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PRELIMINARY TESTS OF A BUFFET STALL-WARNING DEVICE ON A 1/5-SCALE MODEL OF THE REPUBLIC XP-84 AIRPLANE

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PRELIMINARY TESTS OF A BUFFET STALL-WARNING DEVICE ON A 1/5-SCALE MODEL OF THE REPUBLIC XP-84 AIRPLANE

By Warren A. Tucker and Paul Comisarow

SUMMARY

During the first flight tests of the Republic XP-84 airplane it was discovered that there was a complete lack of stall warning. A short series of development tests of a suitable stall-warning device for the airplane was therefore made on a 1/5-scale model in the Langley 300 MPH 7- by 10-foot tunnel. Two similar stall-warning devices, each designed to produce early root stall which would provide a buffet warning, were tested.

It appeared that either device would give a satisfactory buffet warning in the flaps-up configuration, at the cost of an increase of 8 or 10 miles per hour in minimum speed. Although neither device seemed to give a true buffet warning in the flaps-down configuration, it appeared that either device would improve the flaps-down stalling characteristics by lessening the severity of the stall and by maintaining better control at the stall. The flaps-down minimum-speed increase caused by the devices was only 1 or 2 miles per hour.

INTRODUCTION

The first flight tests of the Republic XP-84 no. 1 airplane showed the stalling characteristics to be unsatisfactory (reference 1). The stall occurred, with no preliminary warning, in the form of a roll-off to the left, accompanied by a sudden dropping of the nose. The roll-off was undesirable, but the principal objection of the pilot was that there was an absolute lack of stall warning.

Motion pictures of tufts attached to the wing of the airplane showed that the left wing panel stalled practically as a whole,

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thus accounting for both the roll-off and the lack of warning. Had the initial stall been confined to the region of the wing-fuselage juncture, the rolling tendency would have been smaller, and a warning might have been present in the form of buffeting. Some exploratory flight tests were made with gloves on the wing root leading edge to induce early root stall. These additions were successful in providing a stall warning, but caused unacceptable increases in minimum speed.

Because of the stringent flight schedule occasioned by a restricted power-plant life, it was thought expedient to make further tests in a wind tunnel. Accordingly, the Air Materiel Command, Army Air Forces, requested that development tests of a suitable stall-warning device be made in the Langley 300 MPH 7- by 10-foot tunnel. These tests are reported in the present paper. In undertaking the tests, it was fully realized that the absolute magnitude of the results of wind-tunnel tests would have to be used with discretion when predicting full-scale stalling characteristics.

Two similar stall-warning devices were tested. Each was attached to the wing leading edge at the root and was designed to cause the initial stall to occur at the root, but one extended spanwise twice as far as the other. The spanwise lengths of the devices were kept smaller than those reported in reference 1, since the results of reference 1 (the large increases in minimum speed) indicated that an inordinately large wing area was being affected by the leading-edge gloves. An attempt was made, by correlating the results of force tests and tuft studies, to evaluate the performance of the stall-warning devices as applied to the airplane.

COEFFICIENTS AND SYMBOLS

The results of the tests are presented as standard NACA coefficients of forces and moments. Pitching-moment coefficients are given about the center-of-gravity location shown in figure 1 (26.45 percent of the mean aerodynamic chord). The data are referred to the stability axes, which are a system of axes having their origin at the center of gravity and in which the Z-axis is in the plane of symmetry and perpendicular to the relative wind, the X-axis is in the plane of symmetry and perpendicular to the Z-axis, and the Y-axis is perpendicular to the plane of symmetry. The positive directions of the stability axes, of angular displacements of the airplane and control surfaces, and of forces and moments are shown in figure 2.

The coefficients and symbols are defined as follows:

C_L	lift coefficient (Lift/qS)
C_X	longitudinal-force coefficient (X/qS)
C_m	pitching-moment coefficient (M/qSc')
$-Z$	lift
X Z	forces along respective axes, pounds
M	moment about Y-axis, pound-foot
q	free-stream dynamic pressure, pounds per square foot $\left(\frac{\rho V^2}{2}\right)$
q_t	effective dynamic pressure at tail, pounds per square foot
S	wing area (10.40 sq ft on model)
c'	wing mean aerodynamic chord (M.A.C.) (1.48 ft on model)
V	free-stream air velocity, feet per second
ρ	mass density of air, slug per cubic foot
α	angle of attack of fuselage reference line, degrees
i_t	angle of stabilizer with respect to fuselage reference line, degrees; positive when trailing edge is down
δ_e	elevator deflection with respect to stabilizer chord line, degrees; positive when trailing edge is down
δ_f	slotted-flap deflection with respect to undeflected position, degrees
$C_{L_{trim}}$	value of C_L when $C_m = 0$
$C_{L_{max}}$	maximum value of $C_{L_{trim}}$
V_i	indicated airspeed, miles per hour

AIRPLANE, MODEL, AND APPARATUS

The Republic XP-84 airplane is a single-place, single-jet, low-midwing fighter, and has been described in reference 2.

The 1/5-scale model has also been described in reference 2. For the present tests, the slotted flap was used, as was the revised horizontal tail, which was set at -1.0° for all tests. The landing gear was retracted for all tests. All tests were made with the model blower unit inoperative and with the duct open. A three-view drawing of the model and a photograph of the model in the tunnel are shown in figures 1 and 3, respectively.

The two stall-warning devices tested on the model are shown in figure 4. The data of references 3 and 4 were used as a basis for the design of the warning devices. It is thought that the high-speed performance of the airplane should be little affected by the devices, since in this flight condition the devices should be very near the stagnation point.

To increase the effective Reynolds number for a given tunnel speed, a turbulence net was used (the net may be seen in fig. 3). The turbulence net was a standard fish net made of 3/16-inch diameter cotton twine with a square mesh $1\frac{1}{4}$ inches on a side, and was located in the tunnel 97 inches upstream of the center line of the balance frame.

TESTS

Test Conditions

The tunnel dynamic pressure was held at 40.03 pounds per square foot for all tests. Based on the model wing mean aerodynamic chord of 1.48 foot, this corresponds to a Reynolds number of 1.73×10^6. Through sphere pressure-measurement tests after the method of reference 5, the turbulence factor with the net in place was found to be 2.24, so that the effective Reynolds number of the tests was 3.88×10^6. (The Reynolds number of the full scale airplane at maximum lift is about 7×10^6, flaps down, 9×10^6, flaps up.)

Corrections

No corrections for tares caused by the model support system have been applied to the data. Jet-boundary corrections have been applied to the angles of attack, the longitudinal-force coefficients, and the pitching-moment coefficients. The following corrections, obtained from reference 6, were added to the test data:

$$\Delta\alpha = 1.00\ C_L$$

$$\Delta C_X = -0.0175\ {C_L}^2$$

$$\Delta C_m = -8.65C_L\left(\frac{0.216}{\sqrt{q_t/q}} - 0.166\right)\left(\frac{\partial C_m}{\partial i_t}\right)$$

where $\Delta\alpha$ is in degrees.

Test Procedure

Tuft studies of the right wing were made flaps up, and flaps down 30°, with the model in the clean condition (no stall-warning device) and with both stall-warning devices. The behavior of the tufts, besides being observed visually, was also recorded with a motion-picture camera.

For the same configurations noted above, tests through the angle-of-attack range were made with various elevator deflections, and the force data were recorded.

PRESENTATION OF RESULTS

An outline of the figures presenting the results is given below:

	Figure
A. Initial stall patterns	5
B. Elevator tests[1]	
$\delta_f = 0^\circ$	6
$\delta_f = 30^\circ$	7
C. Elevator deflection required to trim	8

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[1] Figures 6(a) and 6(b) include separate "ladder" plots of the pitching-moment coefficients.

DISCUSSION

Tuft Studies

No stall-warning devices.- With no stall-warning device on the wing the stall was very abrupt, both flaps up and flaps down. The initial stall occurred over the large areas shown in figure 5 and then spread very rapidly over the rest of the wing. This observation was in agreement with the results of tuft studies on the full-scale airplane (reference 1).

It was noted while making preliminary tuft studies that in the flaps-up configuration with no stall-warning device that the left wing panel stalled about 2° earlier than the right panel. Except for these first studies, tufts were attached only on the right wing.

Stall-warning devices nos. 1 and 2.- With either of the two stall-warning devices attached, a gradual and desirable stall progression was evident, both flaps up and flaps down. In each case, the initial stall occurred at a slightly lower angle of attack than for the corresponding configuration with no stall-warning device. The initial stall covered a relatively small area as shown in figure 5, and gradually spread forward and outboard as the angle of attack was increased.

Stall Warning

In the flaps-up configuration, complete sets of elevator tests were obtained for the clean wing and for stall-warning device No. 1. For this condition, then, a fairly complete analysis of the stall warning can be made. This will be discussed first. The results of the tests in the other configuration will then be discussed in a somewhat different vein.

Flaps up, stall-warning device No. 1.- The type of stall warning that can be expected is shown by the estimated elevator-to-trim curves of figure 8 taken from the data of figure 6. The buffet region and the points of complete wing stall were estimated from the tuft studies. For the clean wing, the lack of stall warning is evident; as the stick is pulled back, practically the entire wing suddenly stalls with no preliminary buffeting or marked increase in stick travel. This behavior was noted in the flight tests reported in reference 1.

With stall-warning device No. 1 installed, a stall warning in the form of buffet may be expected to occur at an up-elevator deflection of about 11°. As the stick is pulled back beyond this point, no further speed reduction will result, but the buffeting should become more severe as the result of a spreading root stall. It will be noted that although minimum speed is reached at the same point at which buffeting begins, the airplane should remain controllable with further backward movement of the stick almost until full-up elevator (27.5°) is reached, since it is not until an up elevator of 25° that the entire wing stalls. This action should constitute a satisfactory stall warning.

It will be noted from the curves of figure 8 that the elevator is sufficiently powerful to stall the airplane for the two cases presented. An inspection of the data of figures 6 and 7 shows that for all configurations tested, the airplane may be stalled by use of the elevator.

Time did not permit making any complete sets of elevator tests other than those just discussed. Therefore the results of the remainder of the tests are analyzed in a slightly different form. (See table I.) The values presented in table I are the angles of attack for initial stall and maximum lift, and the corresponding trim lift coefficients and indicated airspeeds for a gross weight of 13,000 pounds. (The wing area of the airplane is 260 sq ft.) The angles of attack for the initial stall were determined from the tuft studies. The other quantities were obtained from the force-test data of figures 6 and 7. It should be remembered that the preliminary tuft studies showed a slight difference in stall angle between the left and right wing panels, so that the absolute values of the quantities in table I must be regarded with caution.

Flaps up, stall-warning device No. 2.- About the same behavior can be expected as for device No. 1, with perhaps an additional advantage in the form of a slight speed margin between the first warning and the complete stall.

Flaps down 30°, stall-warning devices Nos. 1 and 2.- It appears that for the flaps-down cases, no stall warning in the form of buffeting or increased stick travel can be expected, since the angles of attack for initial stall and $C_{L_{max}}$ are practically equal. (The angles for initial stall were not so clearly defined as for the flaps up cases, so that the tabulated values are given as approximate.) As the stick is pulled back to reach an angle of attack higher than that for initial stall, the lift will therefore drop, instead of remaining approximately constant as in the flaps-up cases. There seems to be a slight angle-of-attack margin for device No. 2, but the margin is too small to allow saying definitely that there will be any buffet warning.

Although the devices tested apparently will not provide a true buffet stall warning in the flaps down configuration, they should serve to improve the flaps-down stall characteristics. It should first be noted that the angles of attack for $C_{L_{max}}$ given in table I for $\delta_f = 30^{\circ}$ are lower than those at which the entire wing was stalled (for $\delta_f = 0^{\circ}$, the two angles were the same). As was pointed out in the discussion of the flaps-down tuft studies, the entire inboard half of the wing stalled at $C_{L_{max}}$ when no stall-warning device was used. With either stall-warning device, the stalled portion at $C_{L_{max}}$ was much smaller, so that the stall would be expected to be less severe. In particular, if any slight asymmetry existed in the airplane, causing a tendency to roll off at the stall, the tendency to roll would be less violent with the stall-warning devices. Further, the stall progression was seen to be much more gradual when either stall-warning device was used, so that it would be expected that better control would be maintained after $C_{L_{max}}$ is reached. The effect of the more gradual stall progression is also evidenced in the somewhat less rapid drop-off of the lift curves beyond $C_{L_{max}}$ (fig. 7) with the stall-warning devices attached.

Minimum Speed

A desirable stall-warning device would be one that performed its function with no decrease in $C_{L_{max}}$ (and therefore no increase in minimum speed). The values of $\Delta C_{L_{max}}$ and ΔV_{min} (table I) show that with the flaps up, devices Nos. 1 and 2 increased the minimum speed 10 and 8 miles per hour, respectively. The smallest minimum-speed increase reported in reference 1 was 8 miles per hour; the largest was 35 miles per hour. It is thought that the wind-tunnel results may be conservative by as much as 2 miles per hour. If these increments in minimum speed are considered too large, it may be possible to decrease them by further cutting down the span of the warning device, realizing that too short a device may fail to give an adequate stall warning.

The increases in minimum speed for the flaps-down configuration caused by the devices tested were of the order of 1 or 2 miles per hour.

CONCLUSIONS

The following conclusions are based on the results of tests of two stall-warning devices on a 1/5-scale model of the Republic XP-84 airplane in the Langley 300 MPH 7- by 10-foot tunnel:

1. In the flaps-up configuration, either warning device tested apparently gave a warning in the form of buffeting as the stall was approached. The devices increased the minimum speed by 8 or 10 miles per hour.

2. Neither device seemed to provide a definite buffet warning when the flaps were deflected 30°, but it appeared that the use of either device would improve the flaps-down stalling characteristics by lessening the severity of the stall and by maintaining better control at the stall. The minimum speed increase caused by the devices in the flaps-down configuration was only 1 or 2 miles per hour.

3. Neither stall-warning device decreased the elevator power to such an extent as to prevent stalling the airplane in any of the configurations tested.

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5. Platt, Robert C.: Turbulence Factors of N.A.C.A. Wind Tunnels as Determined by Sphere Tests. NACA Rep. No. 558, 1936.

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TABLE I

INITIAL STALL AND MAXIMUM LIFT AS AFFECTED BY STALL-WARNING DEVICES

δ_f, (deg)	Stall warning device	Lift condition	α, (deg)	$C_{L_{trim}}$	V_i, mph (Gross weight = 13,000 lb)	$\Delta C_{L_{max}}$	ΔV_{min}, (mph)
0	None	Initial stall	18.0	1.13	132		
		$C_{L_{max}}$	18.0	1.13	132		
	No. 1	Initial stall	14.0	.97	142	-0.16	10
		$C_{L_{max}}$	18.0	.97	142		
	No. 2	Initial stall	14.0	.96	143	-0.13	8
		$C_{L_{max}}$	18.0	1.00	140		
30	None	Initial stall	14 (approx.)	1.43	117		
		$C_{L_{max}}$	13.5	1.43	117		
	No. 1	Initial stall	12 (approx.)	1.33	119	-0.05	2
		$C_{L_{max}}$	12.5	1.33	119		
	No. 2	Initial stall	12 (approx.)	1.38	119	-0.02	1
		$C_{L_{max}}$	13.5	1.41	118		

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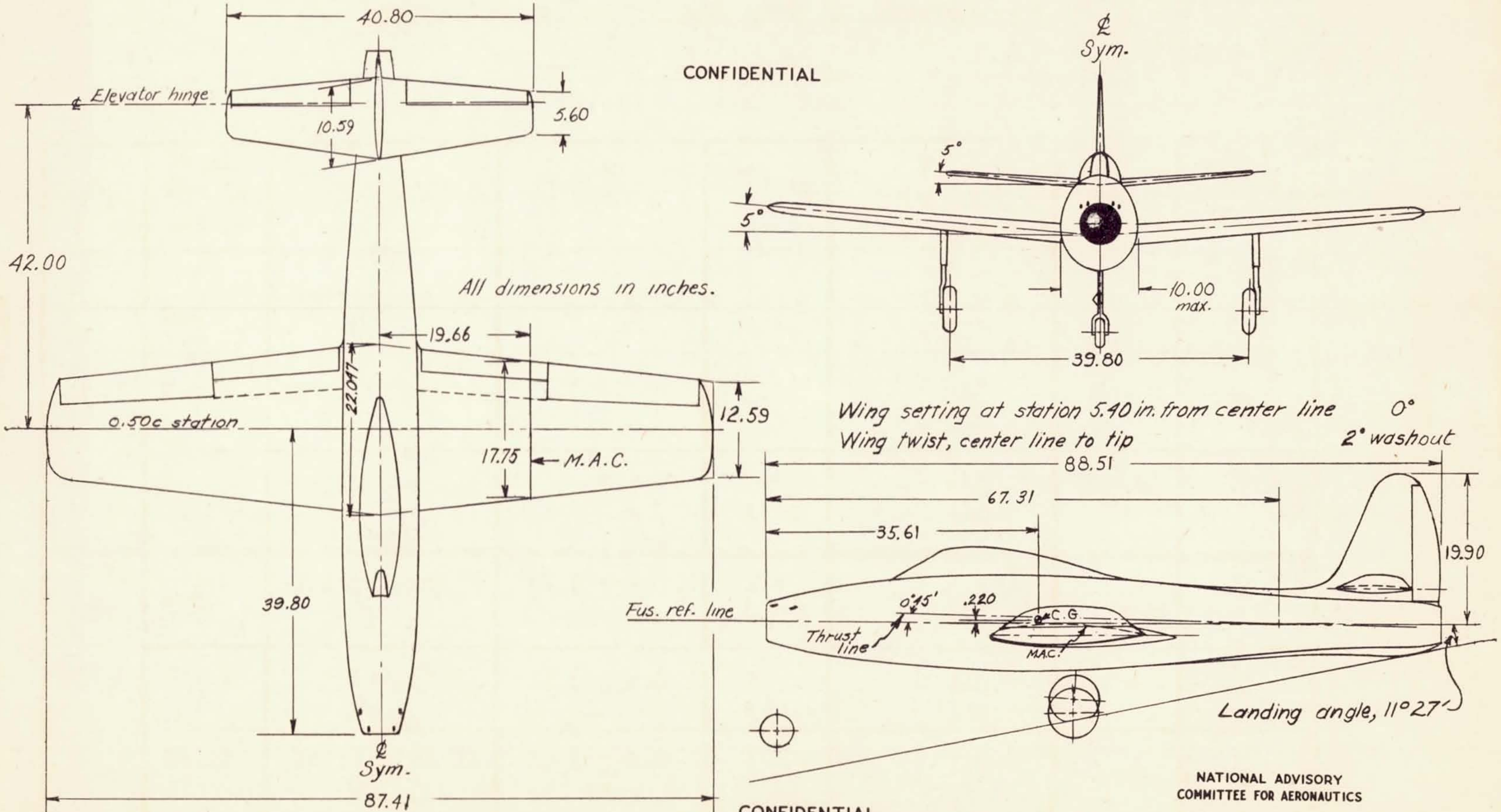

All dimensions in inches.

Wing setting at station 5.40 in. from center line 0°

Wing twist, center line to tip 2° washout

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Figure 1.- The $\frac{1}{5}$-scale model of the Republic XP-84 airplane with the revised horizontal tail.

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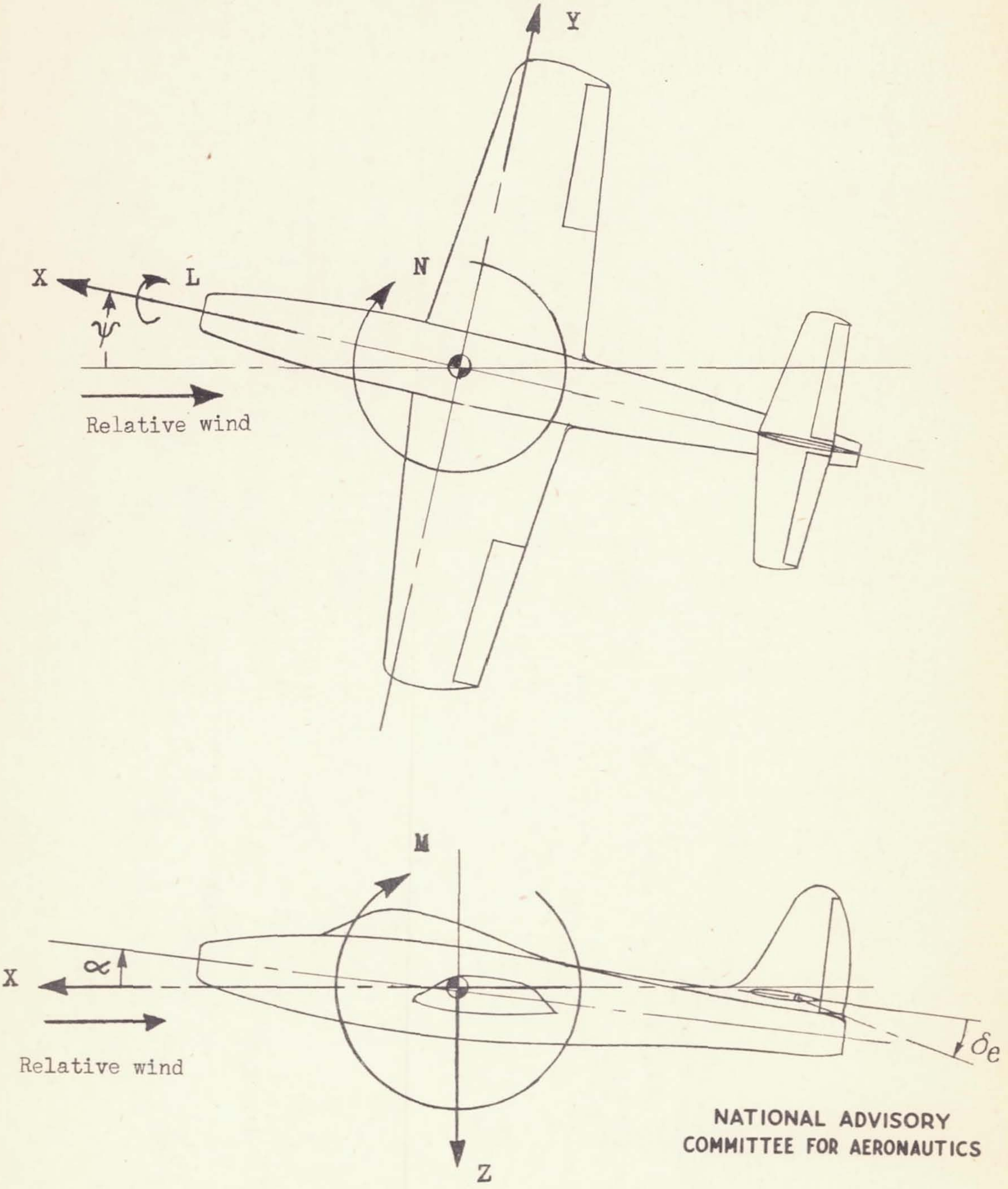

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Figure 2.- System of axes. Positive values of forces, moments, and angles are indicated by arrows.

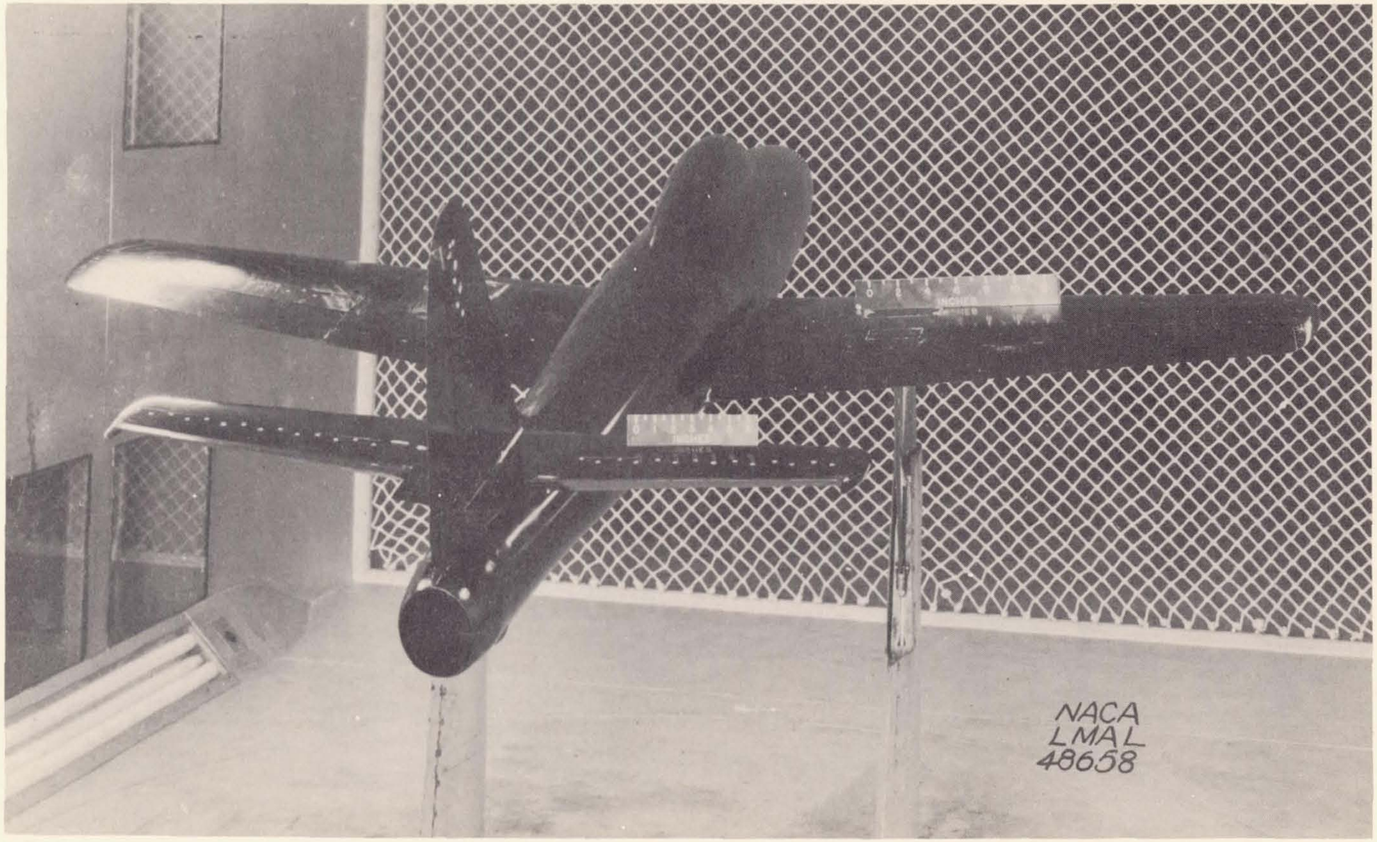

Figure 3.- The $\frac{1}{5}$-scale model of the Republic XP-84 airplane mounted in the Langley 300-mph 7- by 10-foot tunnel with turbulence net in place.

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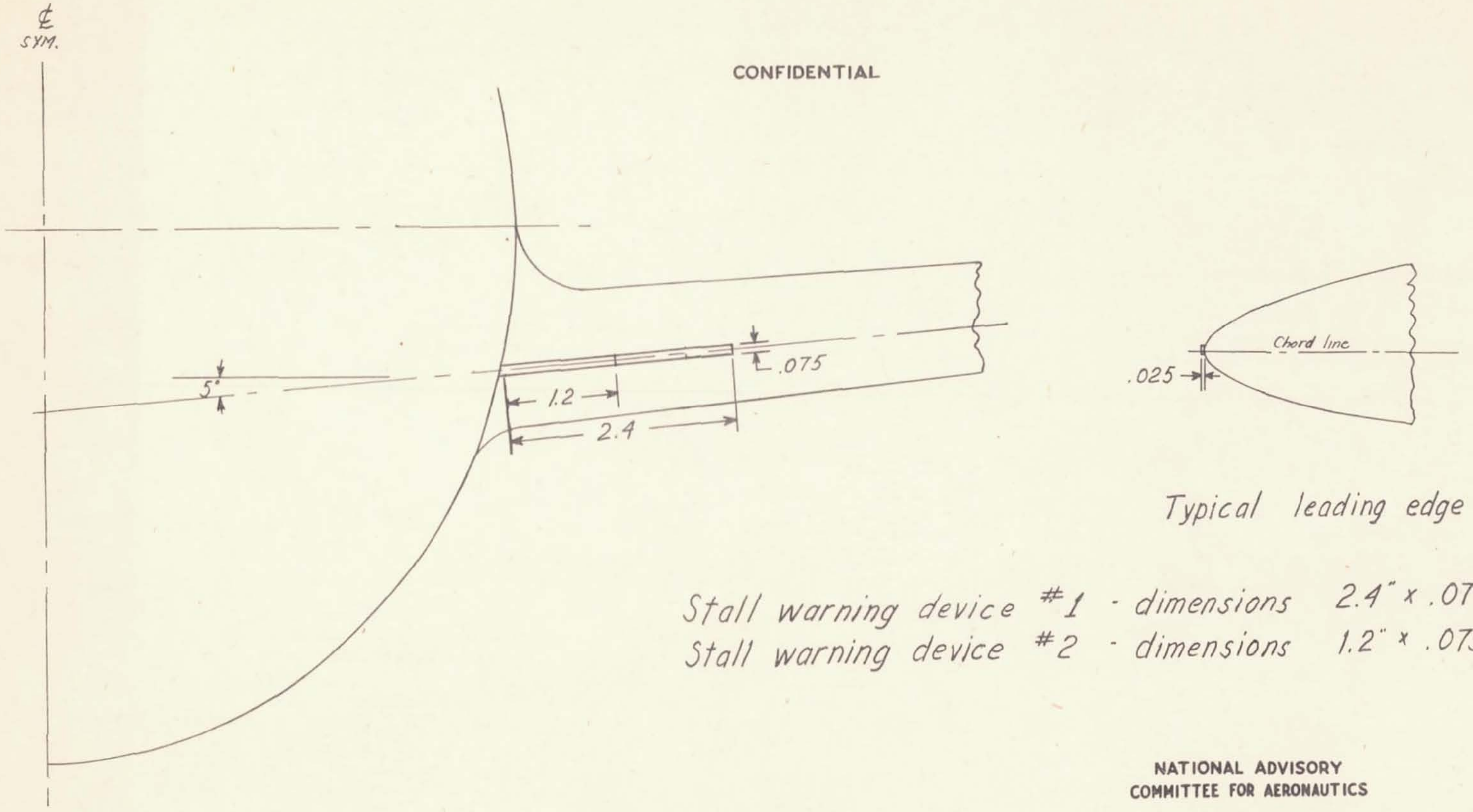

Typical leading edge

Stall warning device #1 - dimensions 2.4" x .075" x .025"
Stall warning device #2 - dimensions 1.2" x .075" x .025"

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Figure 4.- Details of the stall-warning devices and location as tested on the $\frac{1}{5}$-scale model of the Republic XP-84 airplane.

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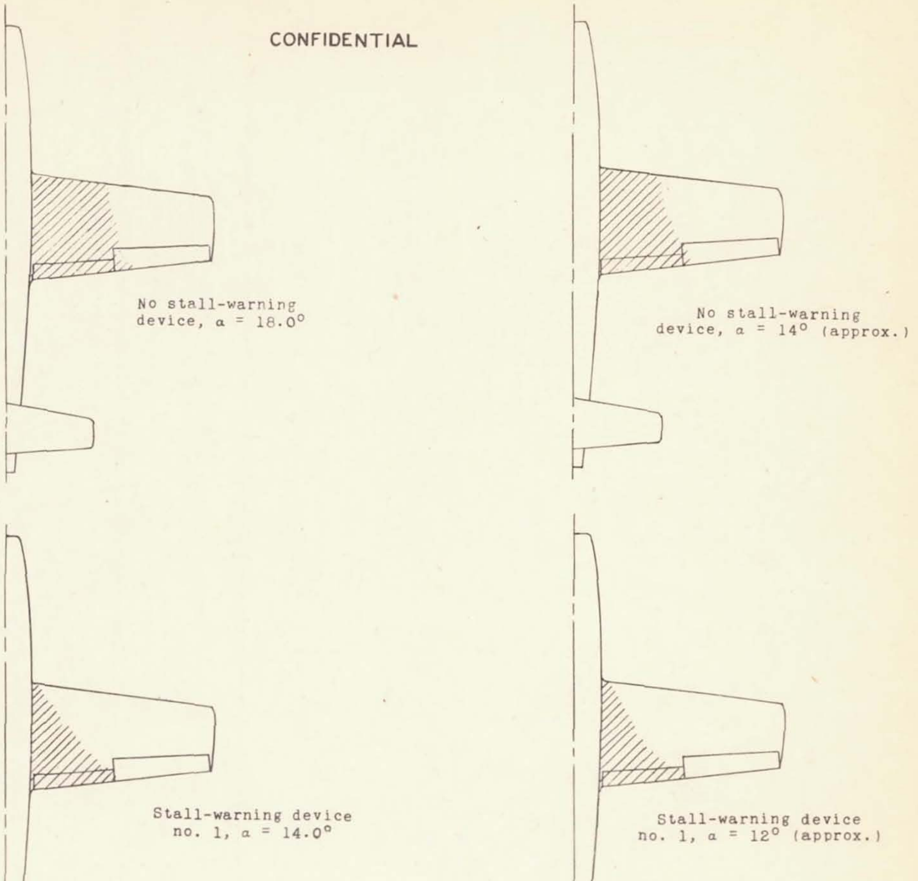

(a) $\delta_f = 0°$

(b) $\delta_f = 30°$

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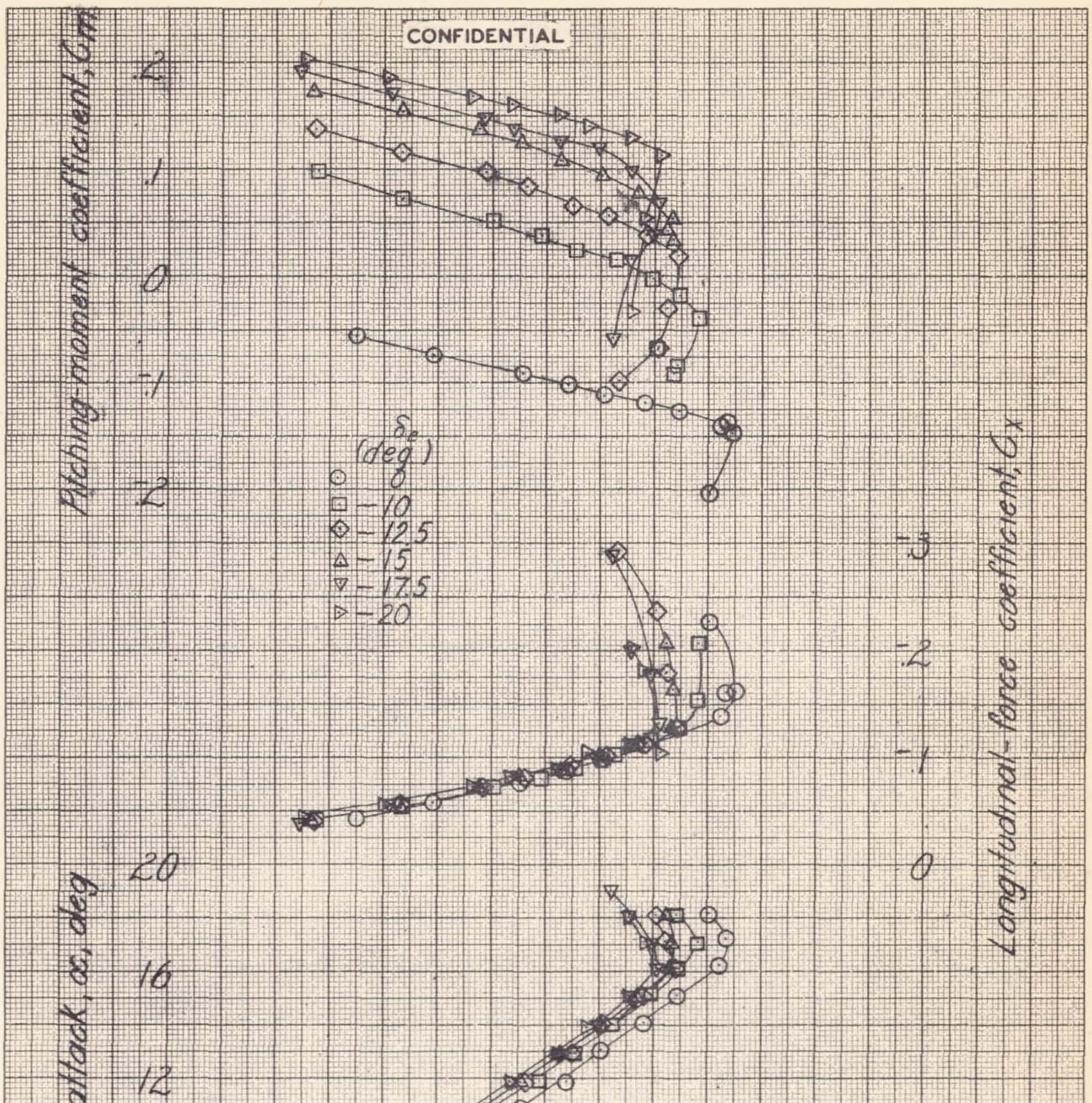
Figure 5.- Initial stall patterns observed in tuft studies on the $\frac{1}{5}$-scale model of the Republic XP-84 airplane.



(a) Clean (no stall-warning device).

Figure 6. - Aerodynamic characteristics in pitch of the 1/5-scale model of the Republic XP-84 airplane $i_t = -1.0°$; $\delta_r = 0°$.

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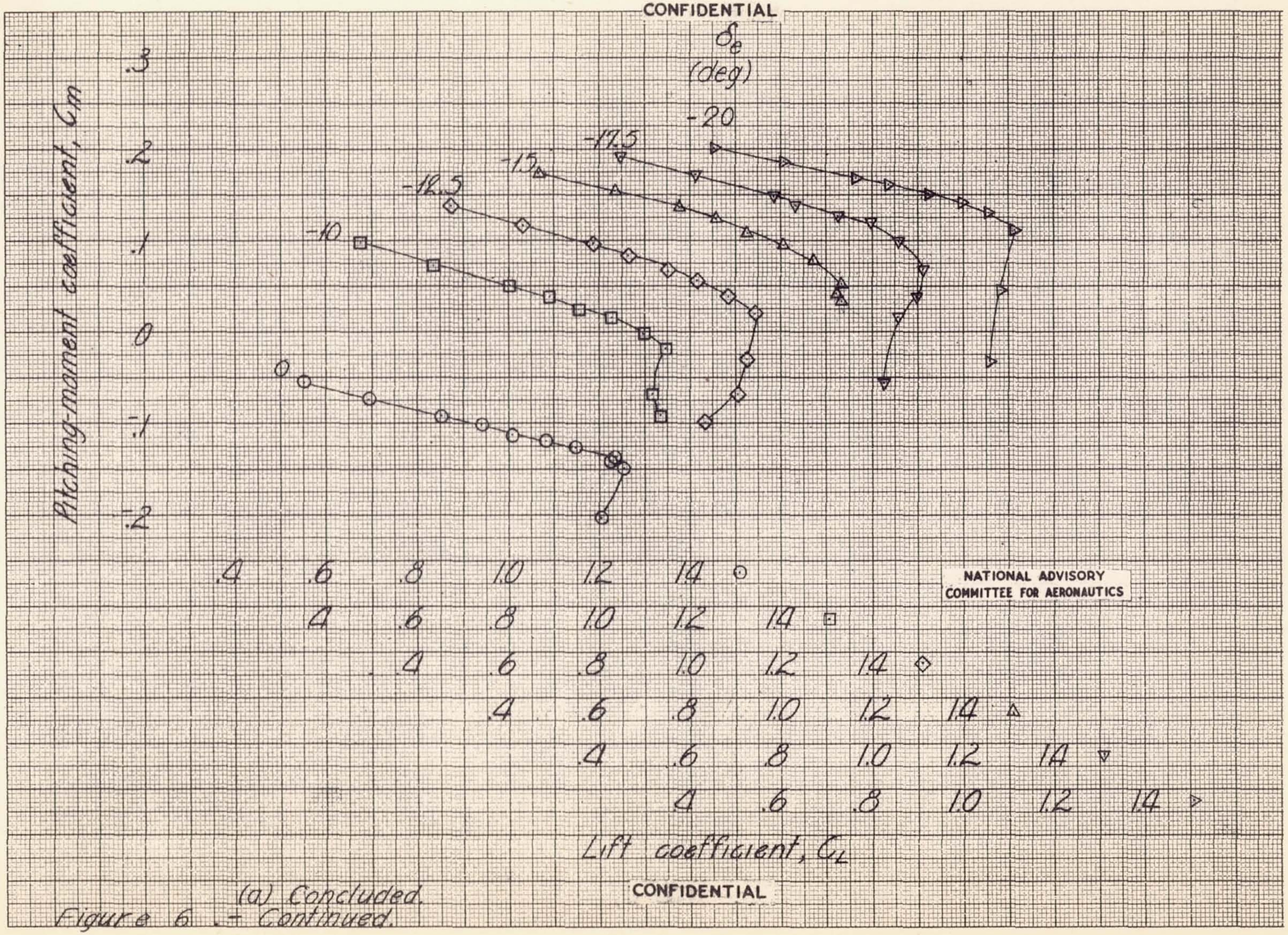

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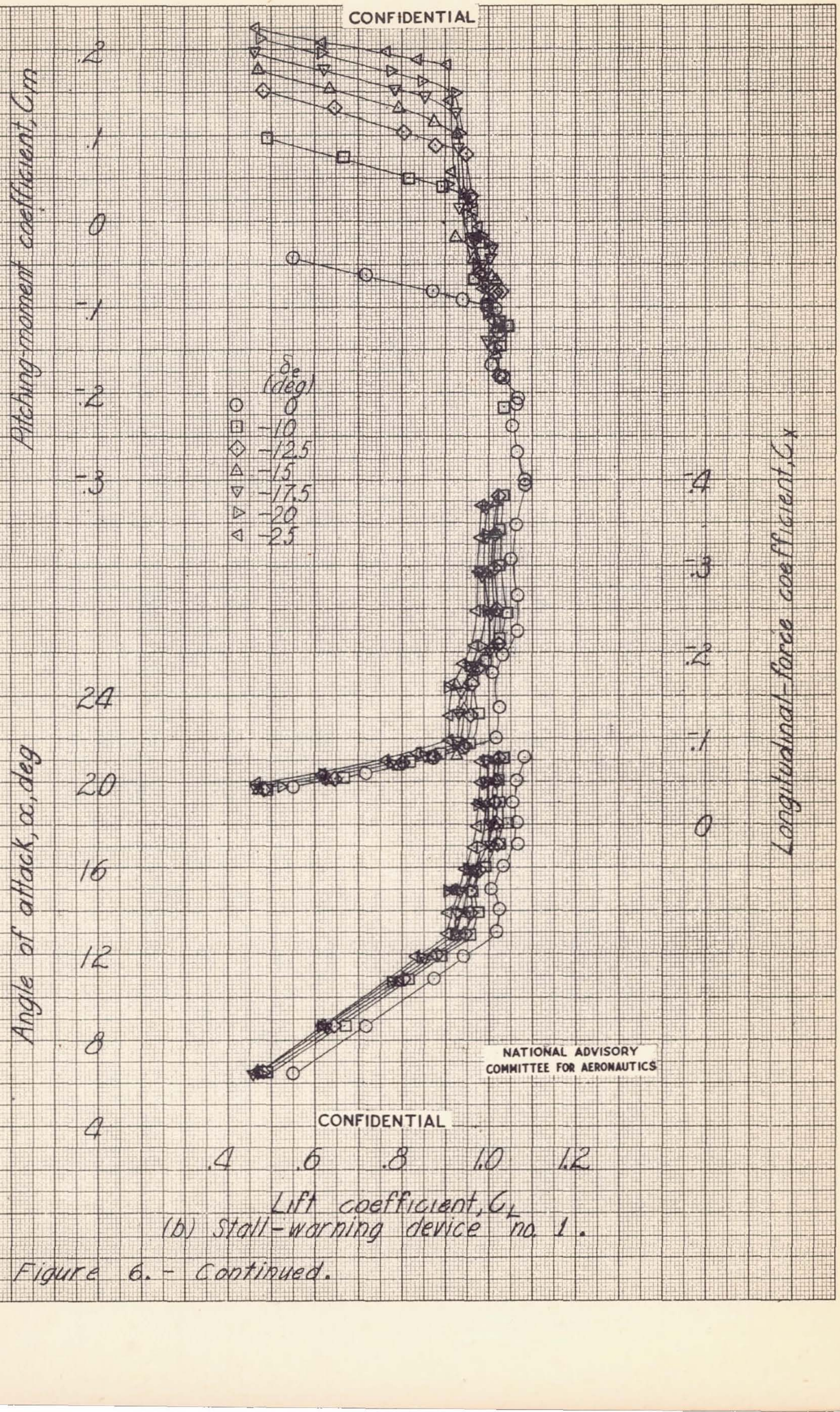
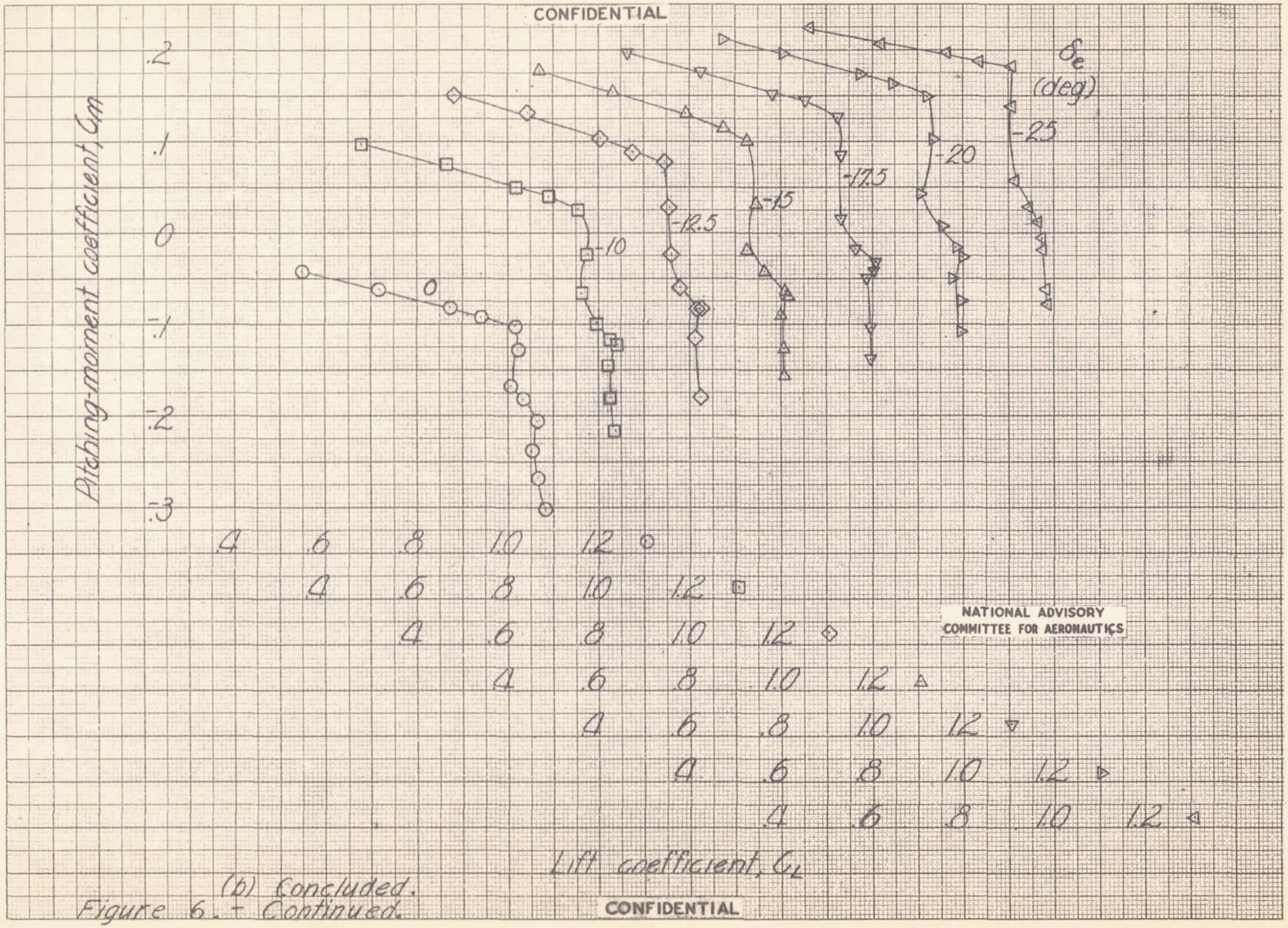
(a) Concluded.

Figure 6. - Continued.



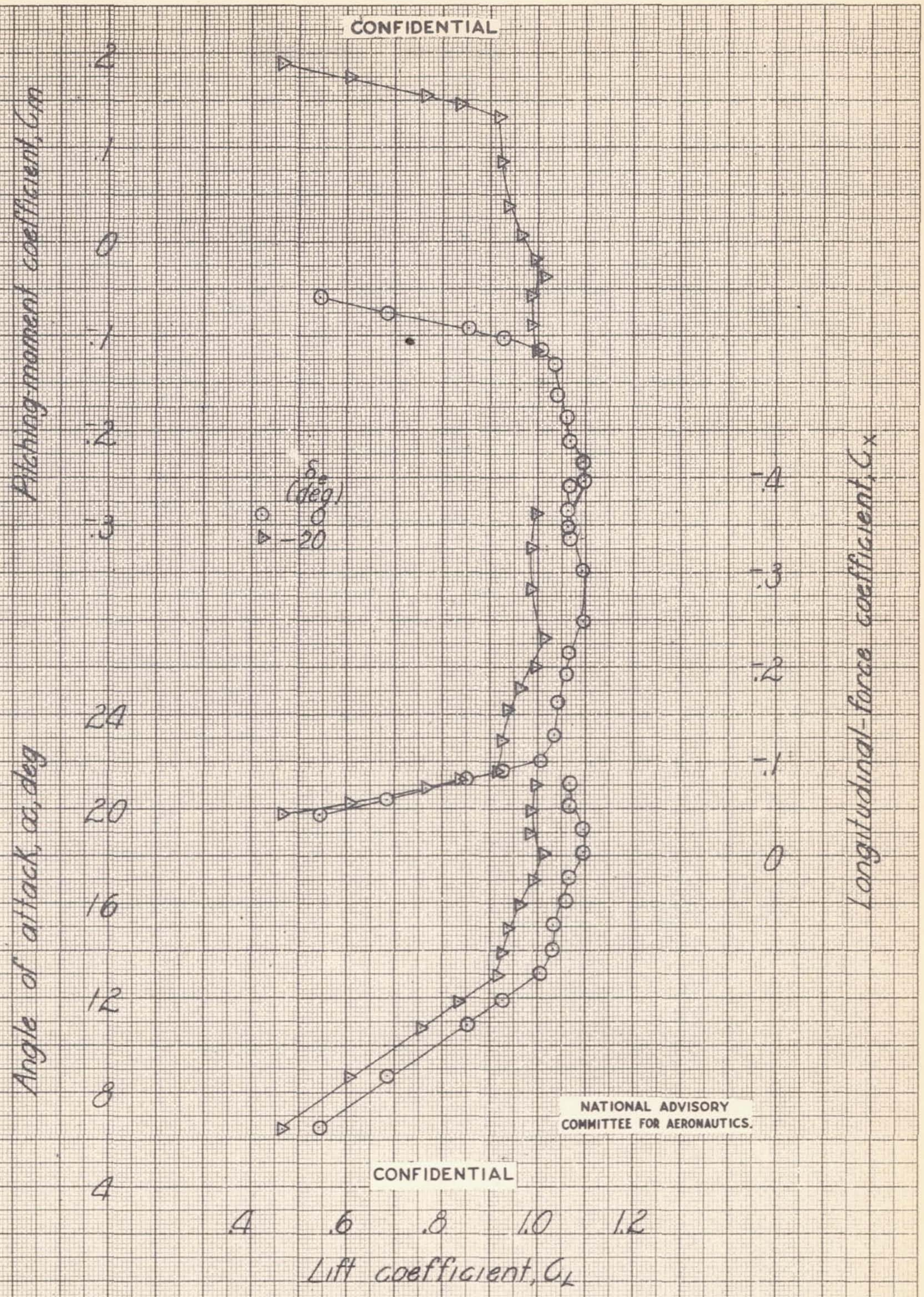
(b) Stall-warning device no. 1.

Figure 6. - Continued.



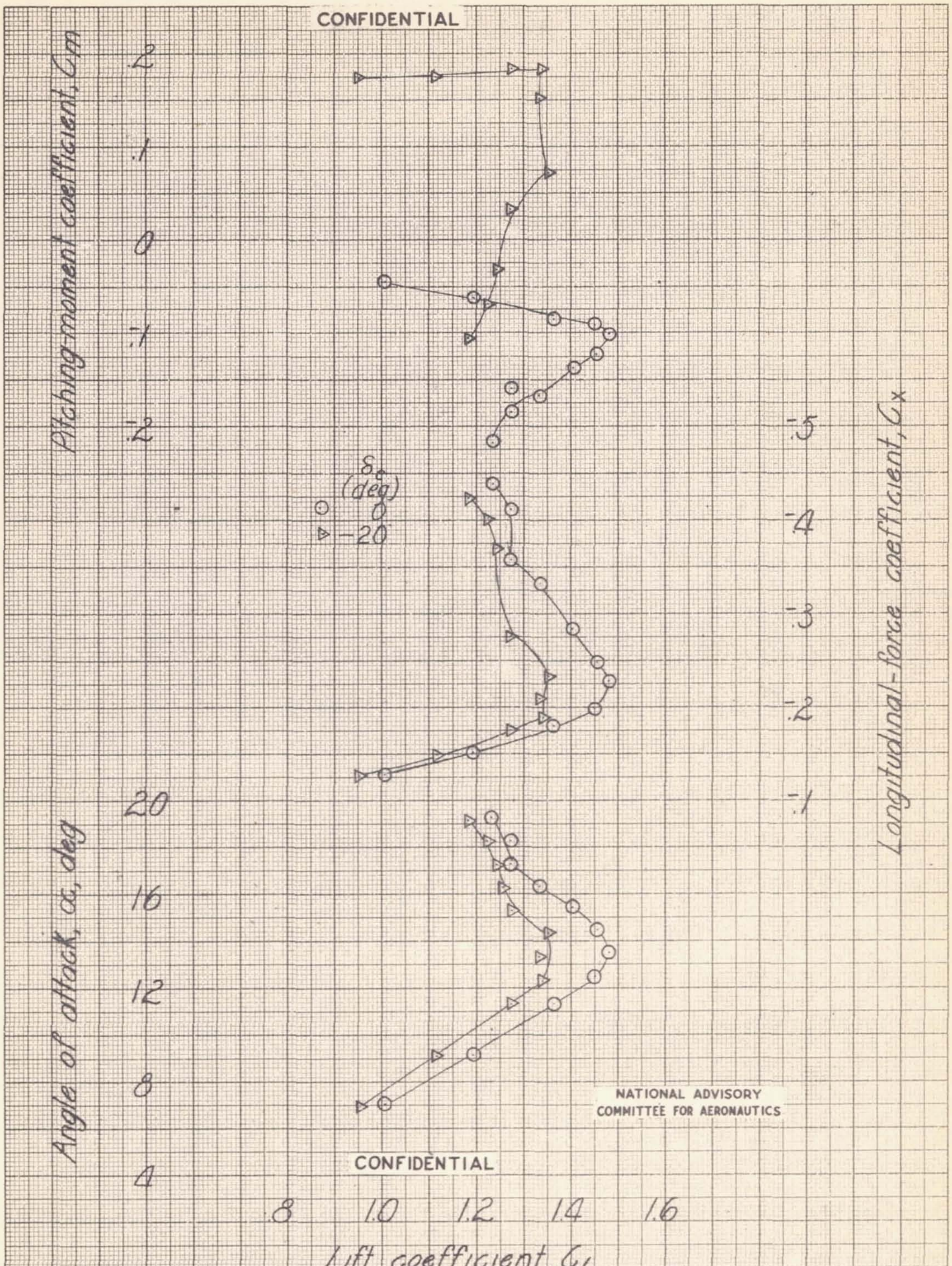
(b) Concluded.

Figure 6.- Continued.



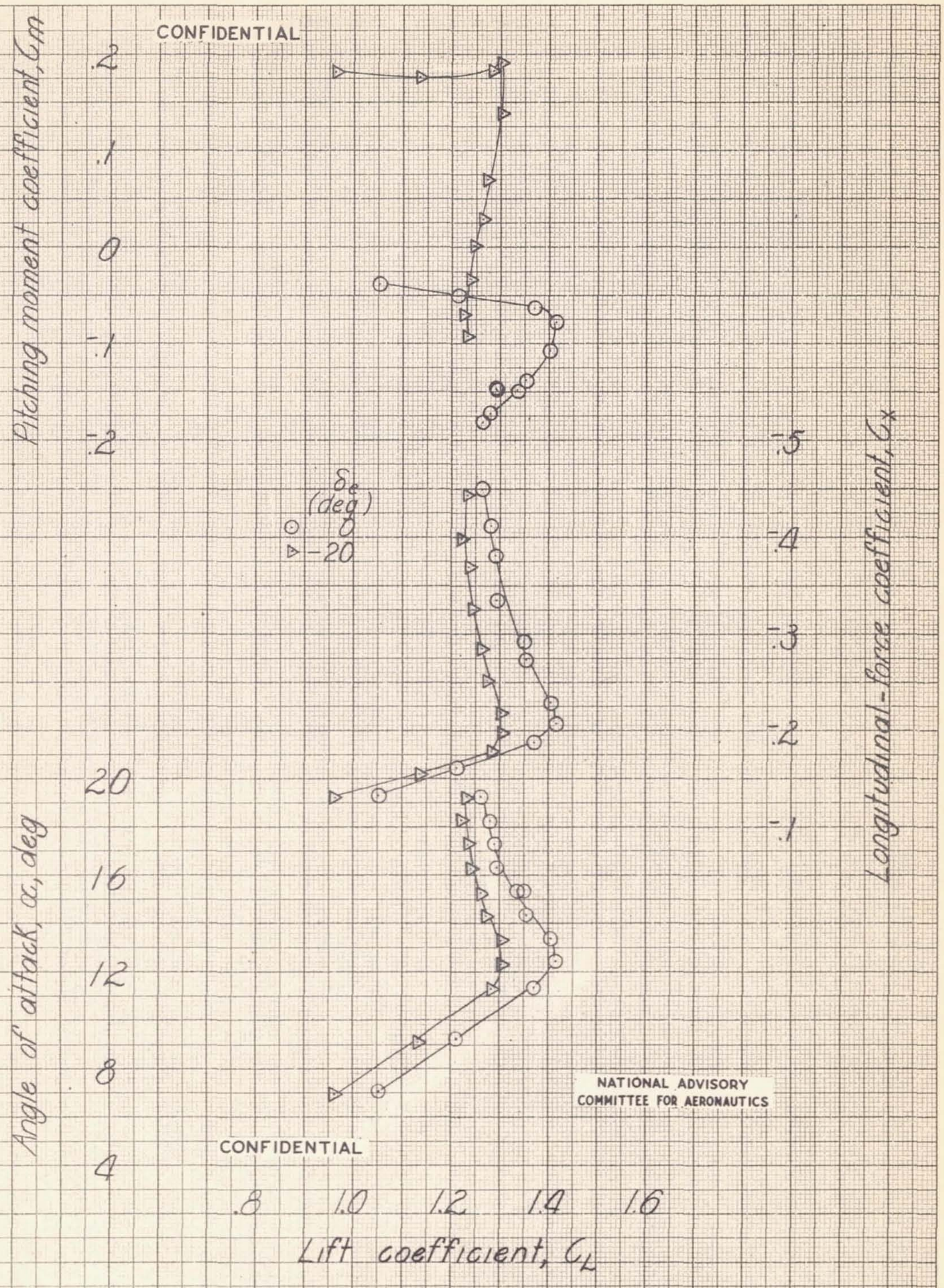
(c) Stall-warning device no. 2.

Figure 6. - Concluded.



(a) Clean (no stall-warning device).

Figure 7. - Aerodynamic characteristics in pitch of the 1/5-scale model of the Republic XP-84 airplane. $i_t = -1.0°$; $\delta_f = 30°$.



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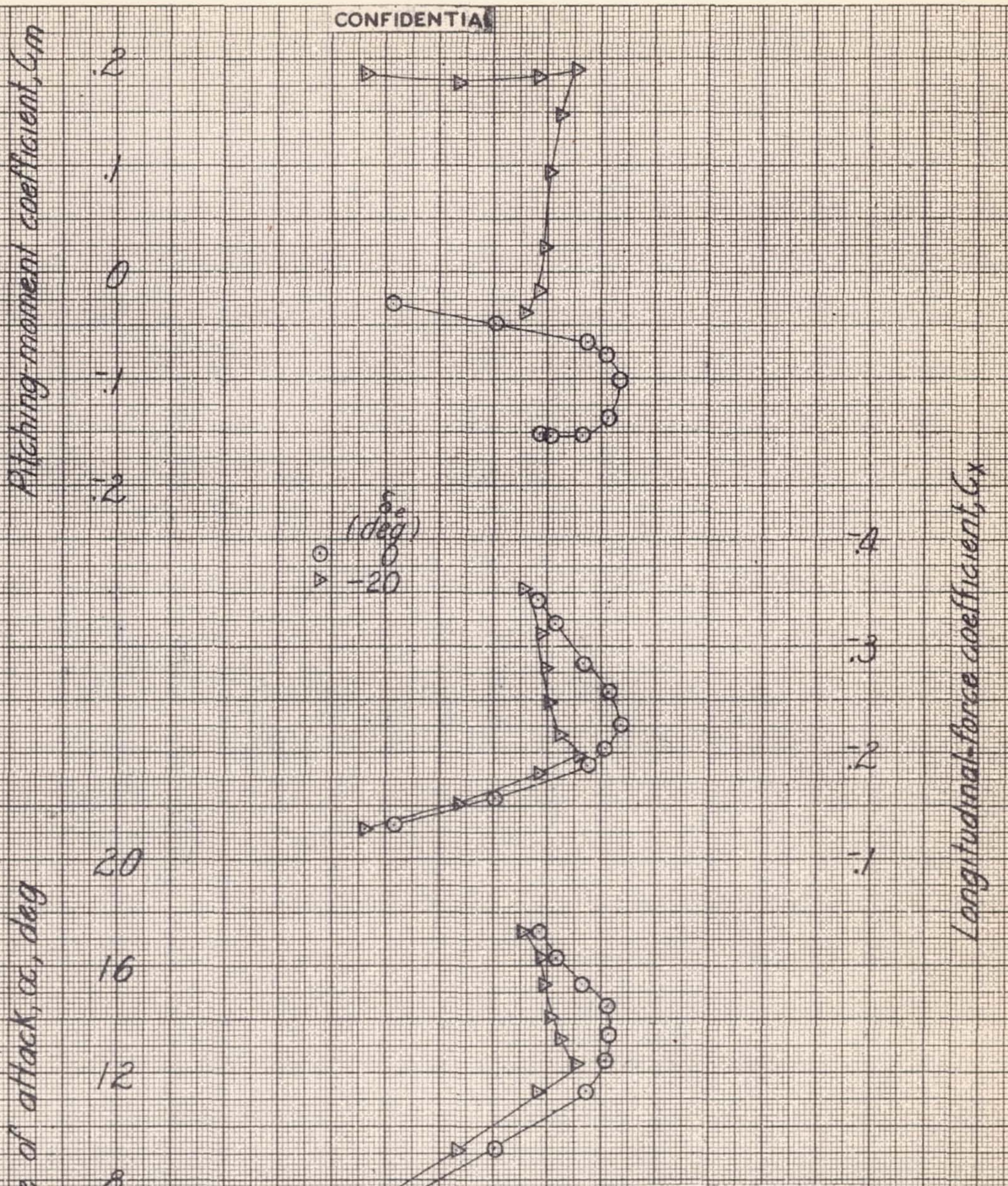
(b) Stall-warning device no. 1.

Figure 7. - Continued.



(c) Stall-warning device no. 2.

Figure 7. - Concluded.

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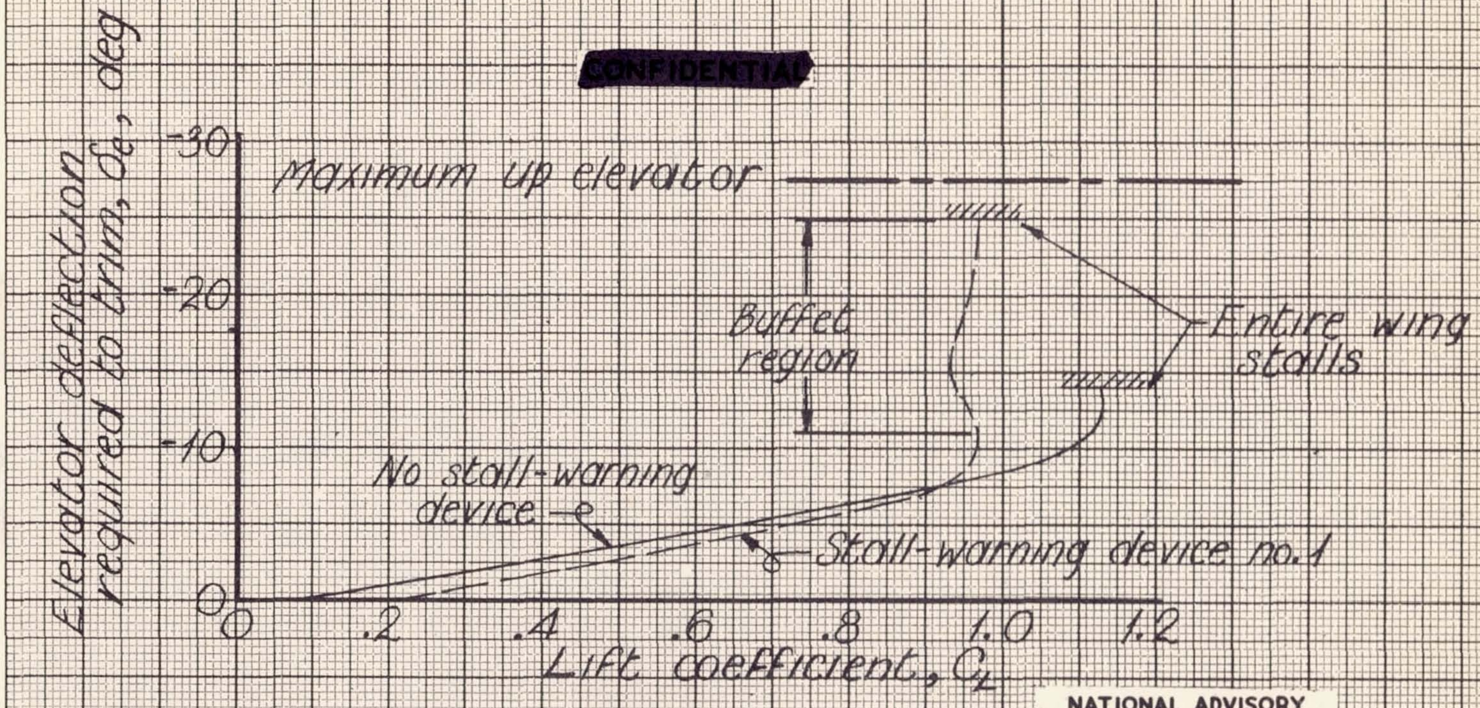

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Figure 8.- Elevator deflection required to trim, as estimated from tests of the 1/5-scale model of the Republic XP-84 airplane. $\delta_f = 0°$; $i_t = -1.0°$.