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RESEARCH MEMORANDUM

LONGITUDINAL FLIGHT CHARACTERISTICS OF THE BELL X-5 RESEARCH AIRPLANE AT 59° SWEEPBACK WITH MODIFIED WING ROOTS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

In an attempt to improve the longitudinal stability characteristics of the Bell X-5 research airplane at 59° sweepback, the wing-root leading edge was modified by replacing the original 52.5° sweptback leading-edge fillets with rounded leading-edge fillets. The data obtained show that the longitudinal stability characteristics, as well as the buffet and drag characteristics, were unaffected by the modification.

INTRODUCTION

The results of a wind-tunnel investigation reported in reference 1 indicated that modifications of the leading-edge fillets of a model similar to the Bell X-5 research airplane substantially improved the longitudinal stability characteristics at high lift conditions. In view of these results a fillet modification similar to one of those investigated in reference 1 has been evaluated in flight on the Bell X-5 airplane at 59° sweepback in an attempt to alleviate the reduction of longitudinal stability discussed in reference 2. This reduction of stability limited the usable range of normal-force coefficient available for performing precise flight maneuvers, although the pilot did not consider the reduction of stability to be dangerous at altitudes above 30,000 feet.

The results of a flight made with the modified leading-edge fillets compared with the results of a flight made with the original fillets are presented in this paper. The flights were made at the NACA High-Speed Flight Research Station, Edwards Air Force Base, Calif.

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SYMBOLS

b	wing span, ft
C_D	drag coefficient, total drag/qS
C_L	lift coefficient, total lift/qS
$C_{m_{\bar{c}/4}}$	pitching-moment coefficient about quarter chord of $\bar{c}$
C_{N_A}	airplane normal-force coefficient, nW/qS
C_{N_t}	tail normal-force coefficient, L_t/qS_t
C_{N_w}	wing normal-force coefficient, $2L_w/qS$ (one wing)
c	chord at any section along span, ft
$\bar{c}$	mean aerodynamic chord, ft
F_e	elevator stick force (pull is positive), lb
g	acceleration due to gravity, ft/sec^2
h_p	pressure altitude, ft
i_t	horizontal-tail angle of incidence, deg
L_t	aerodynamic horizontal-tail load (up tail load positive), lb
L_w	aerodynamic load on one wing (up load positive), lb
M	Mach number
n	airplane normal acceleration, g units
q	dynamic pressure, $\rho V^2/2$, lb/sq ft

S area of wing bounded by leading edge and trailing edge, both extended to airplane line of symmetry and disregarding fillets, $2\int_0^{b/2} c\,dy$, sq ft

S_t area of horizontal tail, sq ft

t time, sec

V free-stream velocity, ft/sec

W airplane gross weight, lb

y lateral distance, ft

α airplane angle of attack, deg

δ_e elevator deflection (down is positive), deg

$\dot{\theta}$ pitching velocity, radians/sec

ρ mass density of air, slugs/cu ft

DESCRIPTION OF THE AIRPLANE

The Bell X-5 research airplane is a single-place, midwing, turbojet-powered airplane on which the sweepback may be varied in flight between 20° and 59°. The data presented in this paper were obtained at a constant sweepback of 59°. The physical characteristics are presented as table I and a three-view drawing at 59° sweepback is shown in figure 1. In this drawing the right wing is shown in the modified condition and the left wing in the original configuration. Figure 2 is a photograph of the airplane at 59° sweepback. A photograph of the original and the modified fillets and a drawing of the two fillets with pertinent dimensions are presented as figures 3 and 4, respectively.

The wing chord parallel to the airplane center line and passing through the wing pivot point (27.72 inches from the plane of symmetry) was decreased 18.85 inches by the modification, with a reduction of 1.37 square feet in the total wing area outboard of this point. The airfoil thickness at the section through the pivot point was increased from 6.94 to 8.27 percent chord by the modification.

INSTRUMENTATION AND ACCURACY

During the tests reported in this paper standard NACA recording instruments were used to measure the following:

Airspeed
Altitude
Normal, longitudinal, and transverse accelerations
Elevator stick force
Pitching angular velocity and acceleration
Yawing angular velocity and acceleration
Rolling angular velocity
Control positions
Sweepback
Horizontal-tail shear and bending moment
Wing shear and bending moment

The estimated errors are as follows:

Mach number	±0.01
Airplane normal-force coefficient	±0.02
Normal acceleration, g	±0.02
Measured tail loads, lb	±75
Measured wing loads, lb	±100
Airplane weight determination, lb	±100

TESTS, RESULTS, AND DISCUSSION

The original and modified wing-root configurations are compared in this paper on the basis of results obtained from stabilizer and elevator maneuvers into the region of reduced stability for both configurations. The tests were made at pressure altitudes from 28,000 to 40,000 feet and ranged in Mach number from that for the approach to an unaccelerated clean stall to a Mach number of 0.97. Figure 5 presents the boundary for the reduction of longitudinal stability through the Mach number range from 0.65 to 0.98 as presented in reference 2 but with points obtained with the modified configuration noted also. Figures 6 to 8 present typical plots of the variation of several parameters with angle of attack from which the points in figure 5 were ascertained. These particular figures are for stall approach, for $M = 0.84$, and for $M = 0.97$, respectively. The point of stability reduction is determined, primarily, from the variation of control deflection with angle of attack and corresponds to the point at which this variation abruptly changes to essentially zero. It may be noted that for several maneuvers this point is not readily apparent, particularly in figure 6. Consequently, the points selected from figures 7 and 8 for inclusion in figure 5 are indicated. The comparison of the points for the modified and unmodified configurations in figure 5 indicate that there was no appreciable effect of the modification.

It is the opinion of the pilot who performed the flight tests that, in general agreement with figure 5, the modified fillets caused little apparent difference in the longitudinal stability characteristics. He did feel, however, that the reduction of stability seemed to occur at a slightly higher C_{N_A} for the modified fillets at Mach numbers near 0.94.

It may be observed in figures 6 to 8 that the maximum C_{N_A} obtained is about 0.1 lower at each of the three Mach numbers for the modified configuration than for the original configuration and the angle of attack for maximum C_{N_A} was from 2.6° to 4.95° lower for the modified wing root than for the original. The lower C_{N_A} and consequent lower angle of attack for the modified configuration can be attributed to the reduced pitching parameter $\frac{\bar{c}}{V}\frac{d\alpha}{dt}$ for the modified wing root due to decreased control deflection. Both maximum C_{N_A} and the angle of attack at which it occurred showed a tendency to decrease with increasing Mach number for the two configurations.

The variation of C_{N_t} with C_{N_A} for both configurations at each of the test Mach numbers is shown in figure 9. The values of the slope of C_{N_t} plotted against C_{N_A} as obtained from figure 9(a) show that the static longitudinal stability of the wing-fuselage combination is considerably different for both configurations in the approach to a clean stall. The slope dC_{N_t}/dC_{N_A} has a value of -0.215 for the original fillets and -0.30 for the modified fillets at lift coefficients below 0.45. For lift coefficients from 0.50 to 0.75 for the original wing root, dC_{N_t}/dC_{N_A} is equal to 0.195, whereas for the modified wing root, it is equal to 0.13.

For Mach numbers of 0.84 and 0.97 it may be observed from figures 9(b) and 9(c) that the variation of tail normal-force coefficient with airplane normal-force coefficient is similar for the original and modified configurations. The point of instability at $M = 0.84$ is at about the same lift as it is for the stall approach, whereas at $M = 0.97$, it occurs at a lower C_{N_A} for both configurations.

The scatter of data points apparent in figure 9(b) above C_{N_A} of 0.6 and in figure 9(c) above C_{N_A} of 0.5 is caused by the high pitching rates resulting from the reduction of longitudinal stability. Although the data have been corrected for pitching acceleration in these regions, the accuracy of these data is reduced.

Figure 10 presents wing normal-force coefficient as a function of airplane normal-force coefficient for both configurations at the test Mach numbers. It may be observed in figure 10 that the variation of wing normal-force coefficient with airplane normal-force coefficient is essentially the same at Mach numbers of 0.84 and 0.97. In the stall approach, however, there is a difference of 0.086 in the slope of the curve of C_{N_W} against C_{N_A} for the two configurations, with the modified wing-root configuration having the steeper slope, an indication that in this condition the wing carries a greater part of the airplane load.

Figure 11 presents the variations of wing pitching-moment coefficient with C_{N_A} for both wing-root configurations. It may be seen from this figure that at Mach numbers of 0.84 and 0.97 the wing pitching-moment coefficient is unaffected by the fillet modification. However, in the approach to a clean stall the modified configuration exhibits slightly greater stability, the slope $dC_{m_{\bar{c}/4}}/dC_{N_A}$ being equal to -0.22 for the original fillets and -0.29 for the modified fillets.

The drag polars for the two configurations are shown in figure 12. In the three polars there are only slight variations of drag coefficient with lift coefficient due to the wing-root modification.

Figure 13 presents sections of records from the three-component recording accelerometer which may be utilized to compare buffet intensities. The buffet intensity is directly proportional to the amplitude of the normal acceleration trace. For each of the test Mach numbers little, if any, difference can be observed between the buffet intensity of the original and modified wing-root configurations.

CONCLUDING REMARKS

A comparison has been made between two configurations of the Bell X-5 research airplane at 59° sweepback, one with the original wing-root fillets and the other with wing-root fillets shown by low-speed wind-tunnel investigation to eliminate the loss of stability at high lift coefficients. The data obtained from the flight investigation, however, show that the longitudinal stability characteristics, as well as the buffet and drag characteristics, were essentially unaffected by the modification.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 13, 1953.

REFERENCES

1. Kemp, William B., Jr.: An Investigation of the Low-Speed Longitudinal Stability Characteristics of a Swept-Wing Airplane Model With Two Modifications to the Wing-Root Plan Form. NACA RM L52E07, 1952.

2. Finch, Thomas W., and Walker, Joseph A.: Static Longitudinal Stability of the Bell X-5 Research Airplane With 59° Sweepback. NACA RM L53A09b, 1953.

TABLE I

PHYSICAL CHARACTERISTICS OF BELL X-5 AIRPLANE

Airplane:	
Weight, lb:	
Full fuel	9960
Less fuel	7850
Power plant:	
Axial-flow turbojet engine	J-35-A-17
Guaranteed rated thrust at 7800 rpm and static sea-level conditions, lb	4900
Center-of-gravity position, percent $\bar{c}$:	
Full fuel	45.6
Less fuel	46.2
Moments of inertia for 59° sweep (clean configuration, full fuel), slug-ft^2:	
About Y-axis	9495
About Z-axis	8040
Over-all height, ft	12.2
Over-all length, ft	33.6
Wing:	
Airfoil section (perpendicular to 38.02-percent-chord line):	
Pivot point	NACA $64_{(10)}$A011
Tip	NACA $64_{(08)}$A008.28
Sweep angle at 0.25 chord, deg	59
Area, sq ft	184.3
Span, ft	20.0
Span between equivalent tips, ft	19.2
Aspect ratio	2.16
Taper ratio	0.4095
Mean aerodynamic chord, ft	10.05
Location of leading edge of mean aerodynamic chord, fuselage station	100.2
Incidence root chord, deg	0
Dihedral, deg	0
Geometric twist, deg	0
Wing flaps (split):	
Area, sq ft	15.9
Span, parallel to hinge center line, ft	6.53
Chord, parallel to line of symmetry at 20° sweepback, in.:	
Root	30.8
Tip	19.2

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TABLE I.- Continued

PHYSICAL CHARACTERISTICS OF BELL X-5 AIRPLANE

Travel, deg	60
Slats (leading edge divided):	
Area, sq ft	14.6
Span, parallel to leading edge, ft	10.3
Chord, perpendicular to leading edge, in.:	
Root	11.1
Tip	6.6
Travel, percent wing chord:	
Forward	10
Down	5
Aileron (45 percent internal-seal pressure balance):	
Area (each aileron behind hinge line), sq ft	3.62
Span parallel to hinge center line, ft	5.15
Travel, deg	±15
Chord, percent wing chord	19.7
Moment area rearward of hinge line (total), in.^{3}	4380
Horizontal tail:	
Airfoil section (parallel to fuselage center line)	NACA 65A006
Area, sq ft	31.5
Span, ft	9.56
Aspect ratio	2.9
Sweep angle at 0.25 chord, deg	45
Mean aerodynamic chord, in.	42.8
Position of 0.25 mean aerodynamic chord, fuselage station	355.6
Stabilizer travel, (power actuated), deg:	
Leading edge up	4.5
Leading edge down	7.5
Elevator (20.8 percent overhang balance, 31.5 percent span):	
Area rearward of hinge line, sq ft	6.9
Travel from stabilizer, deg:	
Up	25
Down	20
Chord, percent horizontal-tail chord	30
Moment area rearward of hinge line (total), in.^{3}	4200
Vertical tail:	
Airfoil section (parallel to rear fuselage center line)	NACA 65A006
Area, sq ft	29.5

TABLE I.- Concluded

PHYSICAL CHARACTERISTICS OF BELL X-5 AIRPLANE

Span, perpendicular to rear fuselage center line, ft	6.25
Aspect ratio	1.32
Sweep angle of leading edge, deg	43
Fin:	
Area, sq ft	24.8
Rudder (23.1 percent overhang balance, 26.3 percent span):	
Area rearward of hinge line, sq ft	4.7
Span, ft	4.43
Travel, deg	±35
Chord, percent horizontal-tail chord	22.7
Moment area rearward of hinge line, $in.^3$	3585

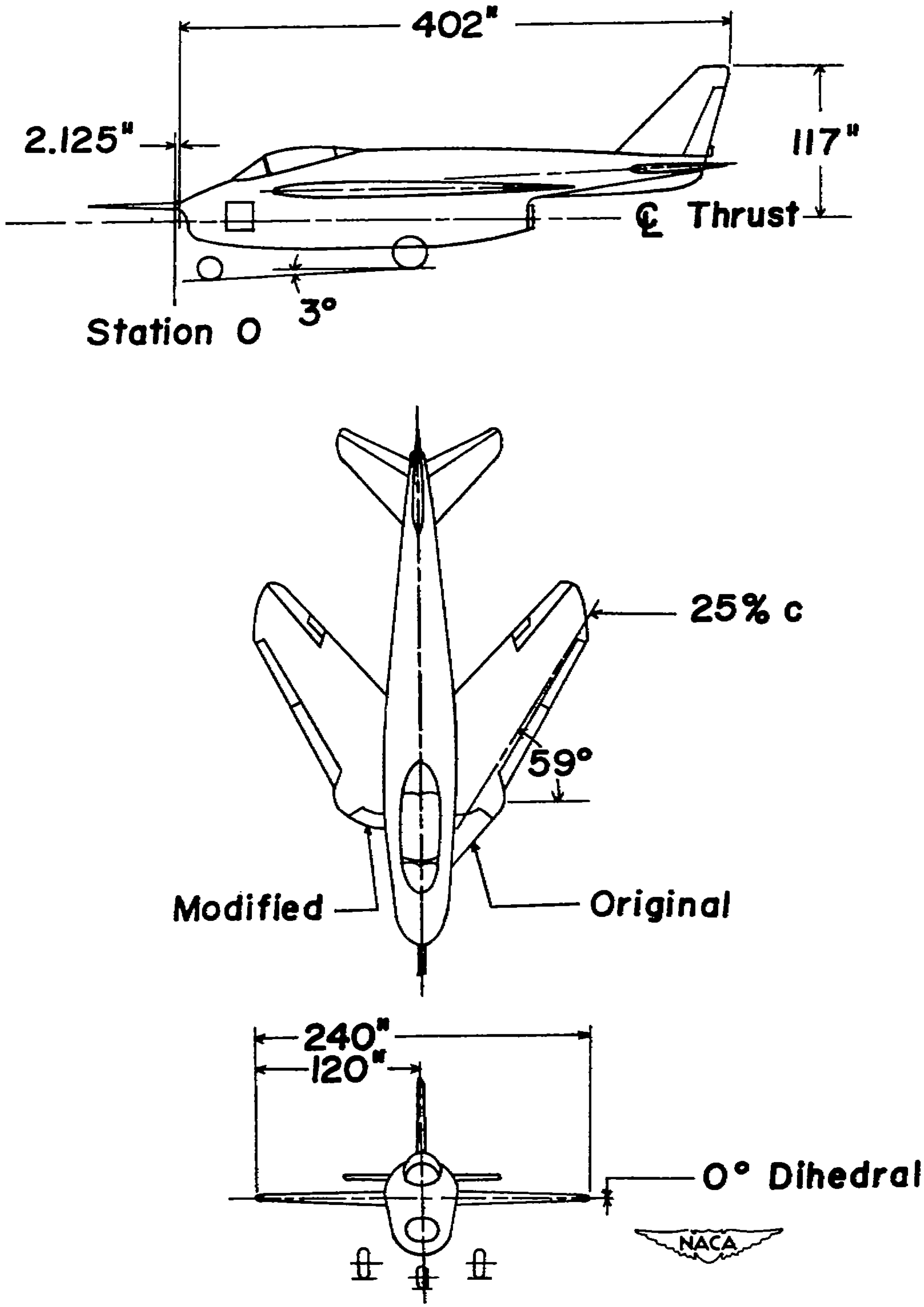

Figure 1.- Three-view drawing of original and modified configurations at 59° sweepback. (Right wing modified, left wing original.)

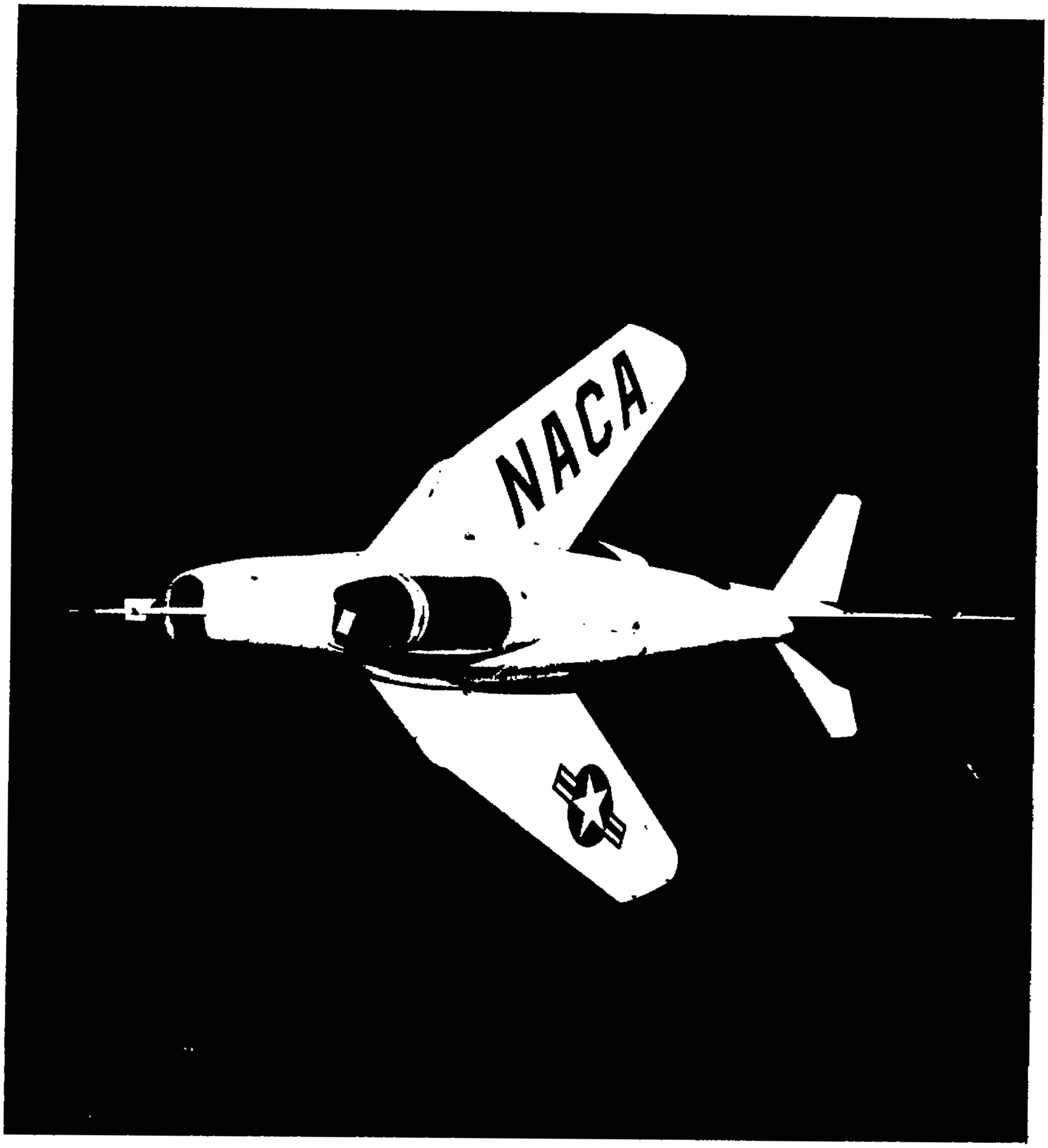

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Figure 2.- Photograph of Bell X-5 research airplane at 59° sweepback.

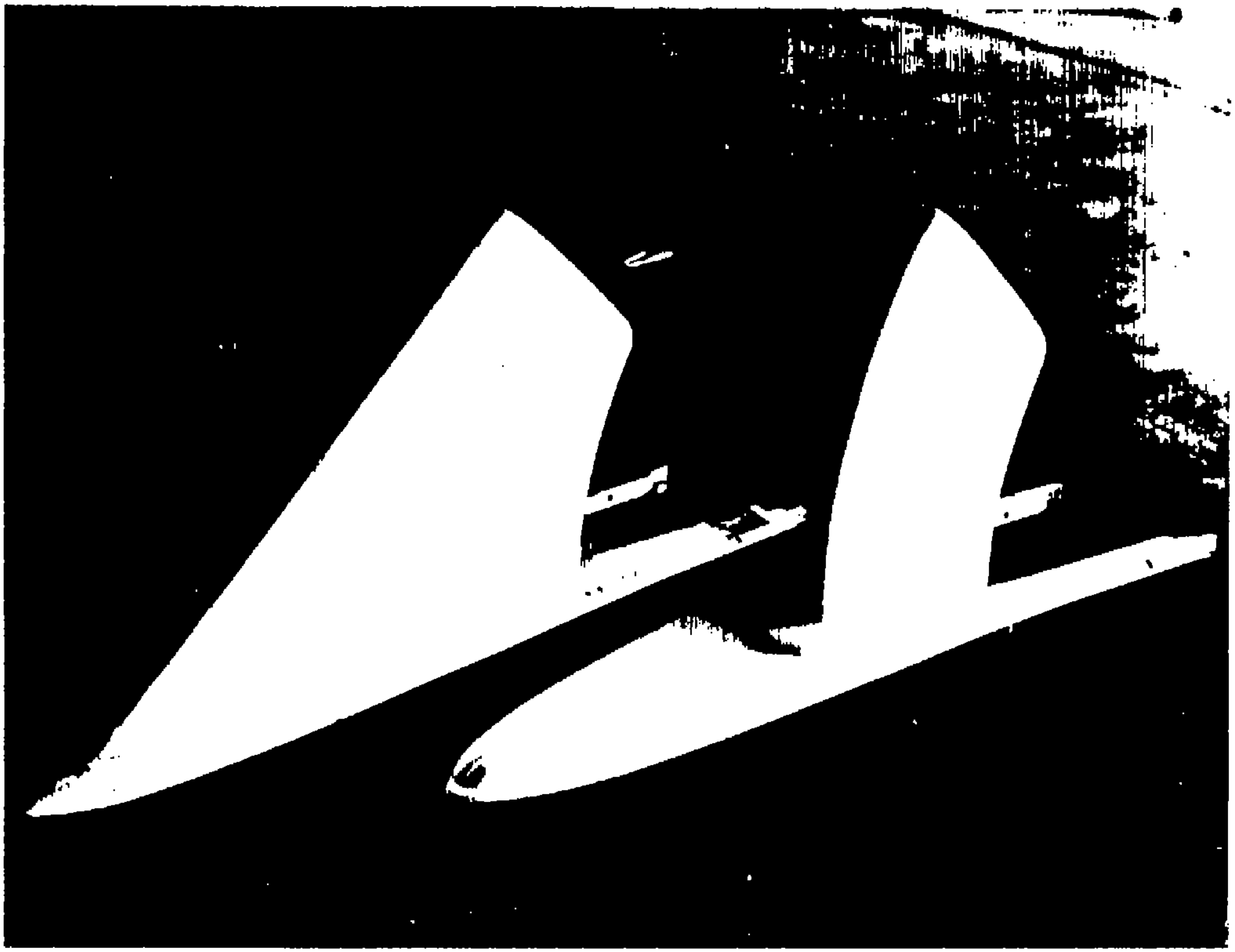

Figure 3.- Photograph of original and modified fillets.

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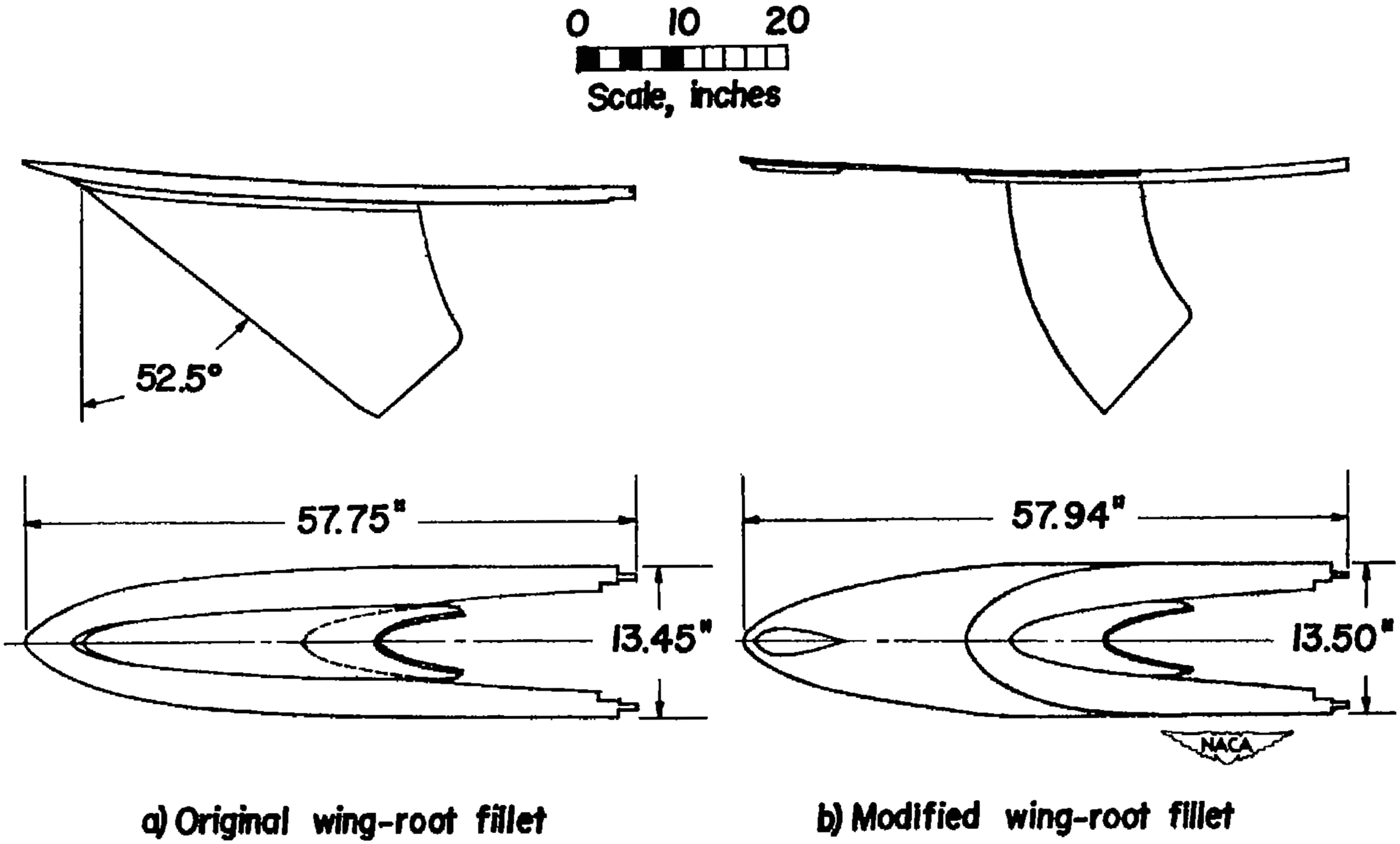

Figure 4.- Two-view drawing of original and modified wing-root fillets.

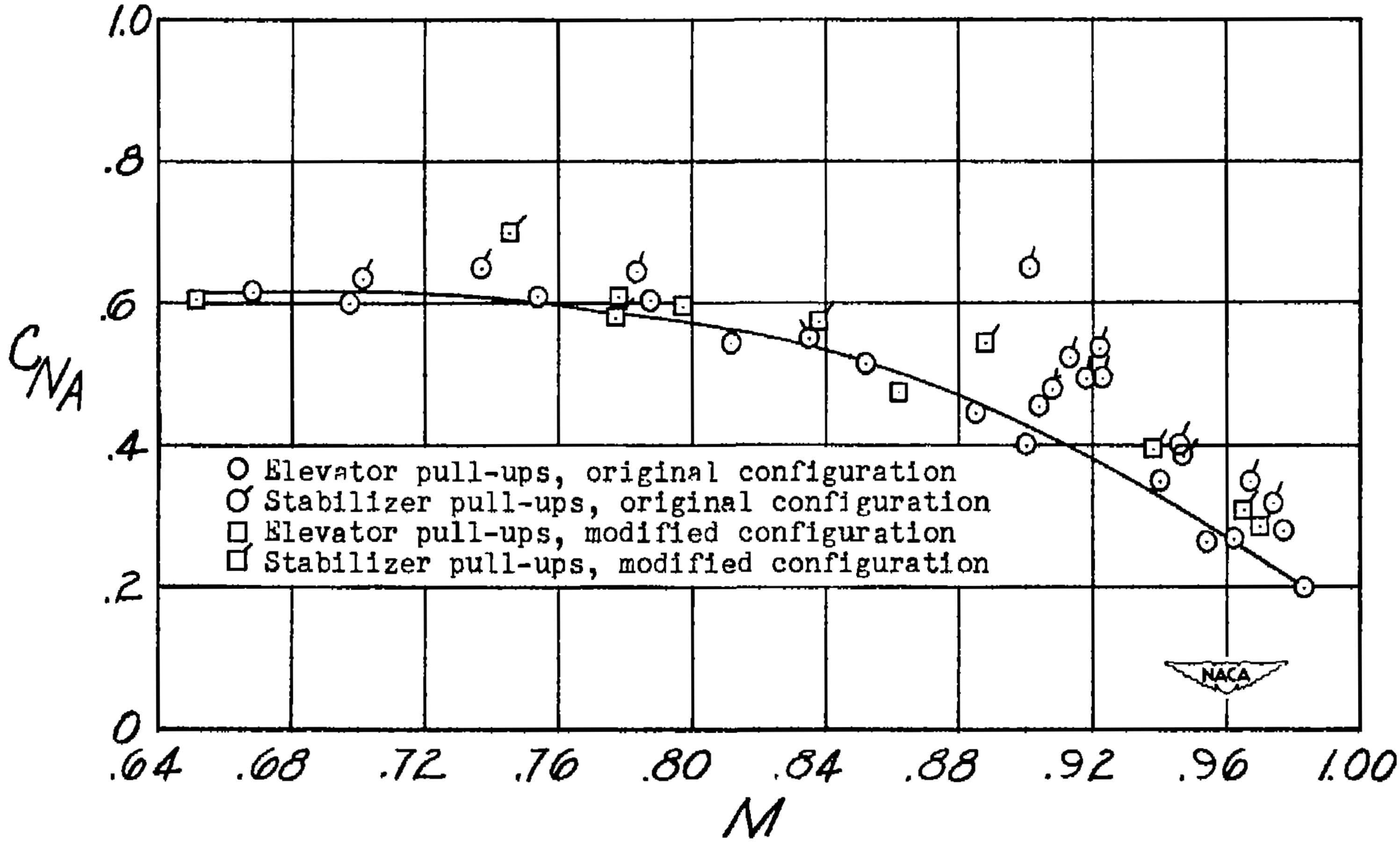

Figure 5.- Boundary for the reduction of longitudinal stability of the Bell X-5 research airplane at 59° sweepback, showing points for original and modified fillet configurations.

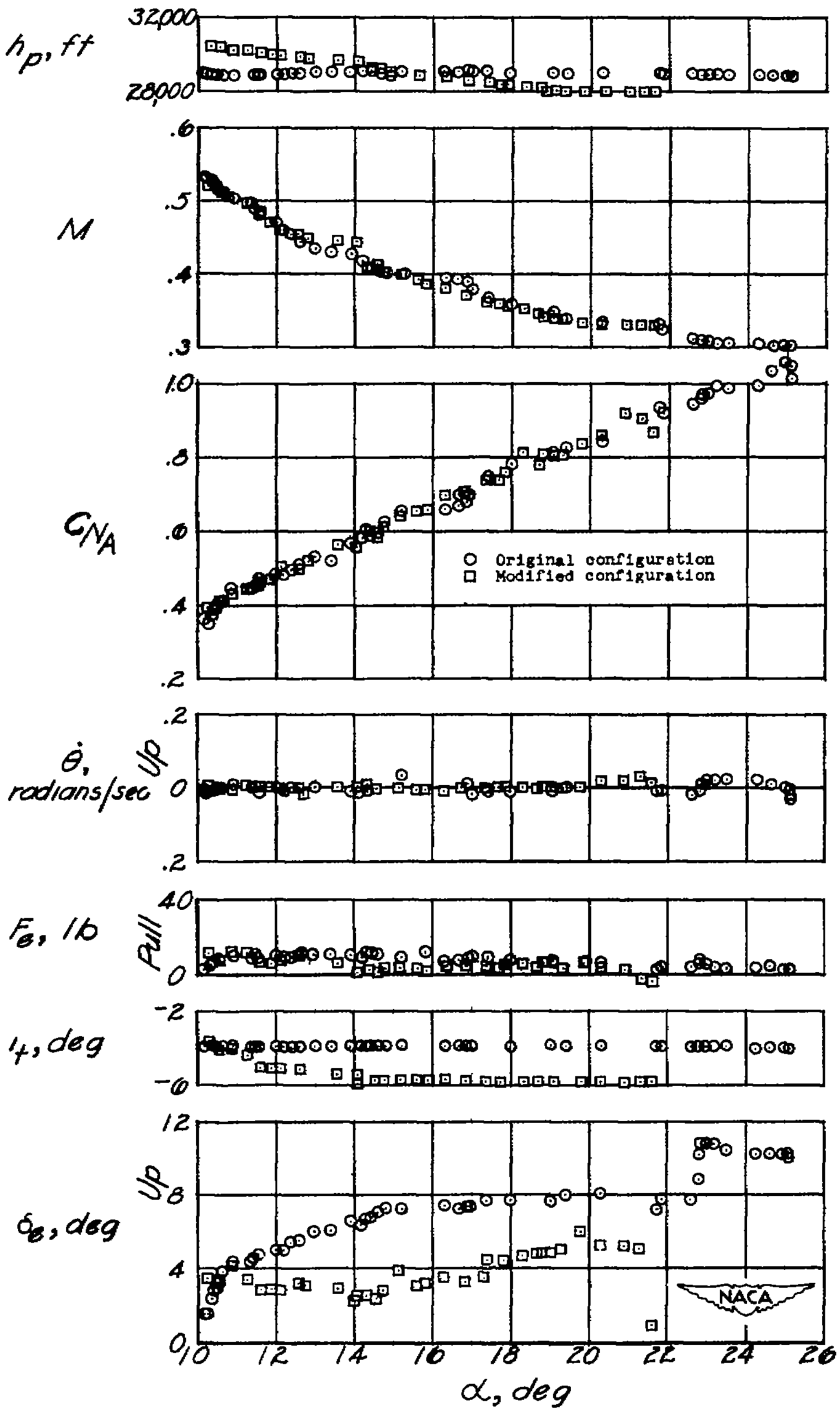

Figure 6.- Approach to an unaccelerated clean stall for the two fillet configurations.

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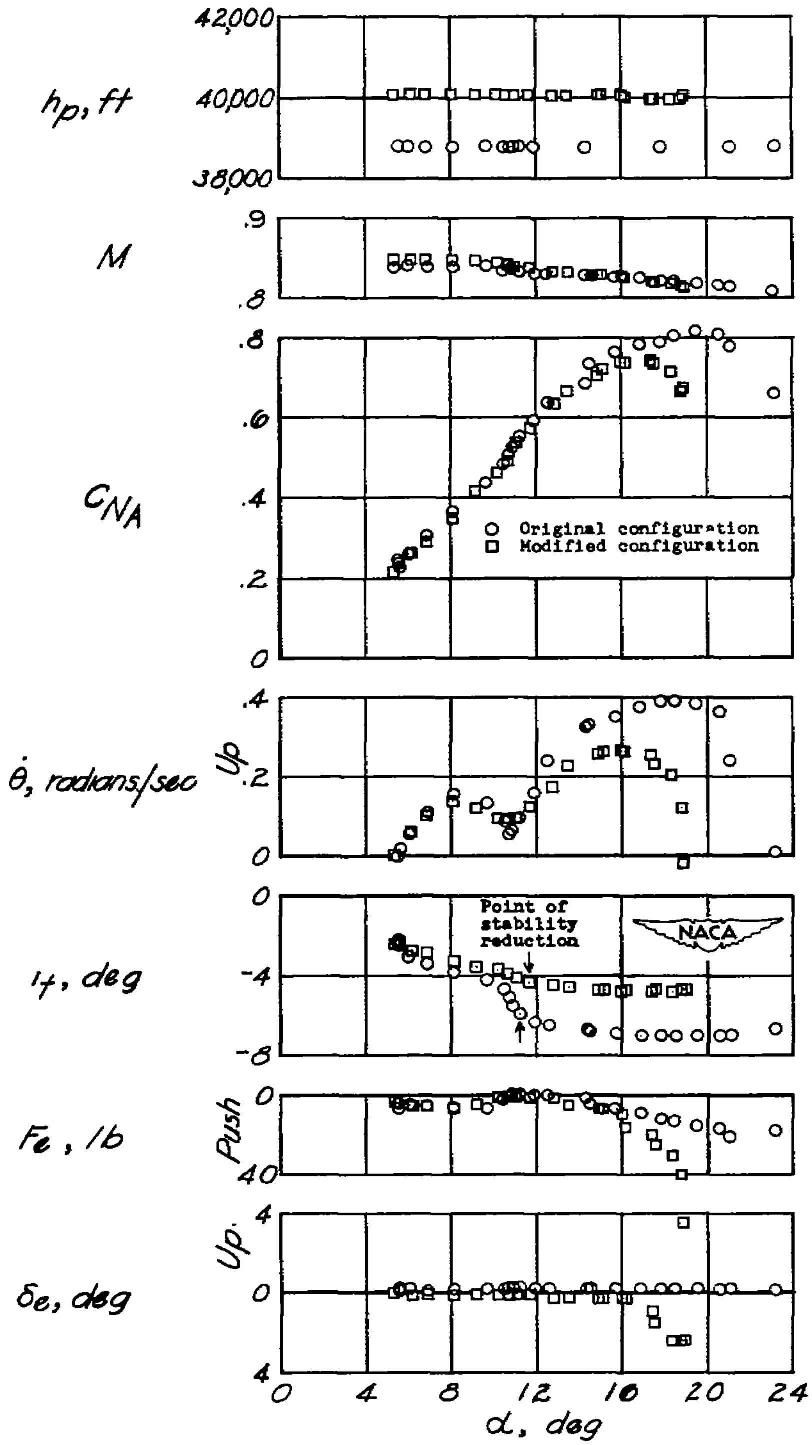


Figure 7.- Stabilizer pull-ups to the stall for the two fillet configurations at a Mach number of approximately 0.84.

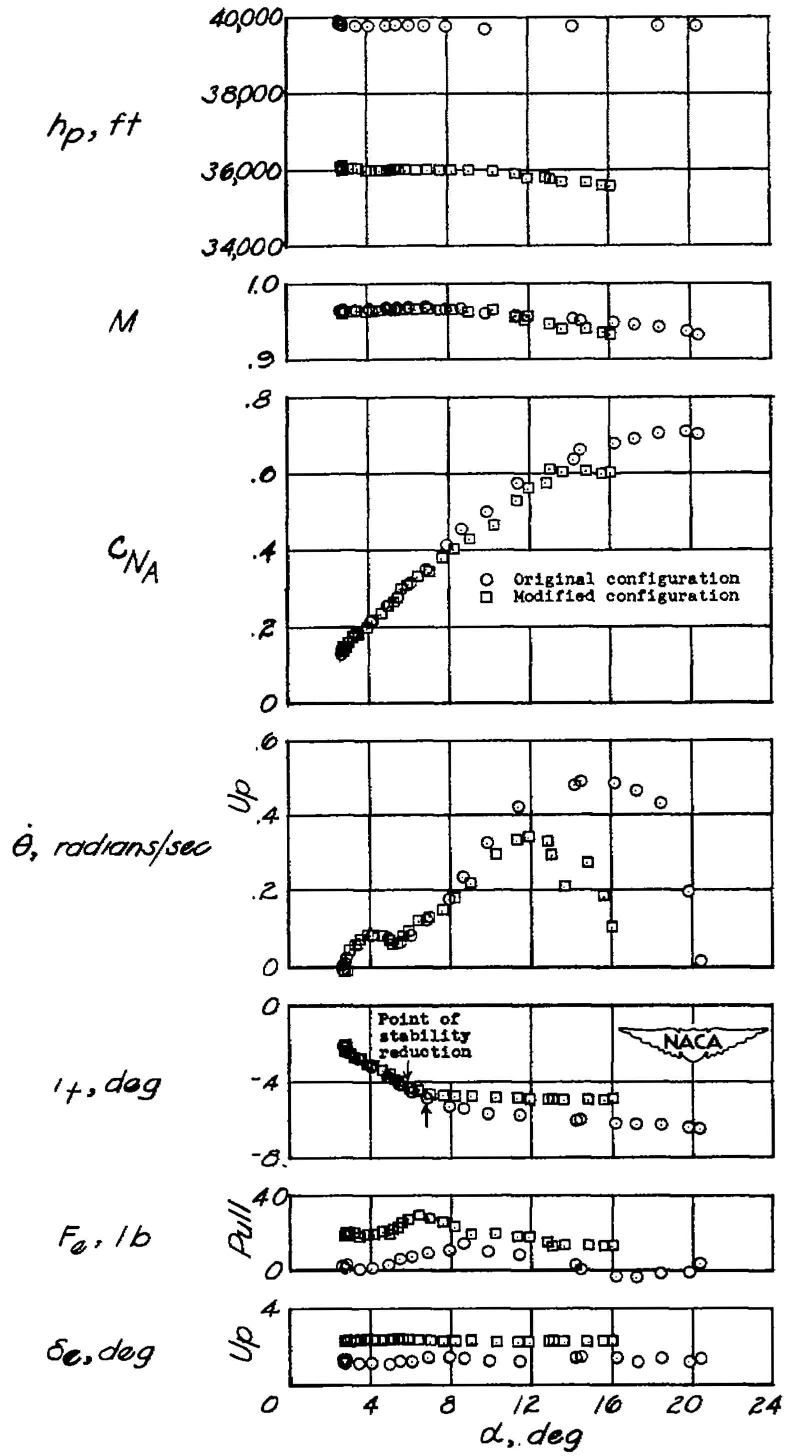
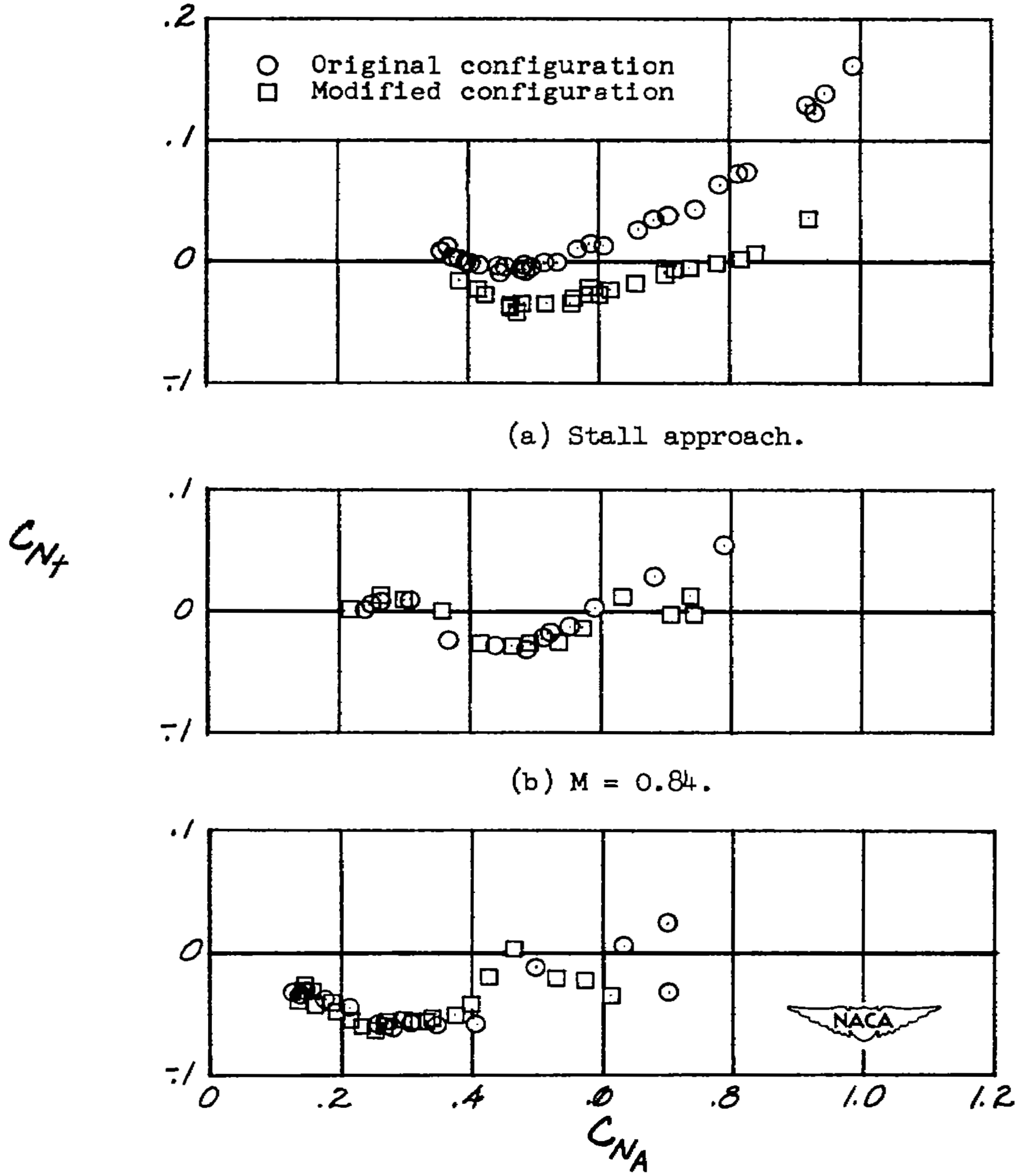


Figure 8.- Stabilizer pull-ups to the stall for the two fillet configurations at a Mach number of approximately 0.97.

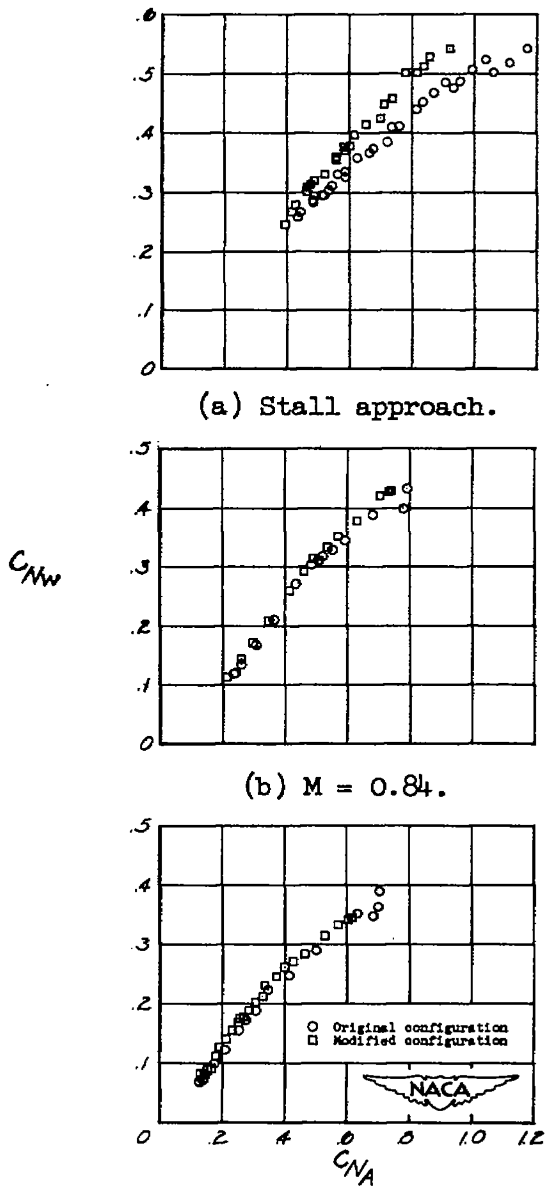


(a) Stall approach.

(b) M = 0.84.

(c) M = 0.97.

Figure 9.- Variation of tail normal-force coefficient with airplane normal-force coefficient for the two fillet configurations at the test Mach numbers.

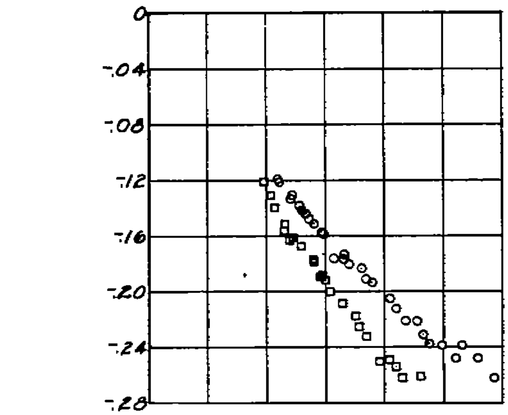


(a) Stall approach.

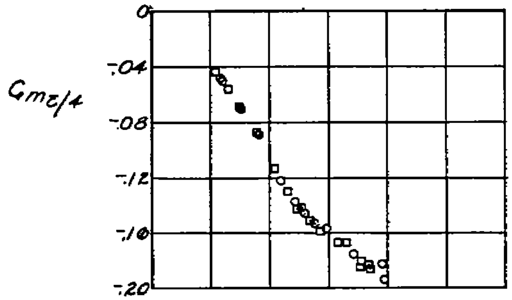
(b) M = 0.84.

(c) M = 0.97.

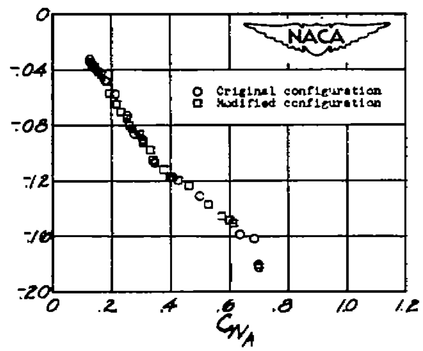
Figure 10.- Variation of wing normal-force coefficient with airplane normal-force coefficient for the two fillet configurations at the test Mach numbers.



(a) Stall approach.



(b) M = 0.84.



(c) M = 0.97.

Figure 11.- Variation of wing pitching-moment coefficient with airplane normal-force coefficient (for one wing outboard of wing-sweep pivot point) for the two fillet configurations at the test Mach numbers.

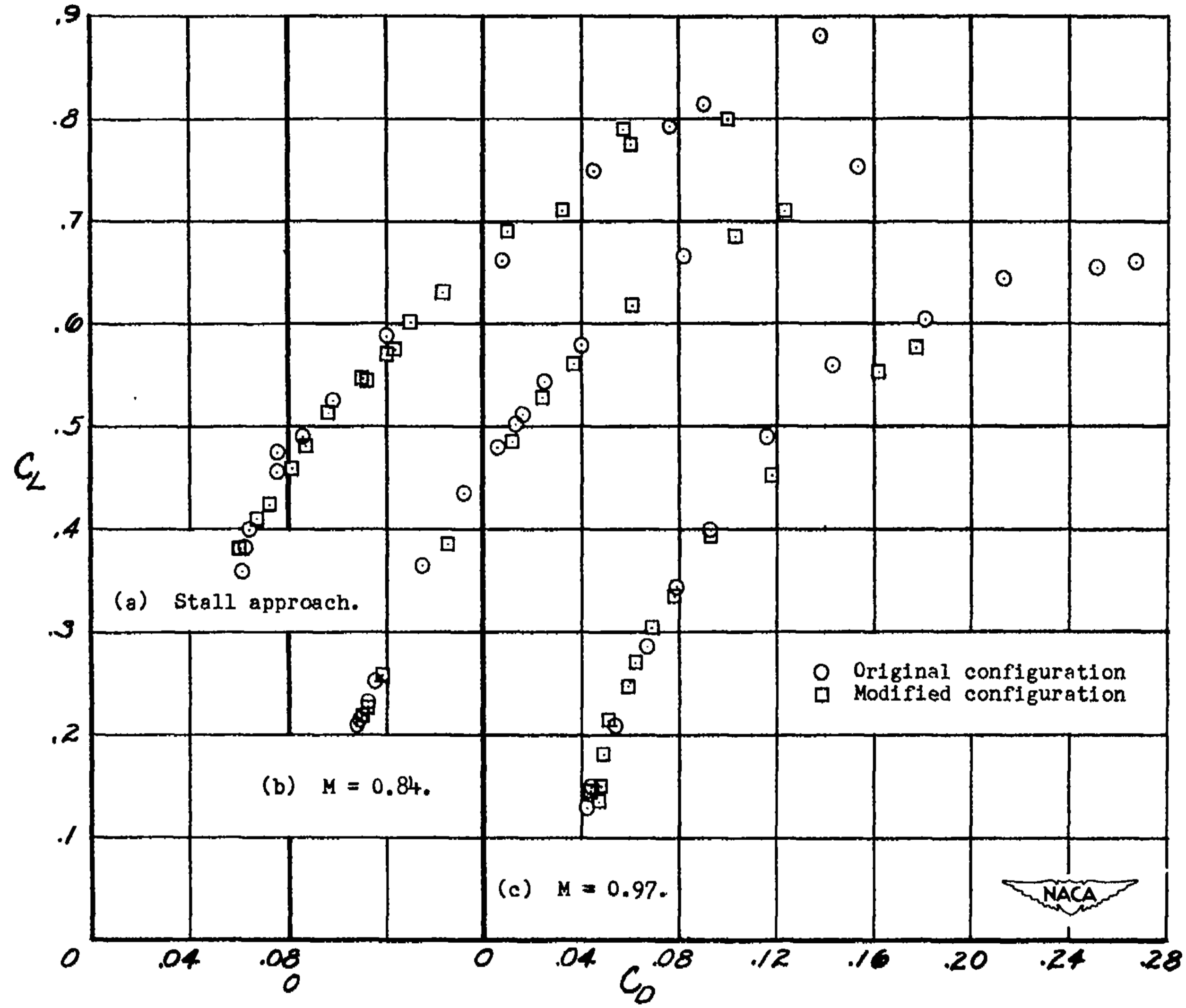
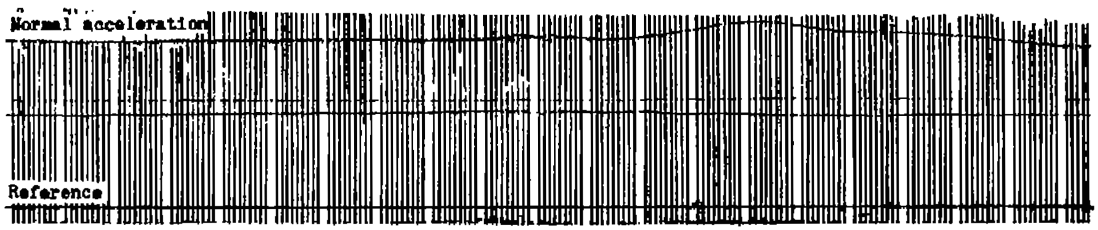
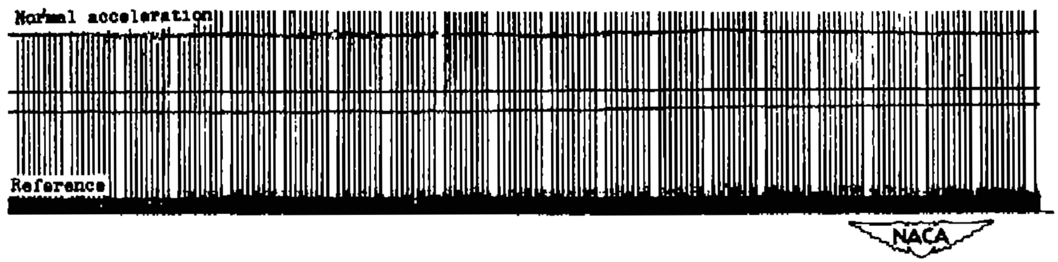


Figure 12.- Airplane polars for the two fillet configurations at the test Mach numbers.

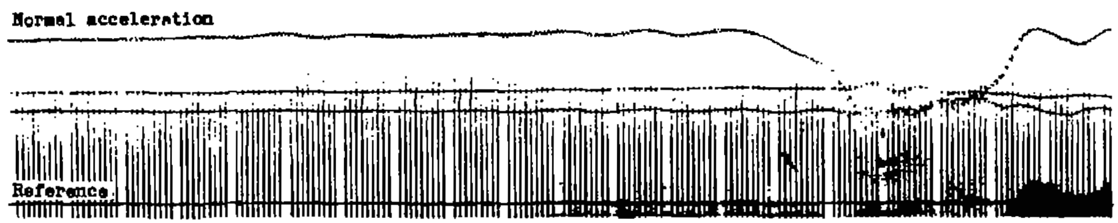


(a) Stall approach, original configuration.

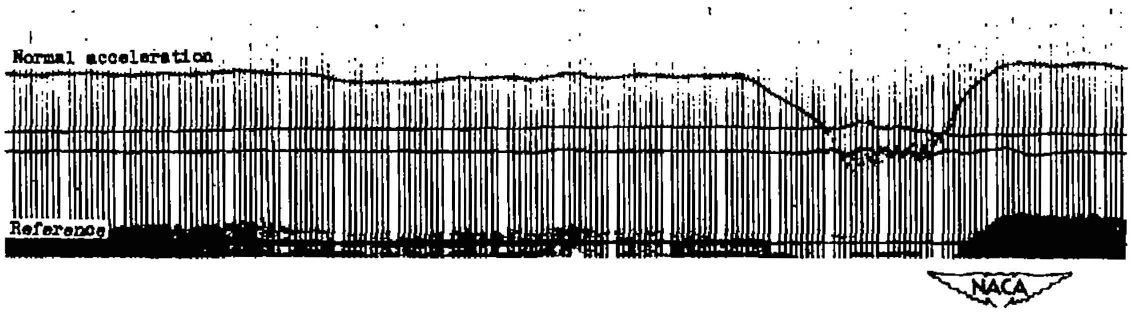


(b) Stall approach, modified configuration.

Figure 13.- Portions of NACA accelerometer records for the two fillet configurations at the test Mach numbers.



(c) M = 0.84, original configuration.



(d) M = 0.84, modified configuration.

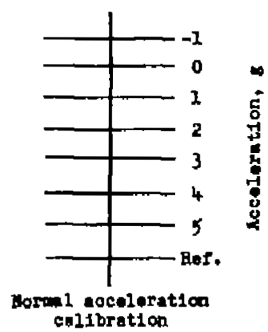
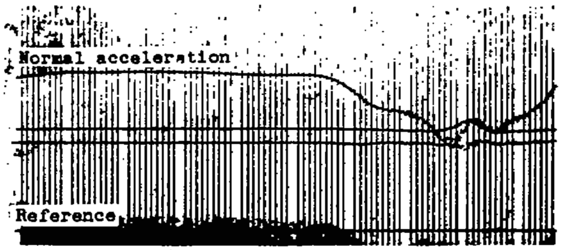
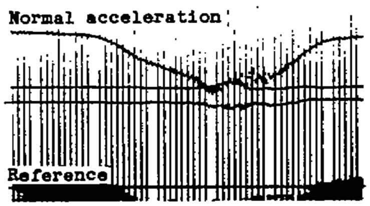


Figure 13.- Continued.



(e) M = 0.97, original configuration.



(f) M = 0.97, modified configuration.

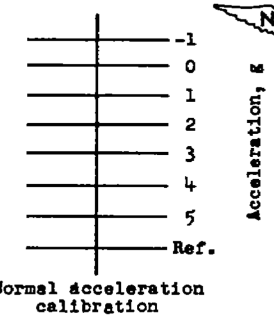


Figure 13.- Concluded.

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