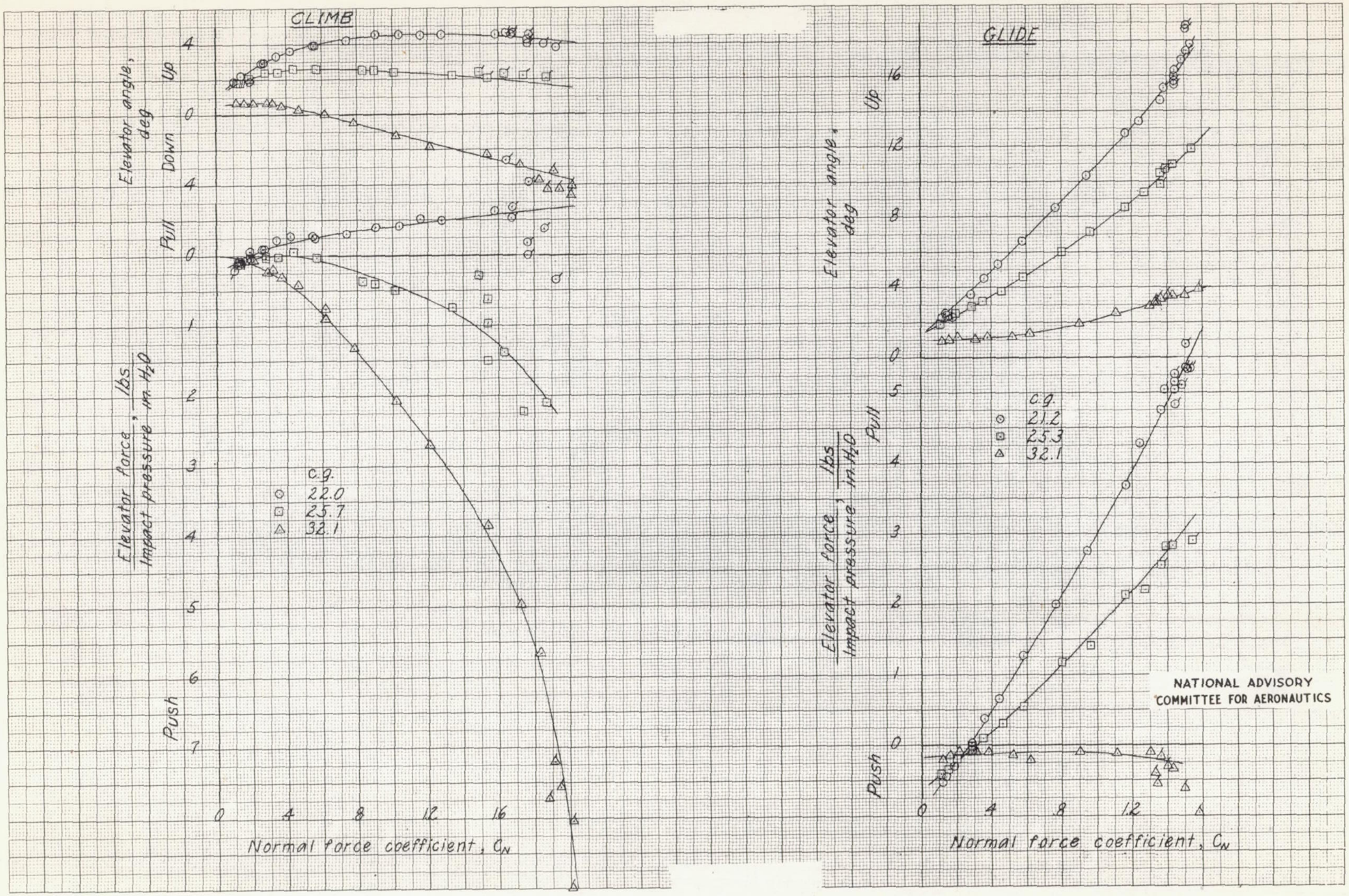
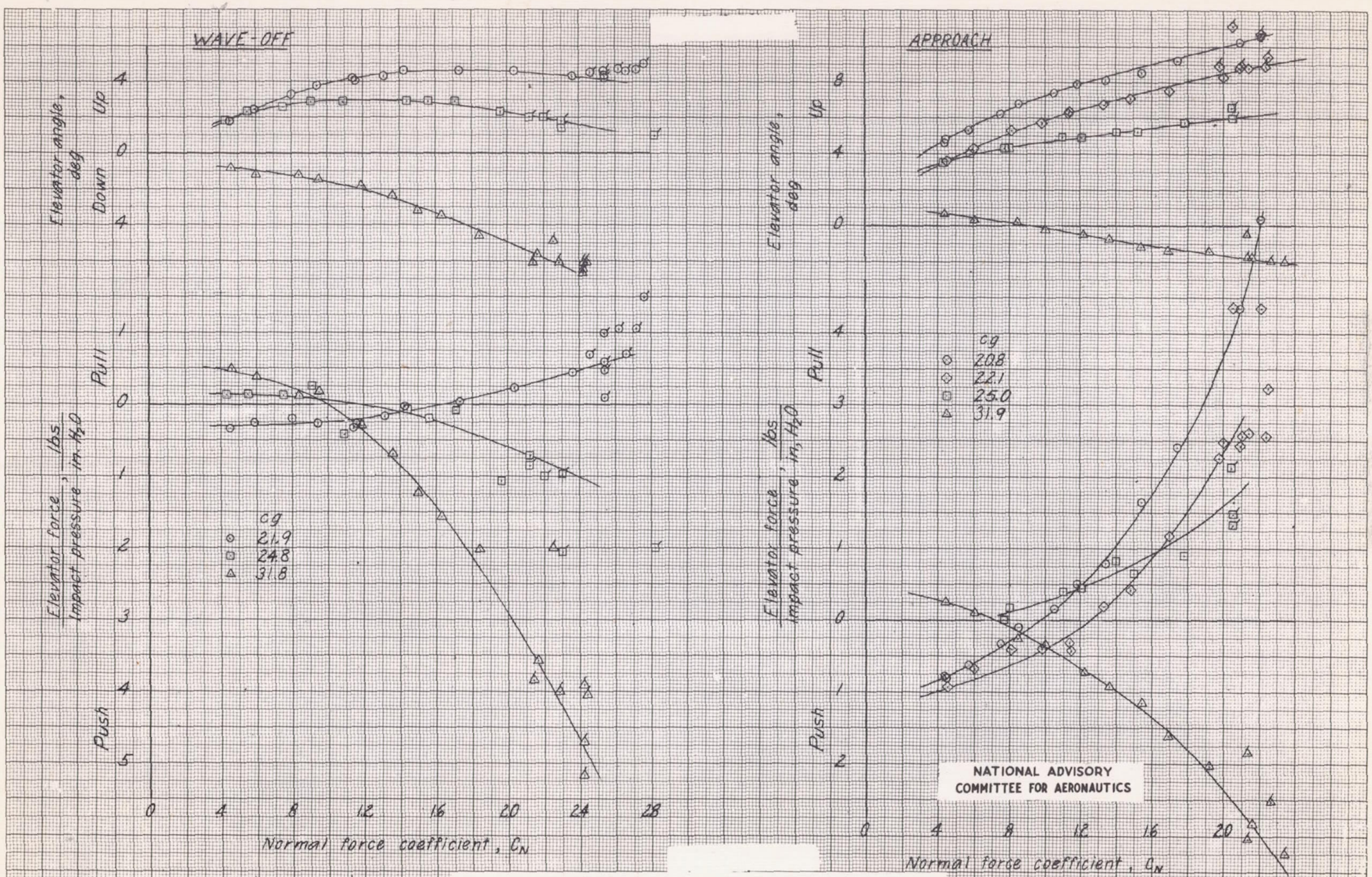


(b) Engine tilted condition
Figure 8. Concluded.



(a) Climb and glide condition

Figure 9. Standard engine installation SB2C-3 airplane static longitudinal stability characteristics as a function of airplane normal force coefficient.



(b) Wave-off and approach condition
Figure 9. Continued.

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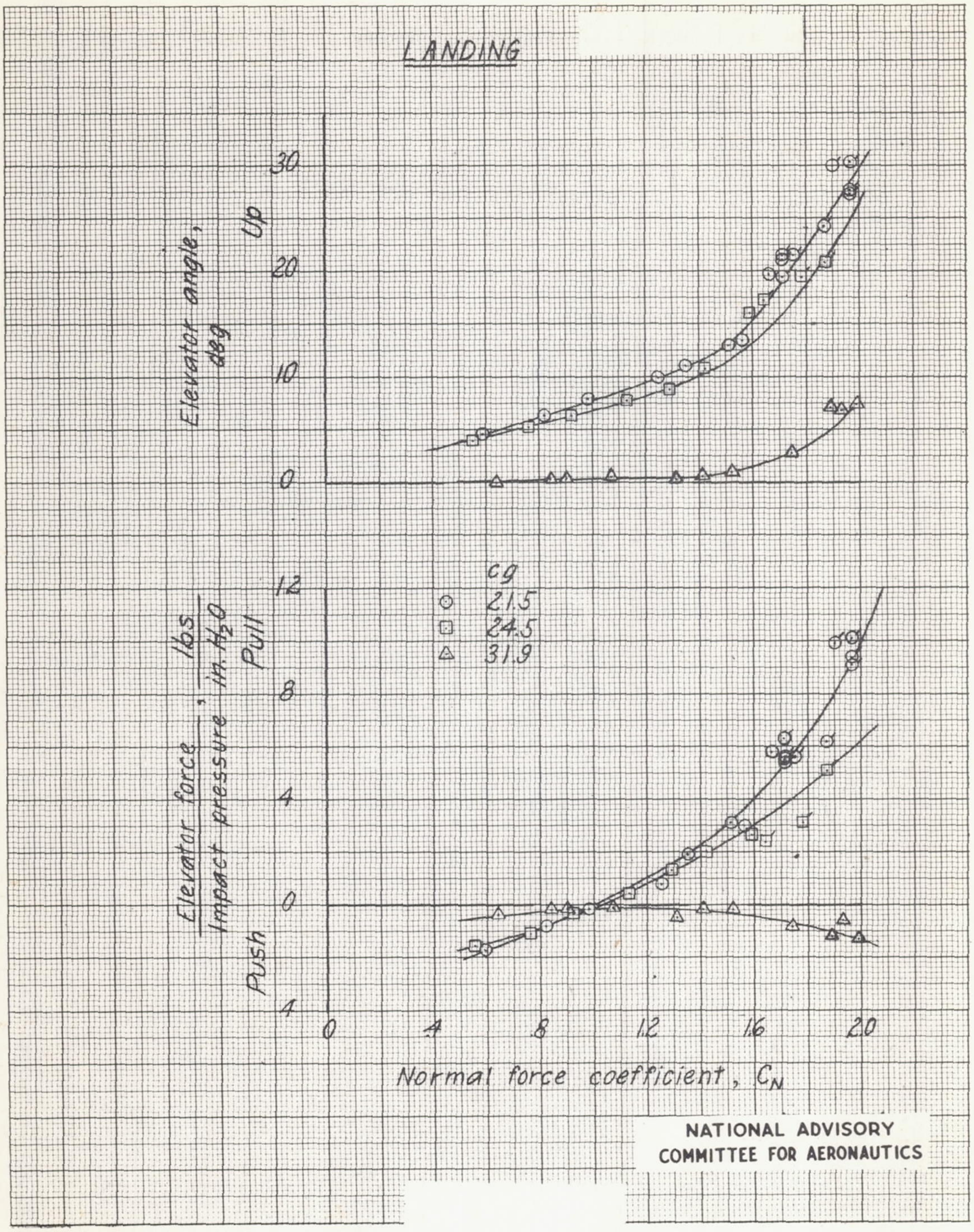

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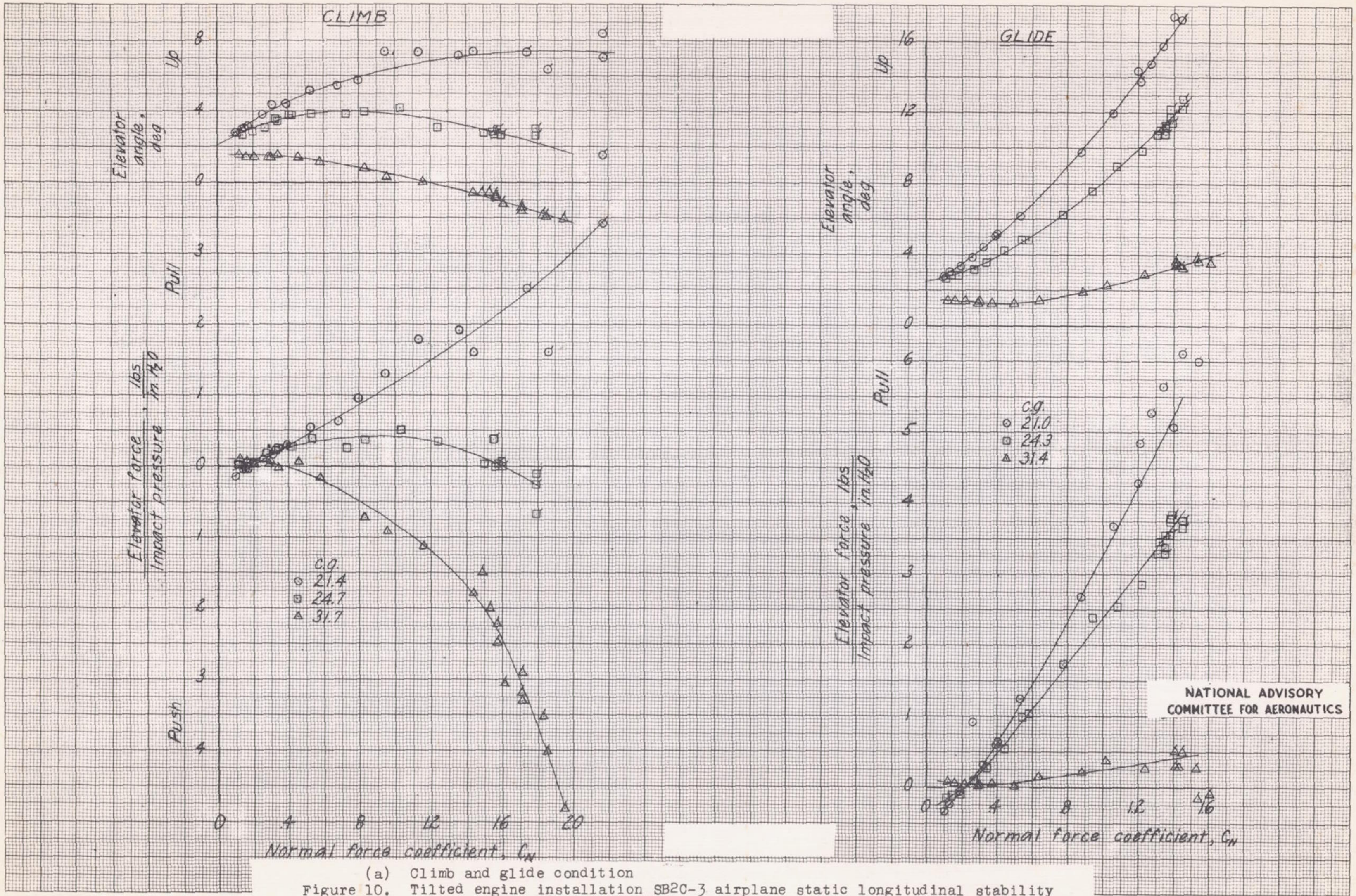
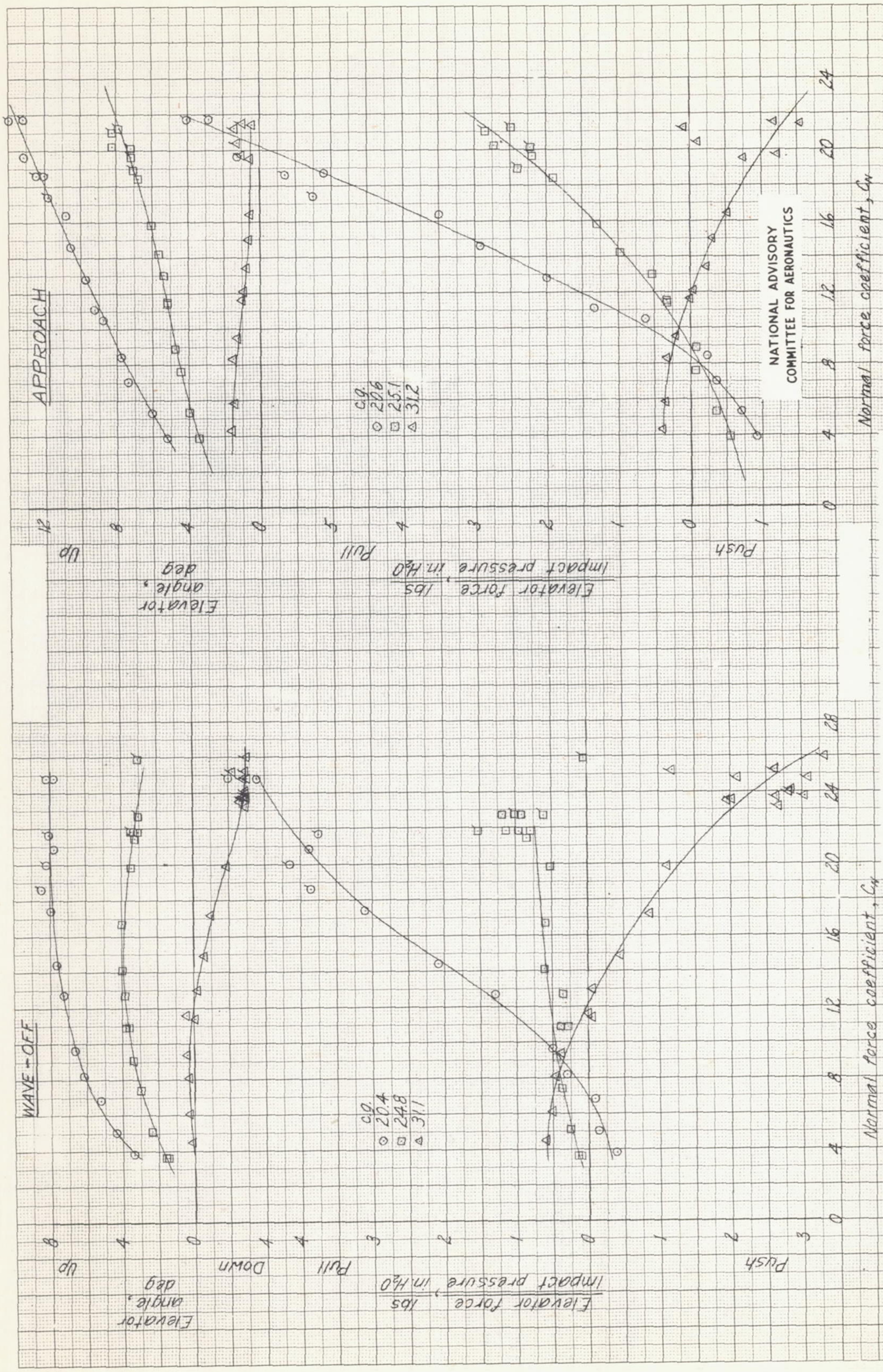
(c) Landing condition
Figure 9. Concluded.



(a) Climb and glide condition

Figure 10. Tilted engine installation SB2C-3 airplane static longitudinal stability characteristics as a function of airplane normal force coefficient.



(b) Wave-off and approach conditions
Figure 10. Continued.

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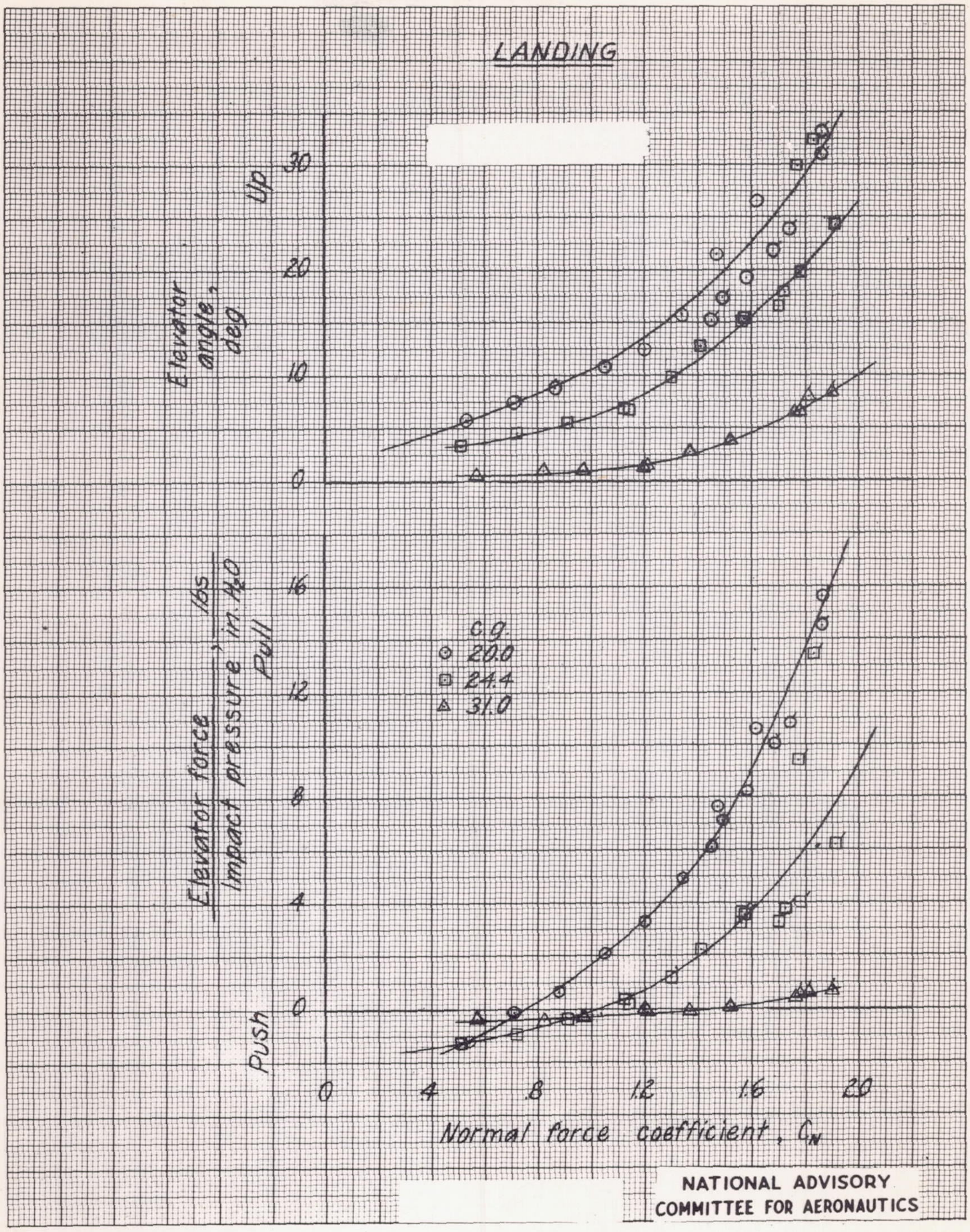
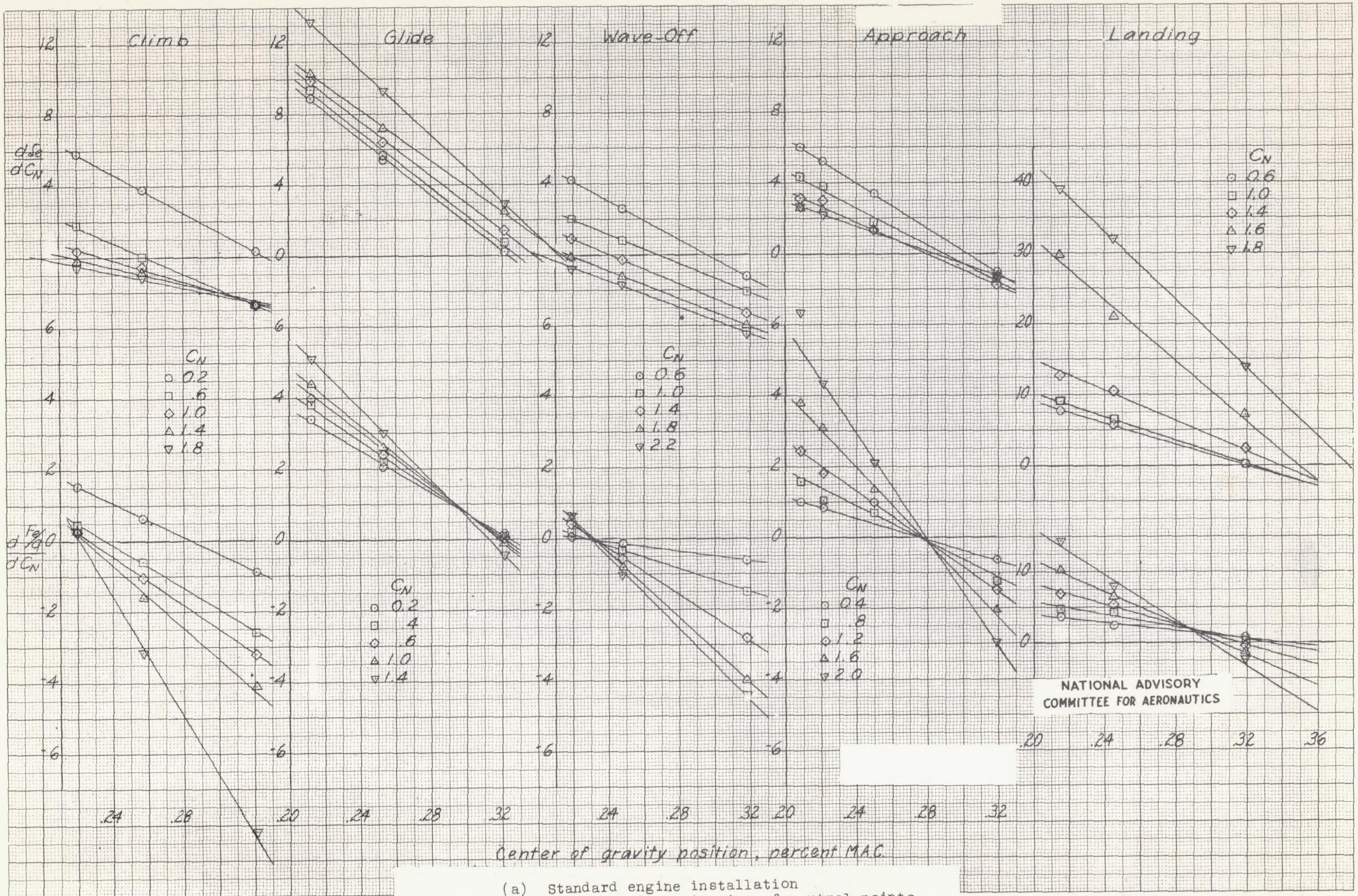


(c) Landing condition
Figure 10. Concluded.



(a) Standard engine installation

Figure 11. Graphical determination of neutral points

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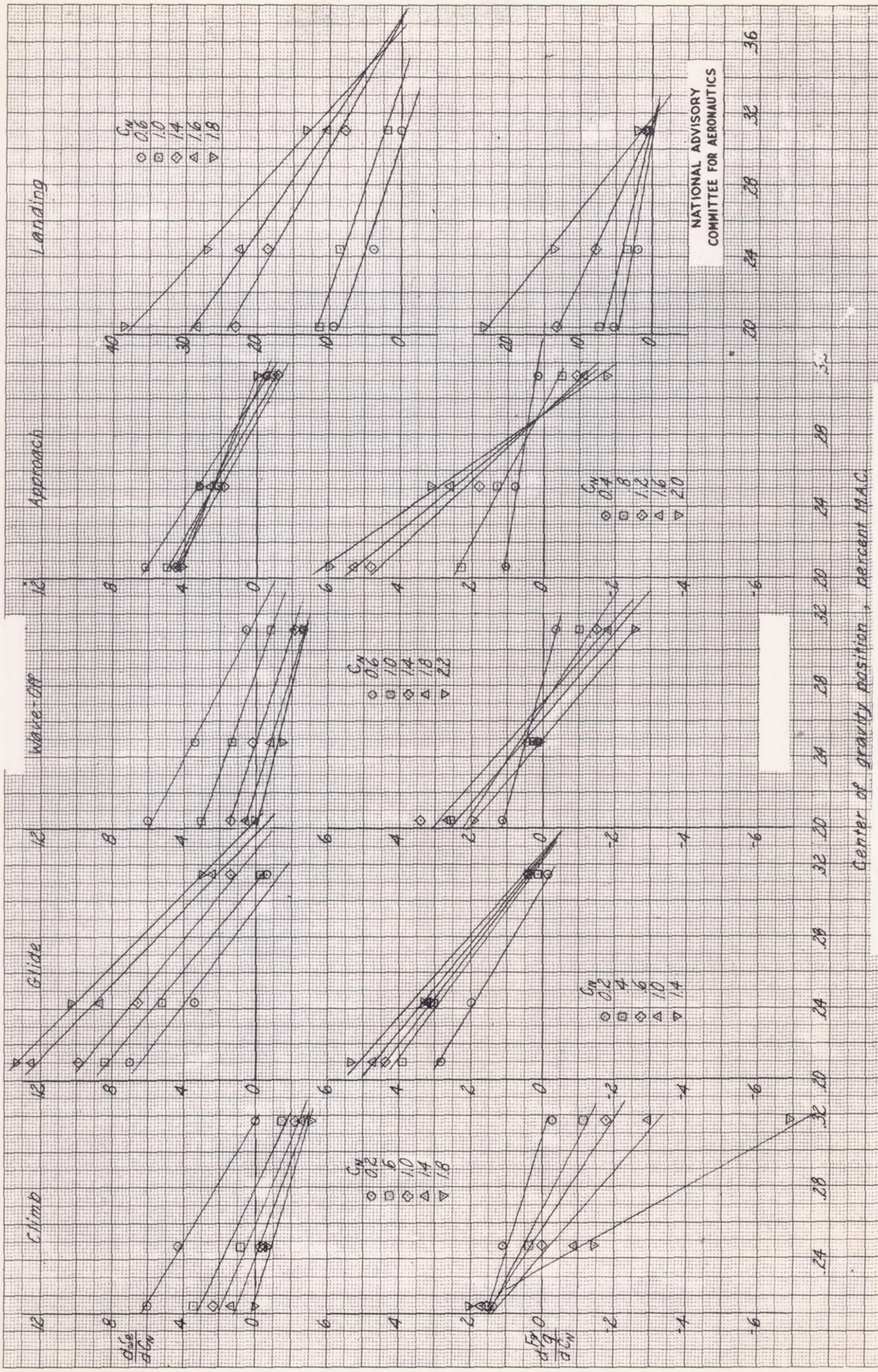

(b) Tilted engine installation
Figure 11. Concluded.

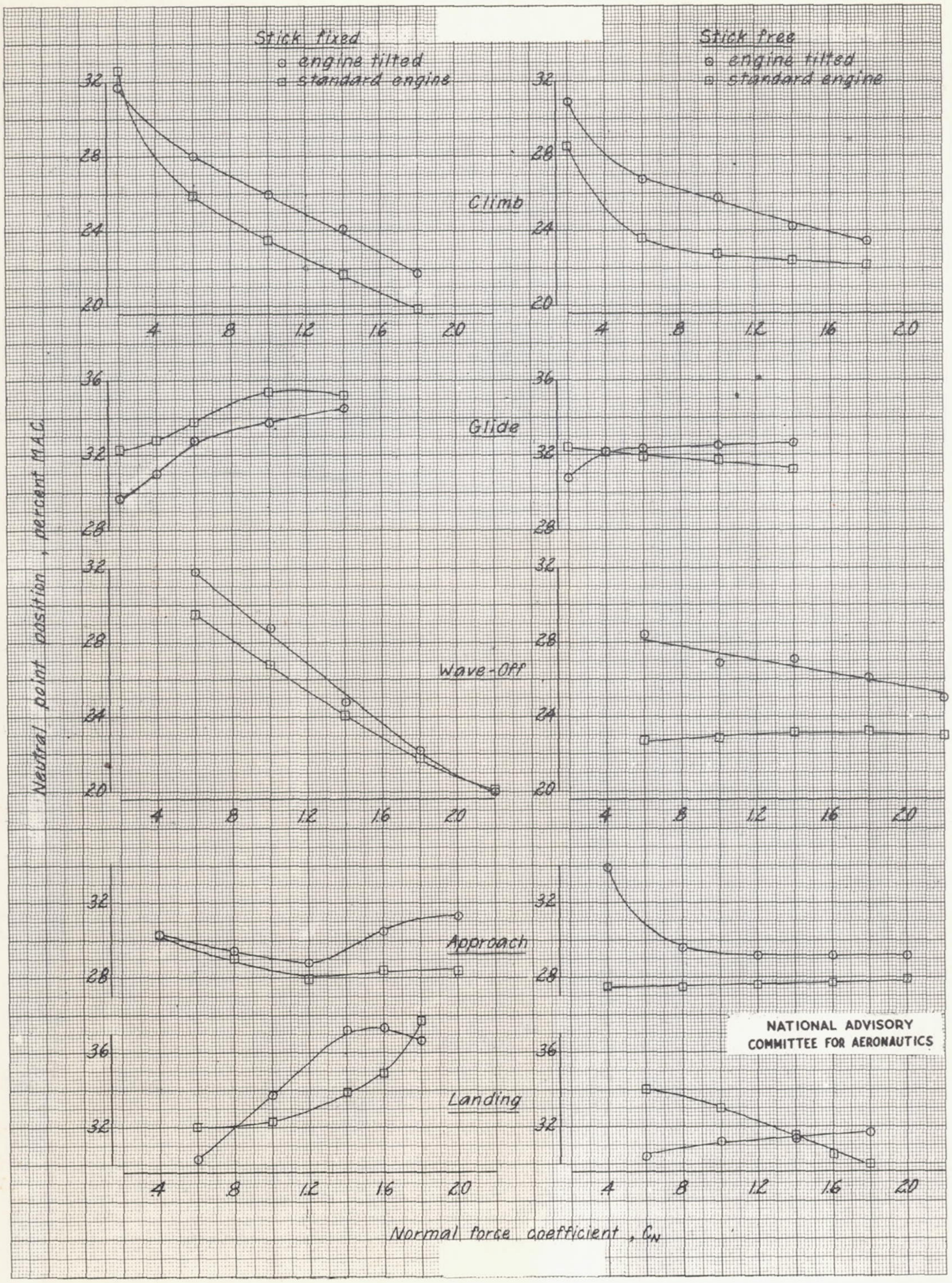

Figure 12. - Variation of neutral point location with airplane normal force coefficient.