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NACA TN No. 1496

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

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INVESTIGATION OF THE FUSELAGE INTERFERENCE ON A PITOT-STATIC TUBE EXTENDING FORWARD FROM THE NOSE OF THE FUSELAGE

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Washington
December 1947

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INVESTIGATION OF THE FUSELAGE INTERFERENCE ON A PITOT-STATIC TUBE EXTENDING FORWARD FROM THE NOSE OF THE FUSELAGE

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SUMMARY

An investigation was made to determine the interference effects of three fuselages on the readings of a pitot-static tube extending various distances forward from the noses of the fuselages. The fuselages used in the investigation were bodies of revolution with maximum diameters equal to 12 percent of the fuselage length and with circular-nose, elliptical-nose, and pointed-nose shapes.

The results of the tests showed that, at 1 fuselage diameter from the nose, the error in static pressure was only about $1\frac{1}{2}$ percent of the impact pressure for the pointed-nose body, about 5 percent of the impact pressure for the elliptical-nose body, and about 10 percent of the impact pressure for the circular-nose body for zero angle of attack of the bodies. As the angle of attack was increased, the interference effect on static pressure decreased.

Comparison of experimental results at zero angle of attack with calculated results indicates that the fuselage interference effect on the pitot-static-tube reading can be calculated with good accuracy for simple bodies of revolution at zero angle of attack.

INTRODUCTION

The choice of a suitable location for the pitot-static tube used to measure airspeed and altitude is important in the design of any airplane but is especially important for experimental airplanes designed to fly at very high speeds. For supersonic speeds, an arrangement is necessary in which the pitot-static tube extends forward of any part of the airplane in order to obtain complete absence of interference from parts ahead of the tube. For most jet airplanes, and especially those with sweptback wings, the only practical location is one in which the tube extends forward from the nose. At subsonic speeds, however, the readings given by such an arrangement of the pitot-static tube are affected by interference, particularly from the airplane fuselage. Since very little data are available for such a pitot-static-tube location, the present investigation was undertaken.

In the present investigation the interference that exists at various distances ahead of bodies of revolution having different nose shapes was determined experimentally at low speeds. The experimental results at zero angle of attack are compared with results calculated from theory in order to determine the reliability of the theory when applied to bodies of the type considered.

SYMBOLS

x	distance along axis of symmetry from nose of body to tube static orifices
D	fuselage diameter
α	angle of attack of pitot-static tube and fuselage
M	Mach number
q_c	free-stream impact pressure
q_{c_o}	impact pressure measured by pitot-static tube at zero angle of attack with no fuselage attached
p_1	static pressure measured by pitot-static tube with no fuselage attached
p_2	static pressure measured by pitot-static tube when mounted ahead of fuselage
H	total head of free stream
Δp	error in static pressure resulting from fuselage interference $\left(-(p_1 - p_2)\right)$

APPARATUS AND TESTS

The tests were made in the 6- by 6-foot test section of the Langley stability tunnel. The basic fuselage used in these tests was a body of revolution formed by revolving a circular arc about the chord. Two modified nose shapes, circular and elliptical, were fitted over the nose of the original fuselage. All the fuselages tested were of the same length and had a maximum diameter equal to 12 percent of their length. Photographs of these fuselages mounted in the tunnel are presented as figure 1. Detailed drawings of these fuselages are given in figure 2. Each nose had a circular hole along the axis of symmetry for mounting the pitot-static tube with provisions for changing the distance of the tube static orifices with respect to the nose.

Two tubes were used in the tests: one a pitot-static tube of $\frac{3}{8}$-inch outside diameter with the static openings about 3-tube diameters behind the nose and the other a static tube of $\frac{1}{8}$-inch outside diameter with the static orifice about $10\frac{1}{2}$-tube diameters behind the nose. Detailed drawings of these tubes are given in figure 3.

Measurements were made for each fuselage with the $\frac{3}{8}$-inch pitot-static tube with and without fuselage at various angles of attack and impact pressures. Tests were made at zero angle of attack with an impact pressure of approximately 65 pounds per square foot and at 0°, 10°, 20°, and 30° angles of attack with an impact pressure of approximately 40 pounds per square foot. For the circular-nose fuselage, additional tests were made at impact pressures of 25 and 16 pounds per square foot for zero angle of attack.

The $\frac{1}{8}$-inch static tube was used to obtain measurements ahead of the circular-nose shape for comparison with the $\frac{3}{8}$-inch pitot-static-tube measurements at zero angle of attack and at an impact pressure of 40 pounds per square foot.

The approximate airspeeds corresponding to the various test impact pressures are as follows:

Free-stream impact pressure (lb/sq ft)	Airspeed (mph)
65	162
40	127
25	100
16	80

RESULTS AND DISCUSSION

For most airplane installations, total head is obtained with very little error throughout a relatively wide range of angle of attack. Since the static pressure registered by a tube ordinarily differs appreciably from true static pressure throughout the angle-of-attack range, all the data presented on interference effects are therefore concerned with the variation of static pressure ahead of the fuselage.

Interference at Zero Angle of Attack

Figure 4 presents the error in static pressure as a fraction of impact pressure $\frac{\Delta p}{q_{c_0}}$ plotted against distance of the tube static orifices ahead of the nose x/D for the three fuselages at zero angle of attack. The circular-nose fuselage, as was expected, had the greatest interference effect and the pointed-nose fuselage had the least.

The decrease of the error with increase of distance of the static orifices from the nose is similar to that obtained for a body of revolution as reported in references 1 and 2. At 1 fuselage diameter from the nose, the error in static pressure is only about $1\frac{1}{2}$ percent of the impact pressure for the pointed-nose body, about 5 percent of the impact pressure for the elliptical-nose body, and about 10 percent of the impact pressure for the circular-nose body.

In order to check the reliability of existing theoretical methods for calculating the interference effect of a fuselage, the experimental results presented herein for zero angle of attack were compared with the theoretical results obtained by the method described in reference 3. This theoretical method is based on a representation of the body by a stepwise distribution of sources and sinks along the axis. The body shapes corresponding to the assumed distributions are shown by dashed lines in figure 2 and are compared with the actual fuselage bodies. The actual body shapes are generally approximated quite accurately by those shapes obtained from the calculations. The discrepancy between the calculated and the actual body shapes is greatest for the circular-nose body; however, closer agreement might be obtained by changing from a stepwise distribution of sources and sinks to a continuous distribution along the axis. The discrepancy between the calculated and the actual body shapes of the elliptical nose probably had a negligible effect on the calculated interference, but the shape could have been calculated with higher accuracy by adding another source line closer to the nose than the source line assumed in the calculations. The source and sink distributions assumed for the representation of the pointed nose body resulted in almost no error in the shape of the body.

The comparison of the calculated interference effect with experimental results obtained at zero angle of attack is shown in figure 4. This comparison shows that the theoretical results are in good agreement with the experimental data. For the elliptical-nose and pointed-nose bodies, the calculated interference effects were found to be somewhat higher than the experimental values. Inasmuch as these bodies were almost exactly simulated by the assumed source and sink representations (fig. 2), the theory appeared to slightly overestimate the interference effect. In the case of the circular nose, figure 4 shows that the theory underestimates the interference effects. These lower calculated values are probably caused by the fact that the assumed source distributions resulted in a nose more pointed than the circular nose tested. (See fig. 2.)

The theoretical method of reference 3, which is for incompressible flow, may be applied to calculate the fuselage interference effects for compressible flow at subsonic speeds by use of the affine transformation given in reference 4. A rule for making such computations may be stated as follows:

The streamline field of a compressible flow for a given body at a subsonic stream Mach number M may be calculated approximately by multiplying the given x-dimensions by the factor $\frac{1}{\sqrt{1 - M^2}}$ and then by calculating the flow about this resulting transformed body in incompressible flow. The pressure and velocity increments for the given body at the Mach number M can then be obtained by multiplying the calculated pressure and velocity increments for the incompressible flow at corresponding points of the transformed body by the factor $\frac{1}{1 - M^2}$.

Effect of Angle of Attack

Figure 5 shows that, for the arrangement tested, the fuselage interference effect on the static pressure decreases as the angle of attack is increased. When considering the effect of angle of attack on the pitot-static-tube readings, it must be remembered that the actual angle at the tube is the sum of the geometric angle and the angle induced by the body. When measurements are made with the tube alone, the angle of attack is essentially the geometric angle. With the body added, however, the effective angle is the geometric angle plus the induced angle. Inasmuch as the magnitude of the induced angle is unknown, the results presented in figure 5 represent the difference between the static pressure readings with and without the fuselage in place at the same geometric angle of attack.

Because of the difference in sensitivity of various tubes to angle of attack, the error resulting from the induced angle would differ for different tubes. The results shown in figure 5 are only applicable, therefore, to the tube used in this investigation. The results in figure 5, however, may be used to obtain an indication of the fuselage interference effect on static pressure at different positions ahead of the bodies for different angles of attack. Figure 6 shows the variation of the static pressure measured with the $\frac{3}{8}$-inch pitot-static tube, without the fuselage, with angle of attack.

Effect of Free-Stream Impact Pressure

In figure 7, data are presented for the circular-nose fuselage at zero angle of attack for several free-stream impact pressures. The effect on interference when the impact pressure is varied over the test range is seen to be small, except for positions close to the nose.

Effect of Tube Diameter

In order to determine the effect of the size of the pitot-static tube relative to the diameter of the fuselage, tests were made with the $\frac{1}{8}$-inch-diameter static tube and compared with the $\frac{3}{8}$-inch-diameter pitot-static tube which was used for the tests described previously. The size of the $\frac{1}{8}$-inch-diameter static tube relative to the diameter of the fuselage tested closely simulates the size of a full-scale pitot-static tube relative to the diameter of the fuselage of a full-scale airplane.

A comparison of the measurements of the interference effects on static pressure as determined by the different-size tubes for the circular-nose fuselage at zero angle of attack is shown in figure 8. This figure shows that for the tube sizes considered, the readings are affected only for positions of the static orifices near the nose of the body. Because of their different diameters, the tubes measure the pressure at different distances from the axis of symmetry; therefore, the aforementioned discrepancy in readings probably was caused by the radial gradient in static pressure that exists near the nose of the body. Moving the orifices approximately 0.25 diameter from the nose causes the readings of both tubes to be nearly coincident.

CONCLUSIONS

Tests were made with bodies of revolution having maximum diameters equal to 12 percent of the body length to determine the interference effect of fuselages on the static pressure readings of a pitot-static tube extending various distances ahead of the fuselages. The results indicate that, at 1 fuselage diameter from the nose, the error in static pressure was only about $1\frac{1}{2}$ percent of the impact pressure for the pointed-nose body, about 5 percent of the impact pressure for the elliptical-nose body, and about 10 percent of the impact pressure for the circular-nose body for zero angle of attack of the bodies. As the angle of attack of the bodies was increased, the interference effect on static pressure decreased.

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Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., August 11, 1947

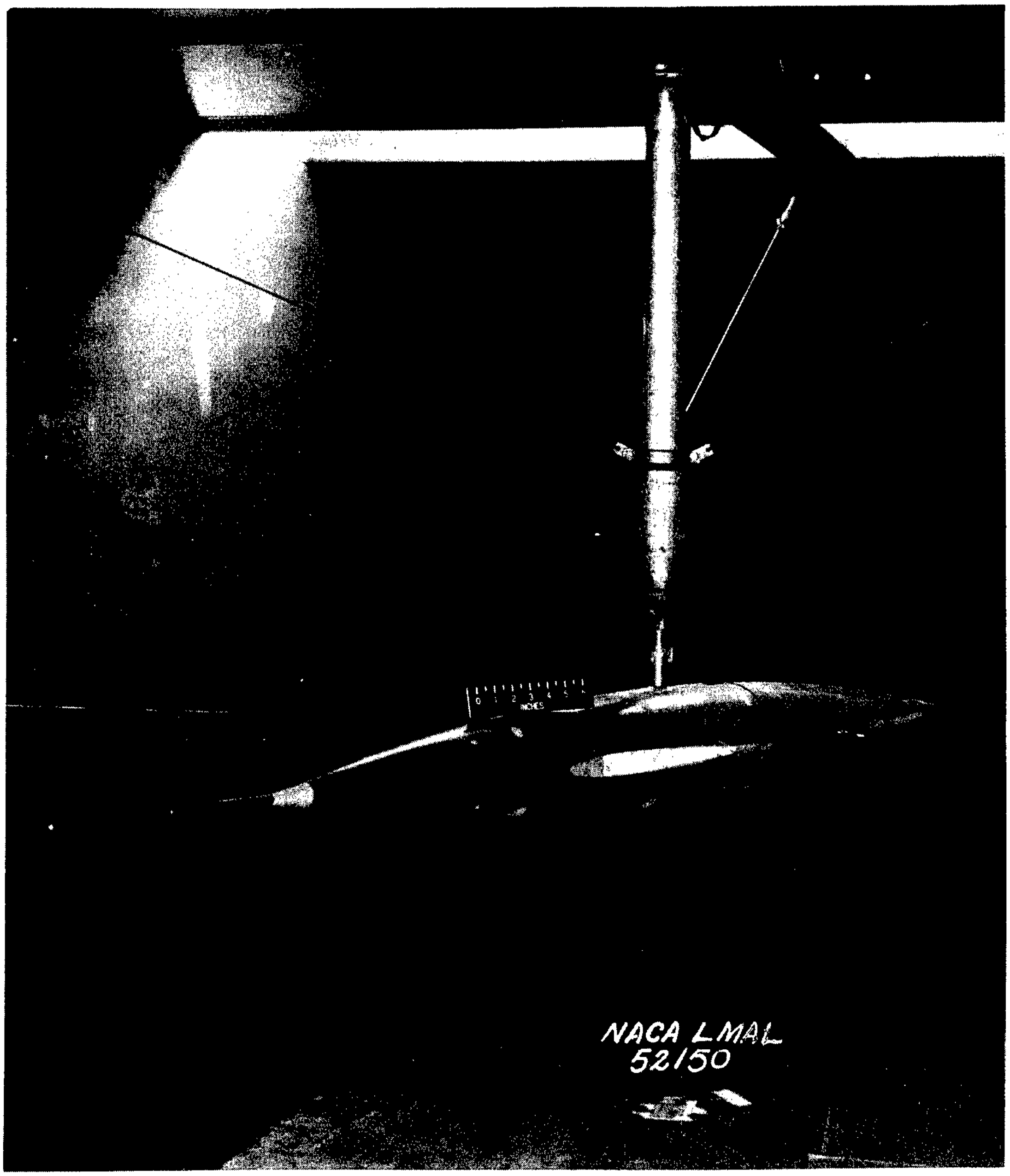
REFERENCES

1. Reid, Elliot G.: Interference Tests on an N.A.C.A. Pitot Tube. NACA Rep. No. 199, 1924.

2. Kumbruch, H.: Pitot-Static Tubes for Determining the Velocity of Air. NACA TM No. 303, 1925.

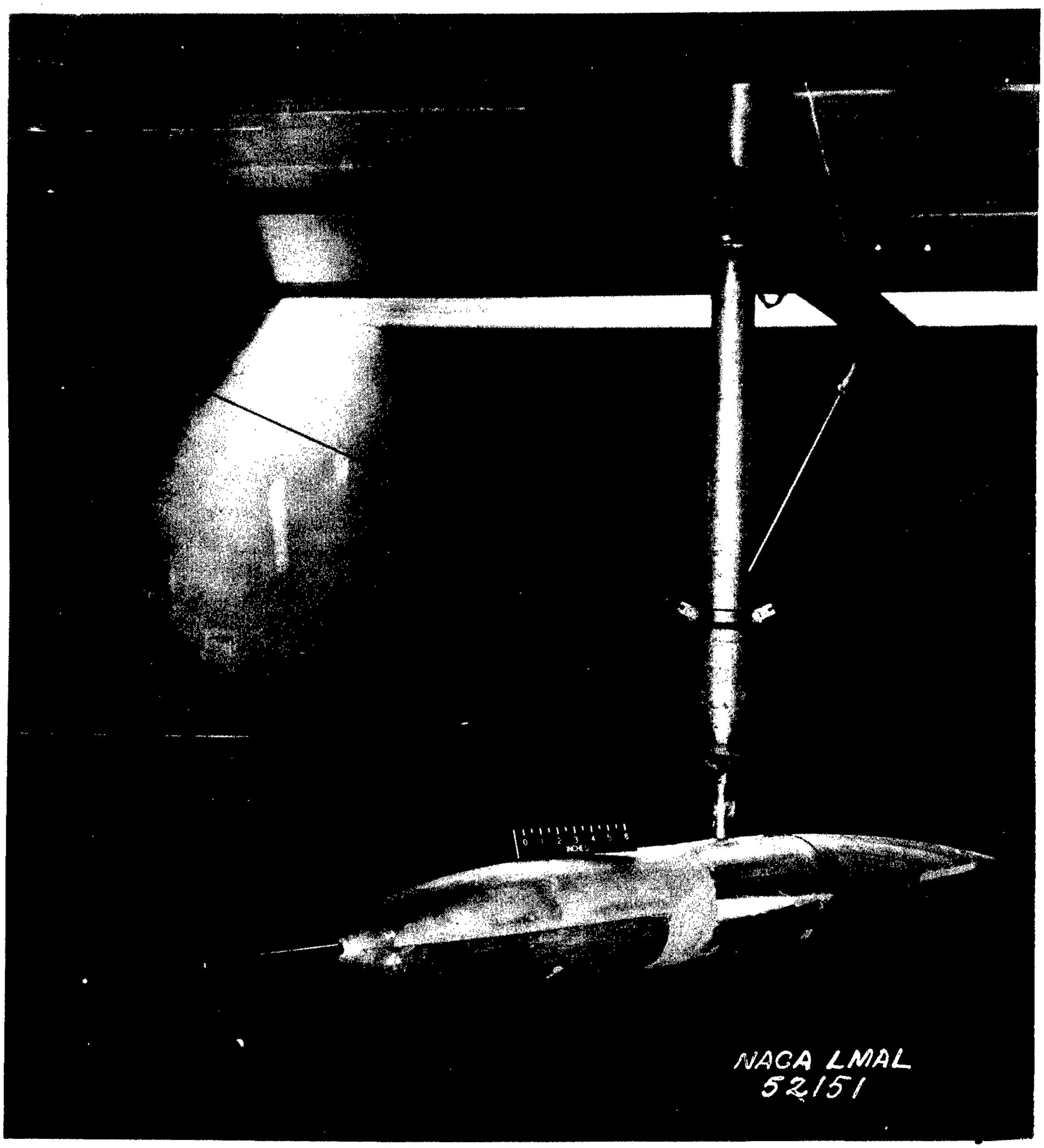
3. von Kármán, Theodor: Calculation of Pressure Distribution on Airship Hulls. NACA TM No. 574, 1930.

4. Lees, Lester: A Discussion of the Application of the Prandtl-Glauert Method to Subsonic Compressible Flow over a Slender Body of Revolution. NACA TN No. 1127, 1946.



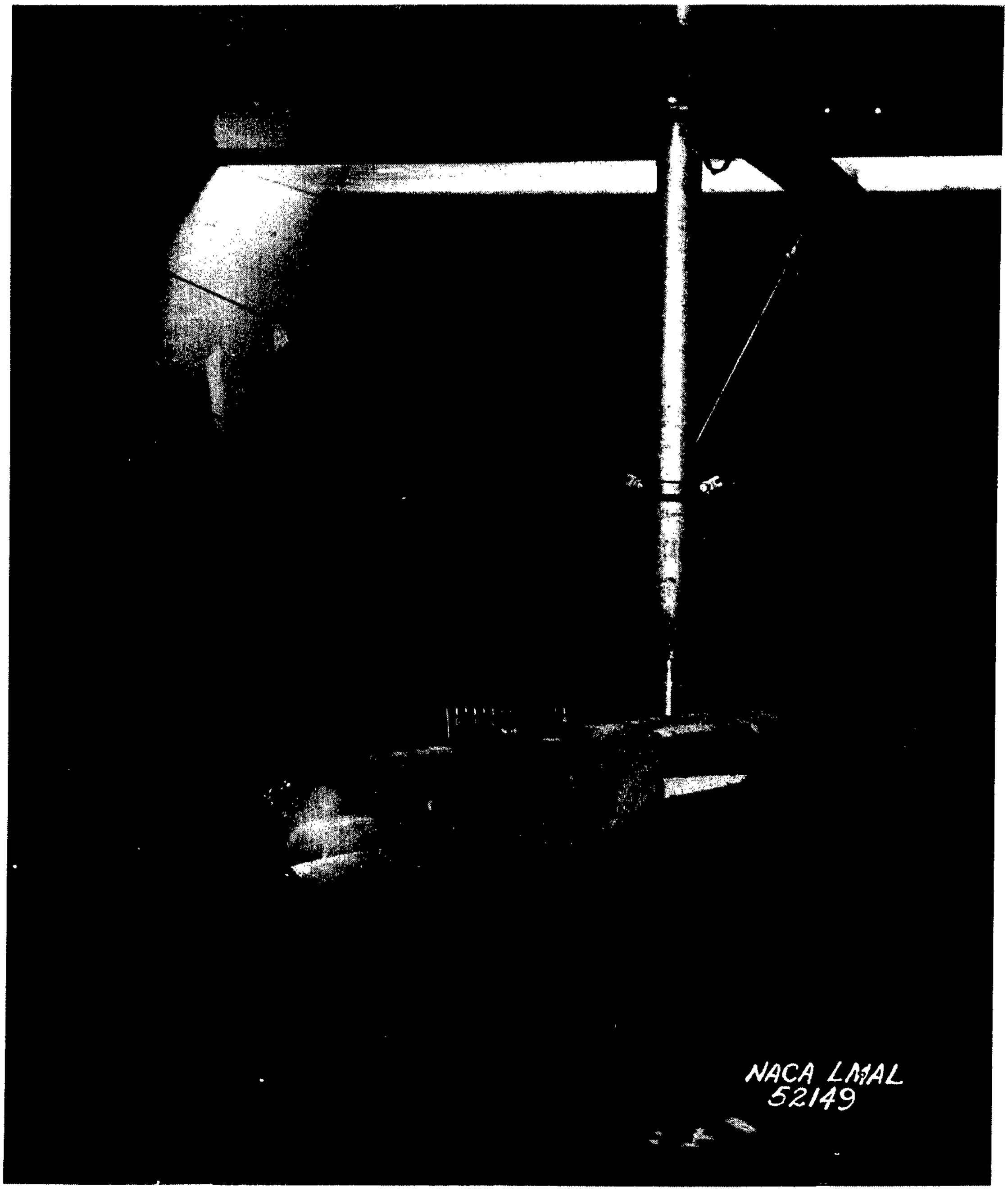
(a) Pointed-nose fuselage.

Figure 1.- Photographs of fuselages and pitot-static tube mounted in the Langley stability tunnel.



(b) Elliptical-nose fuselage.

Figure 1.- Continued.



(c) Circular-nose fuselage.

Figure 1.- Concluded.

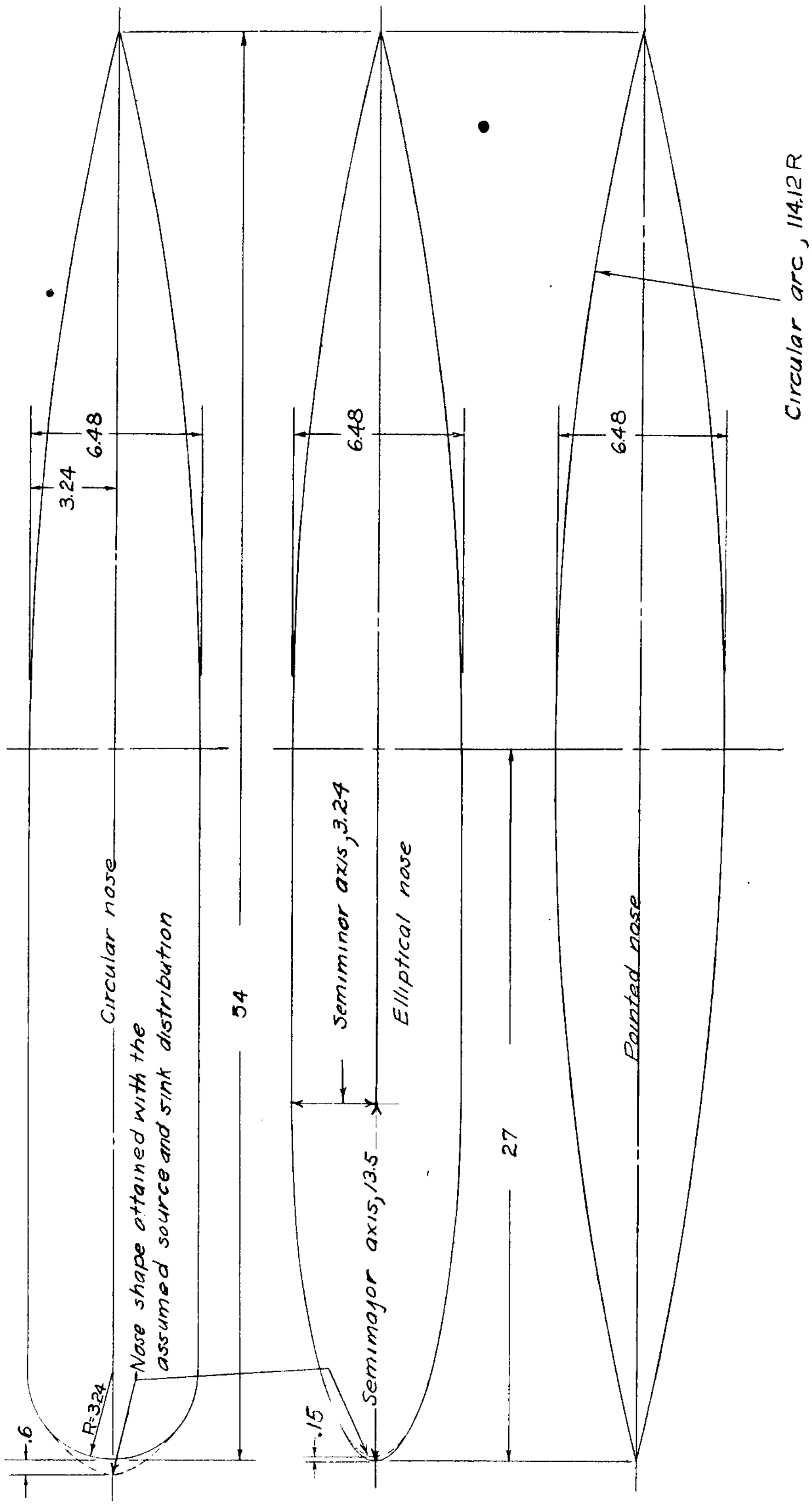


Figure 2.- Details of fuselages used in tests. All dimensions are in inches.

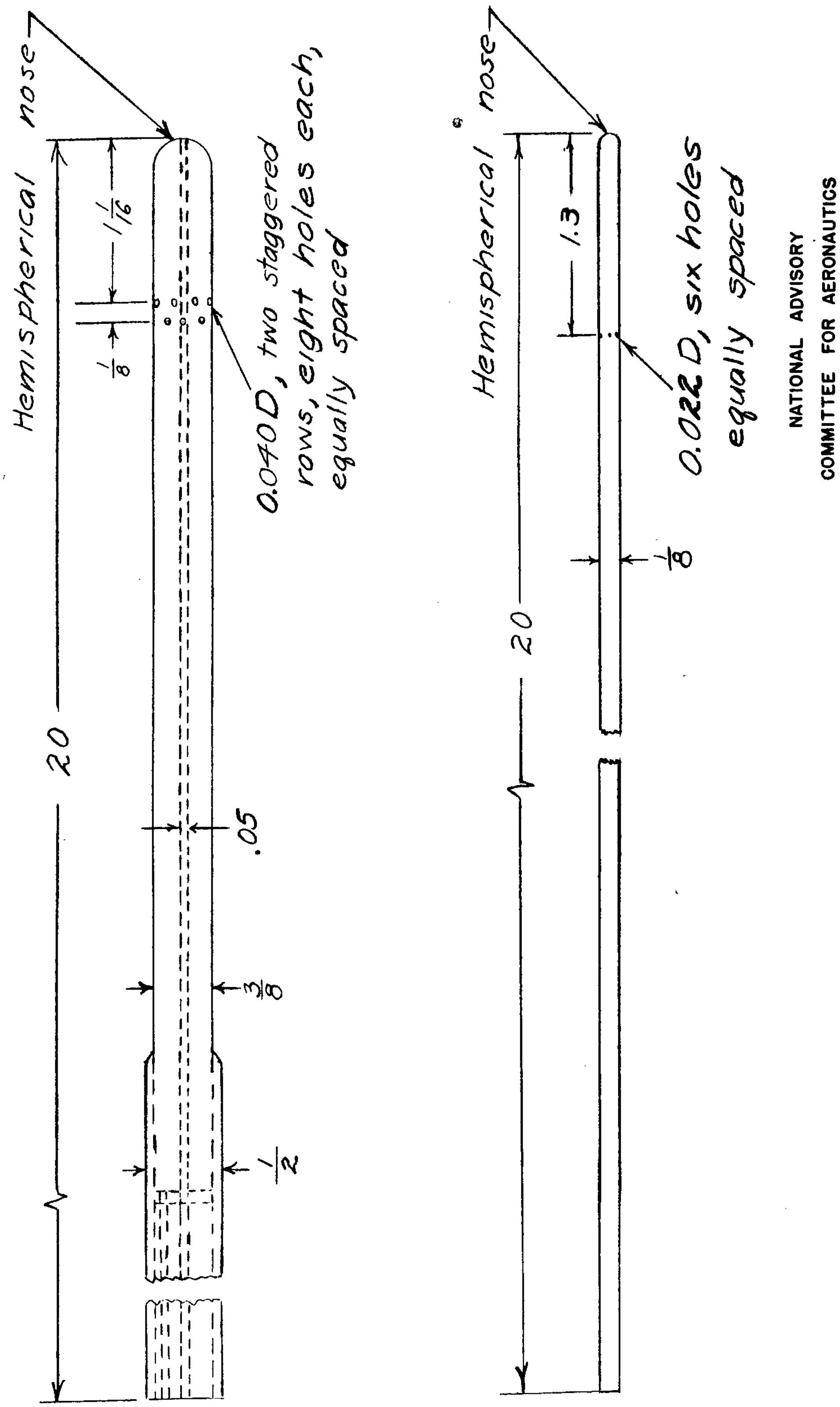


Figure 3.- Details of tubes used in tests. All dimensions are in inches.

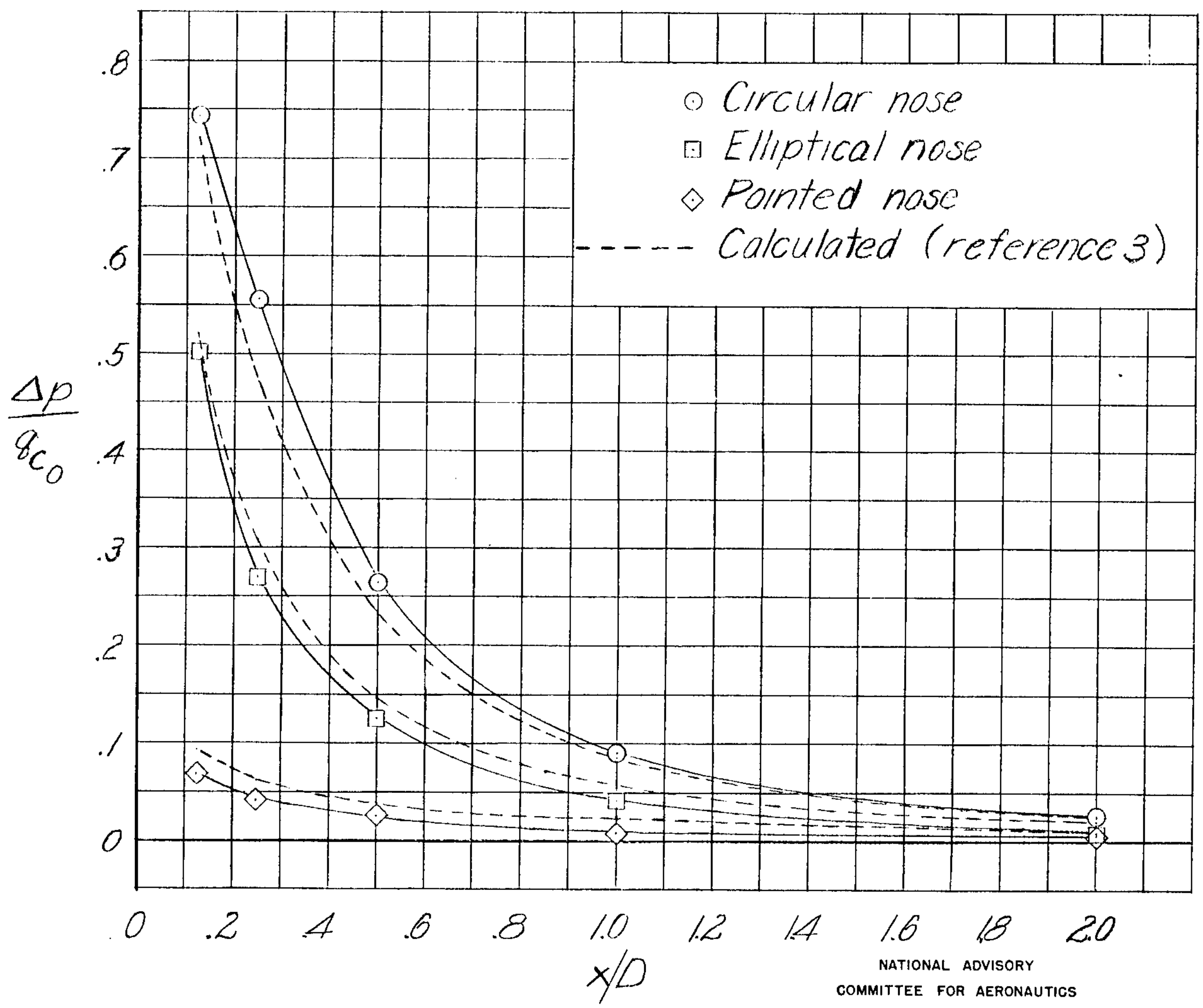


Figure 4.- Effect of fuselage nose shape on the error in static pressure caused by fuselage interference. $\alpha = 0^{\circ}$; $q_c = 65$ pounds per square foot.

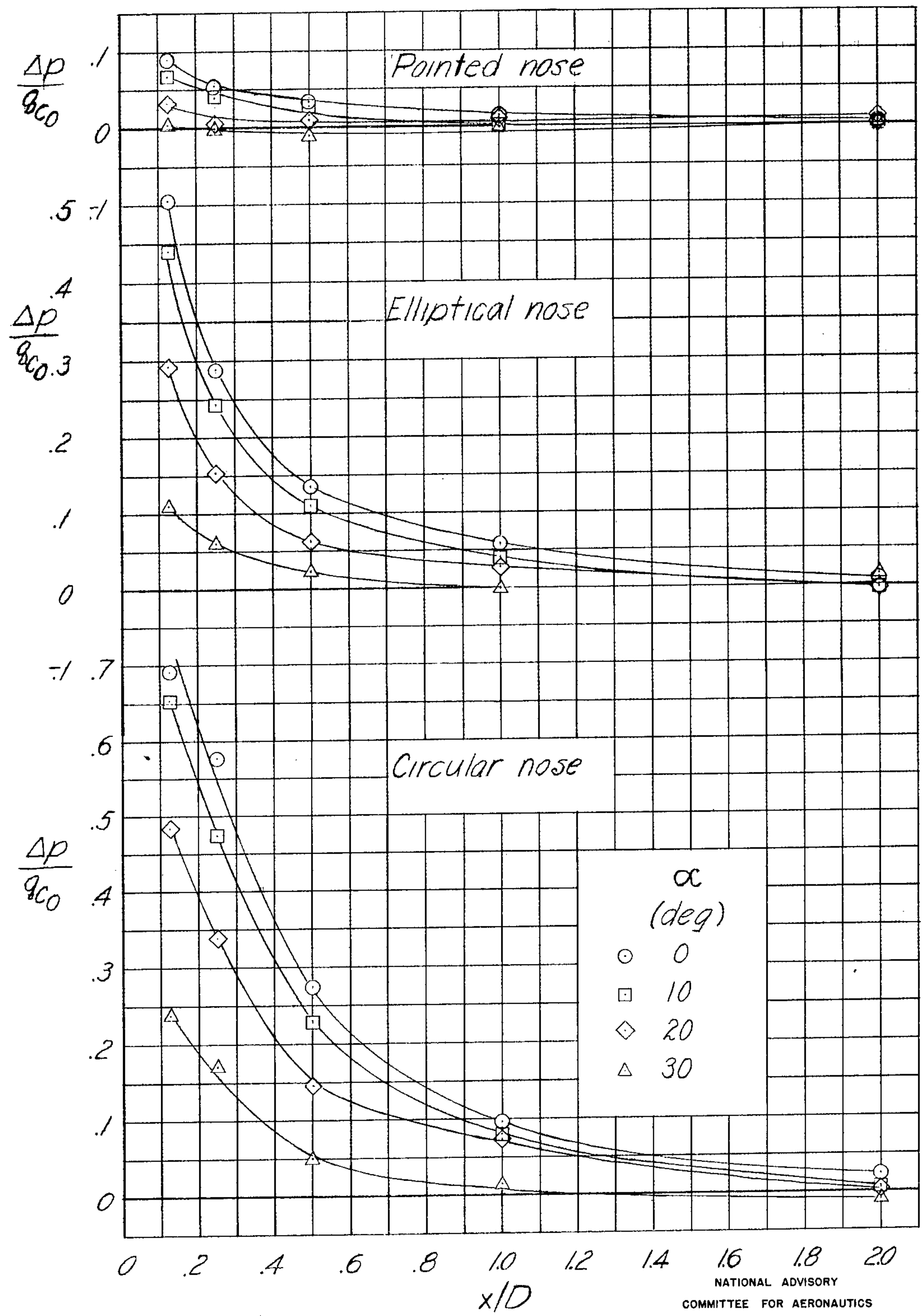


Figure 5.- Effect of angle of attack on the error in static pressure caused by fuselage interference. q_c = 40 pounds per square foot.

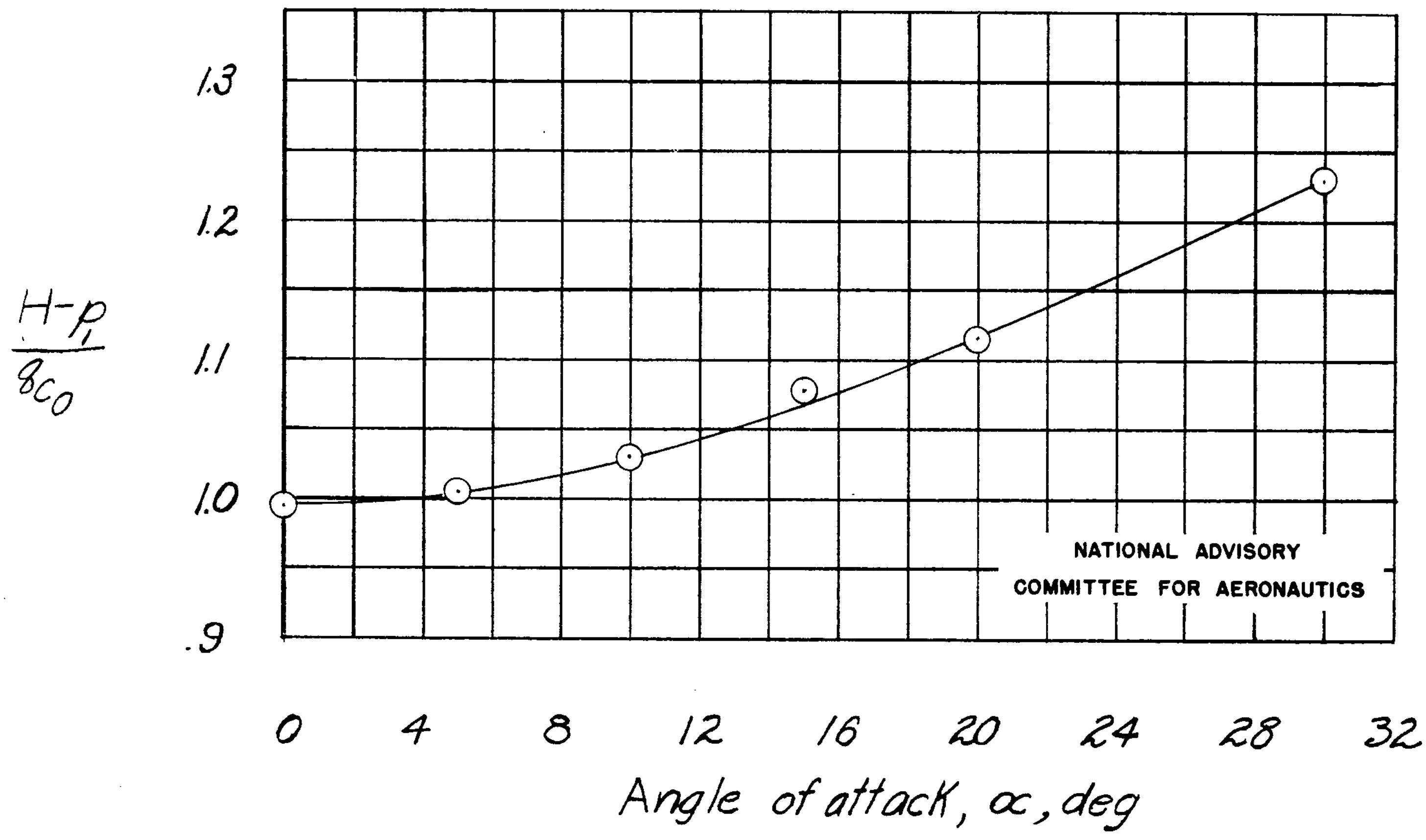


Figure 6.- Calibration of static-pressure error of the $\frac{3}{8}$-inch-diameter pitot-static tube. q_c = 40 pounds per square foot.

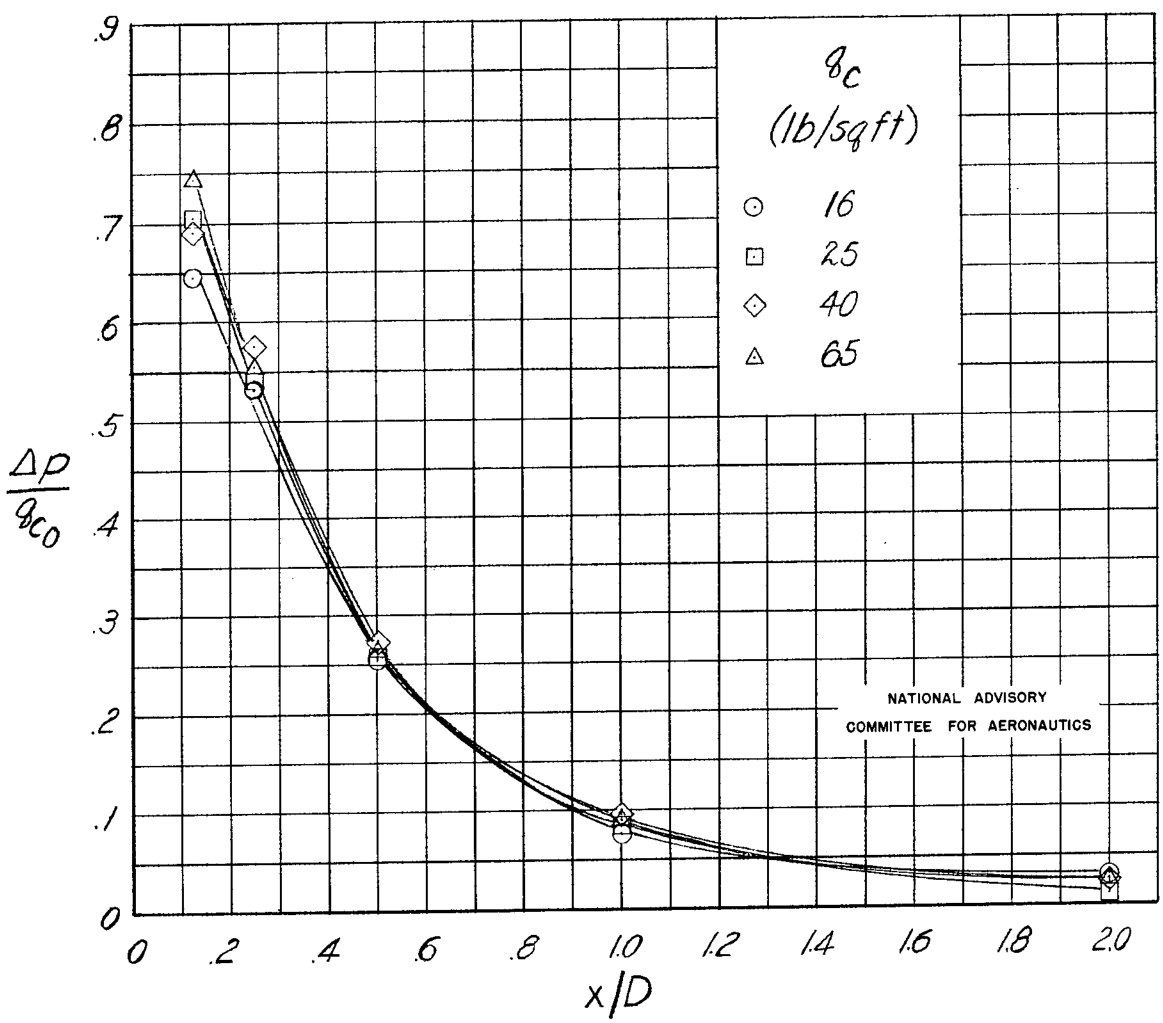


Figure 7.- Effect of free-stream impact pressure on the error in static pressure caused by fuselage interference. Circular-nose fuselage; $\alpha = 0^{\circ}$.

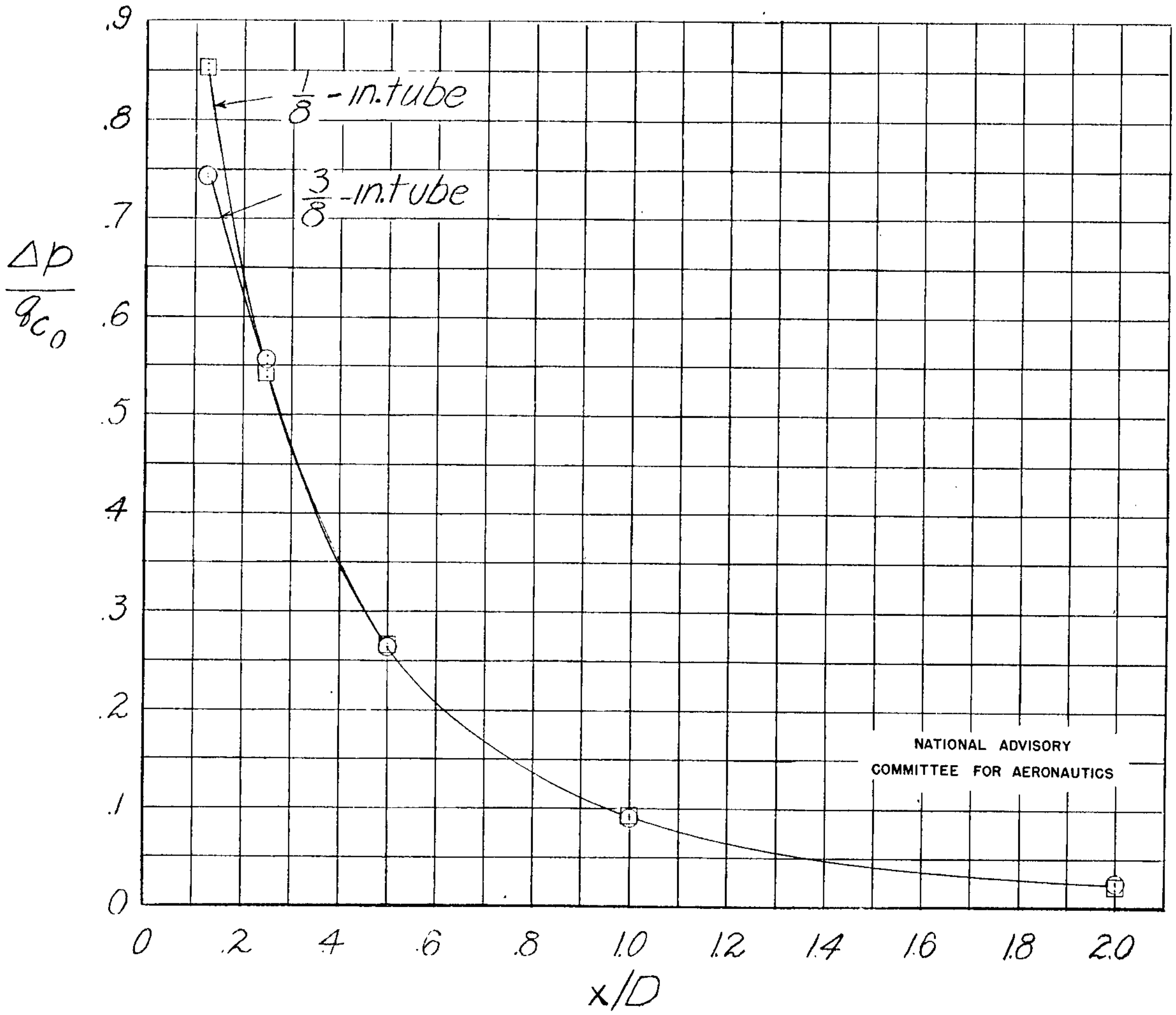


Figure 8.- Effect of tube diameter on the error in static pressure caused by fuselage interference. Circular-nose fuselage; $\alpha = 0^{\circ}$; q_c = 65 pounds per square foot.