

RESEARCH MEMORANDUM

AN INVESTIGATION OF THE CONTROL EFFECTIVENESS OF TIP
AILERONS AND SPOILERS ON A LOW-ASPECT-RATIO
TRAPEZOIDAL-WING AIRPLANE MODEL AT
MACH NUMBERS FROM 1.55 TO 2.35

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SUMMARY

A wind-tunnel investigation has been made of three types of lateral control devices on a low-aspect-ratio trapezoidal wing. Tip ailerons, a plain spoiler, and a vented spoiler were investigated to ascertain the relative characteristics of each system. The tests were conducted at Mach numbers of 1.55, 1.90, and 2.35 and at a Reynolds number of approximately 1.4×10^6 .

The results indicated the superiority in roll power of the tip ailerons over the plain and vented spoilers. With tip ailerons alone, the roll capability was adequate to satisfy the military specification requirement. At 25° deflection, the roll effectiveness of the vented spoiler was more than three times that of the plain spoiler but was sufficient to meet the specifications only at $M = 2.35$.

INTRODUCTION

The loss of effectiveness at high angles of attack and an inherent nonlinear variation of effectiveness with deflection, particularly at low speed, are characteristics of the plain flap type spoiler. In order to alleviate this situation, several means have been utilized. One method of improving the effectiveness is to combine with the spoiler a slot through the wing and a deflector installed on the lower surface of the wing, as presented in references 1 and 2. In addition, relatively low hinge moments can be obtained with the proper projections of the upper-surface spoiler and the lower-surface deflector. Another means of obtaining greater lateral control than is possible with plain spoilers is by the use of all-movable tip ailerons. Inasmuch as the moment of the control forces about a given axis is approximately proportional to the control-area moment about that axis, the tip aileron with its large

lever arm about the roll axis can be expected to be very effective as a roll control. Furthermore, the hinge-moment characteristics can be readily controlled by proper location of the hinge line to balance the forces on the control.

In order to provide a comparison of the effectiveness of plain spoilers, spoiler-slot-deflectors (hereafter referred to as vented spoilers), and all-movable tip ailerons on a trapezoidal wing, an investigation was conducted in the 9- by 7-foot test section of the Ames Unitary Plan wind tunnel. Information regarding this wind tunnel is presented in reference 3. The results are presented and discussed herein.

COEFFICIENTS AND SYMBOLS

The system of axes and positive direction of forces, moments, and angles are presented in figure 1, which shows the coefficients, C_L , C_D , C_m , C_l , C_y , and C_n , referred to the stability axes. The moment center was located at the quarter chord of the wing mean aerodynamic chord. The coefficient C_D was based on the balance drag only (not corrected for base pressure), since the internal drag due to the air flow in the ducts was not measured.

The sign convention of aileron deflection is designated in figure 1; that is, for either left or right aileron, positive direction is defined as trailing edge down.

The following coefficients and symbols are used in this report:

b	wing span, ft
c	wing chord, ft
$\bar{c}$	wing mean aerodynamic chord, ft
C_L	lift coefficient, $\frac{\text{lift}}{qS}$
C_D	drag coefficient, $\frac{\text{drag}}{qS}$
C_m	pitching-moment coefficient, $\frac{\text{pitching moment}}{qS\bar{c}}$
C_l	rolling-moment coefficient, $\frac{\text{rolling moment}}{qSb}$
C_y	side-force coefficient, $\frac{\text{side force}}{qS}$
C_n	yawing-moment coefficient, $\frac{\text{yawing moment}}{qSb}$

$C_{l_{\delta_{tot}}}$	aileron effectiveness for two tip ailerons, rate of change of rolling-moment coefficient with total aileron deflection, per deg
C_{l_p}	rate of change of rolling-moment coefficient with $\frac{pb}{2V}$, per radian
M	Mach number
$\frac{pb}{2V}$	helix angle generated by the wing tip in roll, radians
p	angular velocity in roll, radians/sec
q	free-stream dynamic pressure, lb/sq ft
R	Reynolds number per ft
S	total wing area (projected), sq ft
V	free-stream velocity, ft/sec
α	angle of attack of wing reference chord, deg
β	angle of sideslip of fuselage reference axis, deg
δ	individual tip aileron deflection, positive leading edge upward, deg (Subscripts L and R are used for left and right, respectively.)
δ_{tot}	total tip aileron deflection, $\delta_L - \delta_R$, deg (left and right aileron deflections equal and opposite from an offset neutral position)
δ_s	spoiler deflection, deg
Δ	increment resulting from control deflection

MODEL AND APPARATUS

The model (figs. 2, 3, and 4) consisted of a low-aspect-ratio wing located above the fuselage center line, a "T" tail, and two nacelles, one on each side of the fuselage under the wing-fuselage junction. The wing had a 3.5-percent-thick biconvex airfoil section, an aspect ratio of 3.2, a taper ratio of 0.4, and a leading-edge sweepback of 25.75° . Drawings and details of the model are shown in figures 5, 6, and 7. The geometric characteristics are presented in table I.

Three types of lateral control systems were tested - tip ailerons, plain spoiler, and vented spoiler. Tip ailerons were located on both the left and right wing tips and could be deflected 10° , 20° , or 30° in either direction. For this control configuration, outrigger housings were located inboard of the tip ailerons as shown in figure 3. The plain spoiler was installed on the upper surface of the left wing panel only. This control was investigated at 25° and 50° deflection, which is equivalent to vertical projections from the upper wing surface of approximately 0.03c and 0.06c, respectively. A detail of the combination of 25° plain spoiler and -20° left tip aileron deflections is shown in figure 3. The vented spoiler configuration, installed on the left wing only, consisted of a spoiler mounted on the upper surface of the wing, a slot through the wing, and a deflector installed on the lower surface. Both spoiler and deflector were set at 25° (the only deflection tested), which is equivalent to projections of 0.06c and 0.04c, respectively. With this control device, the outrigger housings were moved outboard to the wing tips and reduced in length (fig. 4). In order to study the effect of air flow through the vented area in the wing, two blockages (17- and 29-percent) were investigated. Blockage was defined as the ratio (in percent) of the blocked area to the total area of the slot. Zero blockage was not possible because of the 0.37-inch-thick chordwise supporting ribs.

PROCEDURE

During the investigation, test data for all configurations were obtained by varying the angle of attack from -3° to 15° at $\beta \approx 0^\circ$. Two of the configurations, complete model and model with -10° left tip aileron, were also investigated through a range of sideslip angles from -3° to 9° at angles of attack of 2° , 5° , and 9° . The Mach numbers were 1.55, 1.90, and 2.35 and the Reynolds number was approximately 1.4×10^6 , based on the wing mean aerodynamic chord.

To obtain the aileron effectiveness, the left tip aileron was deflected from 20° to -30° at increments of 10° . Tests were also run with ailerons deflected differentially from an offset neutral position as shown in the table below.

δ_L , deg	δ_R , deg	δ_{tot} , deg	Offset neutral position, deg	Differential deflection from neutral position, deg
-10	-10	0	-10	0
-20	-10	-10	-15	5
-20	10	-30	-5	15

The two attitudes of the plain spoiler investigated were 25° and 50° deflection. Also investigated was the combination of -20° deflection of the left tip aileron and 25° deflection of the plain spoiler.

The vented spoiler control was deflected only at 25° ; the deflector was set at the same angle. Vent blockages of 17 and 29 percent were investigated.

Tip aileron deflections of 0° and 10° (left aileron) were also run with both horizontal and vertical tails removed in order to evaluate possible interference effects of the flow field in the region of the tail.

The precision of the data is indicated by the last significant figure to which the data are tabulated.

RESULTS AND DISCUSSION

The six-component wind-tunnel data are tabulated in coefficient form in table II. Since the investigation was concerned primarily with lateral control, only the rolling-moment and yawing-moment data of table II have been presented in graphical forms. These summary graphs will be utilized in the following presentation of the control characteristics.

Tip Ailerons

Rolling power.— The variation of incremental rolling-moment coefficient with aileron deflection at various angles of attack is presented in figures 8 and 9. Included are data obtained with ailerons deflected individually and with ailerons differentially deflected from an offset neutral position.¹ In general, aileron effectiveness increased with increasing angle of attack. This effect was substantial at $M = 1.55$, but was less pronounced at $M = 1.90$ and 2.35 . The differential deflection data of figure 9 indicated approximately the same unit effectiveness as that obtained with individual aileron. Based on figure 8, the variation with Mach number of aileron effectiveness for two ailerons deflected differentially from zero neutral position is presented in figure 10. The values of $C_{l_{\delta_{tot}}}$ for the angle-of-attack range indicated were taken as average slopes over the range of aileron angles tested. A decrease in effectiveness with increasing Mach number is evident.

¹Deflecting ailerons differentially from an offset neutral position is envisioned as a means of decreasing local angles of attack at the ailerons when the wing angle of attack is large, thereby maintaining aileron effectiveness.

The test results (table II) obtained with both horizontal and vertical tail surfaces removed indicated nearly the same incremental rolling moments due to aileron deflection as those obtained with the complete model configuration. Accordingly, it can be inferred that wing-tail interference was slight.

Yawing moments due to aileron deflection.- The incremental yawing-moment coefficient due to left tip aileron deflection at zero angle of sideslip is presented in figure 11. The yawing moments due to ailerons deflected differentially from various offset neutral positions are shown in figure 12. The zero neutral position curve is obtained from the data of figure 11; the offset neutral position curves are derived from data obtained with combined left and right ailerons. The curves presented in figure 12 are typical of data for other offsets and total aileron deflections. A close study of figures 11 and 12 reveals that data obtained with ailerons deflected individually are additive; accordingly, data for an individually deflected aileron can be used to predict with reasonable accuracy yawing moments due to differentially deflected ailerons.

Plain Spoiler

Rolling power.- The variation of the incremental rolling-moment coefficient with angle of attack for 25° and 50° deflection of the plain spoiler is presented in figure 13. The effectiveness decreased with increasing angle of attack and Mach number.

Yawing moments due to plain spoiler deflection.- The incremental yawing-moment coefficient due to 25° and 50° deflection of the plain spoiler at zero angle of sideslip is shown in figure 14. The yawing moments were negligible at $M = 1.55$ and 1.90 , and were small, but not adverse, at $M = 2.35$. At high angles of attack the yawing moment and rolling moment were approximately of the same magnitude.

Vented Spoiler

Rolling power.- The variation of incremental rolling-moment coefficient with angle of attack for 25° deflection of the vented spoiler with 17- and 29-percent vent blockages is presented in figure 15. At $M = 1.55$, ΔC_l decreased with increasing angle of attack; at $M = 1.90$ and 2.35 , the effect of angle of attack was slight. The effectiveness decreased with increases in Mach number and vent blockage.

Yawing moment due to vented spoiler deflection.- The incremental yawing-moment coefficient due to 25° deflection of the vented spoiler

with 17- and 29-percent blockages at zero angle of sideslip is shown in figure 16. Favorable yawing moments were indicated throughout the angle-of-attack range at all Mach numbers. The yawing moments with either value of blockage decreased with increasing angle of attack at $M = 1.55$. At $M = 1.90$ and 2.35 , ΔC_n was approximately constant for both blockages for angles of attack up to about 12° . It is evident that the effect of vent blockage was generally small and was only noticeable at $M = 1.90$ for angles of attack greater than 6° .

Comparison of the Various Control Devices

Incremental rolling moments.- A comparison of the incremental rolling-moment coefficients for several lateral control devices is shown in figure 17. The tip ailerons provided, by far, the greatest rolling moments. The vented spoiler, compared with the plain spoiler at the same deflection (25°), was more than three times as effective at $\alpha = 2^\circ$ for all Mach numbers. At high angles of attack the effectiveness of the plain spoiler deteriorated to a negligible amount (fig. 13); the vented spoiler essentially retained its effectiveness (fig. 15).

Roll capability.- The estimated controllability presented as the variation of $pb/2V$ with Mach number for several control systems is shown in figure 18.² The military specification requirement was determined from reference 5 for a representative Class II airplane at an altitude of 40,000 feet. From figure 18 it can be seen that at the lower Mach number the specified rolling rate is attainable only with tip ailerons. Total aileron deflection of 50° will be required at $M = 1.55$; only 10° will be required at $M = 2.35$.

The lack of roll power of the spoilers at the low Mach number is quite apparent; the required $pb/2V$ of 0.066 was far from being satisfied with any spoiler configuration. Only at the higher Mach number was the required value of 0.015 attainable with spoiler configurations. The estimated value of $pb/2V$ based on 50° spoiler and 35° aileron deflections indicated that the roll capability was adequate. It must be realized, however, that the ailerons accounted for more than 69 percent of the roll power.

²For the condition of steady roll about the longitudinal wind axis, the roll helix angle is defined as $pb/2V = C_l/C_{l_p}$, where C_{l_p} is the damping-in-roll derivative of the wing. This equation neglects the damping of other parts of the airplane. Values of C_{l_p} obtained from reference 4 were -0.338, -0.271, and -0.215 at $M = 1.55$, 1.90, and 2.35, respectively. Estimates of $pb/2V$ were made for a rigid wing, that is, no effect of aeroelasticity was considered, and were based on $\alpha = 2^\circ$.

The effects of aeroelasticity on tip aileron effectiveness were approximated by calculating for specified flight conditions the deformation of a typical thin wing structure, and increasing by this amount the aileron deflections that were previously calculated from the experimental results which correspond to a rigid wing. The results are illustrated in the following tabulation:

<u>Mach number</u>	<u>Total aileron deflection</u>	
	<u>Rigid wing</u>	<u>Elastic wing</u>
1.55	50°	60°
1.90	34°	50°
2.35	10°	20°

It is evident that the effects of aeroelasticity are substantial. Aeroelastic effects on vented spoiler effectiveness can also be pronounced. For example, at $M = 2.35$, a spoiler deflection of 25° will produce a $pb/2V$ of 0.024 for a rigid wing but only 0.014 for an elastic wing.

Yawing moments due to lateral control deflection.— Yawing moments are generally considered in the study of lateral control. Figure 12 indicates that favorable yaw due to two ailerons deflected differentially from zero neutral position will be experienced at $\alpha < 4^\circ$ at $M = 1.55$ and 1.90. At greater angles of attack and for all positive angles at $M = 2.35$, aileron deflection will generally result in adverse yawing moments.

When ailerons are differentially deflected from an offset neutral position (fig. 12), the resulting yawing moments at all Mach numbers will be favorable over a larger portion of the angle-of-attack range than those for ailerons deflected from zero neutral position. The angle-of-attack range over which favorable yaw will be experienced becomes larger with increasing initial offset aileron angles.

One advantage of the spoiler type of lateral control device is that the yawing moments produced are generally favorable, or small if adverse. This investigation substantiates this characteristic for, as previously mentioned, the incremental yawing moments due to the plain spoiler deflection were generally small and those due to the vented spoiler were favorable.

CONCLUDING REMARKS

An investigation of the lateral control characteristics of tip ailerons, a plain spoiler, and a vented spoiler on a low-aspect-ratio trapezoidal wing was conducted in the Ames 9- by 7-foot supersonic wind tunnel at Mach number of 1.55, 1.90, and 2.35 and at a Reynolds number of approximately 1.4×10^6 .

Of the three lateral controls investigated, the tip ailerons were by far the most effective. Estimated roll helix angles produced by the tip ailerons were adequate to satisfy the military specification requirement at all Mach numbers. The roll capability of the vented spoiler at 25° deflection satisfied the specification requirement only at $M = 2.35$. The vented spoiler compared with the plain spoiler at the same deflection (25°) was more than three times as effective at low angles of attack. At high angles of attack, the effectiveness of the plain spoiler deteriorated to a negligible amount; the vented spoiler essentially retained its effectiveness.

The effectiveness of tip ailerons generally increased with increase in angle of attack, particularly at $M = 1.55$, and decreased with increasing Mach number. The angle-of-attack range over which tip ailerons provided favorable yawing moments became larger with increasing initial offset angles.

Ames Aeronautical Laboratory
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4. Harmon, Sidney M., and Jeffreys, Isabella: Theoretical Lift and Damping in Roll of Thin Wings with Arbitrary Sweep and Taper at Supersonic Speeds. Supersonic Leading and Trailing Edges. NACA TN 2114, 1950.
5. Anon.: Flying Qualities of Piloted Airplanes. Military Specification Mil-F-8785 (ASG), including Amendment 2, 17 Oct. 1955.

TABLE I.- GEOMETRIC CHARACTERISTICS OF THE MODEL

Wing	
Area (projected), sq ft	1.742
Aspect ratio	3.2
Taper ratio	0.4
Span, ft	2.361
Mean aerodynamic chord, ft	0.783
Root chord, ft	1.054
Leading edge location	
Station, in.	29.25
Water line, in.	6.86
Tip chord, ft	0.422
Dihedral, deg	0
Incidence, deg	2
Sweepback (projected plane), deg	
Leading edge	25.75
Quarter-chord line	19.20
Trailing edge	-3.06
Airfoil section	Biconvex
Percent thickness	3.5
Tip aileron	
Area, sq ft	0.0534
Span at hinge line, ft	0.118
Percent wing semispan	10
Inboard chord, ft	0.485
Tip chord, ft	0.422
Hinge line, percent wing chord	35
Vented spoiler	
Area, sq ft	0.0718
Span, ft	0.703
Chord, percent wing chord	14
Inboard location	
Wing station, in.	3.54
Percent semispan	25
Outboard location	
Wing station at hinge point, in.	11.98
Percent semispan	84.6
Hinge line, percent wing chord	63
Spoiler deflector	
Area, sq ft	0.0513
Span, ft	0.703
Chord, percent wing chord	10
Inboard location	
Wing station, in.	3.54
Percent semispan	25

TABLE I.- GEOMETRIC CHARACTERISTICS OF THE MODEL - Continued

Outboard location	
Wing station, in.	11.98
Percent semispan	84.6
Hinge line, percent wing chord	73
Plain spoiler	
Area, sq ft	0.0323
Span, ft	0.555
Chord, percent wing chord	8
Inboard location	
Wing station, in.	3.97
Percent semispan	28
Outboard location	
Wing station at hinge point, in.	10.62
Percent semispan	75
Hinge line, percent wing chord	69
Fuselage	
Length, ft	4.241
Maximum height, ft	0.300
Maximum width, ft	0.263
Vertical tail	
Area, sq ft	0.292
Aspect ratio	1
Taper ratio	0.67
Span, ft	0.540
Root chord, ft	0.645
Leading edge location	
Station, in.	45.90
Water line, in.	8.10
Tip chord, ft	0.435
Leading edge location	
Station, in.	54.25
Water line, in.	14.58
Sweepback (projected plane), deg	
Leading edge	52.2
Quarter-chord line	50
Trailing edge	42
Airfoil section	NACA 64A007
Horizontal tail	
Area (projected), sq ft	0.354
Aspect ratio	3.5
Taper ratio	0.3
Span, ft	1.110
Root chord, ft	0.495
Leading edge location	
Station, in.	53.11
Water line, in.	14.58

TABLE I.- GEOMETRIC CHARACTERISTICS OF THE MODEL - Concluded

Tip chord, ft	0.143
Dihedral, deg	15
Sweepback (projected plane), deg	
Leading edge	44.93
Quarter-chord line	40
Trailing edge	19.93
Airfoil section	NACA 64A005
Outrigger housing	
With tip aileron configuration	
Length, ft	0.864
Maximum height, ft	0.068
Maximum width, ft	0.045
Leading edge location	
Station, in.	30.83
Water line, in.	6.45
Center line location, wing station, in.	12.16
With vented spoiler configuration	
Length, ft	0.786
Maximum height, ft	0.068
Maximum width, ft	0.045
Leading edge location	
Station, in.	31.71
Water line, in.	6.45
Center line location, wing station, in.	14.16
Tail bullet fairing	
Length, ft	0.871
Maximum height, ft	0.098
Maximum width, ft	0.113
Leading edge location	
Station, in.	51.10
Water line, in.	12.24

TABLE II.- AERODYNAMIC DATA
(a) Basic model with tip aileron

$\alpha, \deg$ $\beta, \deg$ C_L C_D C_m C_l C_Y C_n								$\alpha, \deg$ $\beta, \deg$ C_L C_D C_m C_l C_Y C_n								$\alpha, \deg$ $\beta, \deg$ C_L C_D C_m C_l C_Y C_n							
$\bar{C}_L = 0^\circ; \bar{C}_R = 0^\circ; M = 1.55; R = 1.9 \times 10^6$								$\bar{C}_L = 0^\circ; \bar{C}_R = 0^\circ; M = 1.55; R = 1.8 \times 10^6$								$\bar{C}_L = 0^\circ; \bar{C}_R = 0^\circ; M = 1.55; R = 1.8 \times 10^6$							
-3.6	-0.5	-0.35	0.076	0.169	0.001	-0.00	0.002	9.6	-3.2	-0.2	0.120	-0.113	0.008	0.05	-0.019	5.9	-3.2	0.36	0.076	-0.105	0.009	0.05	-0.019
0	-0.5	-0.08	0.047	0.065	0.000	-0.00	0.003	9.7	-1.2	0.62	0.142	-0.211	0.002	0.01	-0.002	5.9	-2	0.35	0.076	-0.108	-0.003	-0.02	0.010
2.4	-0.5	-0.10	0.048	-0.007	0.000	-0.00	0.003	9.8	-0.8	0.63	0.143	-0.213	-0.005	-0.03	0.015	5.9	-0.8	0.35	0.076	-0.109	-0.005	-0.03	0.015
5.8	-0.5	0.36	0.076	-0.108	-0.001	-0.00	0.004	9.7	2.8	0.62	0.142	-0.206	-0.010	-0.07	0.031	5.8	2.8	0.35	0.076	-0.106	-0.012	-0.07	0.032
8.8	-0.5	0.56	0.123	-0.190	-0.001	-0.00	0.004	9.7	4.8	0.62	0.141	-0.199	-0.015	-0.11	0.045	5.8	4.8	0.35	0.076	-0.104	-0.017	-0.10	0.047
11.7	-0.5	0.74	0.185	-0.251	-0.001	-0.00	0.004	9.7	6.9	0.61	0.140	-0.197	-0.020	-0.15	0.056	5.8	6.8	0.35	0.076	-0.105	-0.022	-0.14	0.060
14.6	-0.5	0.92	0.269	-0.318	-0.001	-0.00	0.003	9.7	8.9	0.61	0.139	-0.204	-0.023	-0.19	0.063	5.8	8.9	0.35	0.076	-0.112	-0.027	-0.17	0.066
$\bar{C}_L = 0^\circ; \bar{C}_R = 0^\circ; M = 1.90; R = 1.7 \times 10^6$								$\bar{C}_L = 0^\circ; \bar{C}_R = 0^\circ; M = 1.90; R = 1.7 \times 10^6$								$\bar{C}_L = 0^\circ; \bar{C}_R = 0^\circ; M = 1.90; R = 1.8 \times 10^6$							
-3.6	-0.3	-0.26	0.063	0.091	0.000	-0.00	0.002	9.6	-3.0	0.51	0.117	-0.174	-0.005	0.04	-0.011	5.7	-3.0	0.28	0.062	-0.093	0.006	0.04	-0.012
0	-0.3	-0.06	0.041	0.027	0.000	-0.00	0.002	9.6	-0.4	0.51	0.116	-0.171	-0.001	-0.01	0.006	5.7	-0.4	0.28	0.061	-0.090	-0.001	-0.01	0.006
2.8	-0.3	0.11	0.043	-0.030	0.000	-0.00	0.002	9.6	1.0	0.51	0.116	-0.171	-0.003	-0.02	0.009	5.7	1.0	0.27	0.061	-0.090	-0.003	-0.02	0.009
5.7	-0.3	0.28	0.062	-0.090	-0.000	-0.00	0.002	9.6	3.0	0.50	0.116	-0.172	-0.007	-0.06	0.018	5.7	3.0	0.28	0.062	-0.094	-0.007	-0.05	0.019
8.6	-0.3	0.45	0.099	-0.151	---	---	---	9.6	5.1	0.51	0.115	-0.174	-0.011	-0.09	0.028	5.7	5.0	0.28	0.062	-0.097	-0.011	-0.08	0.029
11.5	-0.3	0.62	0.154	-0.210	0.000	-0.00	0.002	9.6	7.1	0.50	0.115	-0.176	-0.015	-0.12	0.036	5.7	7.1	0.28	0.063	-0.103	-0.015	-0.12	0.038
14.4	-0.3	0.78	0.226	-0.270	-0.000	-0.00	0.002	9.6	9.1	0.50	0.115	-0.181	-0.019	-0.16	0.044	5.7	9.1	0.28	0.063	-0.112	-0.019	-0.15	0.046
$\bar{C}_L = 0^\circ; \bar{C}_R = 0^\circ; M = 2.35; R = 1.8 \times 10^6$								$\bar{C}_L = 0^\circ; \bar{C}_R = 0^\circ; M = 2.35; R = 1.8 \times 10^6$								$\bar{C}_L = 0^\circ; \bar{C}_R = 0^\circ; M = 2.35; R = 1.8 \times 10^6$							
-3.5	-0.1	-0.19	0.054	0.028	0.001	0.00	-0.000	9.4	-2.9	---	---	---	0.004	0.04	-0.007	5.6	-2.9	0.21	0.051	-0.058	0.004	0.03	-0.007
0	-0.1	-0.04	0.036	-0.007	0.001	0.00	-0.000	9.4	-0.6	0.38	0.089	-0.103	-0.001	-0.00	0.001	5.6	-0.6	0.21	0.050	-0.059	-0.000	-0.01	0.001
2.8	-0.1	0.09	0.037	-0.034	0.001	0.00	-0.000	9.4	1.2	0.39	0.090	-0.107	-0.001	-0.01	0.003	5.6	1.2	0.21	0.050	-0.069	-0.000	-0.01	0.003
5.7	-0.1	0.21	0.050	-0.059	0.001	0.00	-0.000	9.4	3.2	0.39	0.090	-0.117	-0.005	-0.04	0.008	5.6	3.2	0.21	0.050	-0.063	-0.003	-0.03	0.008
8.5	-0.1	0.34	0.077	-0.089	0.001	0.00	-0.001	9.4	5.2	0.39	0.091	-0.130	-0.008	-0.07	0.014	5.6	5.2	0.21	0.051	-0.069	-0.005	-0.06	0.015
11.3	-0.1	0.47	0.118	-0.134	0.001	0.00	-0.001	9.4	7.3	0.40	0.092	-0.146	-0.011	-0.10	0.021	5.6	7.2	0.21	0.051	-0.077	-0.008	-0.09	0.021
14.2	-0.1	0.61	0.176	-0.179	0.001	0.00	-0.001	9.4	9.3	0.40	0.093	-0.161	-0.014	-0.14	0.026	5.6	9.3	0.21	0.051	-0.089	-0.011	-0.12	0.025
$\bar{C}_L = 0^\circ; \bar{C}_R = 0^\circ; M = 1.55; R = 1.8 \times 10^6$								$\bar{C}_L = -10^\circ; \bar{C}_R = 0^\circ; M = 1.55; R = 1.9 \times 10^6$								$\bar{C}_L = -10^\circ; \bar{C}_R = 0^\circ; M = 1.55; R = 1.9 \times 10^6$							
2.4	-3.2	0.09	0.048	-0.001	0.008	0.04	-0.017	-3.6	-0.5	-0.36	0.079	0.178	-0.004	-0.00	-0.002	9.7	-3.2	0.60	0.138	-0.197	0.002	0.05	-0.018
2.4	0.2	0.09	0.047	-0.005	0.003	-0.01	0.009	0	-0.5	-0.10	0.048	0.074	-0.004	-0.01	-0.002	9.7	-1.2	0.60	0.138	-0.202	-0.004	-0.01	-0.002
2.4	0.8	0.10	0.048	-0.006	-0.005	-0.02	0.014	2.9	-0.5	-0.12	0.049	0.016	-0.004	-0.01	0.002	9.7	-0.8	0.61	0.139	-0.205	-0.010	-0.03	0.015
2.4	2.8	0.10	0.048	-0.007	-0.011	-0.06	0.030	5.8	-0.5	-0.34	0.074	-0.01	-0.005	-0.01	0.003	9.7	2.8	0.60	0.138	-0.198	-0.016	-0.08	0.032
2.4	4.8	0.10	0.049	-0.010	-0.017	-0.10	0.045	8.8	-0.5	-0.54	0.119	-0.179	-0.006	-0.01	0.004	9.7	4.9	0.60	0.138	-0.192	-0.021	-0.12	0.046
2.4	6.8	0.10	0.049	-0.019	-0.028	-0.13	0.057	11.7	-0.5	-0.73	0.182	-0.250	-0.006	-0.01	0.005	9.7	6.9	0.60	0.136	-0.191	-0.025	-0.16	0.057
2.4	8.9	0.11	0.049	-0.029	-0.028	-0.16	0.065	14.6	-0.5	-0.91	0.263	-0.310	-0.007	-0.01	0.005	9.7	8.9	0.59	0.135	-0.197	-0.029	-0.19	0.064
$\bar{C}_L = 0^\circ; \bar{C}_R = 0^\circ; M = 1.90; R = 1.8 \times 10^6$								$\bar{C}_L = -10^\circ; \bar{C}_R = 0^\circ; M = 1.90; R = 1.7 \times 10^6$								$\bar{C}_L = -10^\circ; \bar{C}_R = 0^\circ; M = 1.90; R = 1.7 \times 10^6$							
2.3	-3.0	0.08	0.042	-0.020	0.007	0.04	-0.012	0	-0.3	-0.07	0.042	0.031	-0.003	-0.01	-0.000	9.6	-3.0	0.49	0.113	-0.169	0.002	0.04	-0.013
2.3	0.4	0.08	0.041	-0.019	-0.001	-0.01	0.005	-3.6	-0.3	-0.28	0.067	0.098	-0.003	-0.01	-0.001	9.6	-0.4	0.50	0.113	-0.169	-0.005	-0.02	0.004
2.3	1.0	0.08	0.041	-0.020	-0.002	-0.02	0.008	2.8	-0.3	-0.10	0.042	-0.028	-0.003	-0.01	0.000	9.6	1.0	0.50	0.113	-0.169	-0.006	-0.02	0.007
2.3	3.0	0.08	0.041	-0.024	-0.007	-0.05	0.018	5.7	-0.3	-0.27	0.061	-0.090	-0.003	-0.01	0.001	9.6	3.1	0.50	0.114	-0.170	-0.010	-0.06	0.017
2.3	5.1	0.08	0.042	-0.028	-0.012	-0.08	0.028	8.6	-0.3	-0.44	0.097	-0.150	-0.004	-0.00	0.001	9.6	5.1	0.50	0.113	-0.170	-0.014	-0.09	0.028
2.3	7.1	0.08	0.042	-0.036	-0.016	-0.11	0.037	11.5	-0.3	-0.61	0.151	-0.207	-0.004	-0.00	0.001	9.6	7.1	0.49	0.113	-0.172	-0.019	-0.13	0.037
2.3	9.1	0.08	0.042	-0.047	-0.020	-0.14	0.045	14.4	-0.3	-0.77	0.220	-0.266	-0.005	-0.01	0.001	9.6	9.1	0.49	0.113	-0.177	-0.023	-0.17	0.046
$\bar{C}_L = 0^\circ; \bar{C}_R = 0^\circ; M = 2.35; R = 1.8 \times 10^6$								$\bar{C}_L = -10^\circ; \bar{C}_R = 0^\circ; M = 2.35; R = 1.7 \times 10^6$								$\bar{C}_L = -10^\circ; \bar{C}_R = 0^\circ; M = 2.35; R = 1.7 \times 10^6$							
2.3	-2.9	0.06	0.037	-0.029	0.005	0.03	-0.008	-3.5	-0.1	-0.21	0.056	0.032	-0.002	-0.01	-0.001	9.4	-2.9	0.37	0.087	-0.106	0.002	0.03	-0.006
2.3	0.6	0.06	0.036	-0.030	0.000	-0.01	0.002	0	-0.1	-0.05	0.037	-0.004	-0.002	-0.01	-0.000	9.4	-0.6	0.37	0.087	-0.103	-0.004	-0.01	0.002
2.3	1.2	0.06	0.036	-0.031	0.001	-0.01	0.004	2.8	-0.1	-0.07	0.037	-0.031	-0.002	-0.01	0.000	9.4	1.2	0.37	0.087	-0.104	-0.004	-0.02	0.003
2.3	3.2	0.06	0.036	-0.032	-0.003	-0.04	0.010	5.6	-0.1	-0.20	0.049	-0.055	-0.002	-0.00	0.000	9.4	3.2	0.38	0.088	-0.114	-0.008	-0.04	0.009
2.3	5.2	0.06	0.037	-0.035	-0.003	-0.06	0.016	8.5	-0.1	-0.33	0.075	-0.087	-0.002	-0.00	-0.000	9.4	5.2	0.39	0.089	-0.126	-0.011	-0.07	0.015
2.3	7.2	0.06	0.037	-0.039	-0.009	-0.09	0.022	11.3	-0.1	-0.46	0.115	-0.132	-0.003	-0.00	0.000	9.4	7.3	0.39	0.089	-0.141	-0.014	-0.11	0.021
2.3	9.3	0.06	0.037	-0.046	-0.012	-0.12	0.026	14.2	-0.1	-0.60	0.171	-0.175	-0.003	-0.00	0.001	9.4	9.3	0.39	0.091	-0.157	-0.017	-0.14	0.026
$\bar{C}_L = -10^\circ; \bar{C}_R = 0^\circ; M = 1.55; R = 1.9 \times 10^6$								$\bar{C}_L = -10^\circ; \bar{C}_R = 0^\circ; M = 1.55; R = 1.8 \times 10^6$								$\bar{C}_L = -20^\circ; \bar{C}_R = 0^\circ; M = 1.55; R = 1.8 \times 10^6$							
5.8	-3.2	0.34	0.074	-0.095	0.004	0.04	-0.020	2.3	-3.2	0.08	0.048	0.007	-0.005	0.04	-0.019	-3.6	-0.5	-0.38	0.085	0.185	-0.008	0.01	-0.007
5.8	-1.2	0.34	0.074	-0.098	0.003	0.01	-0.003	2.3	-1.2	0.08	0.048	0.003	-0.002	0.01	-0.004	-1.1	-0.5	-0.11	0.053	0.081	-0.009	0.00	-0.005
5.8	0.8	0.33	0.073	-0.099	-0.009	-0.03	0.014	2.3	0.8	0.08	0.048	0.001	-0.009	-0.03	0.012	2.9	-0.5	0.11	0.052	-0.099	-0.009	0.00	-0.003
5.8	2.8	0.33	0.074	-0.098	-0.016	-0.07	0.024	2.3	2.8	0.08	0.048	0.000	-0.015	-0.06	0.028	5.8	-0.5	0.33	0.075	-0.096	-0.010	0.00	-0.000
5.8	4.8	0.33	0.074	-0.096	-0.022	-0.11	0.047	2.3	4.8	0.07	0.048	-0.003	-0.021	-0.10	0.043	8.7	-0.5	0.53	0.119	-0.174	-0.011	0.00	0.002
5.8	6.8	0.33	0.074	-0.097	-0.027	-0.15	0.060	2.3	6.8	0.08	0.049	-0.010	-0.027	-0.14	0.056	11.6	-0.5	0.72	0.181	-0.244	-0.011	0.00	0.003
5.8	8.9	0.33	0.073	-0.104	-0.031	-0.18	0.067	2.3	8.9	0.09	0.049	-0.021	-										

TABLE II.- AERODYNAMIC DATA - Continued
(a) Basic model with tip aileron - Concluded

α , deg	β , deg	C_L	C_D	C_m	C_l	C_Y	C_n	α , deg	β , deg	C_L	C_D	C_m	C_l	C_Y	C_n	α , deg	β , deg	C_L	C_D	C_m	C_l	C_Y	C_n
$\delta_L = -30^\circ; \delta_R = 0^\circ; M = 1.55; R = 1.9 \times 10^6$								$\delta_L = 10^\circ; \delta_R = 0^\circ; M = 1.55; R = 1.9 \times 10^6$								$\delta_L = 20^\circ; \delta_R = 0^\circ; M = 1.55; R = 1.8 \times 10^6$							
-0.1	-0.4	-0.12	0.063	0.090	-0.012	0.01	-0.012	-3.6	-0.5	-0.34	0.075	0.164	0.005	-0.01	0.004	-3.6	-0.5	-0.32	0.078	0.157	0.010	-0.01	0.003
2.9	-4	.10	.061	.000	-.013	.01	-.009	0	-5	-.07	.048	.061	.005	-.01	.004	0	-5	.06	.053	.054	.011	-.01	.001
5.8	-4	.32	.083	-.089	-.014	.01	-.006	2.9	-5	.15	.053	-.028	.005	-.01	.003	2.9	-5	.16	.060	-.035	.011	-.01	-.001
9.3	-4	.55	.134	-.180	-.015	.00	-.003	5.8	-5	.37	.080	-.115	.006	-.01	.002	5.9	-5	.38	.089	-.121	.011	-.00	-.002
12.4	-5	.76	.204	-.255	-.016	-.00	.000	9.3	-5	.61	.140	-.211	.006	-.01	.001	9.3	-5	.62	.150	-.216	.010	-.00	-.003
15.6	-5	.94	.294	-.313	-.017	-.01	.003	12.5	-5	.81	.215	-.282	.005	-.01	.000	12.5	-5	.82	.227	-.289	.009	-.00	-.004
								15.7	-5	1.00	.313	-.348	.004	-.00	-.001	15.2	-4	.98	.307	-.343	.007	-.00	-.005
$\delta_L = -30^\circ; \delta_R = 0^\circ; M = 1.90; R = 1.8 \times 10^6$								$\delta_L = 10^\circ; \delta_R = 0^\circ; M = 1.90; R = 1.7 \times 10^6$								$\delta_L = 20^\circ; \delta_R = 0^\circ; M = 1.90; R = 1.7 \times 10^6$							
-3.6	-2	-.28	.081	.097	-.011	.00	-.010	-3.6	-3	-.25	.064	.092	.004	-.00	.002	-3.5	-3	-.24	.067	.085	.009	-.01	.001
-1	-2	-.08	.055	.031	-.011	.00	-.007	0	-3	-.05	.043	.026	.004	-.00	.002	0	-3	-.04	.047	.020	.009	-.01	-.001
2.8	-2	.08	.053	-.027	-.011	.00	-.006	2.9	-3	.12	.045	-.033	.004	-.00	.001	2.9	-3	.13	.051	-.039	.009	-.00	-.002
5.7	-2	.25	.069	-.088	-.012	.00	-.004	5.7	-3	.29	.065	-.093	.005	-.00	.000	5.8	-3	.30	.072	-.100	.009	-.00	-.003
9.1	-3	.45	.111	-.158	-.012	.00	-.003	9.2	-3	.49	.113	-.167	.005	-.00	-.001	9.2	-2	.50	.121	-.171	.008	-.00	-.006
12.2	-3	.63	.170	-.218	-.013	-.00	-.001	12.3	-3	.67	.178	-.231	.005	-.00	-.002	12.3	-2	.67	.186	-.235	.008	-.00	-.008
								15.5	-3	.84	.261	-.300	.004	-.00	-.004	15.5	-2	.85	.271	-.304	.006	-.00	-.010
$\delta_L = -30^\circ; \delta_R = 0^\circ; M = 2.35; R = 1.8 \times 10^6$								$\delta_L = 10^\circ; \delta_R = 0^\circ; M = 2.35; R = 1.8 \times 10^6$								$\delta_L = 20^\circ; \delta_R = 0^\circ; M = 2.35; R = 1.7 \times 10^6$							
-3.5	-1	-.22	.069	.032	-.009	.00	-.007	-3.5	-1	-.19	.054	.027	.004	.00	-.000	-3.5	-1	-.18	.057	.022	.008	-.00	-.001
-1	-1	-.06	.049	-.003	-.009	.00	-.006	0	-1	-.04	.038	-.009	.004	-.00	-.000	0	-1	-.03	.042	-.013	.008	-.00	-.002
2.8	-1	.06	.047	-.030	-.009	.00	-.005	2.8	-1	.09	.039	-.037	.004	-.00	-.001	2.8	-1	.10	.044	-.040	.008	-.00	-.003
5.6	-1	.19	.057	-.057	-.009	.00	-.004	5.6	-1	.22	.053	-.061	.004	-.00	-.001	5.7	-1	.23	.059	-.065	.008	-.00	-.004
9.0	-1	.34	.087	-.098	-.009	.00	-.003	9.0	-1	.37	.087	-.099	.004	.00	-.002	9.0	-1	.38	.094	-.104	.008	-.00	-.005
12.1	-1	.49	.133	-.145	-.010	.00	-.002	12.1	-1	.52	.137	-.150	.004	.00	-.003	12.1	-1	.52	.142	-.152	.007	-.00	-.006
15.2	-1	.64	.199	-.193	-.011	.00	-.000	15.3	-1	.67	.207	-.201	.005	.00	-.004	15.3	-1	.68	.216	-.205	.007	.01	-.009
$\delta_L = -10^\circ; \delta_R = -10^\circ; M = 1.55; R = 1.8 \times 10^6$								$\delta_L = -20^\circ; \delta_R = -10^\circ; M = 1.55; R = 1.8 \times 10^6$								$\delta_L = -20^\circ; \delta_R = 10^\circ; M = 1.55; R = 1.7 \times 10^6$							
-3.7	-5	-.38	.084	.183	.001	-.01	.002	-3.7	-5	-.39	.091	.192	-.004	-.00	-.004	-3.6	-5	-.37	.086	.180	-.012	.01	-.009
2.9	-5	.11	.051	-.011	-.000	-.01	.004	-1	-5	-.12	.056	.085	-.004	-.00	-.002	0	-5	-.10	.055	.075	-.013	.00	-.005
5.8	-5	.33	.074	-.094	-.000	-.01	.004	2.9	-5	.10	.054	-.005	-.005	-.00	-.000	2.9	-5	.12	.056	-.016	-.014	.00	-.002
9.3	-5	.57	.128	-.188	-.000	-.01	.004	5.8	-5	.32	.076	-.090	-.005	-.00	.001	5.8	-5	.34	.080	-.102	-.016	.00	.002
12.4	-5	.77	.199	-.261	-.000	-.00	.004	9.3	-5	.55	.128	-.183	-.005	-.01	.002	9.0	-5	.56	.130	-.187	-.017	.00	.005
15.7	-5	.95	.290	-.319	-.001	-.01	.003	12.4	-5	.75	.197	-.253	-.006	-.01	.003	11.7	-5	.73	.190	-.251	-.017	.00	.007
-1	-5	-.11	.051	.079	.000	-.01	.003	15.6	-5	.93	.287	-.309	-.006	-.01	.003	14.6	-5	.91	.270	-.310	-.017	.01	.009
$\delta_L = -10^\circ; \delta_R = -10^\circ; M = 1.90; R = 1.7 \times 10^6$								$\delta_L = -20^\circ; \delta_R = -10^\circ; M = 1.90; R = 1.7 \times 10^6$								$\delta_L = -20^\circ; \delta_R = 10^\circ; M = 1.90; R = 1.8 \times 10^6$							
-3.6	-3	-.28	.070	.097	.000	-.01	.003	-3.6	-3	-.29	.076	.099	-.004	-.00	-.001	-3.6	-3	-.27	.073	.096	-.012	.00	-.004
0	-3	-.08	.045	.031	.000	-.00	.003	-1	-3	-.09	.049	.032	-.004	-.00	-.000	0	-3	-.07	.048	.030	-.012	.00	-.002
2.8	-3	.09	.044	-.027	.000	-.00	.003	2.8	-3	.08	.047	-.026	-.004	-.00	.000	2.8	-3	.10	.048	-.030	-.012	.00	-.000
5.7	-3	.26	.061	-.087	.000	-.00	.003	5.7	-3	.25	.063	-.086	-.004	-.01	.001	5.7	-3	.27	.066	-.092	-.012	.00	.001
9.1	-3	.46	.104	-.155	.000	-.00	.003	9.1	-3	.45	.105	-.154	-.004	-.00	.001	8.6	-3	.44	.103	-.152	-.013	.00	.003
12.2	-3	.63	.164	-.214	.000	-.01	.003	12.2	-3	.62	.163	-.213	-.004	-.01	.002	11.5	-3	.61	.157	-.210	-.013	.00	.004
15.4	-3	.80	.243	-.277	-.000	-.01	.003	15.4	-3	.79	.241	-.275	-.005	-.01	.002	14.9	-3	.79	.239	-.279	-.014	.00	.006
$\delta_L = -10^\circ; \delta_R = -10^\circ; M = 2.35; R = 1.7 \times 10^6$								$\delta_L = -20^\circ; \delta_R = -10^\circ; M = 2.35; R = 1.7 \times 10^6$								$\delta_L = -20^\circ; \delta_R = 10^\circ; M = 2.35; R = 1.8 \times 10^6$							
-3.5	-1	-.21	.060	.034	.001	-.00	.000	-3.5	-1	-.22	.064	.036	-.003	-.00	-.002	-3.5	-1	-.21	.061	.031	-.010	.00	-.004
-1	-1	-.06	.040	-.002	.001	-.00	.001	-1	-1	-.07	.043	-.000	-.003	-.00	-.002	0	-1	-.05	.043	-.004	-.010	.00	-.002
2.8	-1	.07	.038	-.029	.001	-.00	.000	2.8	-1	.06	.041	-.027	-.003	-.00	-.001	2.8	-1	.07	.042	-.032	-.010	.00	-.001
5.6	-1	.19	.050	-.052	.001	.00	.000	5.6	-1	.18	.052	-.051	-.003	-.00	-.001	5.6	-1	.20	.055	-.057	-.010	.00	.000
9.0	-1	.34	.081	-.093	.001	.00	-.000	9.0	-1	.34	.082	-.095	-.003	-.00	-.001	8.5	-1	.33	.081	-.091	-.010	.00	.001
12.1	-1	.49	.127	-.141	.001	.00	.000	12.0	-1	.48	.127	-.141	-.003	.00	-.000	11.3	-2	.47	.122	-.136	-.011	.00	.002
15.2	-1	.64	.193	-.189	.001	.00	-.000	15.2	-1	.64	.192	-.188	-.003	.00	-.000	14.7	-2	.63	.189	-.187	-.011	.00	.004

TABLE II.- AERODYNAMIC DATA - Continued
(b) Model less tail

α , deg	β , deg	C_L	C_D	C_m	C_L	C_Y	C_n	α , deg	β , deg	C_L	C_D	C_m	C_L	C_Y	C_n
$\delta_L = 0^\circ; \delta_R = 0^\circ; M = 1.55; R = 1.9 \times 10^6$								$\delta_L = -10^\circ; \delta_R = 0^\circ; M = 1.55; R = 1.9 \times 10^6$							
-3.7	-0.5	-0.29	0.062	0.021	0.002	-0.00	0.000	-3.7	-0.5	-0.31	0.066	0.026	-0.004	-0.00	-0.002
-1.1	-5	-0.06	.037	-.015	.002	-0.00	-0.000	-1.1	-5	-.07	.039	-.010	-0.004	.00	-.001
2.9	-5	.14	.042	-.047	.001	-0.00	-0.000	2.9	-5	.13	.042	-.041	-0.004	.00	-.001
5.9	-5	.34	.068	-.074	.001	.00	-0.001	5.9	-5	.33	.067	-.068	-0.004	.00	-0.000
9.4	-5	.56	.123	-.107	.001	.00	-0.001	9.3	-5	.54	.120	-.096	-0.005	.00	-0.000
12.5	-5	.74	.192	-.131	.001	.00	-0.002	12.5	-5	.72	.187	-.121	-0.006	.00	-0.000
15.8	-5	.91	.281	-.151	.000	.00	-0.002	15.8	-5	.89	.274	-.140	-0.007	.00	.001
$\delta_L = 0^\circ; \delta_R = 0^\circ; M = 1.90; R = 1.8 \times 10^6$								$\delta_L = -10^\circ; \delta_R = 0^\circ; M = 1.90; R = 1.7 \times 10^6$							
-3.6	-3	-.23	.051	.011	.002	-0.00	-0.000	-3.6	-3	-.24	.055	.015	-0.003	.00	-0.002
-1.1	-3	-.05	.032	-.017	.002	-0.00	-0.000	-1.1	-3	-.06	.034	-.013	-0.003	.00	-0.002
2.8	-3	.11	.034	-.041	.002	-0.00	-0.001	2.8	-3	.10	.034	-.037	-0.003	.00	-0.001
5.7	-3	.26	.053	-.065	.001	.00	-0.001	5.7	-3	.26	.053	-.062	-0.003	.00	-0.001
9.2	-3	.45	.097	-.093	.001	.00	-0.001	9.2	-3	.44	.096	-.089	-0.004	.00	-0.000
12.3	-3	.61	.157	-.115	.001	.00	-0.002	12.3	-3	.60	.154	-.109	-0.005	.00	-0.000
15.3	-3	.77	.234	-.132	.000	.00	-0.002	15.3	-3	.76	.230	-.126	-0.005	.00	.000
$\delta_L = 0^\circ; \delta_R = 0^\circ; M = 2.35; R = 1.7 \times 10^6$								$\delta_L = -10^\circ; \delta_R = 0^\circ; M = 2.35; R = 1.7 \times 10^6$							
-3.5	-1	-.19	.043	-.003	.001	.00	-0.000	-3.5	-1	-.20	.046	.000	-0.003	.00	-0.002
0	-1	-.04	.027	-.020	.001	.00	-0.000	0	-1	-.05	.029	-.017	-0.002	.00	-0.001
2.8	-1	.08	.028	-.034	.001	.00	-0.001	2.8	-1	.07	.029	-.032	-0.002	.00	-0.001
5.7	-1	.20	.042	-.051	.001	.00	-0.001	5.7	-1	.20	.042	-.049	-0.002	.00	-0.001
9.0	-1	.35	.075	-.069	.001	.00	-0.001	9.0	-1	.34	.074	-.067	-0.003	.00	-0.000
12.1	-1	.48	.121	-.084	.001	.00	-0.001	12.1	-1	.48	.120	-.082	-0.004	.00	.000
15.3	-1	.62	.186	-.096	.001	.00	-0.001	15.3	-1	.62	.184	-.093	-0.004	.00	.001

(c) Basic model with tip aileron and plain spoiler

α , deg	β , deg	C_L	C_D	C_m	C_L	C_Y	C_n	α , deg	β , deg	C_L	C_D	C_m	C_L	C_Y	C_n	α , deg	β , deg	C_L	C_D	C_m	C_L	C_Y	C_n
$\delta_L = 0^\circ; \delta_R = 0^\circ; \delta_S = 25^\circ;$ $M = 1.55; R = 1.8 \times 10^6$								$\delta_L = 0^\circ; \delta_R = 0^\circ; \delta_S = 50^\circ;$ $M = 1.55; R = 1.8 \times 10^6$								$\delta_L = -20^\circ; \delta_R = 0^\circ; \delta_S = 25^\circ;$ $M = 1.55; R = 1.8 \times 10^6$							
-3.6	-0.5	-0.36	0.086	0.176	-0.004	-0.01	0.004	-3.7	-0.5	-0.38	0.096	0.178	-0.008	-0.01	0.003	-3.7	-0.4	-0.39	0.096	0.191	-0.013	-0.00	-0.005
2.9	-5	-.10	.054	.073	-0.003	-0.01	.004	-1.1	-5	-.11	.063	.076	-0.007	-0.01	.004	-1.1	-5	-.13	.061	.088	-0.013	.00	-0.003
5.8	-5	.12	.056	-.015	-0.003	-0.01	.004	2.9	-5	.11	.062	-.011	-0.006	-0.01	.004	2.9	-5	.10	.059	-.002	-0.012	.00	-0.002
9.3	-5	.34	.080	-.100	-0.003	-0.01	.004	5.8	-5	.33	.085	-.096	-0.006	-0.01	.005	5.8	-5	.31	.080	-.087	-0.012	.00	.000
12.4	-5	.58	.136	-.197	-0.003	-0.01	.004	9.3	-5	.57	.138	-.190	-0.005	-0.01	.005	9.3	-5	.55	.132	-.180	-0.013	.00	.003
15.7	-5	.78	.208	-.272	-0.003	-0.01	.004	12.4	-5	.77	.209	-.264	-0.005	-0.01	.005	12.4	-5	.75	.200	-.250	-0.014	.00	.004
		.97	.301	-.333	-0.002	-0.01	.004	15.7	-5	.96	.300	-.327	-0.004	-0.01	.004	15.6	-5	.93	.290	-.310	-0.015	-0.01	.006
$\delta_L = 0^\circ; \delta_R = 0^\circ; \delta_S = 25^\circ;$ $M = 1.90; R = 1.7 \times 10^6$								$\delta_L = 0^\circ; \delta_R = 0^\circ; \delta_S = 50^\circ;$ $M = 1.90; R = 1.8 \times 10^6$								$\delta_L = -20^\circ; \delta_R = 0^\circ; \delta_S = 25^\circ;$ $M = 1.90; R = 1.7 \times 10^6$							
-3.6	-3	-.27	.072	.104	-0.003	-0.01	.002	-3.6	-3	-.28	.081	.113	-0.006	-0.01	.002	-3.6	-3	-.29	.080	.111	-0.011	-0.00	-0.003
-1.1	-3	-.05	.042	-.010	-0.002	-0.01	.002	0	-3	-.06	.054	.048	-0.005	-0.01	.002	-1.1	-3	-.09	.053	.044	-0.011	-0.00	-0.002
2.8	-3	.10	.047	-.020	-0.002	-0.00	.002	2.8	-3	.08	.052	-.010	-0.005	-0.01	.002	2.8	-3	.08	.050	-.015	-0.010	-0.00	-0.000
5.7	-3	.27	.065	-.084	-0.002	-0.00	.002	5.7	-3	.26	.068	-.076	-0.004	-0.00	.002	5.7	-3	.25	.066	-.079	-0.010	-0.00	.000
9.1	-3	.47	.110	-.157	-0.001	-0.00	.001	9.1	-3	.46	.111	-.150	-0.003	-0.00	.001	9.1	-3	.45	.107	-.152	-0.010	-0.00	.000
12.2	-3	.65	.172	-.220	-0.001	-0.00	.001	12.2	-3	.64	.172	-.215	-0.002	-0.00	.000	12.2	-3	.63	.167	-.213	-0.011	-0.00	.001
15.4	-3	.82	.252	-.285	-0.001	-0.00	.001	15.4	-3	.81	.253	-.282	-0.002	-0.00	.000	15.4	-3	.80	.244	-.276	-0.011	-0.00	.002
$\delta_L = 0^\circ; \delta_R = 0^\circ; \delta_S = 25^\circ;$ $M = 2.35; R = 1.8 \times 10^6$								$\delta_L = 0^\circ; \delta_R = 0^\circ; \delta_S = 50^\circ;$ $M = 2.35; R = 1.8 \times 10^6$								$\delta_L = -20^\circ; \delta_R = 0^\circ; \delta_S = 25^\circ;$ $M = 2.35; R = 1.8 \times 10^6$							
-3.5	-1	-.20	.061	.028	-0.001	.00	-0.003	-3.5	-1	-.21	.068	.036	-0.004	.00	-0.003	-3.5	-1	-.22	.067	.033	-0.008	.00	-0.007
0	-1	-.05	.042	-.010	-0.003	.00	-0.003	0	-1	-.06	.047	-.003	-0.003	.00	-0.003	0	-1	-.06	.046	-.004	-0.008	.00	-0.005
2.8	-1	.08	.041	-.038	-0.000	.00	-0.003	2.8	-1	.07	.045	-.033	-0.002	.00	-0.002	2.8	-1	.06	.044	-.033	-0.007	.00	-0.005
5.7	-1	.20	.053	-.063	-0.001	.00	-0.003	5.6	-1	.20	.056	-.060	-0.002	.00	-0.003	5.6	-1	.19	.054	-.058	-0.007	.01	-0.004
9.0	-1	.35	.084	-.096	-0.001	.00	-0.002	9.0	-1	.35	.086	-.097	-0.002	.01	-0.002	9.0	-1	.34	.083	-.095	-0.007	.00	-0.003
12.1	-1	.50	.131	-.144	-0.000	.01	-0.002	12.1	-1	.50	.133	-.147	-0.001	.00	-0.003	12.0	-1	.48	.129	-.141	-0.007	.00	-0.001
15.2	-1	.65	.198	-.193	-0.000	.01	-0.002	15.2	-1	.65	.200	-.197	-0.001	.01	-0.003	15.2	-1	.64	.193	-.188	-0.008	.00	.000

TABLE II.- AERODYNAMIC DATA - Concluded
(d) Basic model with vented spoiler

α , deg	β , deg	C_L	C_D	C_m	C_l	C_Y	C_n	α , deg	β , deg	C_L	C_D	C_m	C_l	C_Y	C_n	α , deg	β , deg	C_L	C_D	C_m	C_l	C_Y	C_n
$\delta_S = 0^\circ$; blockage 0%; $M = 1.55$; $R = 1.9 \times 10^6$								$\delta_S = 25^\circ$; blockage 17%; $M = 1.55$; $R = 1.9 \times 10^6$								$\delta_S = 25^\circ$; blockage 29%; $M = 1.55$; $R = 1.9 \times 10^6$							
-3.6	-0.5	-0.35	0.076	0.171	0.000	-0.01	0.003	-3.7	-0.5	-0.40	0.109	0.194	-0.011	-0.00	-0.005	-3.7	-0.4	-0.39	0.109	0.193	-0.011	-0.00	-0.004
0	-5	-0.08	0.047	0.067	0.000	-0.01	0.004	-1	-5	-0.14	0.072	0.095	-0.010	-0.00	-0.004	-1	-4	-0.13	0.073	0.093	-0.010	-0.00	-0.004
2.9	-5	.14	0.051	-0.023	-0.000	-0.01	0.004	2.9	-5	.08	0.070	0.009	-0.010	-0.00	-0.003	2.9	-4	.09	0.072	0.006	-0.009	-0.00	-0.003
5.9	-5	.36	0.077	-0.109	-0.000	-0.01	0.004	5.8	-5	.30	0.091	-0.076	-0.010	-0.00	-0.002	5.8	-5	.31	0.093	-0.079	-0.009	-0.00	-0.002
9.3	-5	.60	0.136	-0.204	-0.000	-0.01	0.004	9.3	-5	.55	.143	-0.168	-0.009	-0.00	-0.001	9.3	-5	.55	.146	-0.170	-0.008	-0.00	-0.001
12.5	-5	.81	.211	-0.281	-0.000	-0.01	0.004	12.4	-5	.75	.213	-0.242	-0.009	-0.01	0.001	12.4	-5	.76	.216	-0.240	-0.008	-0.00	0.000
15.7	-5	1.00	.308	-0.346	-0.001	-0.01	0.003	15.7	-5	.94	.305	-0.303	-0.008	-0.01	0.001	15.7	-5	.94	.307	-0.300	-0.008	-0.01	0.001
$\delta_S = 0^\circ$; blockage 0%; $M = 1.90$; $R = 1.8 \times 10^6$								$\delta_S = 25^\circ$; blockage 17%; $M = 1.90$; $R = 1.8 \times 10^6$								$\delta_S = 25^\circ$; blockage 29%; $M = 1.90$; $R = 1.7 \times 10^6$							
-3.6	-3	-.26	.064	.091	0.000	-0.01	.003	-3.6	-3	-.30	.090	.115	-.008	-0.00	-.005	-3.6	-3	-.30	.090	.117	-.007	-0.00	-.005
0	-3	-.06	.042	.025	0.000	-0.01	.003	-1	-3	-.10	.063	.050	-.007	0.00	-.005	-1	-3	-.09	.064	.050	-.006	0.00	-.005
2.8	-3	.10	.046	-.027	0.000	-0.01	.003	2.8	-3	.07	.060	-.007	-.007	0.00	-.004	2.8	-3	.08	.061	-.009	-.006	0.00	-.005
5.7	-3	.28	.062	-.092	-0.000	-0.00	.003	5.7	-3	.24	.075	-.070	-.007	0.00	-.004	5.7	-3	.25	.077	-.073	-.005	0.00	-.005
9.1	-3	---	---	---	0.000	-0.00	.003	9.1	-3	.44	.116	-.142	-.007	0.00	-.005	9.1	-2	.45	.119	-.146	-.005	.01	-.006
12.3	-3	.66	.172	-.227	0.000	-0.00	.003	12.2	-3	.62	.174	-.207	-.007	0.00	-.005	12.2	-2	.63	.179	-.211	-.005	.01	-.007
15.5	-3	.84	.256	-.297	0.000	-0.01	.002	15.4	-3	.80	.255	-.277	-.007	0.00	-.003	15.4	-2	.81	.259	-.282	-.005	.01	-.006
$\delta_S = 0^\circ$; blockage 0%; $M = 2.35$; $R = 1.8 \times 10^6$								$\delta_S = 25^\circ$; blockage 17%; $M = 2.35$; $R = 1.8 \times 10^6$								$\delta_S = 25^\circ$; blockage 29%; $M = 2.35$; $R = 1.7 \times 10^6$							
-3.5	-1	-.20	.054	.029	.001	-0.00	.000	-3.5	-1	-.22	.076	.043	-.005	.01	-.008	-3.5	-1	-.22	.077	.044	-.004	.01	-.008
0	-1	-.04	.037	-.006	.001	0.00	.000	-1	-1	-.07	.055	.003	-.005	.01	-.008	-1	-1	-.06	.056	.003	-.004	.01	-.008
2.8	-1	.08	.037	-.034	.001	-0.00	.000	2.8	-1	.06	.053	-.027	---	---	---	2.8	-1	.05	.053	-.019	-.004	.01	-.008
5.7	-1	.21	.051	-.059	.001	0.00	.000	5.6	-1	.19	.063	-.055	-.004	.01	-.007	5.6	-1	.19	.065	-.056	-.003	.01	-.009
9.0	-1	.36	.084	-.098	.001	0.00	-0.00	9.0	-1	.34	.093	-.102	-.005	.01	-.008	9.0	-1	.35	.096	-.104	-.003	.01	-.009
12.1	-1	.51	.133	-.148	.001	0.00	-0.00	12.0	-1	.49	.140	-.154	-.005	.01	-.008	12.1	-1	.50	.143	-.157	-.003	.01	-.009
15.3	-2	.67	.203	-.199	.001	0.00	-0.01	15.2	-1	.64	.205	-.204	-.006	.01	-.010	15.2	-1	.65	.210	-.206	-.004	.02	-.011

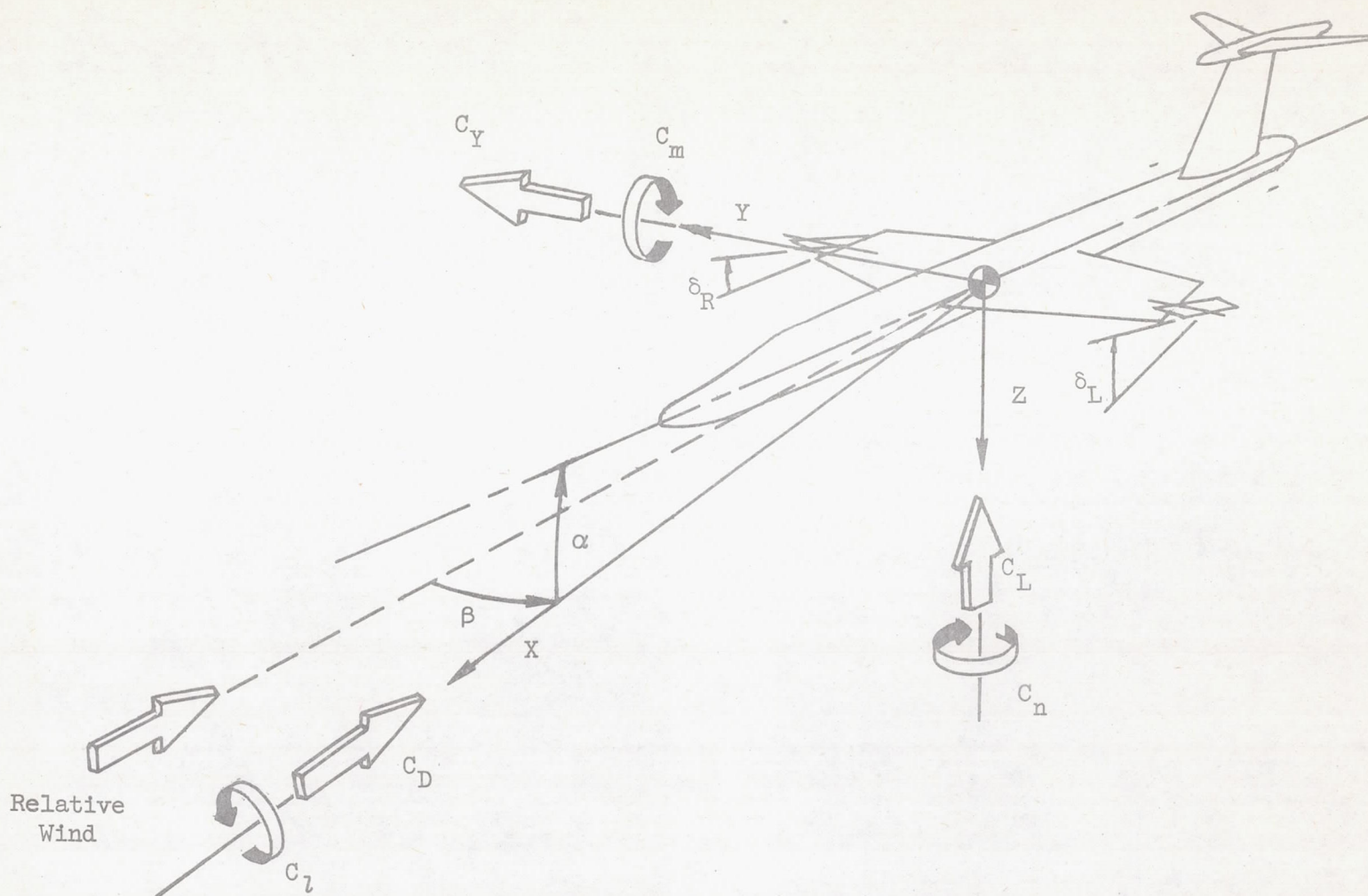
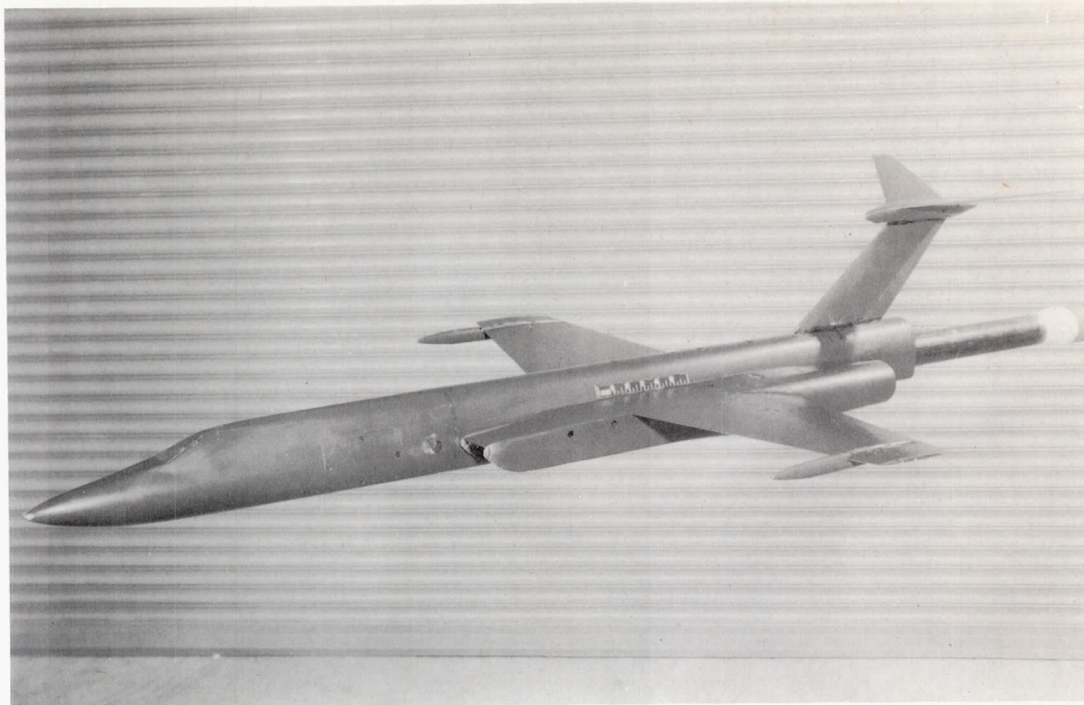
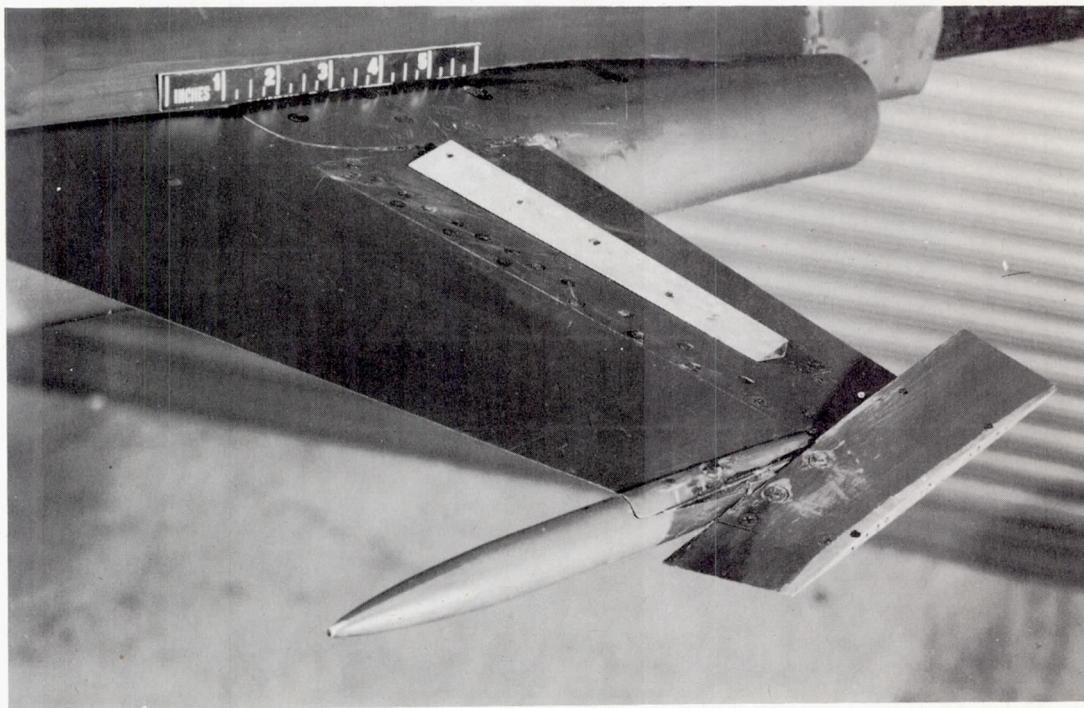


Figure 1.- System of axes and positive direction of forces, moments, and angles.



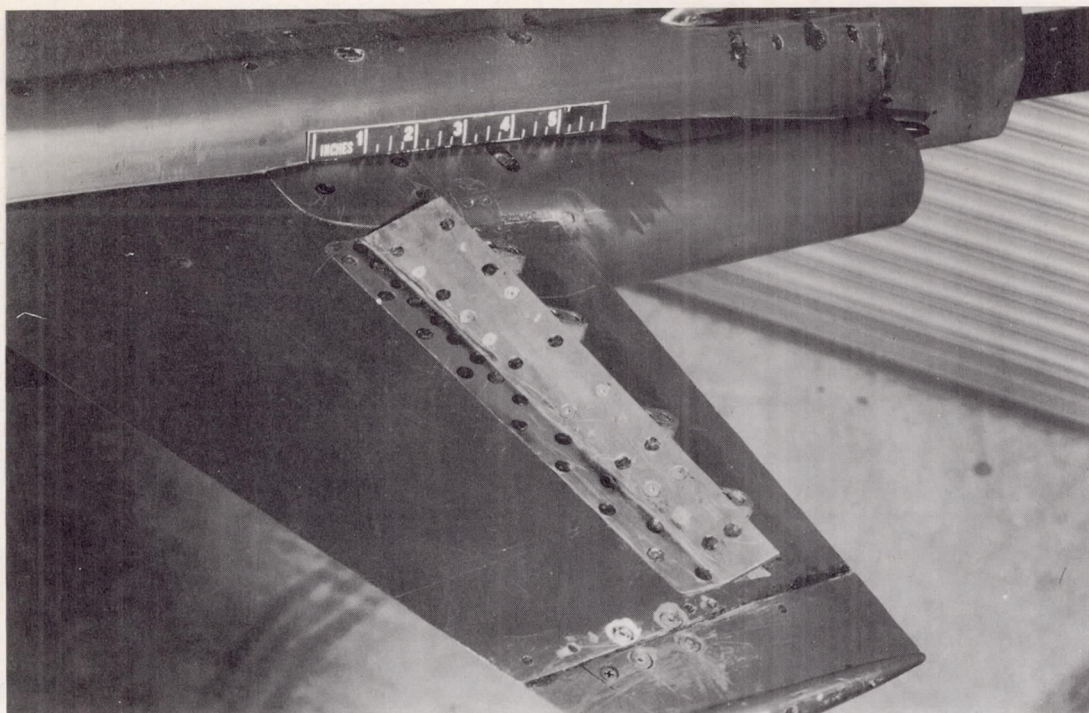
A-22344

Figure 2.- Three-quarter front view of the model with tip ailerons.



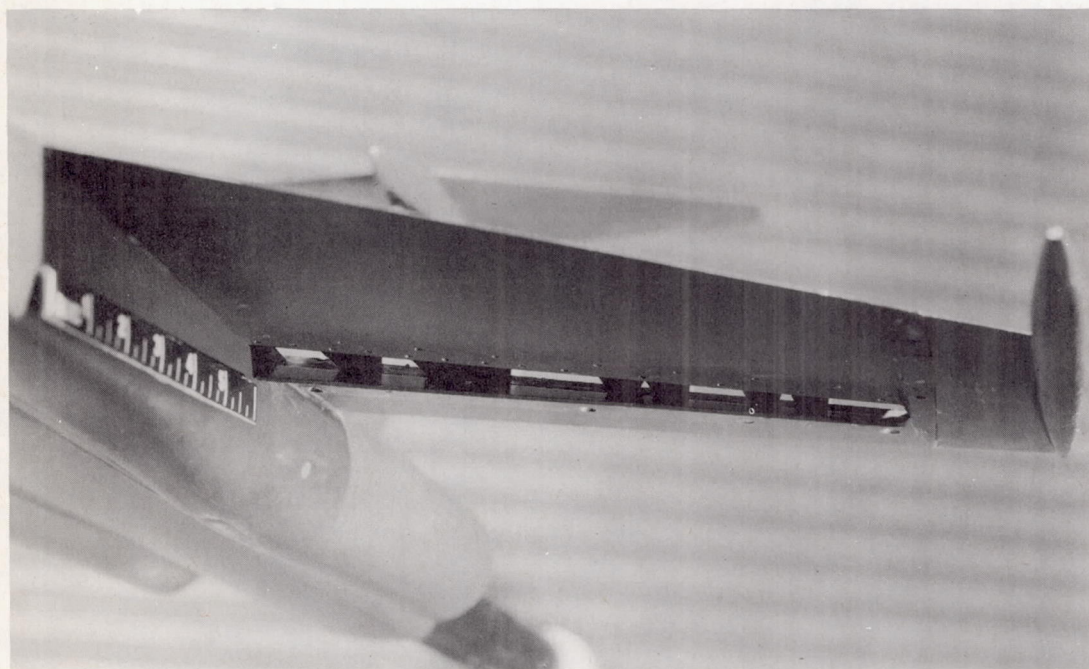
A-22347

Figure 3.- Detail of the tip aileron and plain spoiler.



(a) Spoiler on the upper surface.

A-22348



(b) Deflector on the lower surface; 29-percent blockage.

A-22349

Figure 4.- Detail of the vented spoiler.

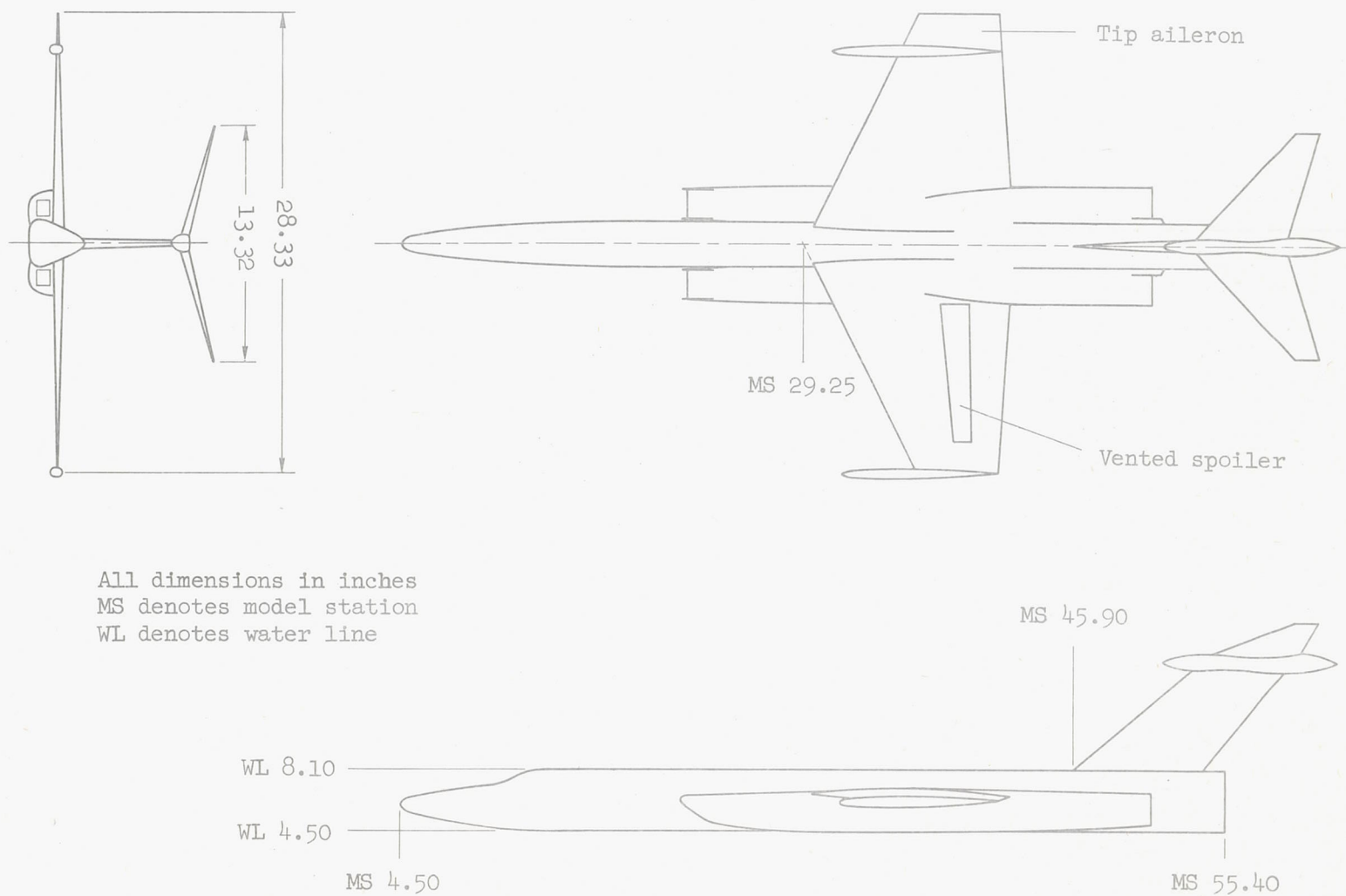


Figure 5.- Three-view sketch of the model.

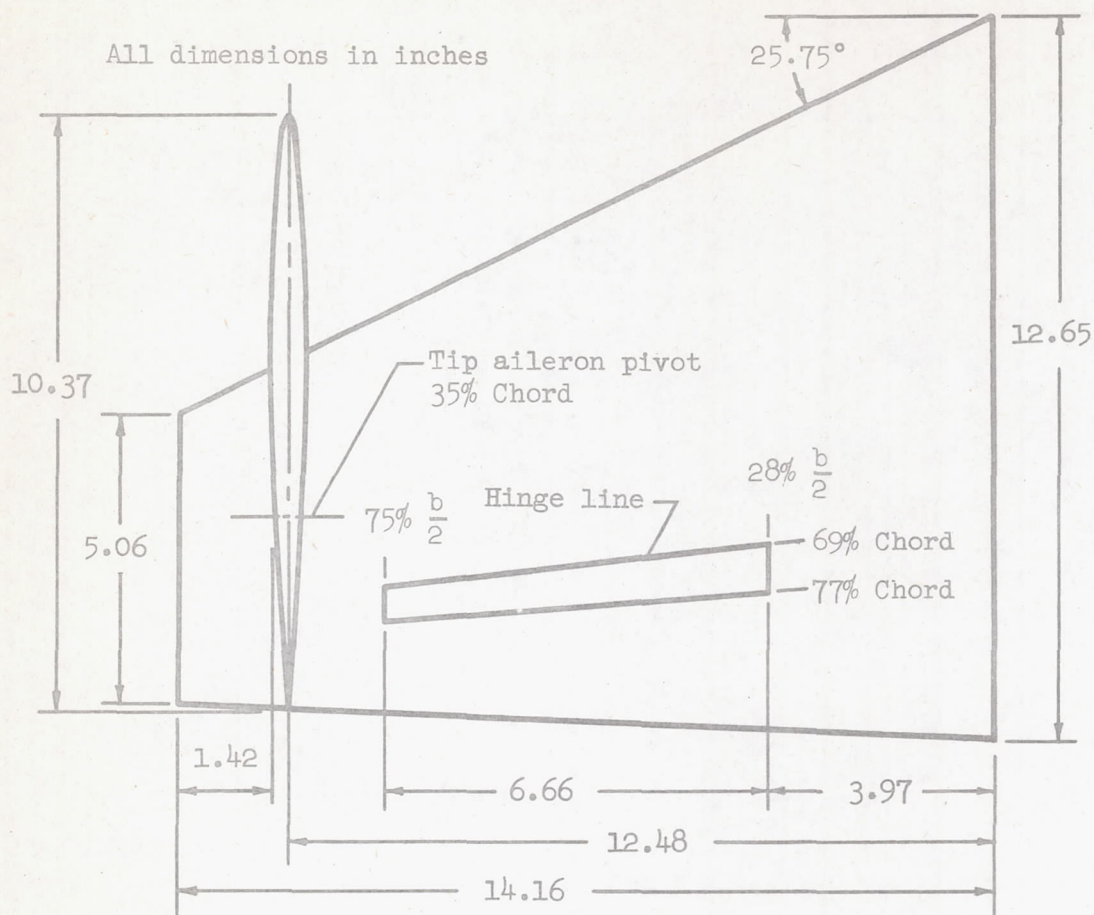


Figure 6.- Detail sketch of the tip aileron and plain spoiler.

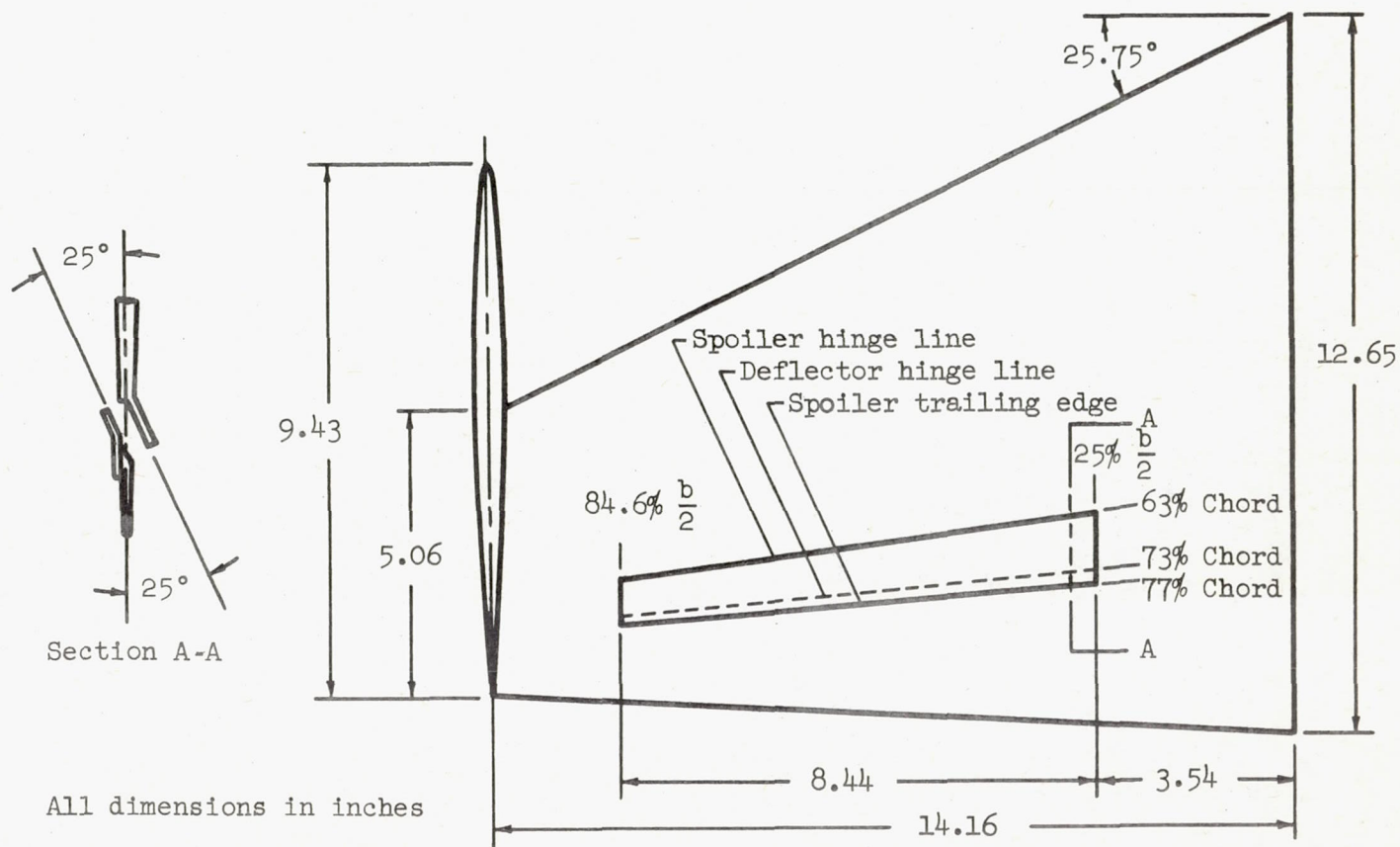


Figure 7.- Detail sketch of the vented spoiler.

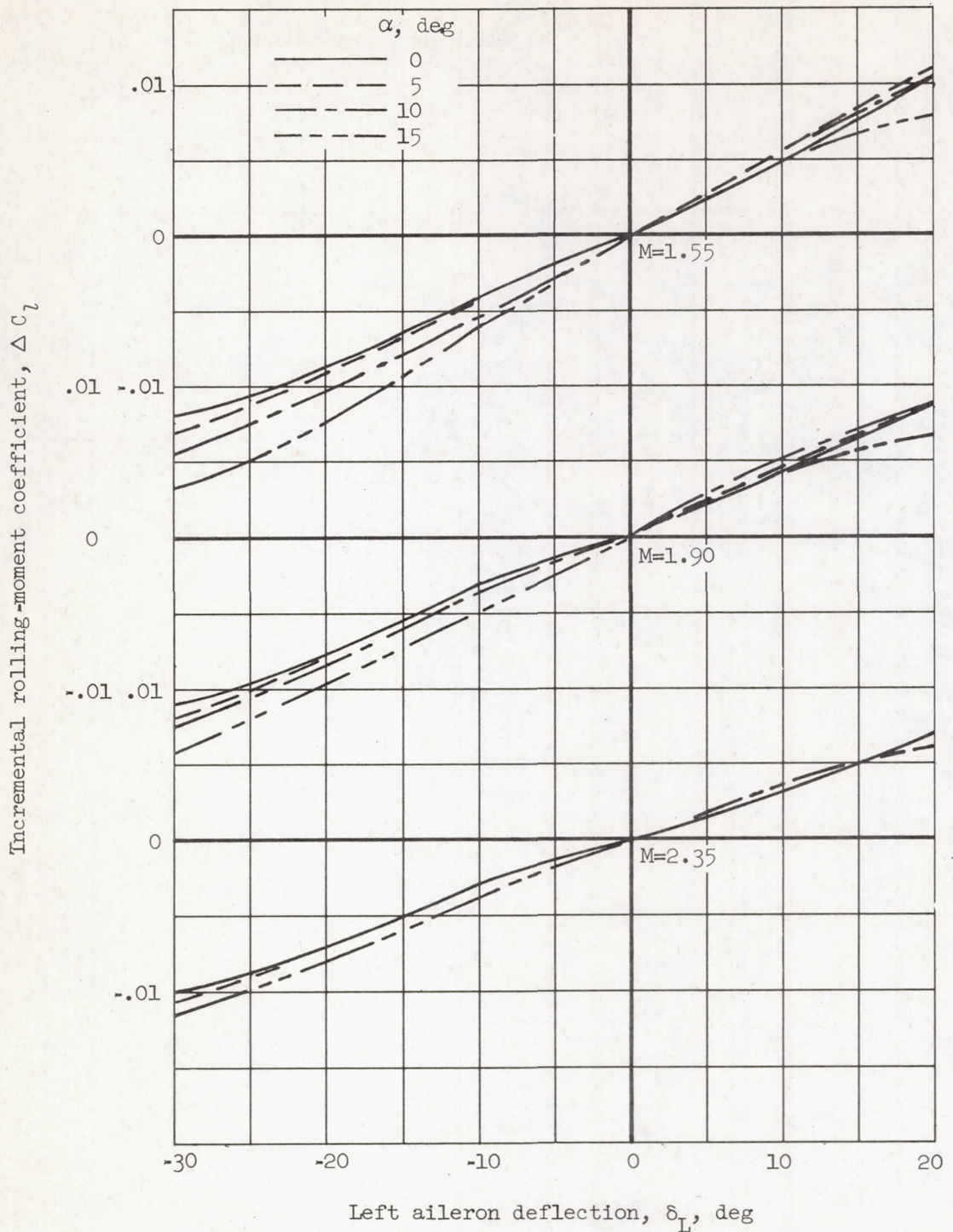


Figure 8.- The variation of incremental rolling-moment coefficient with left tip aileron deflection.

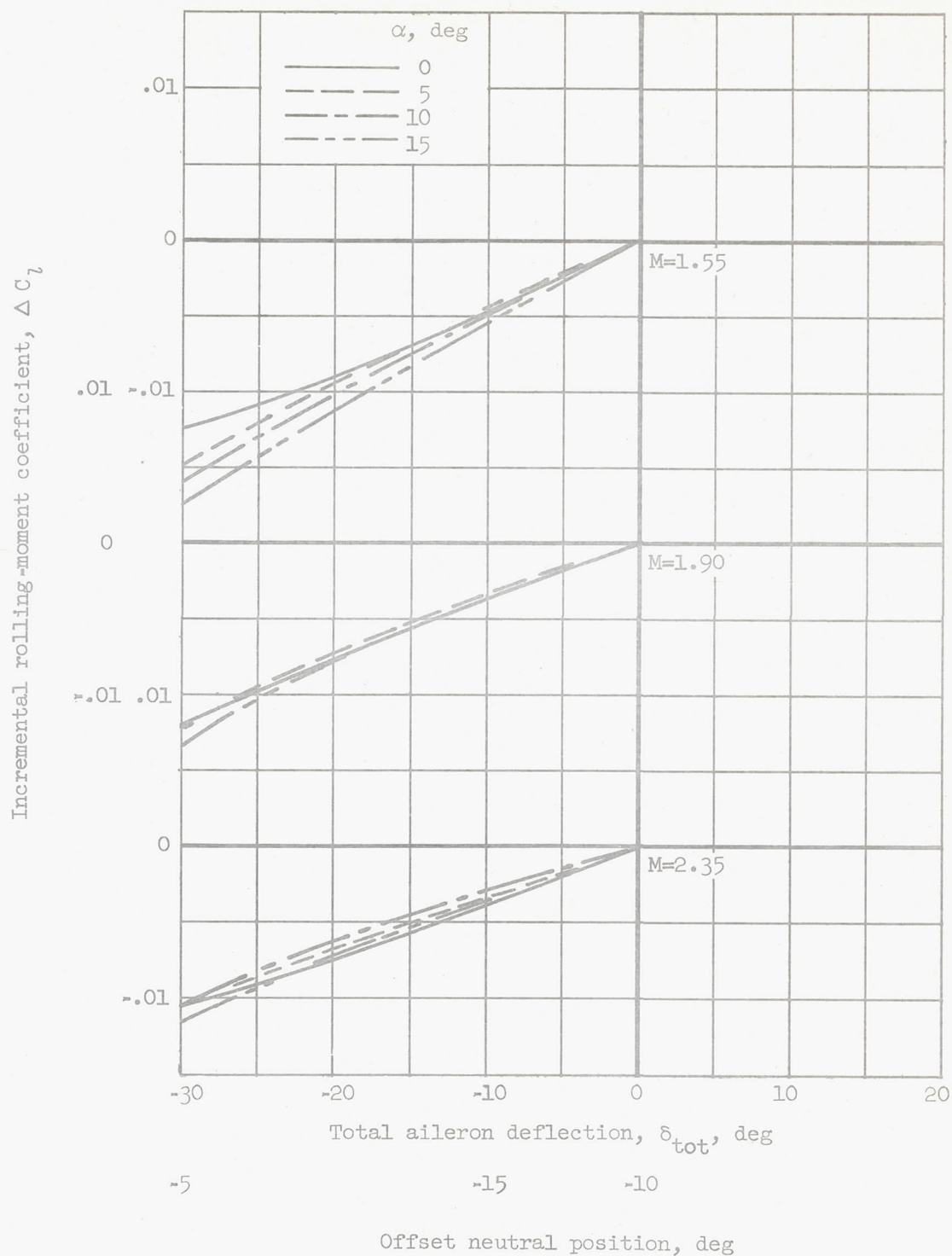


Figure 9.- The variation of incremental rolling-moment coefficient with total aileron deflection for various offset neutral positions.

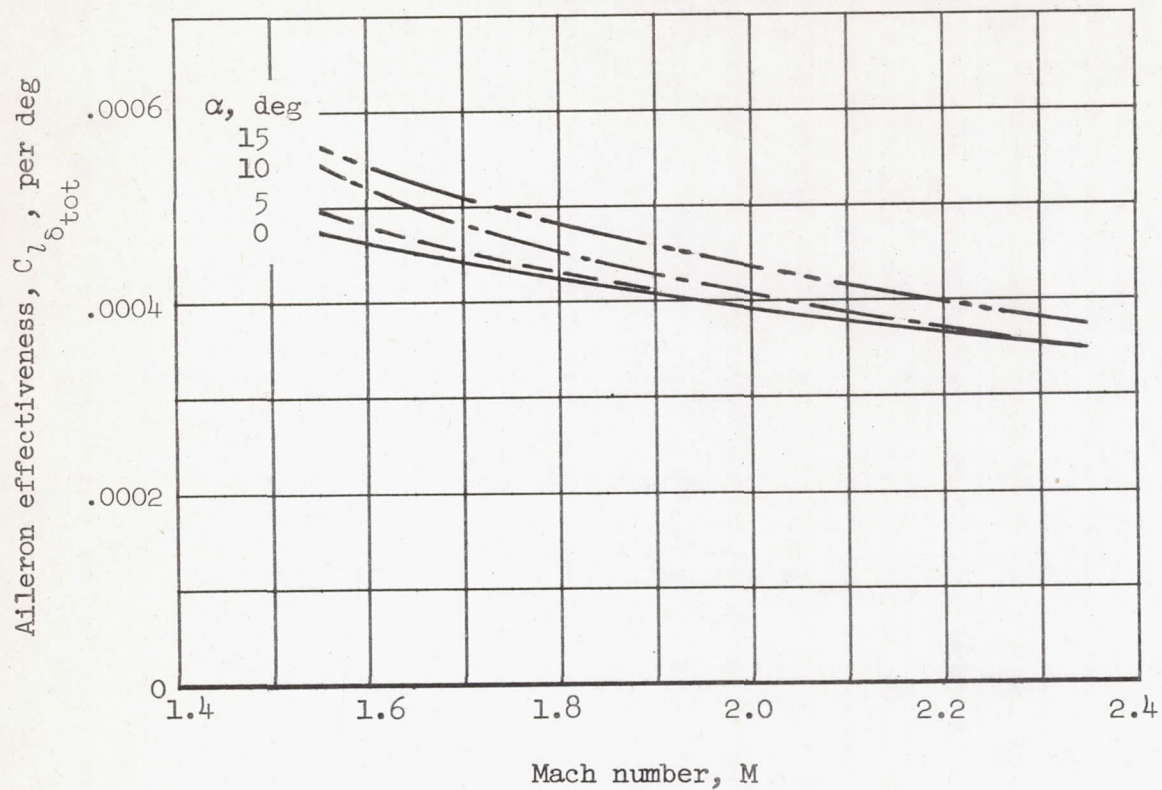


Figure 10.- The effect of Mach number on aileron effectiveness based on differential aileron deflection.

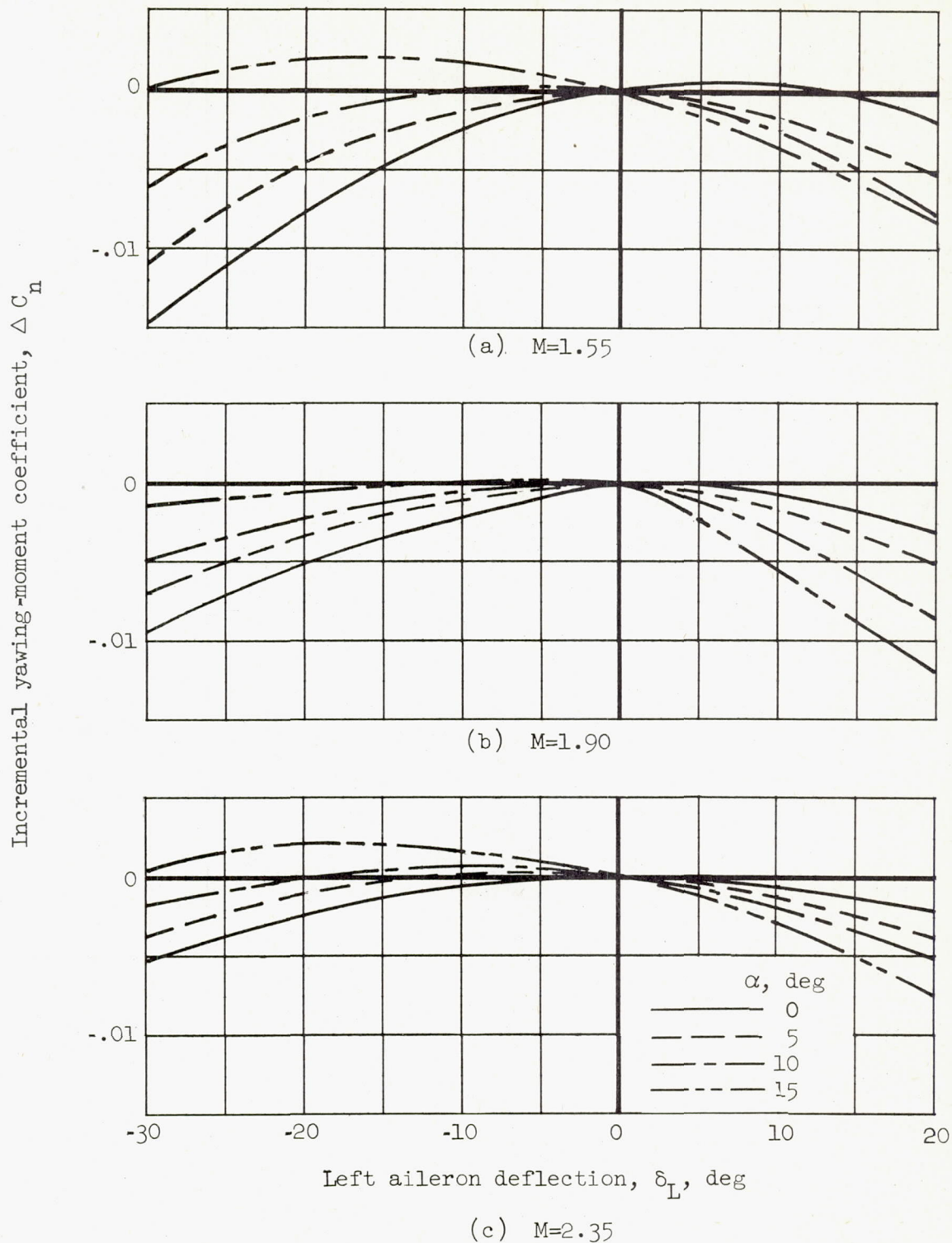


Figure 11.- The incremental yawing-moment coefficient due to left tip aileron deflection; $\beta \approx 0^\circ$.

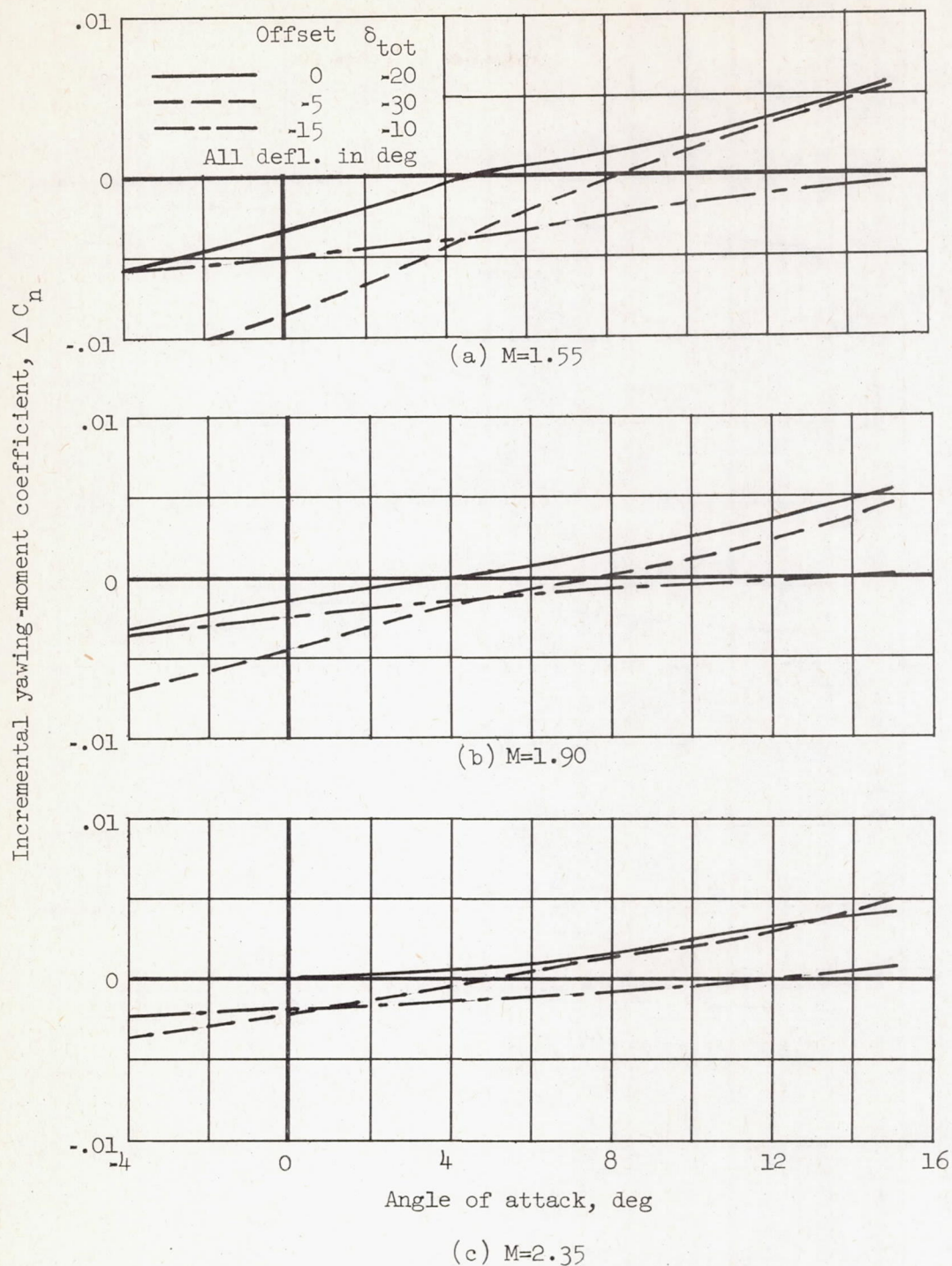


Figure 12.- The incremental yawing-moment coefficient due to total aileron deflection; $\beta \approx 0^\circ$.

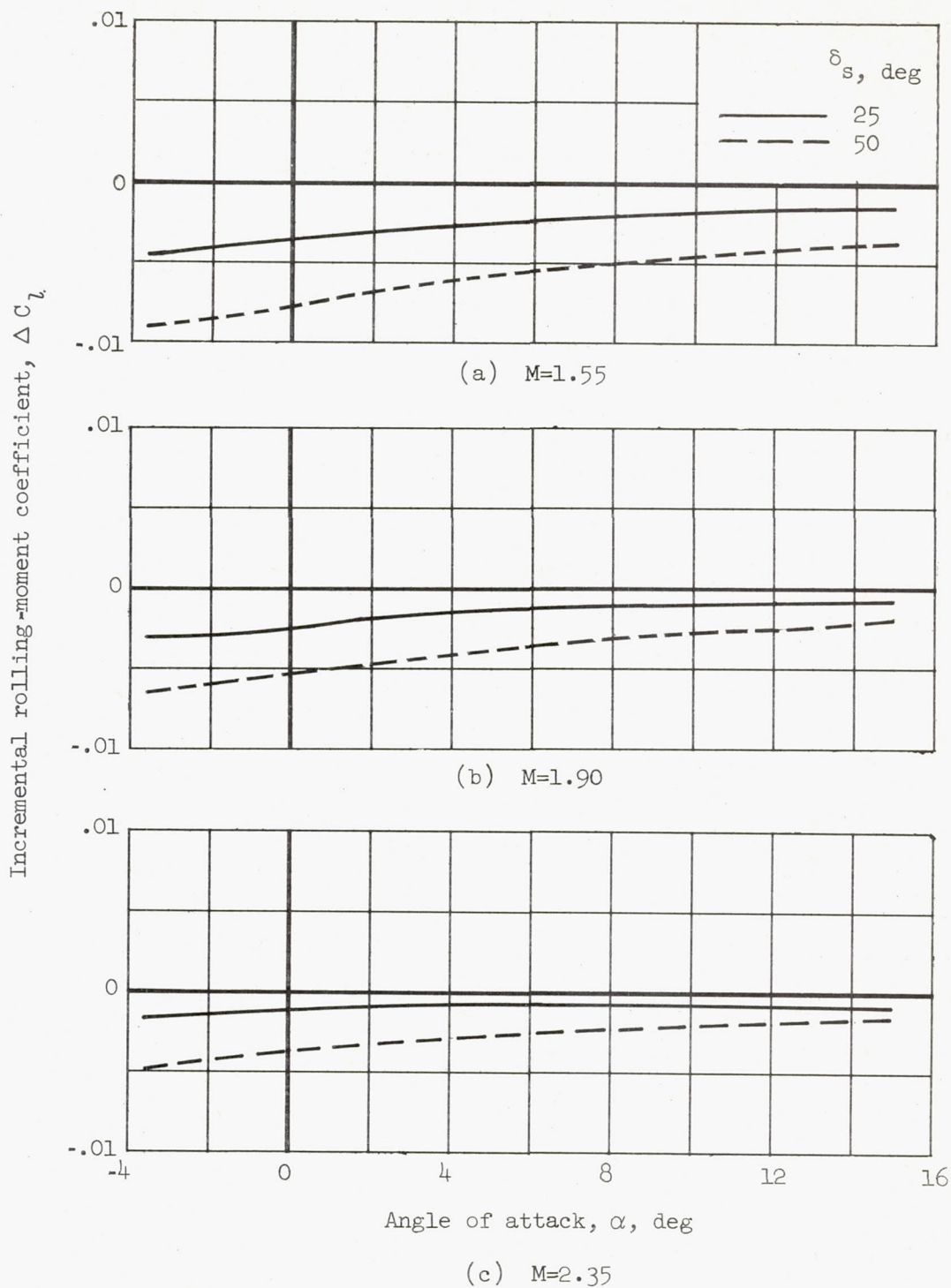


Figure 13.- The incremental rolling-moment coefficient for 25° and 50° deflection of the plain spoiler.

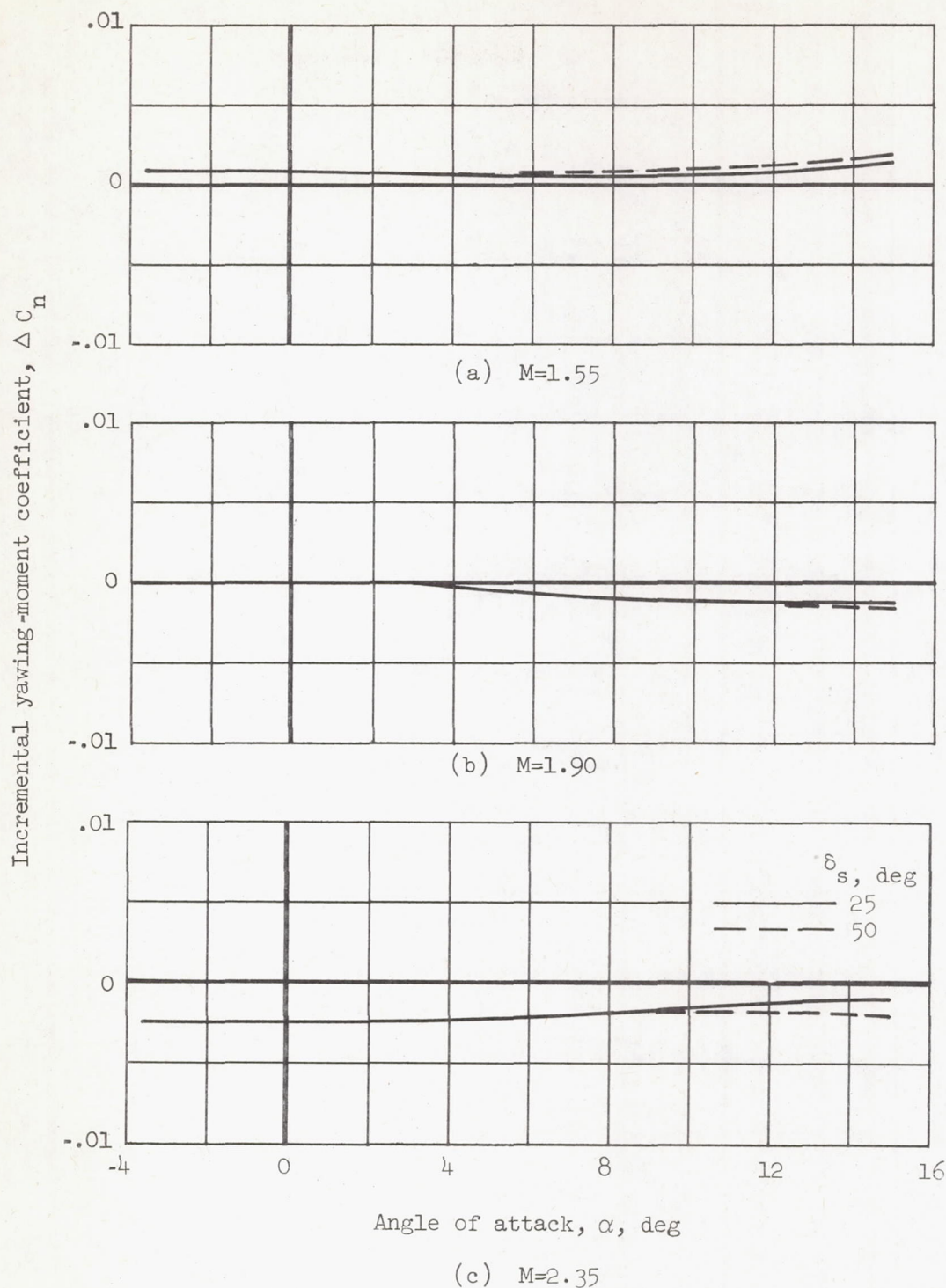


Figure 14.- The incremental yawing-moment coefficient due to 25° and 50° deflection of the plain spoiler; $\beta \approx 0^\circ$.

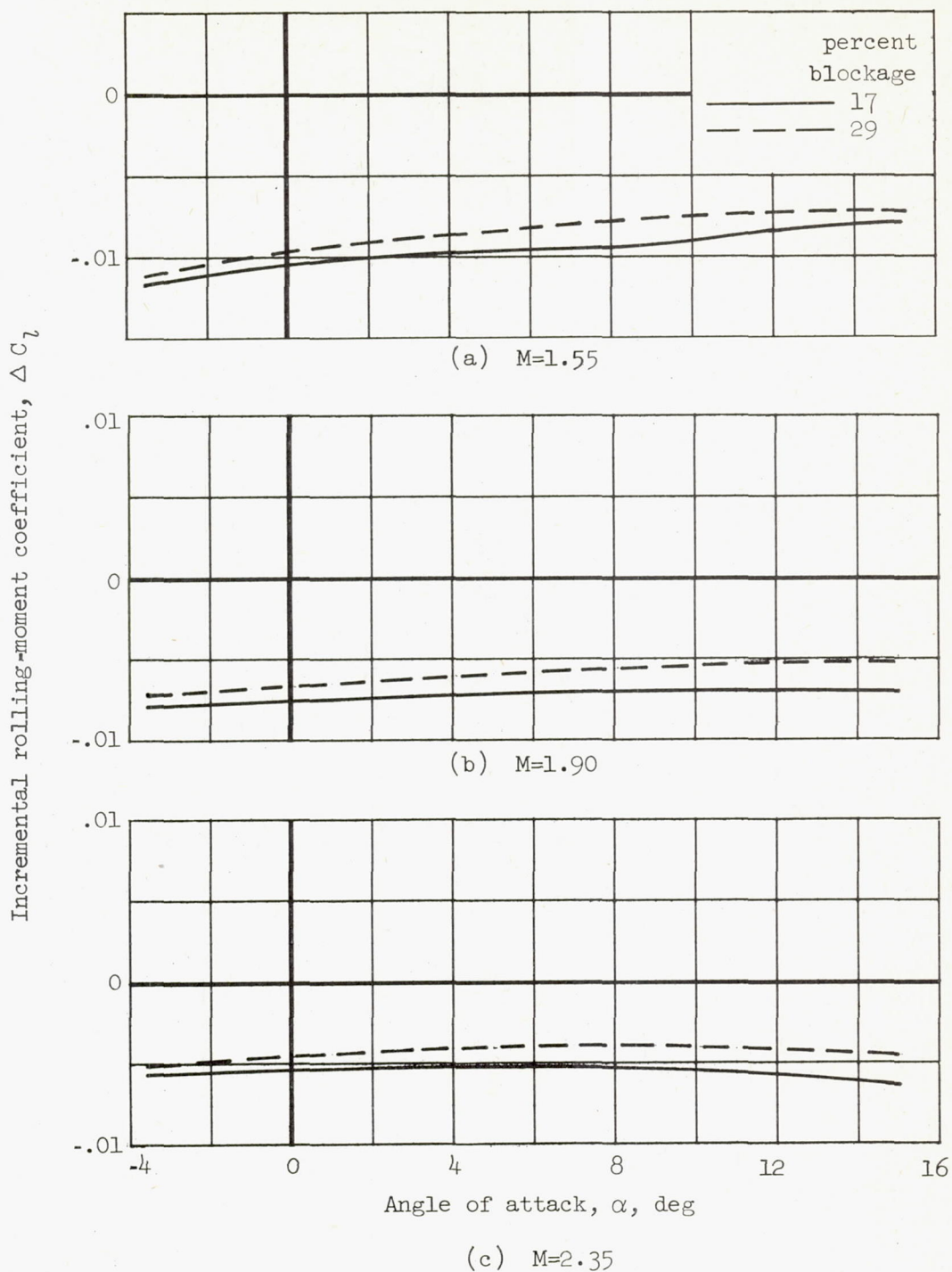


Figure 15.- The incremental rolling-moment coefficient for 25° deflection of the vented spoiler with 17- and 29-percent vent blockage.

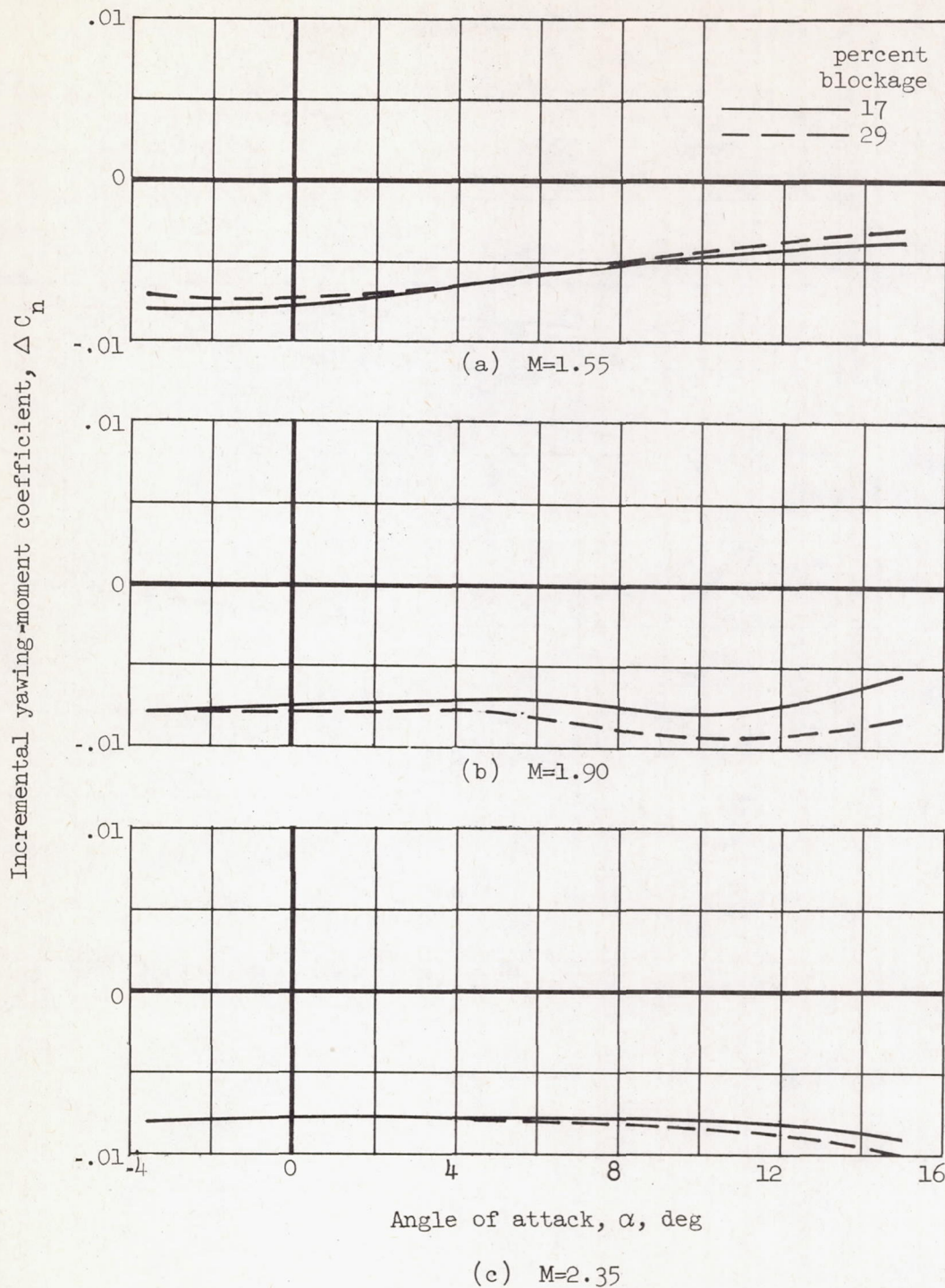


Figure 16.- The incremental yawing-moment coefficient due to 25° deflection of the vented spoiler with 17- and 29-percent vent blockage; $\beta \approx 0^\circ$.

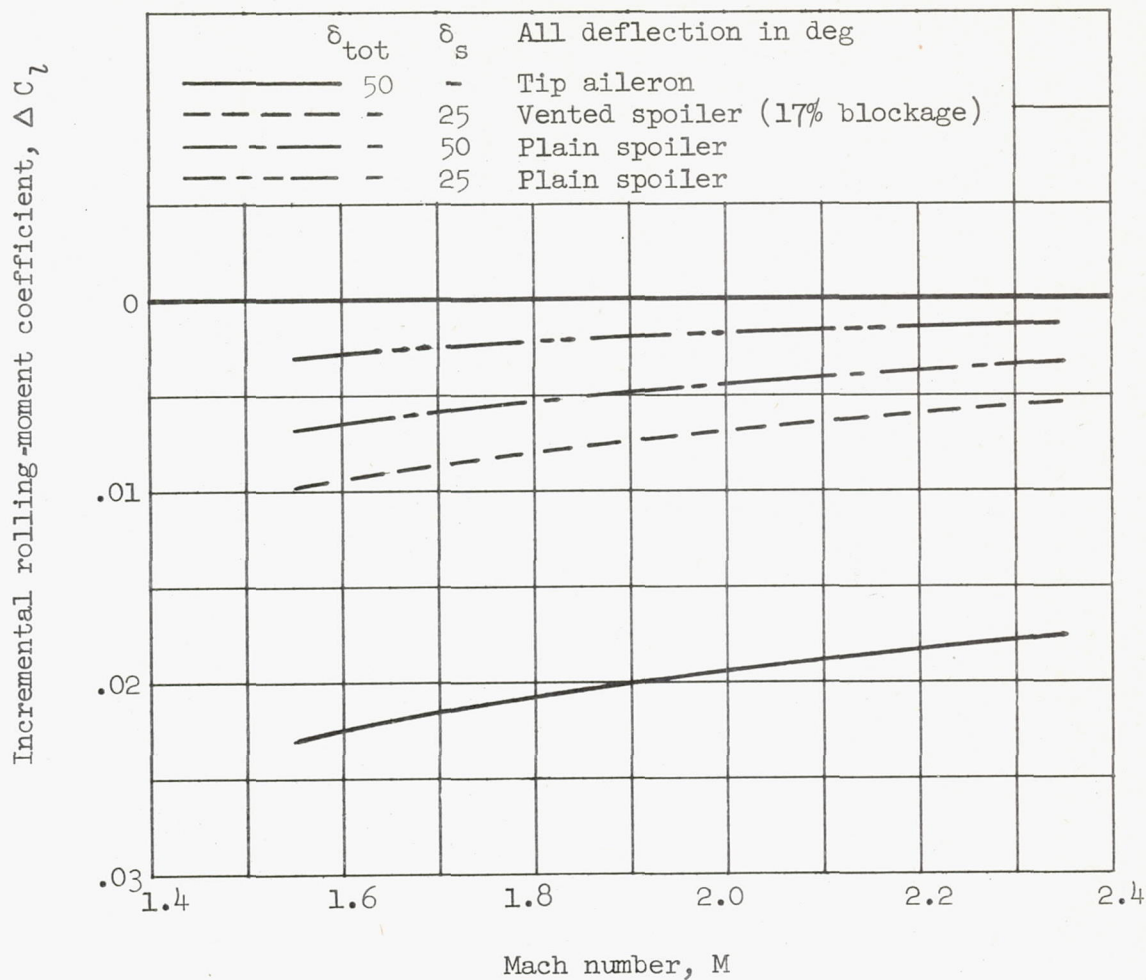


Figure 17.- The effect of Mach number on the incremental rolling-moment coefficient for several lateral control devices; $\alpha = 2^\circ$.

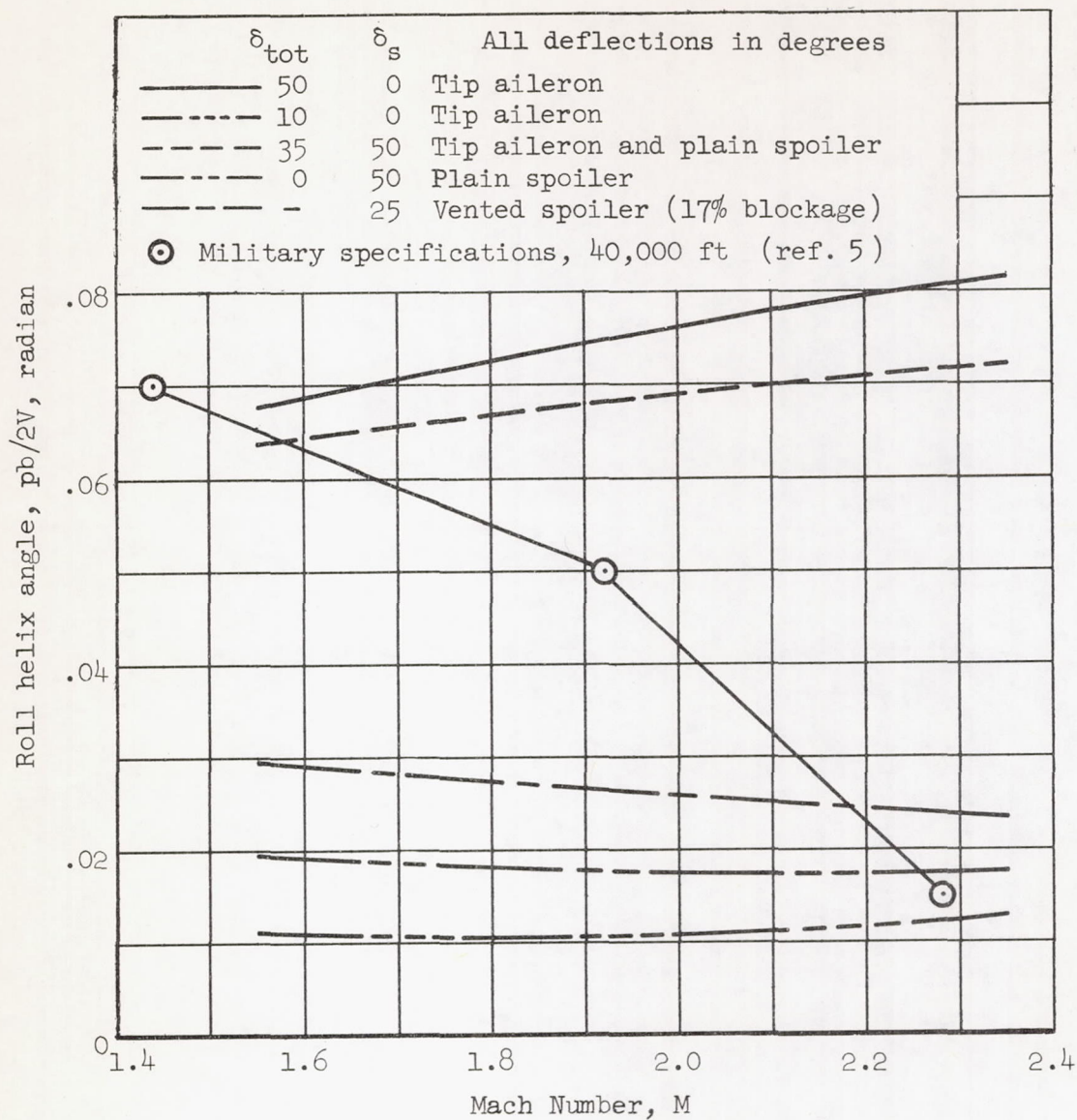


Figure 18.- Roll capability of the various lateral control systems; $\alpha = 2^\circ$.