NASA TECHNICAL NOTE

NASA TN D-4034

EFFECTS OF TWO PROBE ANTENNAS ON AERODYNAMIC CHARACTERISTICS OF APOLLO SPACECRAFT AT MACH 10.03

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

An investigation has been made in the Langley 15-inch hypersonic flow apparatus at a Mach number of 10.03 to determine the effects of two interchangeable probe antennas on the aerodynamic characteristics of a model of the Apollo reentry vehicle. Tests were made at a Reynolds number, based on model maximum diameter, of 0.37×10^6 at angles of attack from about -1.8° to 30.2° at a sideslip angle of 0°. In addition, tests were made at angles of sideslip from -4° to 4° at an angle of attack of approximately 18.7°.

The results of the investigation indicated that the only significant effect of adding either probe antenna to the basic configuration was a reduction in pitching-moment coefficient and a corresponding decrease in trim angle of attack. Trim angle of attack decreased by about 1.2° and 1.7° as a result of adding the standoff probe antenna and the close-in probe antenna, respectively, to the basic vehicle.

INTRODUCTION

Almost everyone is familiar with the so-called communications blackout during the reentry of space vehicles into the earth's atmosphere. Ideally, one would like to be able to communicate with the vehicle throughout reentry. Many researchers (for example, see ref. 1) have indicated that this phenomenon, which is associated with the plasma sheath about the vehicle, can be reduced or circumvented by the injection of foreign material such as water into the plasma sheath, thereby reducing the free-electron concentration in the plasma. One method suggested by the National Aeronautics and Space Administration to improve the communications with the Apollo reentry vehicle during the blackout period is the injection of water through a probe antenna that extends through the bow shock of the vehicle.

In order to determine the effects of such a probe antenna on the aerodynamic characteristics of the Apollo vehicle, an experimental program has been initiated. The present paper reports the results of an investigation to determine the effects of two different

probe antenna configurations on the aerodynamic characteristics of the Apollo reentry vehicle at a Mach number of 10.03. The investigation was made in the Langley 15-inch hypersonic flow apparatus at a Reynolds number, based on model maximum diameter, of 0.37×10^6 and at angles of attack from about -1.8^O to 30.2^O at a sideslip angle of 0°. Also, all configurations were tested through an angle-of-sideslip range from -4° to 4° at an angle of attack of approximately 18.7^O.

SYMBOLS

All the force and moment coefficients are referred to the body-axis system with the exception of the lift and drag coefficients, which are referred to the stability-axis system. The origin of these axis systems is located 0.2552D aft of the heat shield and 0.0390D below the model center line.

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

C_D drag coefficient

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

C_L lift coefficient

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

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

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

C_p local pressure coefficient

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

D maximum model diameter, 7.620 centimeters

q free-stream dynamic pressure, newton/meter^2

S reference area, $\dfrac{\pi D^2}{4}$, 45.604 centimeters^2

α angle of attack, degrees

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β angle of sideslip, degrees

η angle between local normal to surface and free-stream velocity vector, degrees.

MODELS

Drawings of the models are shown as figure 1 and photographs of the model configurations are presented as figure 2. The basic configuration was a 0.019481-scale model of the Apollo reentry module. Provisions were made for the two different probe antennas to be mounted interchangeably on the lower surface of the basic model; these probe antennas were mounted in such a manner that the plane of symmetry of the model with probe antenna was the angle-of-attack plane. The design of the standoff probe antenna (fig. 1(b)) was based on the requirement to minimize interference heating and the requirement that the probe be attached to the spacecraft in such a manner that it would not interfere structurally with the heat shield. The design of the close-in probe antenna (fig. 1(c)) was based on probe structural considerations and also the requirement to minimize interference heating. In order to test over the desired angle-of-attack range, the model was installed on the balance and support strut at an angle of 19° from the model center line in the angle-of-attack plane. (See fig. 2.)

APPARATUS AND TESTS

The investigation was made in the Langley 15-inch hypersonic flow apparatus. This facility is a blowdown tunnel which operates at a Mach number of 10.03, stagnation pressures up to 10 342 kN/m^2, and stagnation temperatures up to 1089° K. A brief description of this facility and typical Mach number distributions are given in reference 2. Forces and moments were measured with a sting-supported, internally mounted, six-component strain-gage balance.

The tests were made at a tunnel stagnation pressure of approximately 5702 kN/m^2 and at a stagnation temperature of approximately 870° K. The stagnation temperature used in these tests is below the theoretical temperature required to prevent liquefaction of the air during the expansion in the tunnel; however, an investigation reported in the appendix of reference 3 showed that no effective condensation would exist at the present test conditions. The test stagnation pressure and stagnation temperature correspond to a Reynolds number, based on the maximum diameter of the model, of 0.37×10^6. The basic Apollo model and the model with the close-in probe antenna were tested through an angle-of-attack range from about -1.8^O to 30.2^O at a sideslip angle of 0°. The model with the standoff probe antenna was tested only through an angle-of-attack range from

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about 14.8° to 30.0° at a sideslip angle of 0°. All configurations were tested through an angle-of-sideslip range from about -4° to 4° at an angle of attack of approximately 18.7°.

ACCURACY AND CORRECTIONS

The accuracies of the force and moment coefficients (based on balance accuracy), the angle of attack, and the angle of sideslip are within the following limits:

C_N . . . . ±0.01
C_A . . . . ±0.02
C_m . . . . ±0.003
C_l . . . . ±0.003
C_n . . . . ±0.003
C_Y . . . . ±0.004
C_L . . . . ±0.01
C_D . . . . ±0.02
α, deg . . . . ±0.1
β, deg . . . . ±0.1

Angle of attack and angle of sideslip have been corrected for sting and balance deflections due to aerodynamic loads.

RESULTS AND DISCUSSION

The effects of the standoff probe antenna and the close-in probe antenna on the longitudinal aerodynamic characteristics of the Apollo model can be seen in figures 3 and 4, respectively. The effects of the two probe antennas on the shock pattern about the Apollo model can be seen by comparing the schlieren photographs presented as figure 5. As can be seen in figures 3 and 4, the addition of either of the probe antennas had a significant effect only on the pitching-moment characteristics of the Apollo model. The addition of either probe antenna caused a reduction in pitching-moment coefficient at a given angle of attack. As a result of this reduction in C_m, the trim angle of attack of the basic model with the assumed moment reference center was reduced from about 21° to 19.8° by the addition of the standoff probe antenna, and from about 21° to 19.3° by the addition of the close-in probe antenna. Reference 4 indicates that the sting support can have considerable effect on the pitching-moment characteristics of Apollo models. Therefore, the aforementioned values of trim angle of attack could possibly be affected by the sting-support interference. However, the differences in trim angle should be valid in any case. The close-in probe antenna also causes a small decrease in the longitudinal stability of the model; however, the standoff probe antenna had essentially no effect on stability.

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Also shown in figure 3 are the modified Newtonian estimates $\left(C_p = 1.825 \cos^2\eta\right)$ of the longitudinal aerodynamic characteristics of the basic Apollo model. The modified Newtonian theory is in fair agreement with the experimental data.

The effects of the probe antennas on the lateral and directional aerodynamic characteristics of the model at an angle of attack of approximately 18.7° are shown in figure 6. Schlieren photographs showing the effects of the probe antennas on the shock pattern about the model at various angles of sideslip are presented as figure 7. The addition of the standoff probe antenna to the basic model had essentially no effect on the directional and lateral characteristics of the Apollo vehicle. The addition of the close-in probe antenna, however, did cause a small increase in directional stability, but did not affect the other lateral and directional characteristics.

CONCLUSIONS

An investigation has been made in the Langley 15-inch hypersonic flow apparatus at a Mach number of 10.03 to determine the effects of two interchangeable probe antennas on the aerodynamic characteristics of a model of the Apollo reentry vehicle. Tests were made at a Reynolds number, based on model maximum diameter, of 0.37×10^6 at angles of attack from about -1.8° to 30.2°. In addition some tests were made at angles of sideslip from -4° to 4°.

The results of the investigation indicated that the only significant effect of adding either probe antenna to the basic configuration was a reduction in pitching-moment coefficient, which resulted in a corresponding decrease in trim angle of attack. Trim angle of attack decreased by about 1.2° and 1.7° as a result of adding the standoff probe antenna and the close-in probe antenna, respectively.

Langley Research Center,
    National Aeronautics and Space Administration,
        Langley Station, Hampton, Va., March 17, 1967,
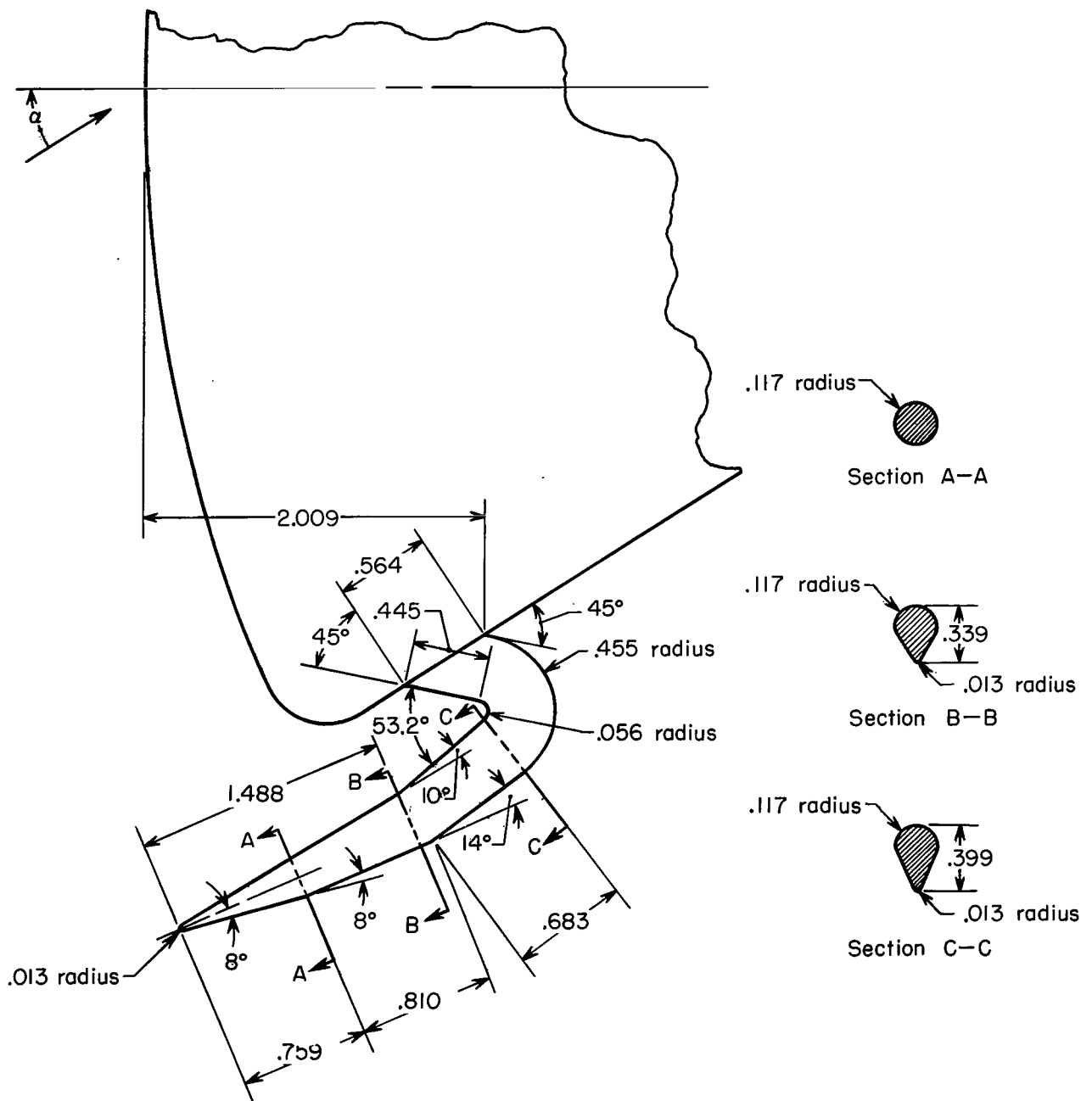   125-21-02-09-23.

REFERENCES

1. Huber, Paul W.; and Sims, Theo E.: The Entry-Communications Problem. Astronaut. Aeron., vol. 2, no. 10, Oct. 1964, pp. 30-40.

2. Putnam, Lawrence E.; and Brooks, Cuyler W., Jr.: Static Longitudinal Aerodynamic Characteristics at a Mach Number of 10.03 of Low-Aspect-Ratio Wing-Body Configurations Suitable for Reentry. NASA TM X-733, 1962.

3. Putnam, Lawrence E.: Investigation of Effects of Ramp Span and Deflection Angle on Laminar Boundary-Layer Separation at Mach 10.03. NASA TN D-2833, 1965.

4. Stivers, Louis S., Jr.: Effects of a Sting Support on the Supersonic Force and Moment Characteristics of an Apollo Model at Angles From -30° to +185°. NASA TM X-1081, 1965.
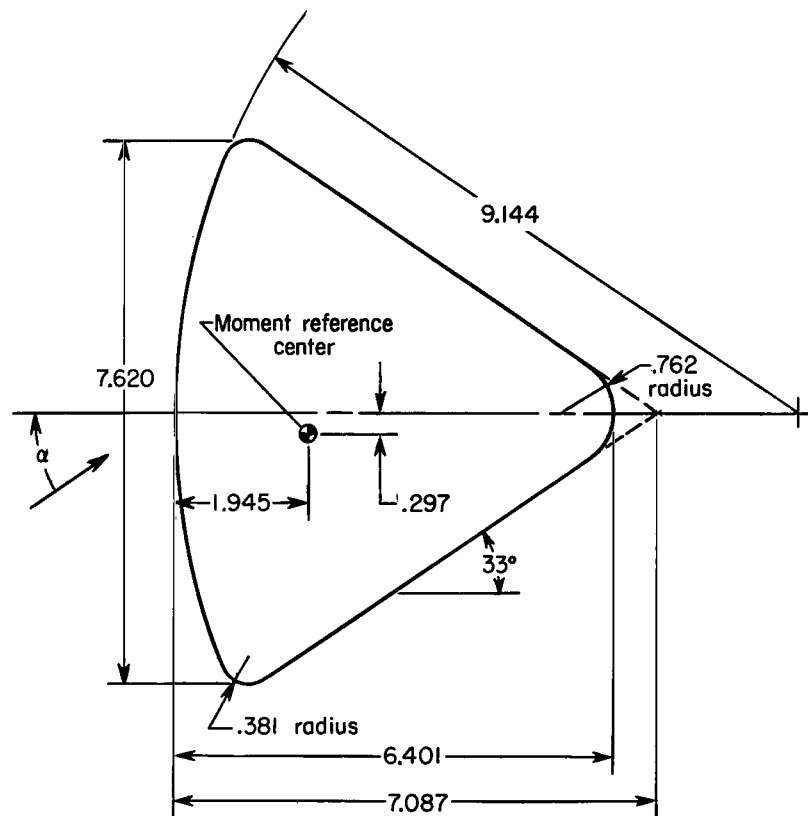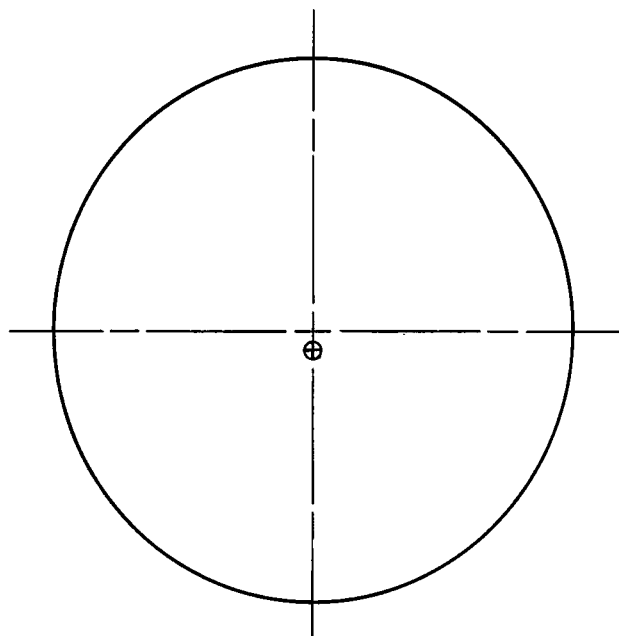
(a) Basic Apollo model.

Figure 1.- Drawings of models. (All dimensions are in centimeters unless otherwise noted.)

.117 radius

Section A–A

.117 radius
.339
.013 radius

Section B–B

.117 radius
.399
.013 radius

Section C–C

(b) Location and details of standoff probe antenna.

Figure 1.- Continued.
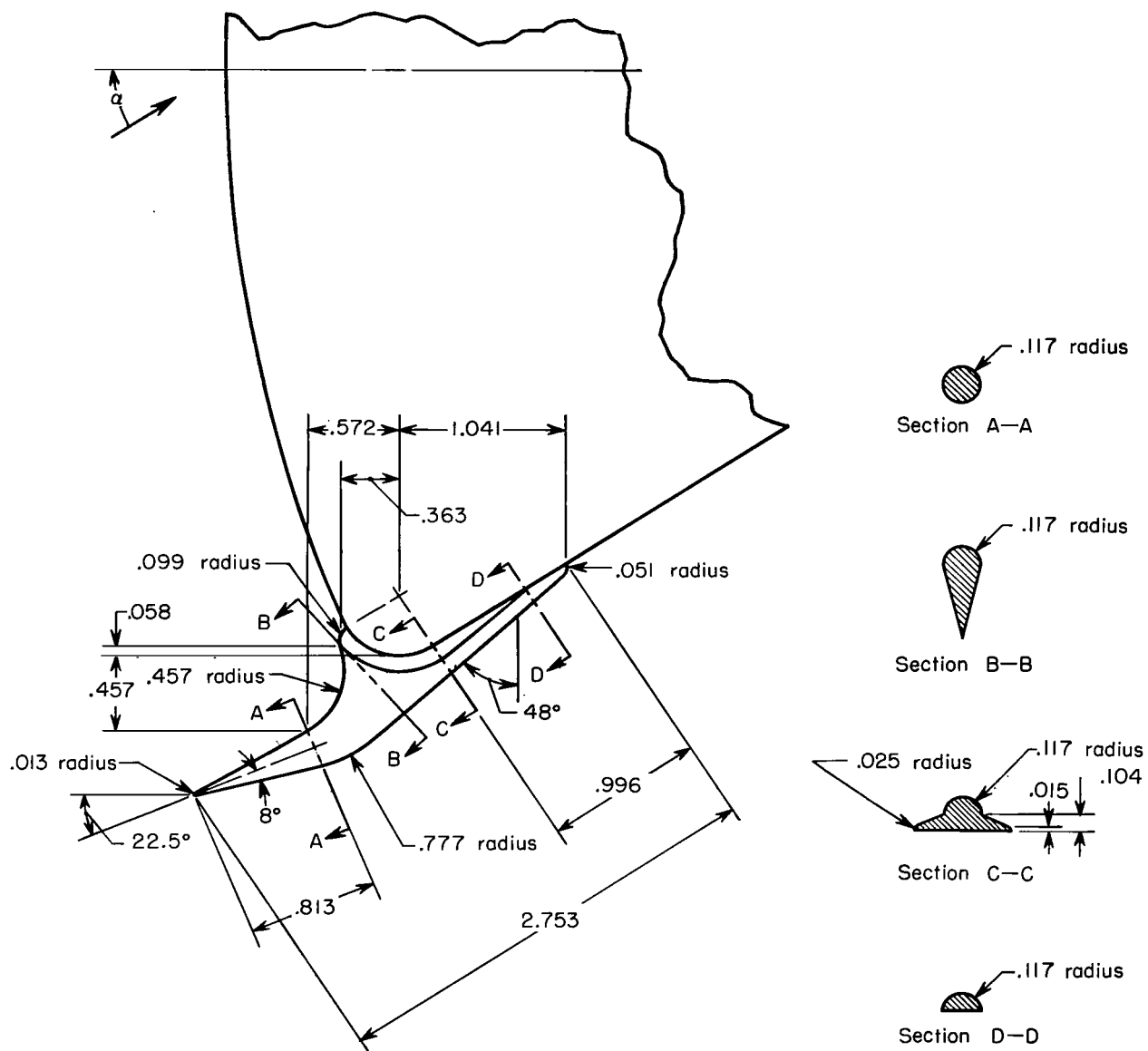
(c) Location and details of close-in probe antenna.

Figure 1.- Concluded.
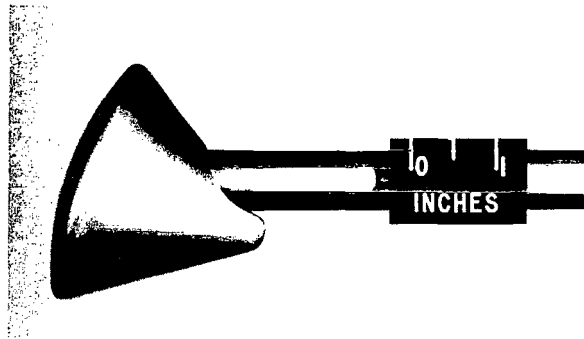
(a) Basic Apollo model.   L-66-5724
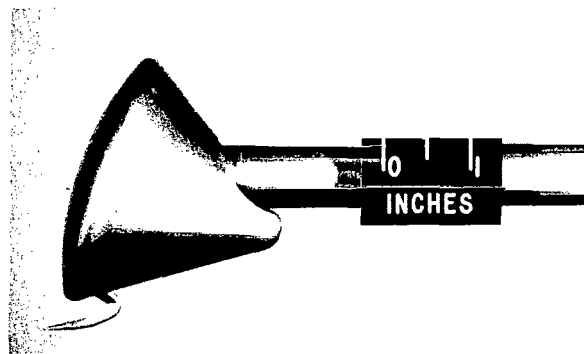
L-66-5720
(b) Apollo model with standoff probe antenna.
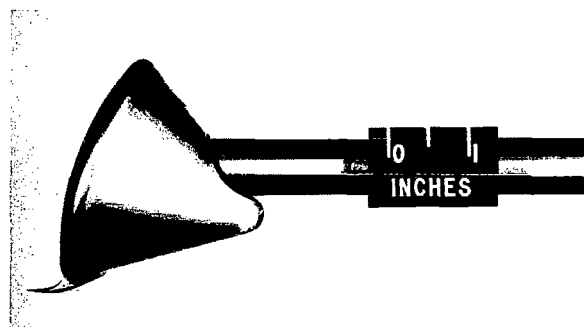
(c) Apollo model with close-in probe antenna.
L-66-6430
Figure 2.- Photographs of models. (1 inch = 2.54 cm.)

- - - Model alone, modified Newtonian theory
- o   Model alone
- □   Model with standoff probe
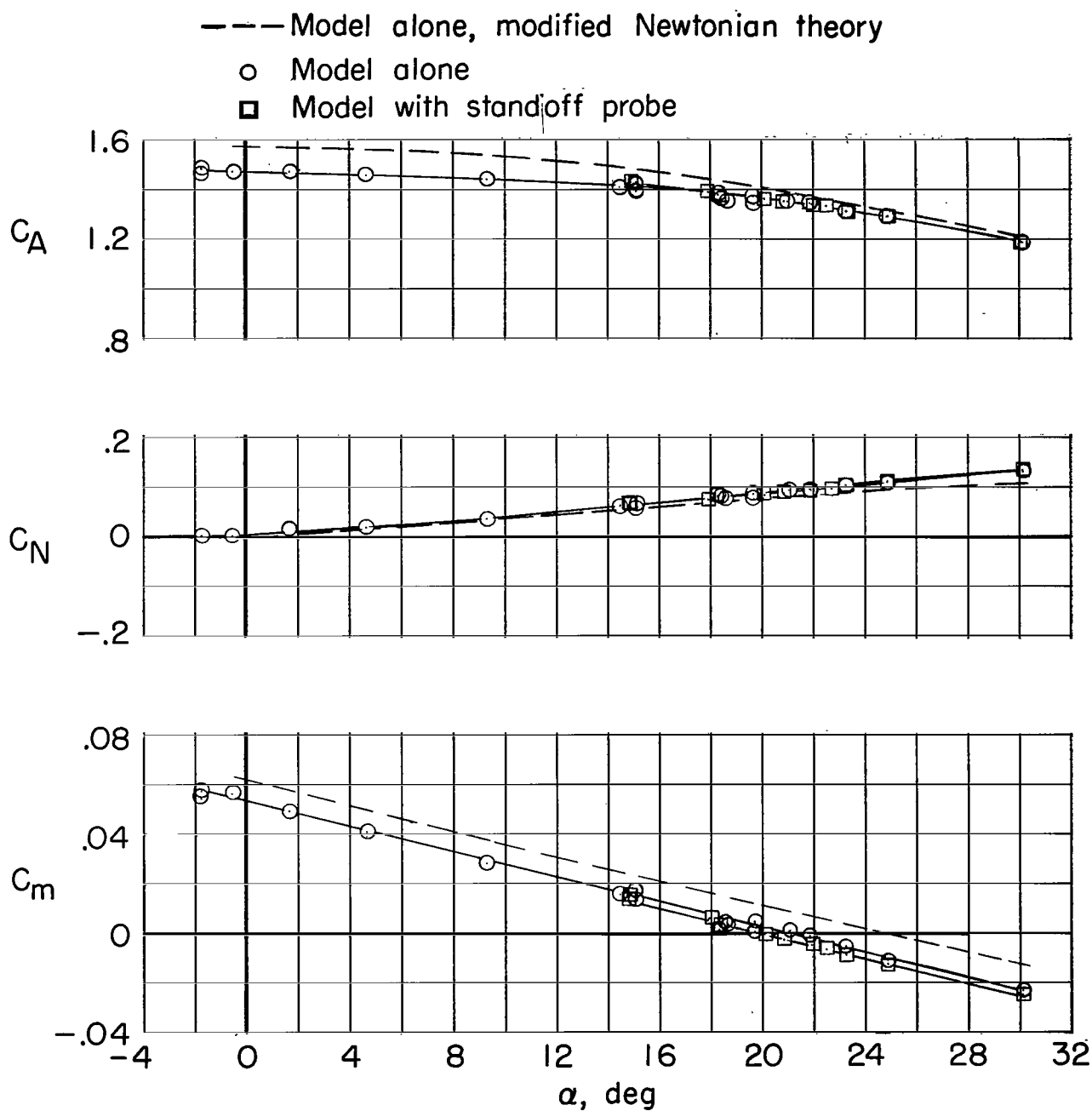
(a) Variation of C_m, C_N, and C_A with α.

Figure 3.- Effects of standoff probe antenna on longitudinal aerodynamic characteristics of Apollo model. $\beta = 0^0$.
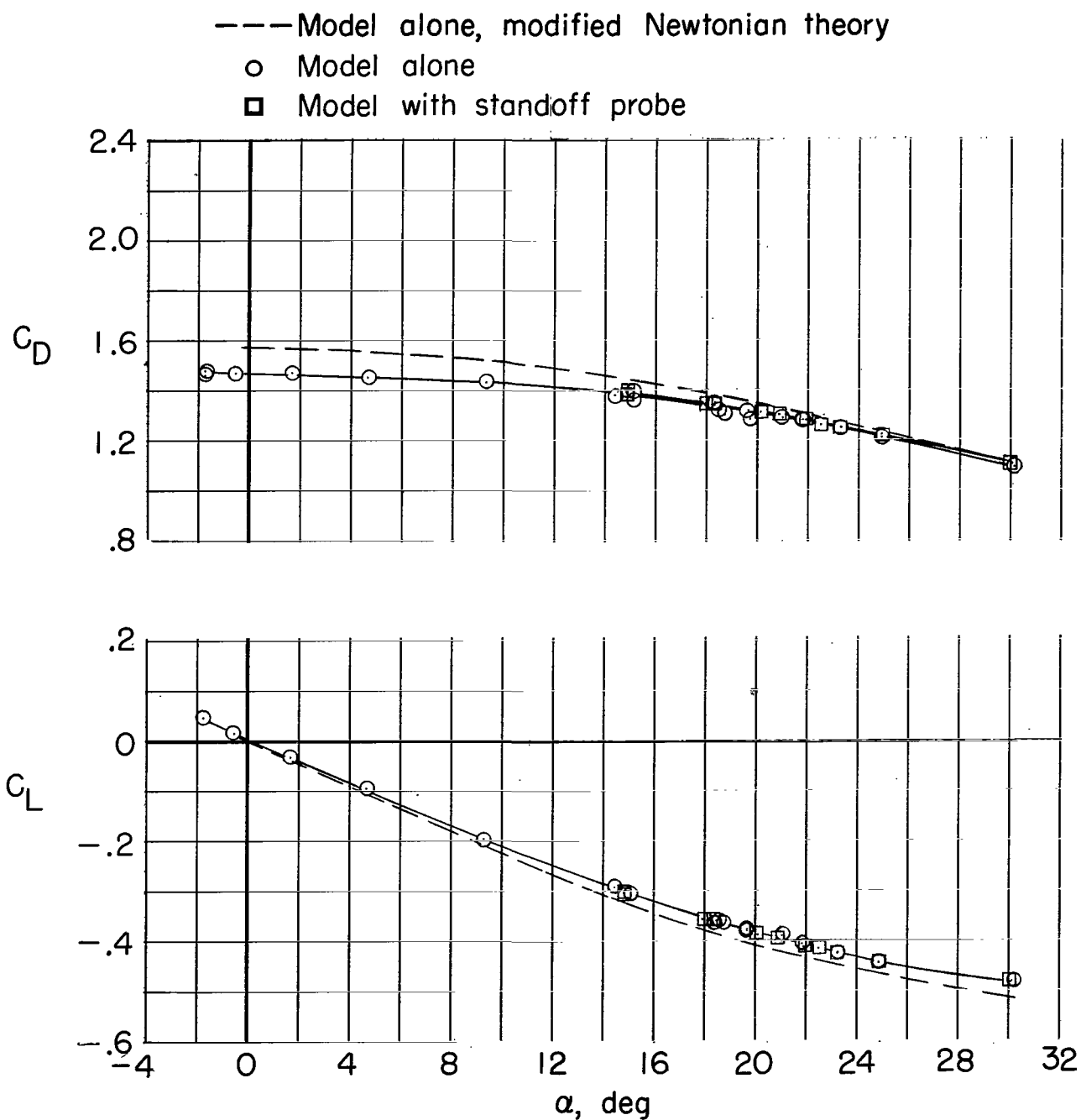
(b) Variation of C_L and C_D with α.

Figure 3.- Concluded.
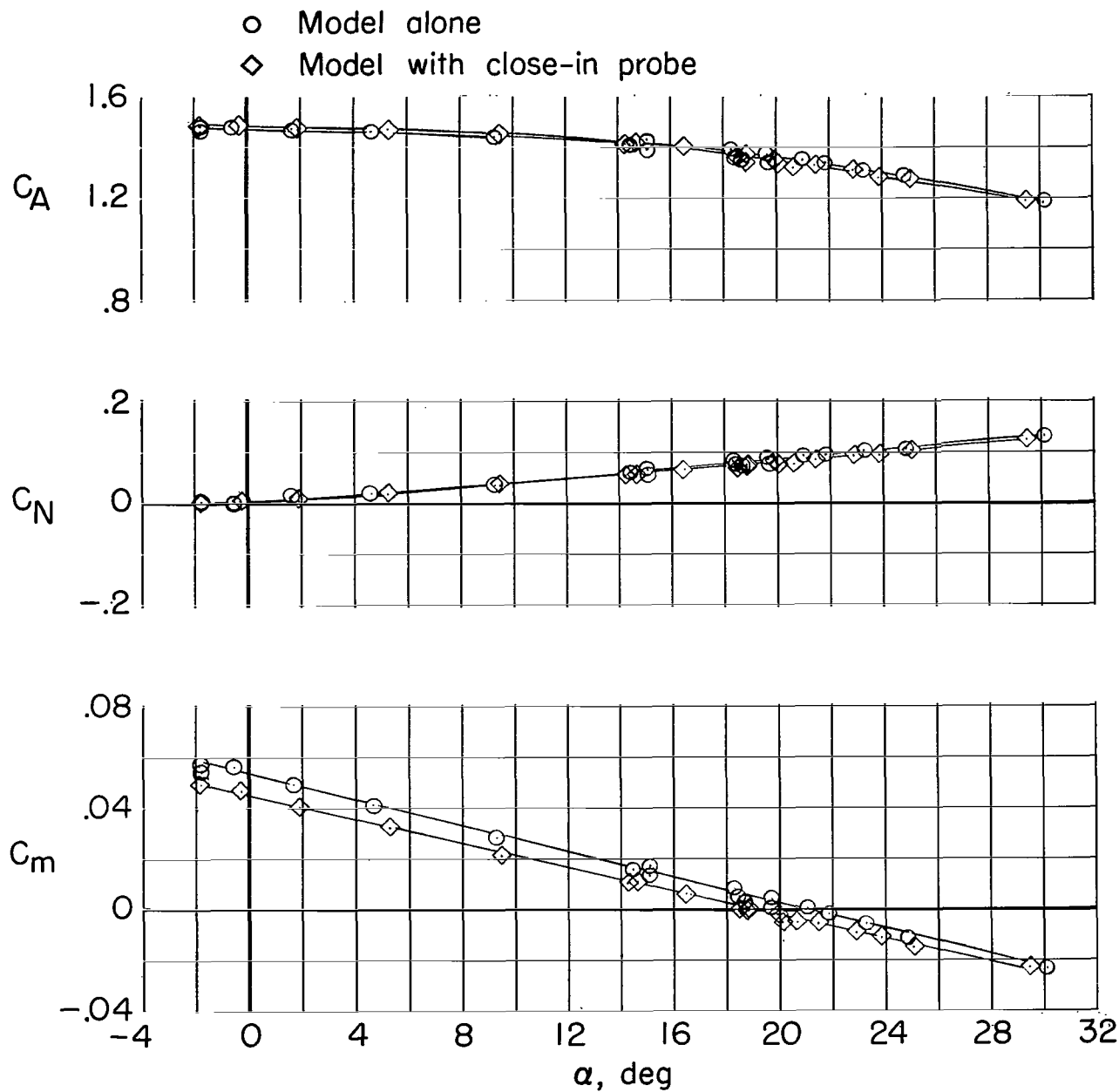
(a) Variation of C_m, C_N, and C_A with α.

Figure 4.- Effects of close-in probe antenna on longitudinal aerodynamic characteristics of Apollo model. $\beta = 0^o$.

(b) Variation of C_L and C_D with α.

Figure 4.- Concluded.

Basic Apollo model

Apollo model with
standoff probe

Apollo model with
close-in probe

$\alpha = 9.3°$

$\alpha = 14.8°$

$\alpha = 9.5°$

$\alpha = 19.6°$

$\alpha = 20.1°$

$\alpha = 20.1°$

$\alpha = 24.9°$

$\alpha = 24.9°$

$\alpha = 25.1°$

$\alpha = 30.2°$

$\alpha = 30.0°$

$\alpha = 29.5°$
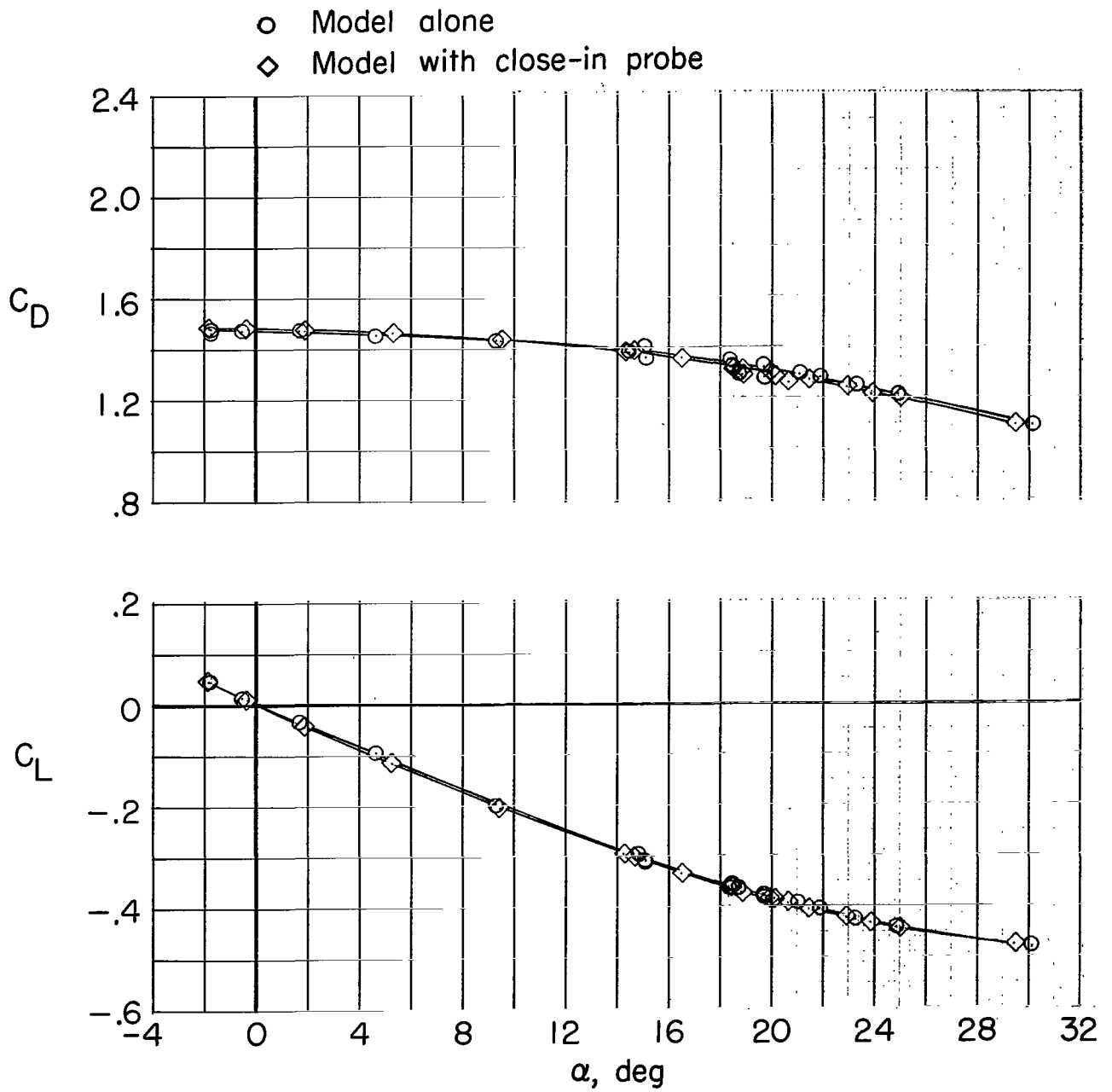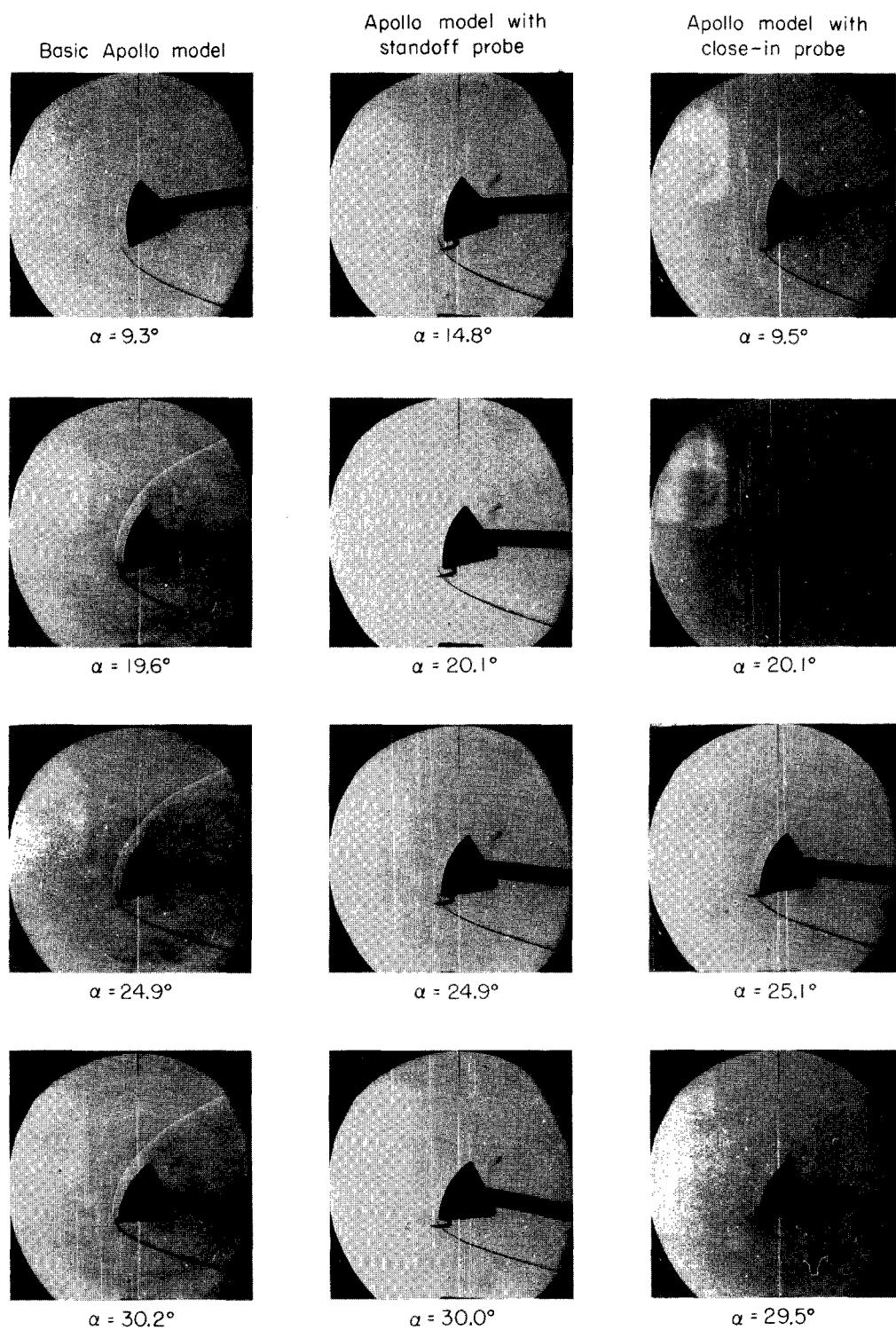
Figure 5.- Schlieren photographs of models at various angles of attack. $\beta = 0°$.   L-67-975
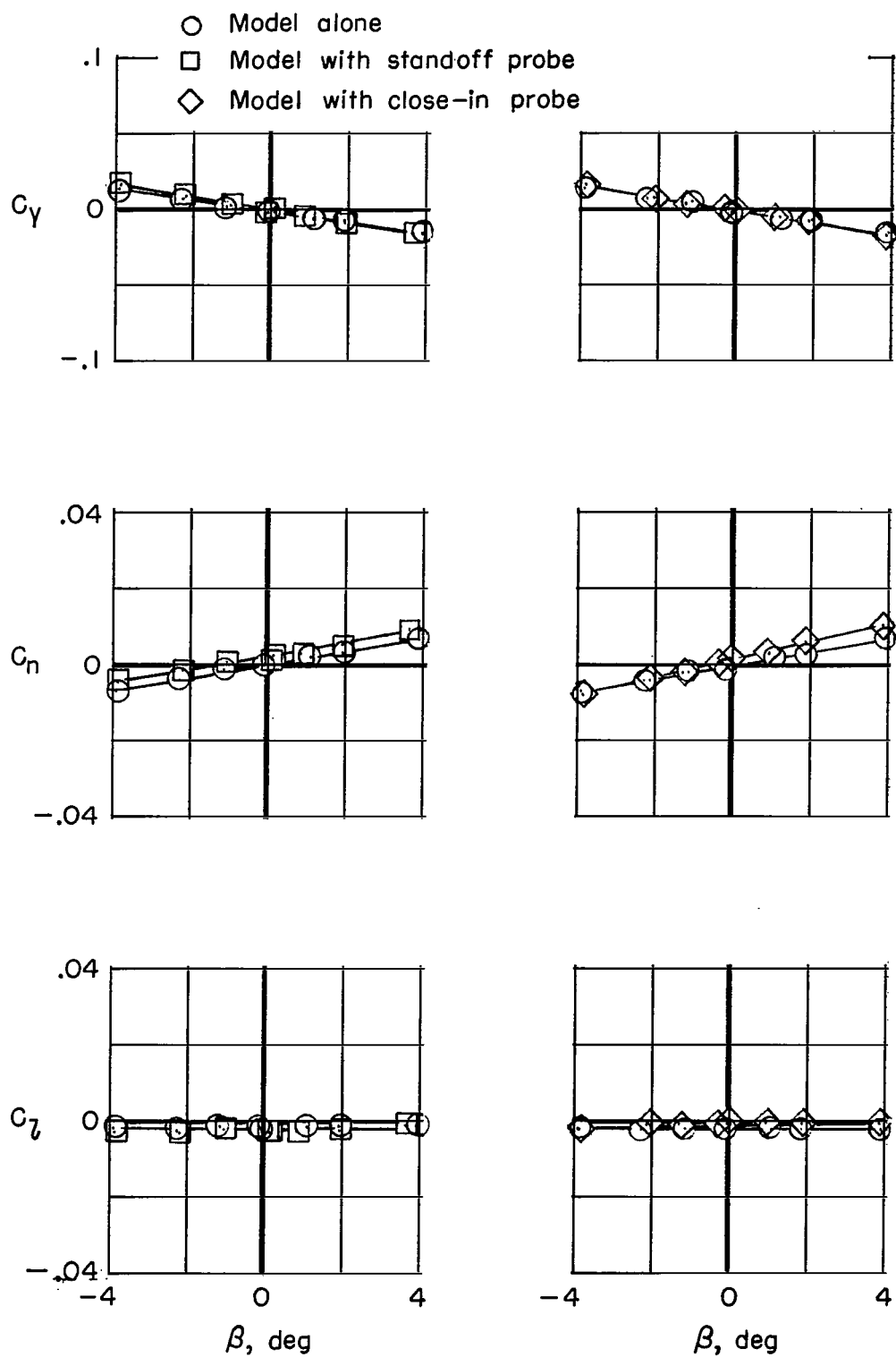
Figure 6.- Effects of probe antennas on lateral and directional aerodynamic characteristics of Apollo model at $\alpha \approx 18.7^0$.

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Apollo model with
standoff probe
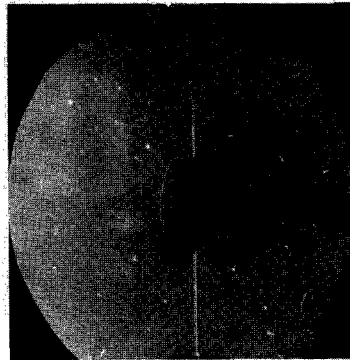
Apollo model with
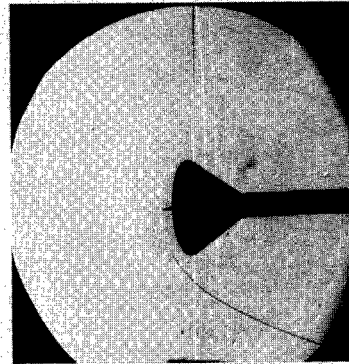close-in probe

$\beta = 3.6°$
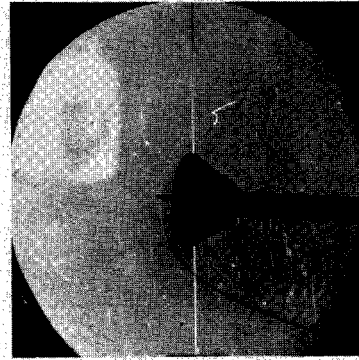
$\beta = 3.8°$

Basic Apollo model
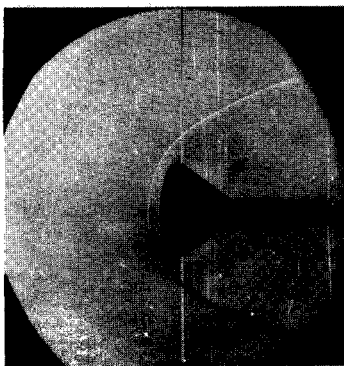
$\beta = -0.1°$
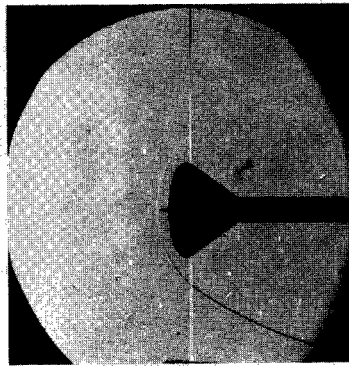
$\beta = 0.1°$
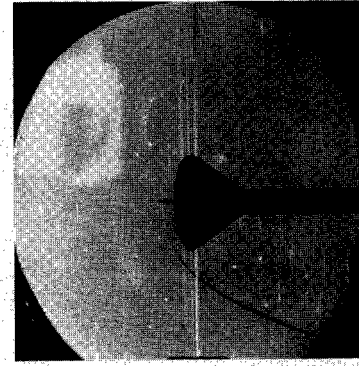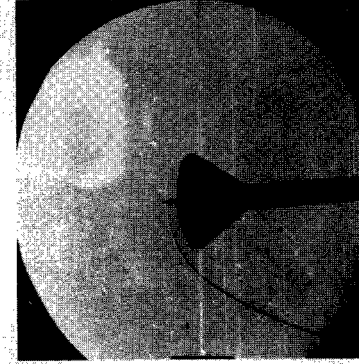
$\beta = -0.3°$
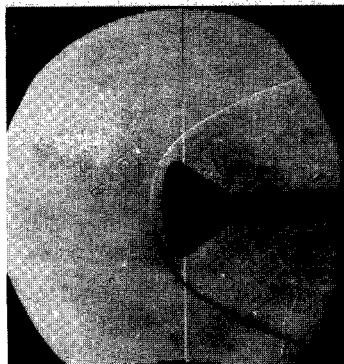
$\beta = -3.9°$

$\beta = -3.8°$

$\beta = -3.9°$

Figure 7.- Schlieren photographs of models at various angles of sideslip. $\alpha \approx 18.7°$.

L-67-976

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