NASA TECHNICAL MEMORANDUM

NASA TM X-2340

NASA TM X-2340

AERODYNAMIC CHARACTERISTICS AT
MACH NUMBERS FROM 1.60 TO 2.16 OF
A BLUNT-NOSE MISSILE MODEL HAVING
A TRIANGULAR CROSS SECTION AND
FIXED TRIFORM FINS

by William J. Monta

Langley Research Center
Hampton, Va. 23365

1. Report No. NASA TM X-2340	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle AERODYNAMIC CHARACTERISTICS AT MACH NUMBERS FROM 1.60 TO 2.16 OF A BLUNT-NOSE MISSILE MODEL HAVING A TRIANGULAR CROSS SECTION AND FIXED TRIFORM FINS		5. Report Date August 1971
		6. Performing Organization Code
7. Author(s) William J. Monta		8. Performing Organization Report No. L-7179
9. Performing Organization Name and Address NASA Langley Research Center Hampton, Va. 23365		10. Work Unit No. 136-63-02-22
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		13. Type of Report and Period Covered Technical Memorandum
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A wind-tunnel investigation has been conducted to determine the aerodynamic characteristics of a triform finned missile configuration having a body of triangular cross section and a flat-faced nose. The investigation included the effects of nose corner radius, fin span, and fin asymmetry for providing rolling moment. The tests were conducted at Mach numbers of 1.60, 1.75, and 2.16, for a unit Reynolds number of 8.2×10^6 per meter (2.5×10^6 per foot). The angle of attack was varied from about -6° to 20° for a series of model roll orientations between 0° and 180°.

17. Key Words (Suggested by Author(s)) Aerodynamic characteristics Static stability Triform missile	18. Distribution Statement Unclassified — Unlimited		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 26	22. Price* $3.00

AERODYNAMIC CHARACTERISTICS AT MACH NUMBERS
FROM 1.60 TO 2.16 OF A BLUNT-NOSE MISSILE MODEL HAVING A
TRIANGULAR CROSS SECTION AND FIXED TRIFORM FINS

By William J. Monta
Langley Research Center

SUMMARY

A wind-tunnel investigation has been conducted to determine the aerodynamic characteristics of a triform finned missile configuration having a body of triangular cross section and a flat-faced nose. The investigation included the effects of nose corner radius, fin span, and fin asymmetry for providing rolling moment. The tests were conduced at Mach numbers of 1.60, 1.75, and 2.16 for a unit Reynolds number of 8.2×10^6 per meter $(2.5 \times 10^6$ per foot). The angle of attack was varied from about -6° to 20° for a series of model roll orientations between 0° and 180°.

The results indicate that the model has a pitchup tendency in the flat-top orientation and a pitchdown tendency in the flat-bottom orientation. For intermediate roll orientations the model generated large lateral forces and moments at the higher angles of attack. Decreasing the nose corner radius resulted primarily in an increase in axial force. Increasing the fin span by approximately 20 percent increased the normal-force-curve slope and moved the aerodynamic center rearward approximately 3 percent of the body length. A fin configuration employing asymmetric leading and trailing edges was effective in producing rolling moment throughout the test range of angle of attack and Mach number.

INTRODUCTION

The Langley Research Center has conducted a wind-tunnel investigation to determine the aerodynamic characteristics of a triform finned missile configuration having a body of triangular cross section and a flat-faced nose. Also investigated were the effects of nose corner radius, fin span, and fin asymmetry for providing rolling moment.

The tests were conducted in the Langley Unitary Plan wind tunnel at Mach numbers of 1.60, 1.75, and 2.16 for a unit Reynolds number of 8.2×10^6 per meter $(2.5 \times 10^6$ per foot). The angle of attack was varied from about -6° to 20° for a series of model roll orientations between 0° and 180°.

SYMBOLS

The aerodynamic force and moment data are referred to the body-axis system. The moment data are referred to the 50-percent body length station. Values are given in both SI and U.S. Customary Units. The measurements and calculations were made in U.S. Customary Units. Symbols used are defined as follows:

A area of reference circle that encompasses the body cross section, 0.00670 m^2 (0.0721 ft^2)

b fin panel span, m   (ft)

C_A axial-force coefficient, $\dfrac{\text{Axial force}}{qA}$

$C_{A,c}$ chamber axial-force coefficient, $\dfrac{\text{Chamber axial force}}{qA}$

$C_{A,o}$ axial-force coefficient at $\alpha = 0^\circ$

C_l rolling-moment coefficient, $\dfrac{\text{Rolling moment}}{qAd}$

C_m pitching-moment coefficient, $\dfrac{\text{Pitching moment}}{qAd}$

C_{m_α} slope of pitching-moment curve near an angle of attack of 0°, per degree

C_N normal-force coefficient, $\dfrac{\text{Normal force}}{qA}$

C_{N_α} slope of normal-force curve near an angle of attack of 0°, per degree

C_n yawing-moment coefficient, $\dfrac{\text{Yawing moment}}{qAd}$

C_Y side-force coefficient, $\dfrac{\text{Side force}}{qA}$

d diameter of reference circle that encompasses the body cross section, 9.235 cm (3.636 in.)

l body length, 91.935 cm (36.195 in.)

M free-stream Mach number

q free-stream dynamic pressure, N/m^2 (lb/sq ft)

2

r_n nose corner radius, m (ft)

$\dfrac{x_{ac}}{l}$ distance from model nose tip (sta. 0) to aerodynamic center, referenced to body length

α angle of attack, degrees

ϕ roll orientation of model (measured clockwise when viewed from rear; $\phi = 0^{\circ}$ when the flat side of body is on top), degrees

Model component designations:

N_1, N_2 nose components

F_1, F_2, F_3 fin components

APPARATUS AND METHODS

Tunnel

Tests were conducted in the low Mach number test section of the Langley Unitary Plan wind tunnel, which is a variable-pressure continuous-flow facility. The test section is approximately 1.22 m (4 ft) square and 2.1 m (7 ft) long. The nozzle leading to the test section is of the asymmetric sliding-block type which permits a continuous variation in Mach number from about 1.5 to 2.9.

Model

The details of the model are shown in figure 1. The body had a triangular cross section with rounded edges. Two nose sections (designated N_1 and N_2) were provided that were slightly larger in cross section than the body and had flat faces with a corner radius of 2.54 cm (1.00 in.) and 1.27 cm (0.50 in.), respectively. Fixed fins were located on the rounded edges of the body near the base. A dummy set of fin supports were provided to simulate folding-fin attachments. Three sets of fins were provided. Two of these which are designated F_1 and F_2 had symmetrical wedge-shaped leading edges, blunt trailing edges, and an exposed span of 5.08 cm (2.0 in.) and 6.10 cm (2.40 in.), respectively. The third set of fins (designated F_3) differed from the F_2 fins only by having asymmetrically beveled leading and trailing edges (see fig. 1(b)) to induce a rolling moment to the model.

Test Conditions and Instrumentation

The test conditions for the investigation were as follows:

Mach number	Stagnation temperature		Stagnation pressure		Unit Reynolds number	
	$^{\circ}$K	$^{\circ}$F	kN/m^2	lb/sq ft abs	1/m	1/ft
1.60	339	150	68.28	1426	8.2×10^6	2.5×10^6
1.75	339	150	71.72	1498	8.2	2.5
2.16	339	150	85.61	1788	8.2	2.5

Tests were made through an angle-of-attack range from -6° to 20°. The dewpoint was maintained below 239° K $(-30^{\circ}$ F) in order to assure negligible condensation effects. Boundary-layer transition strips were composed of 0.16-cm-wide (0.06-in.) bands of No. 60 sand (0.03 cm or 0.011 in. nominal height). On the model nose the strips were located 2.5 cm (1.0 in.) axially from the tip of the nose; and on the fins, 1.0 cm (0.4 in.) aft of the leading edge.

Aerodynamic forces and moments were measured by means of a six-component electrical strain-gage balance housed within the model. The balance, in turn, was rigidly fastened to a sting support and then to the tunnel support system. Model chamber pressure was measured by means of a single static orifice placed in the balance cavity.

Corrections

The angle of attack was corrected for both tunnel flow angularity and deflection of the sting-balance combination due to aerodynamic loads. The axial-force-coefficient data have been adjusted to correspond to free-stream static pressure acting over the model base. Typical chamber axial-force coefficients are presented in figure 2.

PRESENTATION OF RESULTS

DISCUSSION

Longitudinal Characteristics

The basic longitudinal aerodynamic characteristics of the test configurations $(N_1 F_1$, $N_2 F_1$, $N_2 F_2$, and $N_2 F_3)$ are presented in figures 3 and 4 for $\phi = 0^O$ and $\phi = 180^O$, respectively. Decreasing the nose corner radius from 2.54 cm (1.00 in.) (N_1) to 1.27 cm (0.50 in.) (N_2) produced little change in the longitudinal characteristics, other than an increase in axial force. The increase in fin span from 5.08 cm (2.0 in.) (F_1) to 6.10 cm (2.40 in.) (F_2) led to an increase in normal-force coefficient of about 15 percent and produced a more stable configuration. The asymmetric fin (F_3) had the same longitudinal characteristics as the symmetric fin of the same size (F_2). The effects of each of the configuration changes were the same at both $\phi = 0^O$ (fig. 3) and $\phi = 180^O$ (fig. 4).

The effect of model roll attitude ϕ on the longitudinal characteristics was investigated for $N_1 F_1$ (fig. 5). The flat-top configuration ($\phi = 0^O$) exhibits a pitchup tendency; whereas, the flat-bottom configuration ($\phi = 180^O$) has a pitchdown tendency (increasing stability with increasing angle of attack). The pitch characteristics at intermediate roll orientations vary between these two conditions. There is also a greater increase in the slope of the normal-force curve with increasing angle of attack for the flat-bottom model as compared with the flat-top model which in conjunction with the C_m variation, indicates a more rearward location of the center of pressure for the flat-bottom model.

A summary of longitudinal parameters is presented in figure 6. This figure more clearly illustrates the increase in axial-force coefficient with decrease in nose corner radius, as well as the shift in aerodynamic-center location and the corresponding increase in C_{N_α} due to increase in fin span. The 20-percent increase in fin span between F_1 and F_2 results in the aerodynamic center of the configuration moving aft by about 3 percent of the body length. Two points that might be noted are the small forward shift in aerodynamic-center location with increase in Mach number, and the slight increase in $C_{A,o}$ with increase in Mach number.

Lateral Characteristics

The effect of model roll attitude on the lateral characteristics was investigated for the $N_1 F_1$ configuration only and the results are presented in figure 7. For asymmetric roll attitudes ($\phi \neq 0^O$ or 180°), C_l, C_n, and C_Y values remain relatively small for angles of attack up to about 6°. A large increase in these lateral coefficients occurs, however, with further increase in angle of attack. The variation of lateral characteristics with model roll attitude is presented in figure 8 for several angles of attack. The large variation of the lateral characteristics with model roll orientation at the higher angles of attack can be seen clearly.

The asymmetric fin configuration $\left(N_2 F_3\right)$ is effective in producing a nearly constant increment in rolling moment at all test angles of attack (fig. 9). There is little change in C_l with test Mach number or between the flat-bottom and the flat-top configurations.

CONCLUDING REMARKS

Tests of a triangular-shaped missile having a blunt nose and fixed triform stabilizing fins have been conducted at Mach numbers from 1.60 to 2.16. The results indicate that the model has a pitchup tendency in the flat-top orientation and a pitchdown tendency in the flat-bottom orientation. For intermediate roll orientations the model generated large lateral forces and moments at the higher angles of attack. Decreasing the nose corner radius resulted primarily in an increase in axial force. Increasing the fin span by approximately 20 percent increased the normal-force-curve slope and moved the aerodynamic center rearward approximately 3 percent of the body length. A fin configuration having asymmetric leading and trailing edges was effective in producing rolling moment throughout the test range of angle of attack and Mach number.

Langley Research Center,
    National Aeronautics and Space Administration,
        Hampton, Va., July 7, 1971.
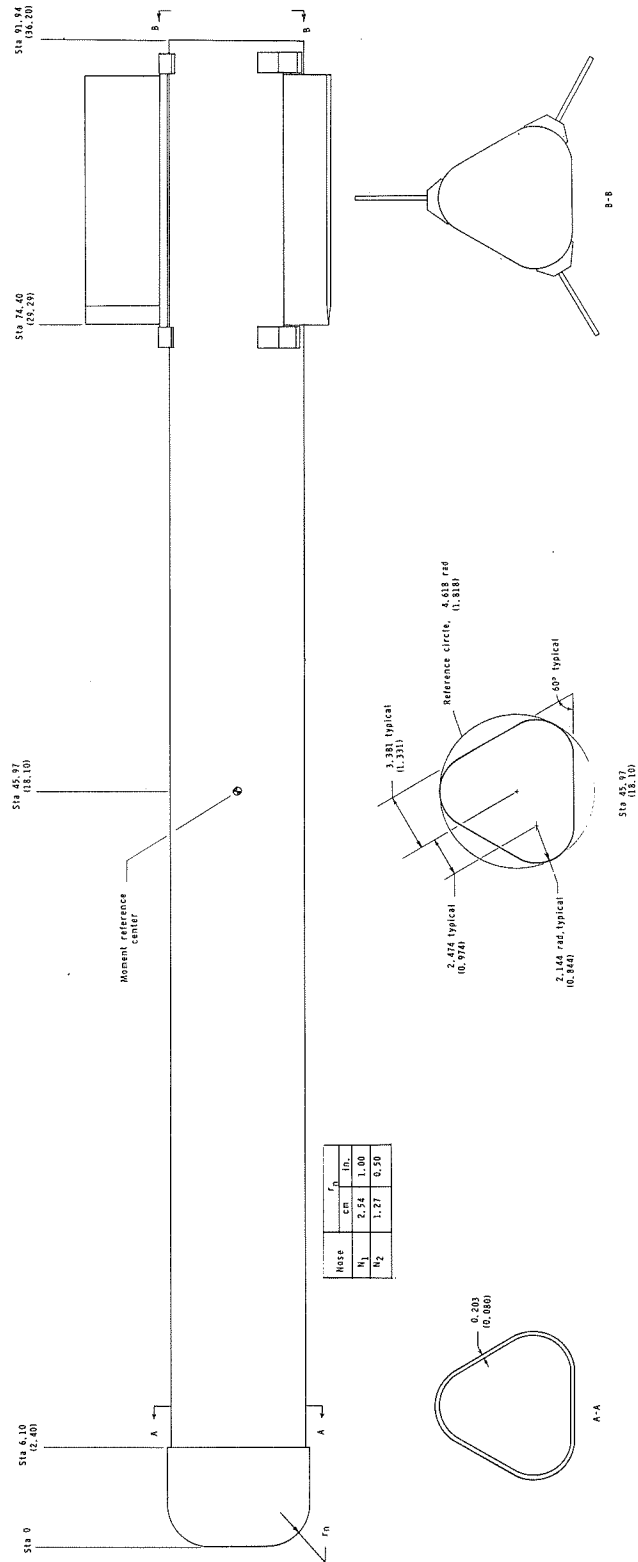
(a) Model assembly.

Figure 1.- Sketch of model. All linear dimensions are given in centimeters and parenthetically in inches. $\phi = 180^{\circ}$.
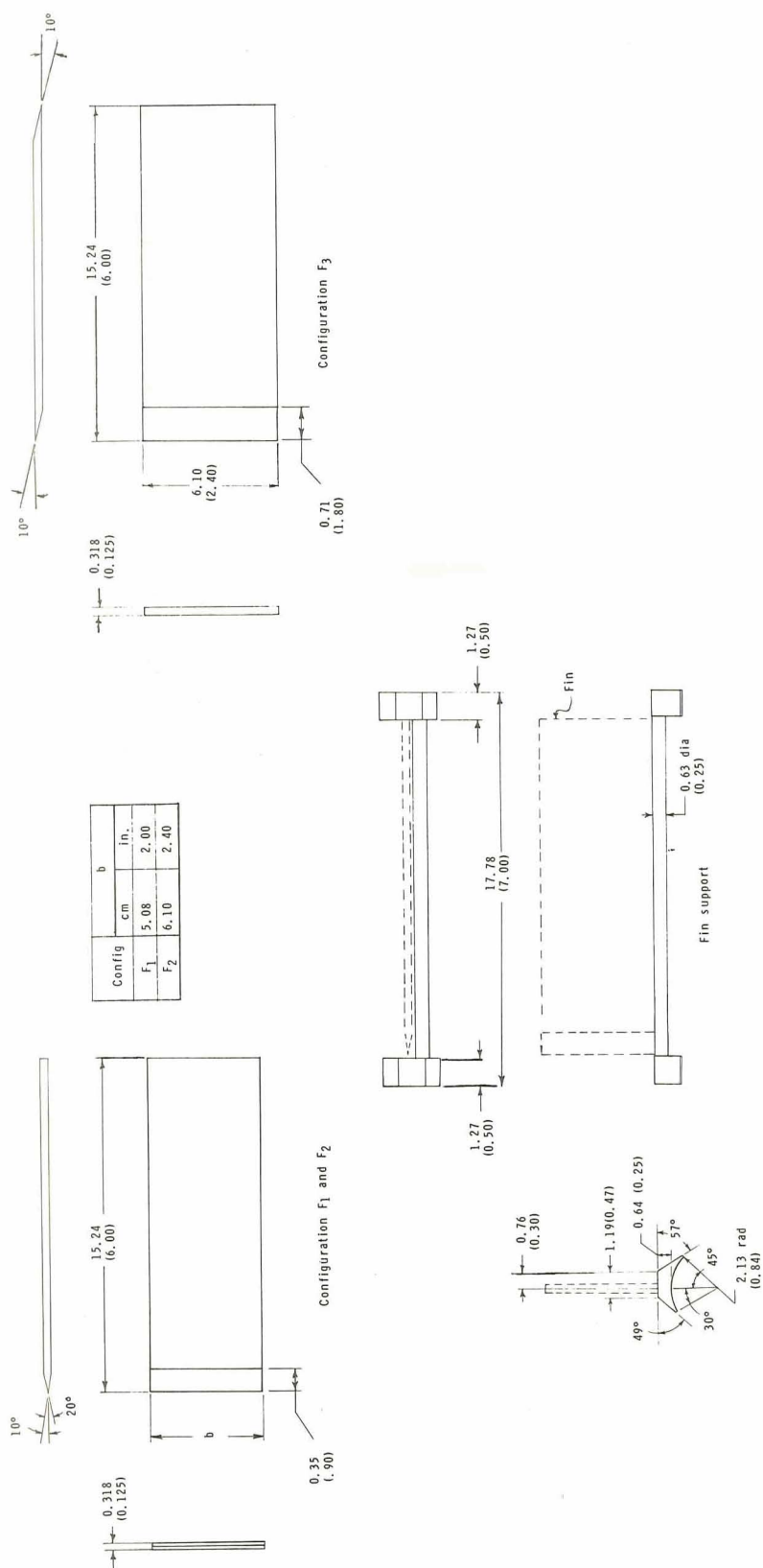
(b) Details of fins.

Figure 1.- Concluded.

8
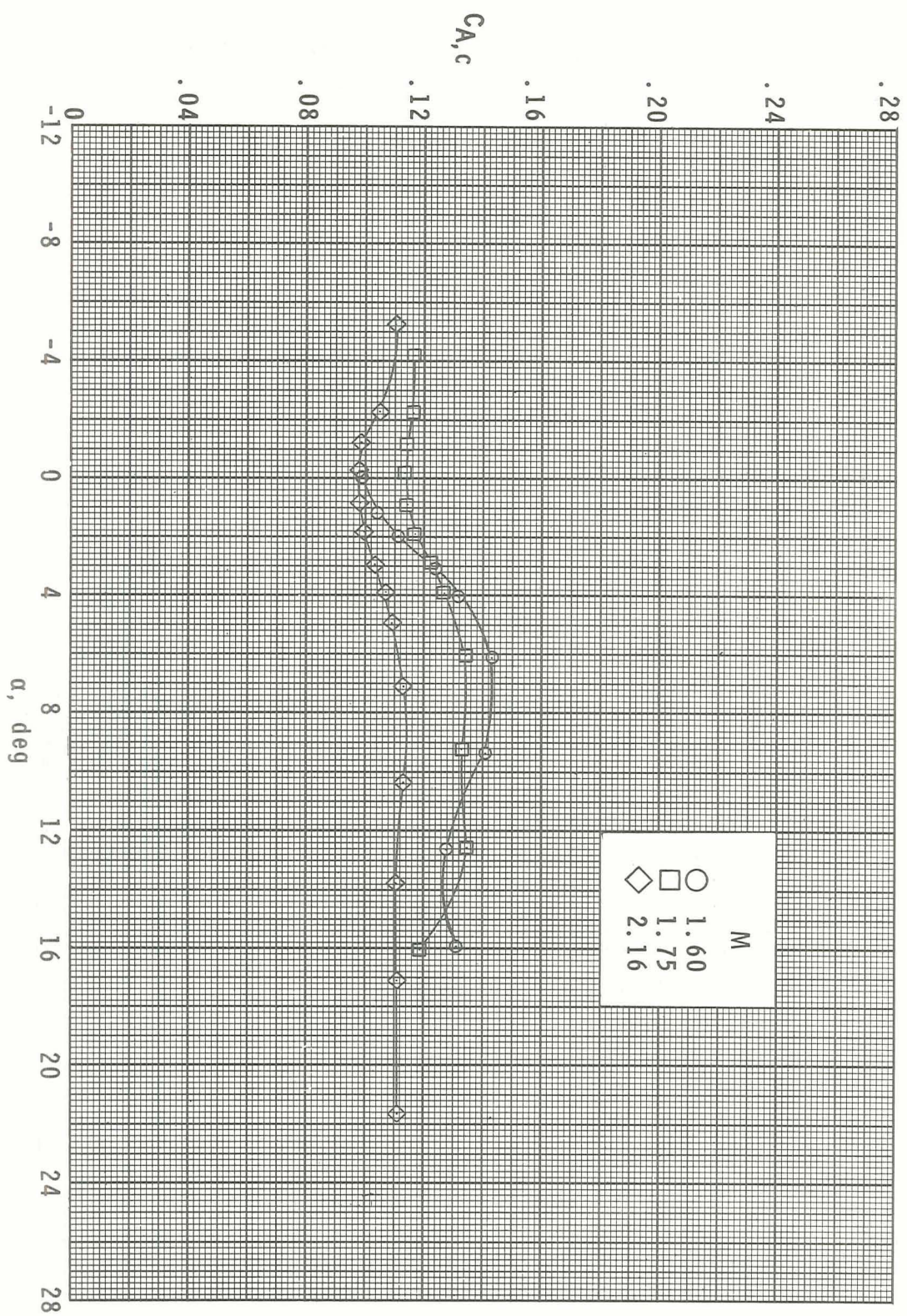
Figure 2.- Typical variation of chamber axial-force coefficient with angle of attack. N_1F_1; $\phi = 0^o$.
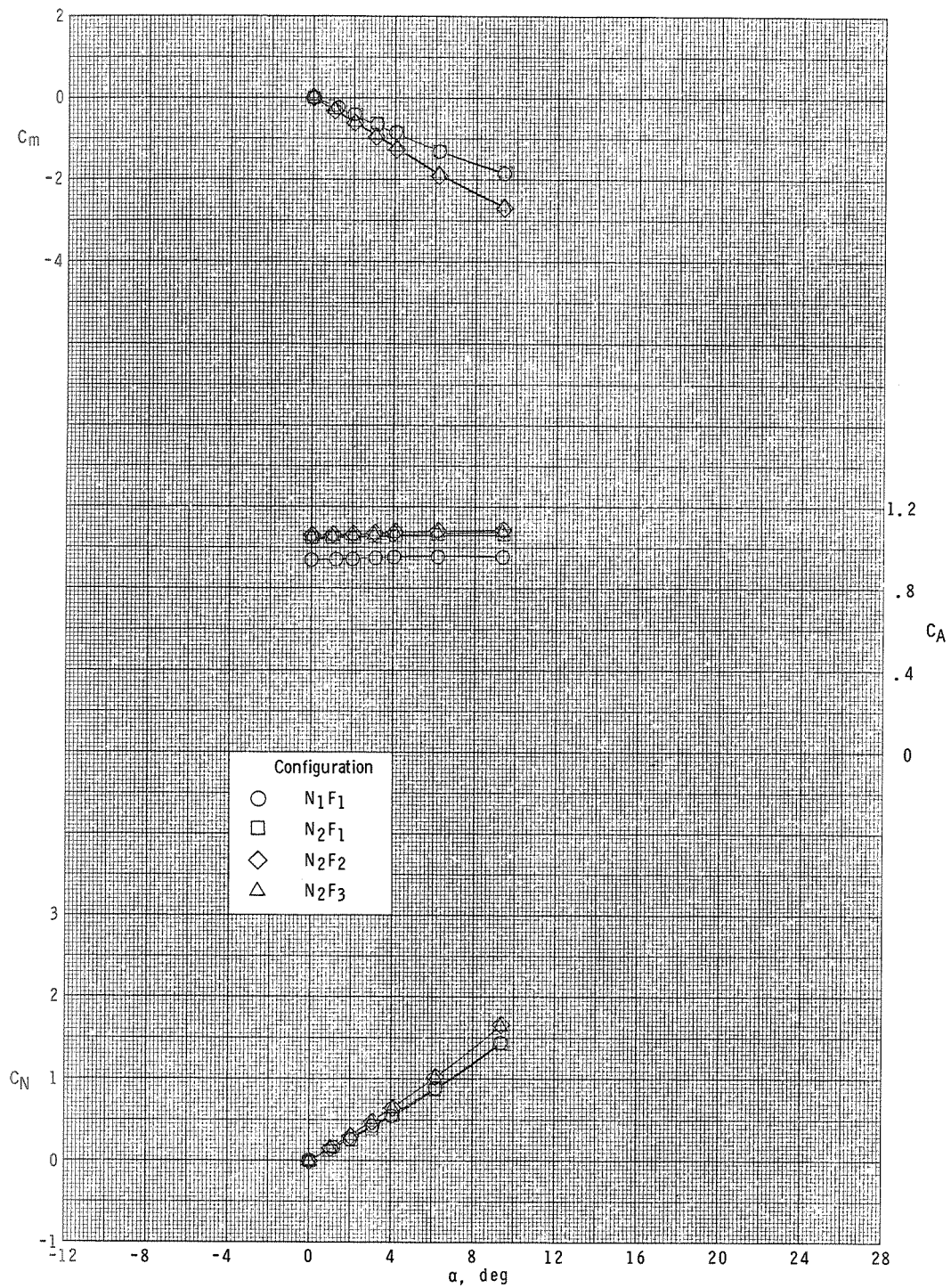
(a) M = 1.60.

Figure 3.- Effect of nose and fin geometry on the longitudinal characteristics. $\phi = 0^O$.
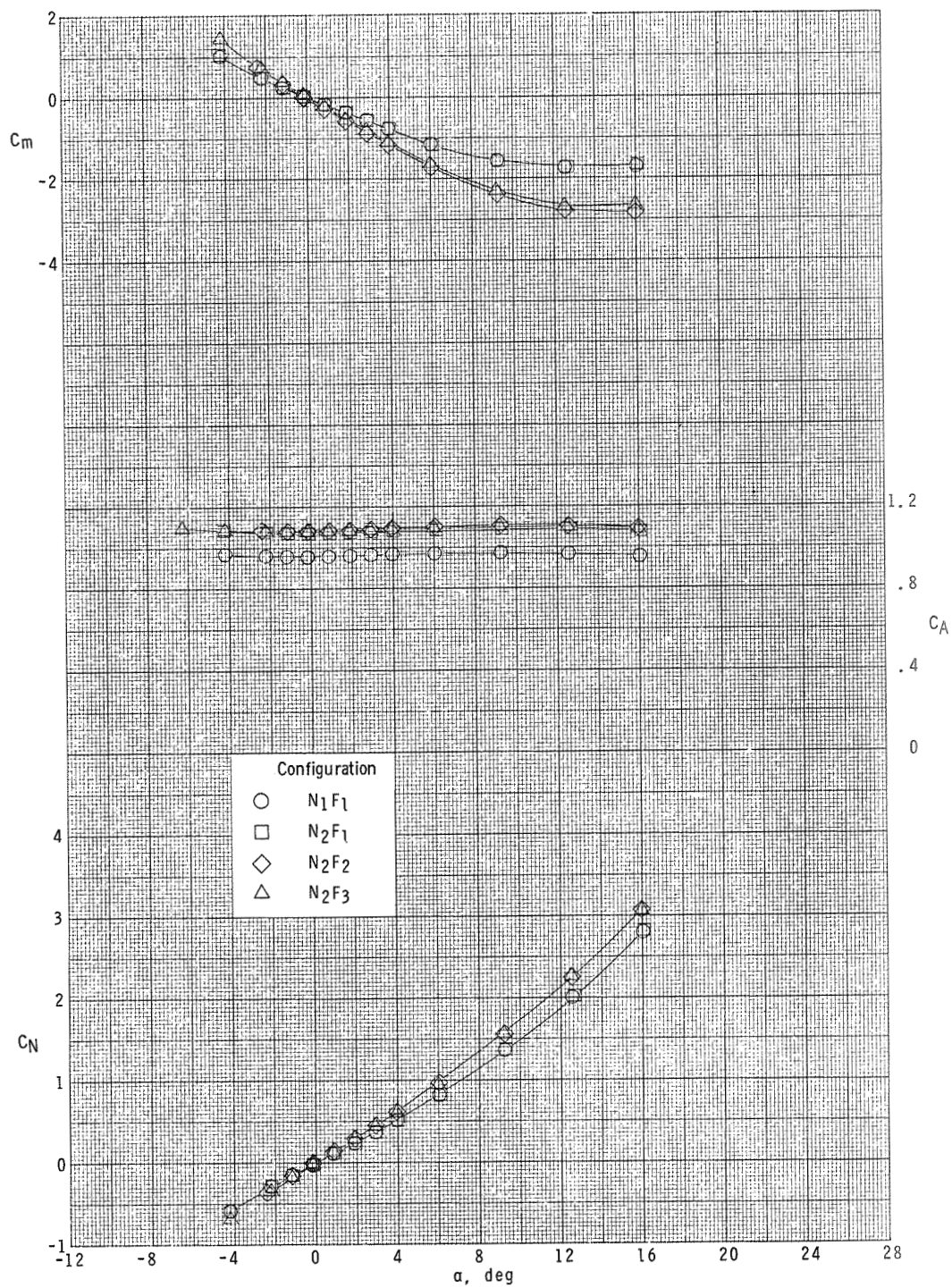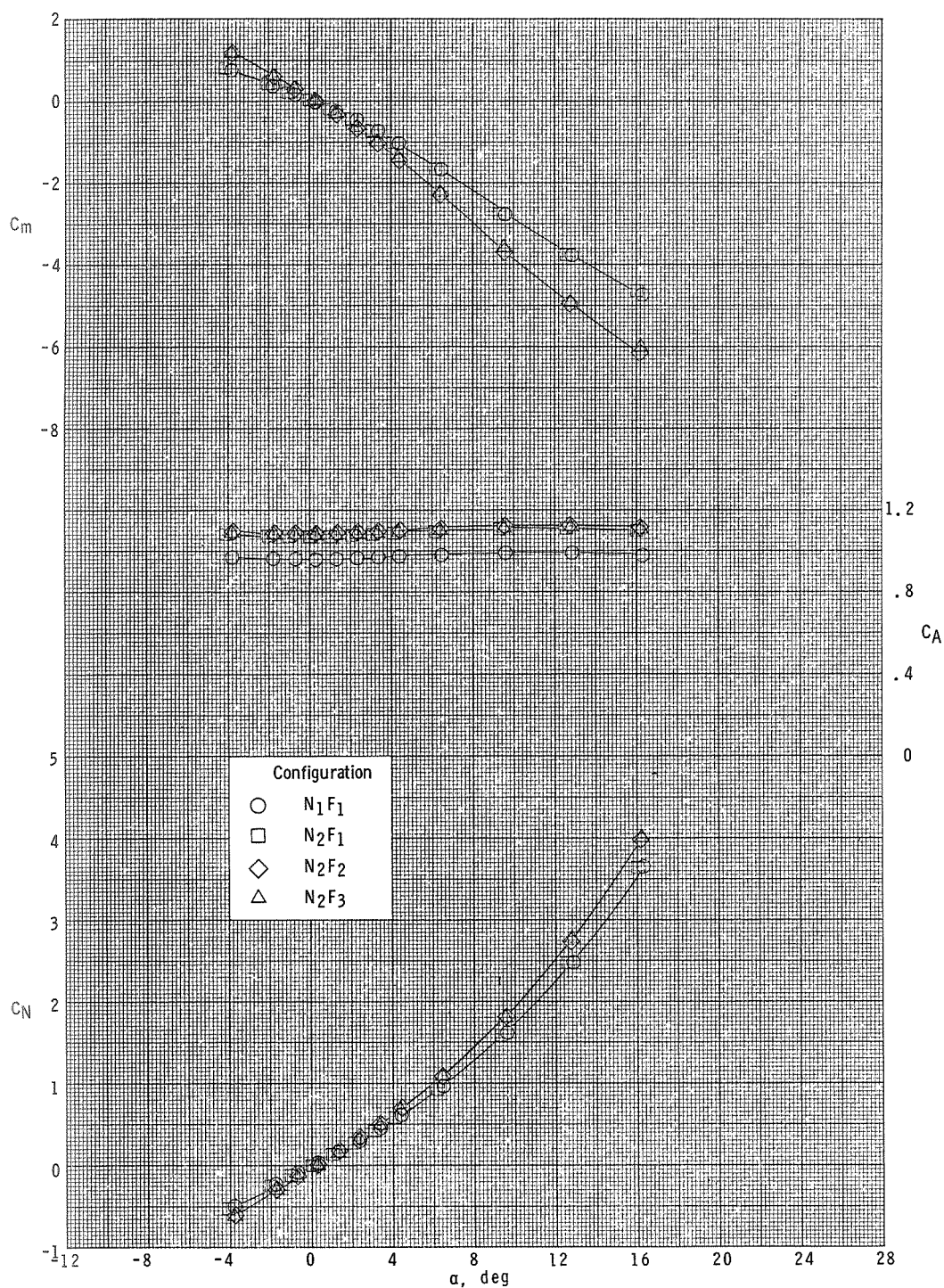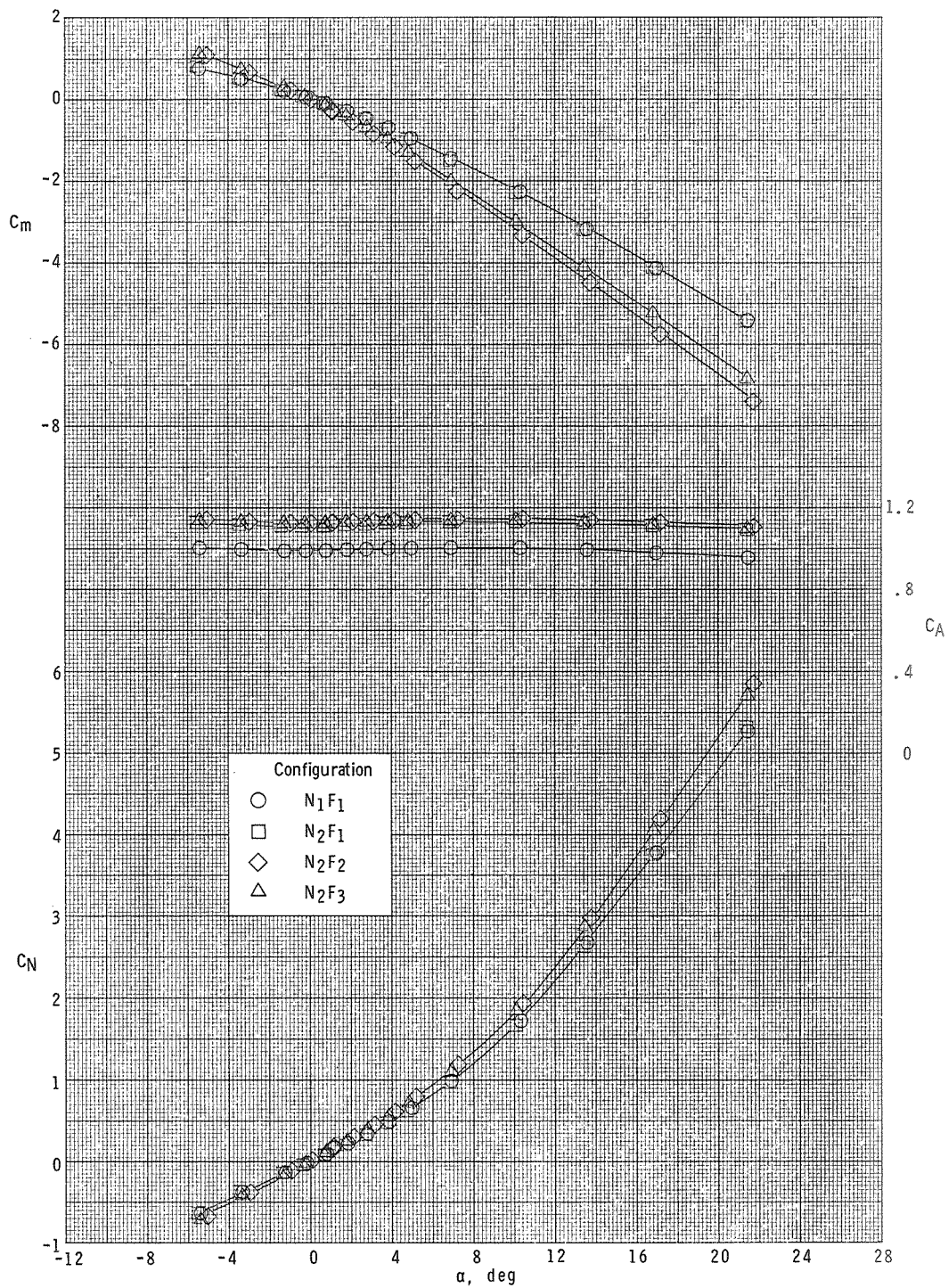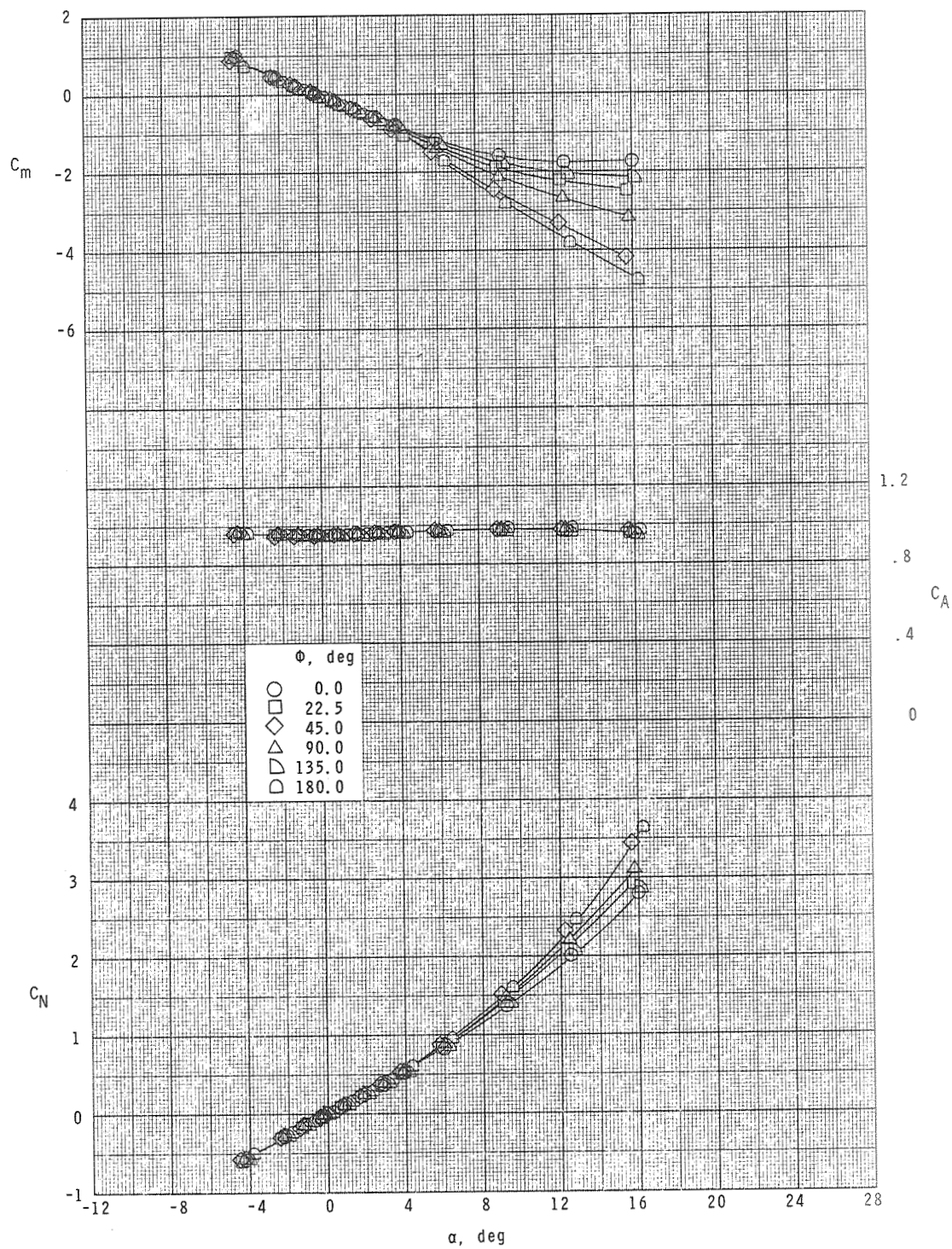
(b) M = 1.75.

Figure 3.- Continued.
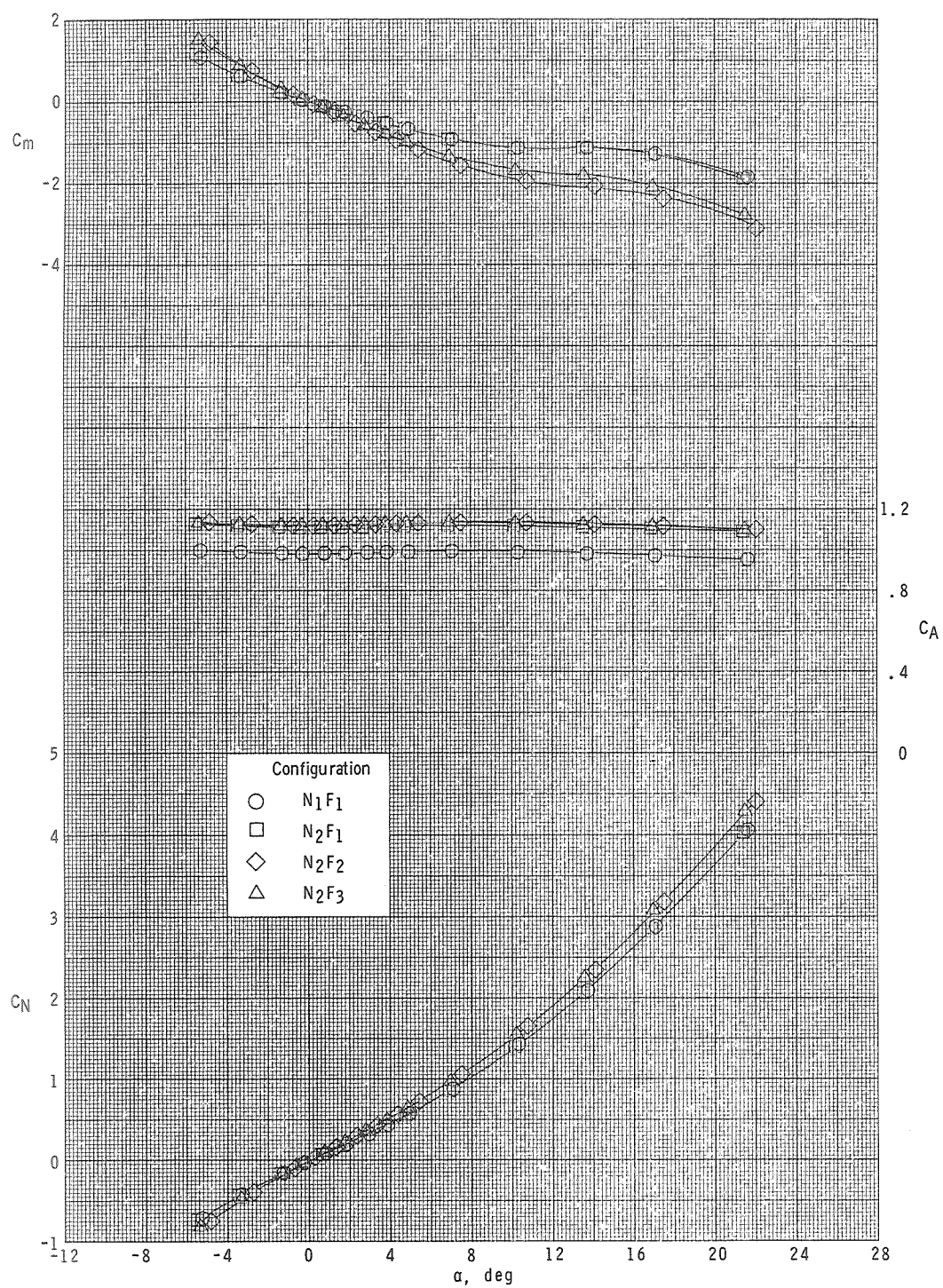
(c) M = 2.16.

Figure 3.- Concluded.
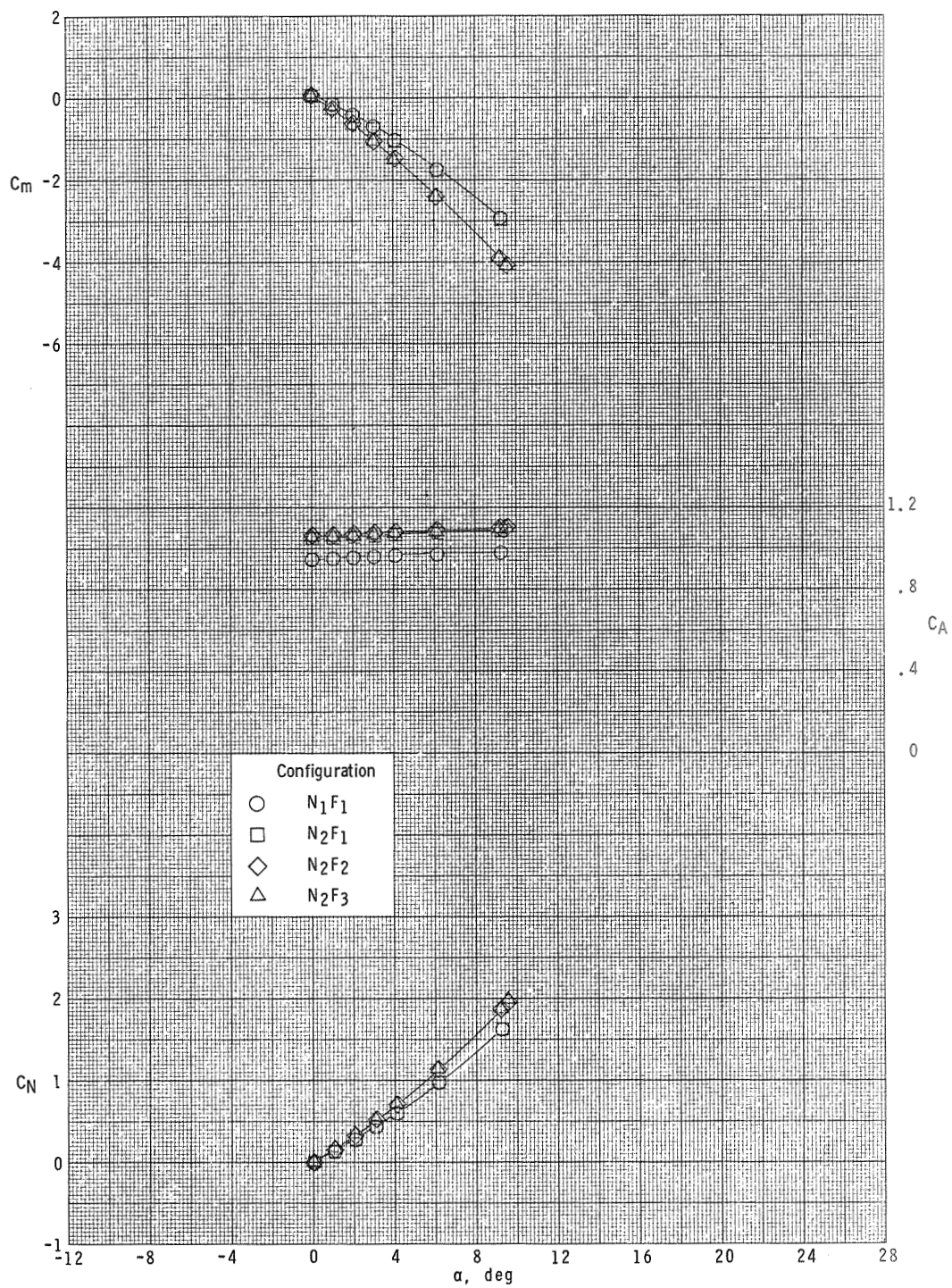
(a) M = 1.60.

Figure 4.- Effect of nose and fin geometry on the longitudinal characteristics. $\phi = 180^{\circ}$.

(b)   M = 1.75.

Figure 4.- Continued.

(c)   M = 2.16.

Figure 4.- Concluded.
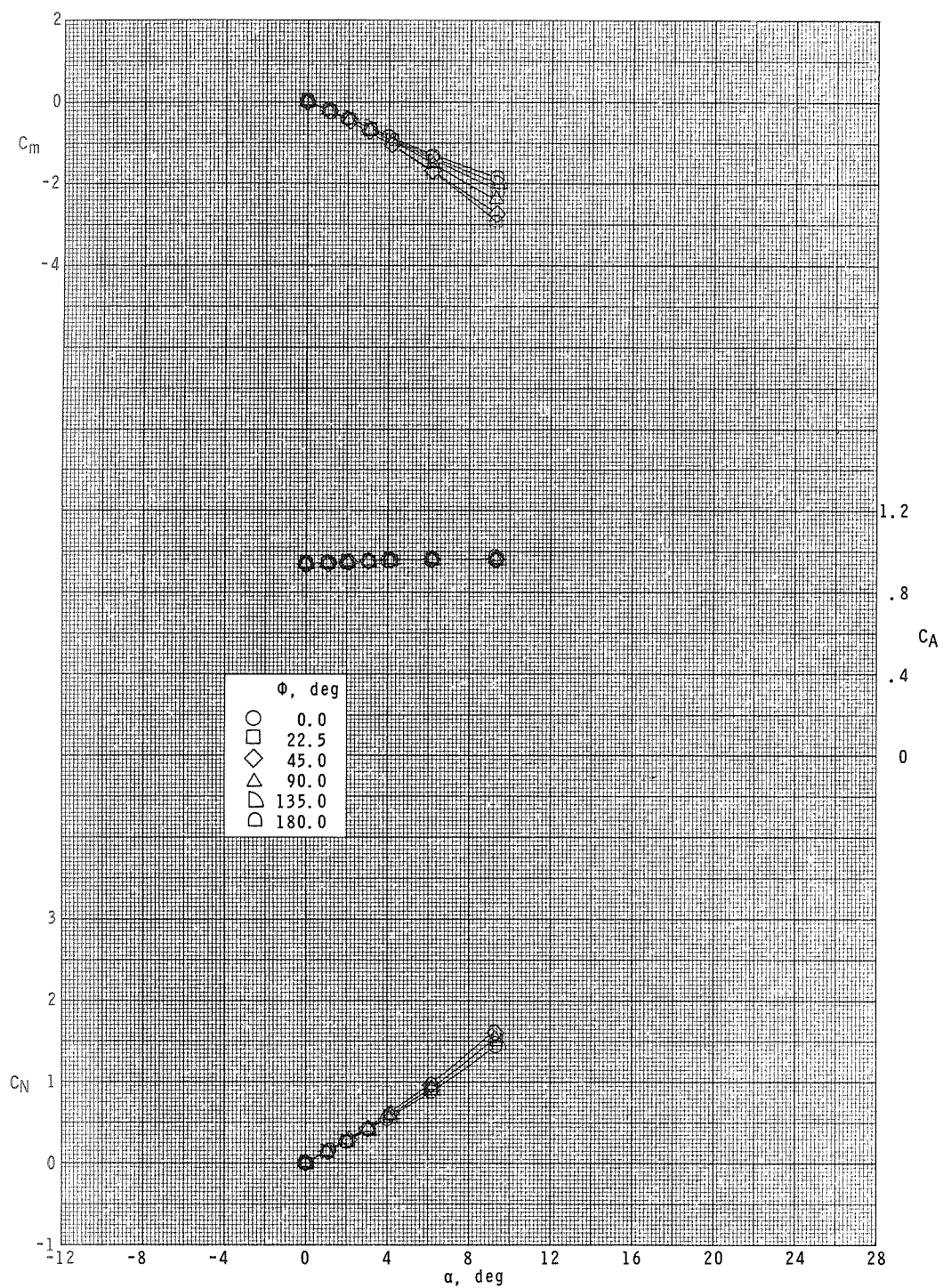
(a) M = 1.60.

Figure 5.- Effect of model roll attitude ϕ on the longitudinal characteristics. N_1F_1.

(b) M = 1.75.

Figure 5.- Continued.
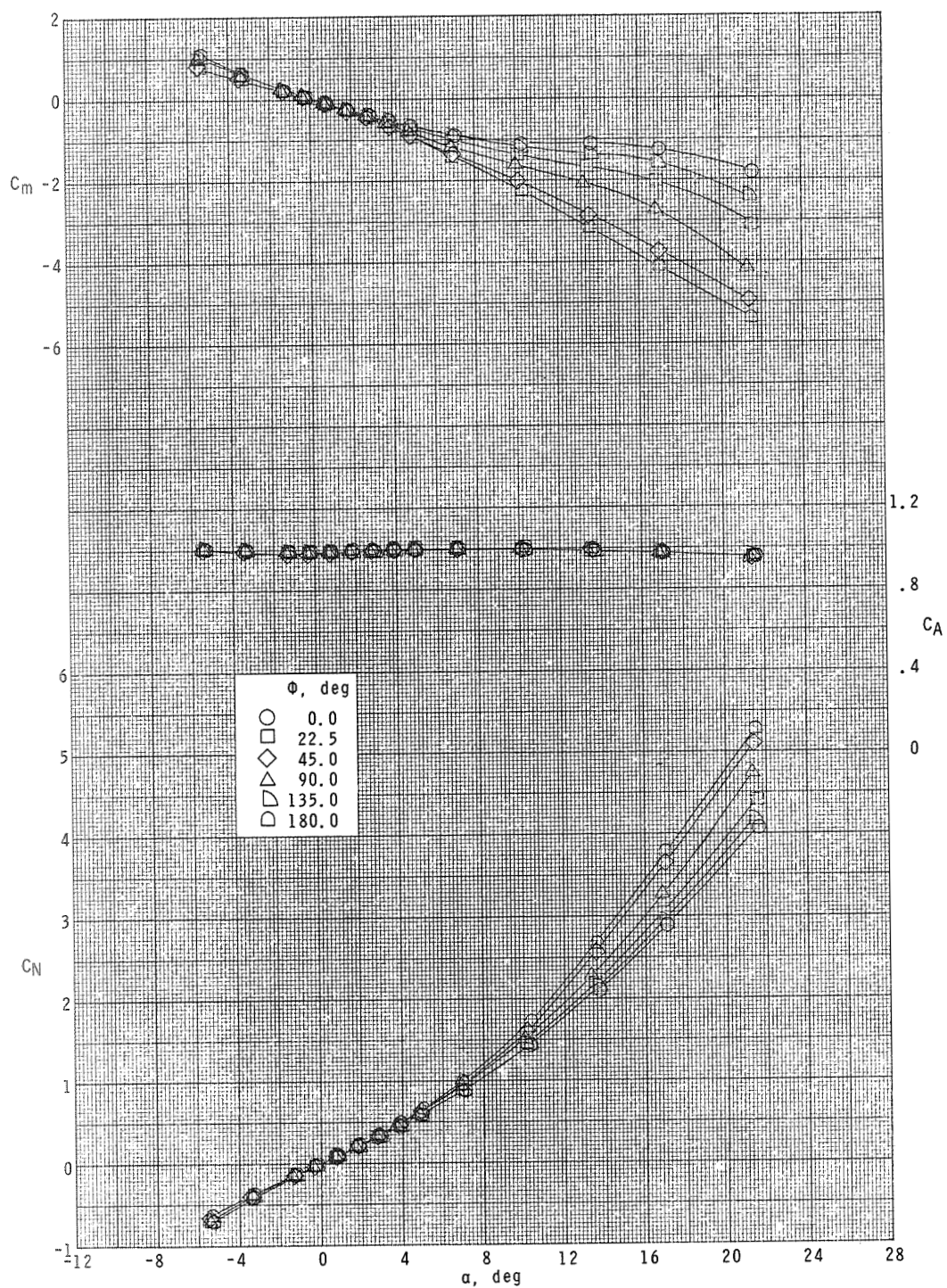
(c) M = 2.16.

Figure 5.- Concluded.
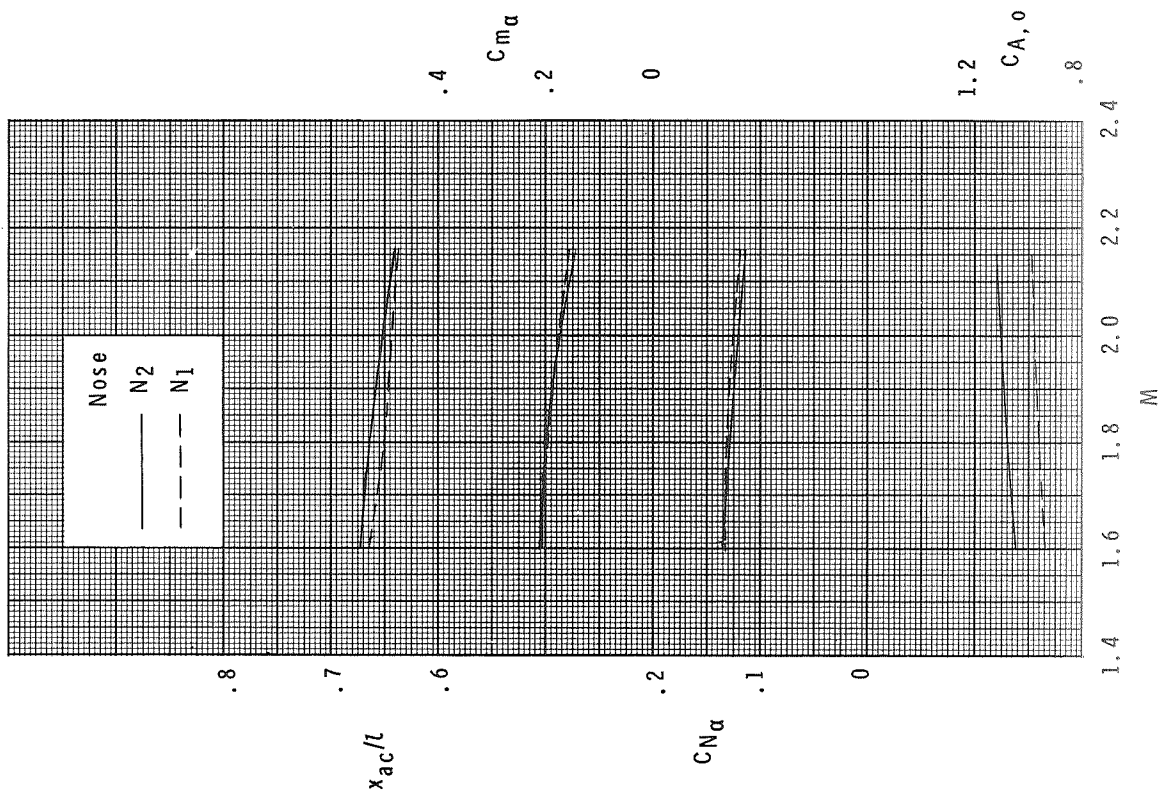
(a) Configuration with F_1.
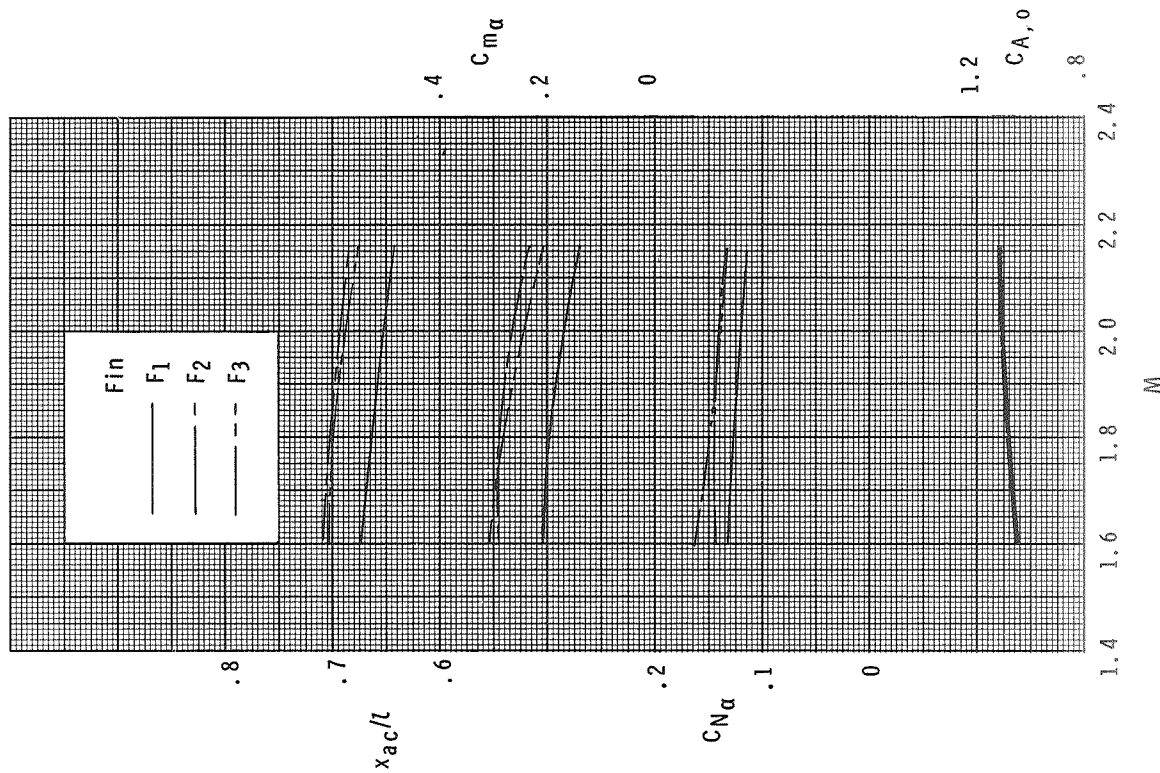
(b) Configuration with N_2.

Figure 6.– Summary of longitudinal parameters.
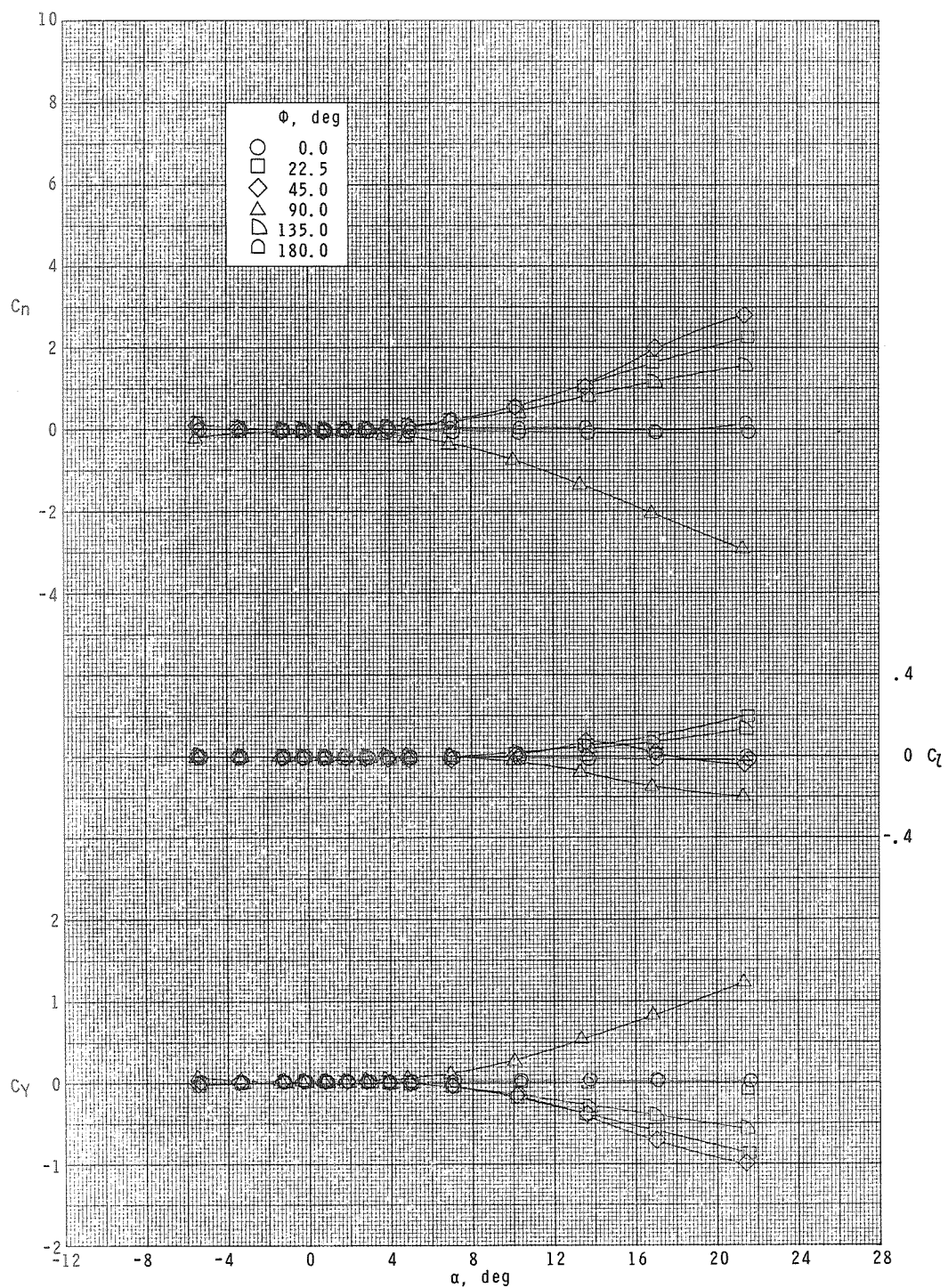
19
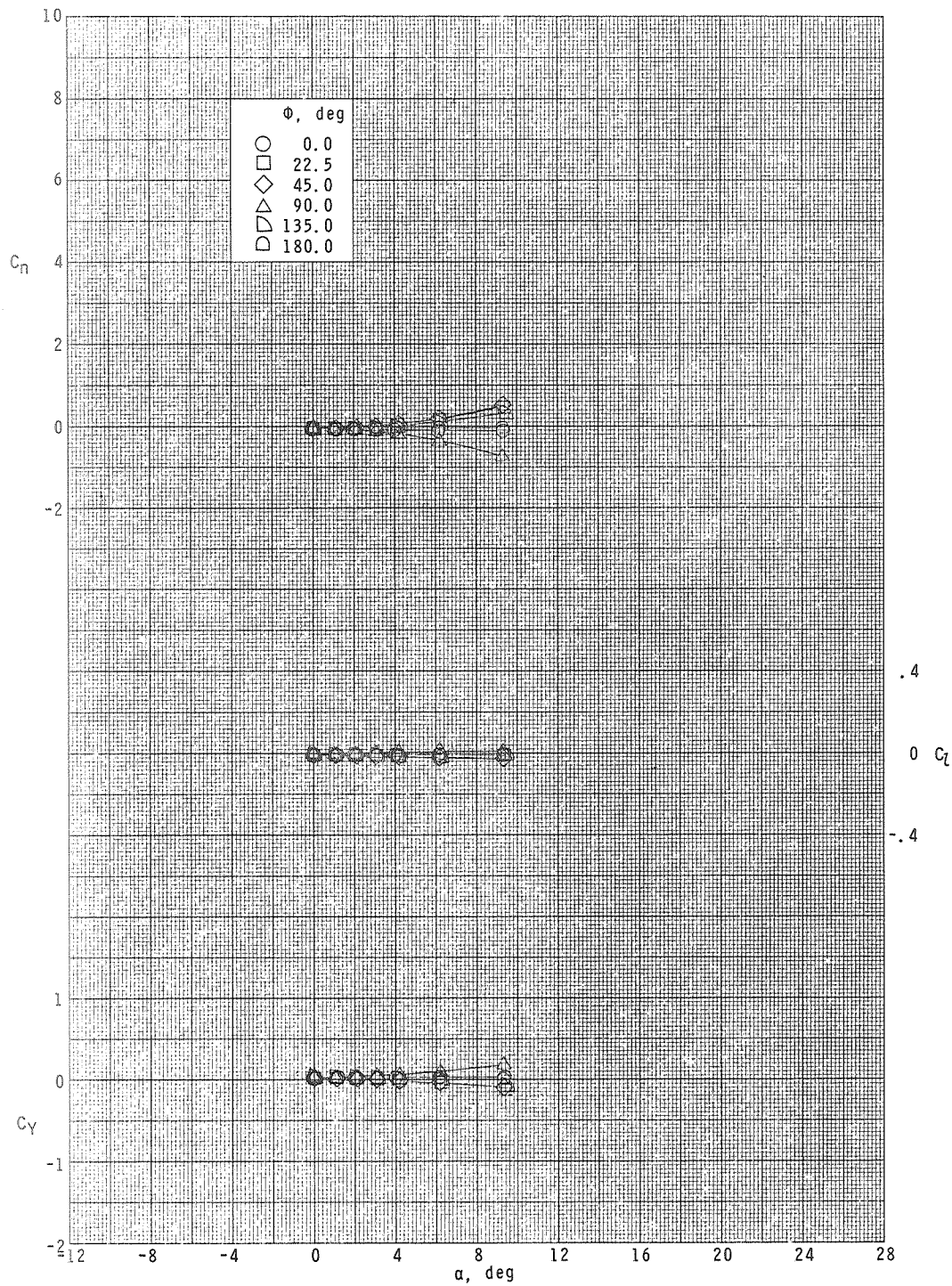
(a) M = 1.60.

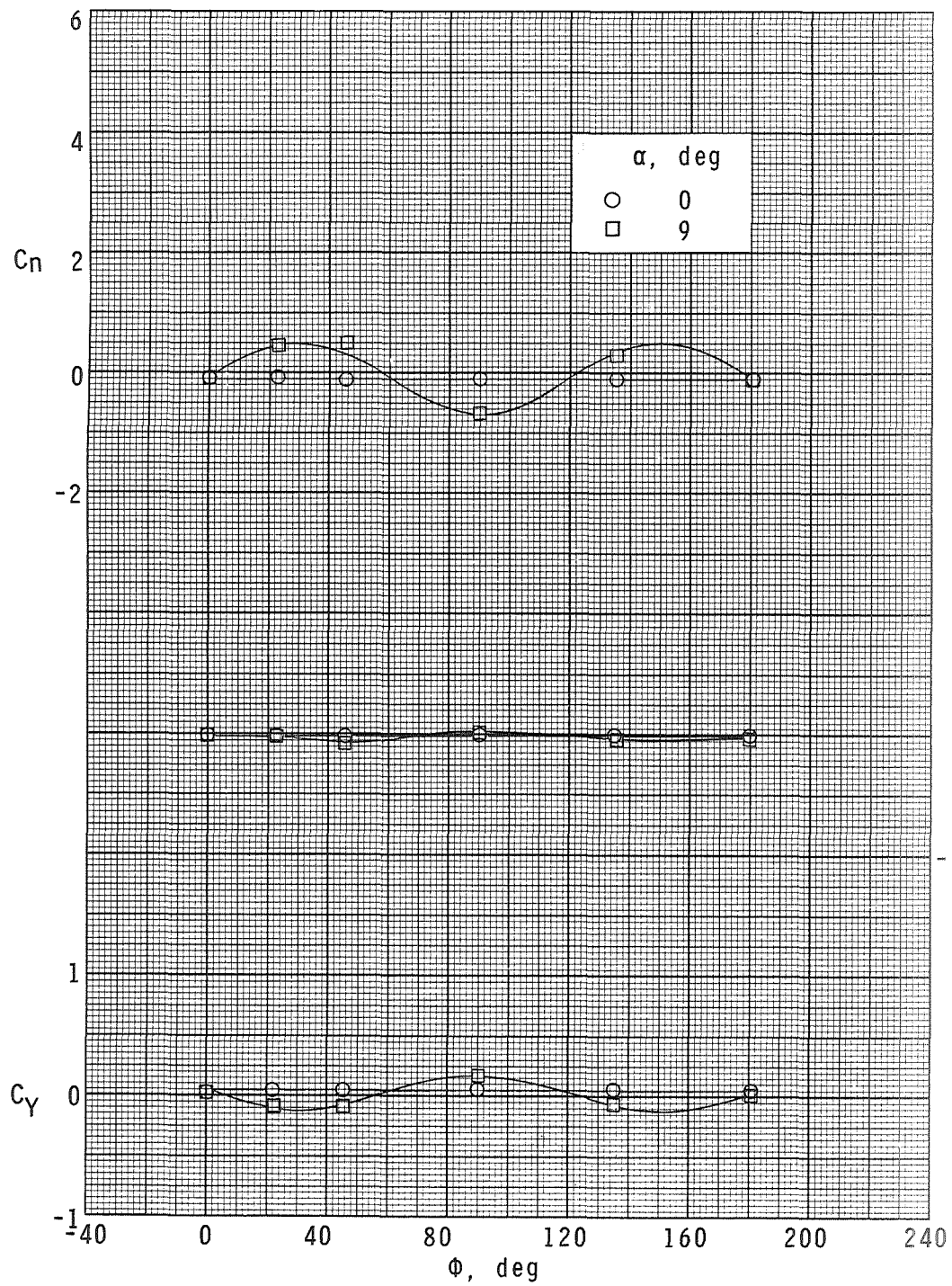Figure 7.- Effect of model roll attitude ϕ on the lateral characteristics. N_1F_1.
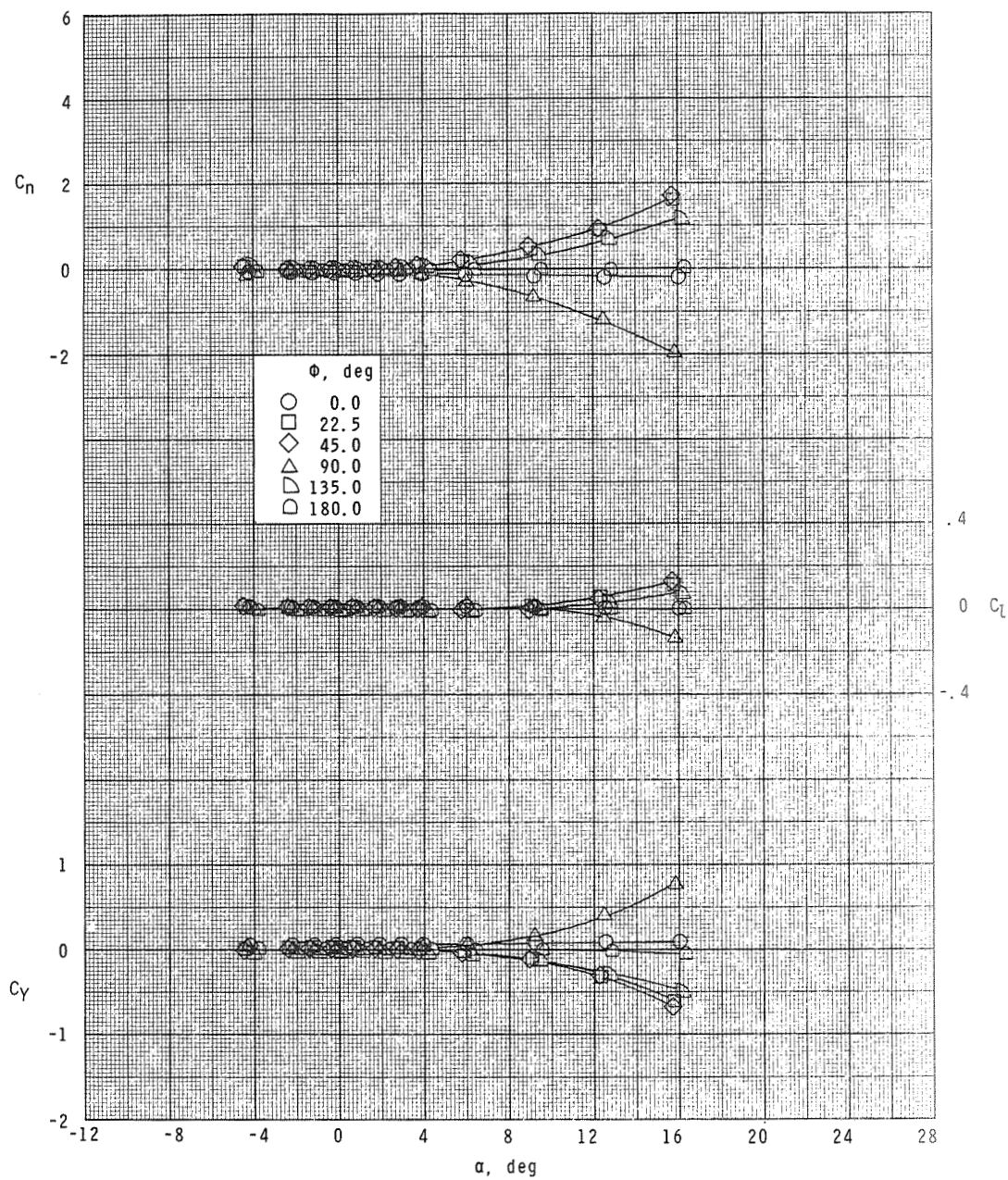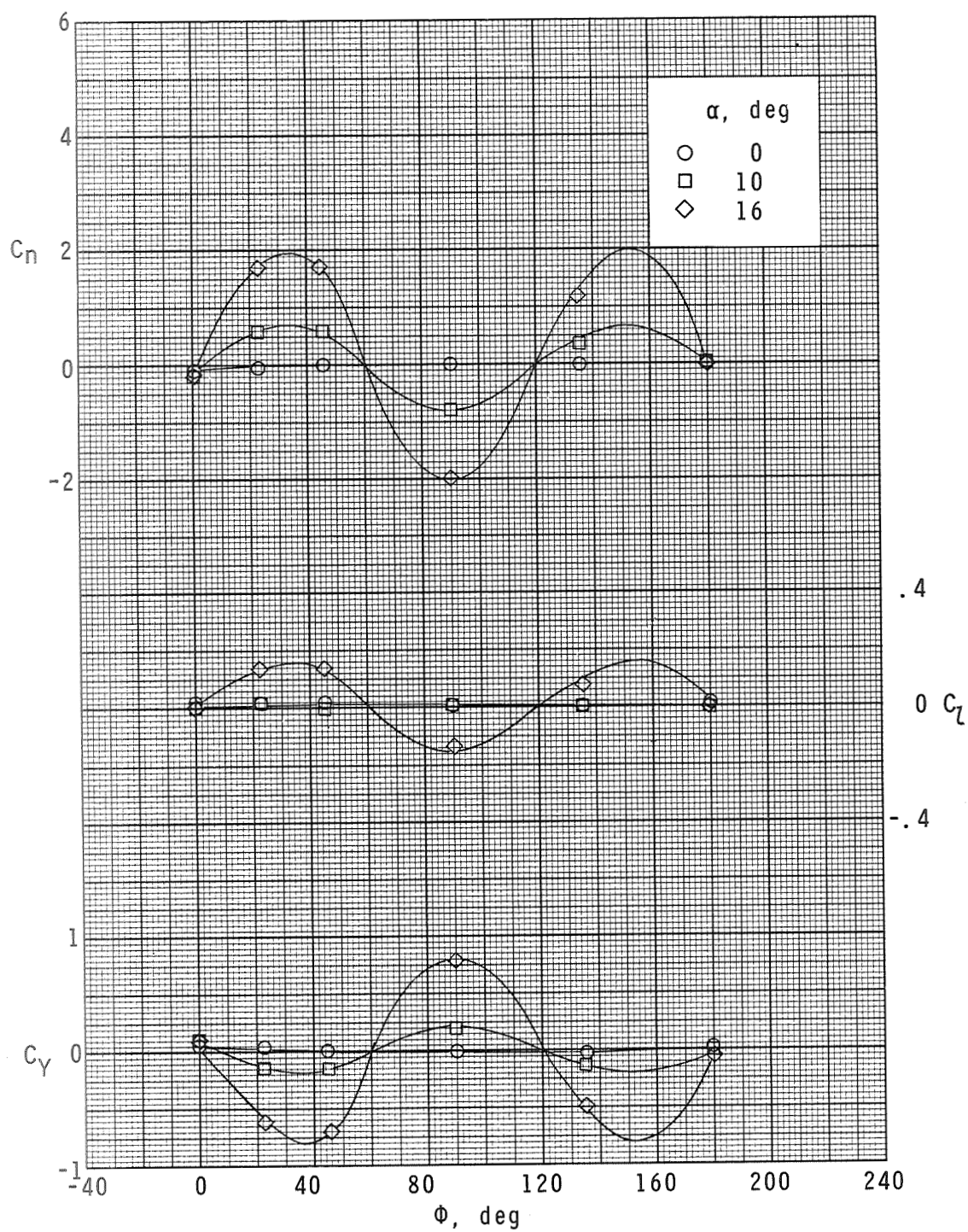
(b)   M = 1.75.

Figure 7.- Continued.
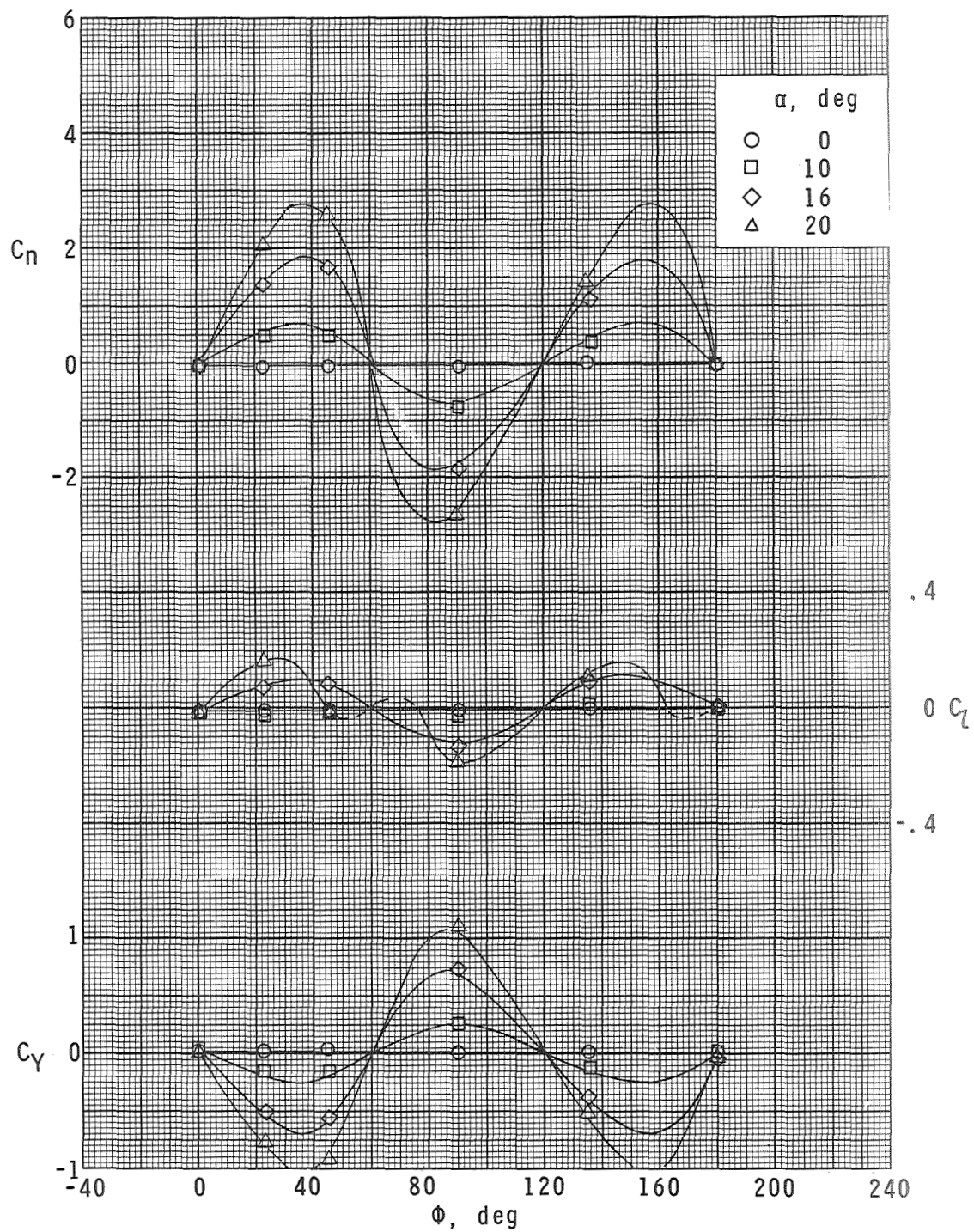
21

(c) M = 2.16.

Figure 7.- Concluded.

(a) M = 1.60.

Figure 8.- Summary of the effect of model roll attitude on the lateral
characteristics. N_1F_1.

23

(b) M = 1.75.

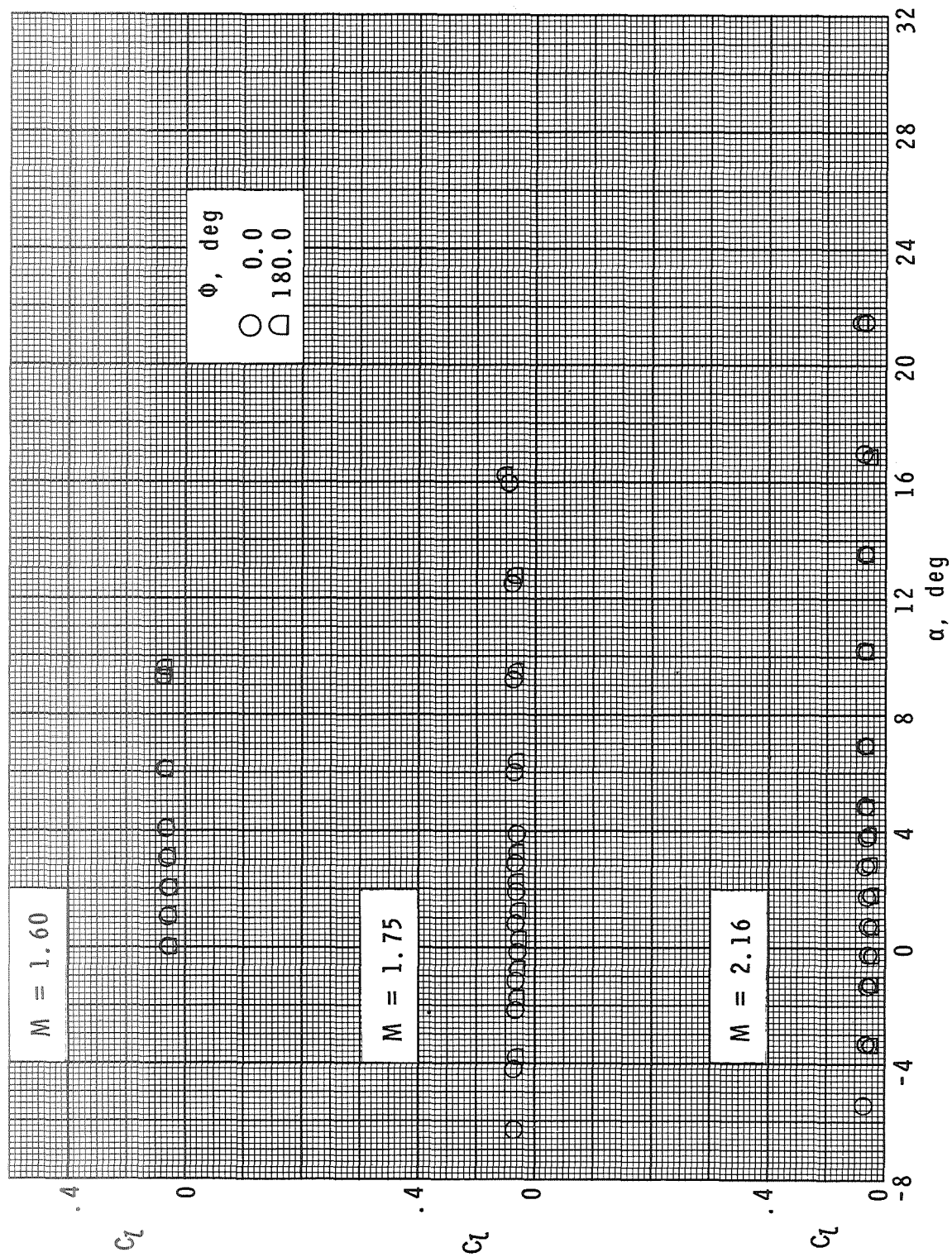Figure 8.- Continued.

(c) M = 2.16.

Figure 8.- Concluded.

Figure 9.- Roll effectiveness of asymmetric fin. N_2F_3.

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

— NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION OFFICE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D.C. 20546