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RESEARCH MEMORANDUM

for the

U. S. Air Force

TRANSONIC-WIND-TUNNEL TESTS OF THE AERODYNAMIC CHARACTERISTICS OF A 0.15-SCALE MODEL OF THE NORTH AMERICAN AVIATION 255-INCH FIN-STABILIZED EXTERNAL STORE

COORD NO. AF-AM-4

By Thomas L. Fischetti

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

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SUMMARY

An investigation has been made in the Langley 8-foot transonic tunnels on the aerodynamic characteristics of a 0.15-scale model of the North American Aviation 255-inch fin-stabilized external store over a maximum Mach number range of 0.60 to 1.2 and on the effects of mounting lugs, of fin orientation, of fin aspect ratio, and of fixed transition. The Reynolds number (based on a body length of 37.50 inches) varied from 9.8×10^6 to 13.1×10^6.

The results indicate that the static margin of the finned store at low lift coefficients was only 9 percent of body length at subsonic Mach numbers and was reduced to zero at a Mach number of 1.0. Increasing the fin aspect ratio from 1.82 to 2.41 increased the subsonic static margin to 18 percent and provided a minimum margin of 9 percent near a Mach number of 1.0. Store mounting lugs or fin orientation had only small effects on the aerodynamic characteristics of the basic store.

INTRODUCTION

At the request of the U. S. Air Force, the aerodynamic characteristics of a 0.15-scale model of the North American Aviation 255-inch fin-stabilized external store were investigated at transonic and moderate supersonic speeds in the Langley 8-foot transonic tunnel and the Langley 8-foot transonic pressure tunnel.

The effects of mounting lugs and fins on the aerodynamic characteristics of the basic store were investigated in the Langley 8-foot transonic tunnel at Mach numbers of 0.60 to 1.03. The effects of fixed transition and increased fin aspect ratio were obtained at Mach numbers up to 1.2 in the Langley 8-foot transonic pressure tunnel.

The data presented herein are for an angle-of-attack range which generally varied from -4° to 10° and for Reynolds numbers (based on a store length of 37.50 inches) of 9.8×10^{6} to 13.1×10^{6}.

SYMBOLS

C_L lift coefficient, Lift/q_oS

C_D drag coefficient, Drag/q_oS

C_m pitching-moment coefficient about the store center of gravity (see fig. 1), Moment/q_oSL

C_{D_b} base chord-force coefficient, $\dfrac{(P_b - P_o)S_b}{q_oS}$

C_{D_o} drag coefficient at zero lift

$\Delta C_D = C_D - C_{D_o}$

C_{d_c} drag coefficient which would be experienced by a circular cylinder section of radius r at Reynolds numbers and Mach numbers based on the diameter and the cross component of velocity

S body frontal area (0.134 sq ft)

S_b body base area (0.0058 sq ft)

q_o free-stream dynamic pressure, lb/sq ft

P_o free-stream static pressure, lb/sq ft

P_b static pressure at model base, lb/sq ft

C_{L_α} lift-curve slope, deg

M_o free-stream Mach number

R Reynolds number (based on L)

L reference body length (37.50 in.)

x longitudinal distance measured from store center of gravity (positive when forward of center of gravity), in.

ϕ angle of fin axes with respect to body axes (zero with fins orientated with body axes), deg (See fig. 1.)

α angle of attack, deg

η ratio of the drag coefficient of a circular cylinder of finite length to that of a circular cylinder of infinite length

APPARATUS AND METHODS

Tunnels

The Langley 8-foot transonic tunnels are single-return wind tunnels having test sections which have been slotted longitudinally to allow testing at sonic speed with negligible effects of choking and blockage. Details of the Langley 8-foot transonic tunnel can be found in reference 1. Limited details of the Langley 8-foot transonic pressure tunnel have been presented in reference 2. Both tunnels were operated at atmospheric stagnation pressures for these tests.

Model

The model for this investigation consisted of an aluminum body, two mounting lugs, and four fins. The addition of these components with the mounting lugs in a longitudinal plane through the body axis and with the fin axes orientated at 45° with respect to this plane comprised the store and will be referred to in this report as the basic store. A drawing of the basic store and details of the mounting lugs and fins are shown in figure 1. A photograph of the basic store mounted on the sting support system of the Langley 8-foot transonic tunnel is presented in figure 2. Ordinates for the store body have been tabulated in table I. The store body had a fineness ratio of 7.73; however, the model store body was cut off at 36.55 inches to permit entry of a sting support and the fineness ratio of this body was 7.58. In order to provide clearance between the model fins and the sting, it was necessary to remove approximately 2 percent of the total fin area. The fins, however, were still in close proximity to the model sting and a fouling band was located on the sting in order to detect any fouling between the fins and the sting. The fins had a trapezoidal plan form with an aspect ratio (based on the total area and span of two fins) of 1.82 and a taper ratio 0.329. An increase in fin aspect ratio was obtained by adding a 0.675-inch extension to the fin span. This larger fin had an aspect ratio of 2.41 and a taper ratio of 0.196. The fin airfoil section was a symmetrical double-wedge section with a constant streamwise thickness ratio of 6 percent between the 30- and the 70-percent-chord lines.

Tests and Measurements

Tests were made in the Langley 8-foot transonic tunnel through a Mach number range of 0.60 to 1.03 on the basic store and on the store body without mounting lugs or fins. Tests were also made of store configurations without the mounting lugs but with the fins orientated with the body axes ($\phi = 0^{\circ}$) and rotated 45° with respect to the body axes ($\phi = 45^{\circ}$). These tests were restricted to a top Mach number of 1.03 because of the severity of the boundary-reflected disturbances at higher Mach numbers; however, some additional tests were made in the Langley 8-foot transonic pressure tunnel up to a top Mach number of 1.2 at which point the model was clear of boundary-reflected disturbances. The tests in the Langley 8-foot transonic pressure tunnel were made through a Mach number range of 0.80 to 1.2 on the basic store and of 0.60 to 1.2 on the basic store with the aspect ratio of the fins increased from 1.82 to 2.41. The effects of fixing transition on approximately the forward 2 percent of the store nose with no. 60 grit carborundum (approximately 0.012-inch diameter) were obtained for a few selected Mach numbers. The variation of Reynolds number with Mach number for the tests in both tunnels is shown in figure 3.

The model for all tests was attached to the sting support system by means of a six-component electrical strain-gage balance. Although six-component data were measured during these tests, only the lift, drag, and pitching moments proved to be of interest because of the negligible forces measured by the other components. The angle of attack, which generally varied from -4° to 10°, was controlled remotely and was measured by a pendulum-type inclinometer located in the nose of the model.

Corrections and Accuracy

The lift and drag coefficients for these tests have been adjusted to the conditions of free-stream static pressure at the base of the model. The variation of the base chord-force coefficient with Mach number for several angles of attack and for a number of store configurations is shown in figure 4. No corrections have been applied to the data for any interference effects of the sting support system. For the store configurations investigated in the Langley 8-foot transonic pressure tunnel, a correction has been applied to the drag coefficients to allow for the buoyancy effect of a small longitudinal Mach number gradient. This correction was obtained by utilizing tunnel-free Mach number distributions and its variation with Mach number is shown in figure 5. No buoyancy correction was necessary for the test Mach number range in the Langley 8-foot transonic tunnel. In addition, a correction has been applied to the data obtained in the Langley 8-foot transonic pressure tunnel to allow for a flow angularity of approximately -0.15°.

Considerations of the balance design and the repeatability of the data indicate that the accuracies of the lift, drag, and pitching-moment coefficients were generally better than 0.02, 0.010, and 0.004, respectively. The accuracy of the measured angle of attack was believed to be ±0.15°. The maximum variation of the actual test Mach numbers from the presented nominal Mach numbers is less than 0.005. The local deviations of the free-stream Mach number from the test Mach number (in the region of the model) was less than 0.007 at subsonic Mach numbers; with increase in Mach number, the deviation increased but did not exceed 0.010 at any Mach number in either tunnel.

PRESENTATION OF RESULTS

The lift, drag, and pitching-moment coefficients have been referred to wind axes and are based on a frontal area of 0.134 square foot and a store body length of 37.50 inches. The store body length of 37.50 inches corresponds to an original store which had a lower fineness nose and a full-scale length of 250 inches.

The variations of angle of attack, drag coefficient, and pitching-moment coefficient with lift coefficient for the basic store and the various store configurations are presented in figures 6 to 9. Figure 6 presents the coefficients for the basic store as obtained in both tunnels. The effects of fin orientation on the aerodynamic characteristics of the basic store with mounting lugs removed, as obtained in the 8-foot transonic tunnel, are shown in figure 7. A small discrepancy between the fairing of the store nose radius and the desired coordinates was detected after completion of tests in the Langley 8-foot transonic tunnel. Subsequent tests, in the Langley 8-foot transonic pressure tunnel, were made with both the original nose fairing (fig. 6) and the correct nose fairing. Data for the basic store with the corrected nose fairing are shown in figure 8 with transition natural and fixed and in figure 9 with the fin aspect ratio increased to 2.41. Comparison of figures 6 and 8 indicates that the discrepancy in nose fairing had no effects on the aerodynamic characteristics of the basic store at subsonic speeds and only small effects on the lift and drag coefficients at supersonic speeds. The variations of the coefficients of the store body (having the original nose fairing) with angle of attack are presented in figure 10 and are compared in figure 11 with theoretical coefficients obtained by using the theory of reference 3. The theoretical calculations were made by assuming that $\eta = 0.66$ and $C_{d_c} = 1.2$. These values were obtained from reference 3 for a body fineness ratio of 7.73 and for a crossflow Mach number of less than 0.20. A summary of the variation of the aerodynamic characteristics of the basic store and several store configurations with Mach number is presented in figure 12. It should be noted that no data were recorded between Mach numbers of 1.03 and 1.2; therefore, the fairing of the summary curves in this region was arbitrary.

DISCUSSION

General

The lift, drag, and pitching-moment coefficients of the basic store as obtained in either tunnel, with the exception of a Mach number of 1.03, agreed within the accuracy of the balance repeatability (fig. 6). The differences at 1.03 Mach number can be accounted for by a difference in nominal Mach number of less than 0.005.

Lift Characteristics

The variation of lift coefficient with angle of attack for the basic store and for the various store configurations was generally nonlinear. The nonlinearity was affected by Mach number and was most severe at low angles of attack near a Mach number of 1.0. These nonlinearities were believed to be due to the mounting lugs and the store body. Removing the mounting lugs appears to have reduced the severe nonlinearities in lift coefficient at the low angles of attack for the higher Mach numbers but did not affect the lift coefficients at high angles of attack. (Compare figs. 6(a) and 7(a).) However, the lift measured on the body does show a generally similar nonlinear variation of lift coefficient with angle of attack throughout the Mach number range (fig. 10(a)), and is also in good agreement with that calculated by the theory of reference 3 (fig. 11), thus indicating the origin of the nonlinearities.

Fin orientation had only small effects on the lift coefficients of the basic store (fig. 7(a)). However, as might be expected, increasing the fin aspect ratio approximately 32 percent (from 1.82 to 2.41) increased the lift of the basic store (figs. 6(a) and 9(a)). The lift-curve slope (averaged in the angle-of-attack range of -2° to 2°) for the basic store was increased in magnitude anywhere from 12 to 27 percent over the Mach number range by this increase in fin aspect ratio (fig. 12).

Drag Characteristics

The drag coefficients of the basic store at zero lift was approximately 0.060 at a Mach number of 0.60; with increase in Mach number the drag coefficient increased and was approximately 0.29 at a Mach number of 1.2 (fig. 12). The store mounting lugs, fin orientation or increased fin aspect ratio generally had only small effects on the drag of the basic store over the Mach number range for which data were available. Experimental data for the store body were not obtained above a Mach number of 1.03; therefore in order to evaluate the effects of adding the lugs and fins to the store body at higher Mach numbers the body drag rise has been estimated using the peak drag-rise correlation factor of reference 4. The calculated drag rise was added to the subsonic drag level at a Mach number of 0.95 and this estimated drag level is shown in figure 12. It can be seen from figure 12 that the resulting estimated drag increment due to the lugs and fins at supersonic speeds was approximately two to three times the subsonic increment.

Pitching-Moment Characteristics

The basic store was statically stable at low subsonic Mach numbers but showed a gradual destabilizing tendency at low lift coefficients as the Mach number was increased, and eventually became unstable in this lift range at a Mach number of approximately 1.00 (fig. 6(c)). At the top test Mach number of 1.2, the store was again stable at all lift coefficients. In figure 12 the center of pressure of the basic store (obtained from $\partial C_m/\partial C_L$ at low lift coefficients) indicates a static margin of 9 percent of body length at subsonic Mach numbers. This static margin was insufficient to assure stability throughout the Mach number range, being reduced to zero near a Mach number of 1.0. Increasing the fin aspect ratio by approximately 34 percent increased the subsonic static margin to 18 percent and resulted in a minimum margin of 9 percent at a Mach number of approximately 1.0. Although it is not known whether a static margin of 9 percent is sufficient for satisfactory store release it is indicated in reference 5 that a 20 percent subsonic static margin could be considered as satisfactory for a bomb or missile.

The center of pressure of the store body (obtained from $\frac{\partial C_m}{\partial \alpha}\frac{\partial \alpha}{\partial C_L}$ at low lift coefficients) was approximately 1.35 body lengths forward of the store center of gravity at 0.60 Mach number. Above a Mach number of 0.80, the center of pressure moved further forward, reaching a maximum position of approximately two body lengths forward of the store center of gravity near a Mach number of 1.0. The theory of reference 3 does not indicate any movement of the body center of pressure with Mach numbers; however the large forward location of the body center of pressure at low angles of attack is indicated (fig. 11).

Store mounting lugs or fin orientation had only small effects on the basic store pitching moments. Rotating the fins to orientate them with the body axes ($\phi = 0^{\circ}$) increased the stability at high lift coefficients but did not appreciably affect the instability noted previously at low lift coefficients (fig. 8(c)).

Effect of Transition

With transition fixed, figure 7 indicates that both the lift and drag coefficients of the basic store generally decreased. These effects, however, were inconclusive since transition was not fixed on the store body alone, and since the magnitude of these effects was generally small and in some cases within the accuracy of these data.

CONCLUDING REMARKS

The results of wind-tunnel tests of a 0.15-scale model of the North American Aviation 255-inch fin-stabilized external store indicate that the static margin of the finned store at low lift coefficients was only 9 percent of body length at subsonic Mach numbers and was reduced to zero at a Mach number of 1.0. Increasing the fin aspect ratio from 1.82 to 2.41 increased the subsonic static margin to 18 percent and provided a minimum margin of 9 percent near a Mach number of 1.0. Store mounting lugs or fin orientation had only small effects on the aerodynamic characteristics of the basic store.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., January 17, 1956.

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Aeronautical Research Scientist

Approved: Eugene C. Draley
Chief of Full-Scale Research Division

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5. Muse, T. C., and Bratt, R. W.: Summary of High-Speed Wind-Tunnel Tests of a Douglas Aircraft Store Shape and a 2000-Pound G.P.-AN-M66 Bomb. Rep. No. E.S. 21150, Douglas Aircraft Co., Inc., June 25, 1948.

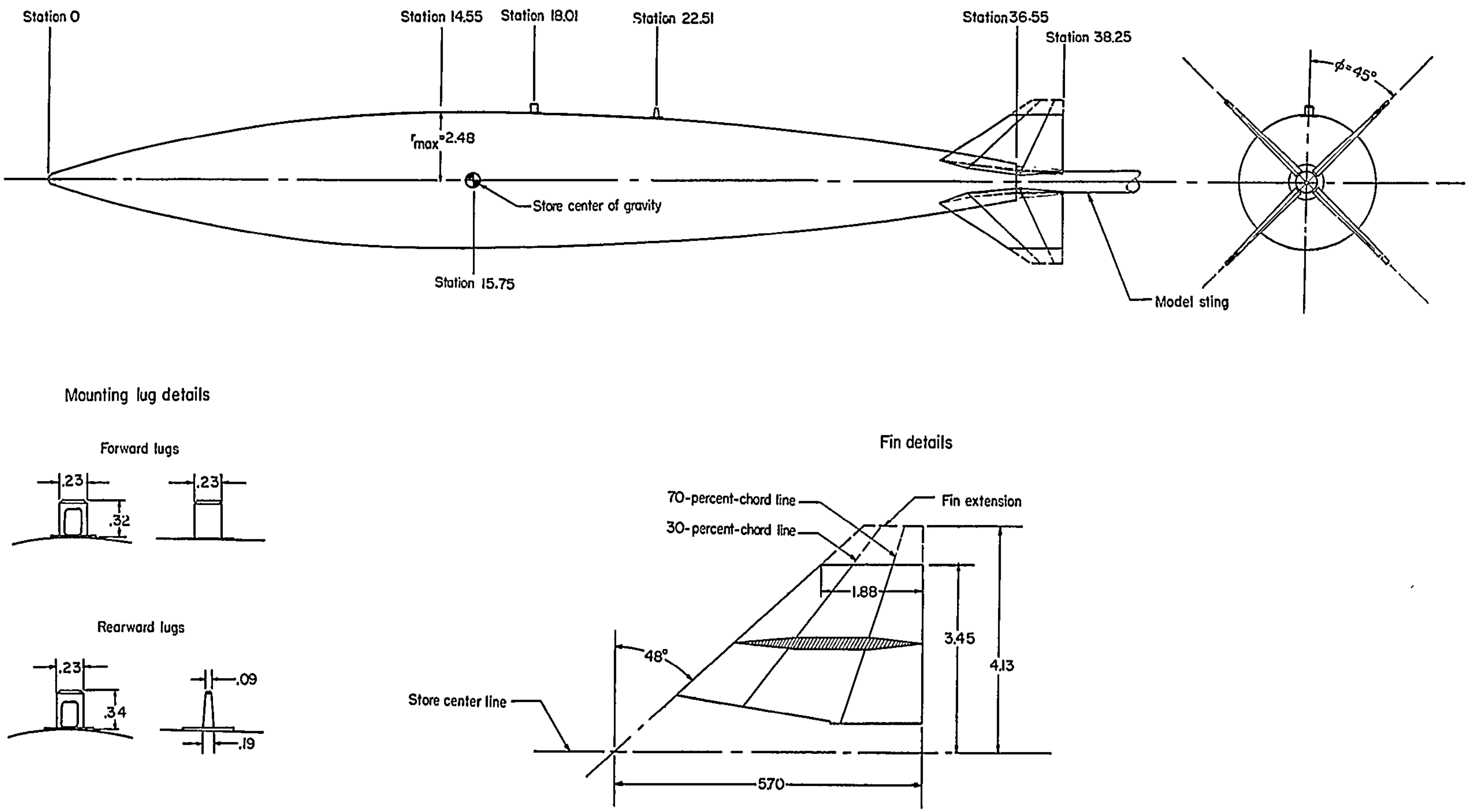
TABLE I

ORDINATES OF STORE BODY

Distance from nose, in.	Radius, in.
0	0
.15	.214
.30	.263
.45	.311
.60	.359
.75	.406
.90	.453
1.05	.498
1.20	.544
1.35	.588
1.50	.633
1.65	.675
1.80	.719
1.95	.761
2.10	.802
2.25	.843
3.00	1.034
3.75	1.209
4.50	1.373
5.25	1.530
6.75	1.820
8.25	2.067
9.75	2.252
11.25	2.363
12.75	2.436
14.25	2.474
15.75	2.469
17.25	2.448
18.75	2.415
20.25	2.370
21.75	2.313
23.25	2.235
24.75	2.127
26.25	1.995
27.75	1.844
29.25	1.673
30.75	1.484
32.25	1.271
33.75	1.026
35.25	.759
36.75	.492
38.25	.225

Store nose radius, 0.227 inch.

[redacted]



[redacted]

Figure 1.- Drawing of the basic store with details of the mounting lugs and fins. All dimensions are in inches unless otherwise noted.

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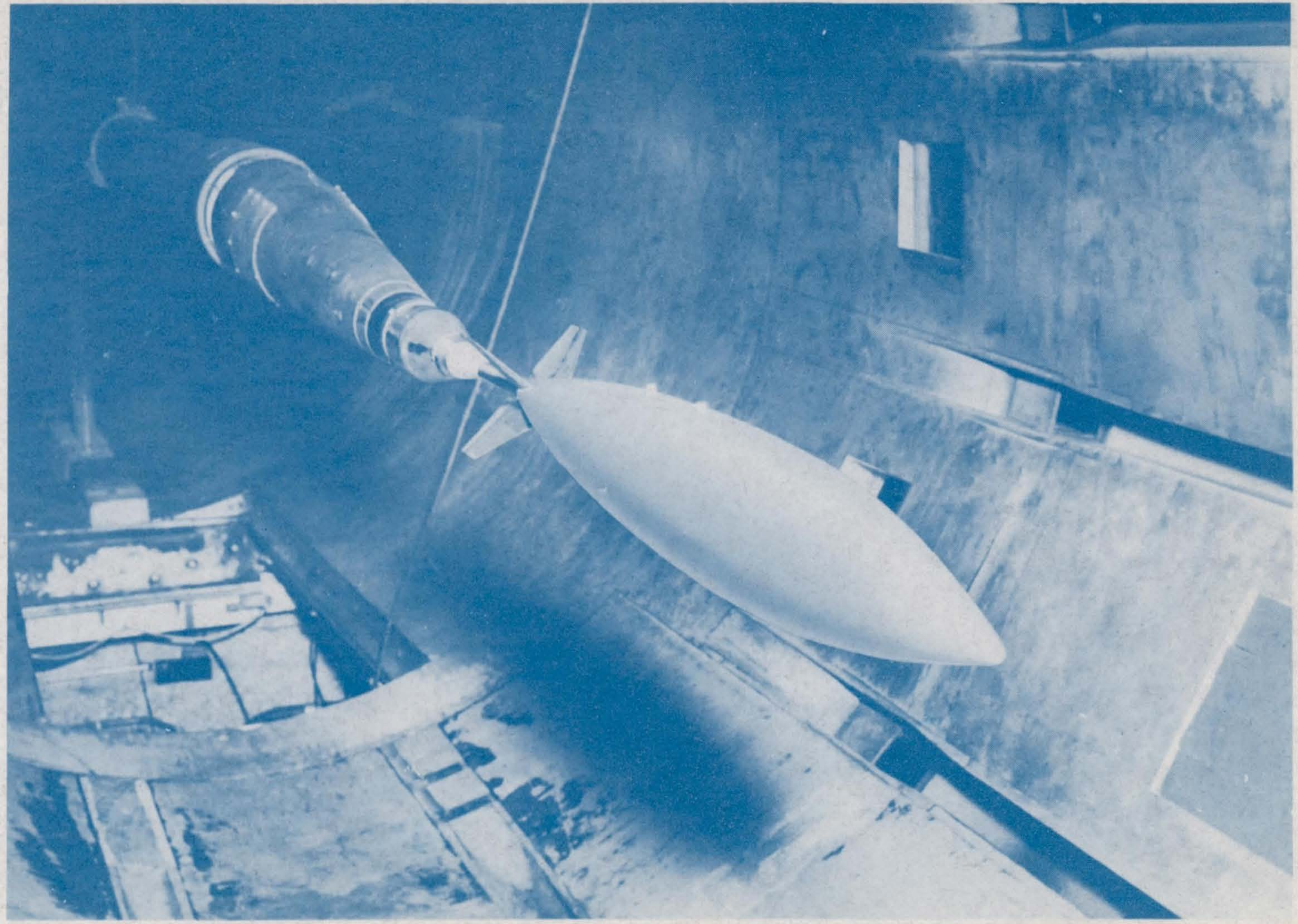

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Figure 2.- The basic store mounted in the Langley 8-foot transonic tunnel.

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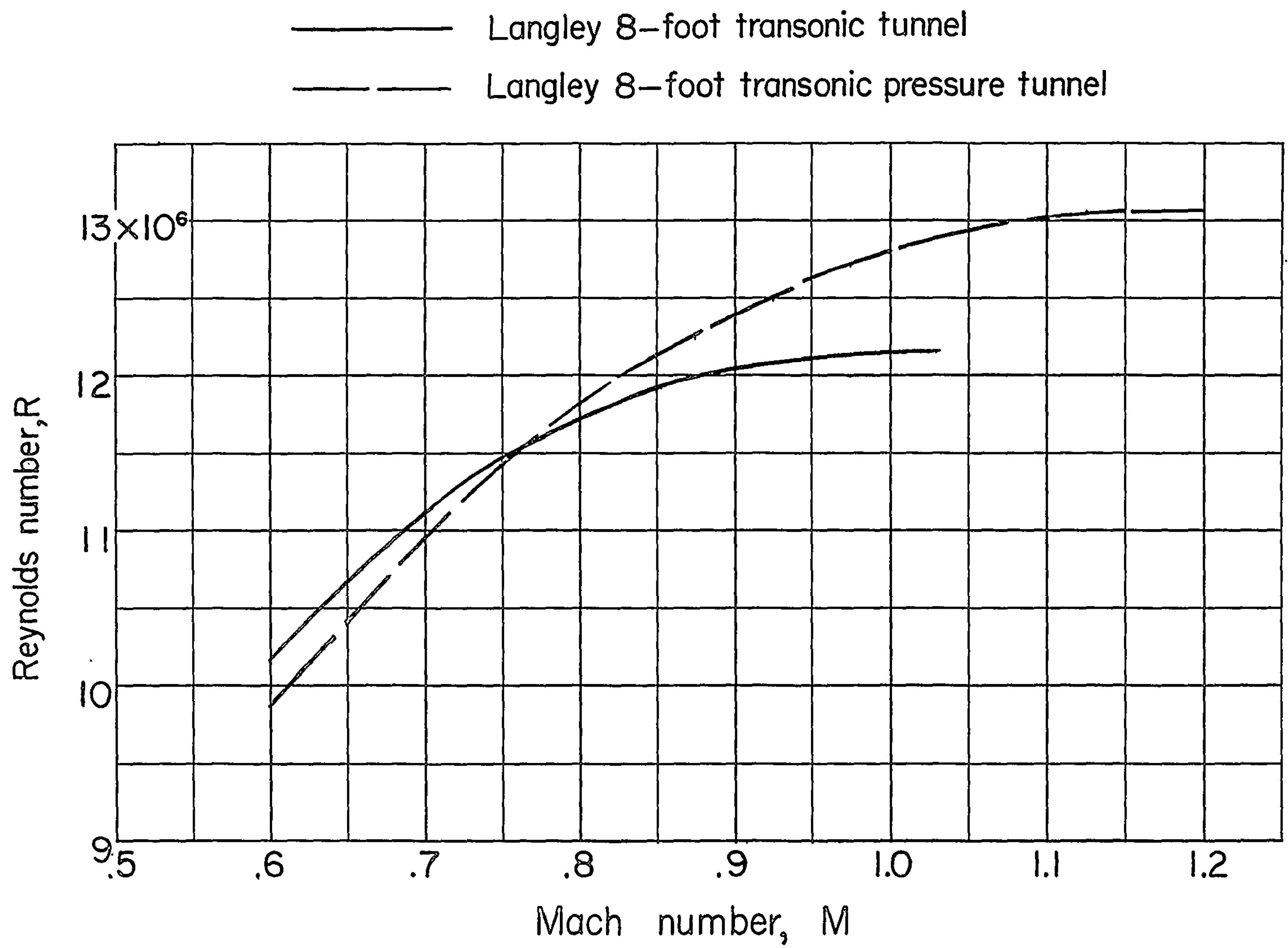

Figure 3.- Variation of the average test Reynolds number with Mach number for tests of the several store configurations.

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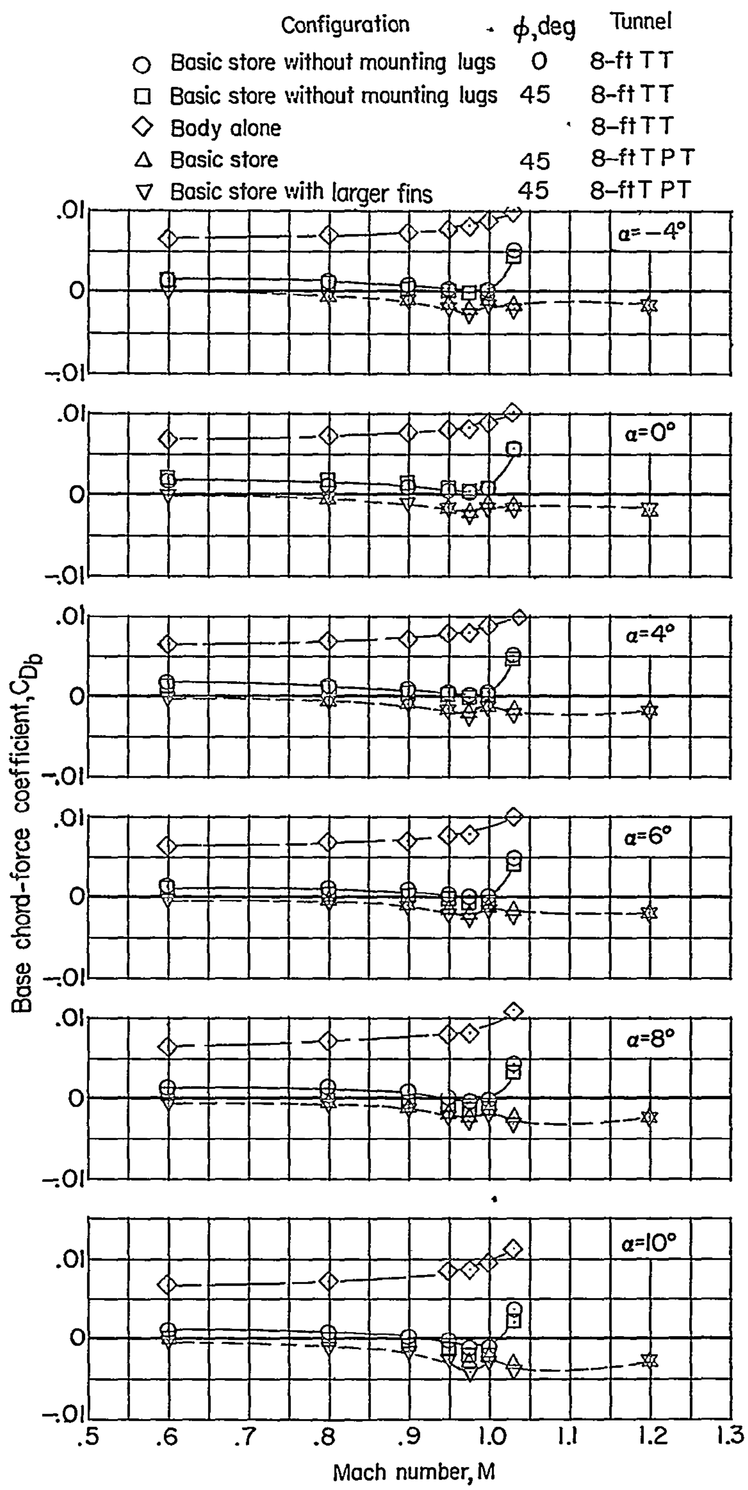

Figure 4.- Variation of base chord-force coefficient with Mach number for tests of the store in both the Langley 8-foot transonic tunnel and the Langley 8-foot transonic pressure tunnel.

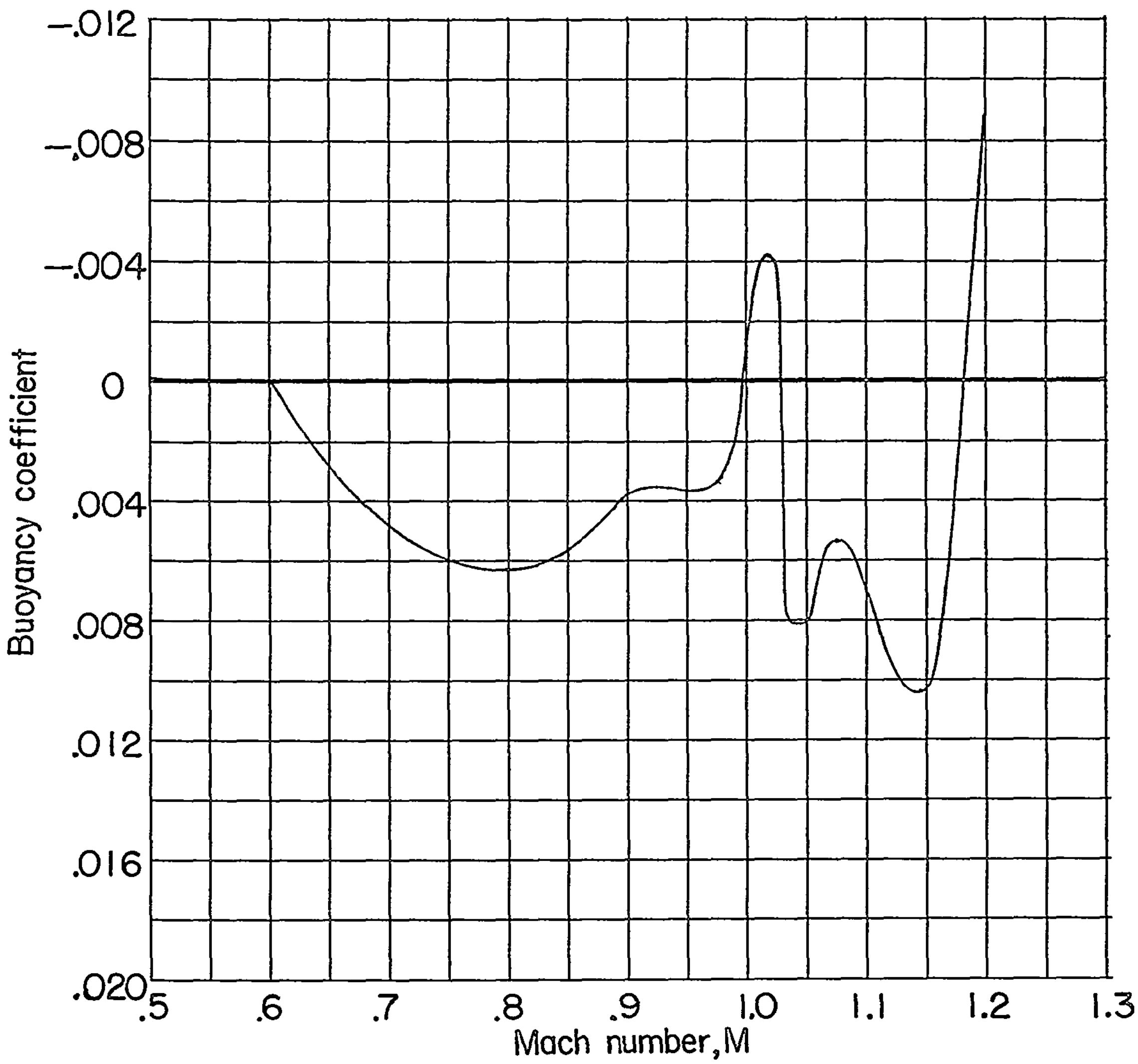

Figure 5.- Variation of buoyancy coefficient with Mach number for tests of the store in the Langley 8-foot transonic pressure tunnel.

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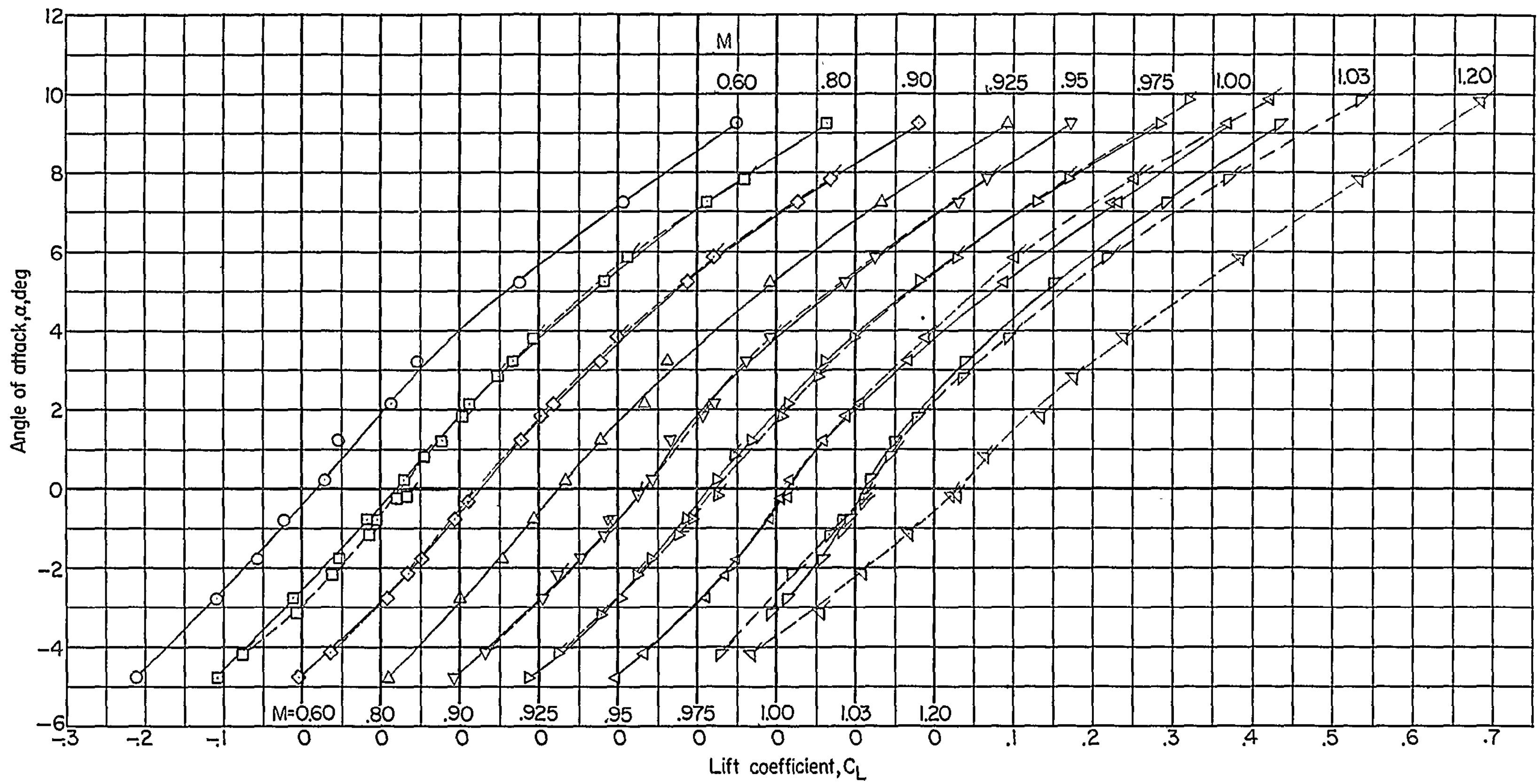

(a) Angle of attack.

Figure 6.- Comparison of the variation with lift coefficient of the aerodynamic characteristics of the basic store (with the original nose fairing) as obtained in the Langley 8-foot transonic tunnel and the Langley 8-foot transonic pressure tunnel. (Unflagged symbols indicate 8-foot transonic-tunnel data and flagged symbols indicate 8-foot transonic-pressure-tunnel data.)

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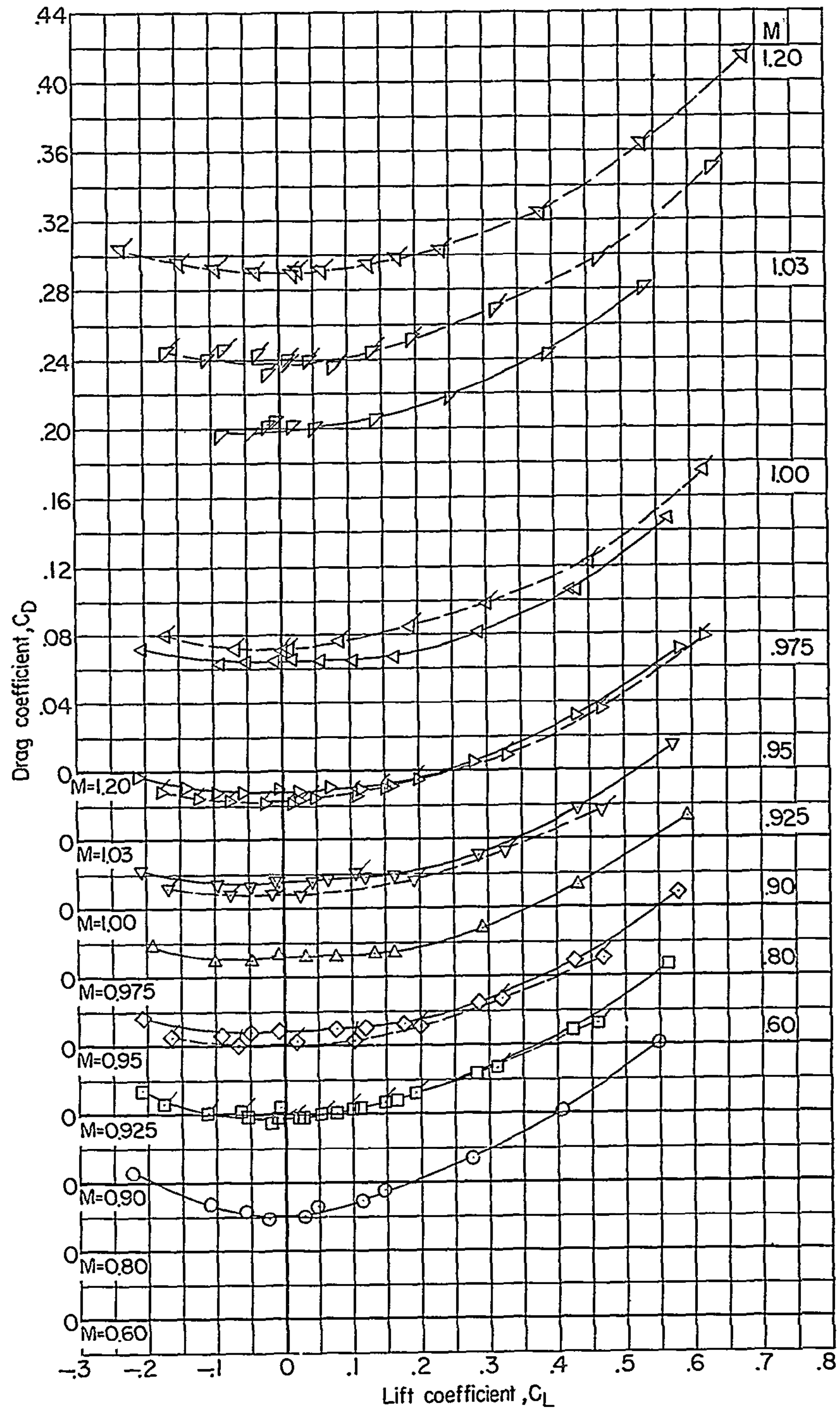
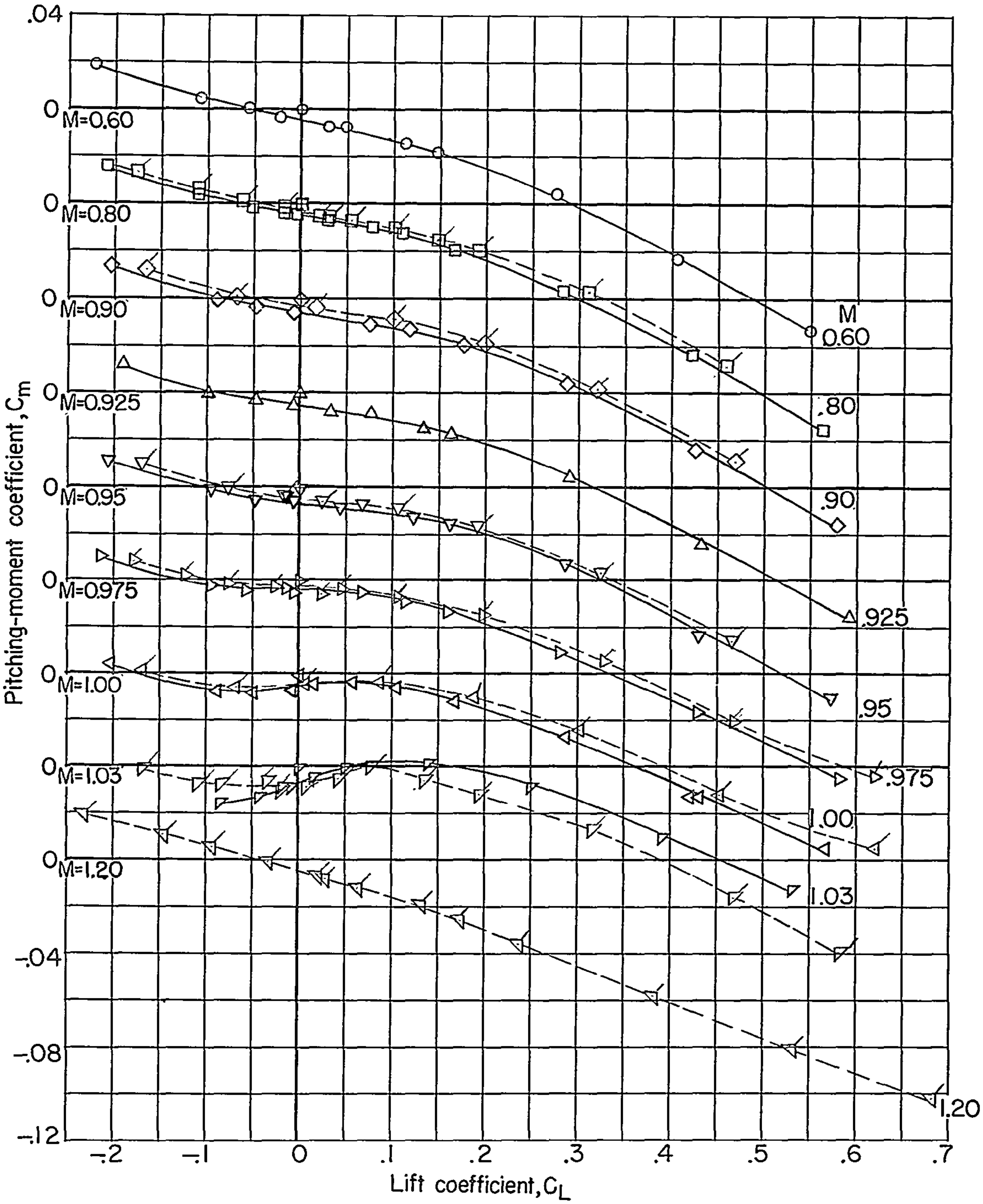


(b) Drag coefficient. (Unflagged symbols indicate 8-foot transonic tunnel data and flagged symbols indicate 8-foot transonic-pressure-tunnel data.)

Figure 6.- Continued.



(c) Pitching-moment coefficient. (Unflagged symbols indicate 8-foot transonic-tunnel data and flagged symbols indicate 8-foot transonic-pressure-tunnel data.)

Figure 6.- Concluded.

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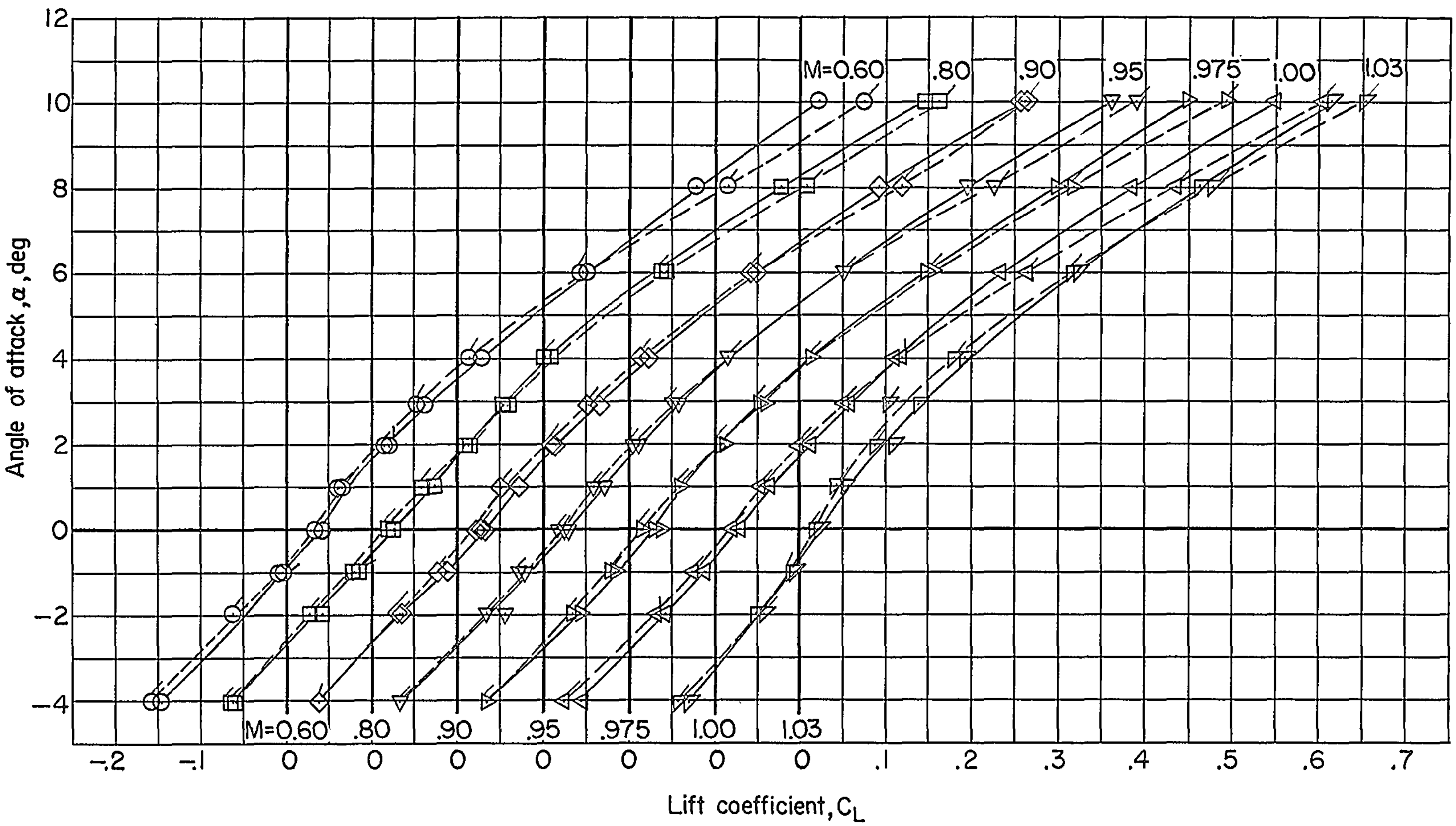

(a) Angle of attack.

Figure 7.- Comparison of the variation with lift coefficient of the aerodynamic characteristics of the basic store (without mounting lugs and with the original nose fairing) with $\phi = 0^\circ$ and 45°. (Unflagged symbols indicate $\phi = 45^\circ$ and flagged symbols indicate $\phi = 0^\circ$.)

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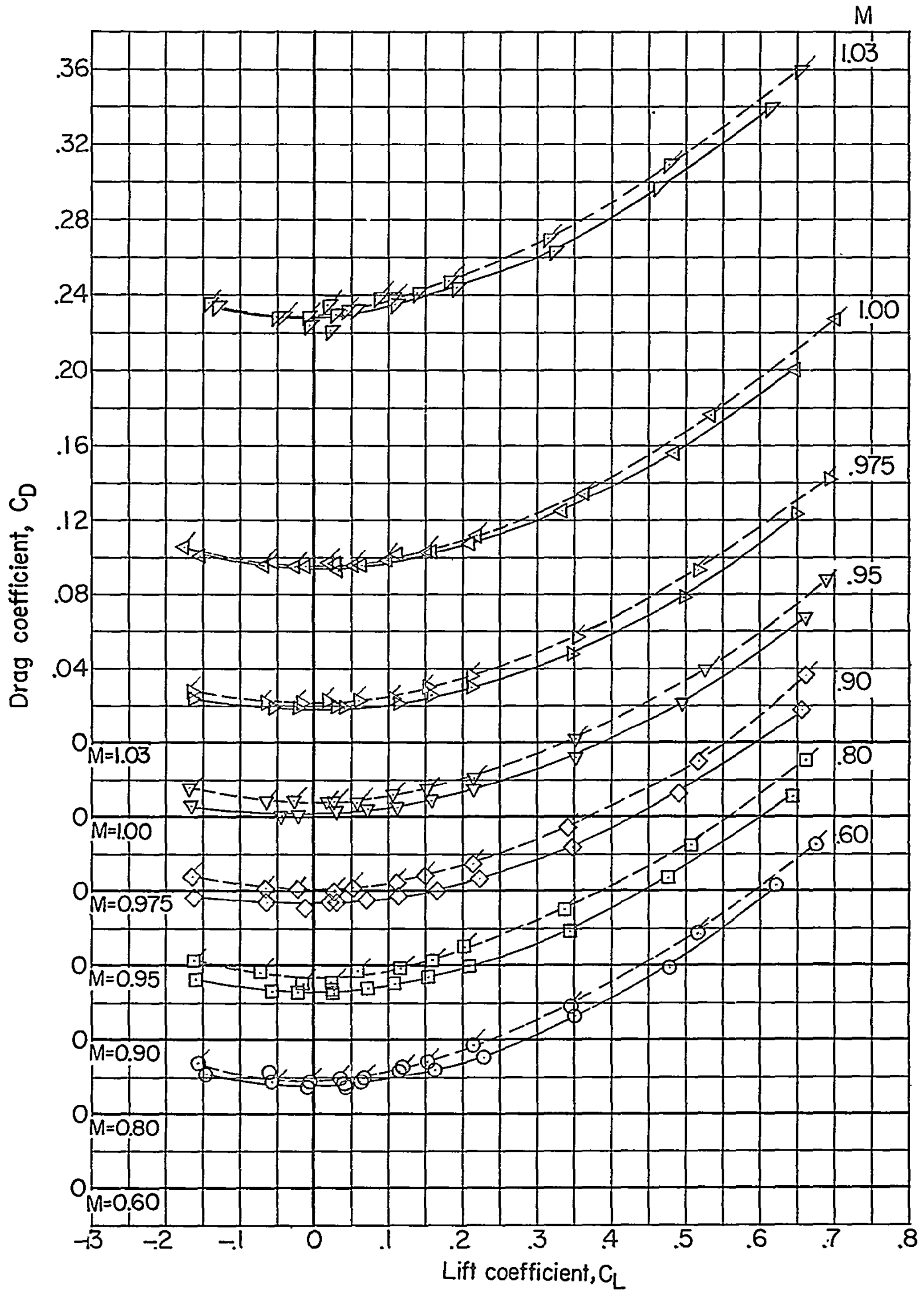
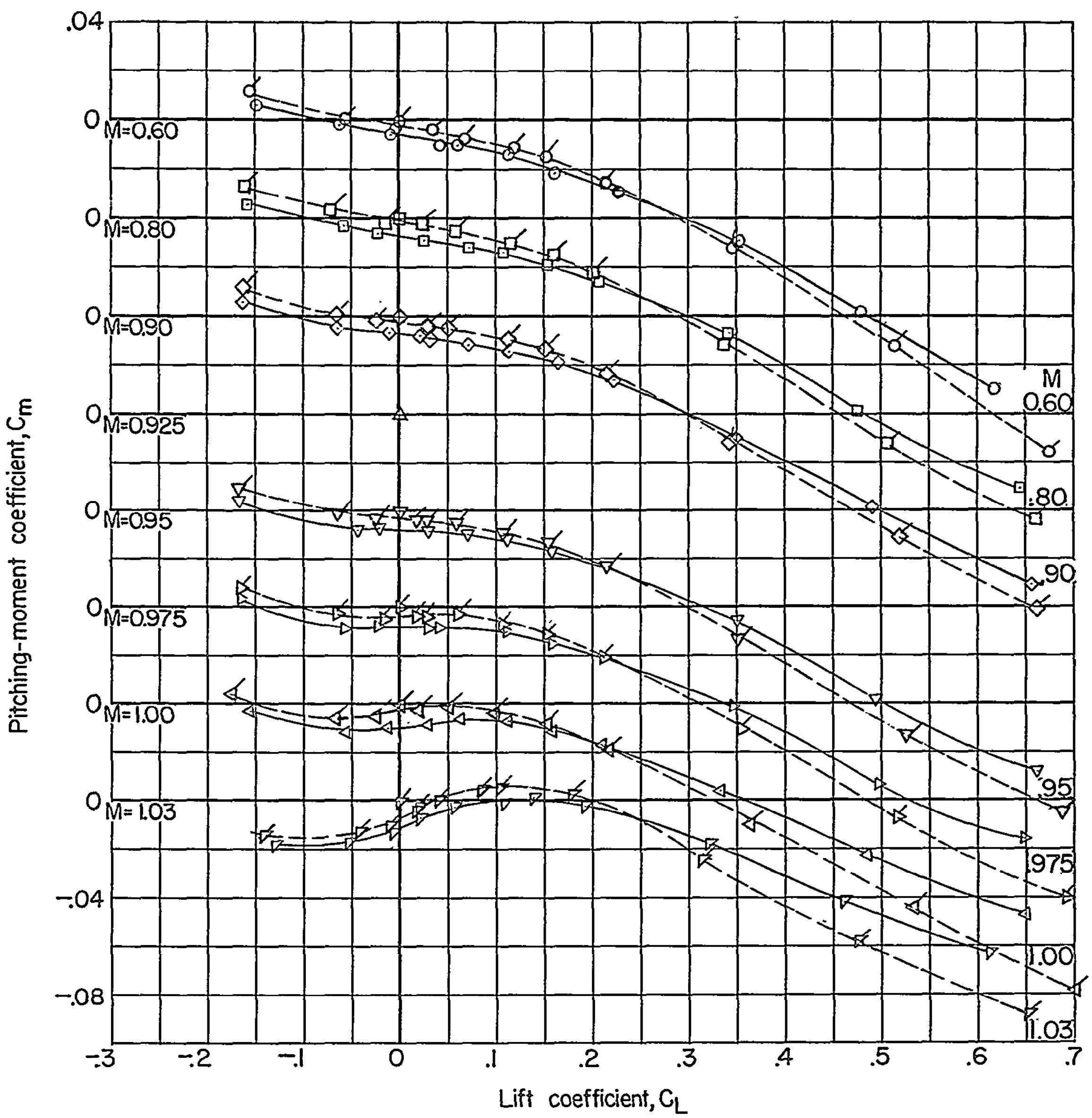


(b) Drag coefficient. (Unflagged symbols indicate $\phi = 45^{\circ}$ data and flagged symbols indicate $\phi = 0^{\circ}$ data.)

Figure 7.- Continued.



(c) Pitching-moment coefficient. (Unflagged symbols indicate $\phi = 45^\circ$ data and flagged symbols indicate $\phi = 0^\circ$ data.)

Figure 7.- Concluded.

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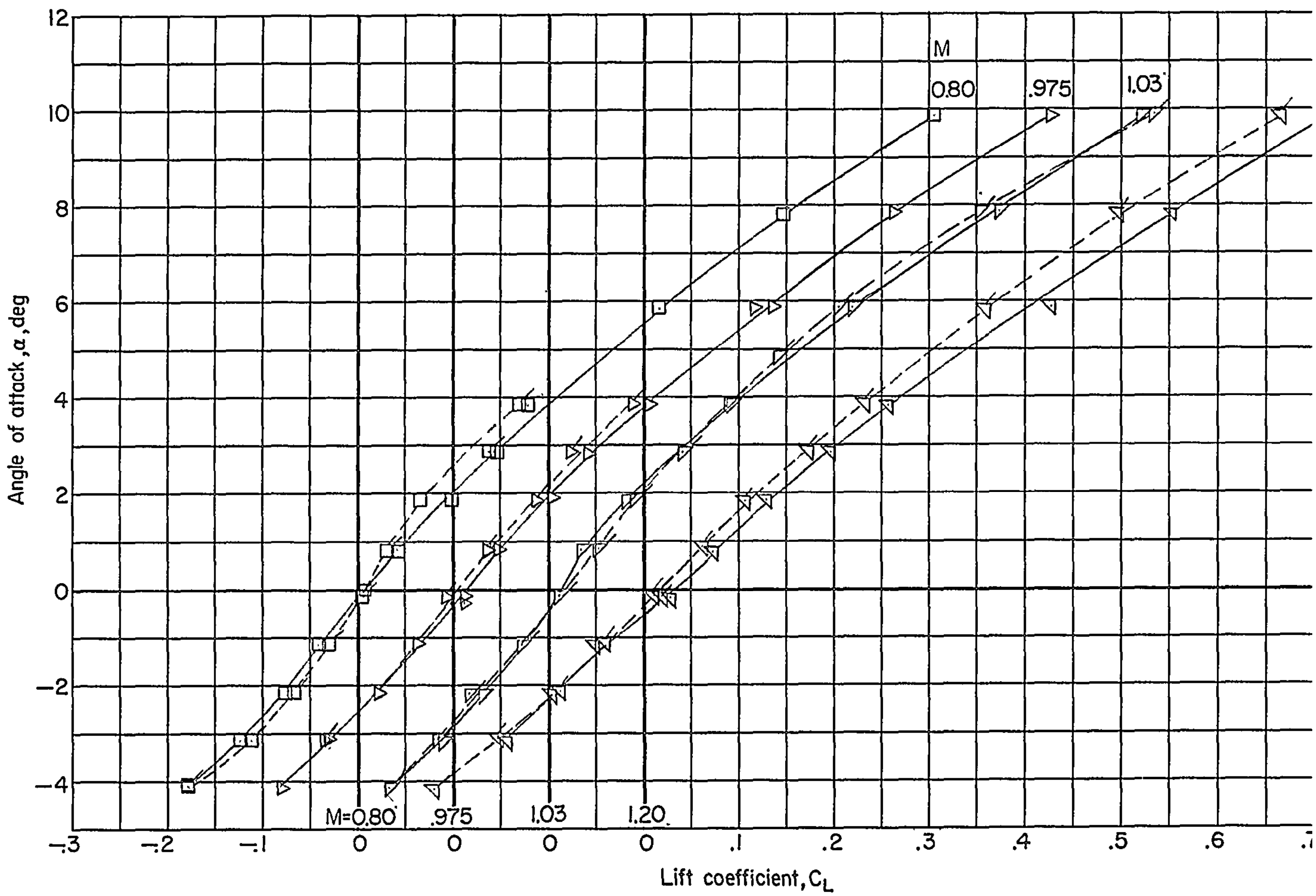
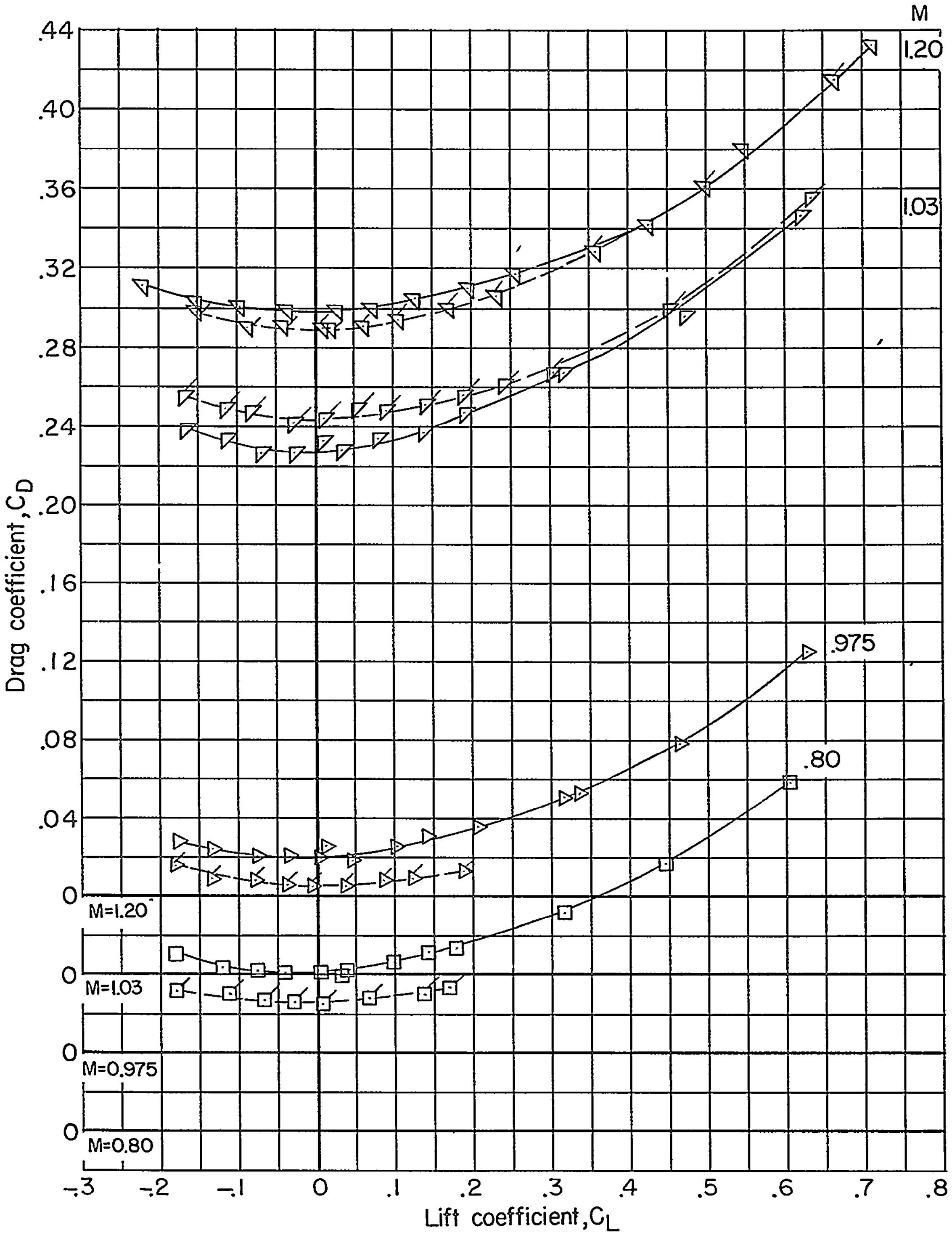


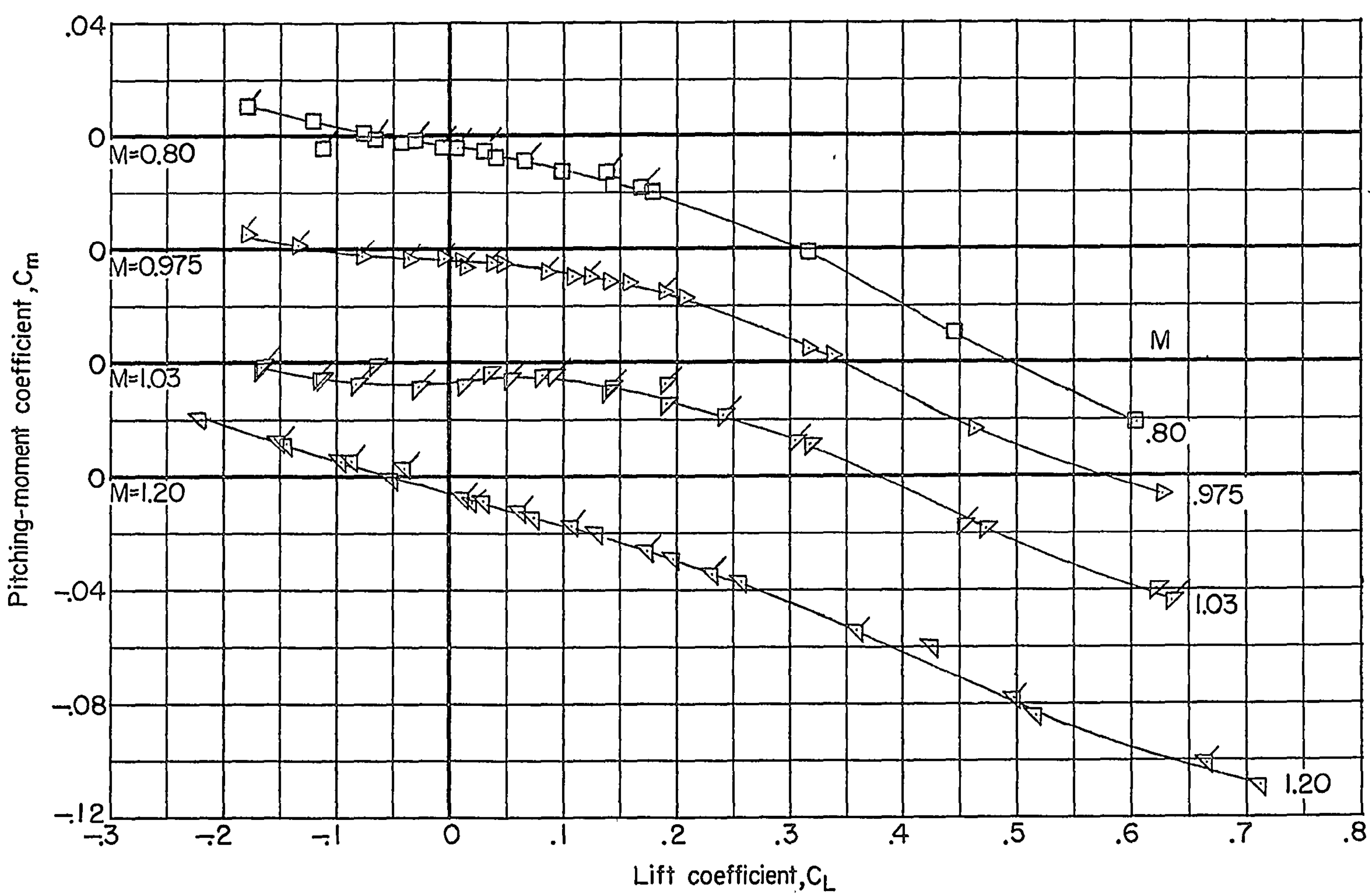
(a) Angle of attack.

Figure 8.- Comparison of the variation with lift coefficient of the aerodynamic character of the basic store (with the correct nose fairing) with transition natural and fixed. (Unflagged symbols indicate transition natural and flagged symbols indicate transition



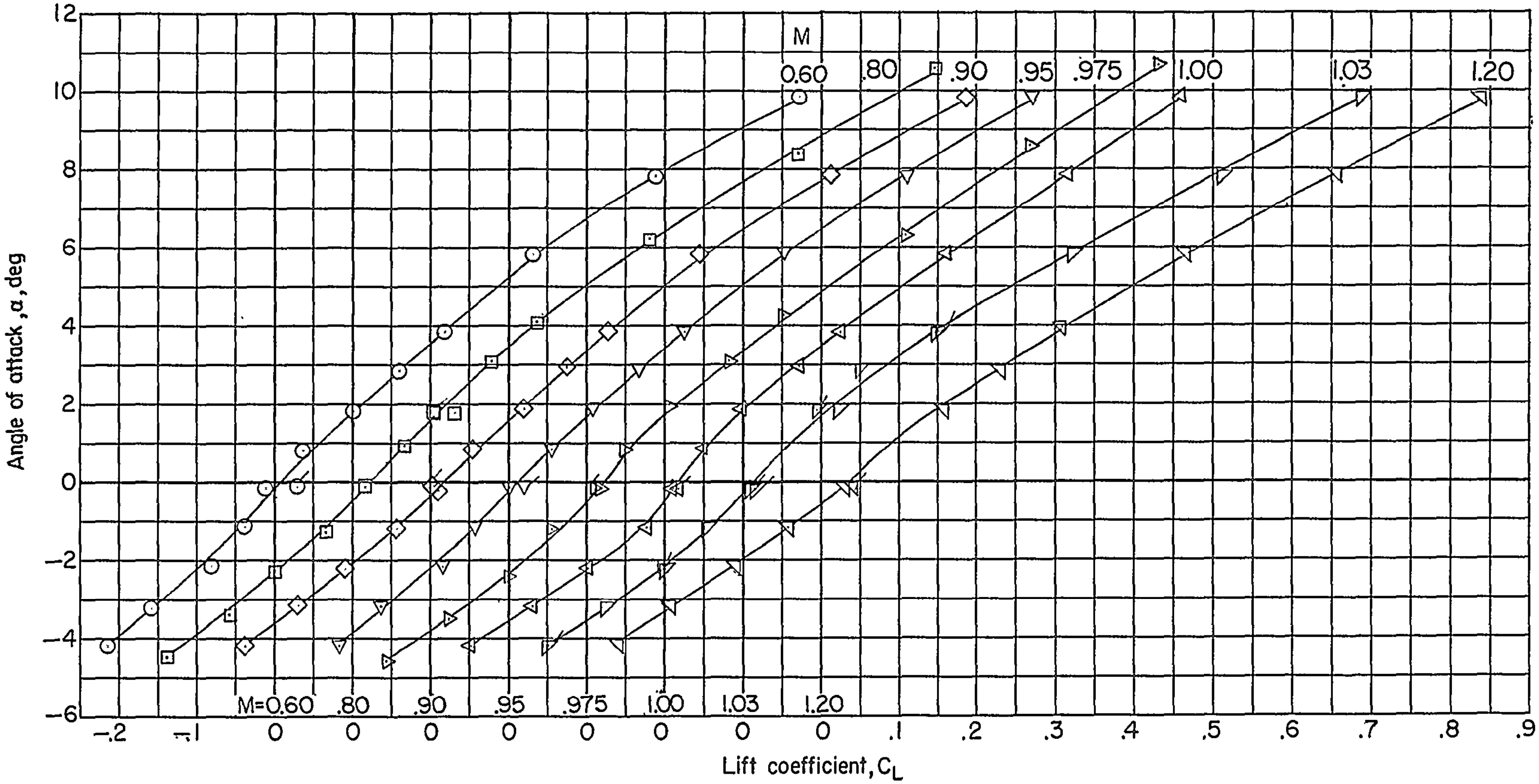
(b) Drag coefficient. (Unflagged symbols indicate transition natural and flagged symbols indicate transition fixed.)

Figure 8.- Continued.



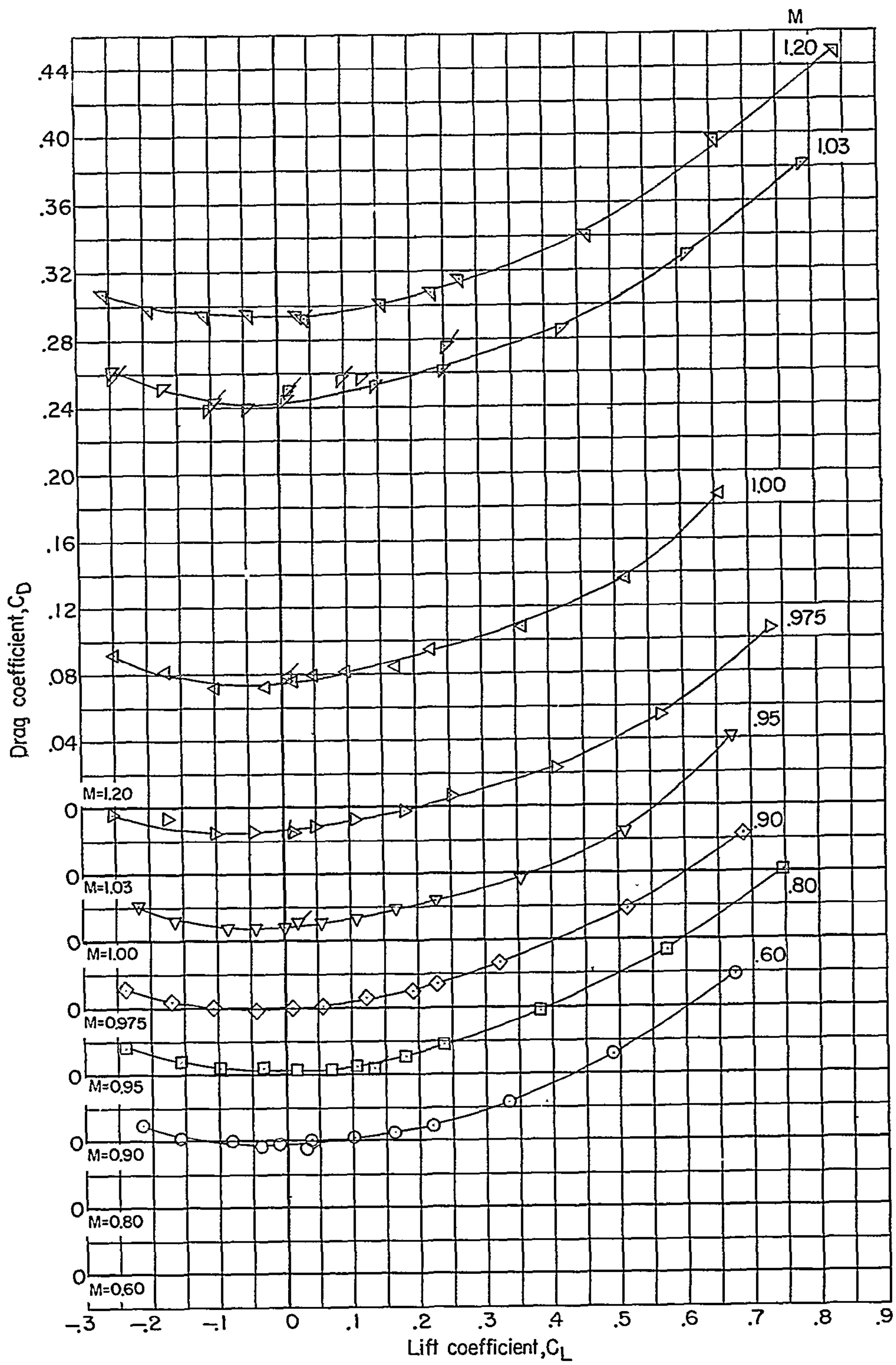
(c) Pitching-moment coefficient. (Unflagged symbols indicate transition natural and flagged symbols indicate transition fixed.)

Figure 8.- Concluded.



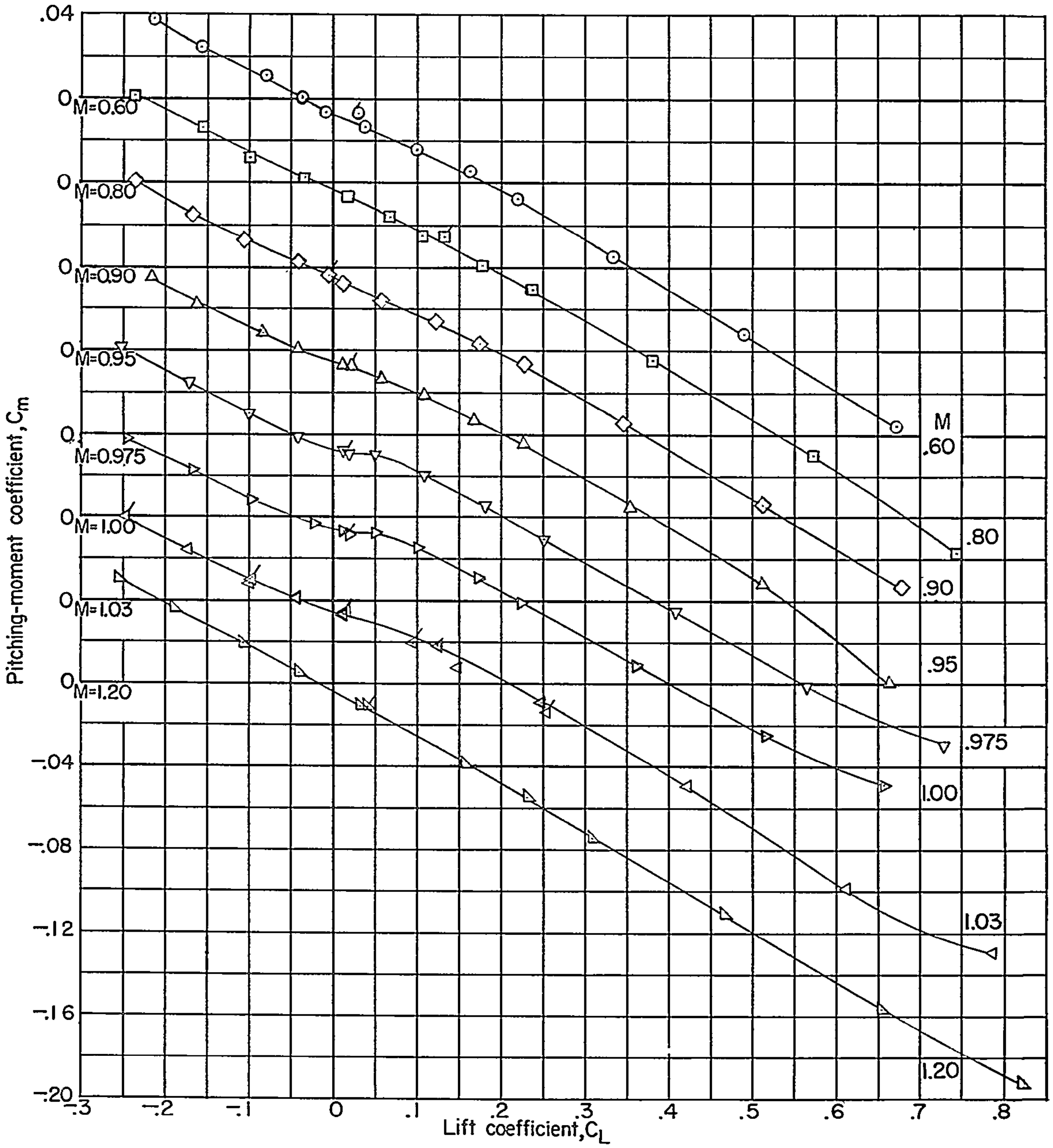
(a) Angle of attack.

Figure 9.- Variation with lift coefficient of the aerodynamic characteristics of the basic store (with the correct nose fairing) with the larger fins. (Flagged symbols indicate repeat points.)



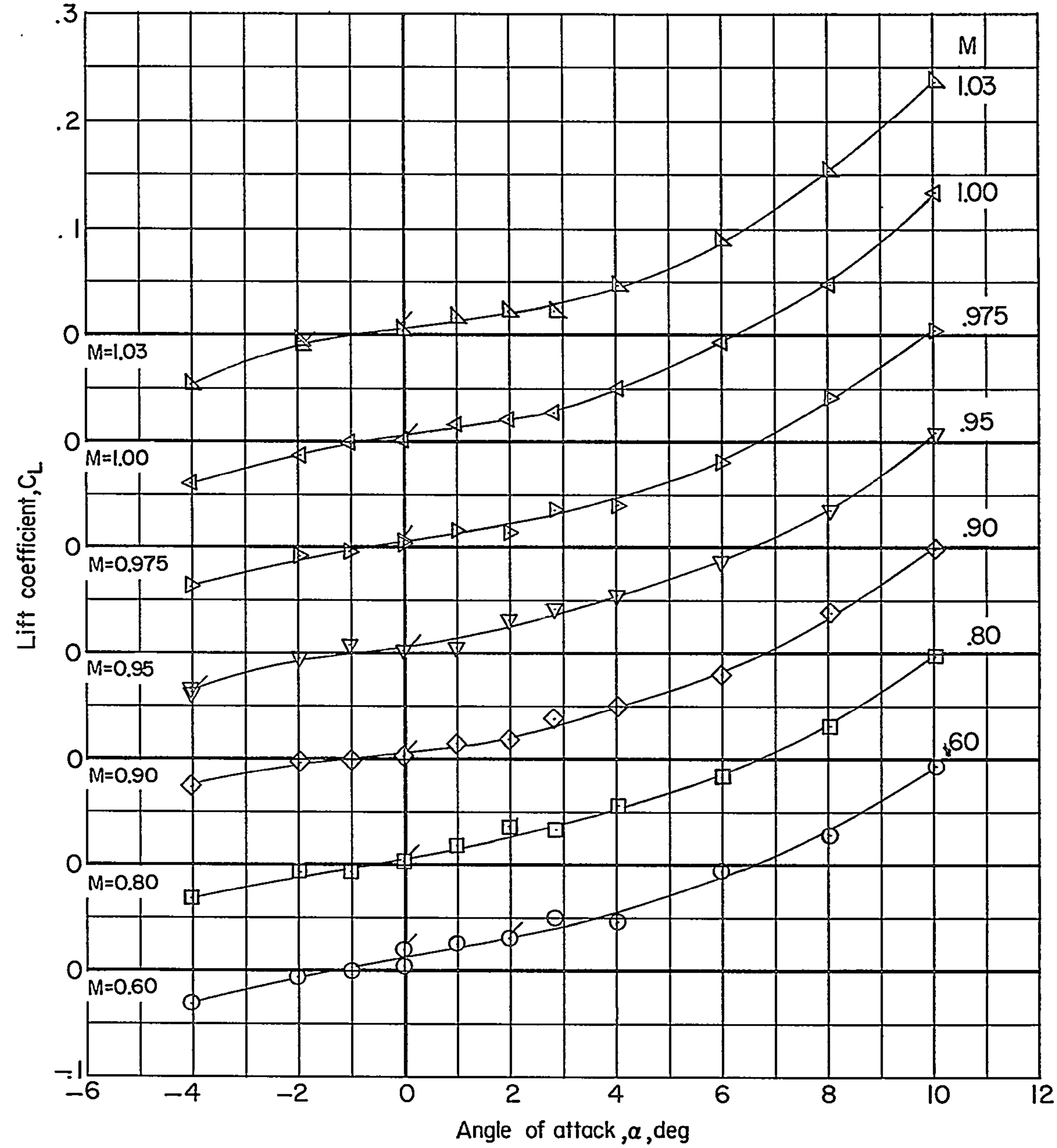
(b) Drag coefficient. (Flagged symbols indicate repeat points.)

Figure 9.- Continued.



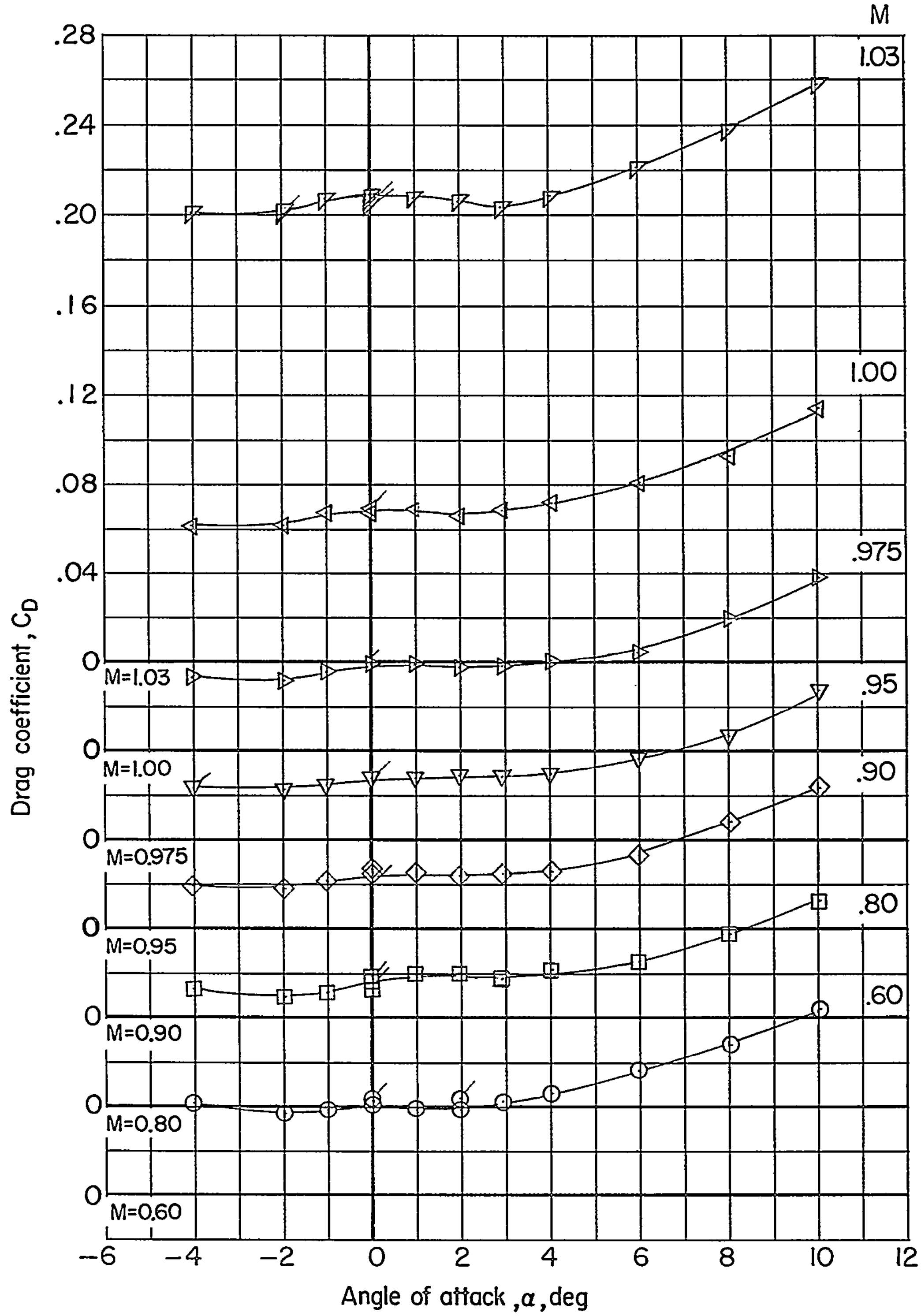
(c) Pitching-moment coefficient. (Flagged symbols indicate repeat points.)

Figure 9.- Concluded.



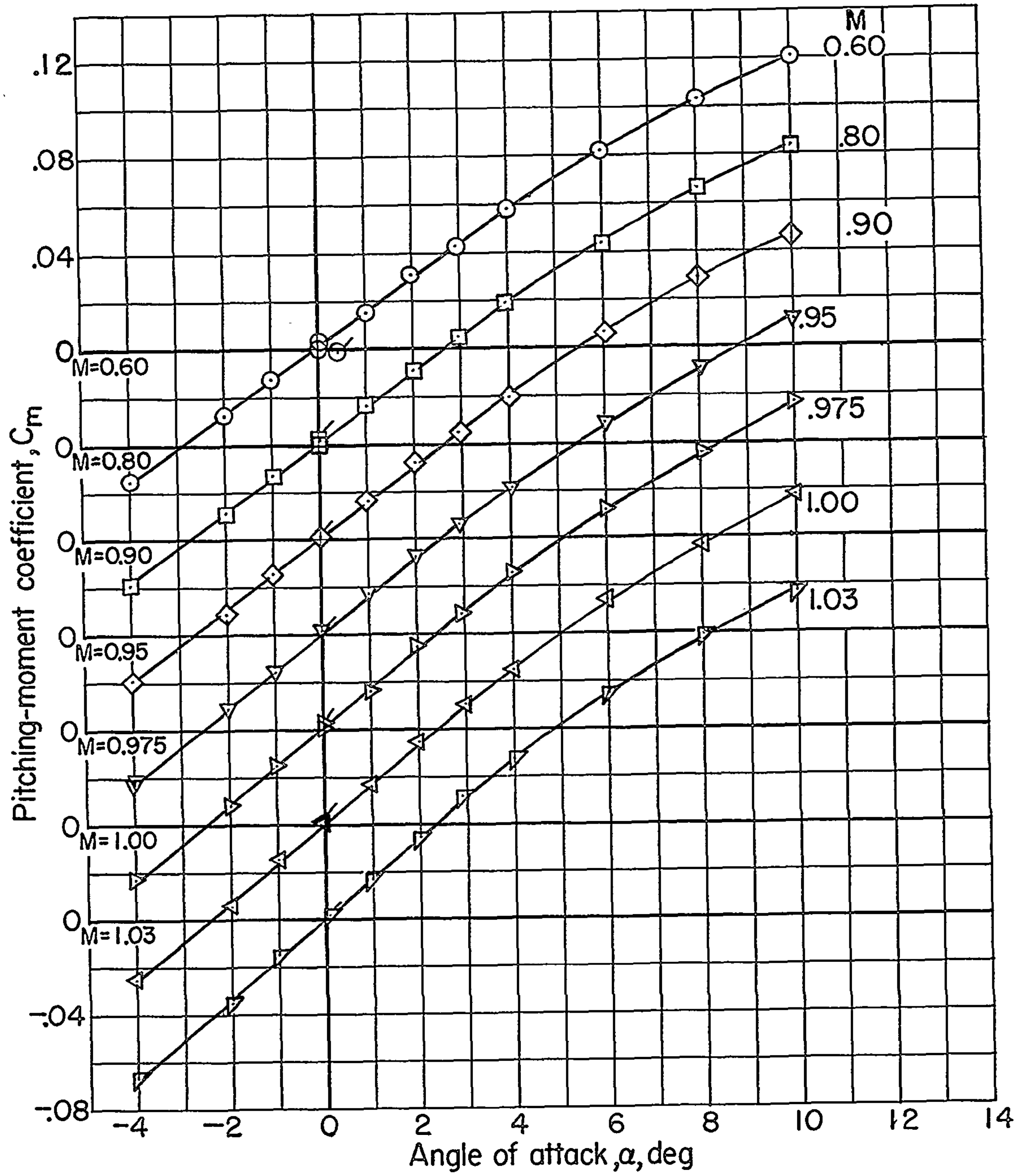
(a) Lift coefficient.

Figure 10.- Variation with angle of attack of the aerodynamic characteristics of the store body with the original nose fairing. (Flagged symbols indicate repeat points.)



(b) Drag coefficient. (Flagged symbols indicate repeat points.)

Figure 10.- Continued.



(c) Pitching-moment coefficient. (Flagged symbols indicate repeat points.)

Figure 10.- Concluded.

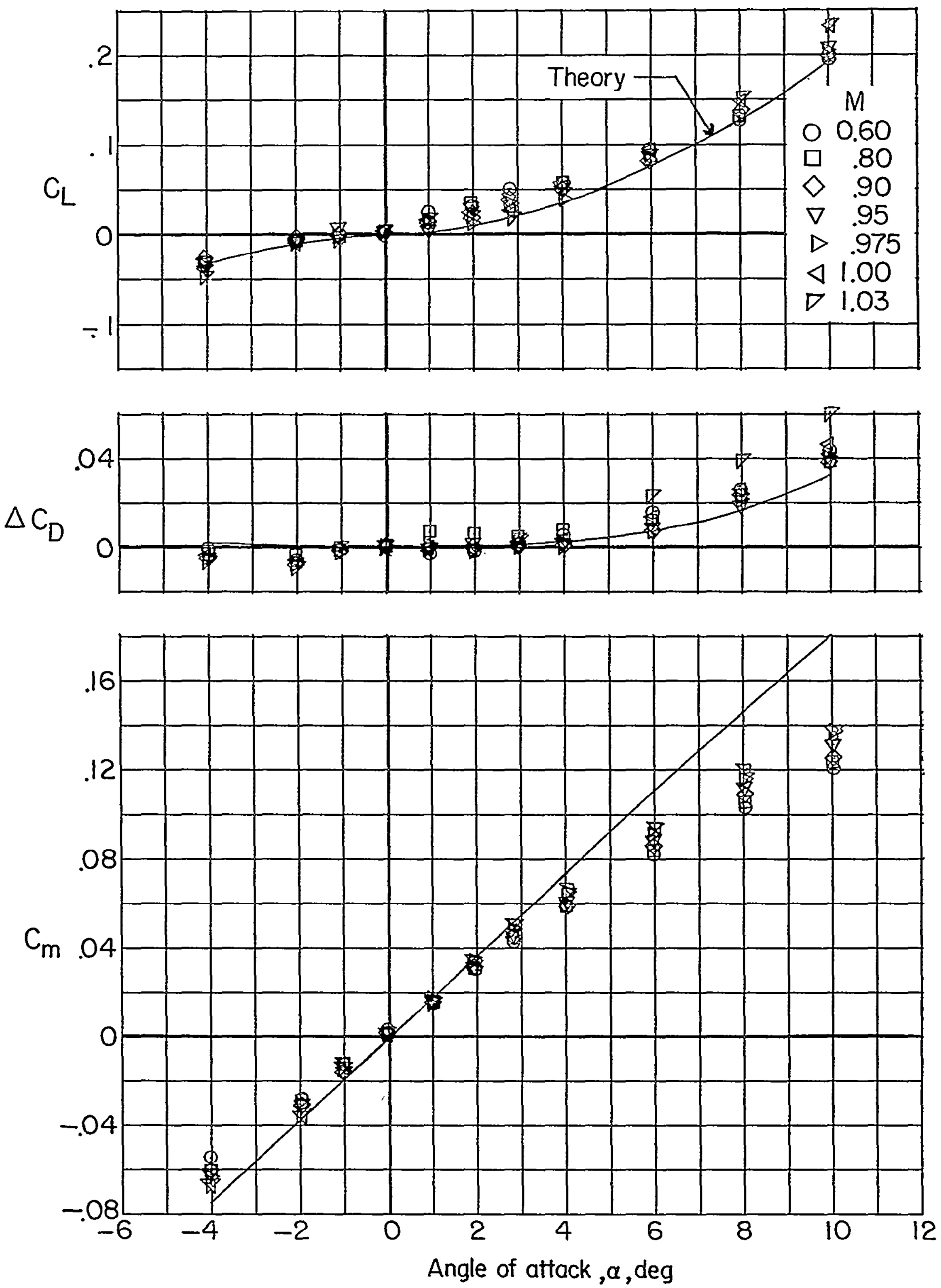


Figure 11.- Comparison of the lift, drag, and pitching-moment coefficients of the store body with those calculated by the theory of reference 3.

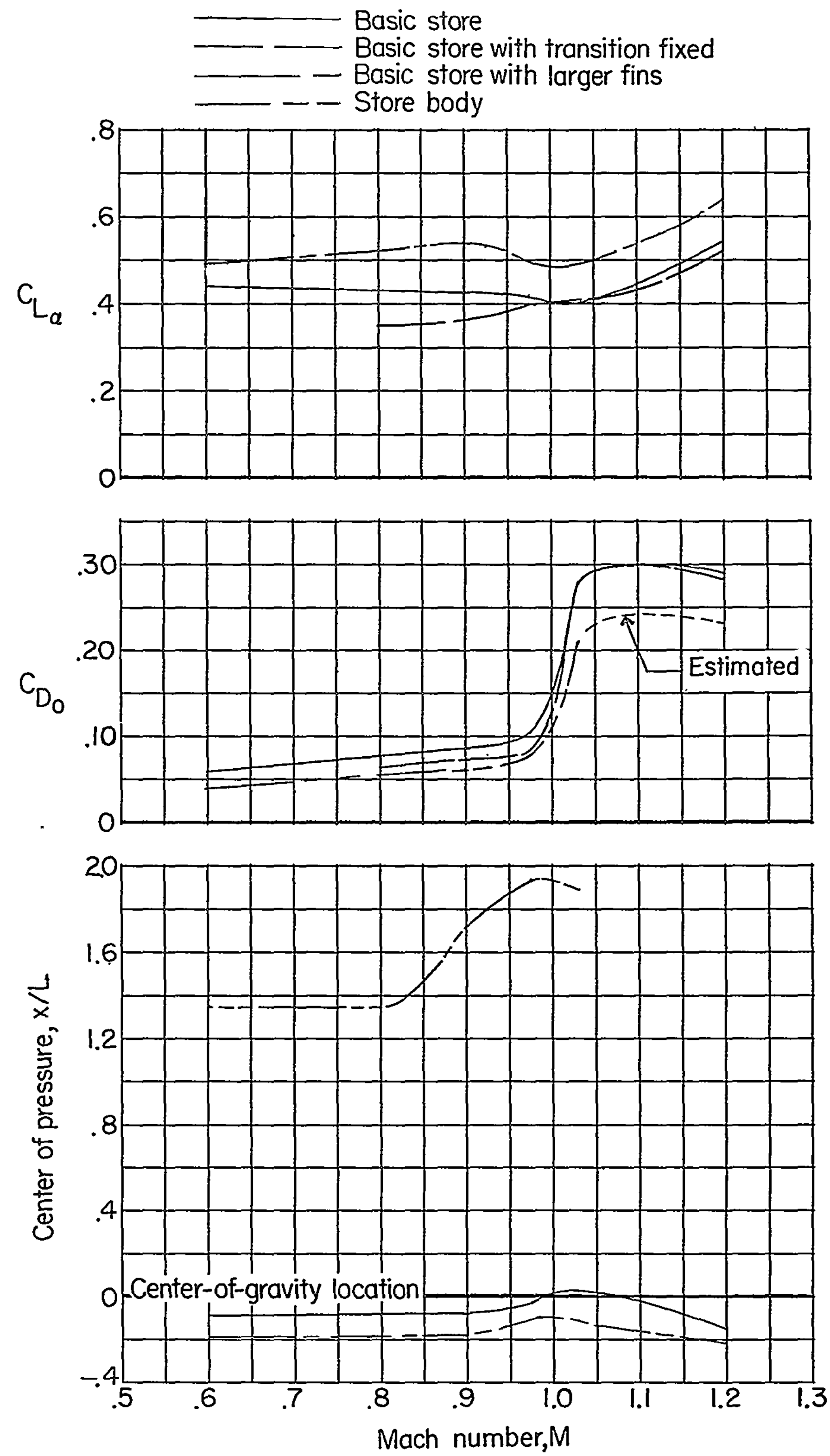


Figure 12.- Summary of the aerodynamic characteristics of several store configurations.

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Tail-Body Combinations - Missiles	1.7.2.1.2
Missiles, Specific Types	1.7.2.2
Stability, Longitudinal - Static	1.8.1.1.1

ABSTRACT

Transonic wind-tunnel tests of the NAA 255-inch fin-stabilized external store indicated that the static margin of the finned store at low lift coefficients was only 9 percent of body length at subsonic Mach numbers and reduced to zero at a Mach number of 1.0. Increasing the fin aspect ratio from 1.82 to 2.41 increased the subsonic static margin to 18 percent and provided a minimum margin of 9 percent near a Mach number of 1.0. Store mounting lugs or fin orientation had only small effects on the aerodynamic characteristics of the store.

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