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RESEARCH MEMORANDUM

THE EFFECT OF BODY CONTOURING ON THE LONGITUDINAL CHARACTERISTICS AT MACH NUMBERS UP TO 0.92 OF A WING-FUSELAGE-TAIL AND SEVERAL WING-FUSELAGE COMBINATIONS HAVING SWEPTBACK WINGS OF RELATIVELY HIGH ASPECT RATIO

By Fred B. Sutton and J. Walter Lautenberger, Jr.

Ames Aeronautical Laboratory
Moffett Field, Calif.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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SUMMARY

An investigation has been conducted to determine the effect of a Küchemann type fuselage modification designed to reduce the interference velocities at the wing-fuselage junctures on the longitudinal characteristics of a wing-fuselage-tail combination and several wing-fuselage combinations. The wing-fuselage-tail combination had a 40° sweptback wing with NACA 64A thickness distribution and the wing-fuselage combinations used a wing with NACA four-digit thickness distribution which was swept back 40°, 45°, or 50°. The tests were made through an angle-of-attack range at Mach numbers varying from 0.60 to 0.92 at a Reynolds number of 2 million.

The fuselage modification for the combinations with 40° of sweepback reduced the drag and increased the lift-drag ratios for moderate lift coefficients at high subsonic speeds. Drag reductions of as much as 18 percent were obtained for the wing-fuselage-tail combination with the 64A thickness distribution and as much as 10 percent for the four-digit wing-fuselage combination. For the combinations with 40° of sweepback, the fuselage modification increased the lift-curve slopes slightly at high subsonic speeds, but had little or no effect on longitudinal stability at most Mach numbers. With the four-digit wings having 45° and 50° of sweepback the effects of the fuselage modification were small and inconsistent at the test Mach numbers.

INTRODUCTION

A series of investigations have been made in the Ames 12-foot pressure wind tunnel to determine the longitudinal characteristics of wings suitable for long-range airplanes capable of moderately high subsonic speeds (refs. 1, 2, 3, and 4). Two twisted and cambered wings of

relatively high aspect ratio, one having NACA four-digit and the other having NACA 64A thickness distribution, were tested with 40°, 45°, and 50° of sweepback. The results presented in references 1, 2, 3, and 4 show that the stability characteristics of these wings could be improved considerably by the use of multiple chordwise wing fences or leading-edge extensions.

The primary purpose of the present phase of the investigation was to determine if the drag of configurations using the subject high-aspect-ratio sweptback wings could be reduced at high subsonic speeds if a relatively simple fuselage modification were made. As these configurations were not intended for flight at high transonic or supersonic speeds, a Küchemann type modification (ref. 5) to reduce the interference velocities at the wing-fuselage juncture was made rather than the more extensive change and reduction in fuselage volume associated with a transonic area-rule modification (ref. 6). The basic and modified fuselages were tested in combination with both wings at 40° of sweepback. In addition, the combination employing the wing with four-digit thickness distribution was tested at 45° and 50° of sweepback with and without the modified fuselage. The 64A wing-body combination was tested with a horizontal tail; the four-digit wing-body combinations were tailless.

NOTATION

All areas and dimensions used in the notation refer to the wings without leading-edge extensions.

A aspect ratio, $\frac{b^2}{2S}$

a mean-line designation, fraction of chord over which design load is uniform

$\frac{b}{2}$ wing semispan perpendicular to the plane of symmetry

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

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

C_m pitching-moment coefficient about the quarter point of the wing mean aerodynamic chord, $\frac{\text{pitching moment}}{qS\bar{c}}$

c local chord parallel to the plane of symmetry

c' local chord perpendicular to the wing sweep axis

$\bar{c}$ mean aerodynamic chord, $\dfrac{\int_0^{b/2} c^2 dy}{\int_0^{b/2} c\, dy}$

$\frac{L}{D}$ lift-drag ratio

M free-stream Mach number

q free-stream dynamic pressure

R Reynolds number based on the wing mean aerodynamic chord

S area of semispan wing

Y lateral distance from plane of symmetry

α angle of attack, measured with respect to a reference plane through the leading edge and root chord of the wings

ξ streamwise distance from the juncture of the leading edge of the 45° sweptback wing with the basic fuselage, dimensionsless with respect to the chord at the juncture

φ angle of twist, the angle between the local wing chord and the reference plane through the leading edge and the root chord of the wing (positive for washin and measured in planes parallel to the plane of symmetry)

η fraction of semispan, $\frac{y}{b/2}$

Λ angle of sweepback of the line through the quarter-chord points of the reference sections

λ wing taper ratio, $\frac{c_t}{c_r}$

$\frac{dC_L}{d\alpha}$ lift-curve slope of the models per deg

$\frac{dC_m}{dC_L}$ pitching-moment-curve slope of the models

Subscripts

r wing root

t wing tip

MODEL

The wing-fuselage-tail and the wing-fuselage combinations employed the twisted and cambered wings, the fuselage, and the horizontal tail used in the investigations described in references 1, 2, 3, and 4. For the present investigation, these components were assembled with the root chord of the wings near the center line of the fuselage at angles of incidence of about 3°. (See fig. 1(a).)

The basic fuselage consisted of a cylindrical midsection with simple fairings fore and aft. The fuselage was modified by contouring axisymmetrically in the vicinity of the wing-fuselage juncture so as to reduce the interference velocities at a Mach number of 0.90. These contours were determined by the Küchemann technique described in reference 5 and were calculated on the basis of the wing thickness distribution at the intersection of the wings with 45° of sweepback and the fuselage. Differences between these contours and those calculated for the wing-fuselage intersections with the wings at 40° and 50° of sweepback were very small, and consequently the contours calculated for the models with 45° of sweepback were used for the other angles of sweep. In this application of the Küchemann method no attempt was made to take account of the effect of wing lift due to angle of attack, wing camber, or wing angle of incidence. The fuselage was constructed from aluminum with the exception of the modified portion which was molded with glass cloth and a polyester resin. The coordinates for the basic fuselage are listed in table I and details of the modified portion of the fuselage are shown on figure 1(b).

The wing sections were derived by combining either an NACA 64A or NACA four-digit thickness distribution with an $a = 0.8$ modified mean line having an ideal lift coefficient of 0.4. These sections were perpendicular to the quarter-chord line of the unswept wing panel and their thickness-chord ratios varied from 14 percent at the root to 11 percent at the tip. Twist was introduced by rotating the streamwise sections of the wings with 40° of sweepback about the original leading edge while maintaining the projected plan form. The variations of twist and thickness ratio along the semispan of the wings are shown in figure 1(c). The angle of sweepback of the four-digit wing was set at 40°, 45°, or 50°; the corresponding aspect ratios were 7.0, 6.0, and 5.0, respectively. The 64A wing was tested only at 40° of sweepback and had a leading-edge extension which extended from 60 percent of the span to the tip. A

detailed description of the wing leading-edge extension is included in reference 4. The wing with NACA four-digit thickness distribution was tested without a leading-edge extension. Both wings were constructed of solid steel and the surfaces were polished smooth.

The horizontal tail, which was used in combination with the wing with NACA 64A thickness distribution, had an aspect ratio of 3.0, a taper ratio of 0.5, 40° of sweepback, and NACA 0010 sections perpendicular to the quarter-chord line. It was mounted on the fuselage center line at an angle of incidence of -4°. The tail was constructed of solid steel and the surfaces were polished smooth.

Figure 2 shows photographs of the model mounted in the wind tunnel and a close-up of a fuselage modification. The turntable upon which the model was mounted was directly connected to the balance system.

Corrections

The data have been corrected for constriction effects due to the presence of the tunnel walls by the method of reference 7, for tunnel-wall interference originating from lift on the model by the method of reference 8, and for drag tares caused by aerodynamic forces on the turntable upon which the model was mounted.

The corrections to dynamic pressure, Mach number, angle of attack, drag coefficient, and pitching-moment coefficient were the same as those used for references 2, 3, and 4, and are listed in table II.

RESULTS AND DISCUSSION

The results of tests on the 64A wing-fuselage-tail combination are presented in figure 3. Figures 4 and 5 present the results of tests on the four-digit wing-fuselage combinations for 40°, 45°, and 50° of sweepback. The test results are summarized in figures 6, 7, and 8.

The 64A Wing-Fuselage-Tail Combination

Figure 3 compares the longitudinal characteristics of the combination with the basic and the modified fuselage. As anticipated, the most noticeable effects of the modification were sizable drag reductions at Mach numbers greater than 0.80 (fig. 3(b)). This effect generally increased with increasing Mach number and lift coefficient. The modification also resulted in small increases in lift-curve slope at Mach numbers greater

than 0.83 (fig. 3(a)). These improvements in the lift and drag characteristics are shown to good advantage by the lift-drag ratios presented in figure 3(c). The modification increased the lift-drag ratios near the maximum by about 17 percent at the highest test Mach numbers. The effect of the modification on the variation of pitching-moment coefficient with lift coefficient (fig. 3(d)) was insignificant at most Mach numbers.

Four-Digit Wing-Fuselage Combinations

The effects of the fuselage modification on the longitudinal characteristics of the wing-fuselage combination having the 40° sweptback four-digit wing are shown in figure 4. These effects were generally similar to, though not so pronounced as, the effects of the modification on the 64A combination. At Mach numbers greater than 0.83, and at moderate to moderately high lift coefficients, drag was usually reduced (fig. 4(b)) and the lift-curve slopes were increased slightly (fig. 4(a)). Lift-drag ratios for the modified and basic models are compared in figure 4(c) for several Mach numbers. The lift-drag ratios were increased slightly at moderate lift coefficients at most Mach numbers as a result of the modification. The modification had practically no effect on the variation of pitching-moment coefficient with lift coefficient (fig. 4(d)).

The longitudinal characteristics of the basic and modified combinations with the wing at 45° and 50° of sweepback are compared in figure 5. At these angles of sweepback the effects of the fuselage modification were small and inconsistent except for small decreases in drag at a Mach number of 0.92. This was probably due to the proximity of the critical Mach numbers of the 45° and 50° combinations to the maximum test Mach number.

Effects of Mach Number

The effects of Mach number on the drag coefficients of the 40° sweptback, 64A wing-fuselage-tail and the 40° sweptback, four-digit wing-fuselage combinations are compared for the basic and modified fuselages for several constant lift coefficients in figure 6. The Mach numbers for drag divergence (defined as the Mach number at which $dC_D/dM = 0.10$) were increased moderately for the 64A combination and slightly for the four-digit combination. At Mach numbers above those for drag divergence the fuselage modification resulted in sizable drag reductions which increased with increasing Mach number for both configurations. The values of drag-divergence Mach number and the corresponding drag coefficients for the combinations with the modified fuselages are compared with those for the basic combinations in the following table:

C_L	M for divergence		C_D for divergence	
	Basic	Modified	Basic	Modified
64A wing-fuselage-tail combination				
0.2	0.878	0.882	0.0220	0.0205
.4	.820	.848	.0236	.0246
.5	.810	.828	.0295	.0297
.6	.800	.815	.0360	.0360
Four-digit wing-fuselage combination				
.2	---	---	---	---
.4	.864	.867	.0227	.0216
.5	.830	.840	.0275	.0275
.6	.788	.788	.0360	.0360

The effect of Mach number on the maximum lift-drag ratios and on the lift coefficients for maximum lift-drag ratios are shown in figure 7. Figure 8 compares the variation with Mach number of the lift-curve and pitching-moment-curve slopes of the modified combinations with those of the basic combinations.

CONCLUSIONS

An investigation has been made to determine the effect of a Küchemann type fuselage modification at the wing-fuselage juncture on the longitudinal characteristics of a wing-fuselage-tail and several wing-fuselage combinations. The following conclusions are indicated:

1. The fuselage modification reduced the drag and increased the lift-drag ratios for moderate lift coefficients at high subsonic speeds for the combinations with 40° of sweepback. Drag reductions of as much as 18 percent were measured for the wing-fuselage-tail combination with the wing having the 64A thickness distribution and as much as 10 percent for the wing-fuselage combination with the wing having the four-digit thickness distribution.

2. For the combinations with 40° of sweepback, the fuselage modification increased the lift-curve slopes slightly at high subsonic speeds but had no significant effect on longitudinal stability at most Mach numbers.

3. The effects of the fuselage modification were small and inconsistent at the test Mach numbers for the four-digit wing-fuselage combinations with the wings at 45° and 50° of sweep.

Ames Aeronautical Laboratory
National Advisory Committee for Aeronautics
Moffett Field, Calif., Oct. 8, 1956

REFERENCES

1. Sutton, Fred B., and Dickson, Jerald K.: A Comparison of the Longitudinal Aerodynamic Characteristics at Mach Numbers Up to 0.94 of Sweptback Wings Having NACA 4-Digit or NACA 64A Thickness Distributions. NACA RM A54F18, 1954.

2. Sutton, Fred B., and Dickson, Jerald K.: The Longitudinal Characteristics at Mach Numbers Up to 0.92 of Several Wing-Fuselage-Tail Combinations Having Sweptback Wings With NACA Four-Digit Thickness Distributions. NACA RM A54L08, 1955.

3. Dickson, Jerald K., and Sutton, Fred B.: The Effect of Wing Fences on the Longitudinal Characteristics at Mach Numbers Up to 0.92 of a Wing-Fuselage-Tail Combination Having a 40° Sweptback Wing with NACA 64A Thickness Distribution. NACA RM A55C30a, 1955.

4. Sutton, Fred B.: The Effect of Leading-Edge Extensions on the Longitudinal Characteristics at Mach Numbers Up to 0.92 of a Wing-Fuselage-Tail Combination Having a 40° Sweptback Wing With NACA 64A Thickness Distribution. NACA RM A55I29, 1955.

5. McDevitt, John B., and Haire, William M.: Investigation at High Subsonic Speeds of a Body-Contouring Method for Alleviating the Adverse Interference at the Root of a Sweptback Wing. NACA RM A54A22, 1954.

6. Whitcomb, Richard T.: A Study of the Zero-Lift Drag-Rise Characteristics of Wing-Body Combinations Near the Speed of Sound. NACA RM L52H08, 1952.

7. Herriot, John G.: Blockage Corrections for Three-Dimensional-Flow Closed-Throat Wind Tunnels, with Consideration of the Effect of Compressibility. NACA Rep. 995, 1950. (Formerly NACA RM A7B28).

8. Sivells, James C., and Salmi, Rachel M.: Jet-Boundary Corrections for Complete and Semispan Swept Wings in Closed Circular Wind Tunnels. NACA TN 2454, 1951.

TABLE I.- COORDINATES OF BASIC FUSELAGE

Distance from nose, in.	Radius, in.	Distance from nose, in.	Radius, in.
0	0	60.00	5.00
1.27	1.04	70.00	5.00
2.54	1.57	76.00	4.96
5.08	2.35	82.00	4.83
10.16	3.36	88.00	4.61
20.31	4.44	94.00	4.27
30.47	4.90	100.00	3.77
39.44	5.00	106.00	3.03
50.00	5.00	126.00	0

TABLE II.- CORRECTIONS TO DATA

(a) Corrections for constriction effects

Corrected Mach number	Uncorrected Mach number	$\frac{q_{corrected}}{q_{uncorrected}}$
0.60	0.590	1.006
.70	.696	1.007
.80	.793	1.010
.83	.821	1.012
.86	.848	1.015
.88	.866	1.017
.90	.883	1.020
.92	.899	1.024

(b) Corrections for tunnel-wall interference

$$\Delta\alpha = 0.455\ C_L$$

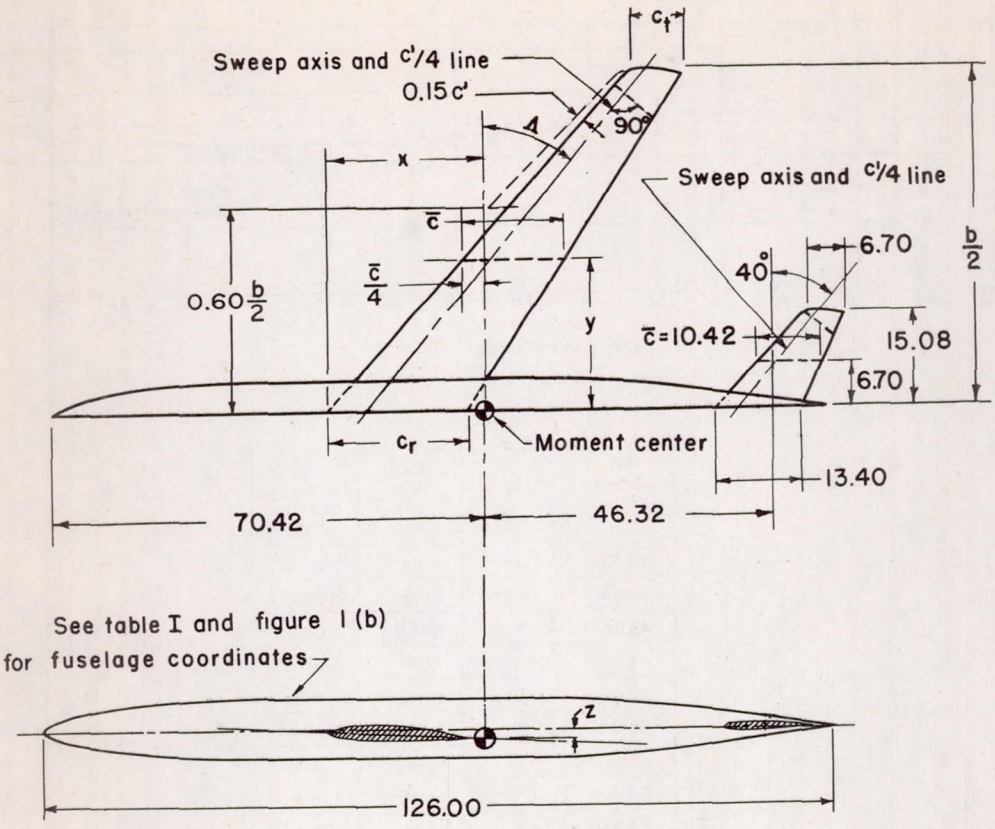
$$\Delta C_D = 0.00662\ C_L^2$$

$$\Delta C_{m_{tail\ off}} = K_1 C_{L_{tail\ off}}$$

$$\Delta C_{m_{tail\ on}} = K_1 C_{L_{tail\ off}} - \left[(K_2 C_{L_{tail\ off}} - \Delta\alpha) \frac{\partial C_m}{\partial i_t} \right]$$

where:

M	K_1	K_2
0.60	0.0038	0.74
.70	.0043	.76
.80	.0049	.79
.83	.0050	.80
.86	.0053	.83
.88	.0054	.84
.90	.0056	.86
.92	.0057	.88

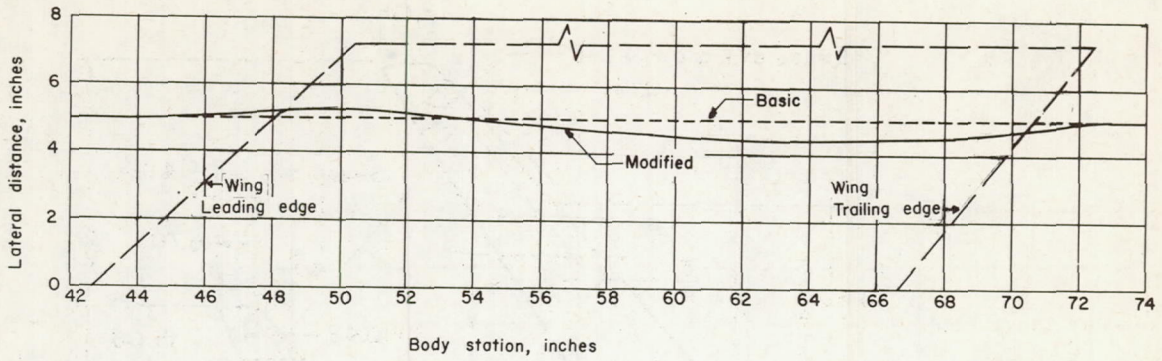


Geometry of the wings											
Λ	A	λ	b/2	c_r	c_t	$\bar{c}$	x	y	z	S	a_r
40°	7.00	0.4	54.61	22.29	8.92	16.56	25.35	23.40	1.45	5.92	3.00°
45°	6.03	0.4	50.41	23.90	9.56	17.76	27.76	21.60	1.45	5.86	2.95°
50°	5.04	0.4	45.82	25.98	10.39	19.30	30.13	19.64	1.45	5.79	2.90°

Note: All dimensions in inches and areas in square feet.

(a) Dimensions.

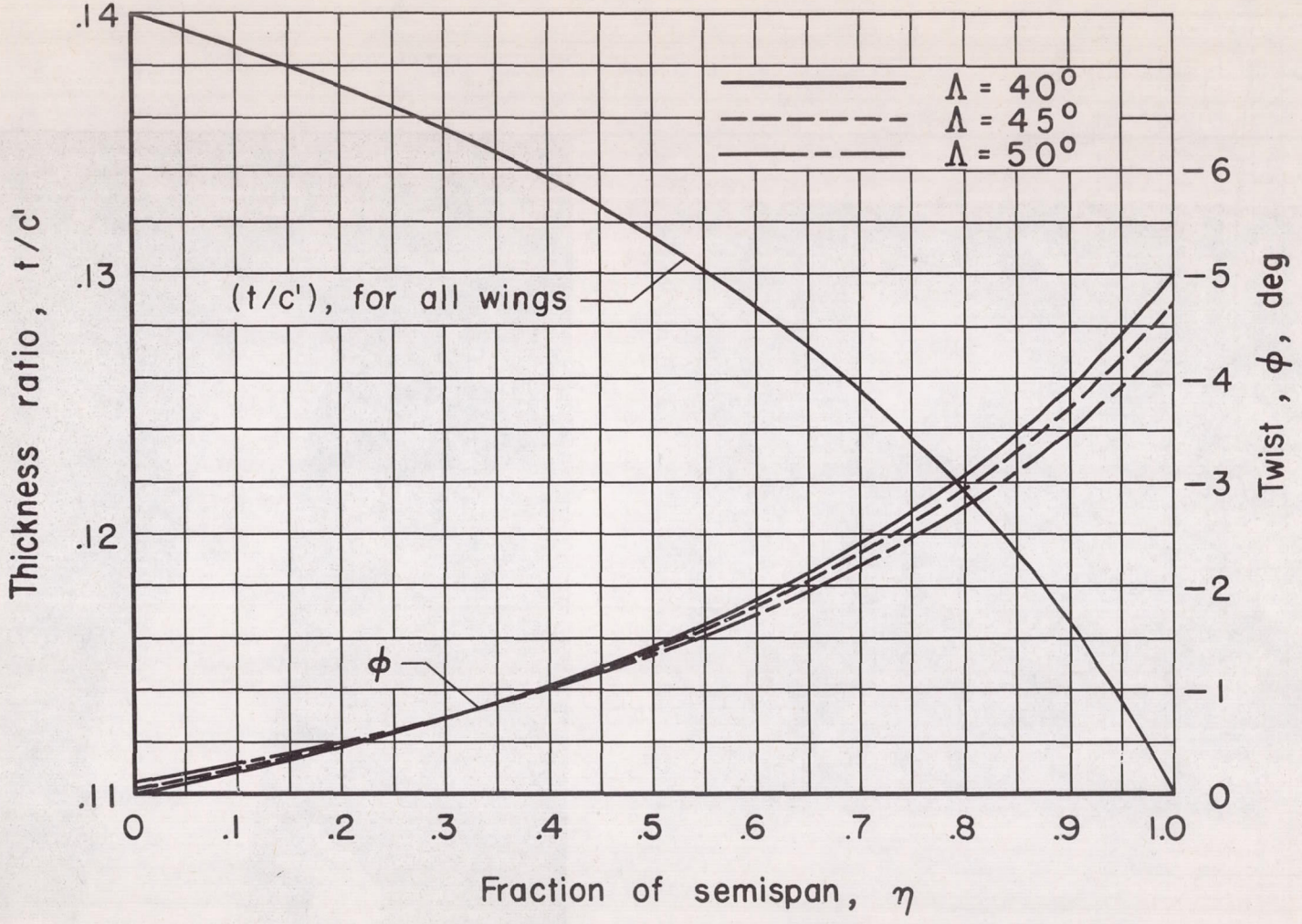
Figure 1.- Geometry of the model.



Body station, inches	ξ	Body radius, inches	
		With 64A wing	With four digit wing
38.437	-0.428	5.000	5.000
39.437	-.384	5.000	5.000
43.567	-.2	5.000	5.000
45.815	-.1	5.047	5.021
48.063	0	5.166	5.197
50.311	.1	5.266	5.294
52.559	.2	5.115	5.105
54.806	.3	4.911	4.867
57.054	.4	4.718	4.689
59.302	.5	4.585	4.583
61.550	.6	4.452	4.478
63.798	.7	4.427	4.461
66.045	.8	4.426	4.473
68.293	.9	4.505	4.539
70.541	1.0	4.799	4.814
72.000	1.065	4.985	4.970
73.000	1.109	5.000	5.000

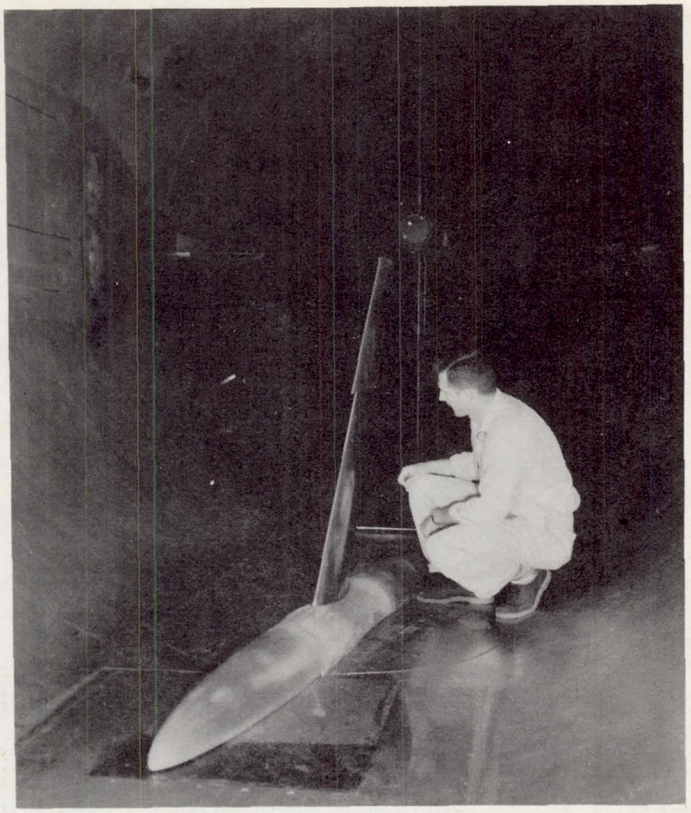
(b) Fuselage contouring details.

Figure 1.- Continued.

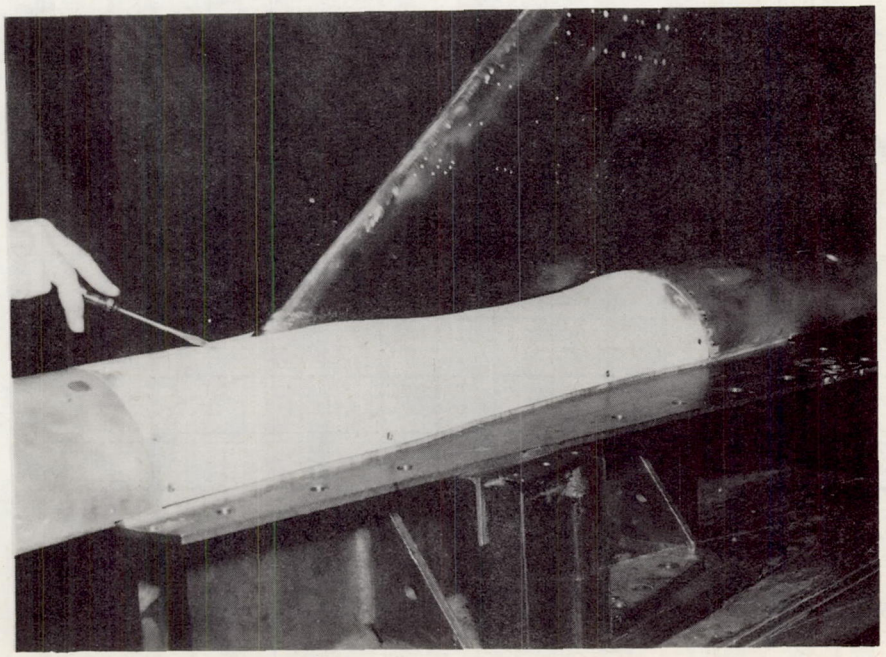


(c) Distribution of twist and thickness ratio.

Figure 1.- Concluded.

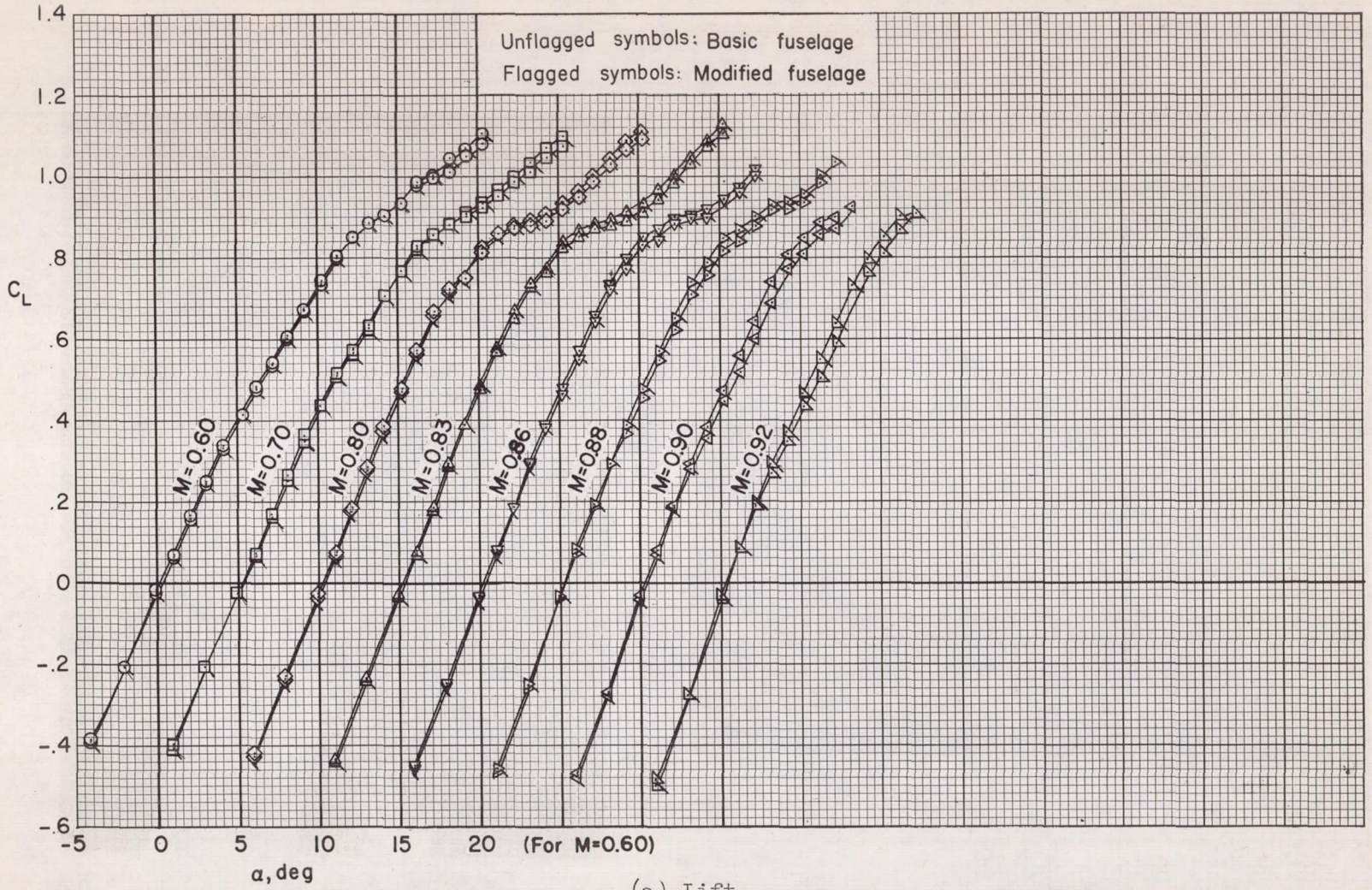


(a) General arrangement. A-21513



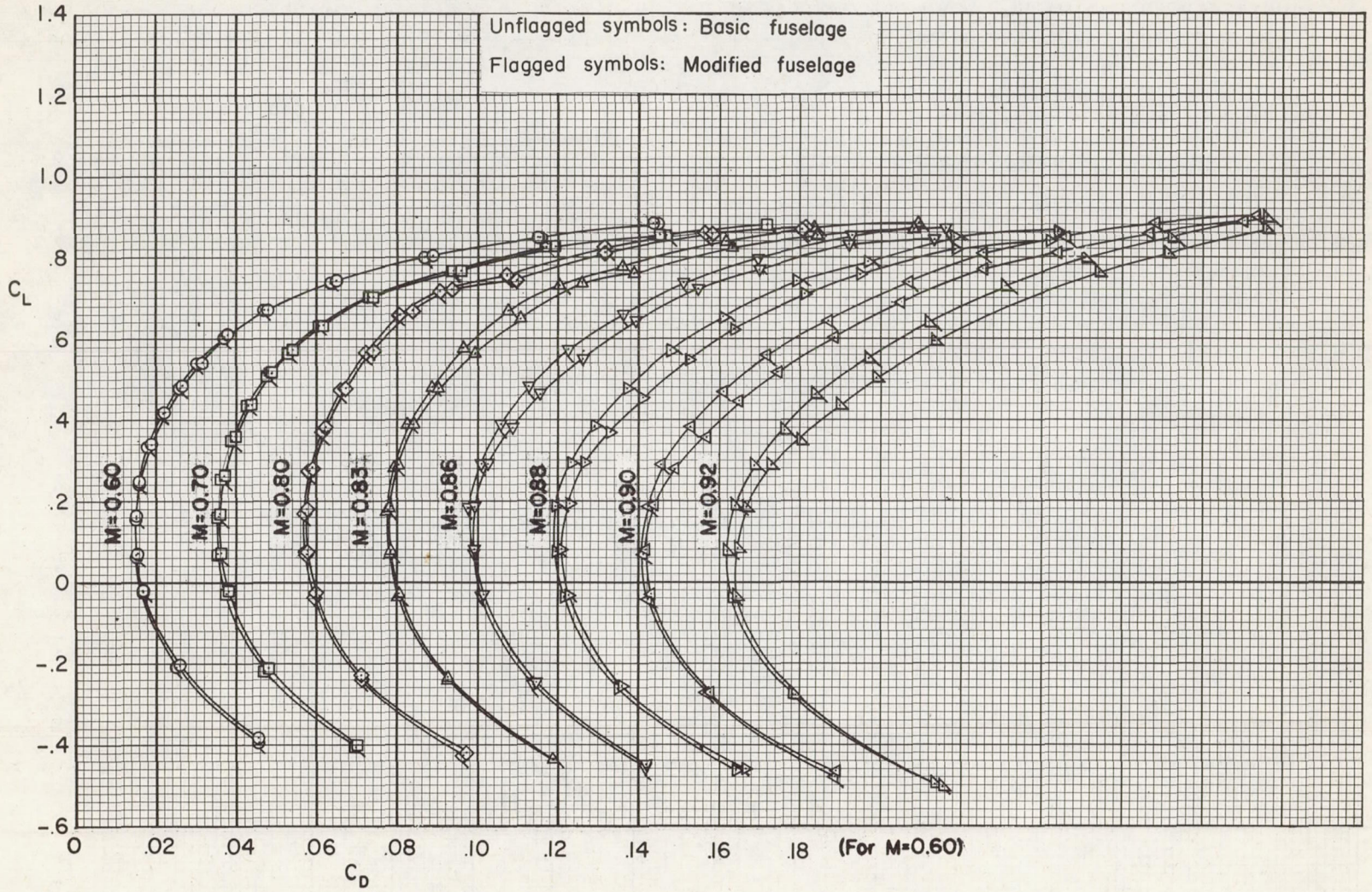
(b) Close-up of fuselage modification. A-21695

Figure 2.- Photographs of one of the models.



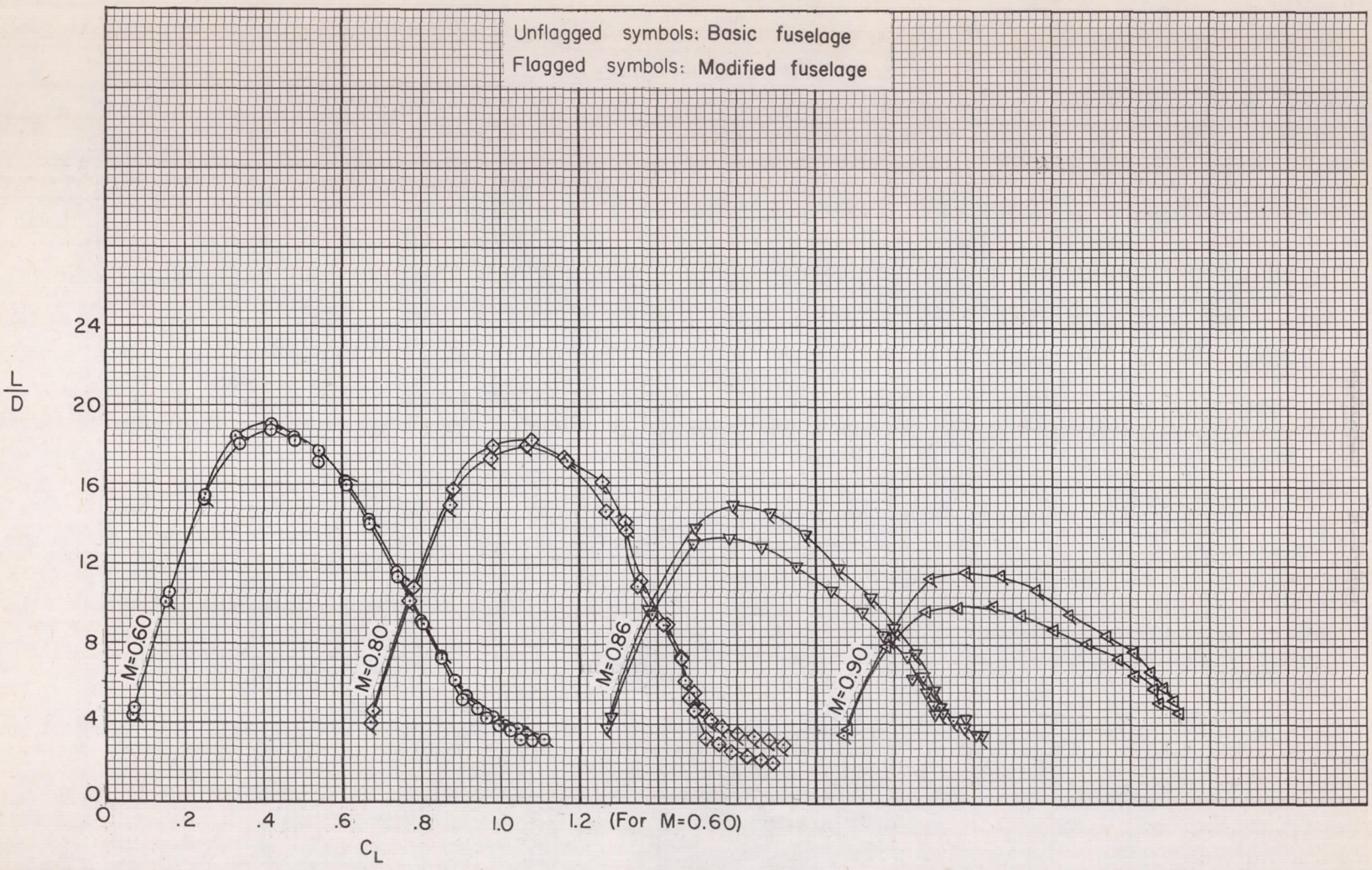
(a) Lift.

Figure 3.- The effect of a fuselage modification on the longitudinal characteristics of a wing-fuselage-tail combination having a wing with 40° of sweepback and NACA 64A thickness distribution.



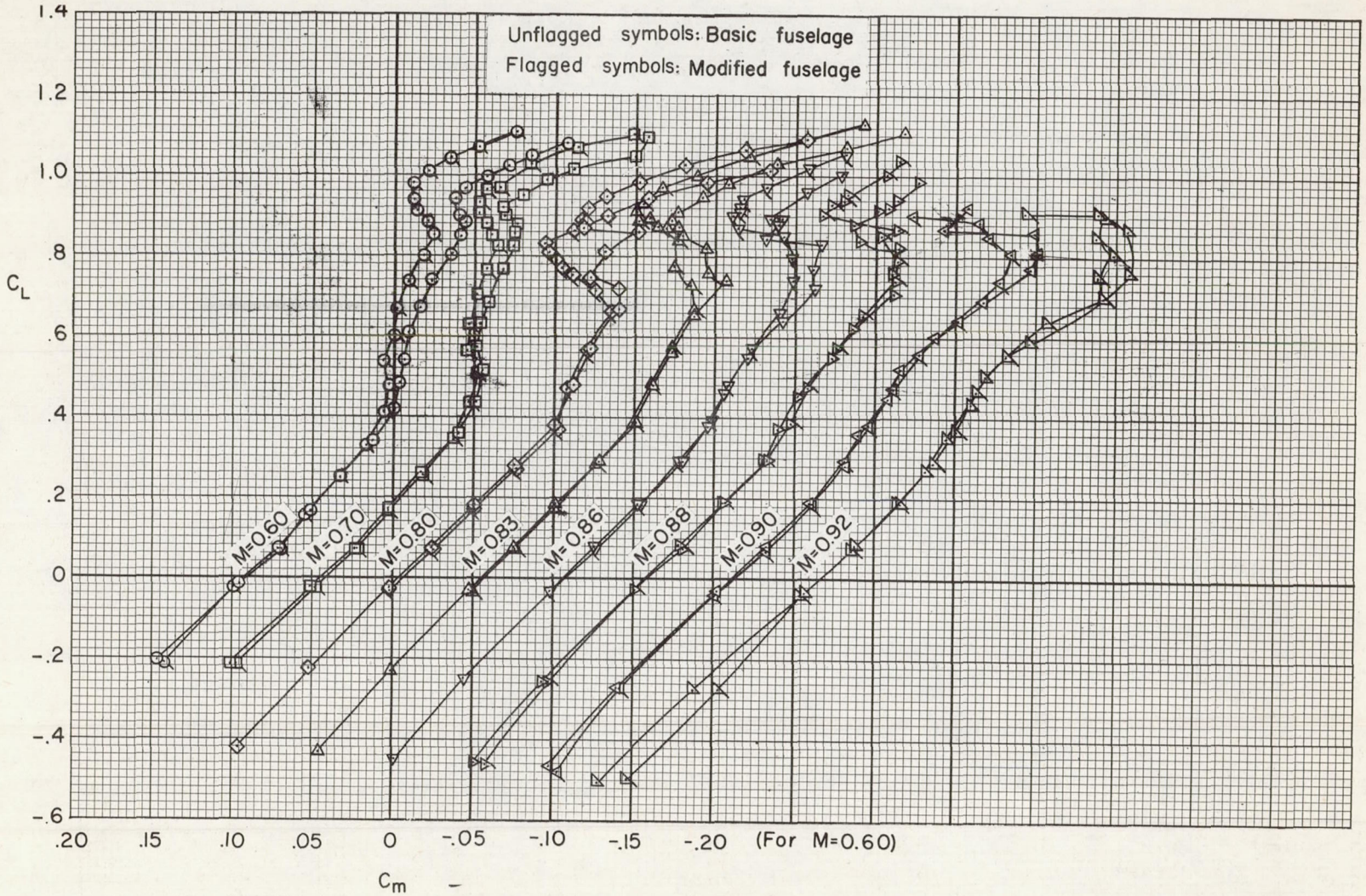
(b) Drag.

Figure 3.- Continued.



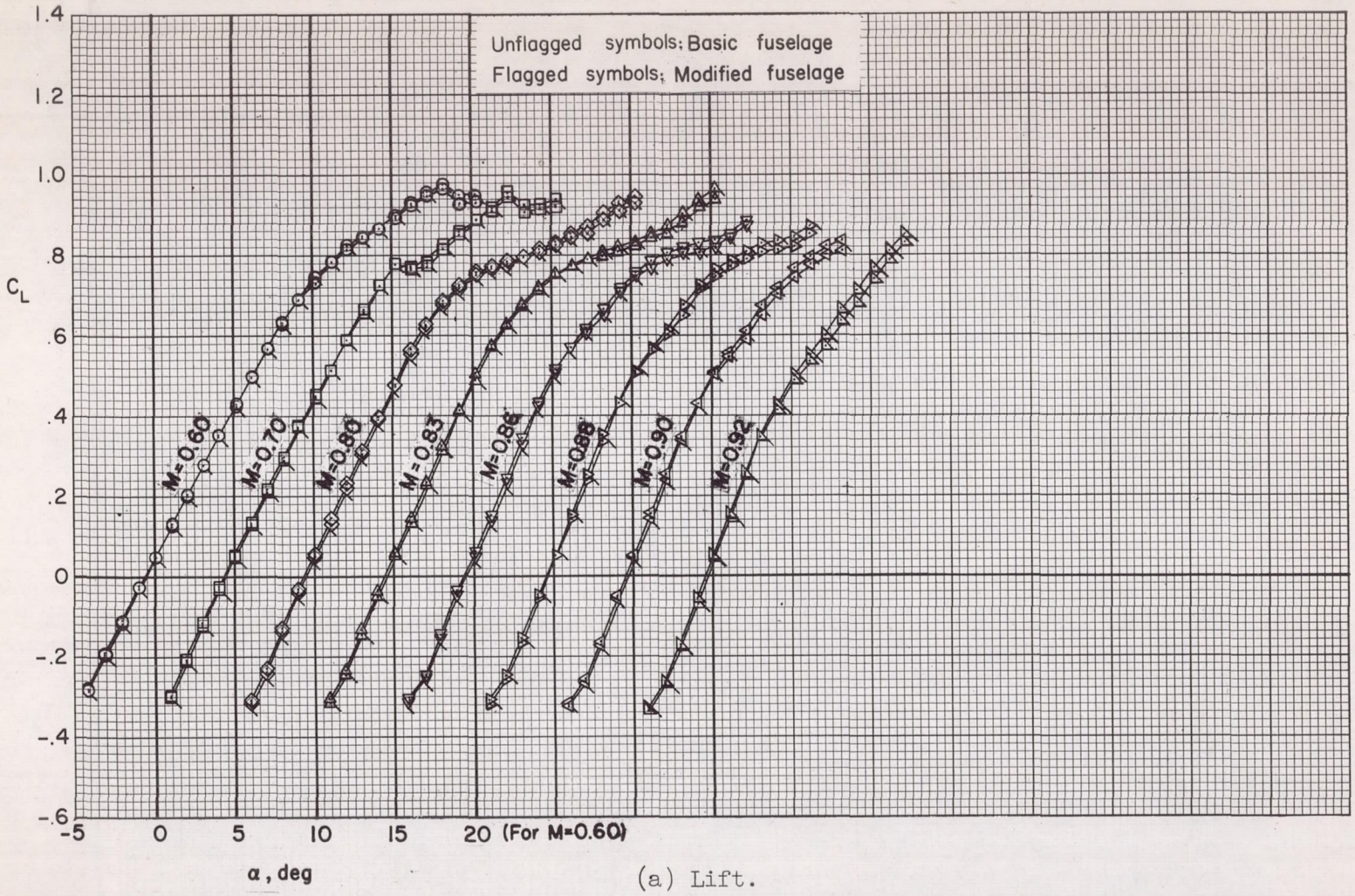
(c) Lift-drag ratio.

Figure 3.- Continued.



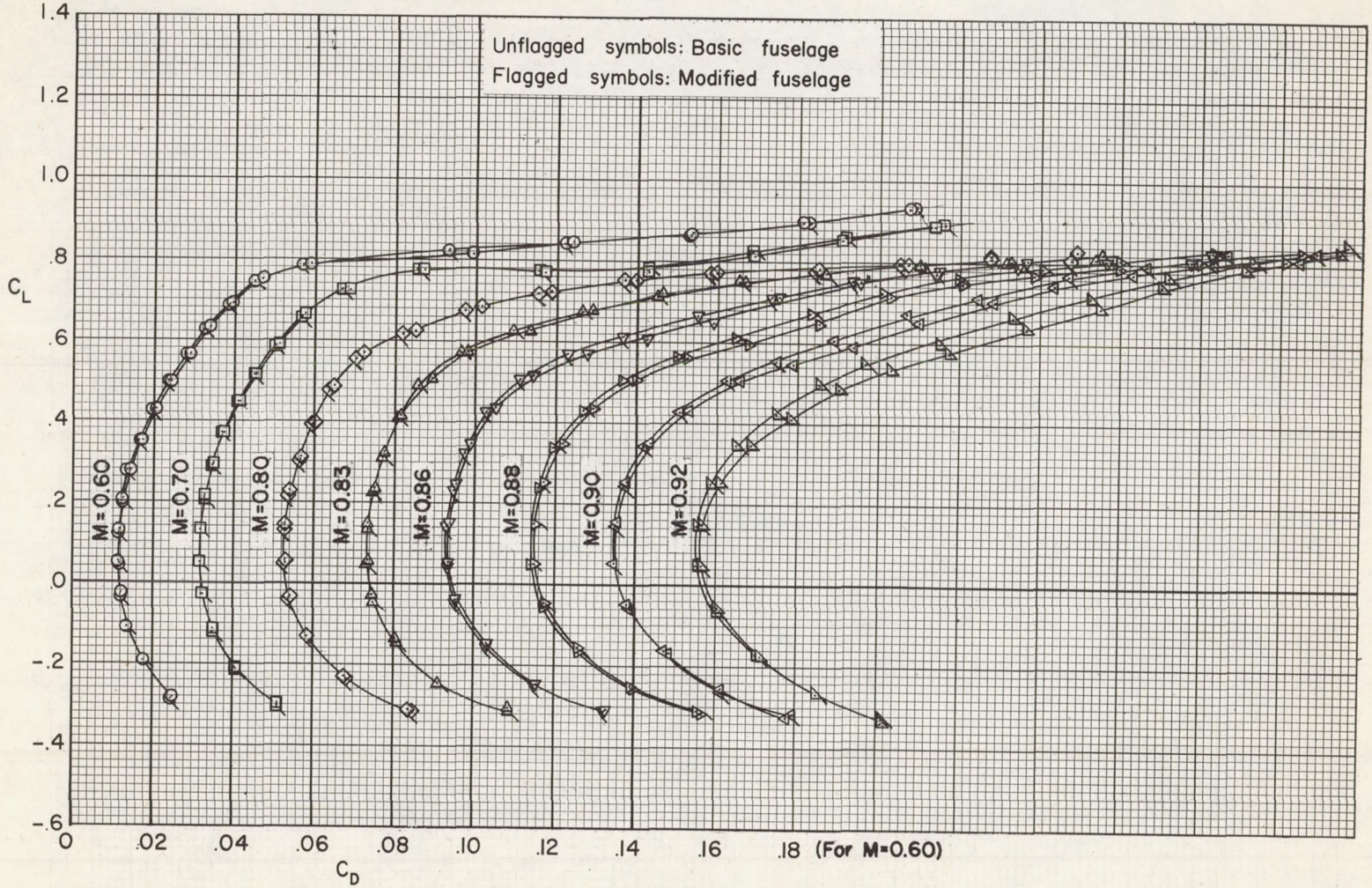
(d) Pitching moment.

Figure 3.- Concluded.



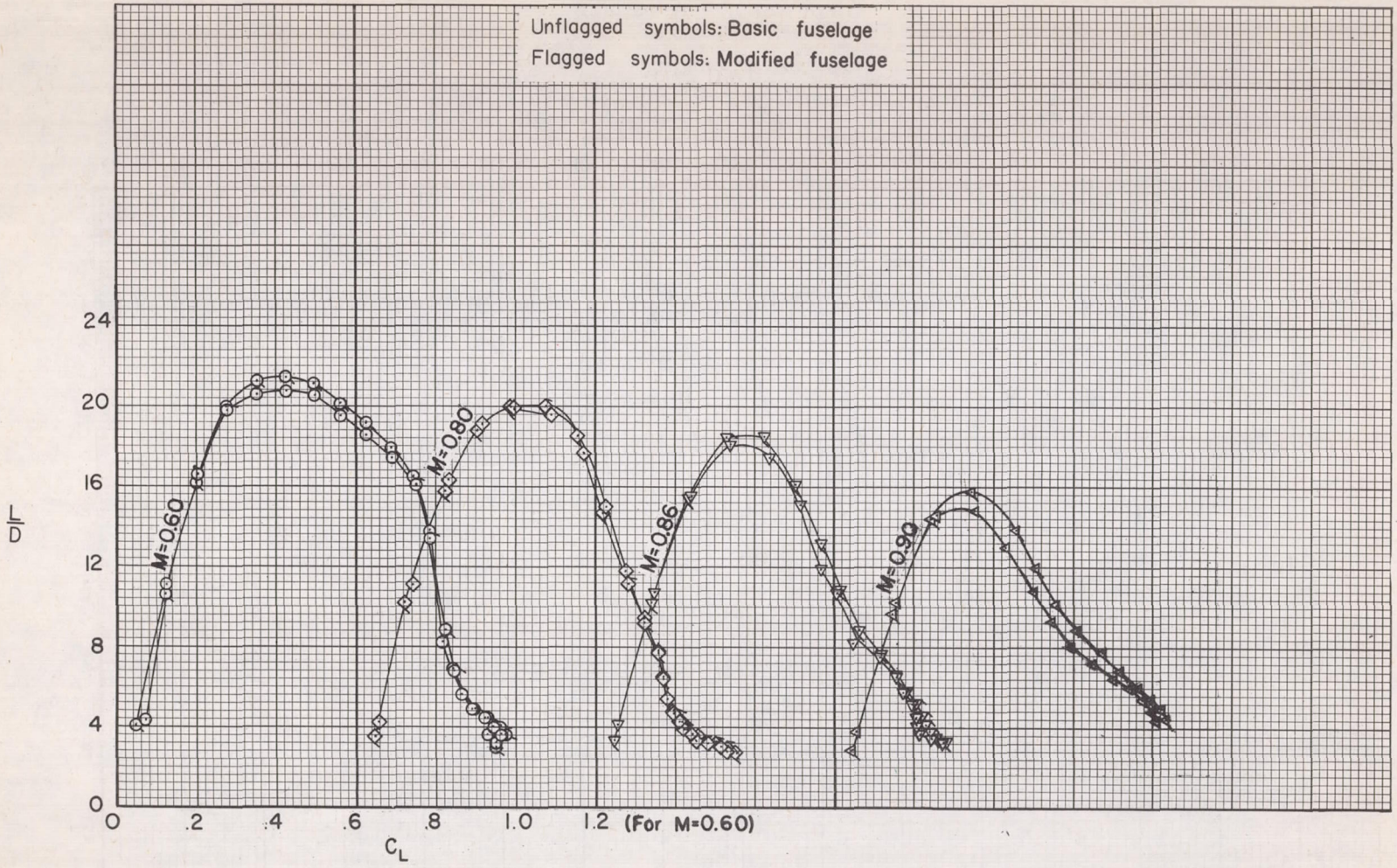
(a) Lift.

Figure 4.- The effect of a fuselage modification on the longitudinal characteristics of a wing-fuselage combination having a wing with 40° of sweepback and NACA four-digit thickness distribution.



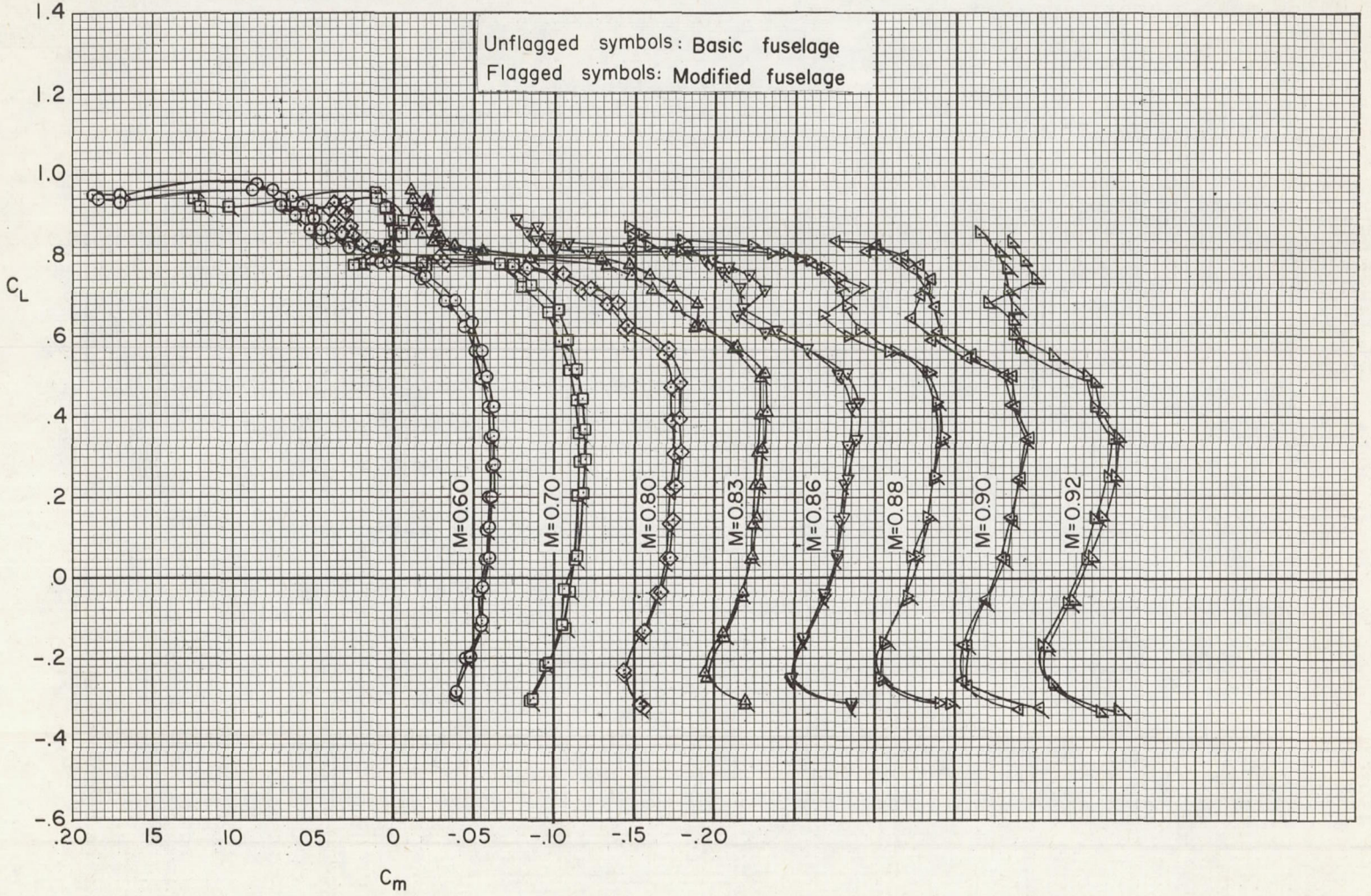
(b) Drag.

Figure 4.- Continued.



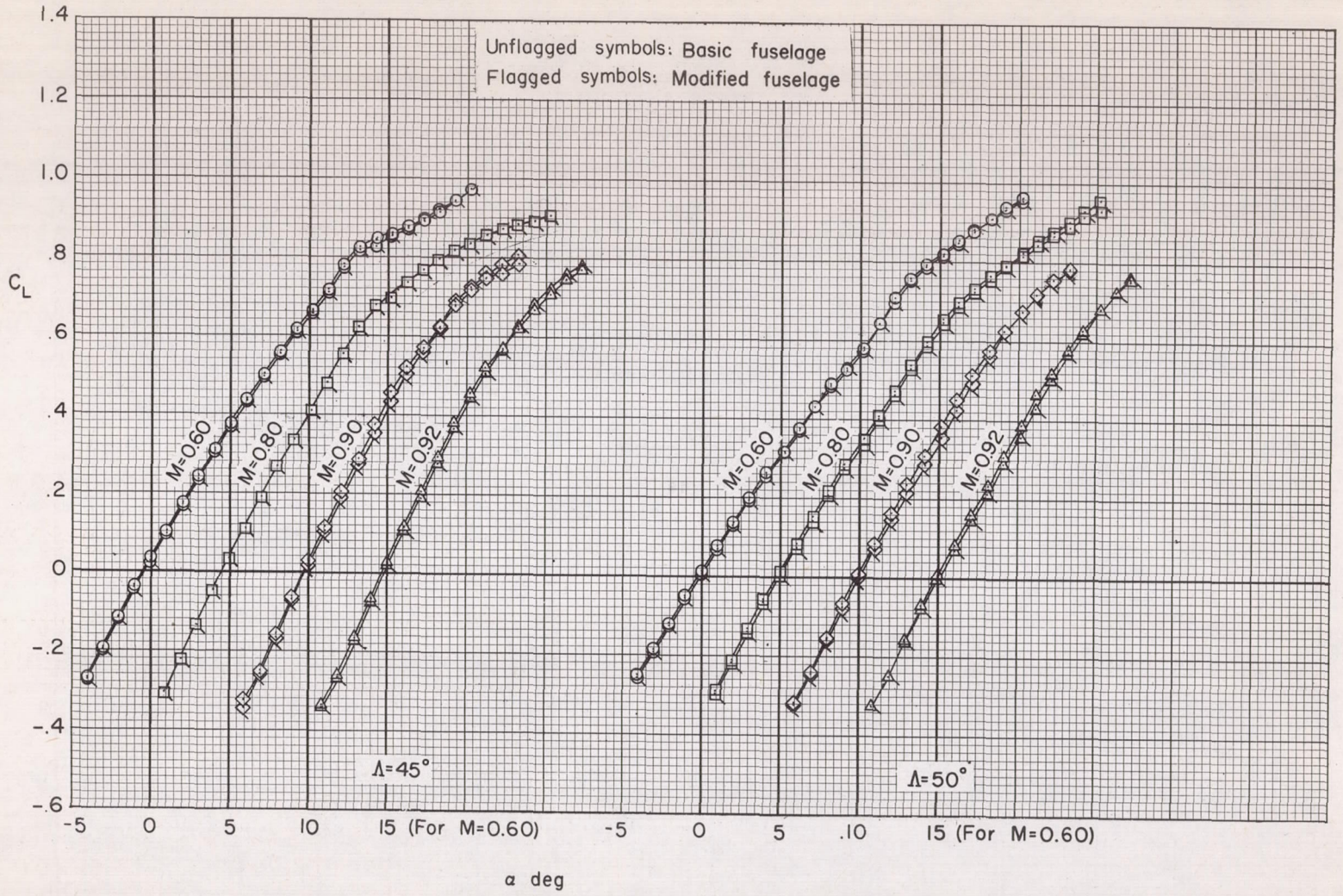
(c) Lift-drag ratio.

Figure 4.- Continued.



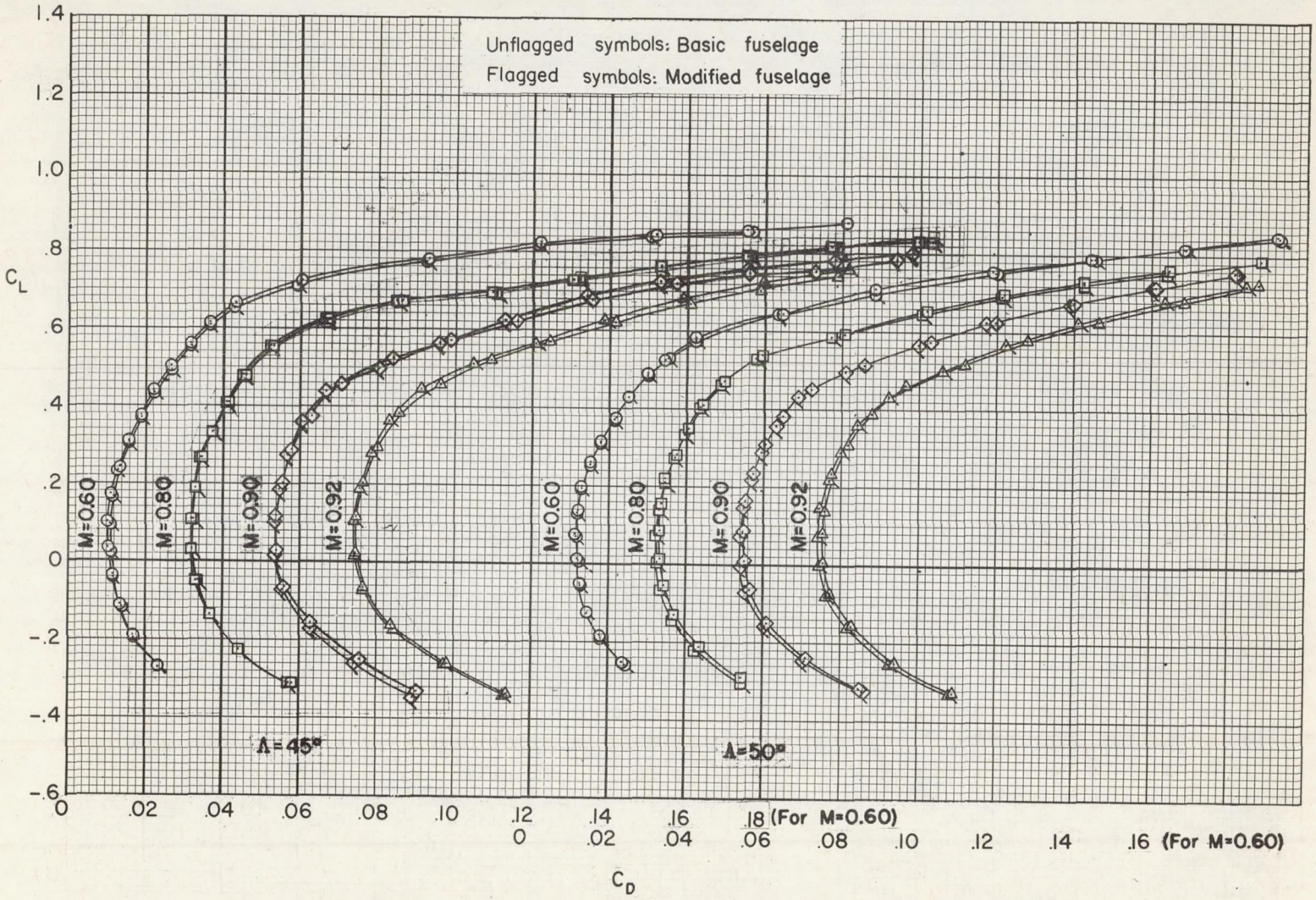
(d) Pitching moment.

Figure 4.- Concluded.



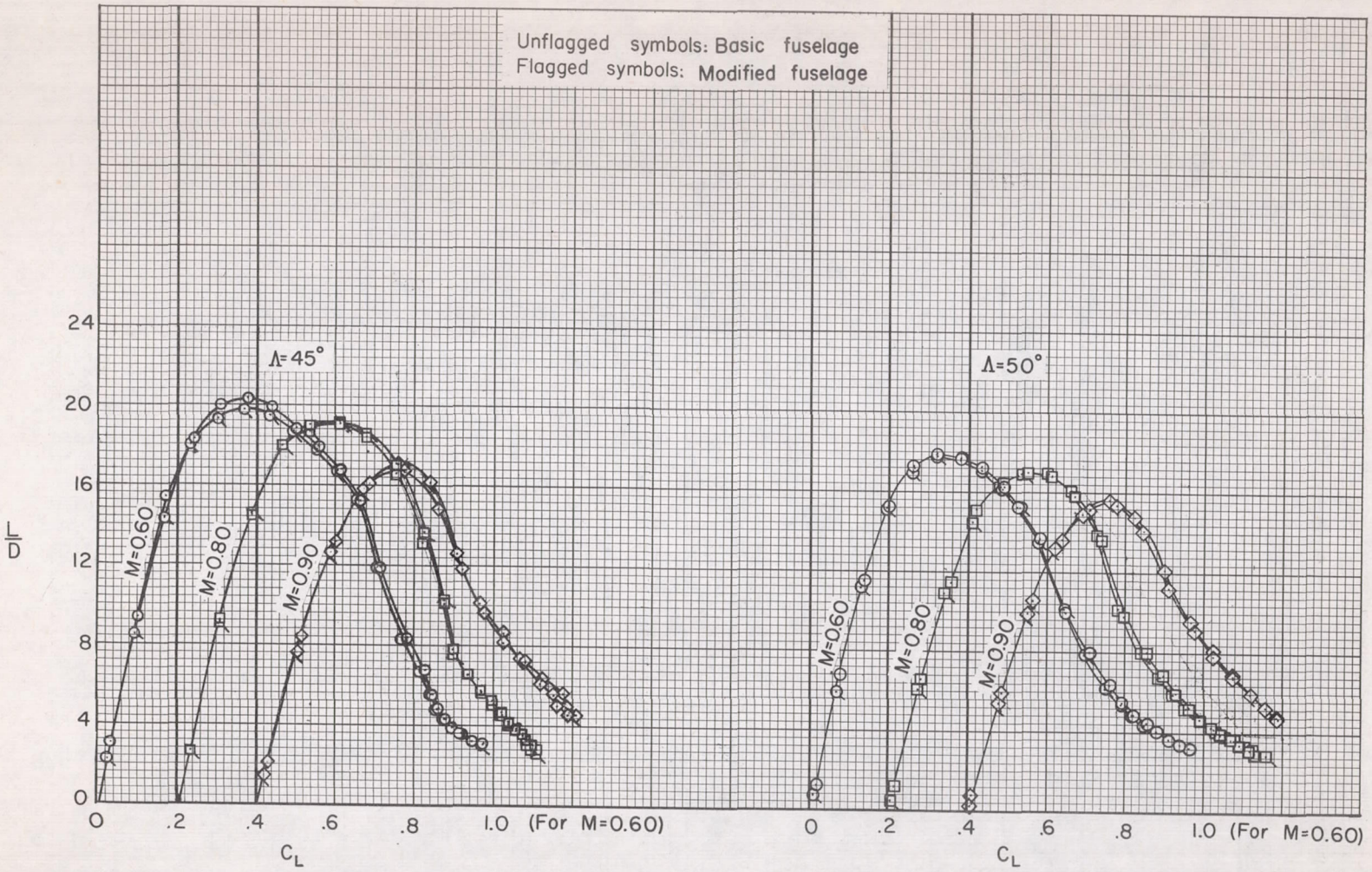
(a) Lift.

Figure 5.- The effect of a fuselage modification on the longitudinal characteristics of wing-fuselage combinations having wings with NACA four-digit thickness distribution and 45° and 50° of sweepback.



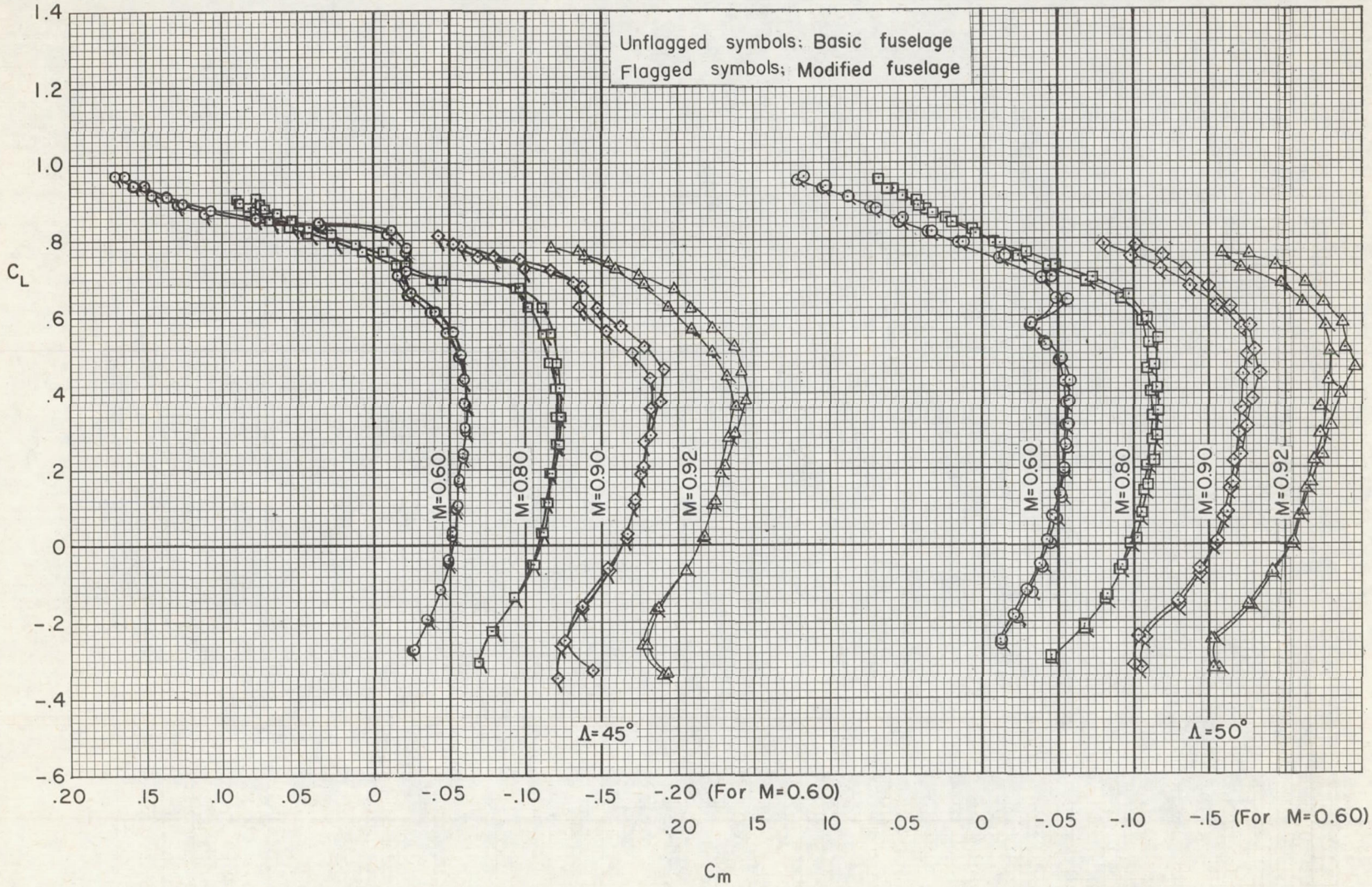
(b) Drag.

Figure 5.- Continued.



(c) Lift-drag ratio.

Figure 5.- Continued.



(d) Pitching moment.

Figure 5.- Concluded.

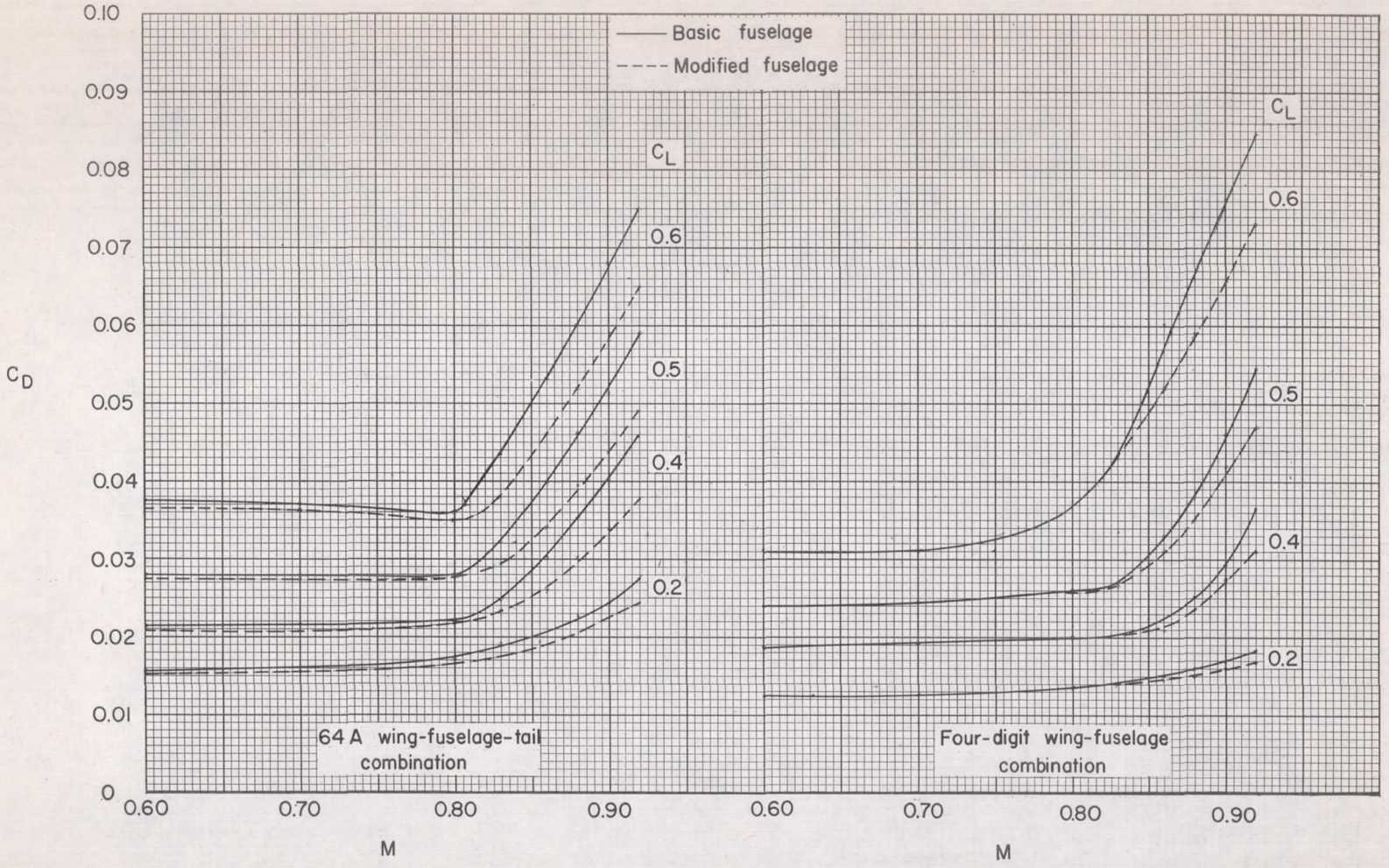


Figure 6.- The variation with Mach number of the drag coefficients of the models with 40° sweptback wings.

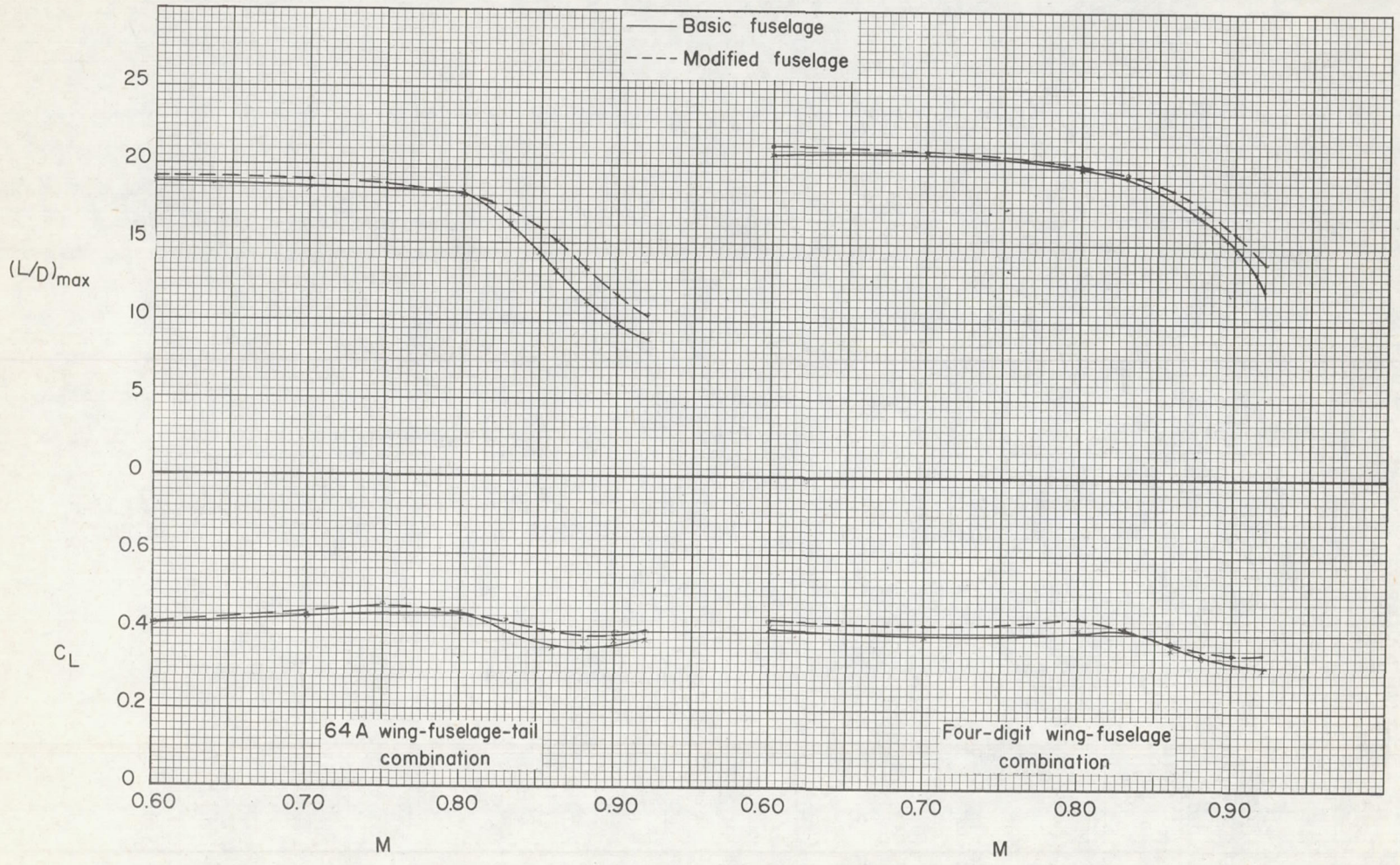


Figure 7.- The variation with Mach number of the maximum lift-drag ratios and the lift coefficient for maximum lift-drag ratios of the models with 40° sweptback wings.

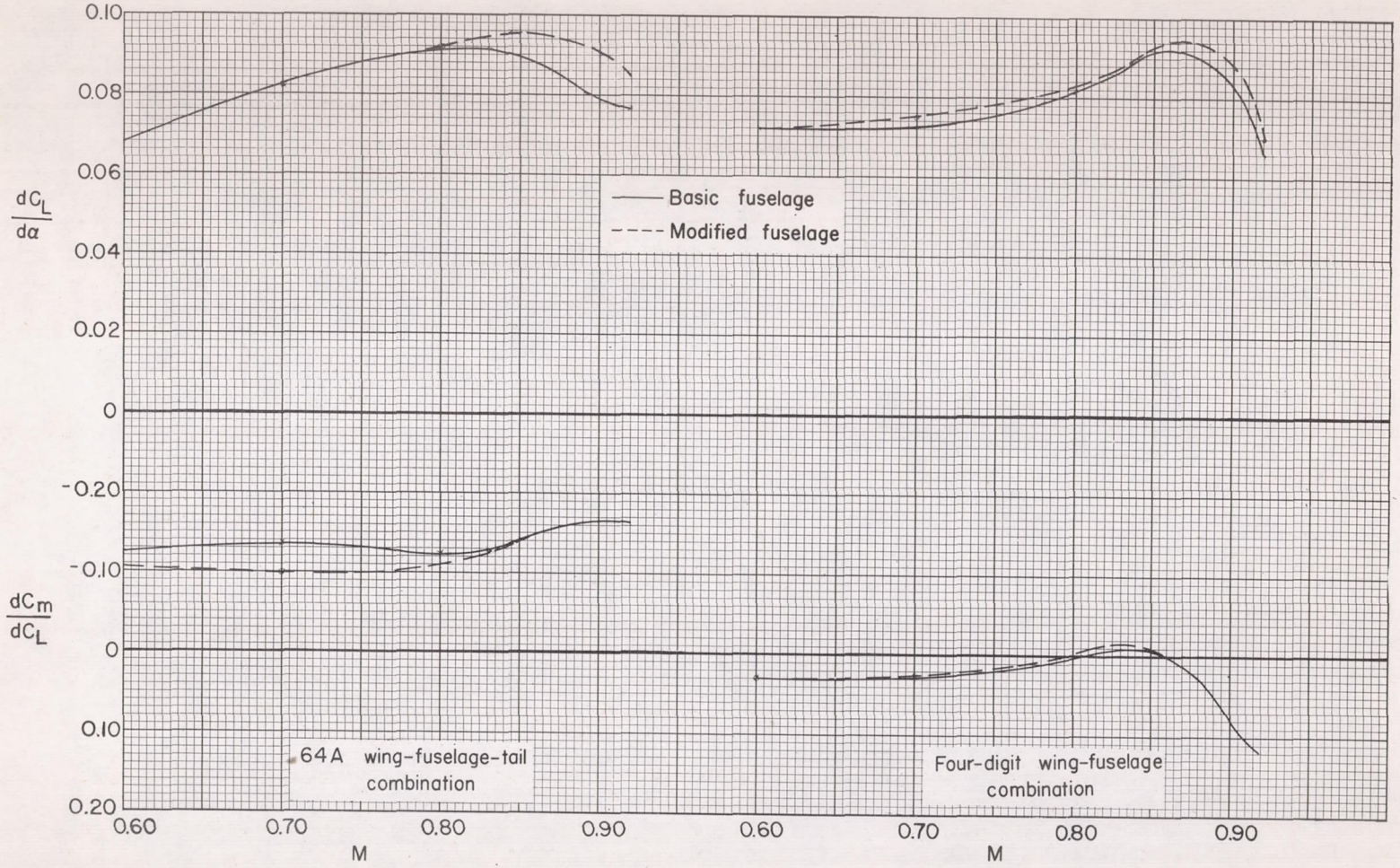


Figure 8.- The variation with Mach number of the slopes of the lift curve and pitching-moment curves of the models with 40° sweptback wings; $C_L = 0.40$.