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RESEARCH MEMORANDUM

THE EFFECT OF LOWER SURFACE SPOILERS ON THE TRANSONIC TRIM CHANGE OF A WIND-TUNNEL MODEL OF A FIGHTER AIRPLANE HAVING A MODIFIED DELTA WING

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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THE EFFECT OF LOWER SURFACE SPOILERS ON THE TRANSONIC TRIM CHANGE OF A WIND-TUNNEL MODEL OF A FIGHTER AIRPLANE HAVING A MODIFIED DELTA WING*

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SUMMARY

In an attempt to find an aerodynamic means of counteracting the transonic trim change of a fighter airplane, lower surface spoilers were tested on a 0.055-scale wind-tunnel model. The Mach number range of the tests was 0.8 to 1.2 at Reynolds numbers of approximately 4 million. Although the spoilers produced a moderate decrease in the trim change at low altitudes, they also produced a large increase in drag. Pressure-distribution tests with external fuel tanks showed large pressure changes on the lower surface of the wing due to the tanks.

INTRODUCTION

Tests were made of a 0.055-scale model of a fighter airplane to investigate a change of trim at transonic speeds which has produced accelerations up to 9g at 0.90 Mach number at low altitude. The trim change of the airplane was caused by two factors, a decrease of longitudinal stability with decreasing Mach number and an increase of control effectiveness with decreasing Mach number. The simultaneous decrease of airplane stability and increase of control effectiveness produce an unfavorable variation of elevon angle with Mach number, which can result in a severe pitch-up if the airplane is trimmed at a Mach number of 0.98 and then decelerated.

Wind-tunnel tests reported in reference 1 showed that installation of pylon-mounted external fuel tanks caused a variation of C_{m_O} with Mach number which reduced the trim change at low altitudes. In the present tests several configuration changes were investigation in an attempt to find one which would produce a variation of C_{m_O} with Mach number similar

*Title, Unclassified

to that produced by the tanks. The configuration changes included upper surface spoilers, lower surface spoilers, external tanks faired into the wings, canard surfaces, wing leading-edge flaps, wing fences, faired bumps on the lower surface near the fuselage, and pylons alone toed out 8°. Of these only the lower surface spoilers had a favorable effect, and the present report deals with the effects of spoilers at several positions on the lower surface of the wing, and with the effect of the external fuel tanks on pitching moment and pressure distribution.

SYMBOLS

b span

c local chord

$\bar{c}$ wing mean aerodynamic chord

C_D drag coefficient, $\frac{\text{drag}}{qS}$

C_{D_o} drag coefficient at zero lift

C_L lift coefficient, $\frac{\text{lift}}{qS}$

C_m pitching-moment coefficient, $\frac{\text{pitching moment about } 0.25\bar{c}}{qS\bar{c}}$

C_{m_o} pitching-moment coefficient at zero lift

ΔC_m pitching-moment coefficient increment

C_p pressure coefficient, $\frac{\text{local pressure minus free-stream static pressure}}{q}$

M free-stream Mach number

q free-stream dynamic pressure

S wing area

W airplane weight

x chordwise distance from the wing leading edge

y spanwise distance from the plane of symmetry

α model angle of attack

δ_e elevon deflection

Subscripts

s spoiler

w wing

MODEL AND EQUIPMENT

The steel model had duct inlets in the wing roots with passages to an annular exit about the sting mounting for simulating the inlet air flow of the airplane. Pressure orifices were provided for measuring wing pressure distribution, the static and total pressure in the ducts, and the static pressure at the duct exit. Figure 1 shows the model mounted in the wind tunnel, and figure 2 is a three-view drawing of the model.

Aerodynamic forces on the model were measured by means of an internal six-component balance which uses electrical-resistance strain gages as the sensing elements. The data were recorded directly on punch cards which were then processed in a digital computer.

The tests were conducted in the Ames 14-foot transonic wind tunnel which has a flexible throat and a perforated test section that permit operation at and near the speed of sound. Figure 3 shows the arrangement of the nozzle and test section.

TESTS

The lower surface spoilers were tested at three spanwise locations and at several chordwise locations. The relative sizes and locations of the spoilers are shown in figure 4, and figure 5 presents a photograph of the model with one of the spoilers installed. An external fuel tank mounted on the model is shown in figure 6.

The tests covered a Mach number range from 0.80 to 1.20 at a Reynolds number of 4×10^6, and the angle of attack was varied from -2° to 8°. Lift and drag coefficients were computed from the measured axial and normal forces. Pitching-moment coefficients were computed for a center-of-gravity location of 25-percent wing mean aerodynamic chord. Chordwise pressure distribution was measured at four stations on the upper surface and at five stations on the lower surface of the wing.

By testing the model both upright and inverted it was found that an upflow existed in the test region at Mach numbers of 1.10 and 1.20, and the data have been corrected for this upflow. The correction was $\Delta\alpha = 0.1^{\circ}$ at $M = 1.10$ and $\Delta\alpha = 0.3^{\circ}$ at $M = 1.20$.

A base-pressure correction based on the pressure inside the balance and the cross-sectional area of the sting was applied to the axial force measurements before the coefficients were computed. Pressure measurements inside the ducts and at the annular exit were used to compute the force on the model due to the duct flow. It was found that the duct force was equivalent to a drag coefficient of approximately 0.0010 at $\alpha = 0^{\circ}$. The data have not been corrected for the effect of the duct flow.

Jet-boundary corrections have not been applied to the data.

RESULTS

The basic force data obtained in the tests are presented in figures 7 through 15 as angle of attack, pitching-moment coefficient, and drag coefficient plotted against lift coefficient for constant Mach numbers. Data for the basic model, shown in figure 7, include both upright and inverted positions corrected for upflow. The data shown in figure 8 are for the tanks-on configuration. Figures 9 through 14 present data for the various spoiler configurations and zero elevon deflection. The data of figure 15 are for the spoiler L_3 and an elevon deflection of -5°.

Chordwise pressure distribution at five spanwise stations is shown in figure 16 for the model with and without external fuel tanks. Data are presented at an angle of attack of 1° for Mach numbers from 0.90 through 1.00.

The variation of pitching-moment coefficient with Mach number at level-flight lift coefficients for three different altitudes is shown in figure 17 for the various test configurations.

A comparison of control effectiveness with and without spoiler L_3 is presented in figure 18. The curves for the model with spoiler were obtained from the data of figures 9 and 15, while those for the basic model were taken from the data of reference 1.

The effects of spoiler location on the drag and pitching-moment characteristics of the model are shown in figures 19 and 20, respectively. Figure 19 shows the variation of zero-lift drag coefficient with Mach number for each of the configurations. Figure 20, where pitching-moment coefficient increment is plotted against the chordwise and spanwise locations of the spoilers, gives an indication of the effect of spoiler location on pitching moments.

DISCUSSION

When accelerating through the transonic speed range this airplane experiences an increase in static longitudinal stability as shown by the data of figure 7(c). The effect of the stability change is shown more clearly by the variation with Mach number of the pitching-moment coefficient for level flight, which is plotted in figure 17(a) for a wing loading of 33 pounds per square foot.

The pitching-moment change plus the large decrease in elevon effectiveness shown in figure 18 requires rapidly increasing up elevon to maintain level flight as the Mach number is increased from 0.94 to 0.98. Rapid deceleration through this range of Mach numbers can produce a severe pitch-up which will result in excessively high load factors at low altitudes.

Effect of External Fuel Tanks

With the external fuel tanks installed on the model there is a positive C_{m_0} shift with increasing Mach number which is shown in figure 8(c). Except for Mach numbers between 0.98 and 1.00, the effect of this shift is to produce a favorable variation of pitching-moment coefficient with Mach number at lift coefficients for level flight at altitudes up to 20,000 feet; but, as may be seen in figure 17(b), the effect of the stability change on C_m at the higher lift coefficients is so great that at an altitude of 45,000 feet there is only a slight improvement over the basic model.

The external tanks produce the above effects on the model by altering the pressure distribution as shown in figure 16. The field of accelerated flow about the tanks and pylons results in a region of low pressure on the lower surface of the wing. As the Mach number increases from 0.90 to 0.98 the low pressure area spreads toward the trailing edge of the wing to produce positive increments in pitching-moment coefficient.

The external tanks caused a large increment in zero-lift drag coefficient. Comparison of figures 19(a) and 19(b) shows that C_{D_0} is increased by about 29 percent at $M = 0.80$ and by about 27 percent at $M = 1.00$.

Effect of Spoilers

The purpose of the spoilers was to produce a C_{m_o} shift similar to that of the external tanks but with a smaller drag penalty. Figure 9(c) shows that spoiler L_3 did cause a positive C_{m_o} shift beginning at $M = 0.94$ and increasing to $M = 1.00$. By comparing figures 17(a) and 17(c) it can be seen that the spoilers L_3 had a negligible effect on the pitching moment up to a Mach number of 0.94 but from $M = 0.94$ to $M = 1.00$ the slope of the curves was reversed from that of the basic model for altitudes up to 20,000 feet. However, as in the case of the tanks, the effect was much reduced at the lift coefficients required for level flight at 45,000 feet. Also, the greater and more abrupt loss of elevon effectiveness in the presence of the spoiler, as shown in figure 18, would partially counteract the effect on the pitching-moment coefficient.

Although the spoiler L_3 had a considerably smaller effect on the pitching-moment characteristics of the model than the tanks, it produced a larger increment in zero-lift drag coefficient at Mach numbers up to 0.96, as shown in figure 19. At $M = 1.00$ to 1.10 the drag of the spoilers was about 50 to 70 percent as great as that of the tanks. In an attempt to reduce their drag increment, the span and area of the spoilers were decreased by about 37 percent. The data of figures 17 and 19 show that at a Mach number of 1.00 this modification, L_{3a}, when compared to the original spoiler L_3, reduced the pitching-moment increment by about 7 percent and the zero-lift drag increment by about 16 percent.

In order to partially determine the effect of spoiler location, spoiler L_{3a} was tested at four other positions designated as A, B, C, and D on the figures. The data of figure 19 indicate that the position of the spoilers had little effect on the zero-lift drag coefficient. However, the magnitude of the pitching-moment increments due to the spoilers was affected appreciably by position as was the variation with Mach number of the pitching-moment coefficient for level flight, which is shown in figure 17. From the summary plots of figure 20 it is apparent that the pitching moment is more sensitive to chordwise position of the spoilers than to their spanwise location. In general, for the portion of the wing covered in the tests, moving the spoilers outward or rearward will produce a positive increment in the pitching-moment coefficient. Also, the pitching-moment increment due to the spoilers develops at a lower Mach number for the aft position.

The spoiler L_{3a} at position A was flight tested. Unpublished flight data show that, in terms of elevon angle required for trim, the spoilers were about 50 percent as effective as the external fuel tanks in reducing the transonic trim change at an altitude of 8000 feet.

CONCLUDING REMARKS

Results of wind-tunnel tests of several lower surface spoiler configurations on a model of a modified delta-wing fighter airplane showed that addition of the spoilers produced a positive pitching-moment increment at transonic speeds which alleviated a transonic trim change. Moving the spoilers rearward increased their effectiveness. There was a loss of elevon effectiveness associated with the spoilers which reduced their beneficial effect. Low altitude flight tests indicate the spoilers to be about 50 percent as effective as external fuel tanks in reducing the trim change at transonic speeds.

The drag increment due to the spoilers was relatively large and was affected very little by the location of the spoilers.

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif., Oct. 7, 1958

REFERENCE

1. Drake, D. E.: Summary and Stability and Control Analysis of Transonic Wind-Tunnel Tests of the Model F4D-1 Airplane. Douglas Rep. No. ES 26179, Feb. 16, 1956.

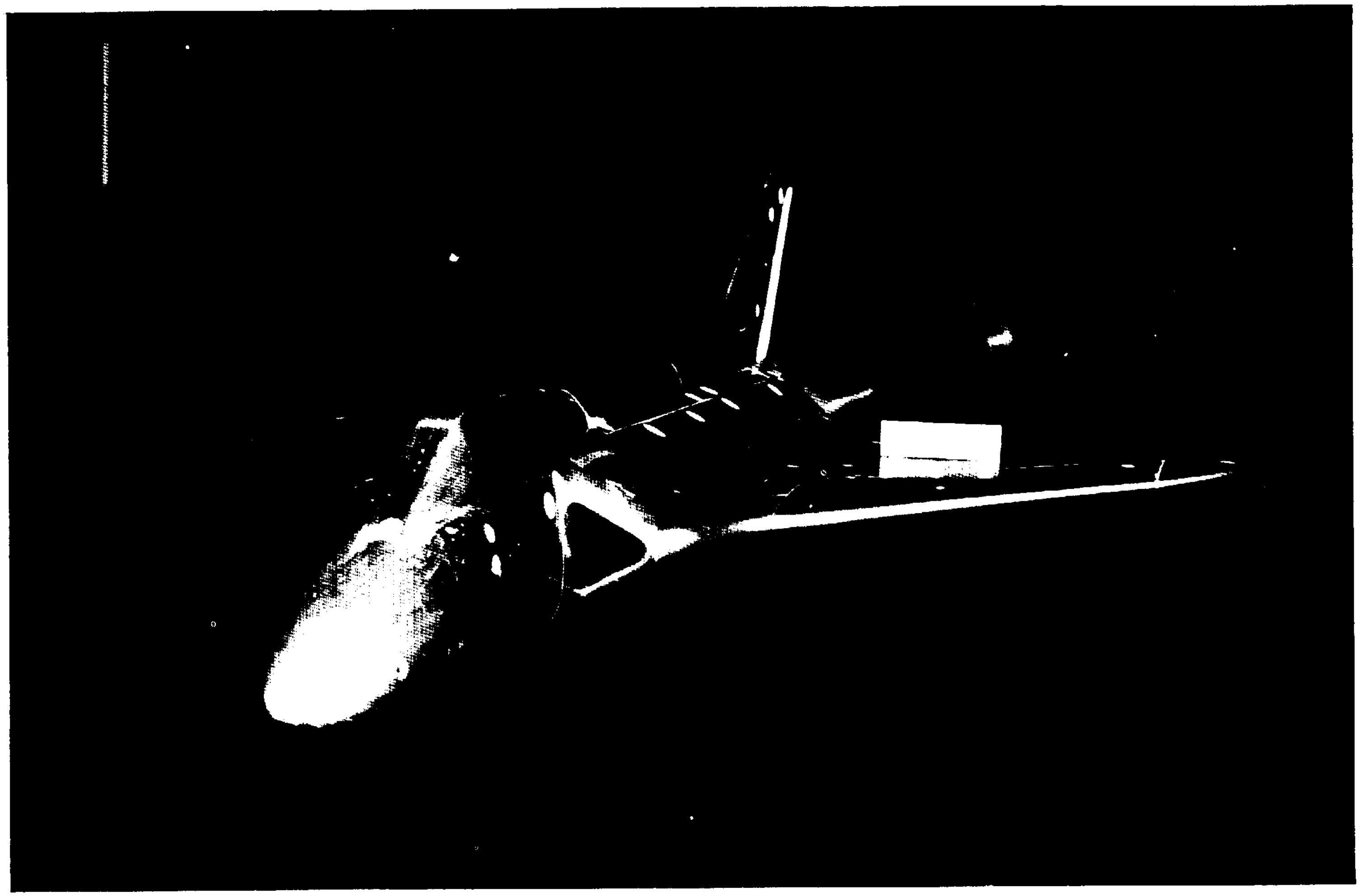

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Figure 1.- The model mounted in the Ames 14-foot transonic wind tunnel.

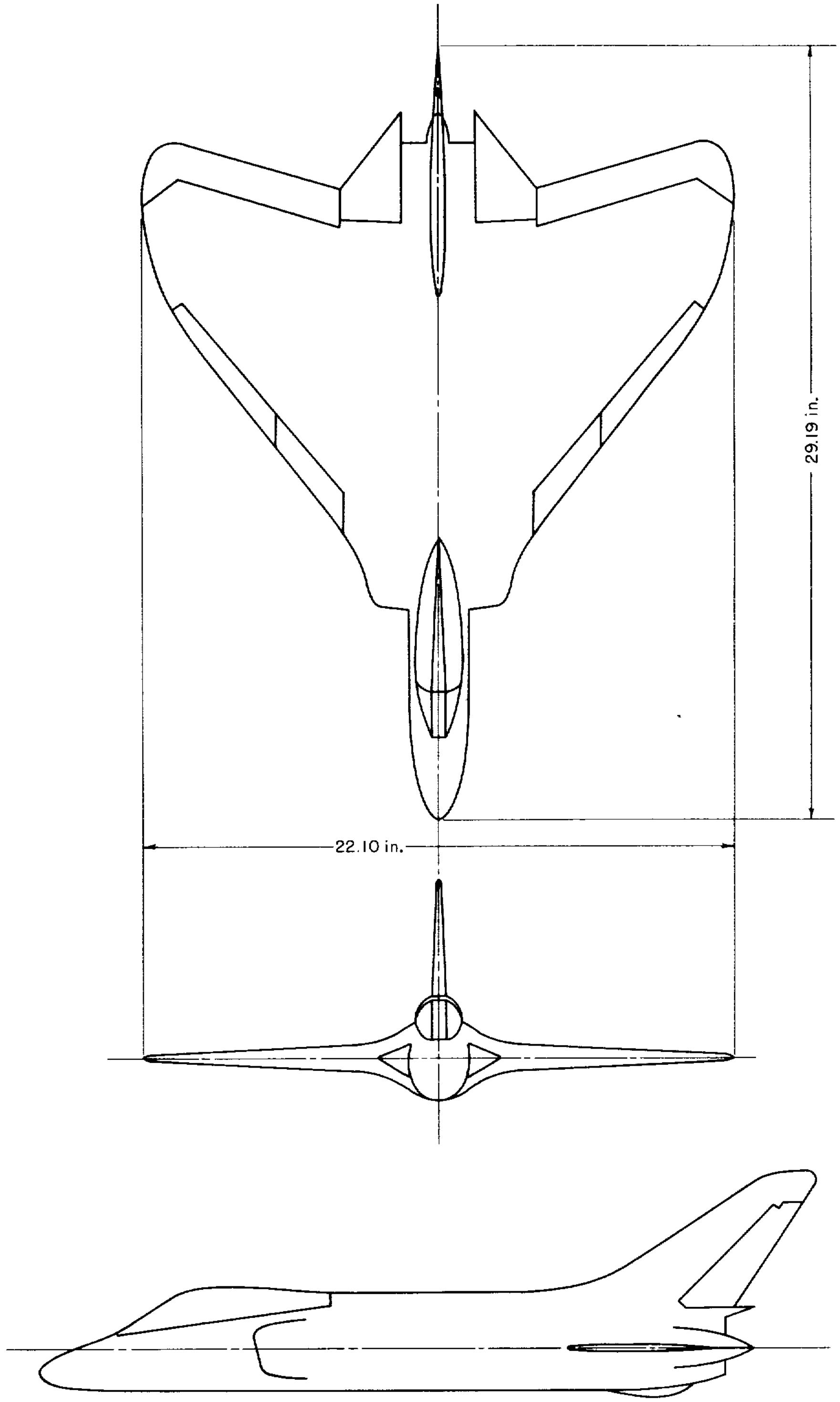


Figure 2.- Dimensions of the airplane model.

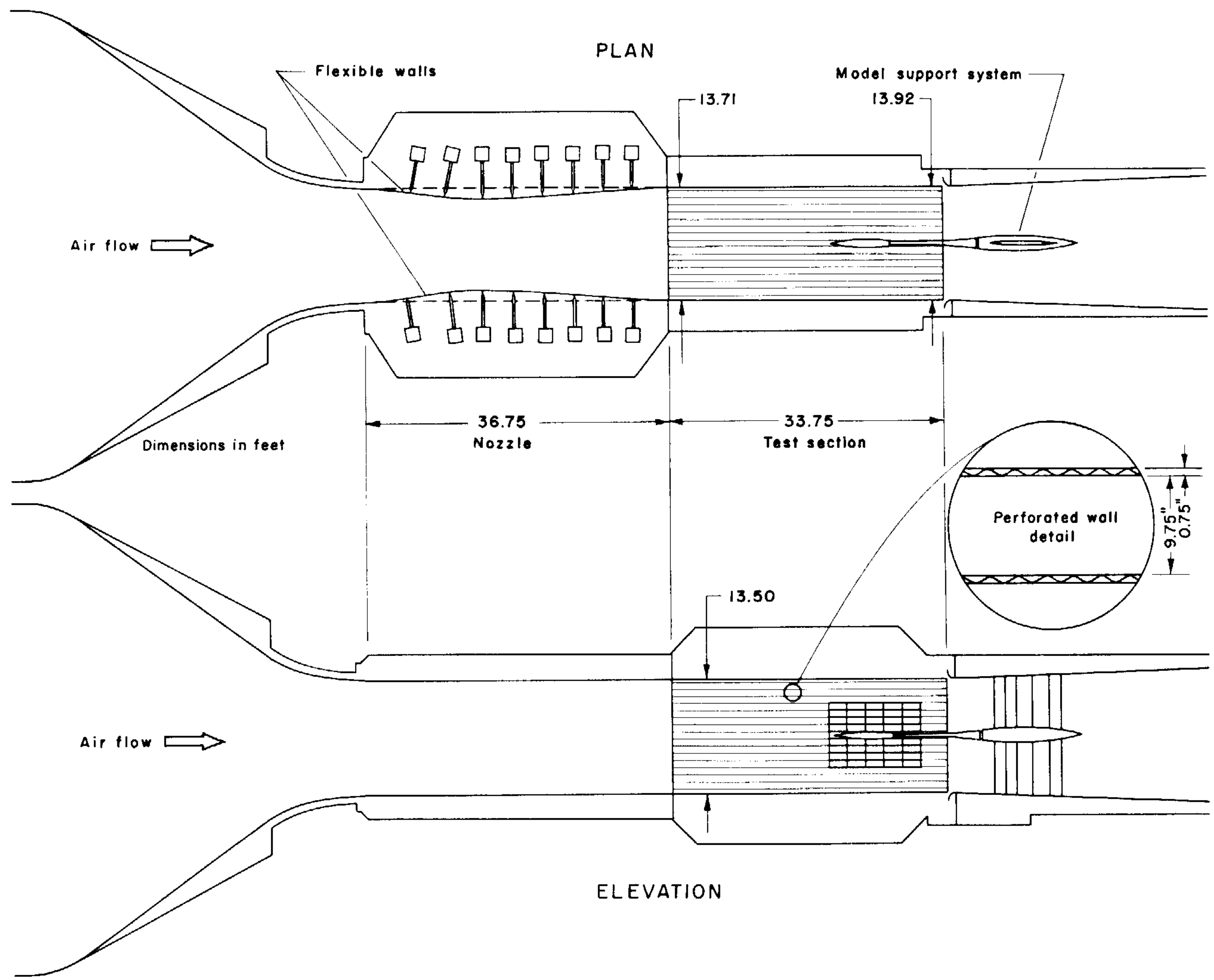
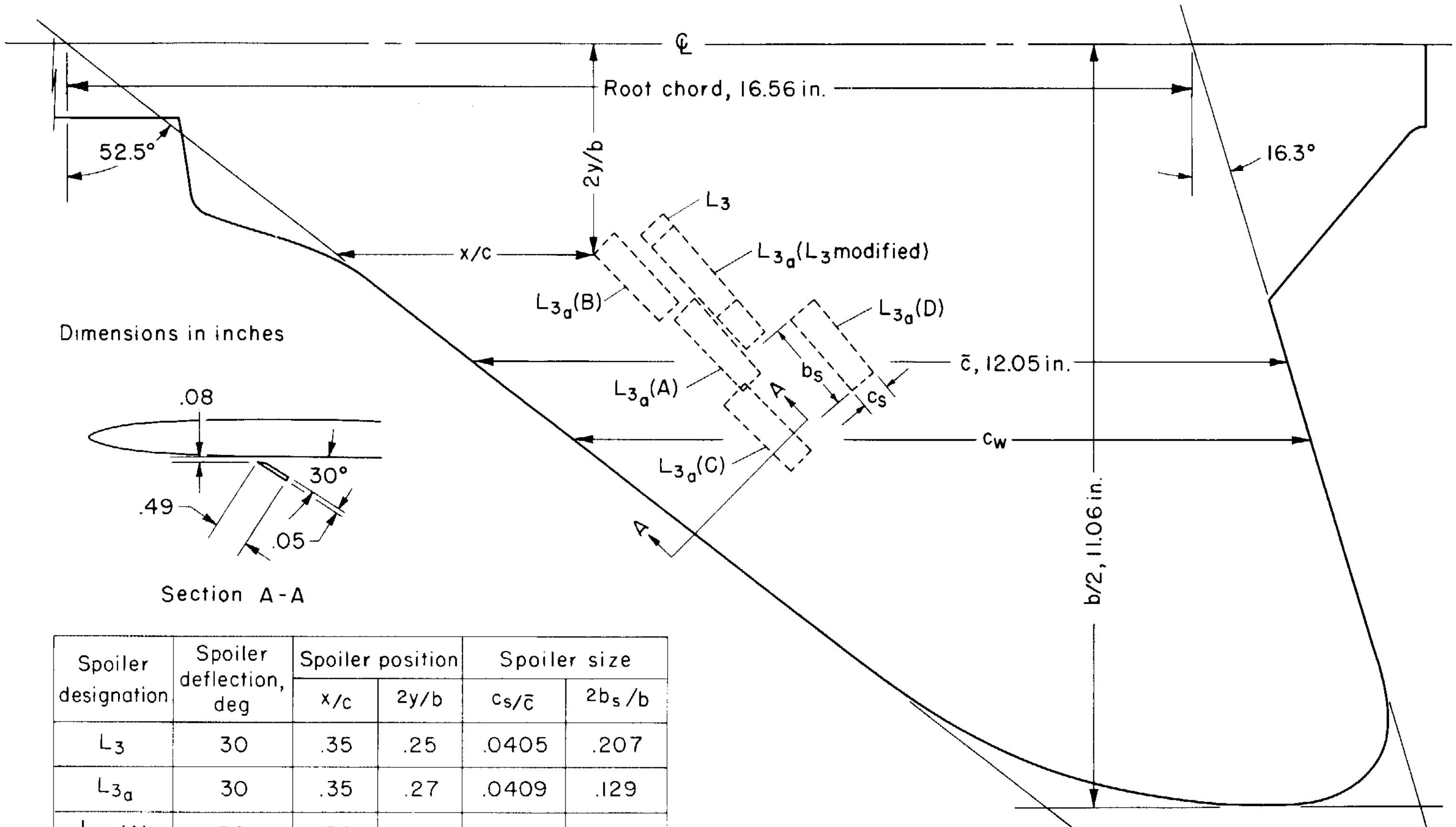


Figure 3.- General arrangement of the test section of the Ames 14-foot transonic wind tunnel.



Spoiler designation	Spoiler deflection, deg	Spoiler position		Spoiler size	
		x/c	2y/b	$c_s/\bar{c}$	$2b_s/b$
L_3	30	.35	.25	.0405	.207
L_{3_a}	30	.35	.27	.0409	.129
L_{3_a}(A)	30	.30	.38	.0409	.129
L_{3_a}(B)	30	.28	.27	.0409	.129
L_{3_a}(C)	30	.25	.47	.0409	.129
L_{3_a}(D)	30	.43	.38	.0409	.129

Figure 4.- The location of lower surface spoilers on the model.

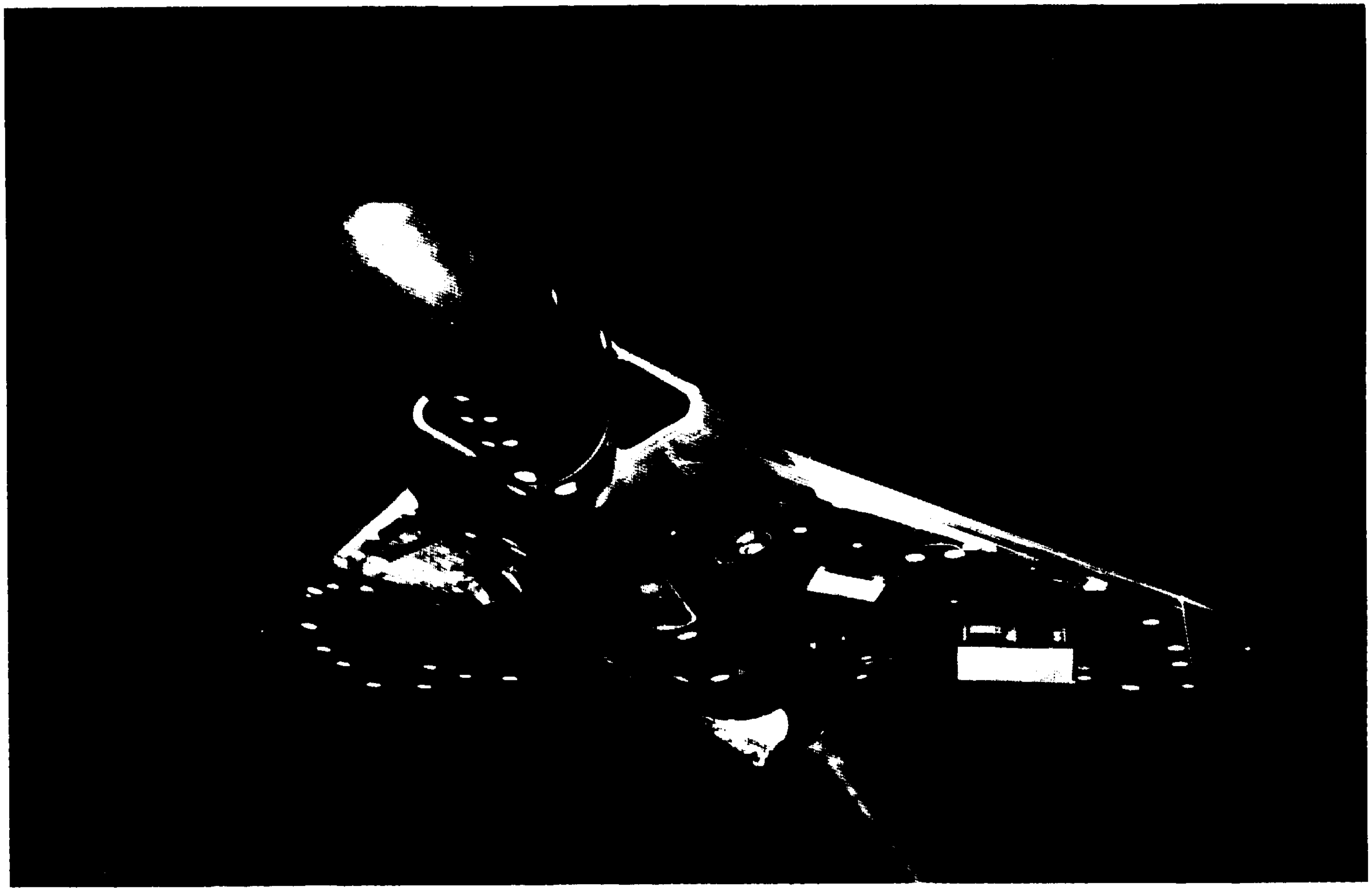


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Figure 5.- The model with spoilers mounted on the lower wing surfaces.

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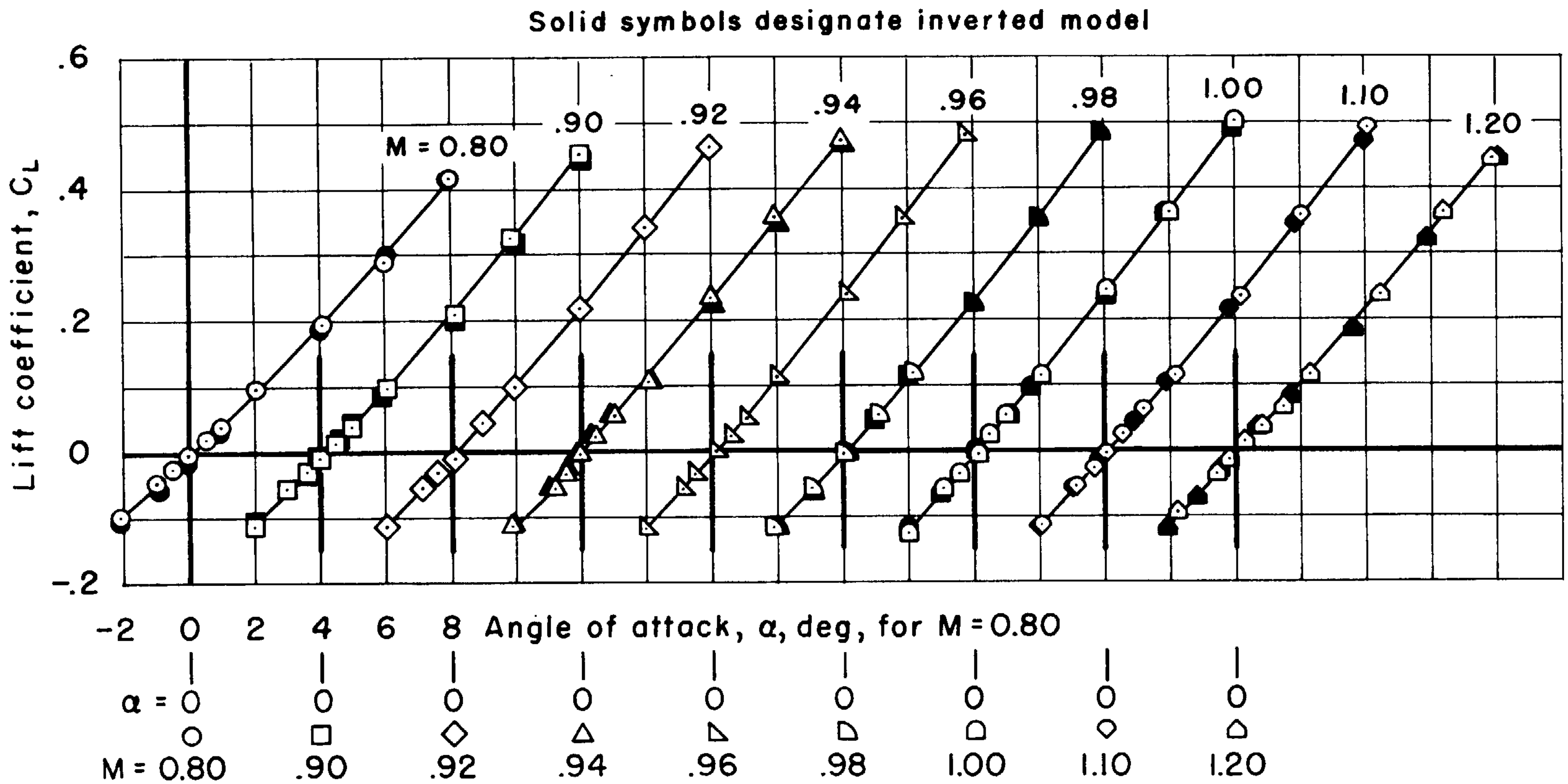
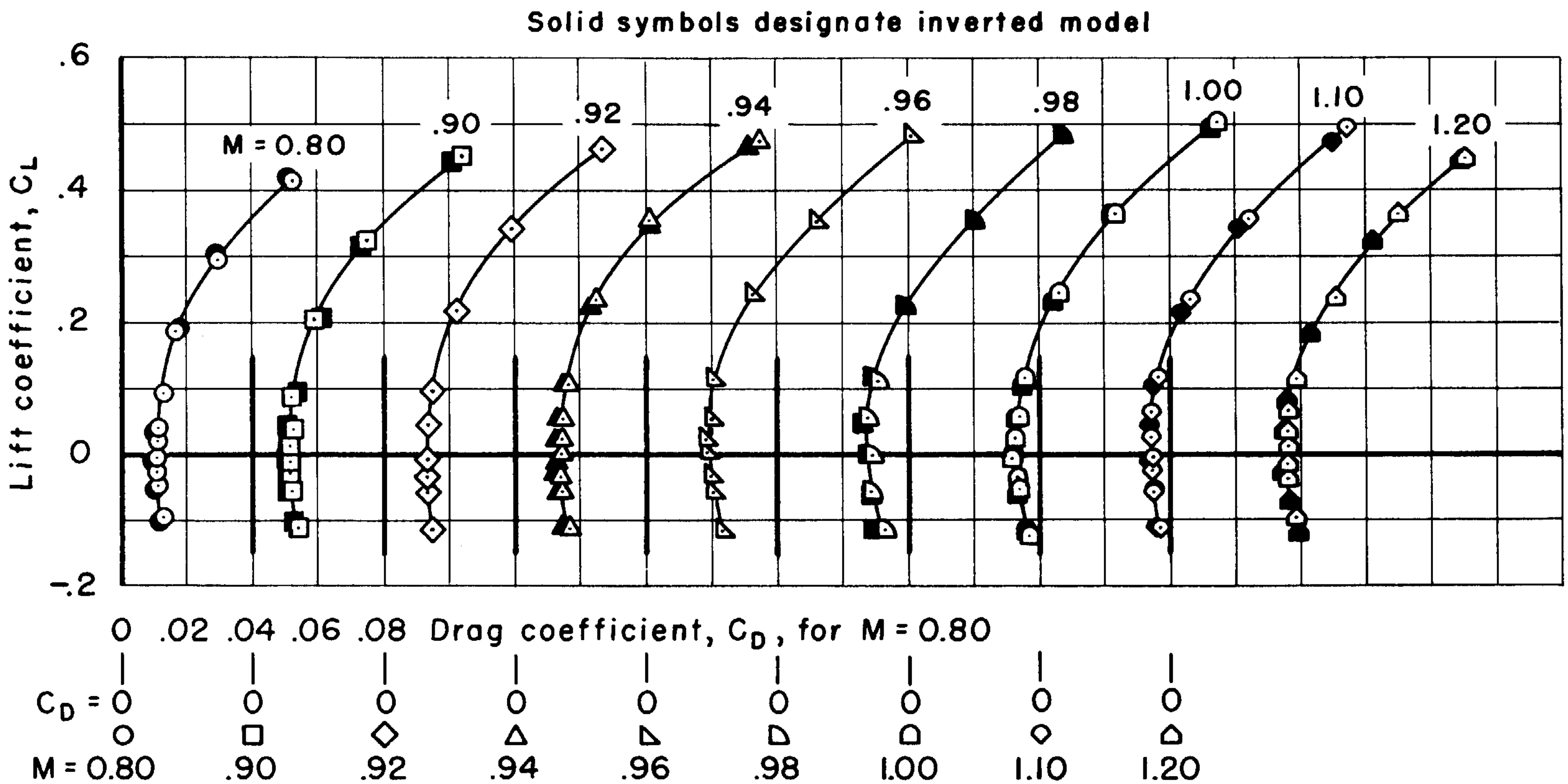
Figure 6.- An external fuel tank mounted on the model.



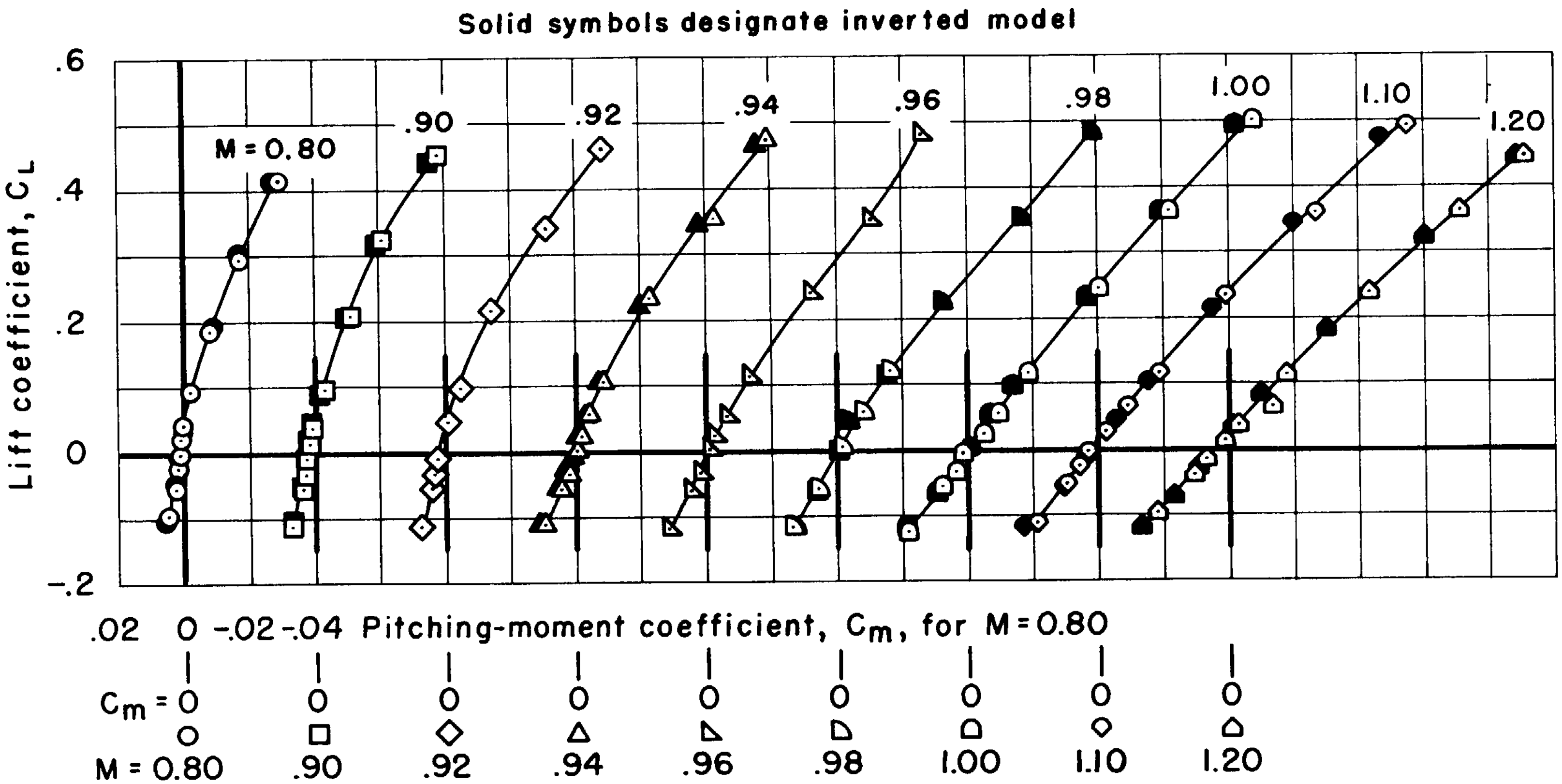
(a) Lift characteristics.

Figure 7.- Aerodynamic characteristics of the basic model.



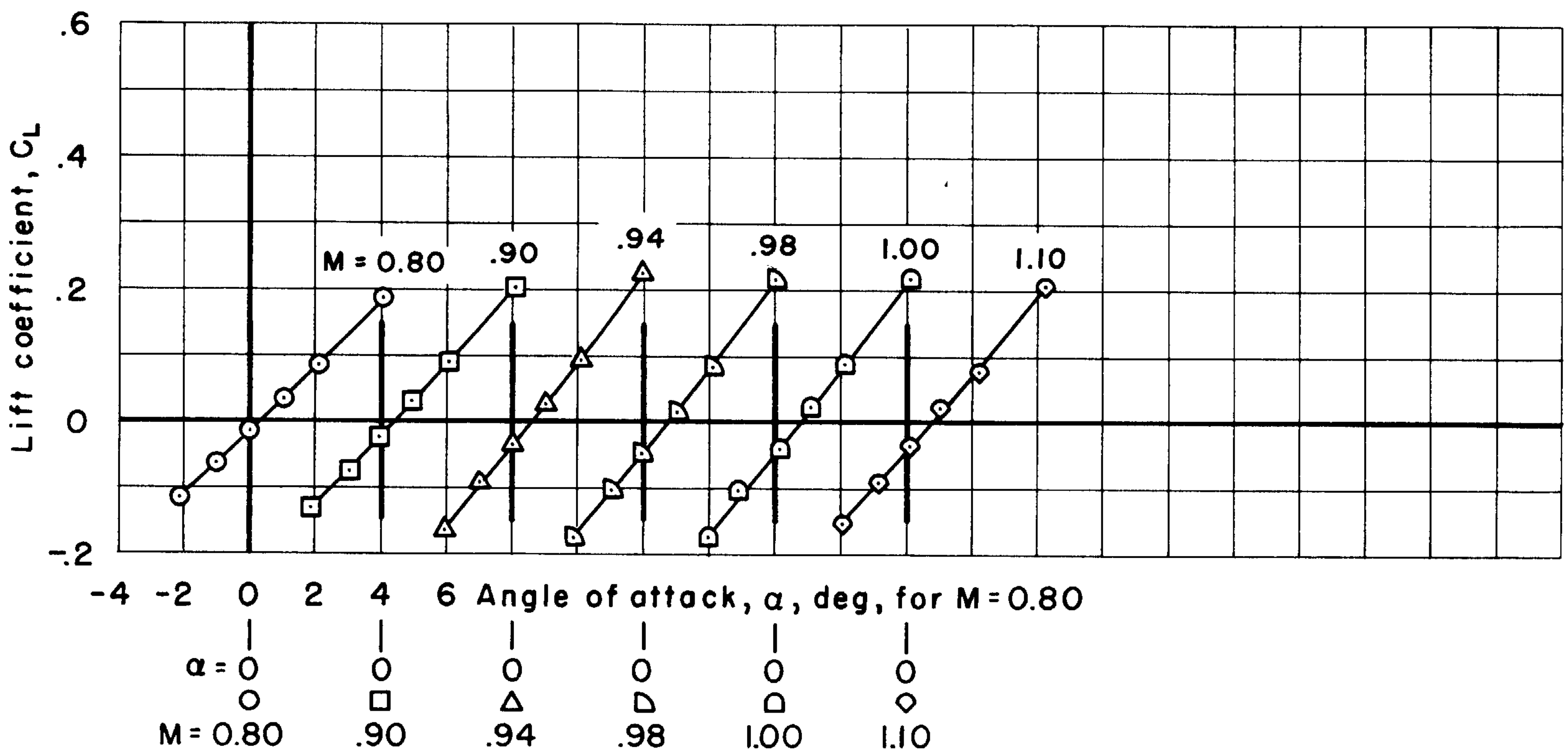
(b) Drag characteristics.

Figure 7.- Continued.



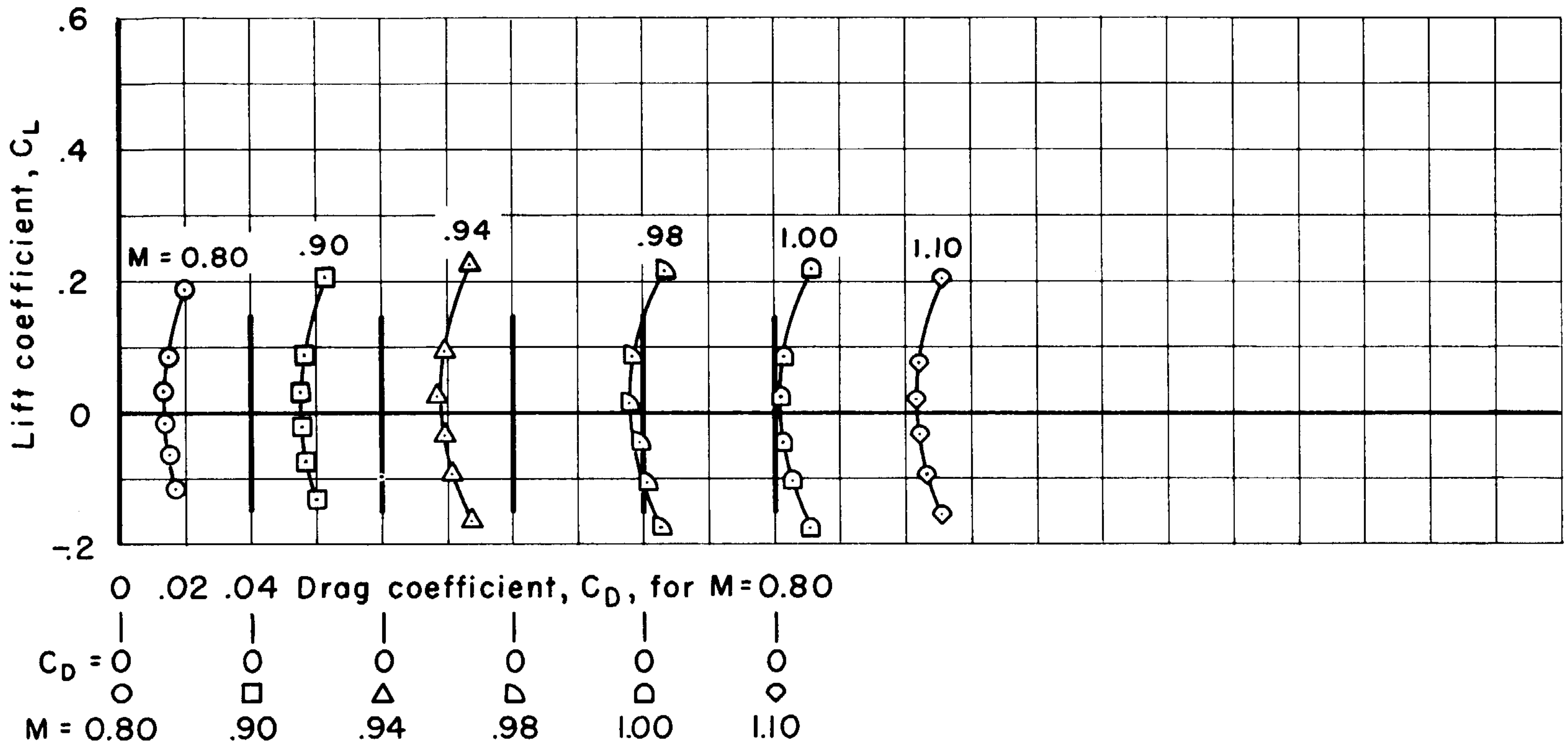
(c) Pitching-moment characteristics.

Figure 7.- Concluded.



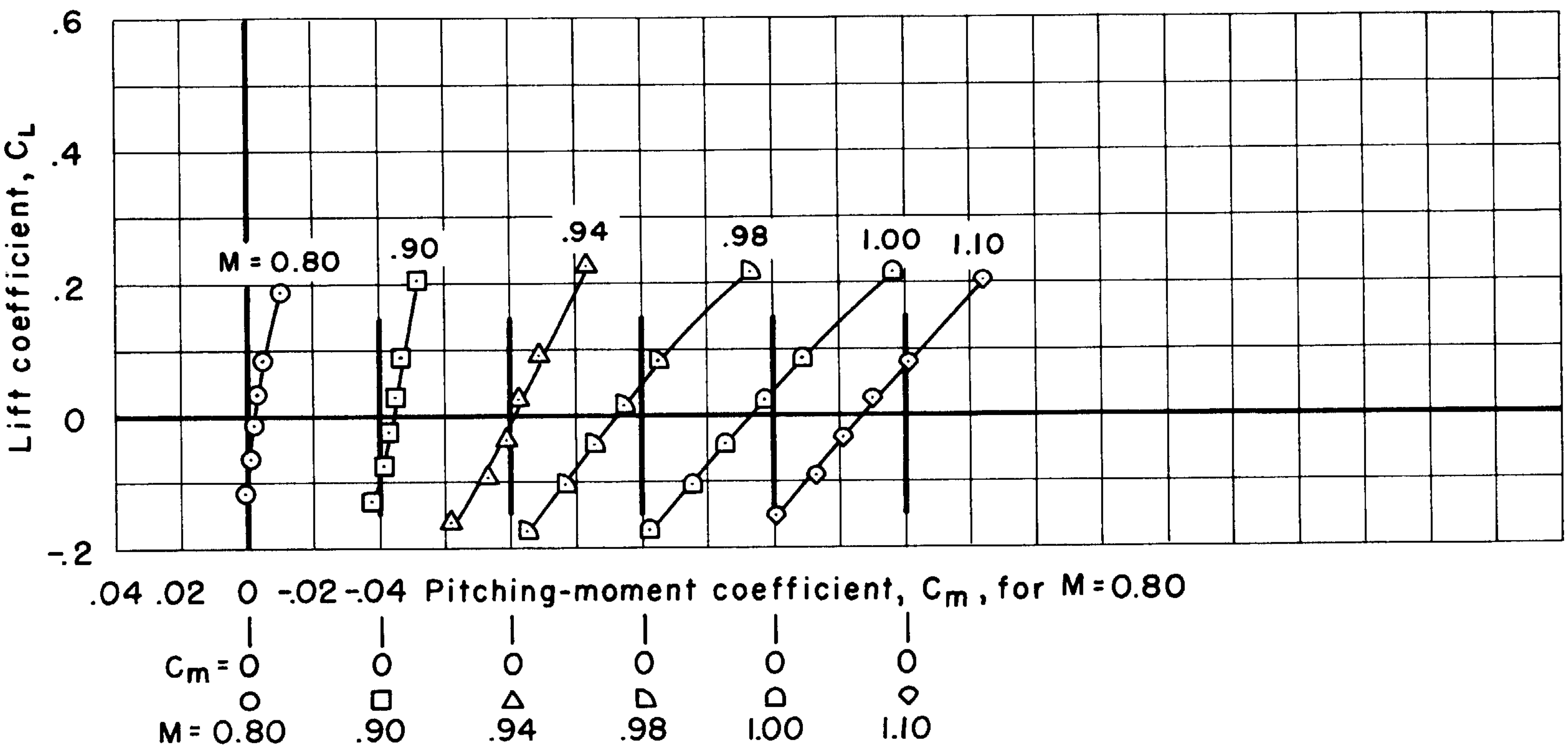
(a) Lift characteristics.

Figure 8.- Aerodynamic characteristics of the basic model plus external fuel tanks.



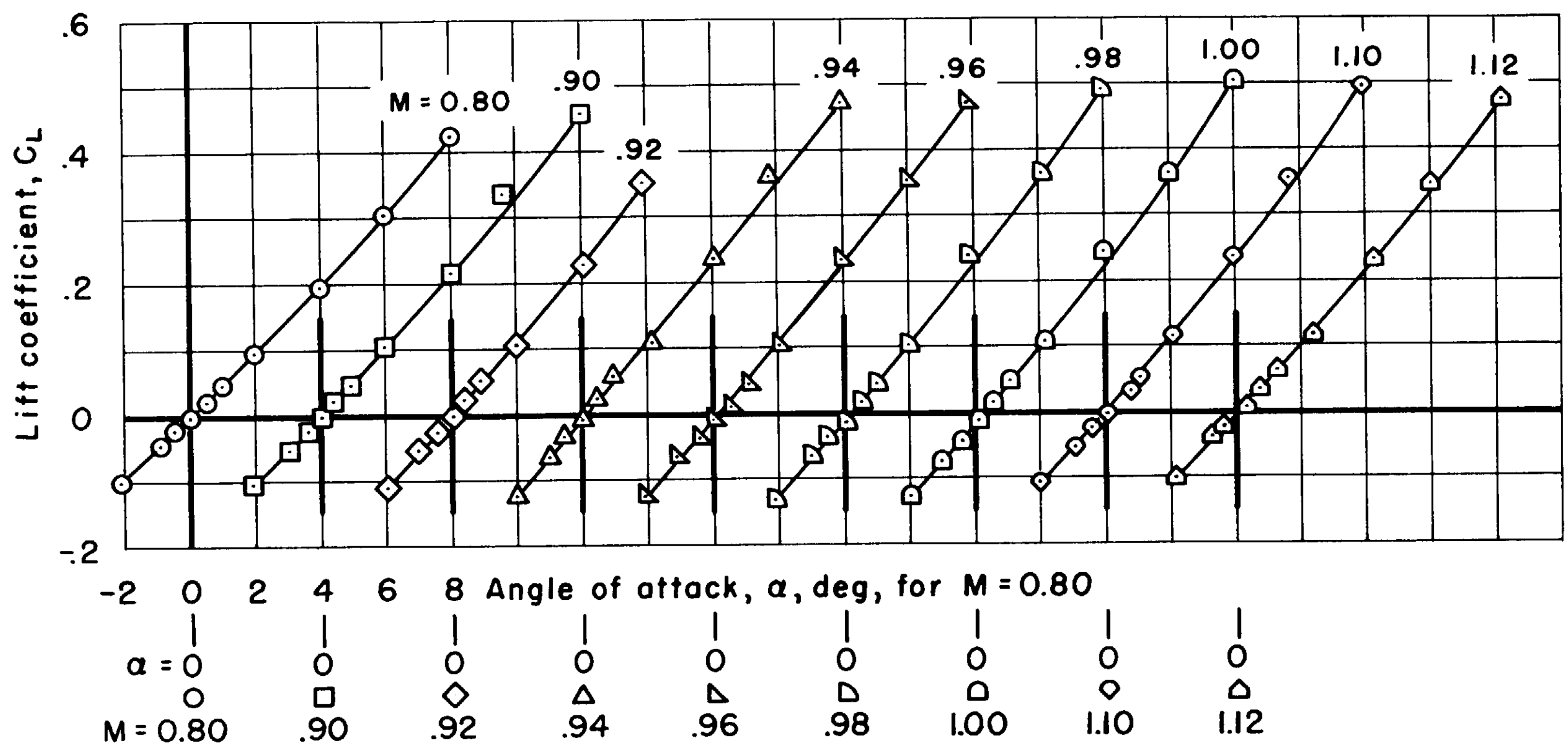
(b) Drag characteristics.

Figure 8.- Continued.



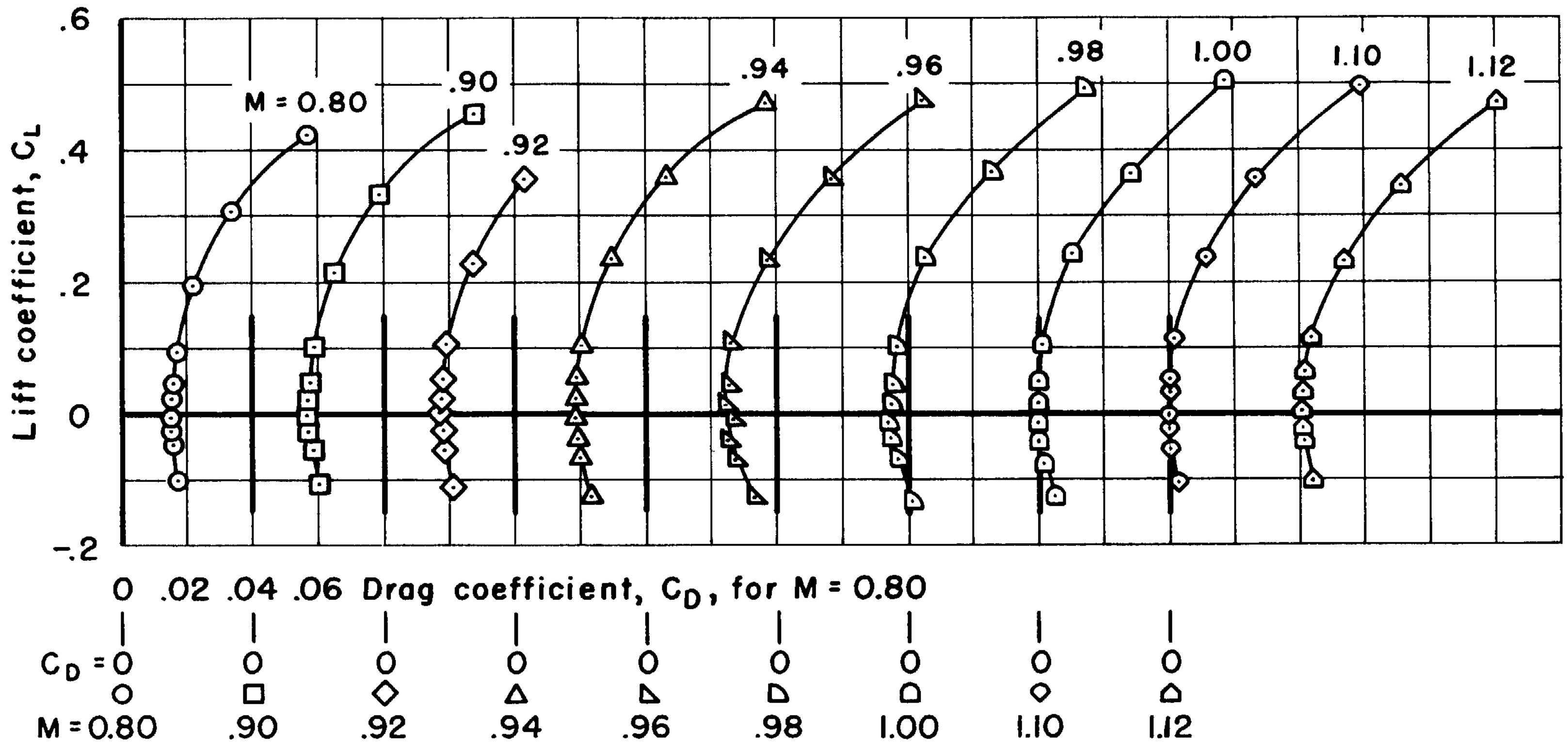
(c) Pitching-moment characteristics.

Figure 8.- Concluded.



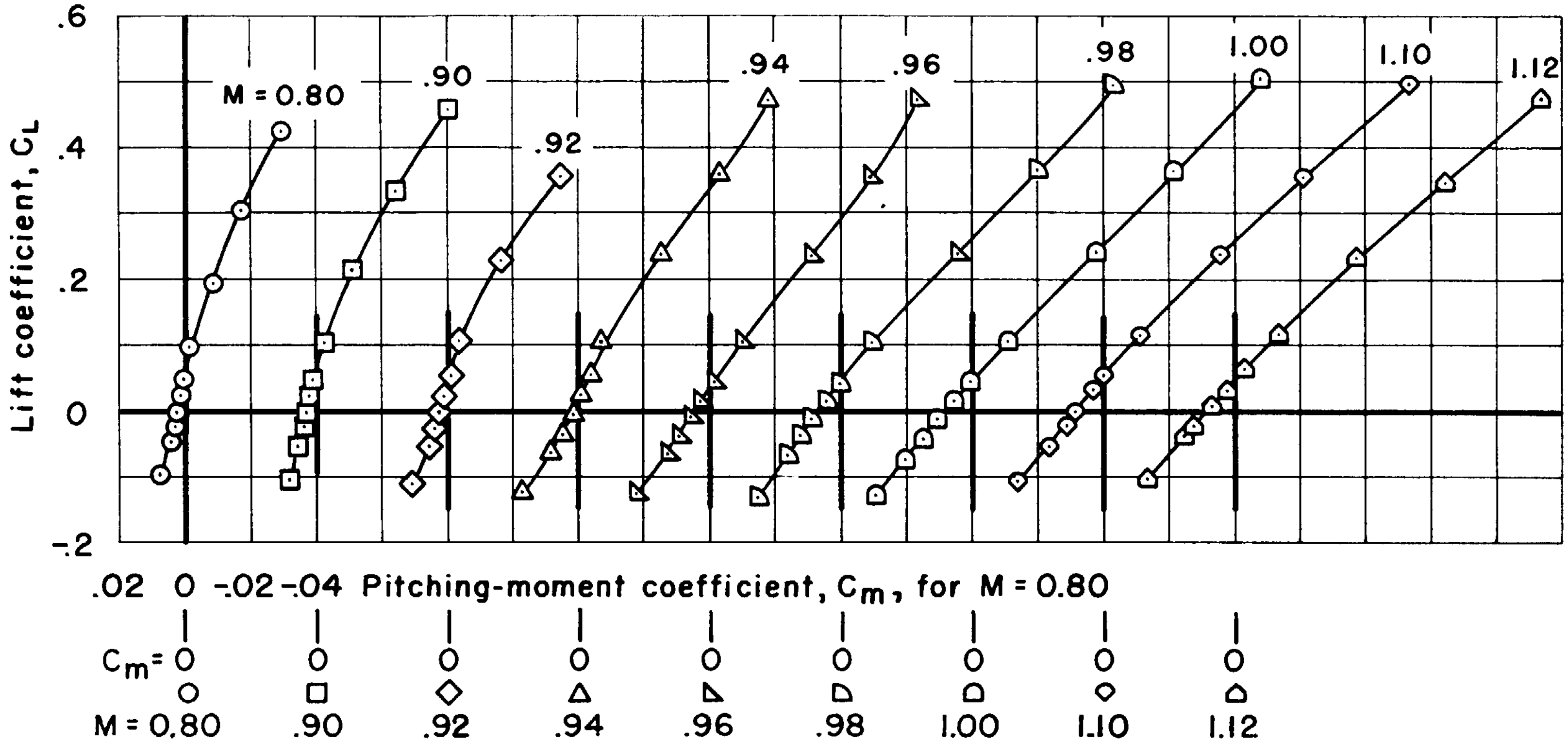
(a) Lift characteristics.

Figure 9.- Aerodynamic characteristics of the basic model plus spoilers L_8.



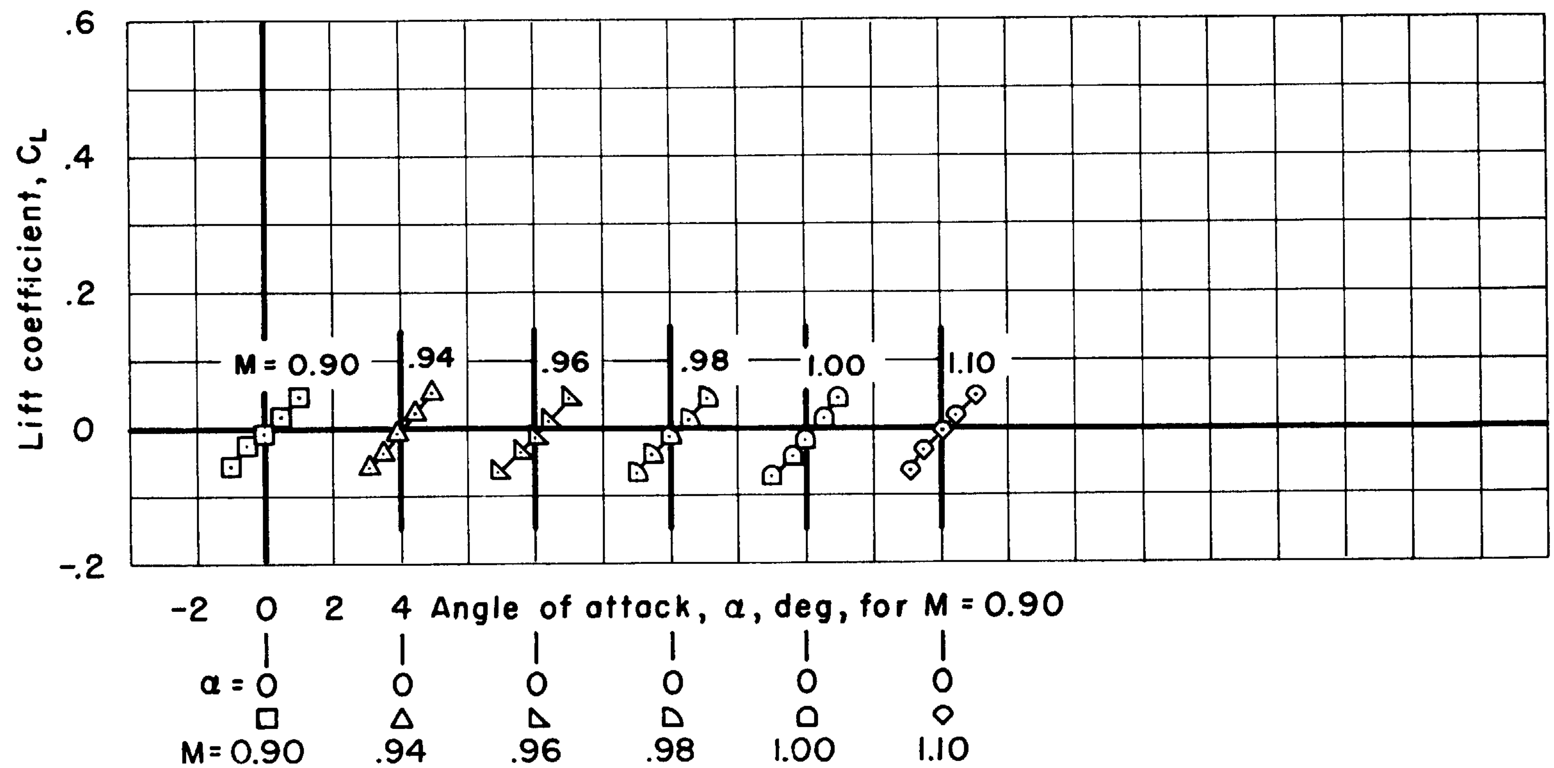
(b) Drag characteristics.

Figure 9.- Continued.



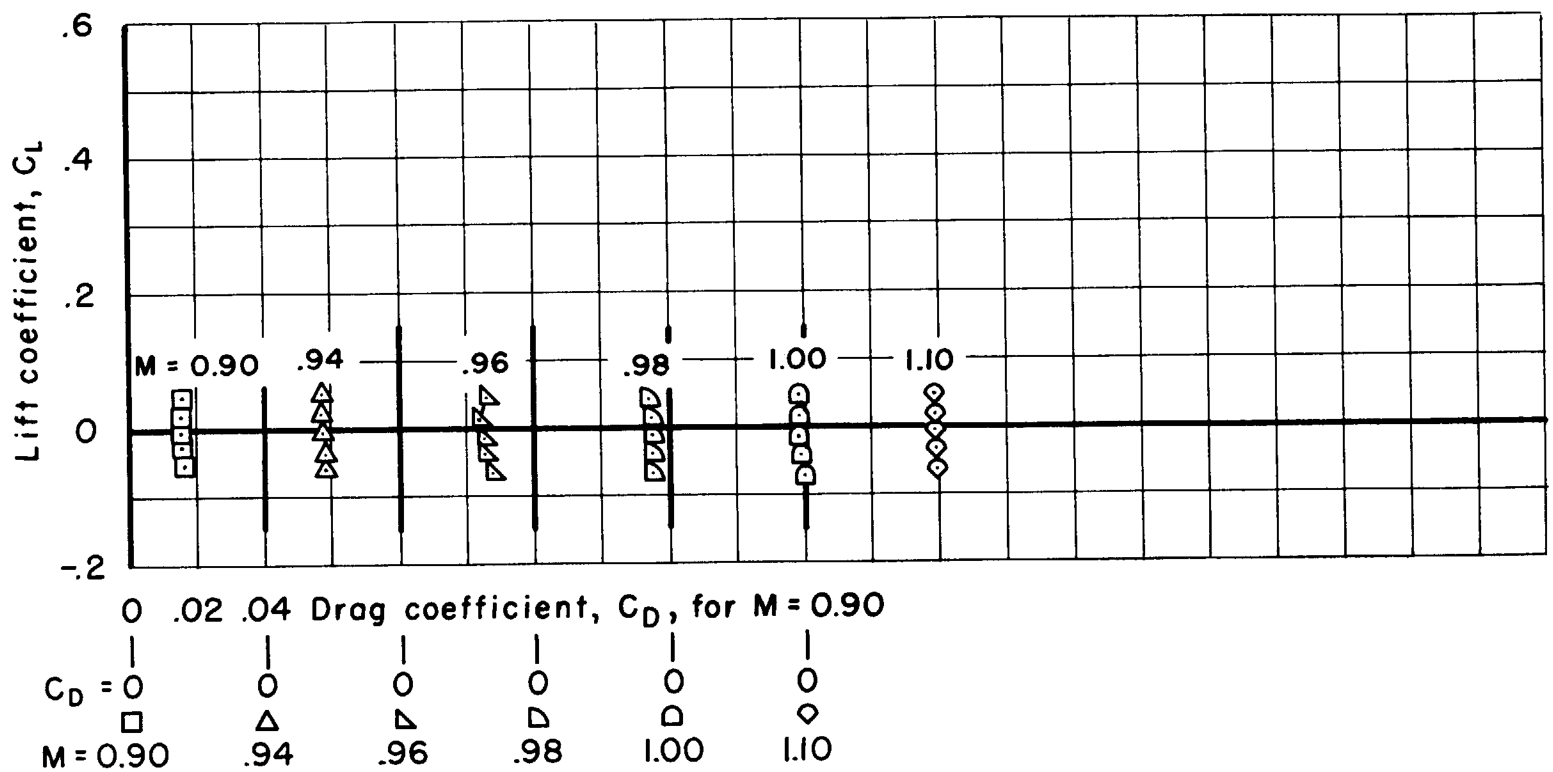
(c) Pitching-moment characteristics.

Figure 9.- Concluded.



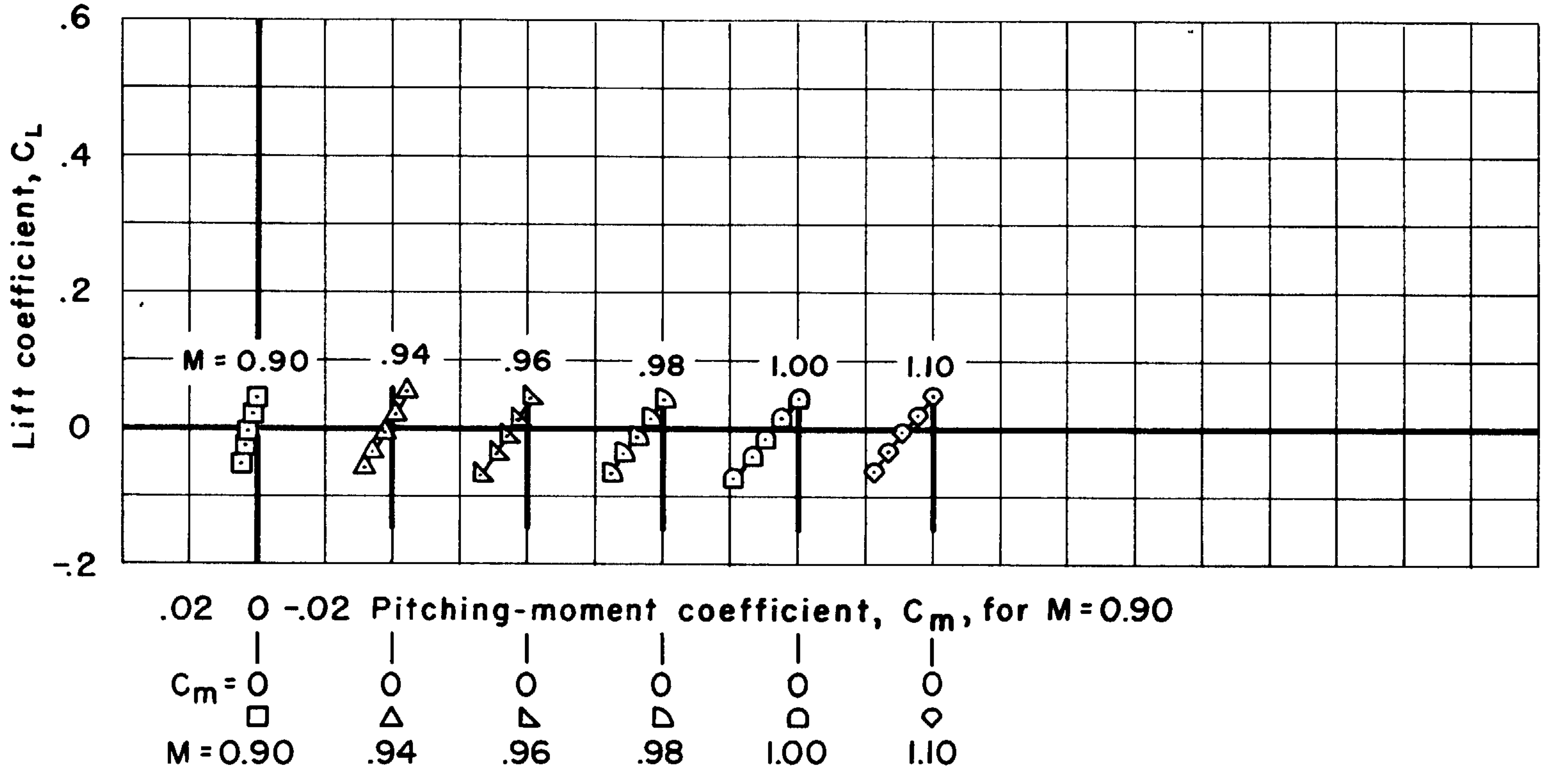
(a) Lift characteristics.

Figure 10.- Aerodynamic characteristics of the basic model plus spoilers L_{S_a}.



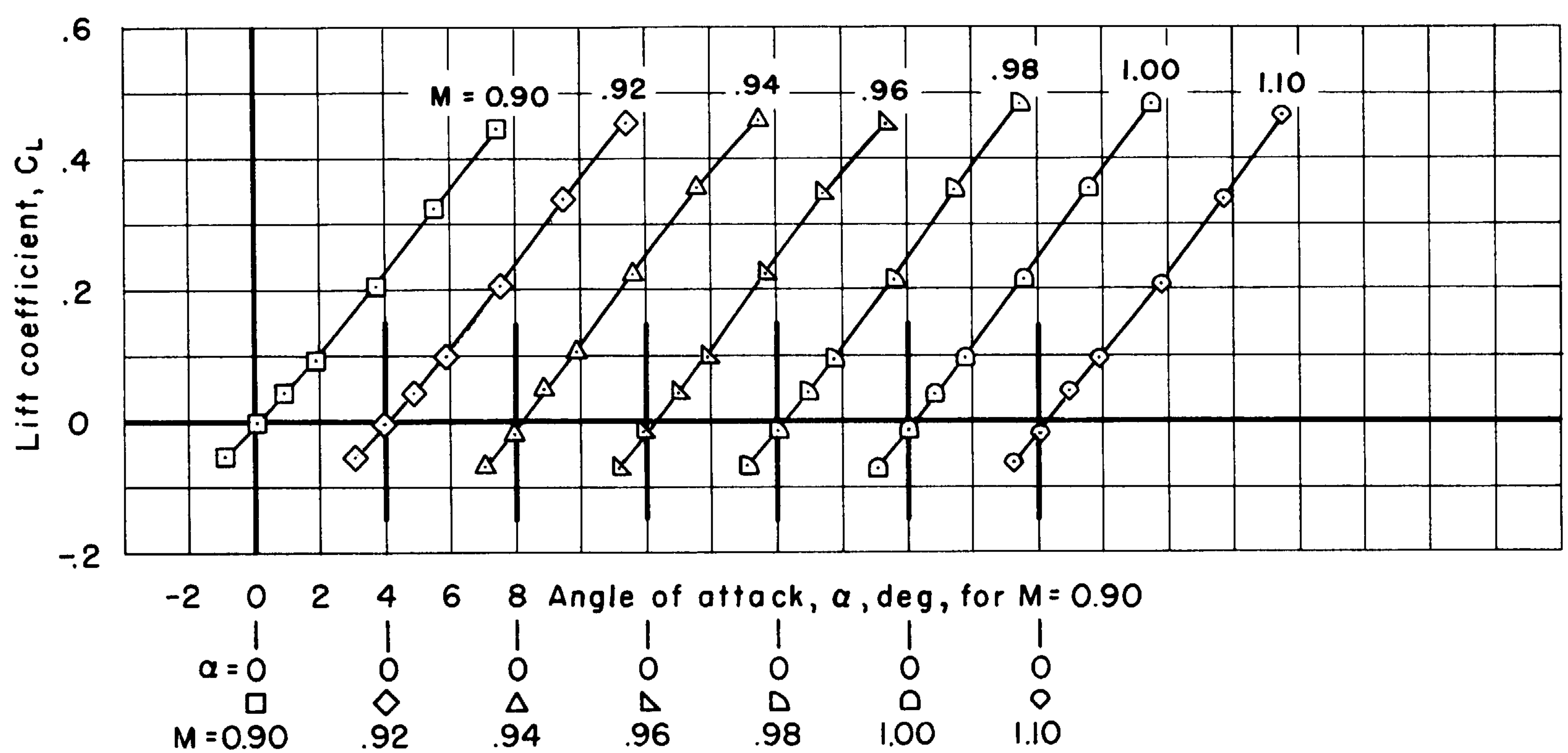
(b) Drag characteristics.

Figure 10.- Continued.



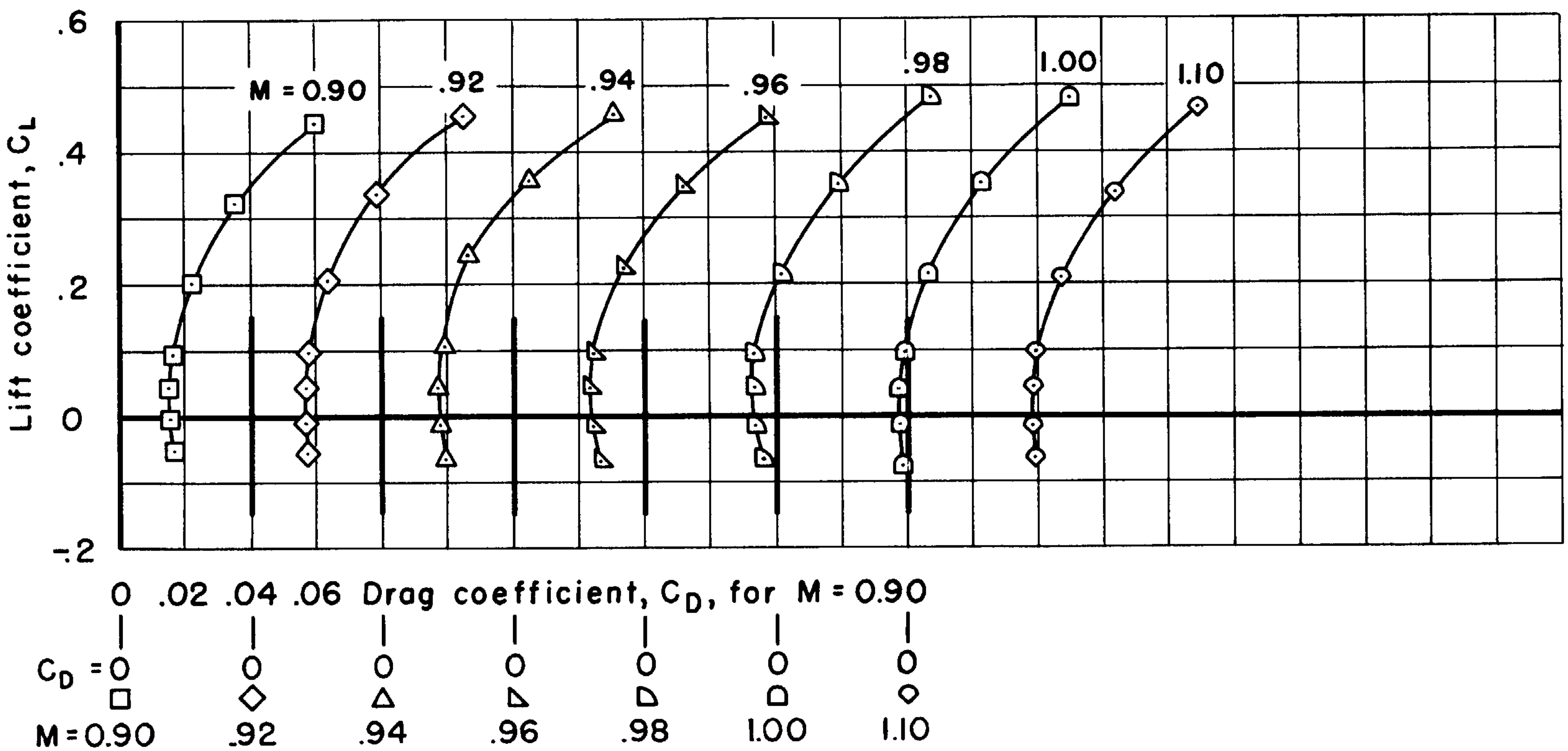
(c) Pitching-moment characteristics.

Figure 10.- Concluded.



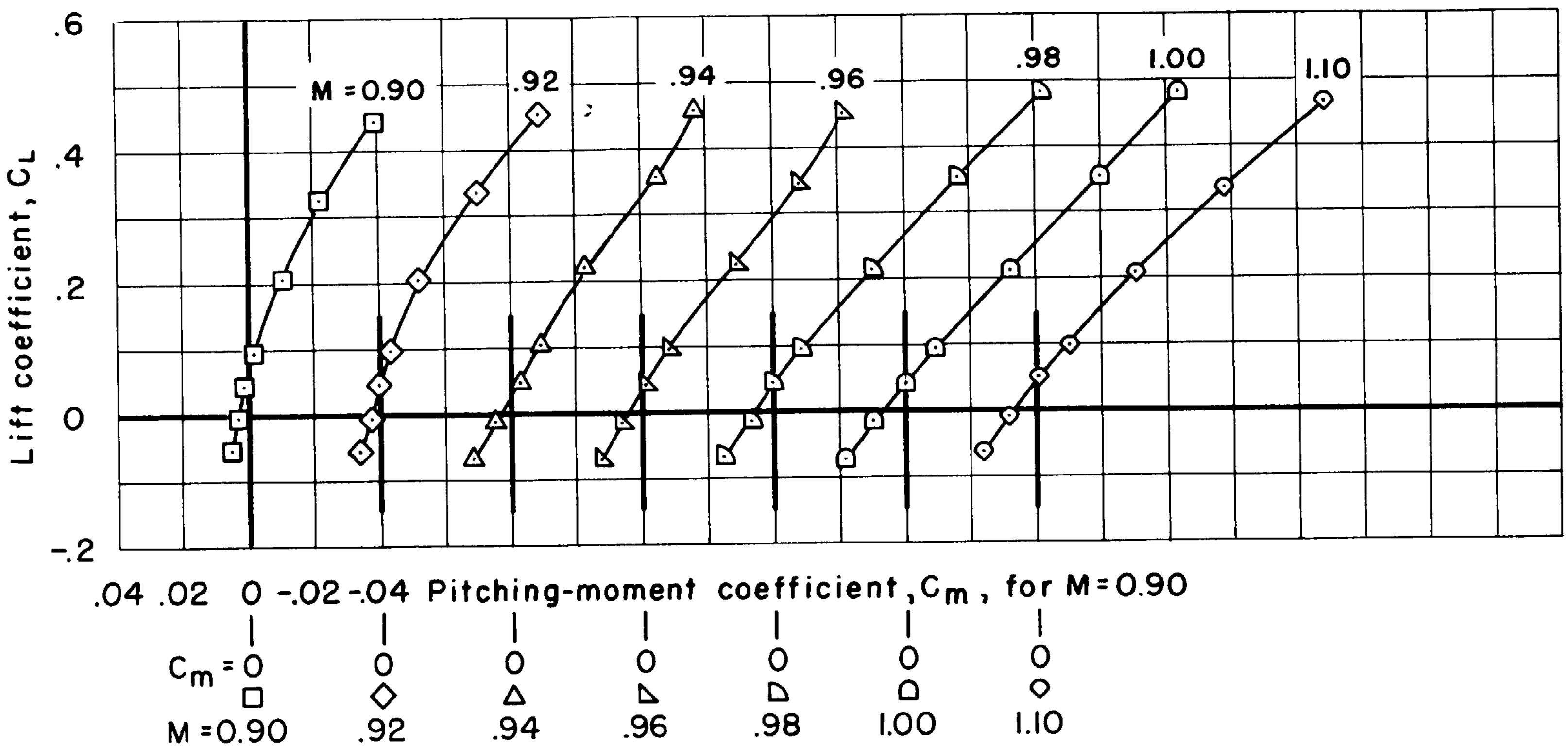
(a) Lift characteristics.

Figure 11.- Aerodynamic characteristics of the basic model plus spoilers $L_{\sigma_a}(A)$.



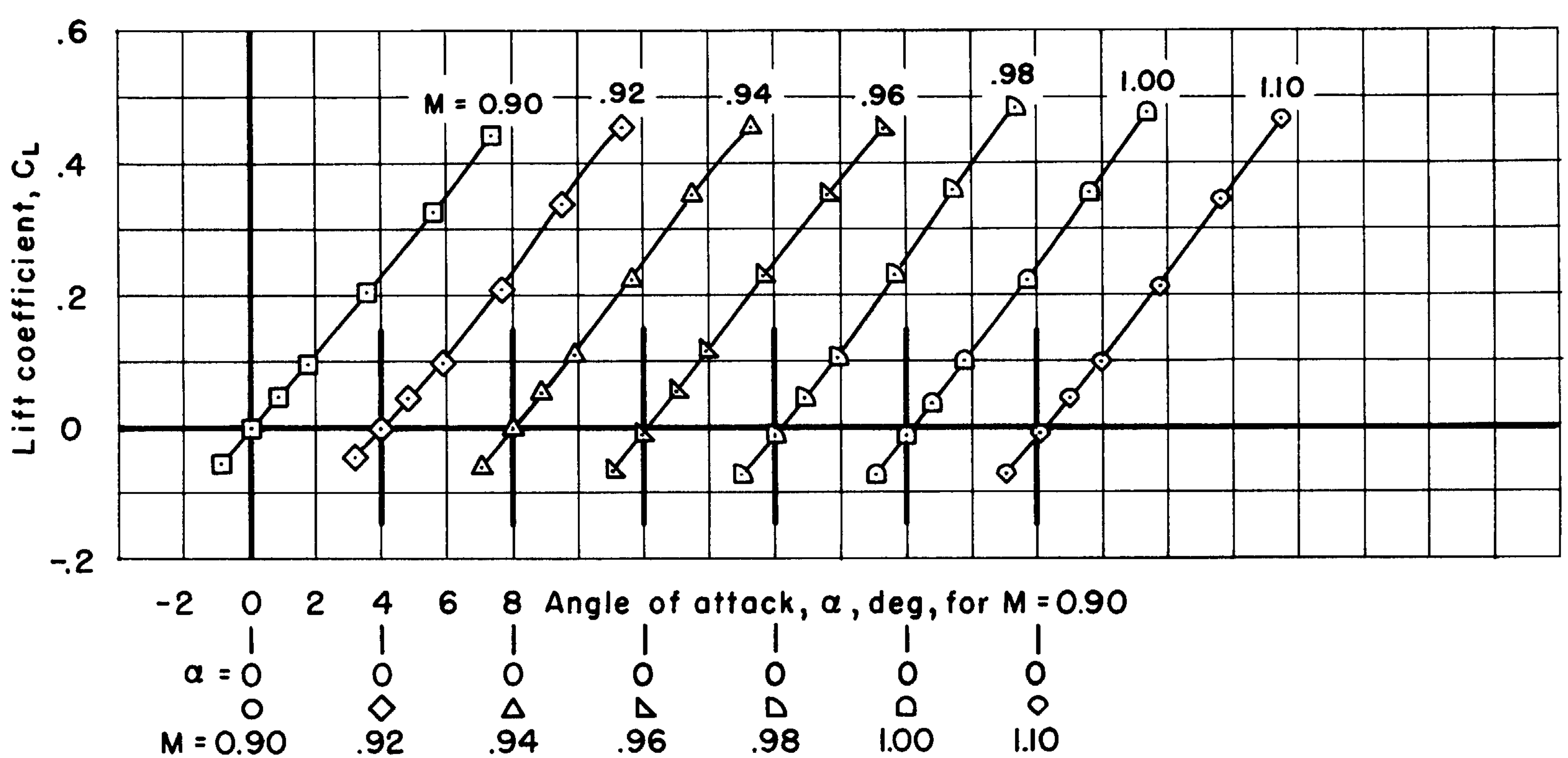
(b) Drag characteristics.

Figure 11.- Continued.



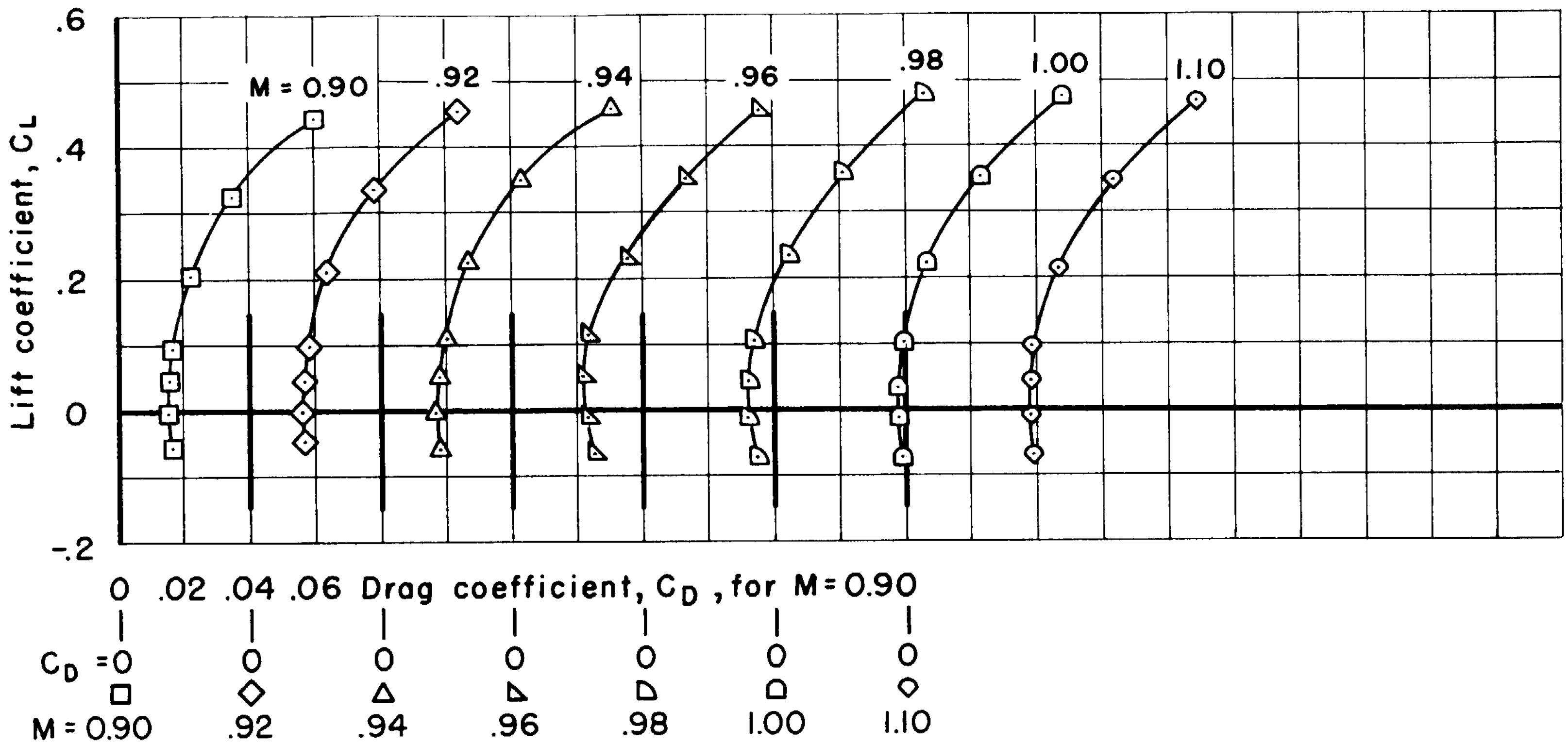
(c) Pitching-moment characteristics.

Figure 11.- Concluded.



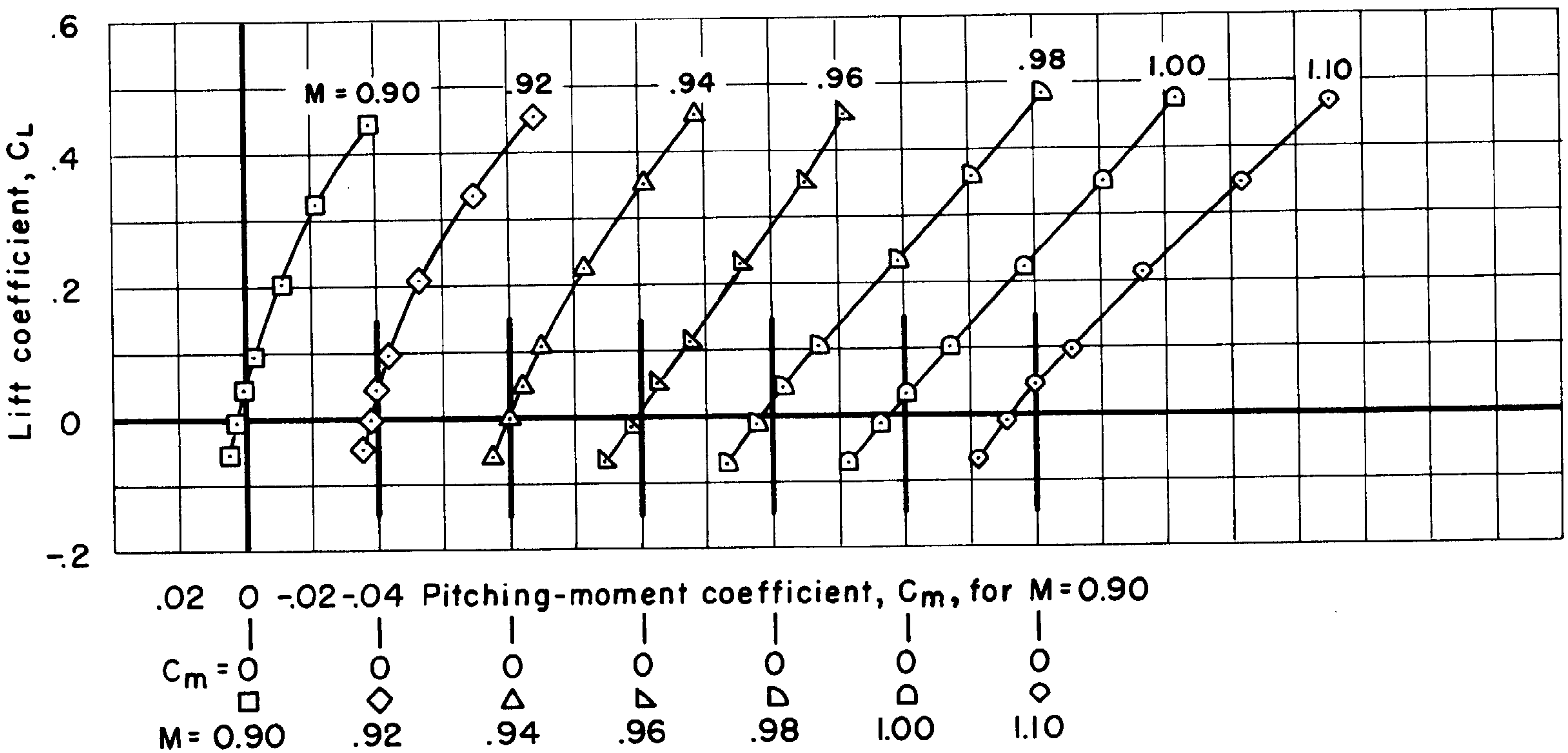
(a) Lift characteristics.

Figure 12.- Aerodynamic characteristics of the basic model plus spoilers $I_{\sigma_a}(B)$.



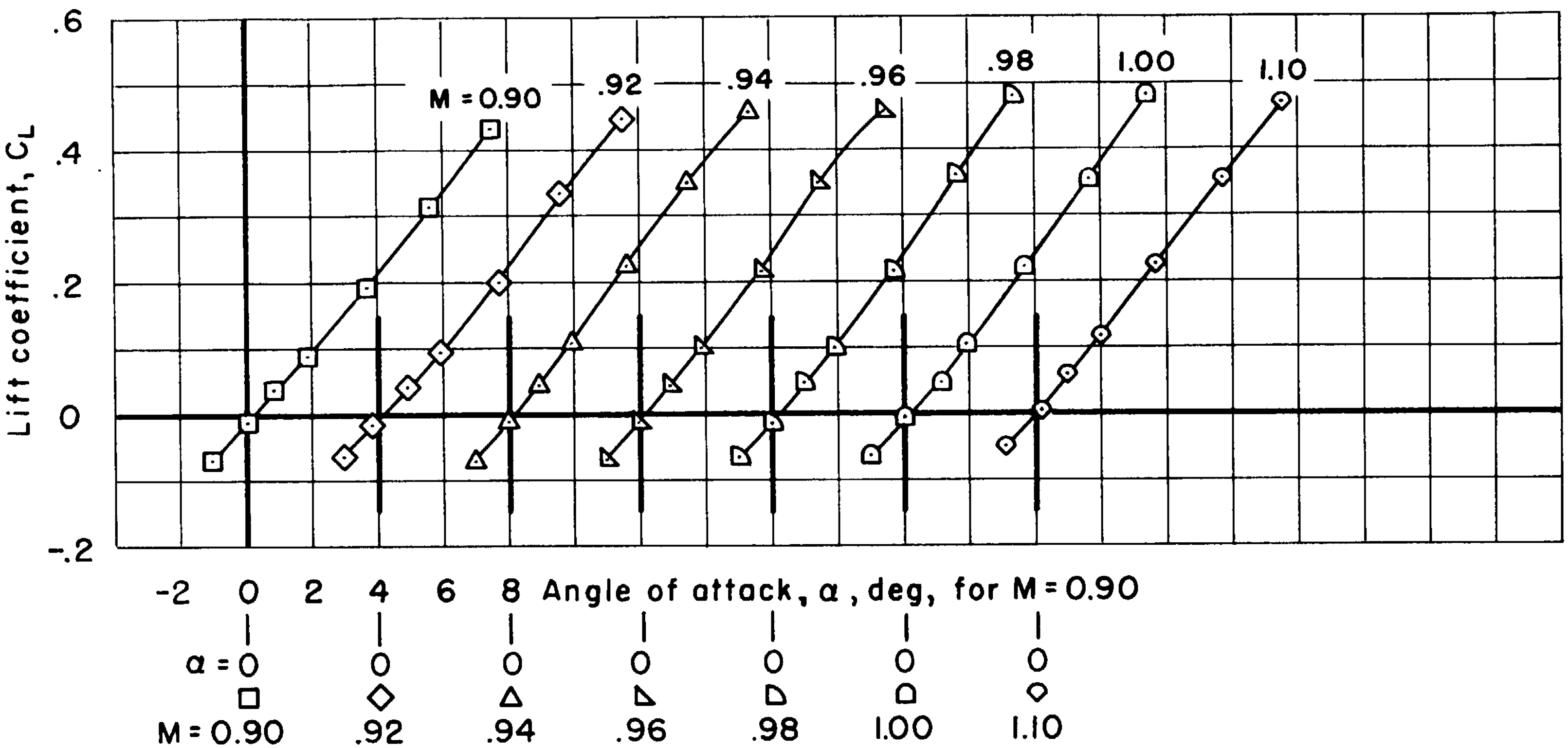
(b) Drag characteristics.

Figure 12.- Continued.



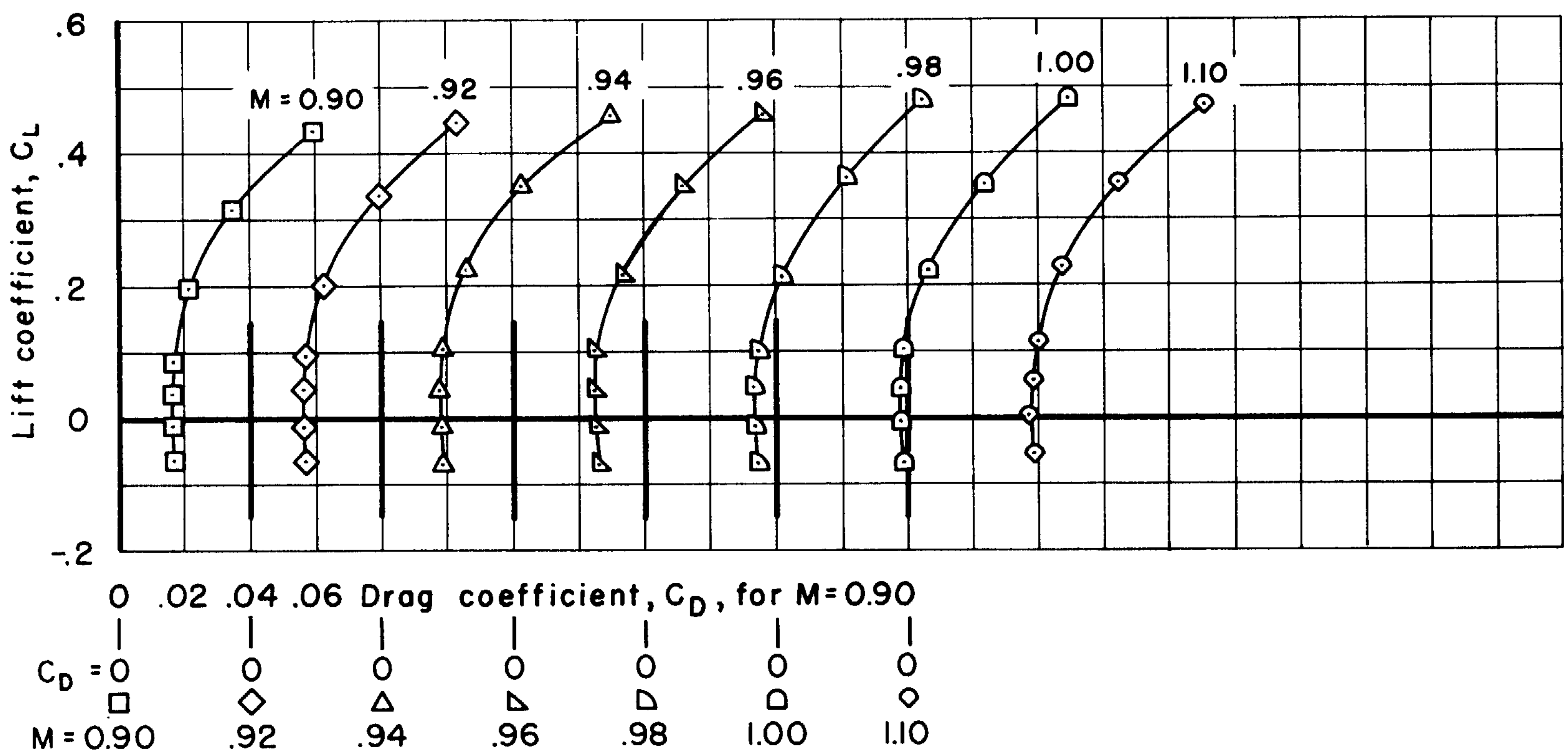
(c) Pitching-moment characteristics.

Figure 12.- Concluded.



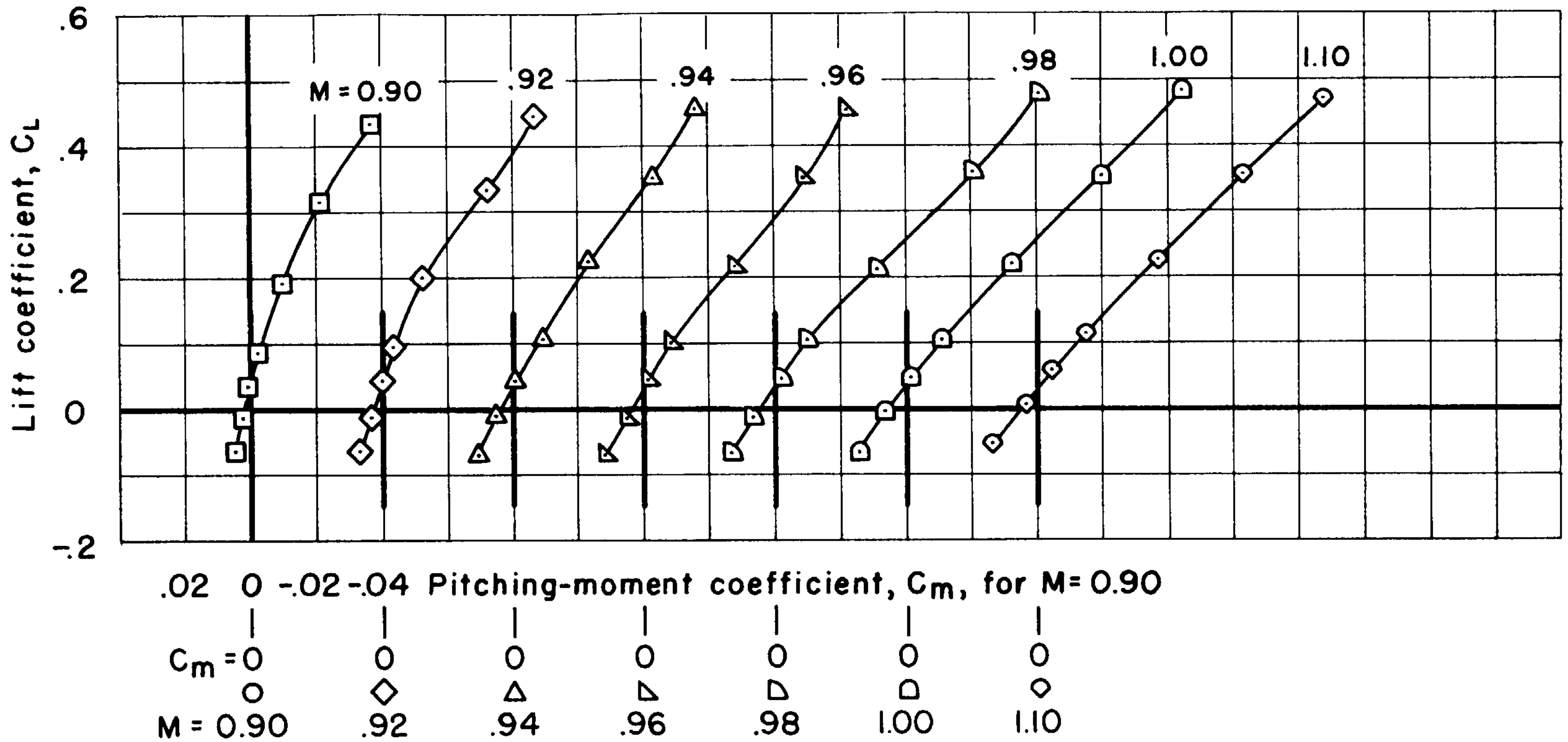
(a) Lift characteristics.

Figure 13.- Aerodynamic characteristics of the basic model plus spoilers $L_{\theta_a}(C)$.



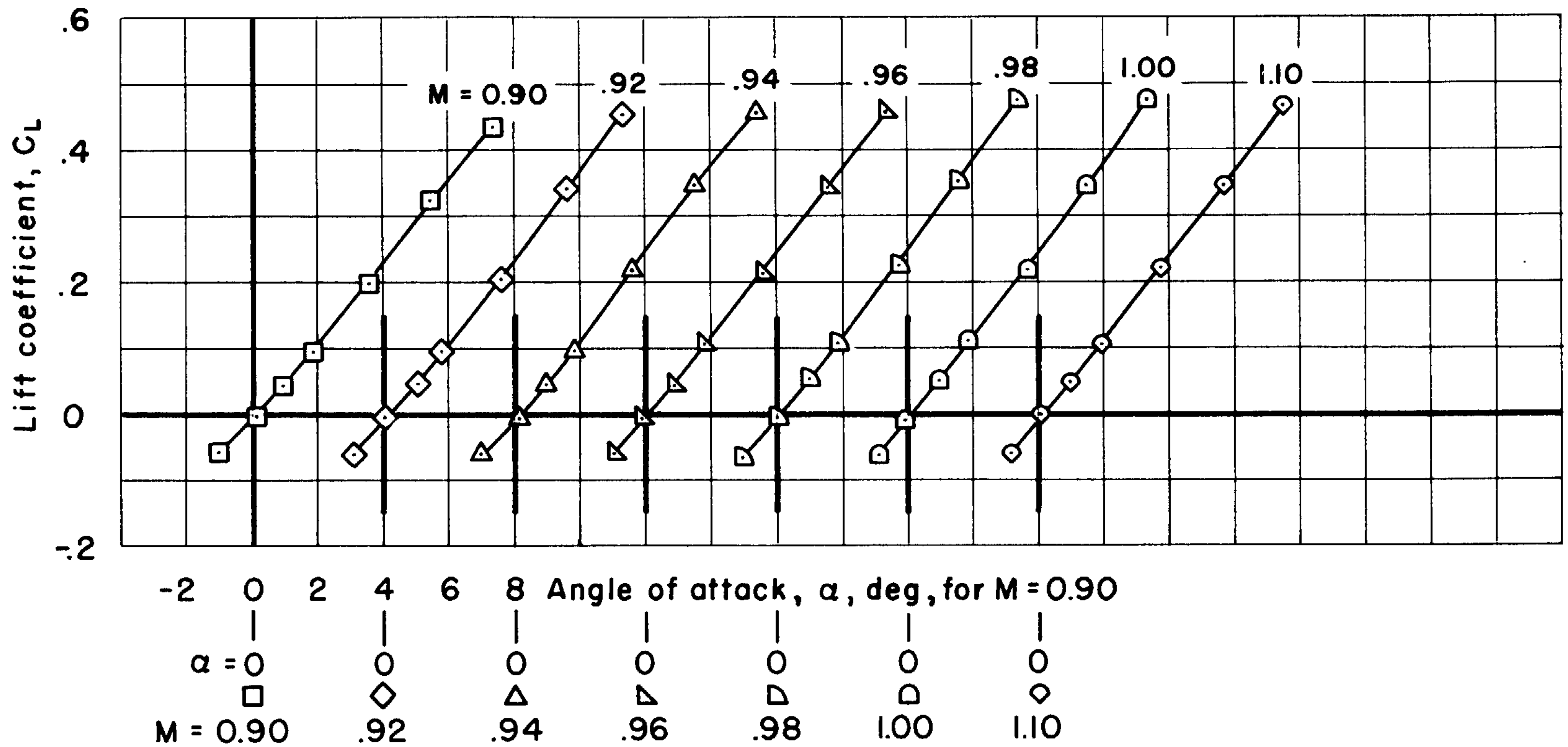
(b) Drag characteristics.

Figure 13.- Continued.



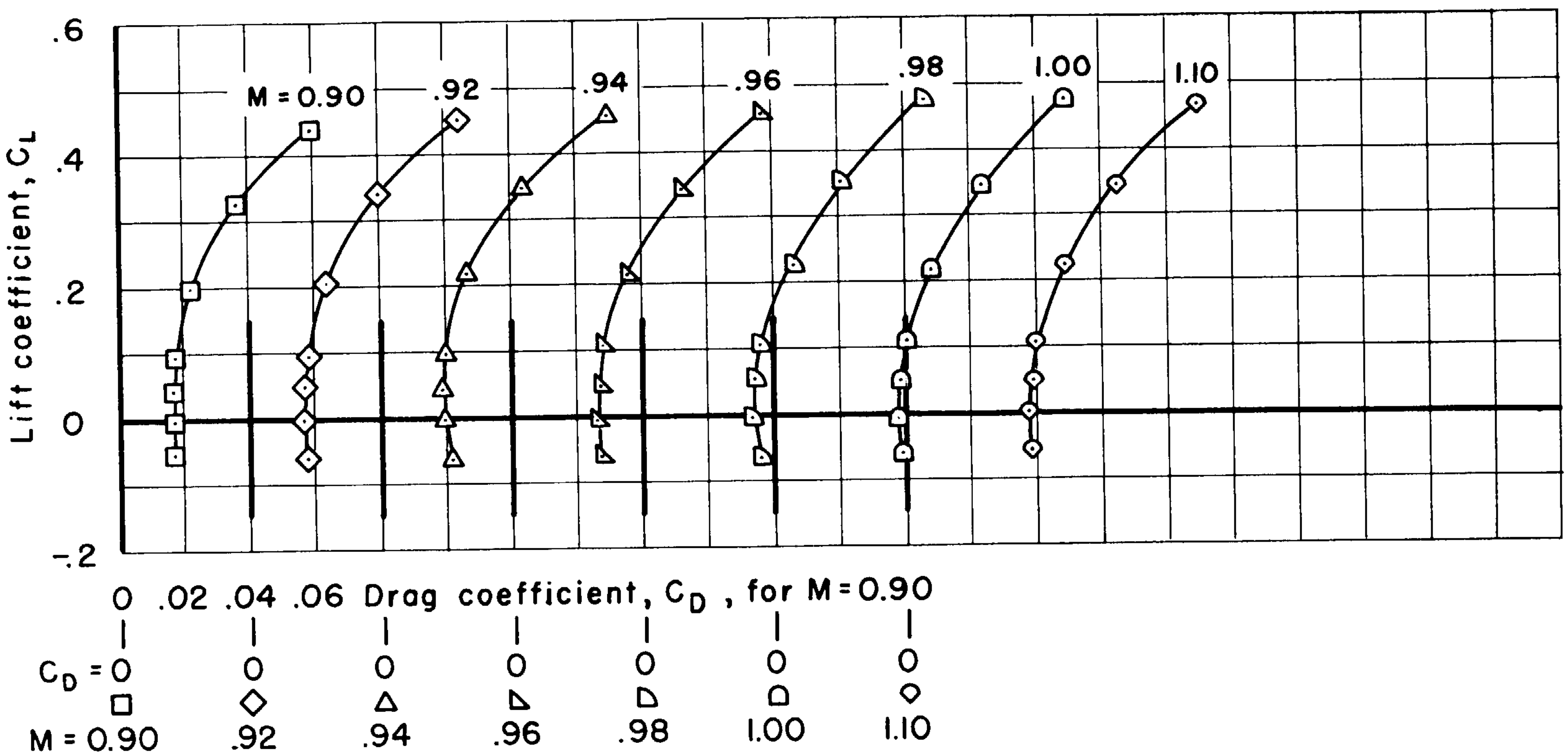
(c) Pitching-moment characteristics.

Figure 13.- Concluded.



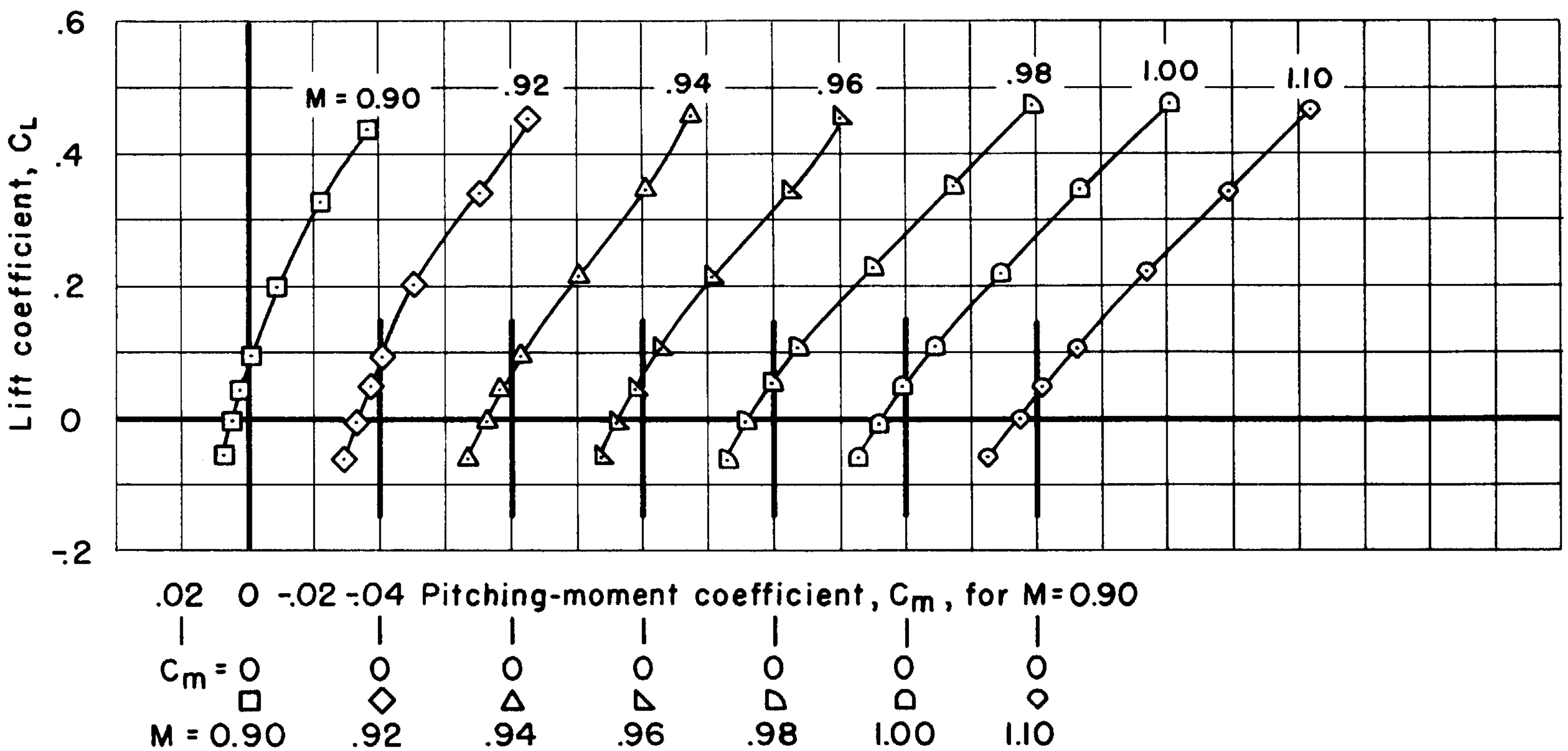
(a) Lift characteristics.

Figure 14.- Aerodynamic characteristics of the basic model plus spoilers $L_{\sigma_a}(D)$.



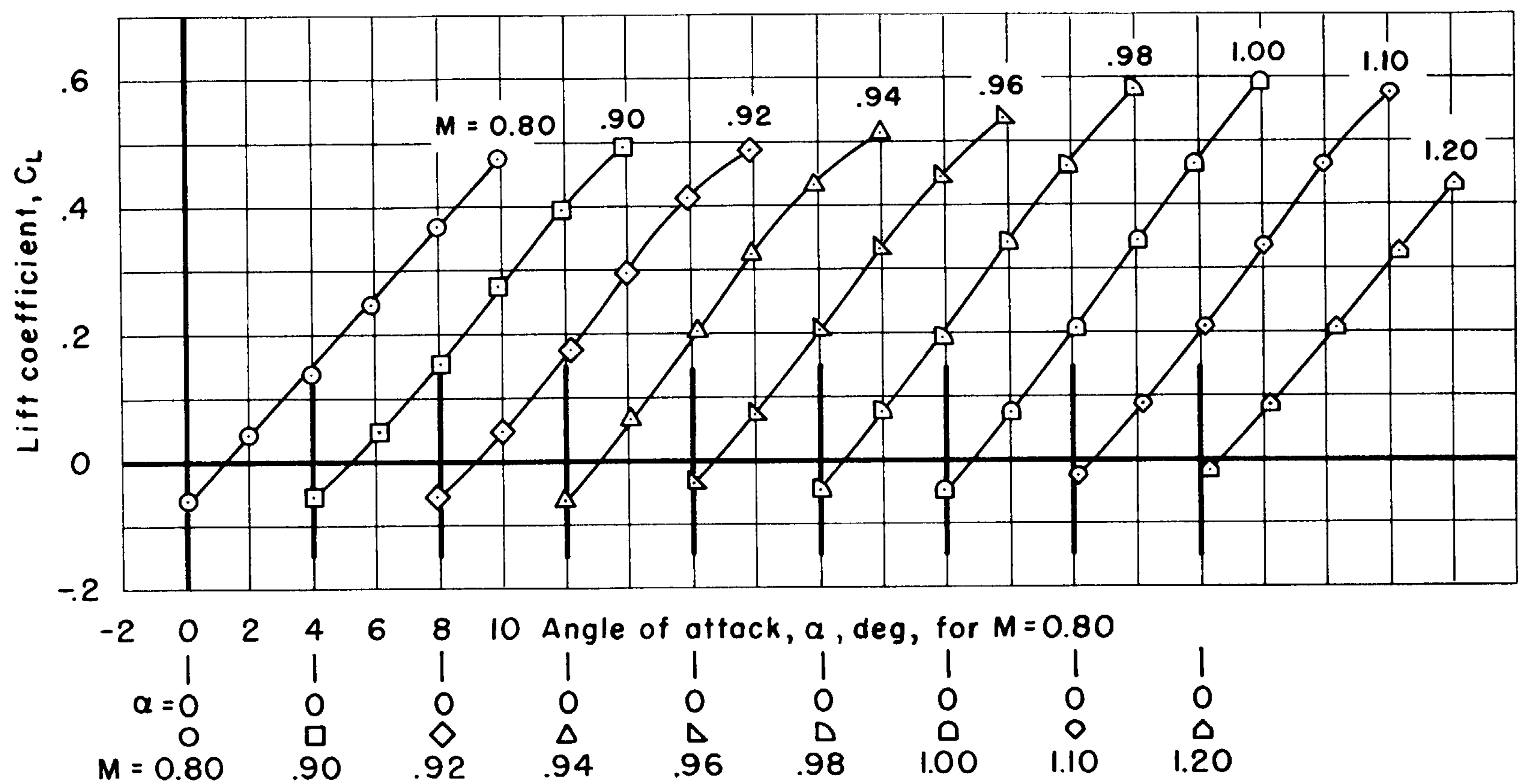
(b) Drag characteristics.

Figure 14.- Continued.



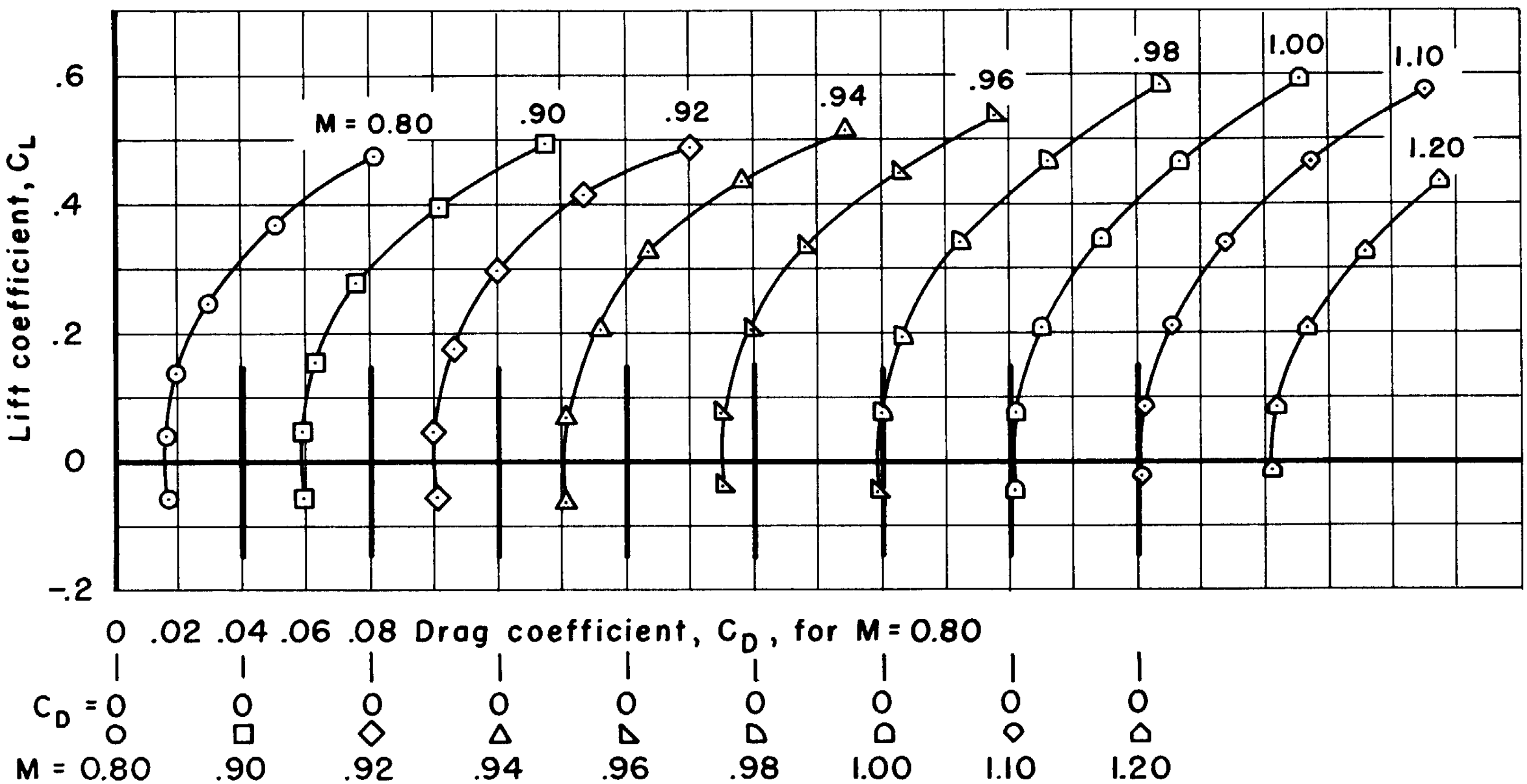
(c) Pitching-moment characteristics.

Figure 14.- Concluded.



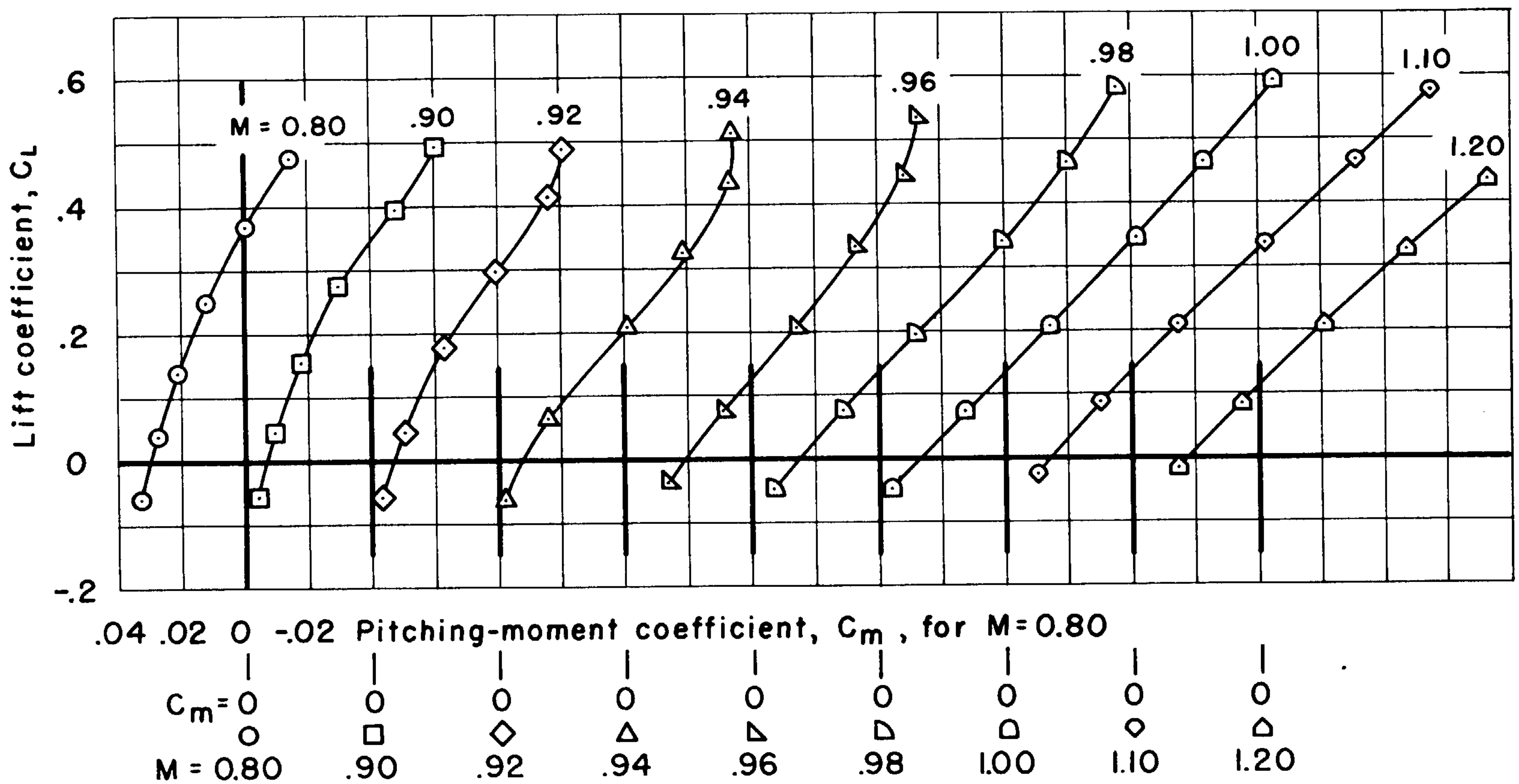
(a) Lift characteristics.

Figure 15.- Aerodynamic characteristics of the basic model plus spoilers I_3; $\delta_e = -5^{\circ}$.



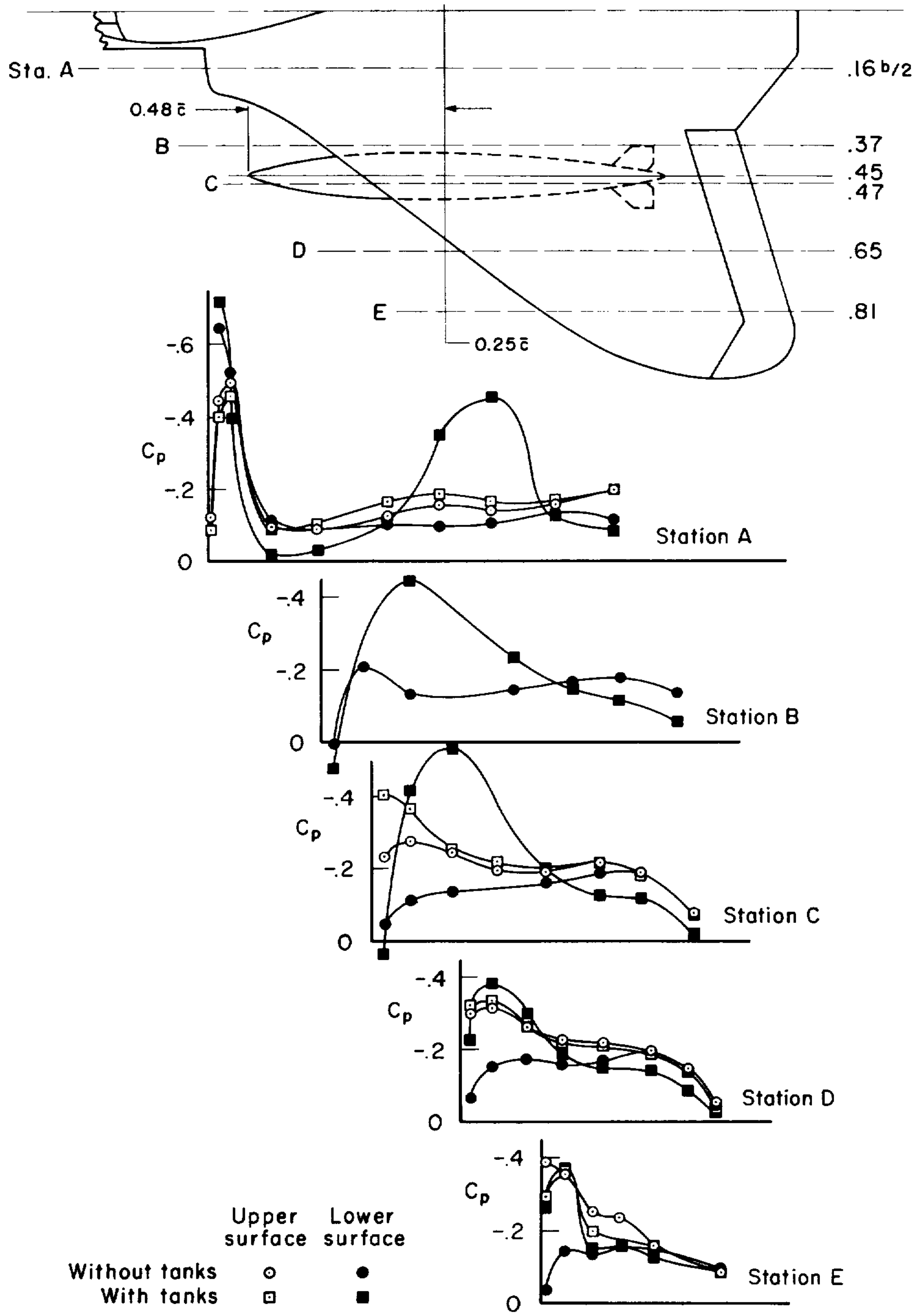
(b) Drag characteristics.

Figure 15.- Continued.



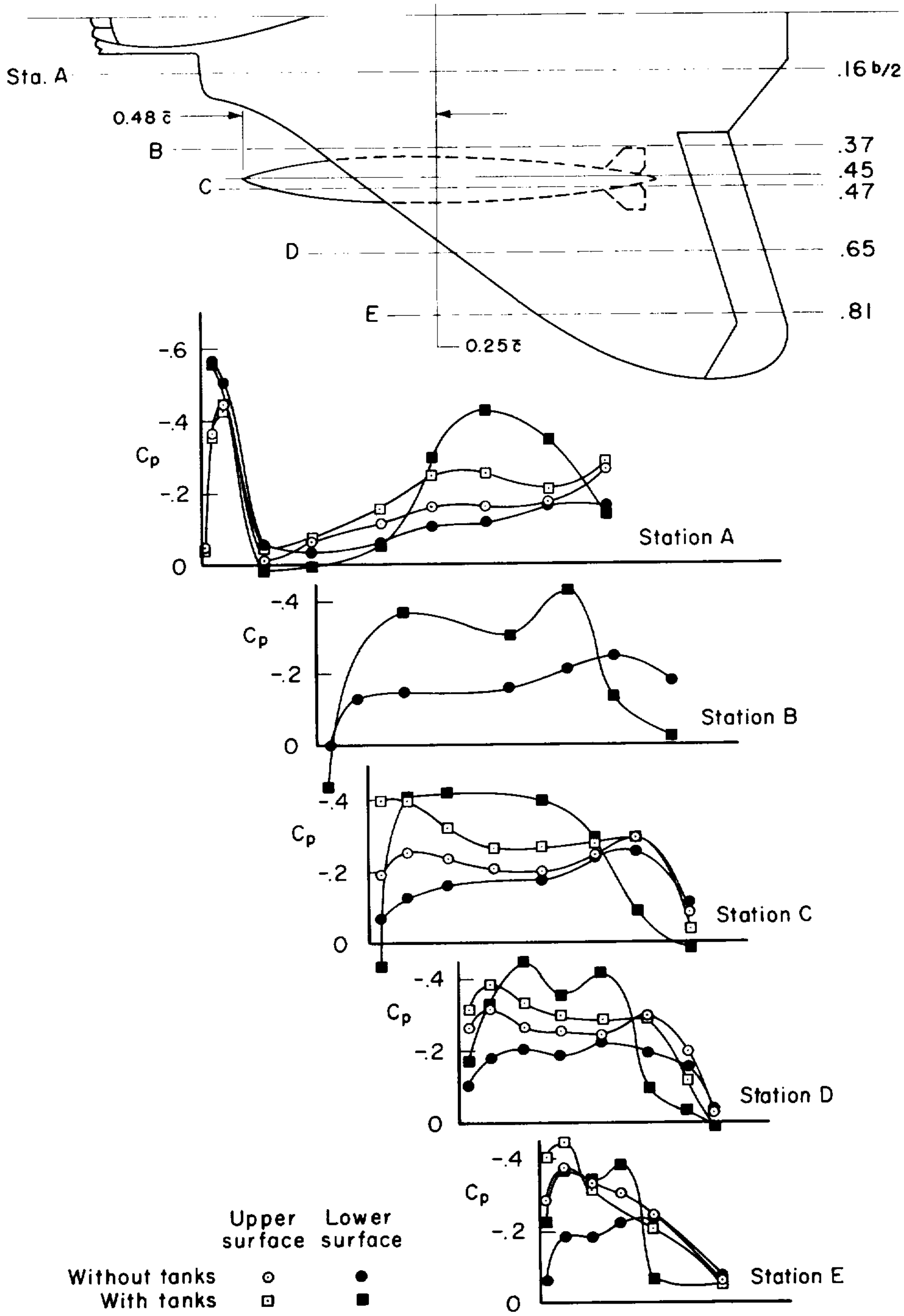
(c) Pitching-moment characteristics.

Figure 15.- Concluded.



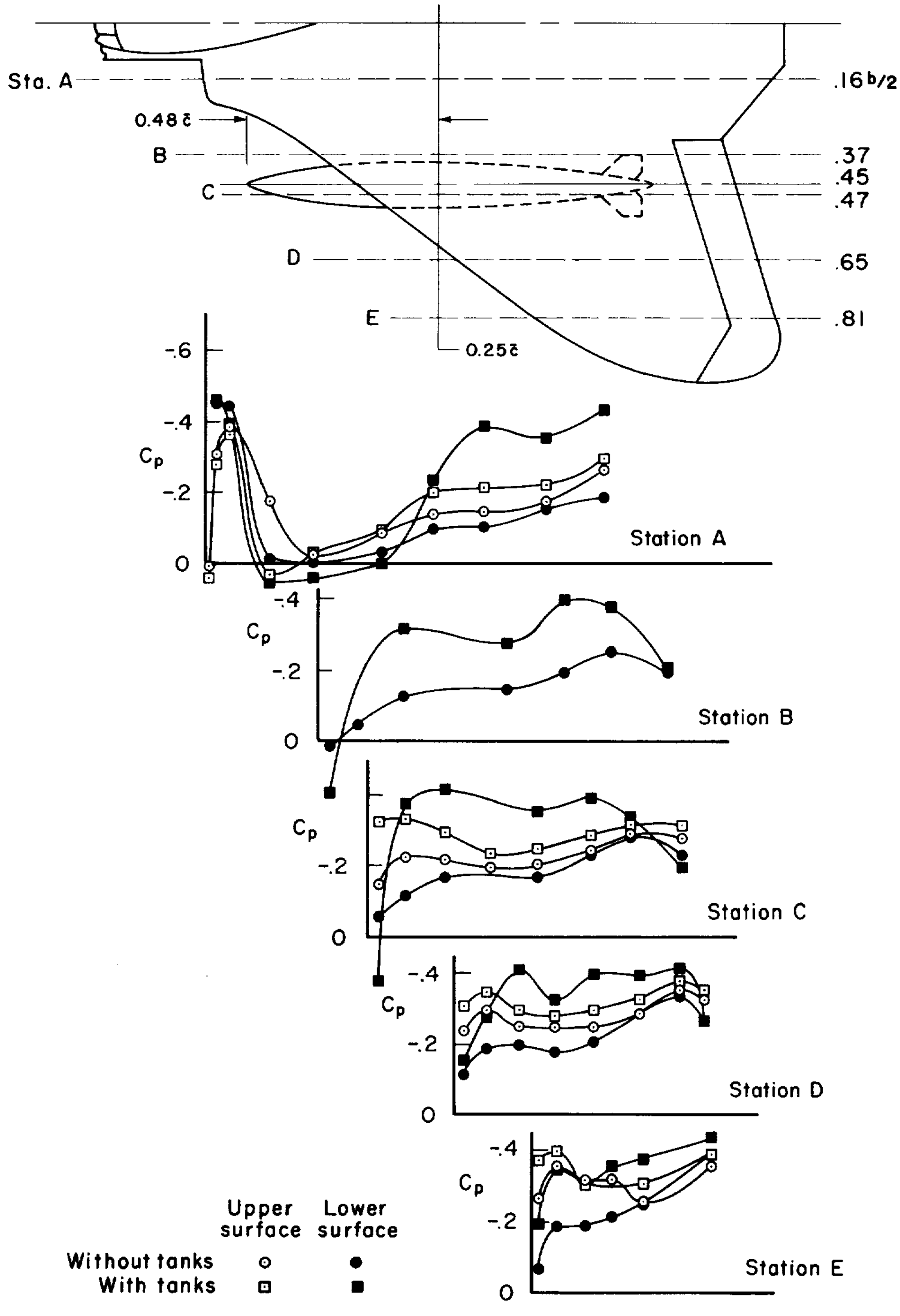
(a) M = 0.90

Figure 16.- The effect of external fuel tanks on wing pressure distribution at $\alpha = 1^{\circ}$.



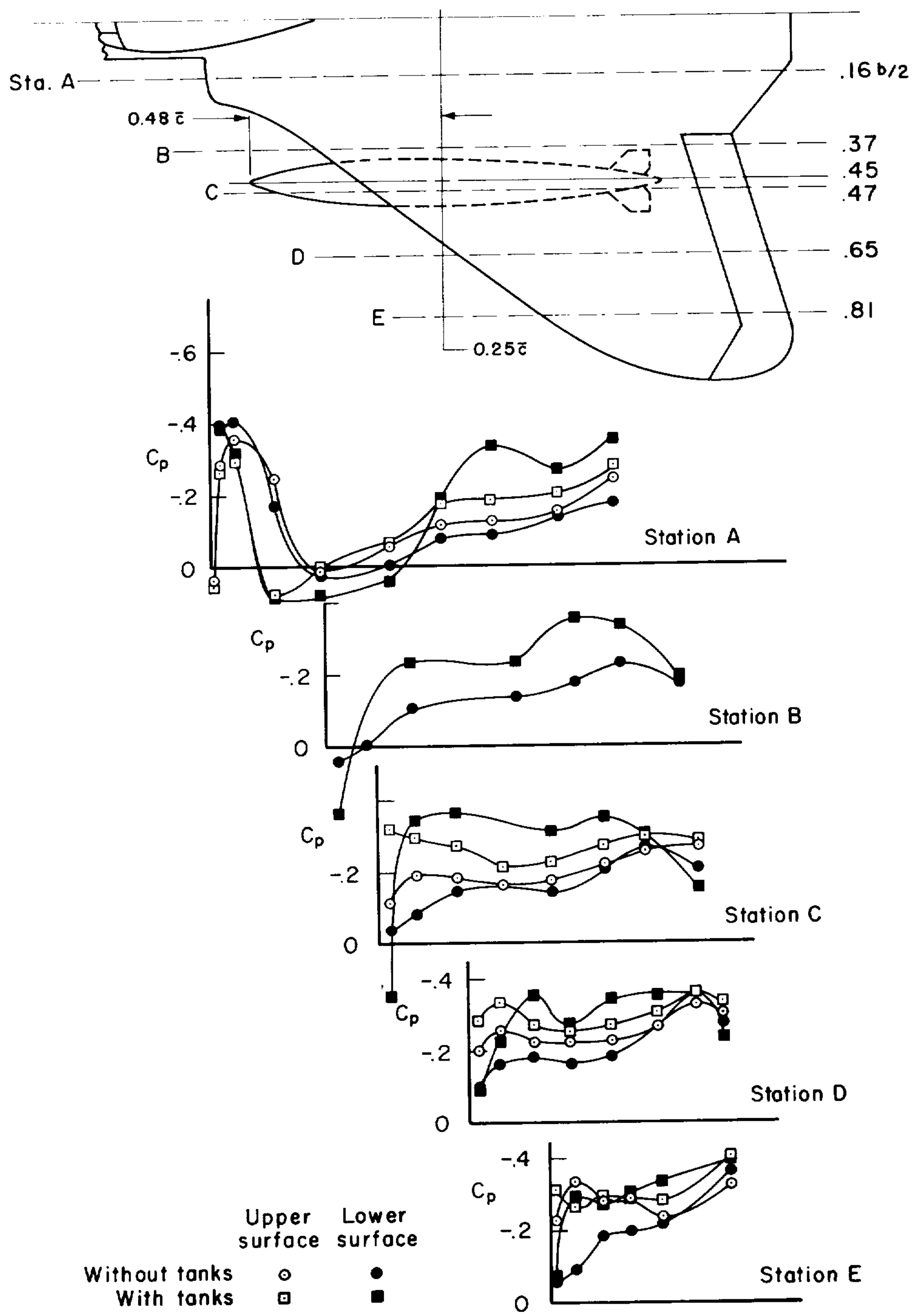
(b) M = 0.94

Figure 16.- Continued.



(c) M = 0.98

Figure 16. - Continued.



(d) M = 1.00

Figure 16.- Concluded.

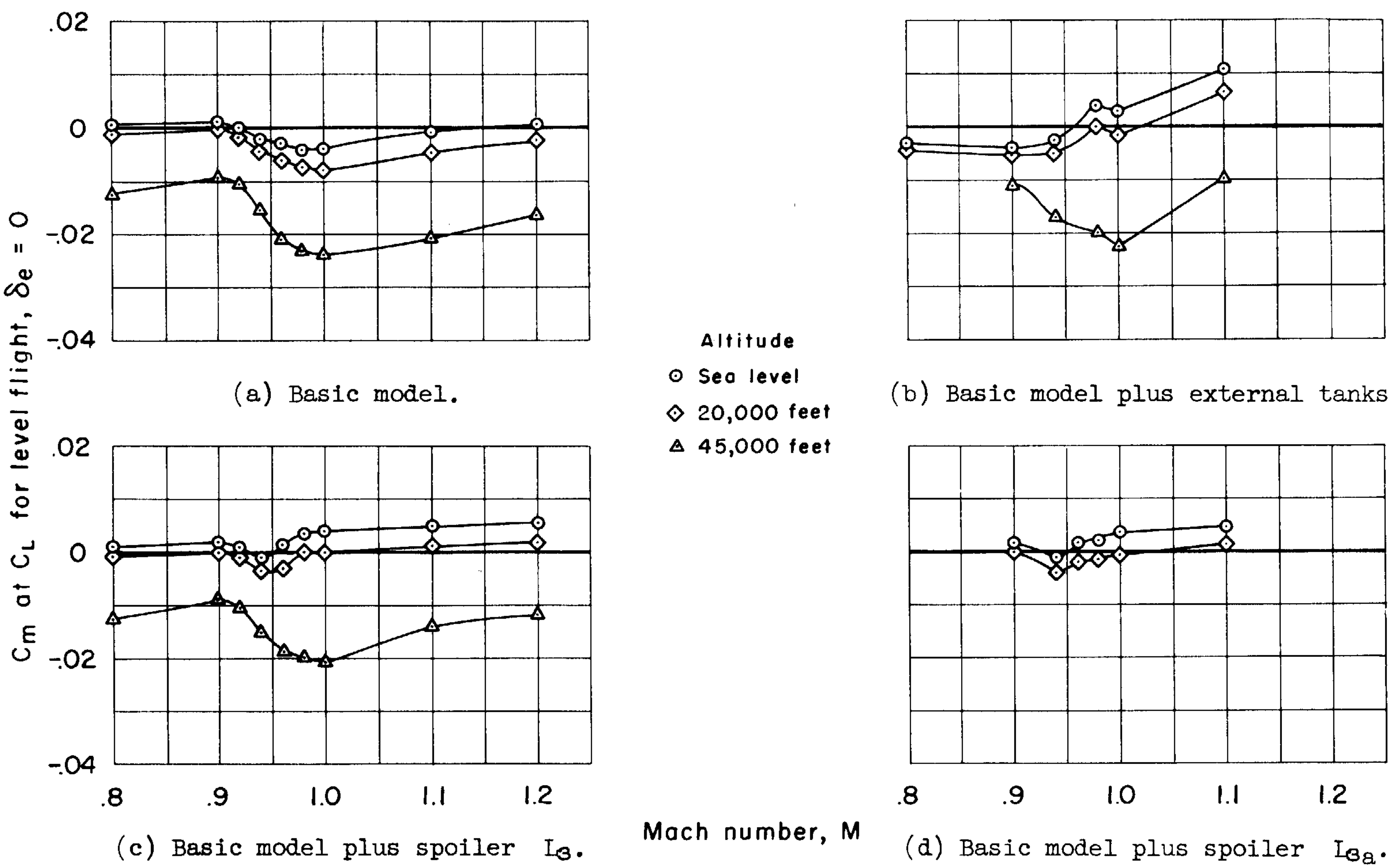
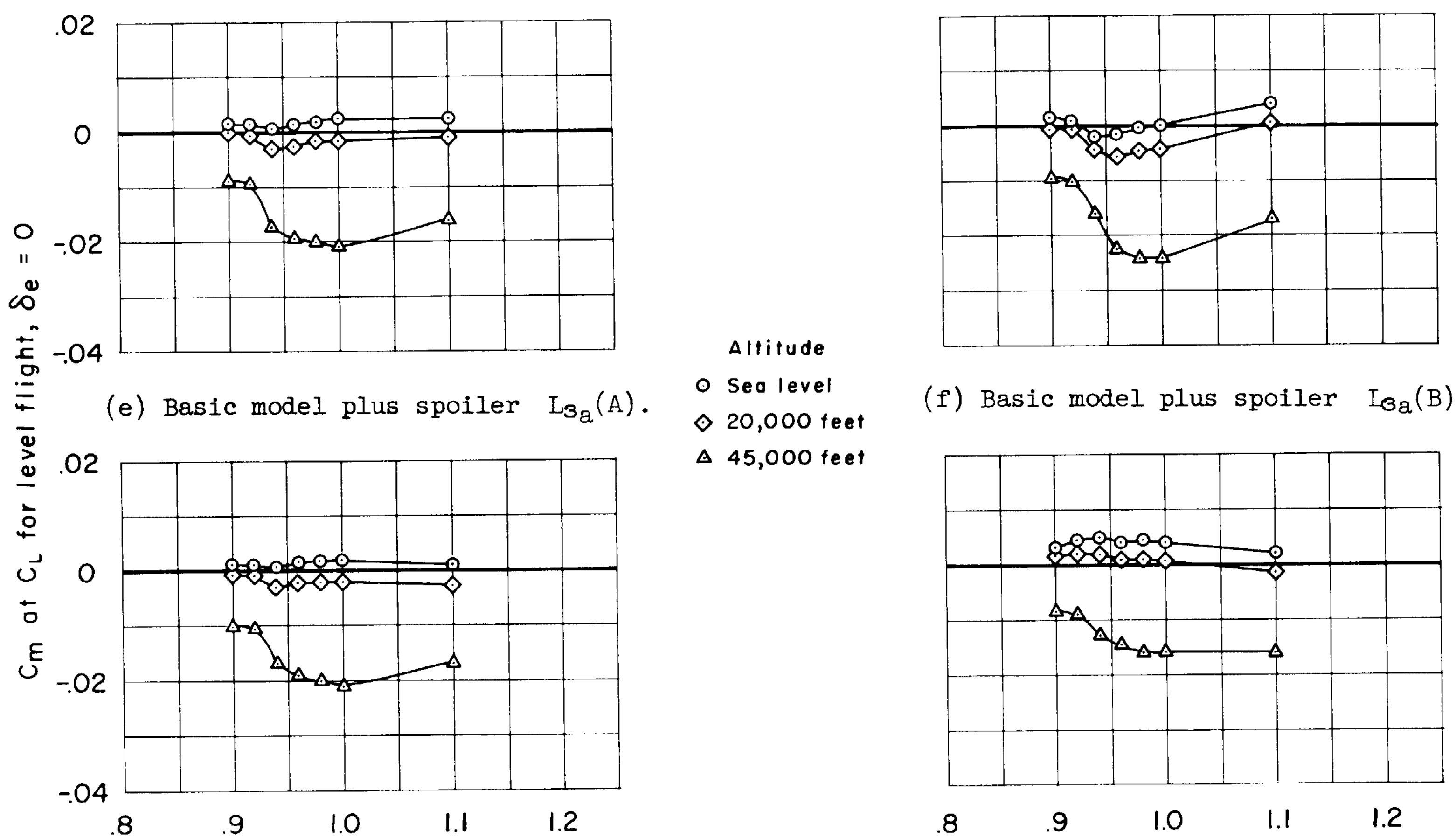


Figure 17.- The variation of pitching-moment coefficient with Mach number at level-flight lift coefficients; δ_e = 0; W/S = 33 pounds per square foot.



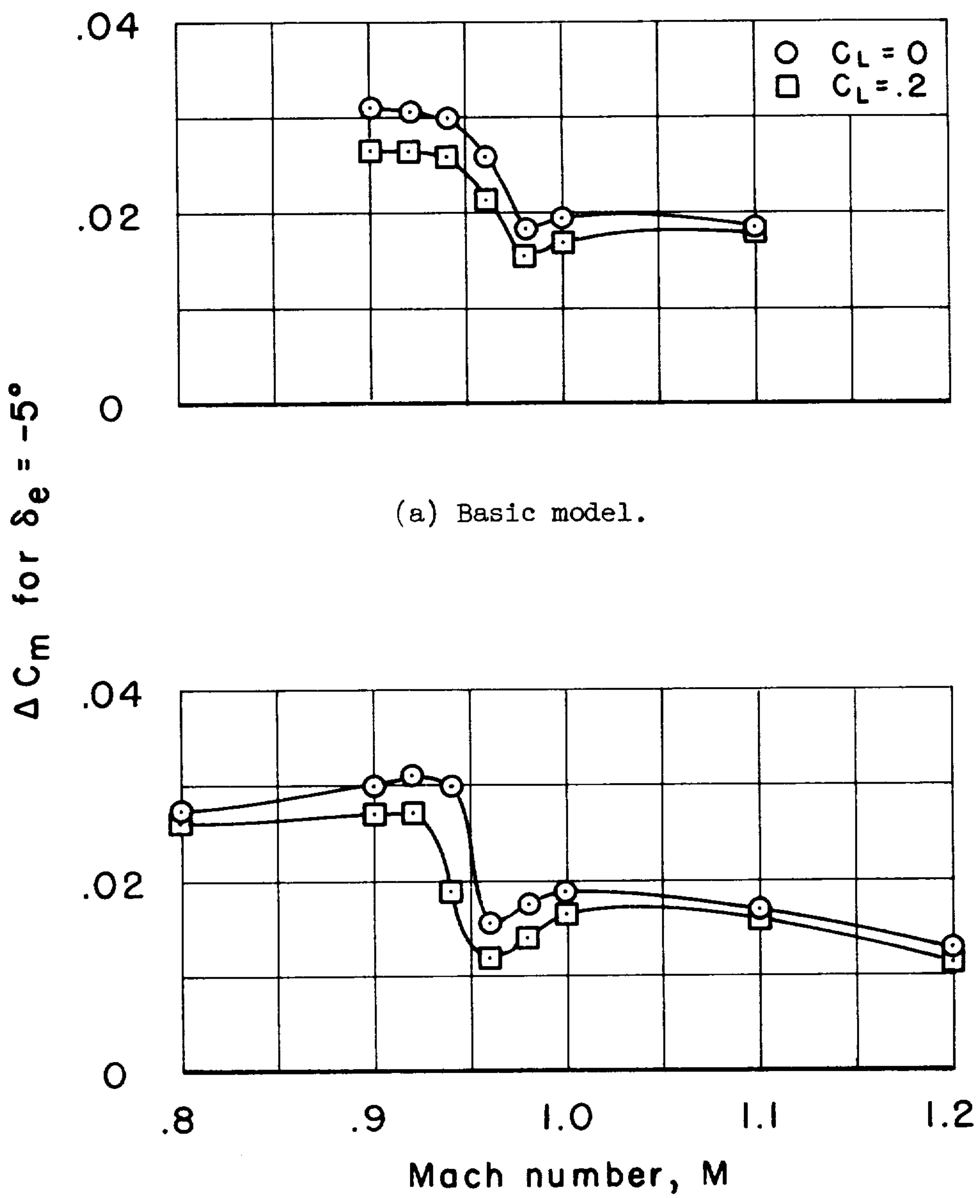
(e) Basic model plus spoiler L_{3_a}(A).

(f) Basic model plus spoiler L_{3_a}(B).

(g) Basic model plus spoiler L_{3_a}(C).

(h) Basic model plus spoiler L_{3_a}(D).

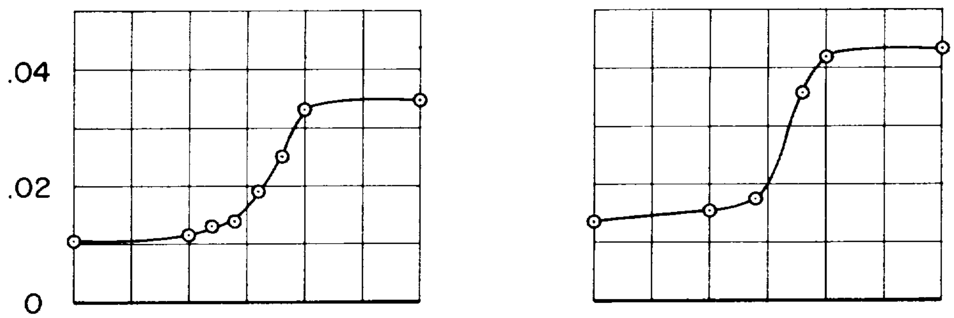
Figure 17.- Concluded.



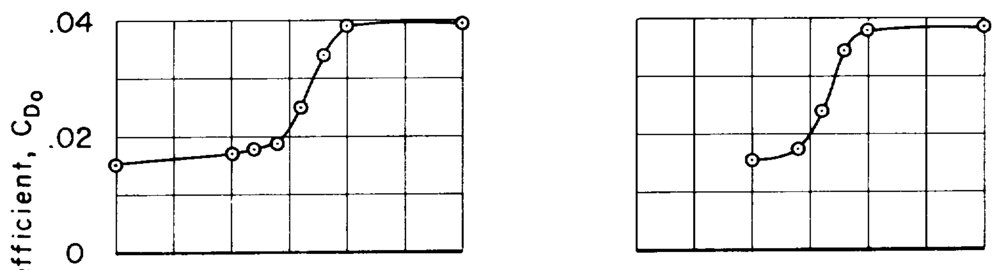
(a) Basic model.

(b) Basic model plus spoiler L_3.

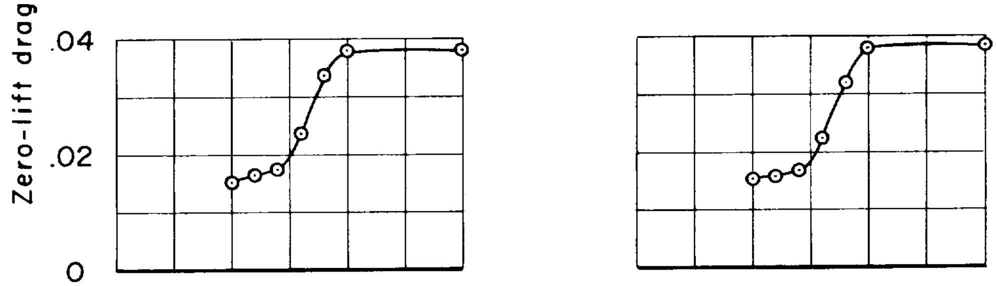
Figure 18.- The variation with Mach number of the pitching-moment coefficient increment due to elevon deflection.



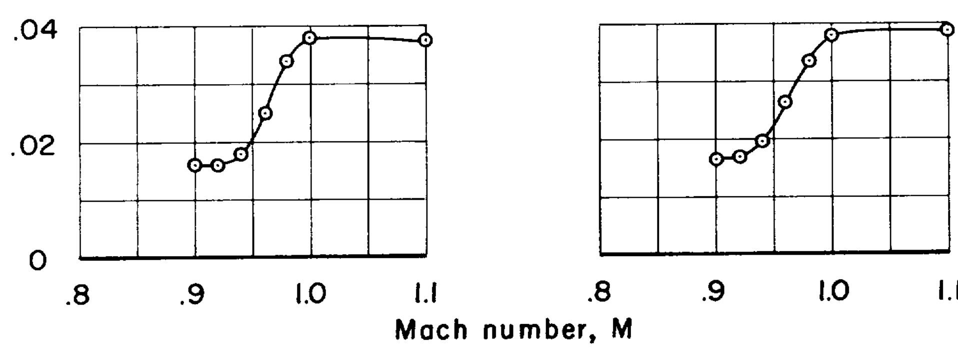
(a) Basic model. (b) Basic model plus tanks.



(c) Basic model plus spoiler L_{θ}. (d) Basic model plus spoiler L_{θ_a}.



(e) Basic model plus spoiler L_{θ_a}(A). (f) Basic model plus spoiler L_{θ_a}(B).



(g) Basic model plus spoiler L_{θ_a}(C). (h) Basic model plus spoiler L_{θ_a}(D).

Figure 19.- The variation of zero-lift drag coefficient with Mach number for several model configurations.

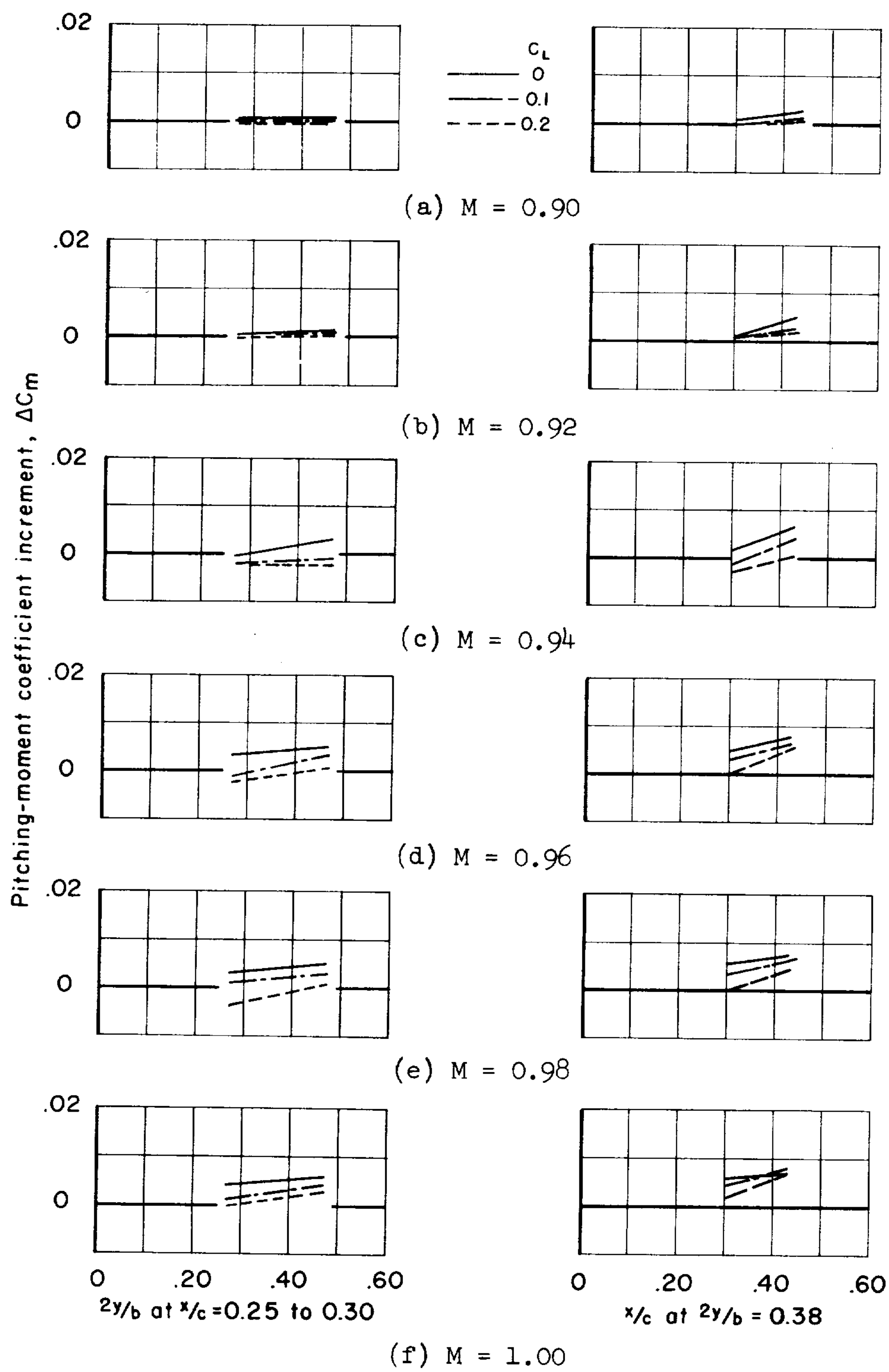


Figure 20.- The effect of spoiler location on the pitching-moment coefficient increment due to the lower surface spoilers on the model.

NASA MEMO 12-27-58A
National Aeronautics and Space Administration.
THE EFFECT OF LOWER SURFACE SPOILERS ON THE TRANSONIC TRIM CHANGE OF A WIND-TUNNEL MODEL OF A FIGHTER AIRPLANE HAVING A MODIFIED DELTA WING. Robert C. Robinson. February 1959. 50p. diagrs., photos. (NASA MEMORANDUM 12-27-58A)
(Title, Unclassified)

Wind-tunnel tests were made over a Mach number range of 0.80 to 1.20 at Reynolds numbers of approximately 4 million to find the effects of lower surface spoilers and external fuel tanks on the pitching-moment characteristics of a 0.055-scale model of a fighter airplane. Data are also presented to show the effect of external fuel tanks on wing pressure distribution.

Copies obtainable from NASA, Washington

1. Controls, Spoiler - Complete Wings (1.2.2.4.2)
2. Mach Number Effects - Complete Wings (1.2.2.6)
3. Stores - Airplane Components (1.7.1.1.5)
4. Airplanes - Specific Types (1.7.1.2)
5. Stability, Longitudinal - Static (1.8.1.1.1)
6. Control, Longitudinal (1.8.2.1)
7. Loads, Aerodynamic - Wings (4.1.1.1)

I. Robinson, Robert C.
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