NASA TECHNICAL MEMORANDUM

NASA TM X-1433

NASA TM X-1433

FORCE MEASUREMENTS ON AXISYMMETRIC MODELS WITH HAMMERHEAD NOSES AT TRANSONIC SPEEDS

by Bruno J. Gambucci and Robert C. Robinson

Ames Research Center
Moffett Field, Calif.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • AUGUST 1967

NASA TM X-1433

FORCE MEASUREMENTS ON AXISYMMETRIC MODELS WITH HAMMERHEAD NOSES AT TRANSONIC SPEEDS

By Bruno J. Gambucci and Robert C. Robinson

Ames Research Center
Moffett Field, Calif.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 – CFSTI price $3.00

FORCE MEASUREMENTS ON AXISYMMETRIC MODELS WITH HAMMERHEAD NOSES AT TRANSONIC SPEEDS

By Bruno J. Gambucci and Robert C. Robinson

Ames Research Center

SUMMARY

A wind-tunnel investigation was conducted to determine normal-force, pitching-moment, and axial-force coefficients for five models with hammerhead noses. Data were obtained for model angles of attack from approximately -1° to $+4^\circ$ and a Mach number range from 0.70 to 1.20. Reynolds number, based on model base diameter, varied with Mach number from 1.81 to 2.19 million.

INTRODUCTION

The fairing over the nose of a launch vehicle sometimes assumes a bulbous shape because the diameter of the payload exceeds that of the last stage of its launch vehicle. This hammerhead fairing protects the payload from the airstream and is designed for minimum weight. The shape of the fairing significantly affects the aerodynamic loads (steady and unsteady) in the transonic speed range. Considerable research has been done to determine the unsteady aerodynamic loads on various hammerhead nose shapes. Dynamic test results of a wind-tunnel investigation of some models with hammerhead noses are presented in reference 1. In references 2 and 3, static and fluctuating pressures were measured on models with similar nose configurations.

As noted, a variety of data is available for hammerhead shaped configurations, but static-force measurements are lacking. Static-force data obtained in connection with the dynamic tests reported in reference 1 and presented herein include normal-force, pitching-moment, and axial-force coefficients for five hammerhead configurations. Most of these configurations are not practical because they are subject to dynamic instability at some flow conditions. The data for other flow conditions should be useful for estimating static loads and for determining aerodynamic influence coefficients for design purposes.

NOTATION

C_A axial-force coefficient, $\frac{\text{axial force}}{qS}$

C_m pitching-moment coefficient, $\frac{\text{pitching moment}}{qSd}$

C_N normal-force coefficient, $\frac{\text{normal force}}{qS}$

d model base diameter

M Mach number

q free-stream dynamic pressure

S model base area

α angle of attack

MODELS AND TESTS

The models used in this test program (fig. 1) were identical to five of the models employed for the dynamic tests of reference 1. The model identification numbers indicate that they were part of a large series of configurations tested in earlier work. Model 24 was derived from model 8(a) by changing the nose from 30° to 15° (fig. 1(a)). Model 23 was the result of reducing the boattail angle to 10° (dashed line) from the 20° boattail angle of model 22 (fig. 1(b)). Model 7(b) (fig. 1(c)) has a shallow boattail angle and an elliptical nose with no discontinuities.

The models were sting mounted in the wind tunnel. A cylindrical fairing several base diameters long was clamped to the sting. The normal and axial forces were measured by an internal strain-gage balance. The moment center used in computing the pitching moment was located in the base plane for each model as shown in figure 1. A photograph of model 7(b) mounted on the wind-tunnel model support system is shown in figure 2.

The tests were conducted in the Ames 14-Foot Transonic Wind Tunnel. The Mach number was varied from 0.70 to 1.20 with corresponding Reynolds number variations from 1.81 to 2.19 million based on model base diameter. The model angle of attack was varied from $\alpha = -1^\circ$ to $+4^\circ$. Data beyond $\alpha = 4^\circ$ were not obtained because of model strength limitations. The models were designed for dynamic testing which required light weight; therefore, the model structure could not safely sustain the aerodynamic loads at $\alpha > 4^\circ$. A detailed description of the model construction technique is given in reference 1.

PRECISION OF DATA

In the data acquisition procedure, energizing the print-out circuit causes three data points to be recorded in succession over a short period of time. The coefficients were computed from the average of the three points. However, under some flow conditions, the individual points differ greatly from the average. Figure 3 shows the deviations of the individual data points from their average values for model 24 in steady and unsteady airflow conditions. The unsteady flow is a fluctuation between separated and attached flow in the boattail region that causes large buffeting forces on the model as reported in references 1 and 4. The deviations of the individual readings from their average were approximately 0.005 for normal-force coefficient and 0.025 for pitching-moment coefficient when the airflow conditions over the model were steady. When the conditions were unsteady, C_N and C_m fluctuated as much as 0.023 and 0.05, respectively, at $\alpha = 0^{\circ}$.

Axial-force coefficient (not shown) fluctuated as much as 0.026 for unsteady airflow conditions and 0.002 for steady airflow conditions.

The model angle of attack was set within $\pm 0.1^{\circ}$, and the wind-tunnel free-stream Mach number was measured within ± 0.005.

RESULTS AND DISCUSSION

The normal-force and pitching-moment coefficients measured for the five models of this investigation are presented in figures 4 to 8 as a function of angle of attack for a range of Mach numbers. A close examination of the C_m data for models 8(a) (30° nose and 8.2° boattail), 23 (10° boattail), and 24 (15° nose and 8.2° boattail) (figs. 4, 5, and 6, respectively) reveals that all three configurations have regions of static stability, as evidenced by the negative slope of the data. It is also shown that these regions occurred over a narrow range of Mach numbers and model angles of attack for each of the three models. The region of negative C_m slope corresponds to the conditions where dynamic instability was observed in reference 1 for these same configurations. The C_N data for the three models show discontinuities at the test conditions for which the airflow was unsteady, primarily from $\alpha = -1^{\circ}$ to $+1^{\circ}$. This region corresponds to that where the largest deviations in the data were recorded; hence, the dashed line fairing is used to indicate uncertainties. The deviations for the regions of uncertainties were shown in figure 3.

The discontinuities in the C_N and C_m data for $\alpha = 0^{\circ}$ at $M = 1.19$ for model 22 (20° boattail) (fig. 7) also correspond to a region of dynamic instability (ref. 1). At all other test conditions the force data for model 22 were quite smooth, indicating the airflow conditions were steady over the model. Model 7(b) (elliptical nose and $6\text{-}1/2^{\circ}$ boattail angle) is the only configuration where steady airflow conditions prevailed throughout the test (fig. 8). The lowest levels of normal-force and pitching-moment coefficients were obtained with model 8(a), while model 22 had the highest C_m and C_N values.

Axial-force coefficients are presented for all the models at $\alpha = 0$ in figure 9. Angle-of-attack data were not presented for C_A since the variations due to angle of attack were insignificant. Model 7(b) had the lowest values of axial force over the Mach number range of the investigation and model 8(a) had the highest values (fig. 9).

The wind-tunnel operating procedure was to record data at discrete Mach numbers beginning with the lowest and increasing to the upper limit established for each configuration. With model 8(a), the data at $M = 1.00$ were repeated after decreasing the wind-tunnel free-stream velocity from $M = 1.19$. Figure 10 shows that the C_m and C_N curves at $M = 1.00$ depend on whether that Mach number was approached from a higher or lower Mach number. The flow was separated from the boattail area when the data were taken after increasing the Mach number, while for the data taken after decreasing the Mach number the flow was attached. This kind of "hysteresis" effect for separated flow regions has been previously observed for blunt bodies in transonic flow (see, e.g., ref. 5).

CONCLUDING REMARKS

Force measurements for five hammerhead configurations were obtained in a wind-tunnel investigation. The Mach number was varied from 0.70 to 1.20, and model angle of attack was varied from -1° to $+4^\circ$.

For three configurations the curve for pitching-moment coefficient had a negative slope over a narrow range of model angles of attack and free-stream Mach numbers. In a previous investigation these three configurations were found to be dynamically unstable at the angles of attack when the C_m slope was negative. The highest pitching moments and normal forces were obtained from model 22 which had a 20° boattail. Model 8(a) (30° nose and 8.2° boattail) produced the lowest pitching moment and normal force, but the highest axial force.

Model 7(b), with the elliptical nose and shallow boattail angle ($6\text{-}1/2^\circ$), had the lowest axial forces and steady airflow throughout the range of the tests.

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif. 94035, May 29, 1967
124-11-04-09-00-21

REFERENCES

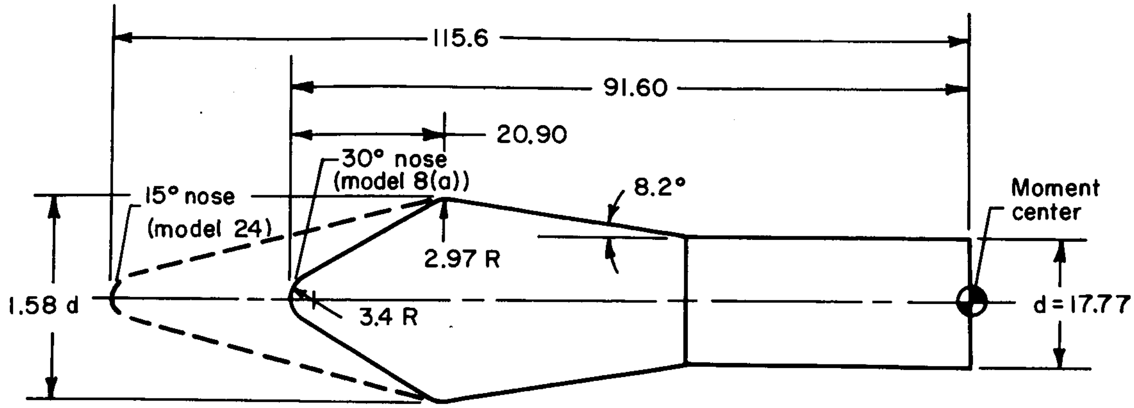
1. Robinson, Robert C.: A Wind-Tunnel Investigation of the Dynamic Stability of Axisymmetric Models With Hammerhead Noses in Transonic Flow. NASA TM X-787, 1963.

2. Coe, Charles F.: Steady and Fluctuating Pressures at Transonic Speeds on Two Space-Vehicle Payload Shapes. NASA TM X-503, 1961.

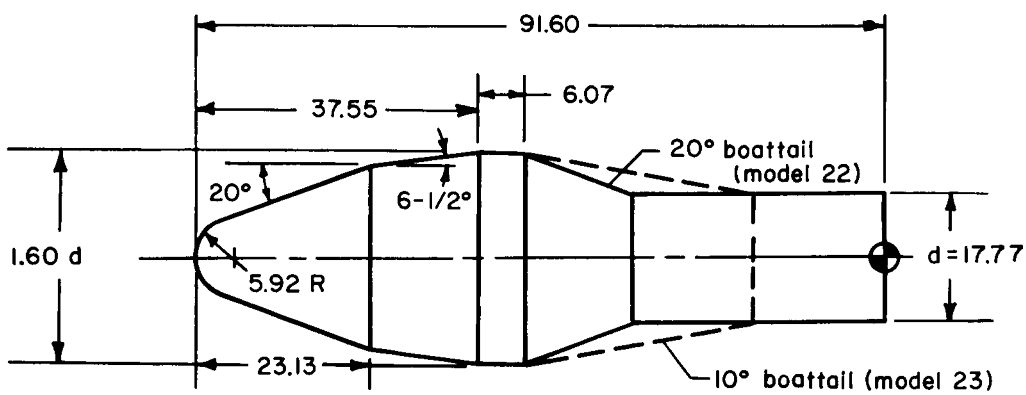
3. Coe, Charles F.; and Nute, James B.: Steady and Fluctuating Pressures at Transonic Speeds on Hammerhead Launch Vehicles. NASA TM X-778, 1962.

4. Cole, Henry A., Jr.: Dynamic Response of Hammerhead Launch Vehicles to Transonic Buffeting. NASA TN D-1982, 1963.

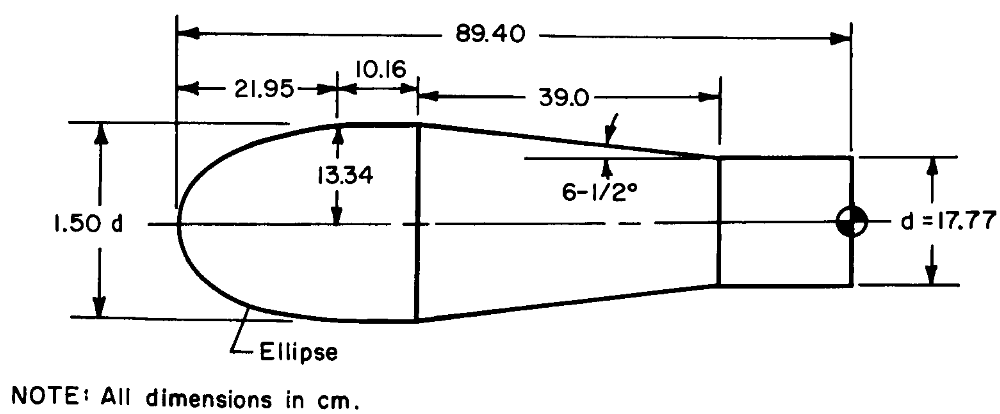
5. Reese, David E., Jr.; and Wehrend, William R., Jr.: An Investigation of the Static and Dynamic Aerodynamic Characteristics of a Series of Blunt-Nosed Cylinder-Flare Models at Mach Numbers From 0.65 to 2.20. NASA TM X-110, 1960.



(a) Models 8(a) and 24.



(b) Models 22 and 23.

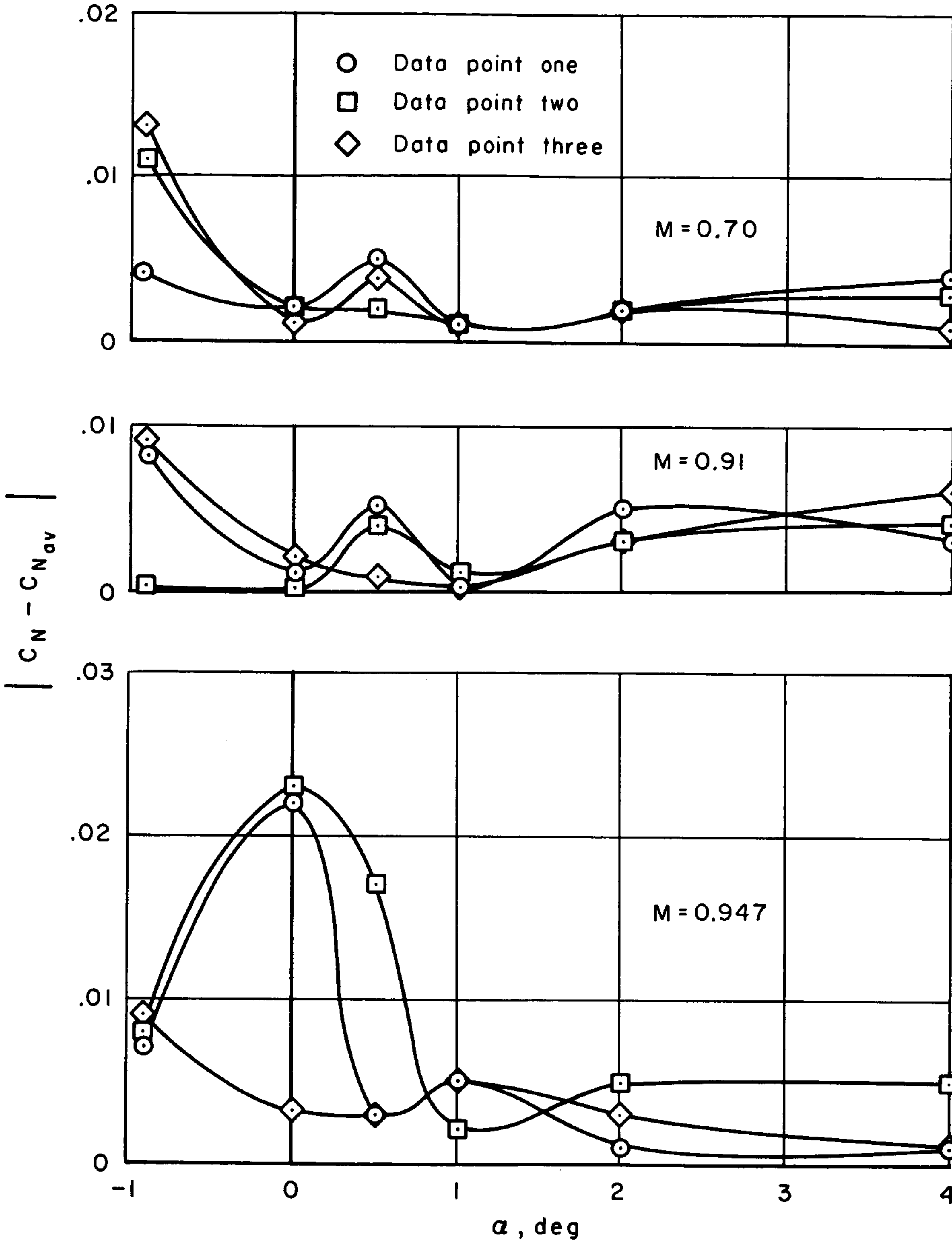


(c) Model 7(b).

Figure 1.- Sketches of models.

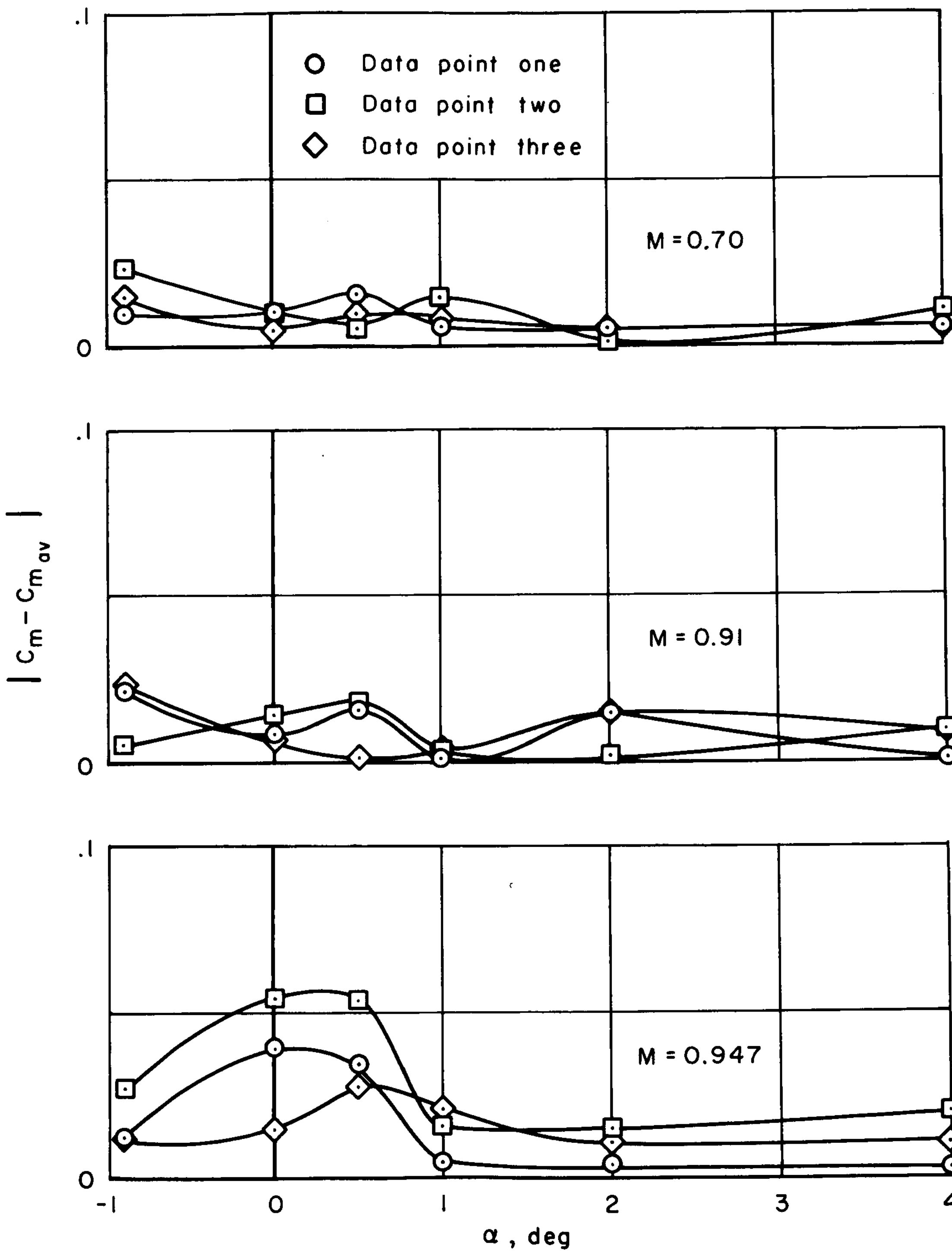
A-27766

Figure 2.- Model 7(b) installed in the wind tunnel.



(a) Normal force.

Figure 3.- Typical deviations of force measurements in steady and unsteady airflow for model 24.



(b) Pitching moment.

Figure 3.- Concluded.

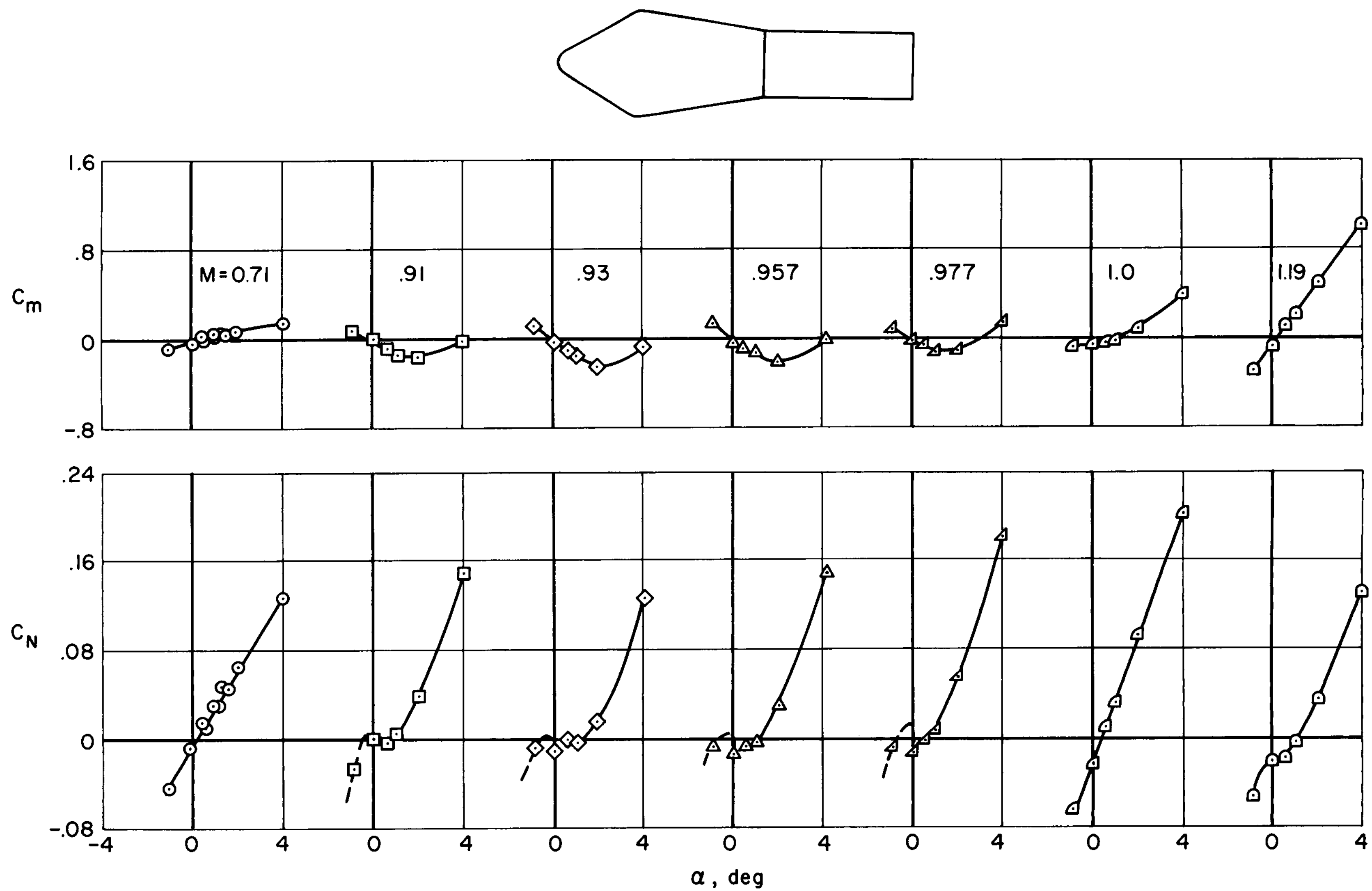


Figure 4.- Normal-force and pitching-moment coefficients for model 8(a).

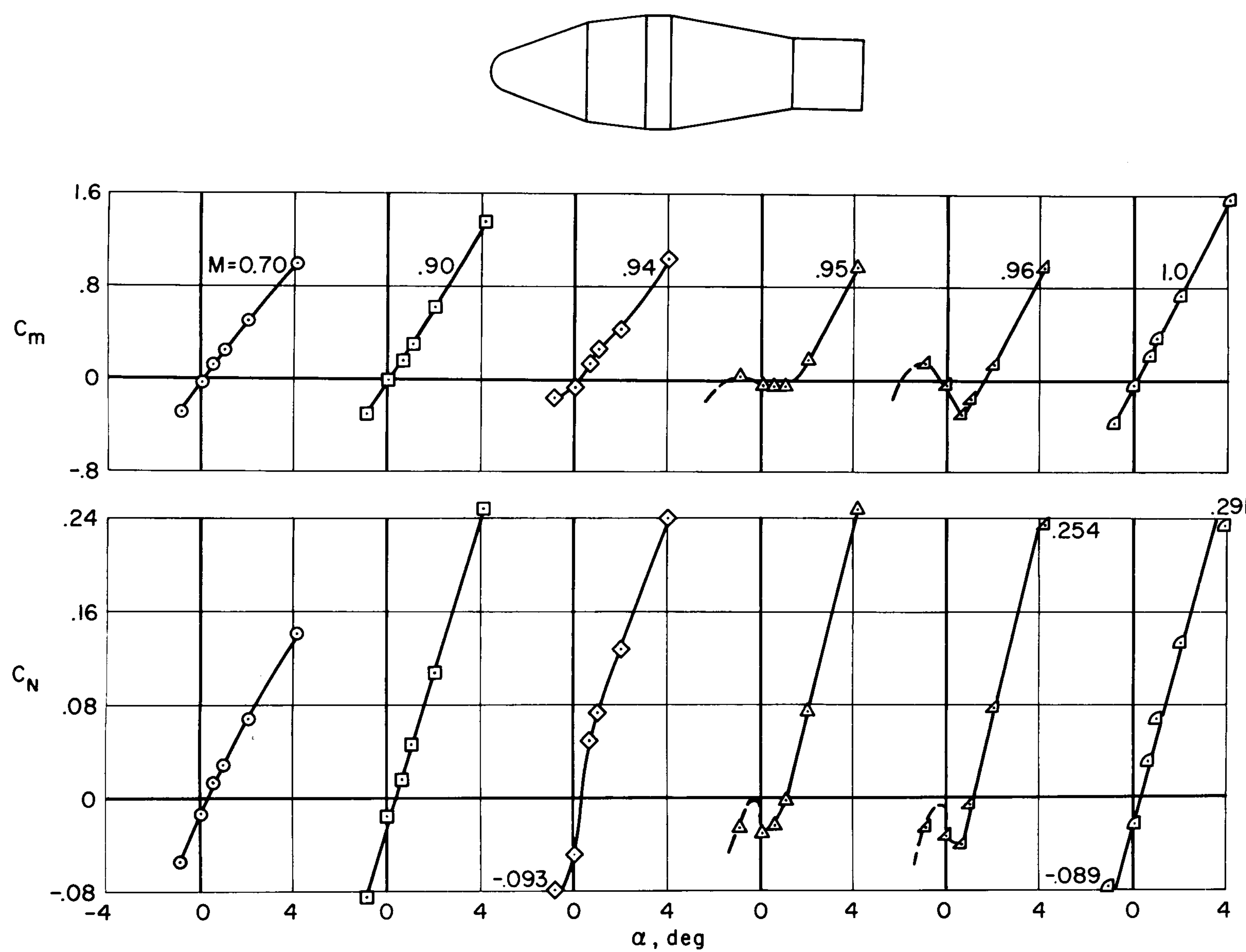


Figure 5.- Normal-force and pitching-moment coefficients for model 23.

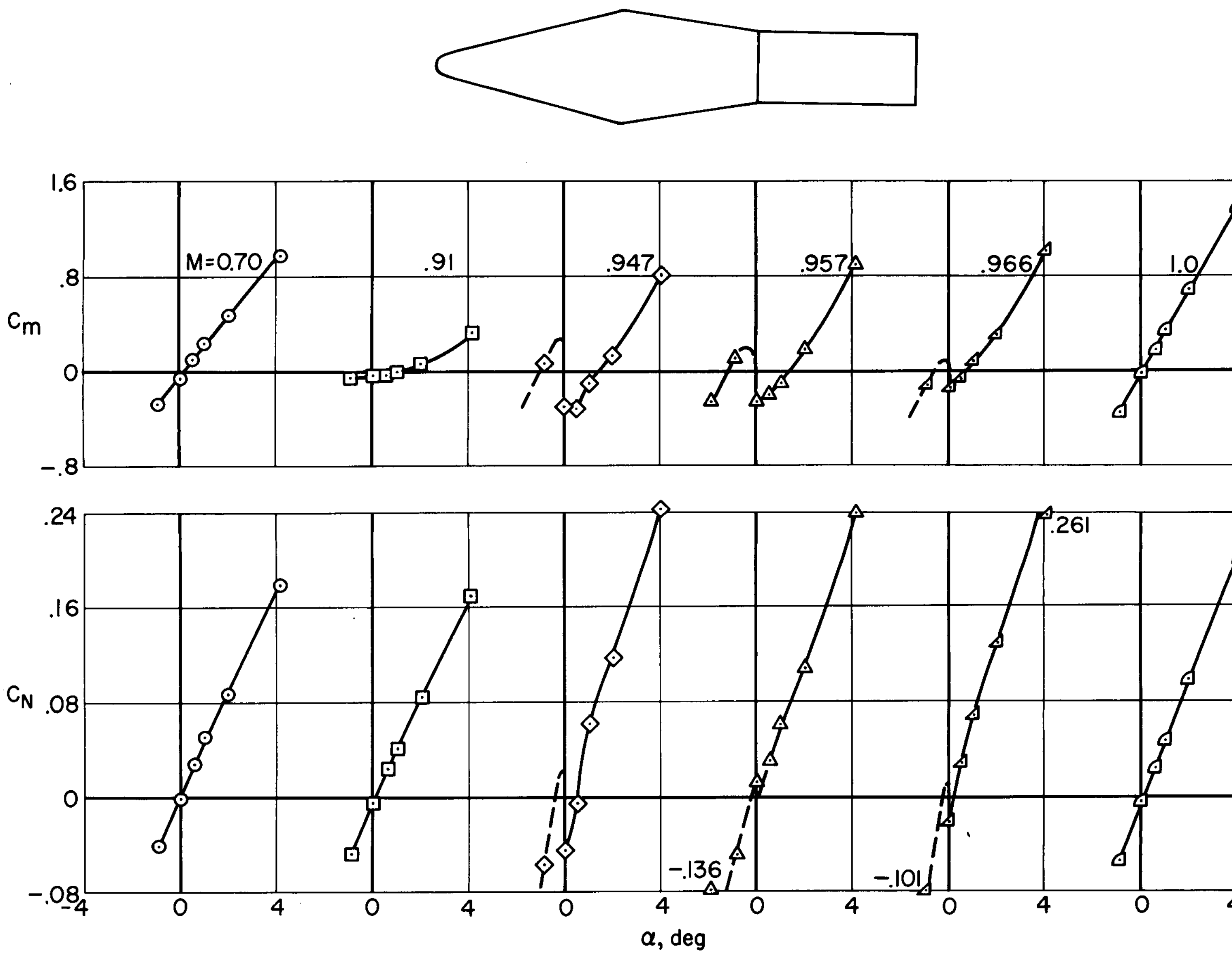


Figure 6.- Normal-force and pitching-moment coefficients for model 24.

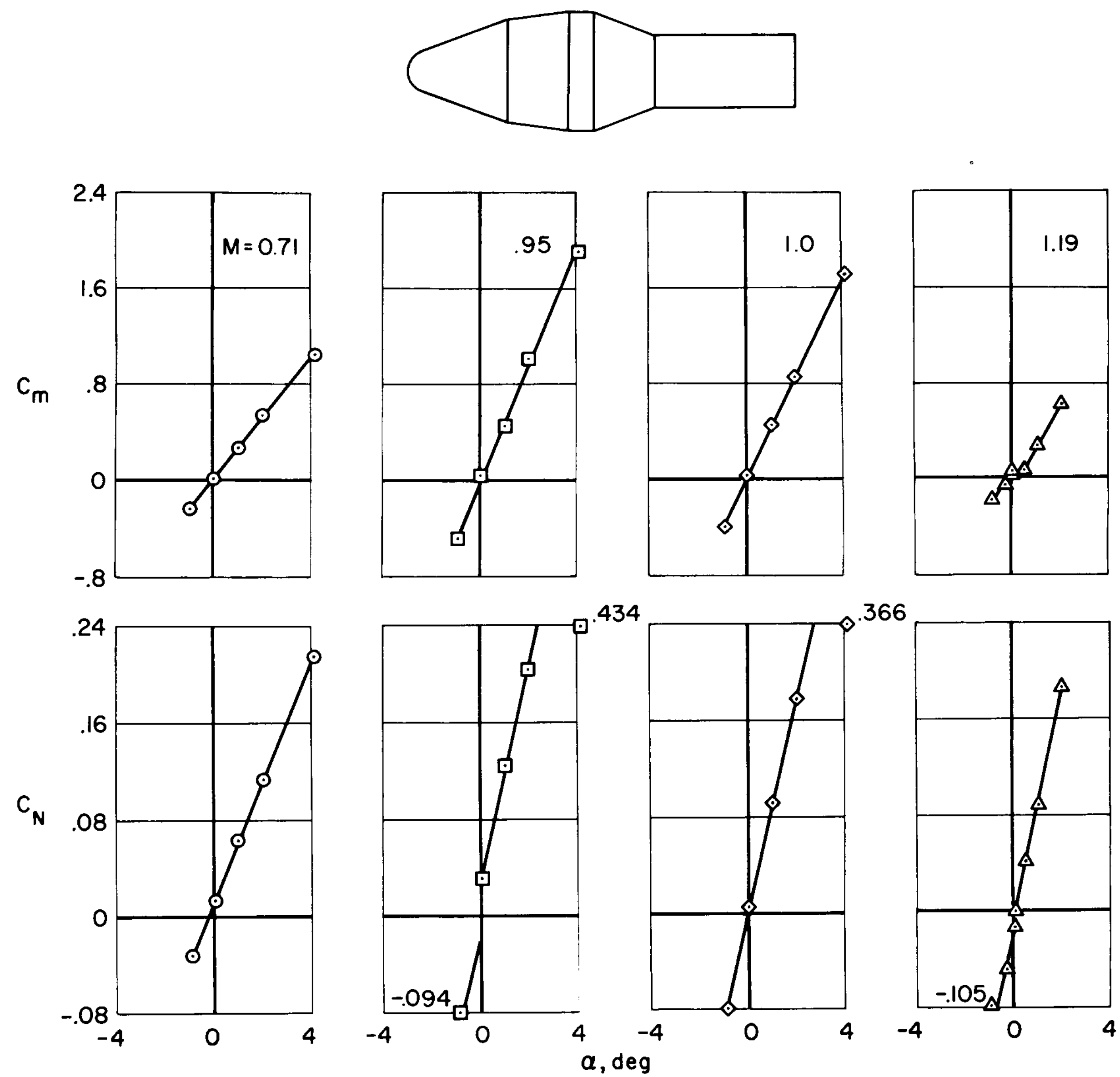


Figure 7.- Normal-force and pitching-moment coefficients for model 22.

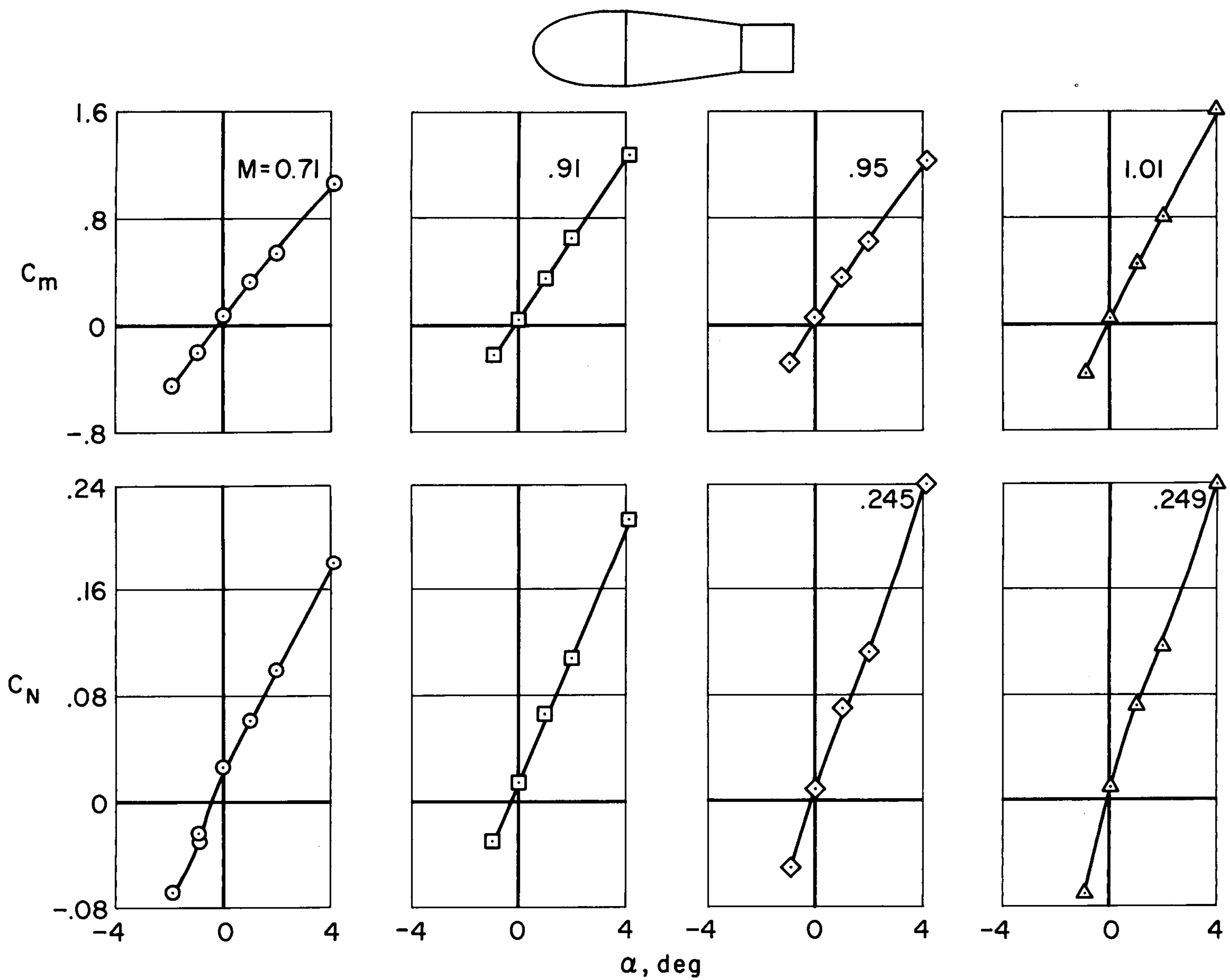


Figure 8.- Normal-force and pitching-moment coefficients for model 7(b).

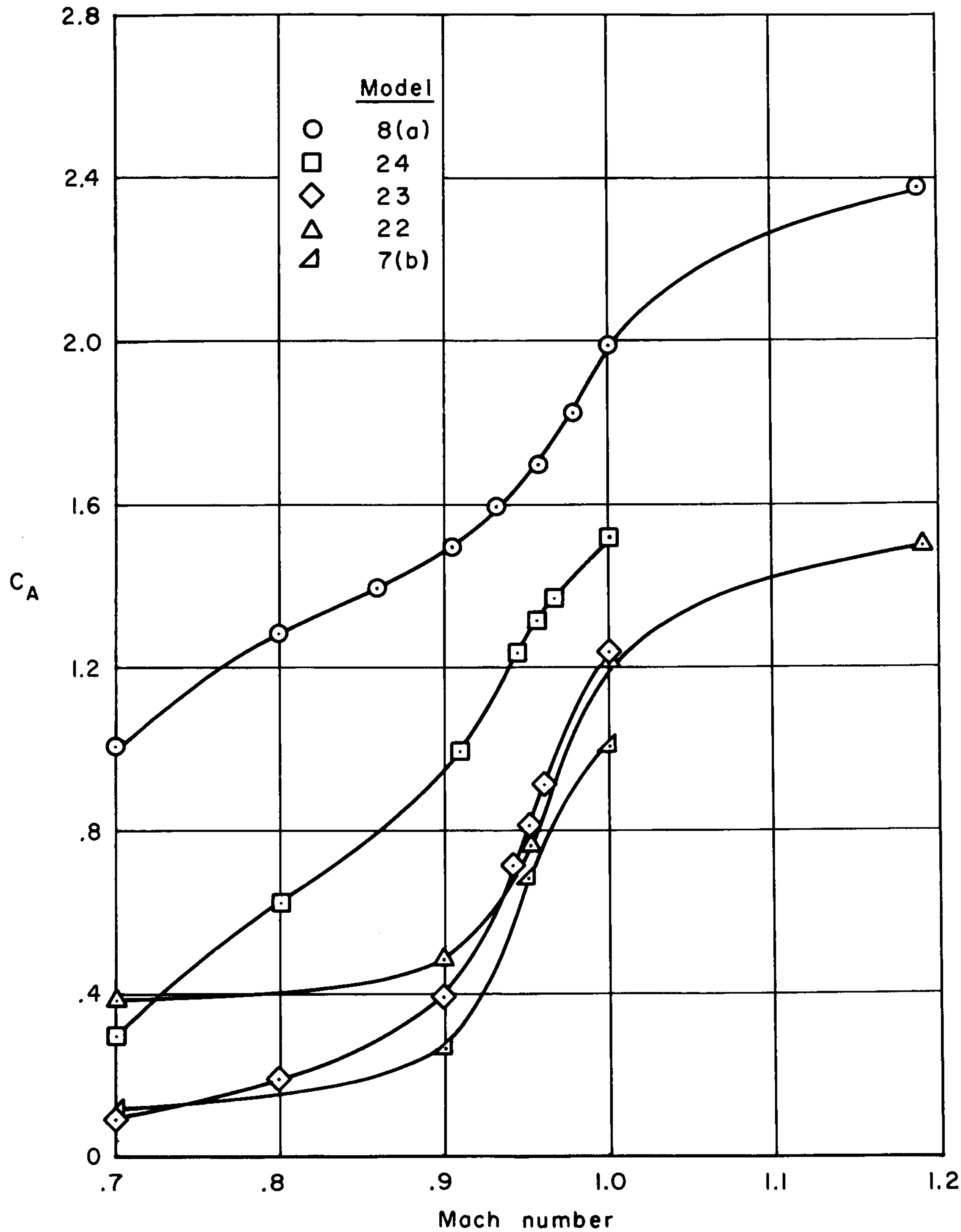


Figure 9.- Axial-force coefficients for the five models at $\alpha = 0^{\circ}$.

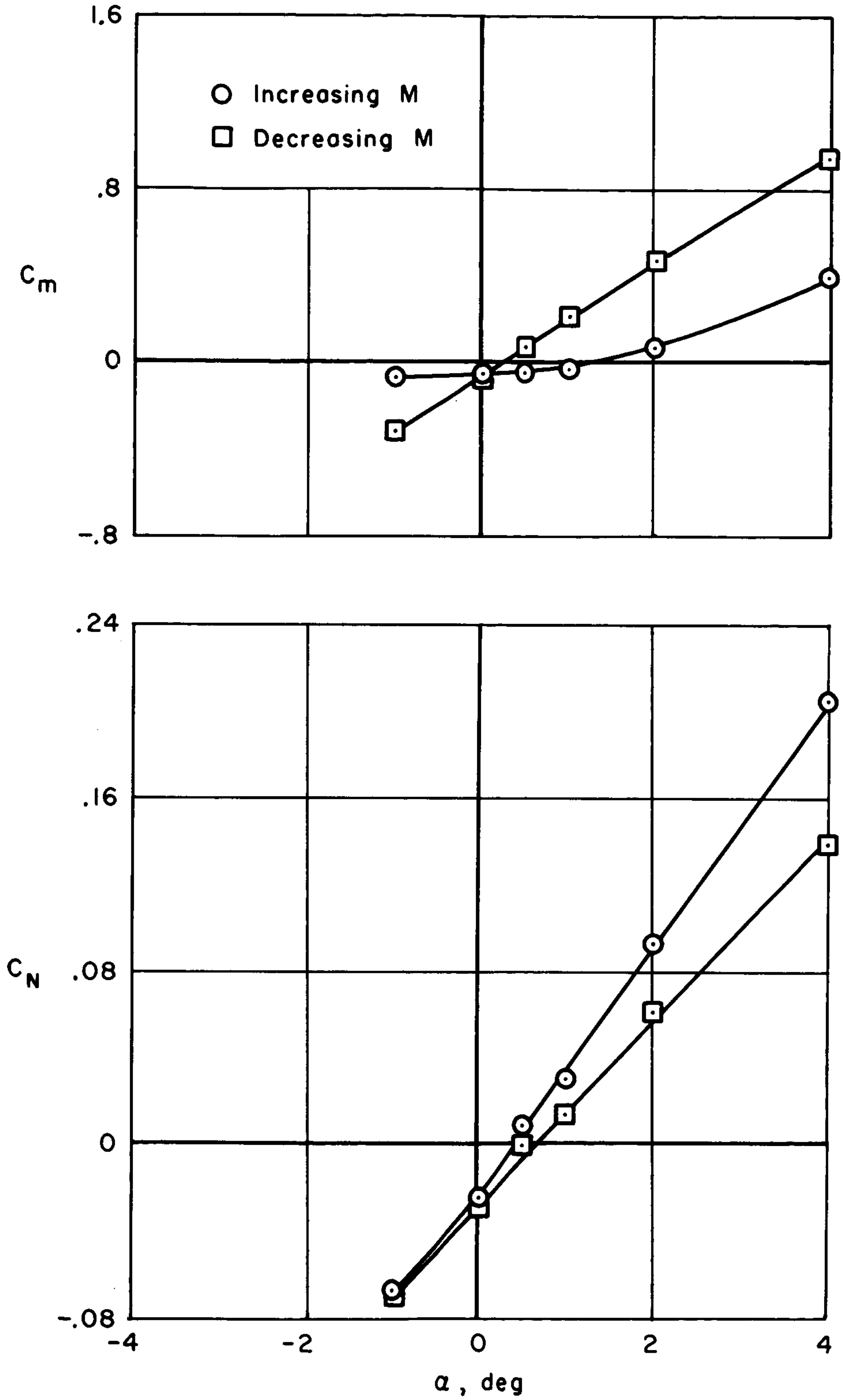


Figure 10.- The effect of increasing and decreasing Mach number on force measurements for model 8(a) at M = 1.00.

"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 Notes, and Technology Surveys.

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

SCIENTIFIC AND TECHNICAL INFORMATION DIVISION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546