NASA TECHNICAL NOTE

NASA TN D-3718

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SUBSONIC LONGITUDINAL AERODYNAMIC CHARACTERISTICS OF A 40° SEMIAPEX ANGLE CONICAL REENTRY CONFIGURATION

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • NOVEMBER 1966

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SUMMARY

A wind-tunnel investigation has been made to determine the subsonic longitudinal aerodynamic characteristics of a 40° semiapex angle conical reentry configuration having several nose-to-base radii bluntness ratios. The longitudinal center-of-pressure locations near zero angle of attack were aft of the base for all nose bluntness ratios over the subsonic Mach number range investigated. The only notable effect of increasing nose bluntness for a given Mach number was a slight rearward movement of the center-of-pressure location relative to that of the sharp apex configuration.

INTRODUCTION

Considerable aerodynamic research has been conducted by the National Aeronautics and Space Administration and others on low-fineness-ratio bodies of varying shapes and bluntness having applications as possible manned or unmanned reentry configurations. (See, for example, refs. 1 to 6.) Blunted conical shapes of very low fineness ratio (that is, 0.5 to 1.0) are particularly desirable as unmanned reentry vehicles since increases in cone angle and nose bluntness result in considerable reductions in total entry heating and the associated higher deceleration levels are acceptable for payload instrumentation.

The present investigation was made to provide the subsonic longitudinal aerodynamic characteristics for a 40° semiapex angle conical reentry configuration having nose-to-base radii bluntness ratios of 0, 0.2, and 0.4. The investigation was conducted in the Langley high-speed 7- by 10-foot tunnel at angles of attack from approximately -2° to 47° over a Mach number range from 0.200 to 0.583.

SYMBOLS

The data presented herein were computed about the body axis system and nondimensionalized with respect to the maximum cross-sectional area and maximum diameter of the cone. The moment reference point was located at the intersection of the axis of symmetry with the plane of maximum cross section.

C_A	axial-force coefficient, $\frac{\text{Axial force}}{qS}$
$C_{A,o}$	axial-force coefficient at $\alpha = 0^{o}$
C_m	pitching-moment coefficient, $\frac{\text{Pitching moment}}{qSd}$
C_{m_α}	longitudinal stability parameter, per degree
C_N	normal-force coefficient, $\frac{\text{Normal force}}{qS}$
C_{N_α}	normal-force-curve slope, per degree
d	base diameter, 0.4064 meter
l	cone length (measured from apex to station for maximum cross section), 0.2426 meter
M	Mach number
N_{Re}	Reynolds number, $\frac{\rho V l}{\mu}$
q	free-stream dynamic pressure, newtons/meter^2
r	nose radius, meters
R	base radius, 0.2032 meter
S	base area (cross sectional), 0.1297 meter^2
V	free-stream velocity, meters/second
$\frac{x_{cp}}{l}$	longitudinal center-of-pressure location expressed in body lengths from nose $(\alpha \approx 2^{o})$, $1 - \frac{C_{m_\alpha}}{C_{N_\alpha}}\left(\frac{d}{l}\right)$
α	angle of attack, degrees

ρ density of air, kilograms/meter^3

μ viscosity of air, $\frac{\text{kilograms}}{\text{meter-second}}$

MODEL

The wind-tunnel model of the present investigation was a right circular cone having a semiapex angle of 40° and a sharp-edged slightly convex base. Model drawings and a photograph are included in figures 1 and 2, respectively.

The base cap of the model was formed by a spherical segment having a radius of 0.9144 meter. Nose-to-base radii bluntness ratios (referred to cross-section radius at base) of 0, 0.2, and 0.4 were made possible by the use of replaceable nose caps.

TESTS AND CORRECTIONS

The present investigation was conducted in the Langley high-speed 7- by 10-foot tunnel at Mach numbers from 0.200 to 0.583. Average test Reynolds numbers are shown as a function of Mach number in figure 3. The model was tested at angles of attack from approximately -2° to 47° and utilized a sting-mounted, six-component strain-gage balance to provide force and moment measurements. A differential pressure transducer was used to measure pressure differences between the central region of the spherical base cap and the sting cavity.

Jet boundary and blockage corrections have been applied to the data (where applicable) in accordance with the methods outlined in references 7 and 8, respectively. The angle-of-attack data have also been corrected to account for sting and balance deflection under load. No corrections to the axial-force data were made to account for pressure differences across the region of the spherical base cap containing the sting cavity since pressure measurements indicated only insignificant corrections. Total axial-force data (including base drag) are presented herein since the model represents an unpowered reentry configuration. No attempt was made to fix transition during the wind-tunnel investigation.

RESULTS

The longitudinal aerodynamic characteristics for the 40° semiapex angle conical reentry configuration are presented in figure 4 for the various nose bluntness ratios over the Mach number range investigated.

The positive values of C_m noted at $\alpha = 0$ are equivalent to a 0.0203-meter vertical displacement of the axial-force vector relative to the balance moment reference point. This discrepancy is attributed to possible errors in model-balance construction and/or wind-tunnel installation. The discrepancies noted in C_A and C_m at $\alpha \approx 24^o$ are indicative of sting support interference on model base pressures for the sting knuckle setting visible in figure 2. This knuckle setting was required to obtain aerodynamic data at the high angles of attack (24^o to 47^o) of the investigation. Variations of the aerodynamic parameters x_{cp}/l, C_{N_α}, and $C_{A,o}$ are shown in figure 5 as a function of Mach number.

The most forward center-of-pressure location ($\alpha \approx 2^o$) for the 40^o semiapex angle cone was found to occur at $0.13l$ aft of the maximum cross section for the sharp apex configuration ($r/R = 0$) at a Mach number of 0.583. (See fig. 5.) Center-of-pressure locations aft of the configuration base are desirable for unmanned reentry configurations in that they allow uncomplicated longitudinal payload balancing to achieve acceptable static longitudinal stability levels in nose-forward flight attitudes.

Increasing the nose-to-base radii bluntness ratio from the sharp apex conditions to a value of 0.4 produced slight rearward movements in center of pressure throughout the Mach number range investigated with no appreciable effect on C_{N_α} and $C_{A,o}$. Increasing test Mach numbers from 0.200 to 0.583 produced increases in C_{N_α} and $C_{A,o}$ and a slight forward movement of the center of pressure.

CONCLUSIONS

An investigation has been made in the Langley high-speed 7- by 10-foot tunnel to determine the subsonic longitudinal aerodynamic characteristics of a 40^o semiapex angle conical reentry configuration having several nose-to-base radii bluntness ratios. Investigation results may be summarized by the following observations:

1. The longitudinal center-of-pressure locations near zero angle of attack were aft of the base for all nose bluntness ratios over the subsonic Mach number range investigated.

2. The only notable effect of increasing nose bluntness for a given Mach number was a slight rearward movement of the center-of-pressure location relative to that of the sharp apex configuration.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., August 25, 1966,
124-07-03-05-23.

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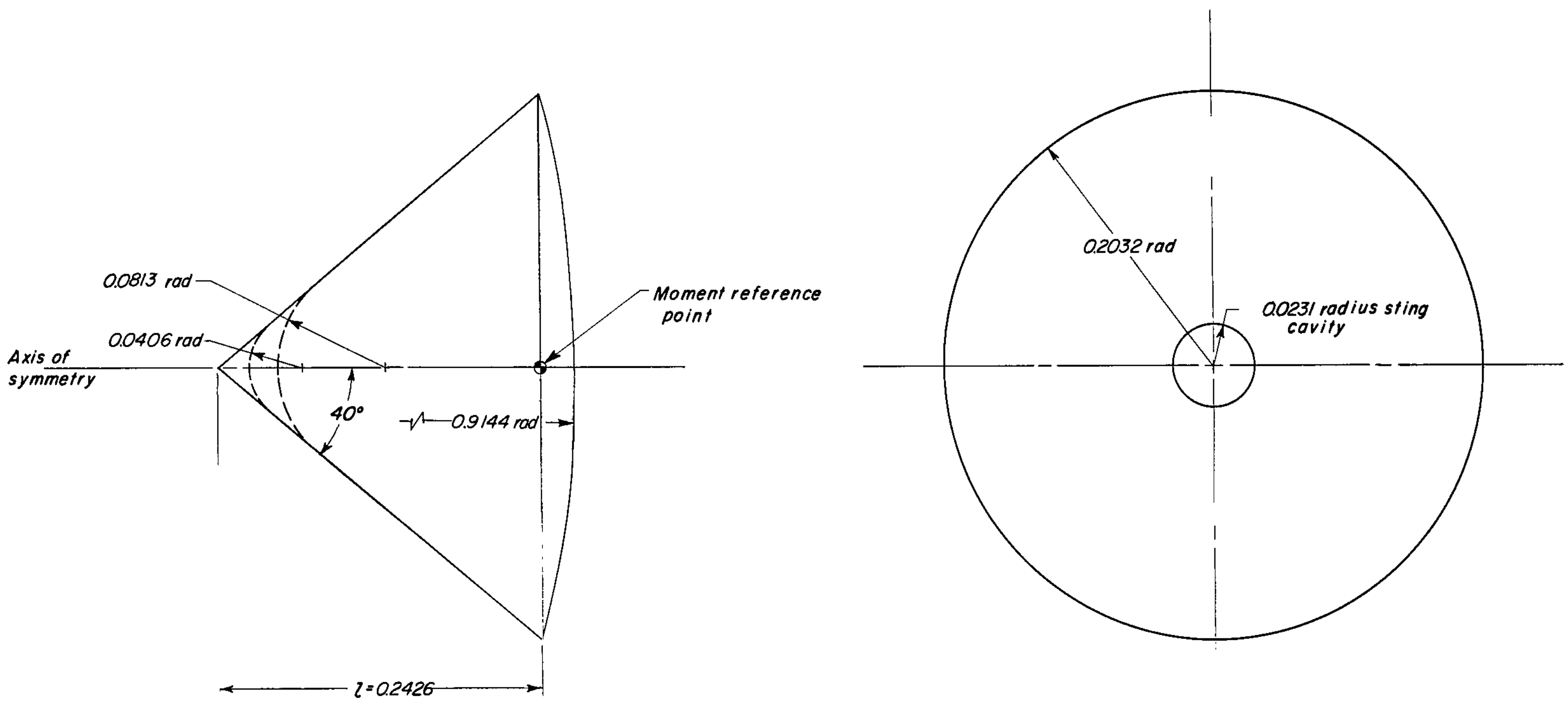

Figure 1.- Geometric characteristics of model tested. All dimensions are in meters unless otherwise specified.

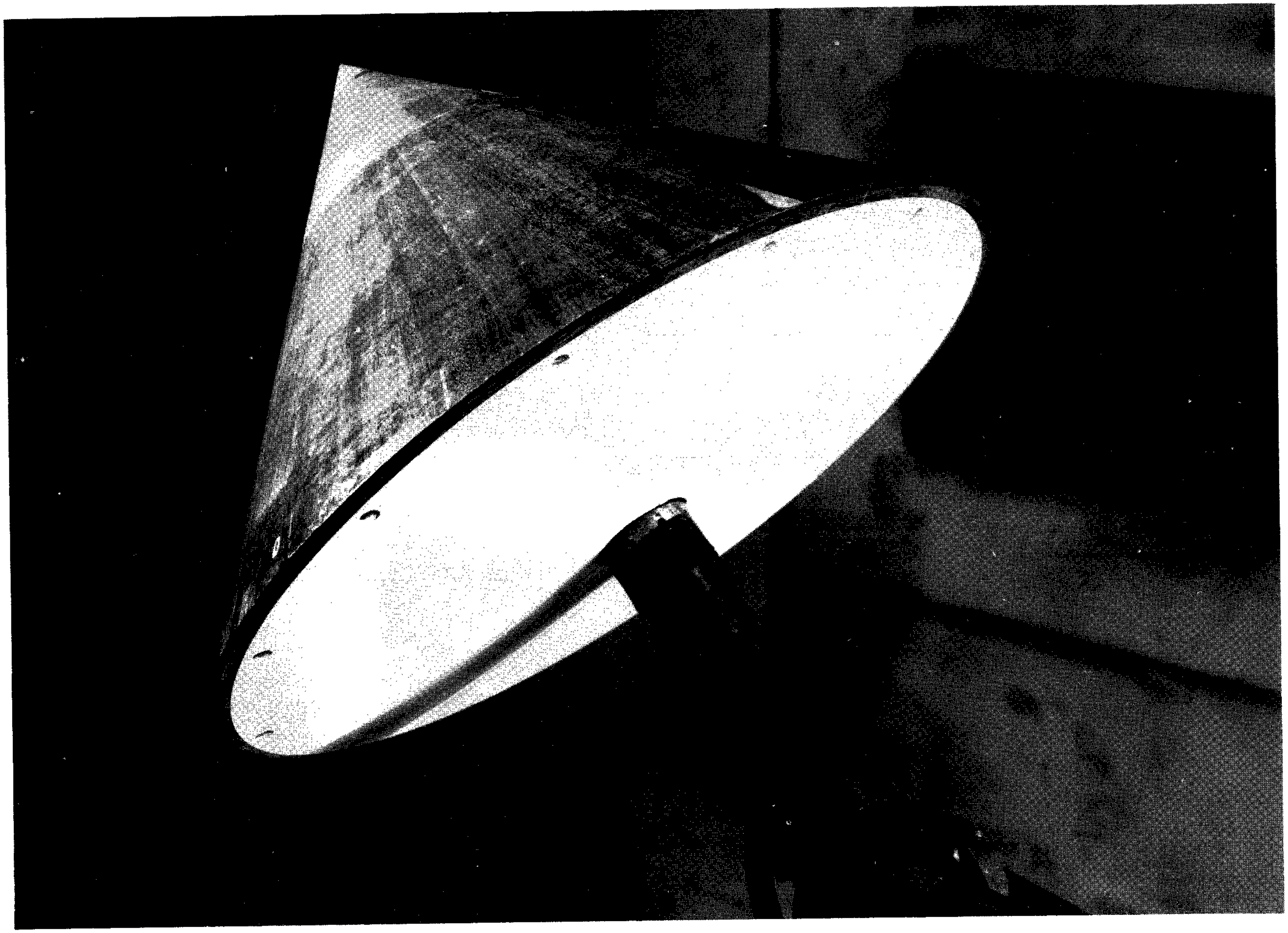

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Figure 2.- Three-quarter side view of 80^{0} cone model having $r/R = 0$.

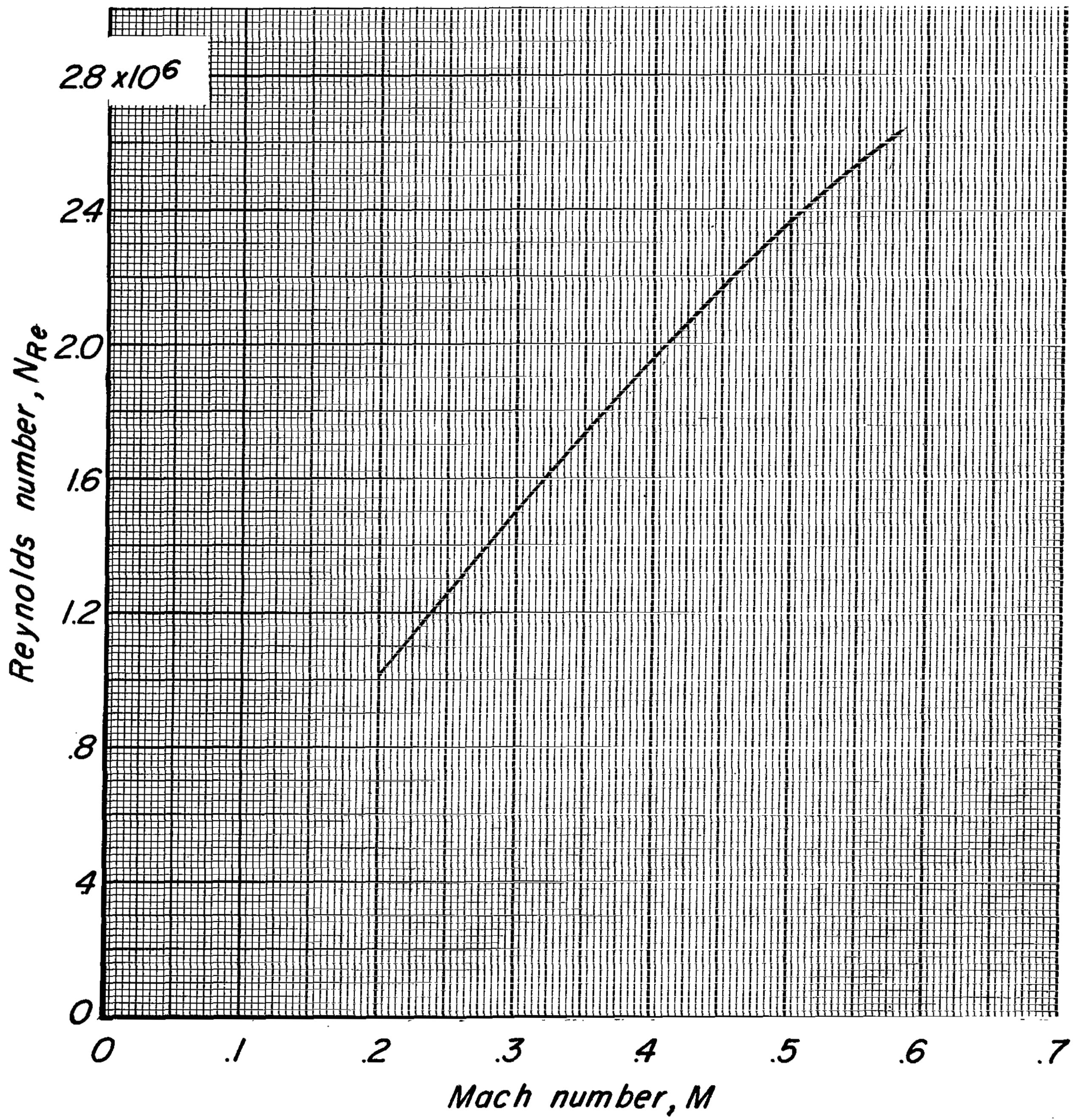
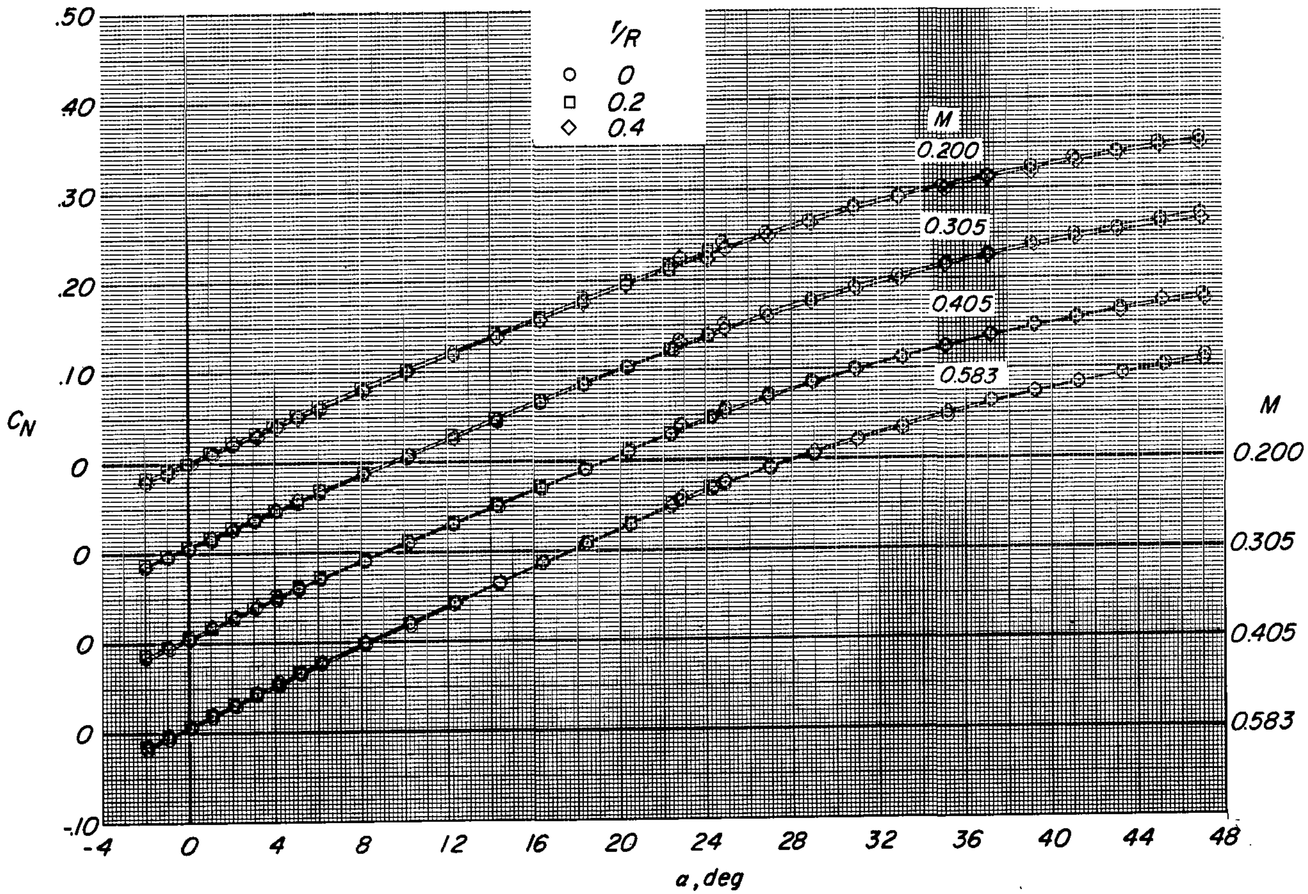
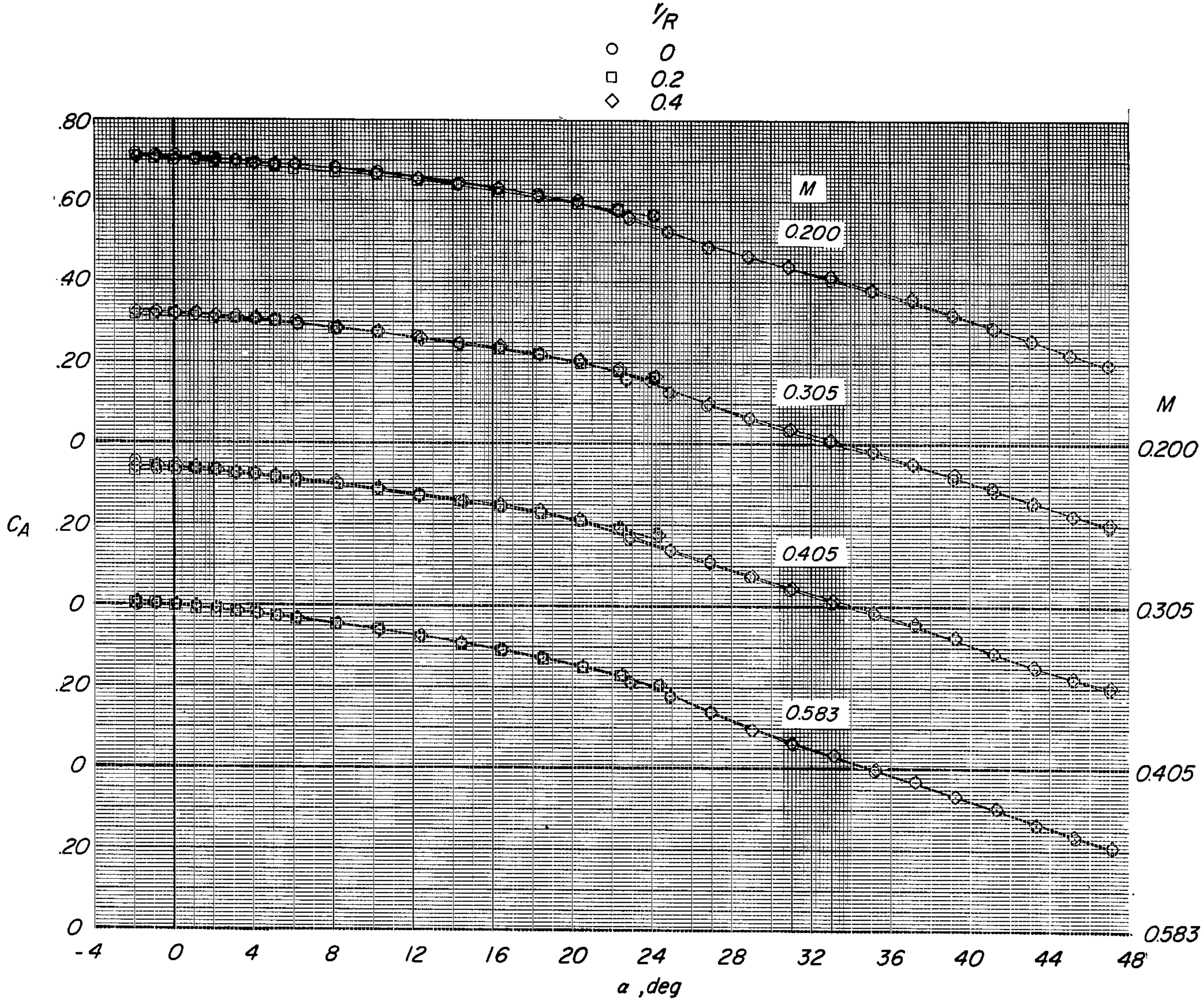


Figure 3.- Variation of average test Reynolds number (based on model length) with Mach number.



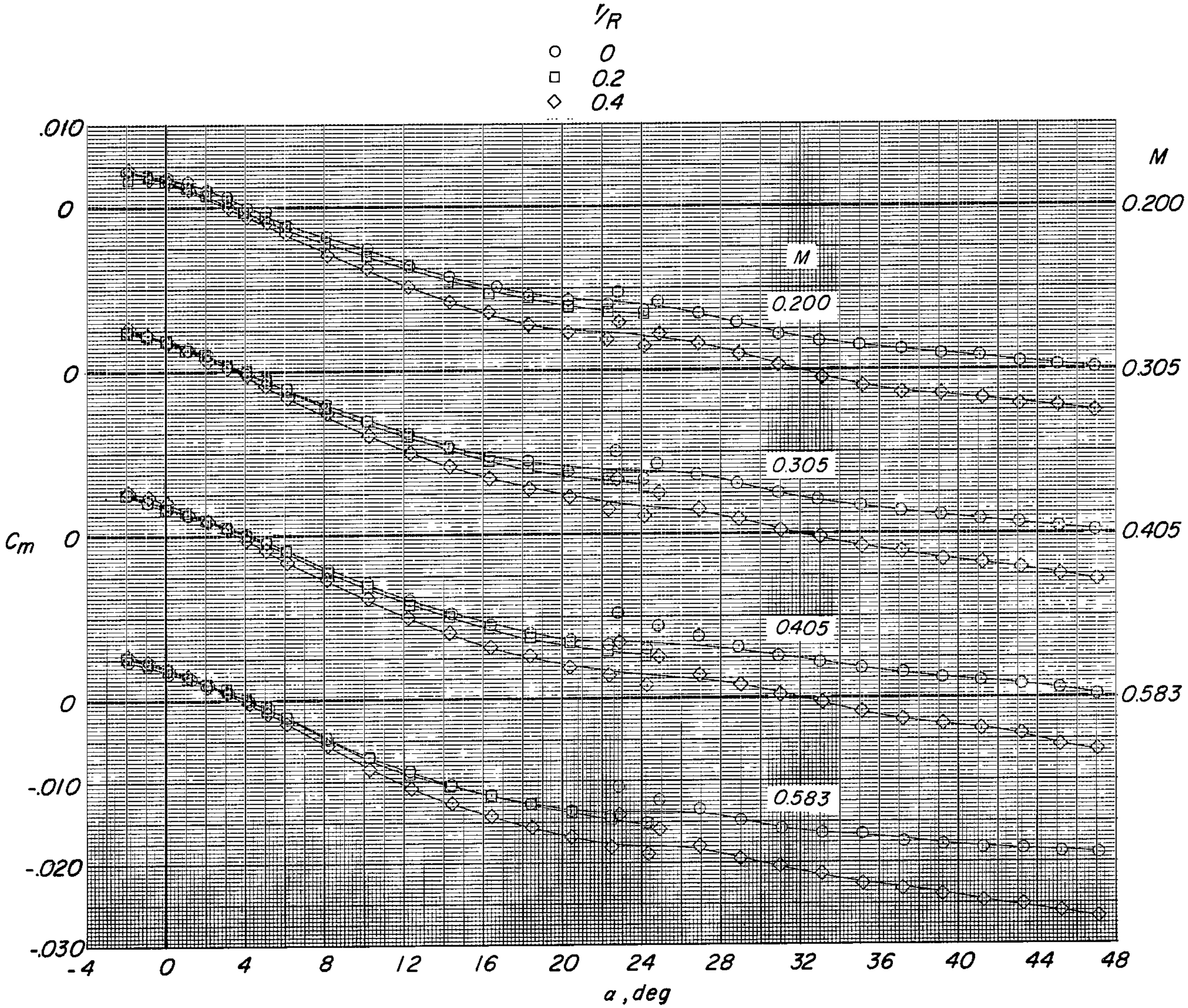
(a) Variation of C_N with α.

Figure 4.- Effect of nose-to-base radii bluntness ratio on the longitudinal aerodynamic characteristics for the configuration.



(b) Variation of C_A with α.

Figure 4.- Continued.



(c) Variation of C_m with α.

Figure 4.- Concluded.

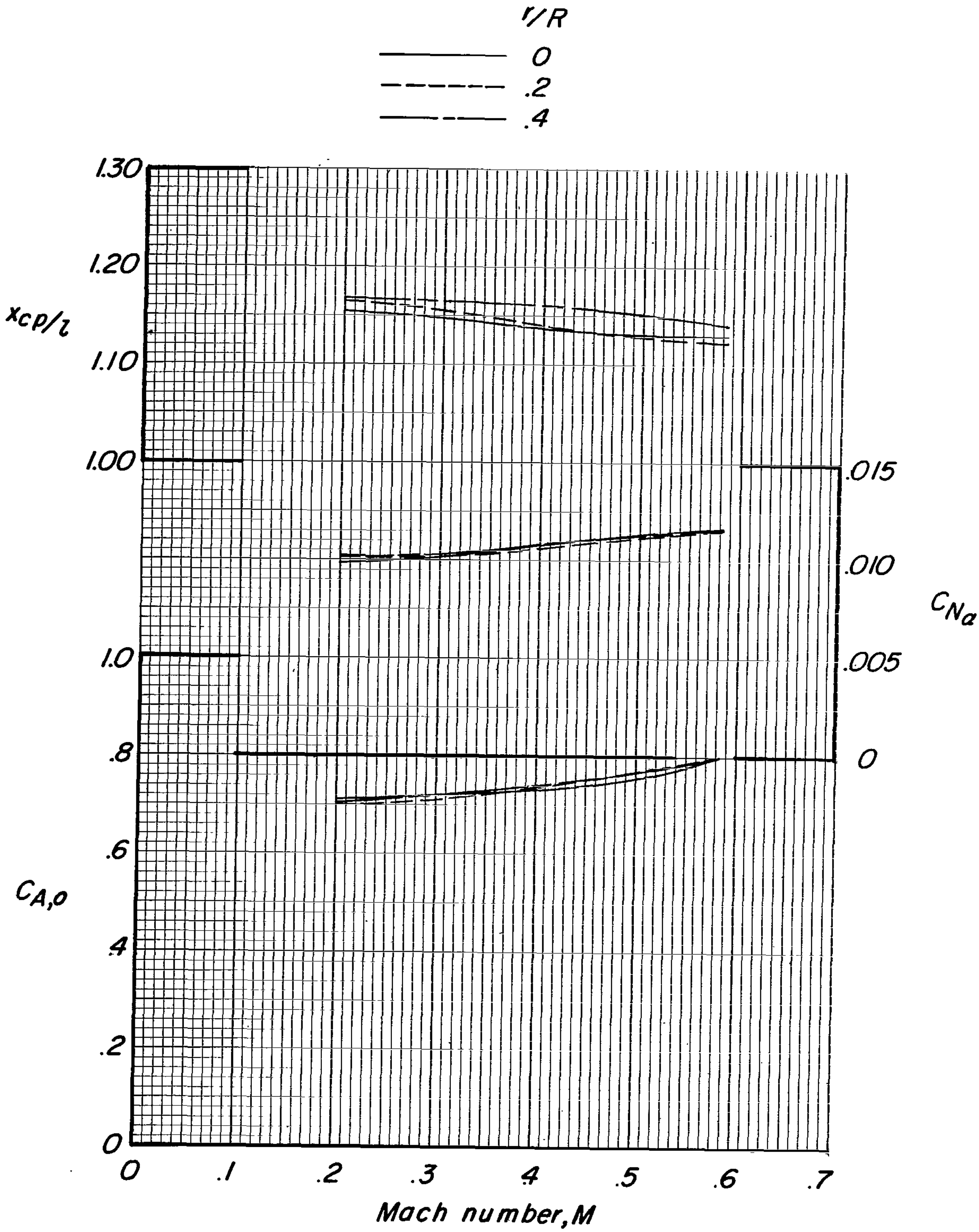


Figure 5.- Summary of aerodynamic parameters x_{cp}/l, C_{N_α}, and $C_{A,o}$ for various nose bluntness ratios and Mach numbers.

NASA-Langley, 1966 L-5160

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