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RESEARCH MEMORANDUM

WING-FLOW INVESTIGATION OF A 45° CONE AS AN ANGLE-OF-ATTACK MEASURING DEVICE AT TRANSONIC SPEEDS

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NATIONAL ADVISORY COMMITTEE
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SUMMARY

A preliminary study has been made by the NACA wing-flow method to investigate the feasibility of determining angle of attack in transonic flight by means of pressure measurements on the surface of a cone. Pressures were measured on the lower and upper meridians of the surface of a cone with a 45° apex angle through an angle-of-attack range of from -10° to 50° at Mach numbers between 0.7 and 1.1.

An analysis of the results of this preliminary investigation has indicated that a cone is of possible use for the measurement of angle of attack in transonic flight. The difference in pressure coefficient between the lower and upper meridians on the surface of the cone varied nearly linearly with angle of attack at a rate of about 0.04 per degree throughout the angle-of-attack range tested. Also, the difference of pressure coefficient was sensibly independent of Mach number within the Mach number range at all angles of attack tested. Further wind-tunnel tests will be required to assess accurately the value of the cone as an angle-of-attack measuring device, especially for combined angles of attack and yaw, and to determine the optimum apex angle for the cone.

INTRODUCTION

The measurement of angle of attack of an airplane, long of great value in research, has lately become a topic of widespread interest in connection with rocket gunnery for tactical aircraft. For research purposes the measurement of angle of attack is usually accomplished with a free-floating vane; however, this device due to its fragility has been considered undesirable for use on tactical aircraft.

It has been suggested that a cone might prove to be useful on aircraft by providing an adequately sensitive measurement of angle of attack throughout the Mach number range. Furthermore, a cone would be less susceptible to damage than a vane. When the total pressure at the nose of a cone and the static pressure on the upper and lower meridians on the surface of a cone with a given apex angle are known, angle of attack, stream static pressure, and Mach number may be calculated from either supersonic theory or from predetermined calibration. A supersonic investigation of the flow about a cone of 15° apex angle at a Mach number of 1.59 and through an angle-of-attack range (0.28° to 16.1°) is presented in reference 1. However, no information on the flow about cones at transonic speeds is yet available.

As a means of determining the type of angle-of-attack calibration to be expected from cones in the transonic speed range, tests have been conducted on a 45° cone by the NACA wing-flow method. The investigation covered a range of angles of attack of -10° to 50° at zero yaw angle and a range of Mach numbers from 0.7 to 1.1.

SYMBOLS

M	stream Mach number
p_U	static pressure on upper cone surface
p_L	static pressure on lower cone surface
q	dynamic pressure $\left(\frac{\rho V^2}{2}\right)$
$\Delta p/q$	difference in pressure coefficient $\left(\frac{p_L - p_U}{q}\right)$
V	true airspeed
α	angle of attack
ρ	stream density

APPARATUS AND PROCEDURE

The details of the conical tube used in the present investigation are shown in figure 1 and a photograph is presented in figure 2. This conical tube consisted of a cone having a 45° apex angle and a 1-inch base diameter mounted on a cylindrical afterbody. Four principal orifices (0.0785 inch in diameter) equally spaced around the cone were located 0.674 inch aft of the nose. Two other orifices were located on the upper surface of the cone; one, 0.267 inch forward and another, 0.267 inch aft of the upper principal orifice. Of the six orifices, only the upper and lower principal orifices were used in the present investigation.

The conical tube was mounted 6 inches above the surface of the airplane wing as shown in figure 3 and alined parallel with the wing surface. A motor-driven actuator provided a continuous variation of angle of attack of 20° at the rate of 2° per second in a plane parallel to the wing surface so that the conical tube was always at zero yaw. The axis of rotation was at the apex of the cone. The range of angle of attack (-10° to 50°) was covered in three steps (-10° to 10°, 0° to 20°, and 30° to 50°) with the use of supporting struts which are shown in figure 3. The conical tube was first rotated through a -10° to 10° angle range, then from 0° to 20° in order to check the effect of different struts, and finally from 30° to 50° to obtain data at higher angles.

Tests were made by diving an F-51-D airplane through an altitude range of from 28,000 to 15,000 feet at local Mach numbers from 0.7 to 1.1. During each test run of approximately 10 seconds, the Mach number over the wing surface was held constant while the conical tube moved through 20° of travel. The model pressures, local static pressure, airplane impact and static pressures, model and flow angles, and normal acceleration were continuously recorded and synchronized by means of standard NACA instruments. The Mach number at the model position was determined as a function of airplane lift coefficient and airplane Mach number from a previous calibration of the flow over the wing surface at the model position.

RESULTS AND DISCUSSION

The difference in pressure coefficient $\Delta p/q$ between the lower and upper meridians on the cone surface is shown in figure 4 as a function of angle of attack α for several Mach numbers from 0.7 to 1.1. It is to be noticed that the variation of $\Delta p/q$ with α is nearly linear for angles of attack throughout the range of the tests (-10° to 50°). Throughout the range of the investigation there is no preceptible change in sensitivity with Mach number. It would appear, therefore, that the conical tube would be capable of providing an acceptable measurement of angle of attack through the transonic flight range of current airplanes.

Although the variation of $\Delta p/q$ with α is very near linear, a mean error of about 1 degree in α is apparent by the fact that the data do not directly pass the origin of the coordinates. It will also be noted that a considerable amount of scatter of the data is in evidence in figure 4, sometimes amounting to as much as $\pm 1.5^\circ$. Close examination of figure 4, however, will reveal no consistent variation of $\Delta p/q$ with Mach number within the test range. These discrepancies are believed to have arisen primarily from the small amount of play that is known to have been present in the actuating mechanism. Also, the supporting struts for the conical tube are certain to have been deflected somewhat under the air loads, especially at the higher angles of attack. Errors of this nature, arising from the elasticity of the supporting struts, have not been estimated. The lag in the recorded pressures resulting from the rate of descent of the airplane and the rotation of the model has been estimated and found to be negligible.

Since the present results indicate that $\Delta p/q$ varies almost linearly with α and there is no consistent variation of $\Delta p/q$ with Mach number, the conical tube appears to possess desirable characteristics for determining angle of attack throughout the transonic speed range. Further wind-tunnel studies will be required at subsonic and supersonic speeds in order to assess more accurately the value of the conical tube as an angle-of-attack measuring device throughout the entire Mach number range. In particular, the effect of combined angle of attack and yaw must be investigated, and the optimum apex angle of the cone must be defined. The results of the present investigation will also be of use in interpolating the wind-tunnel results through the transonic speed range.

CONCLUSIONS

A study of pressure measurements on a cone of 45° apex angle made at angles of attack from -10° to 50° and zero yaw angle through a Mach number range of from 0.7 to 1.1 by means of the NACA wing-flow method has indicated that:

(1) It appears to be possible to use a cone for determination of angles of attack of aircraft at transonic speeds by means of pressure measurements.

(2) The difference in pressure coefficient between the lower and upper meridians on the surface of the cone varied nearly linearly with angle of attack at a rate of about 0.04 per degree throughout the tested angle-of-attack range (-10° to 50°).

(3) The difference in pressure coefficient between the lower and upper meridians on the surface of the cone was sensibly independent of Mach number within the range of the tests ($M = 0.7$ to $M = 1.1$) at all angles of attack tested.

(4) Further wind-tunnel tests will be required to assess accurately the value of the cone as an angle-of-attack measuring device, especially for combined angles of attack and yaw and to determine the optimum apex angle for the cone.

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REFERENCE

1. Cooper, Morton, and Webster, Robert A.: The Use of an Uncalibrated Cone for Determination of Flow Angles and Mach Numbers at Supersonic Speeds. NACA TN 2190, 1951.

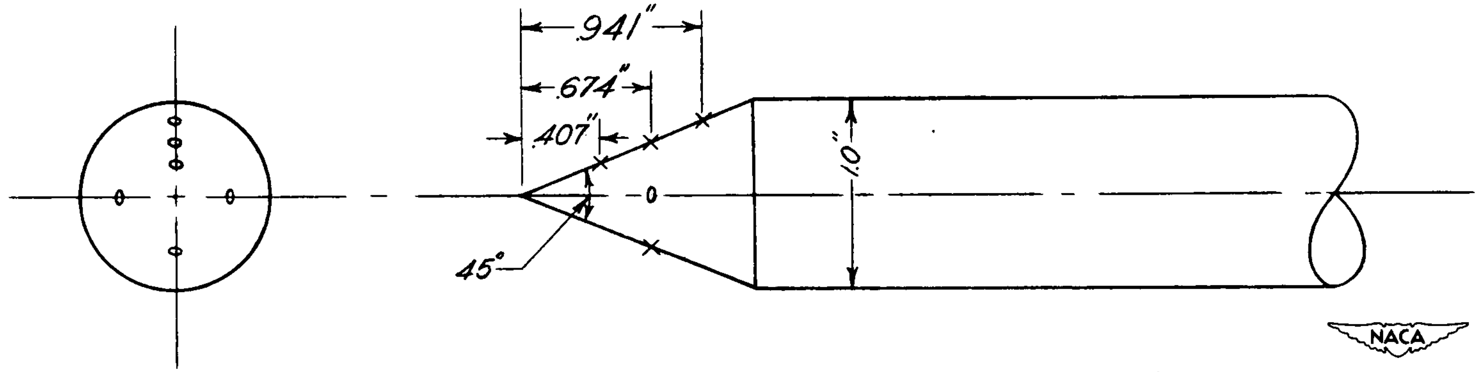

Figure 1.- Sketch of the conical tube showing dimensions and orifice locations.

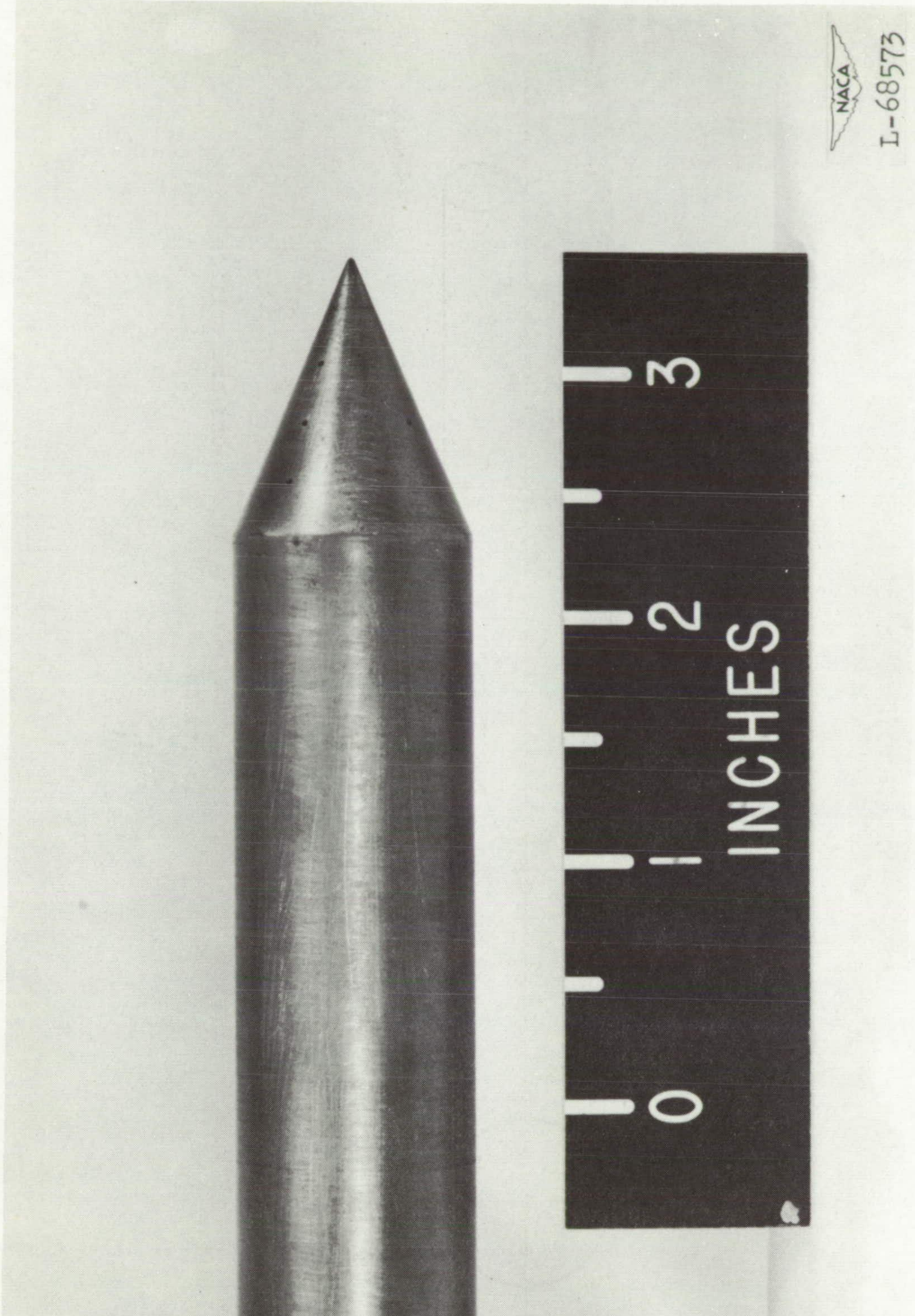

Figure 2.- Conical tube.

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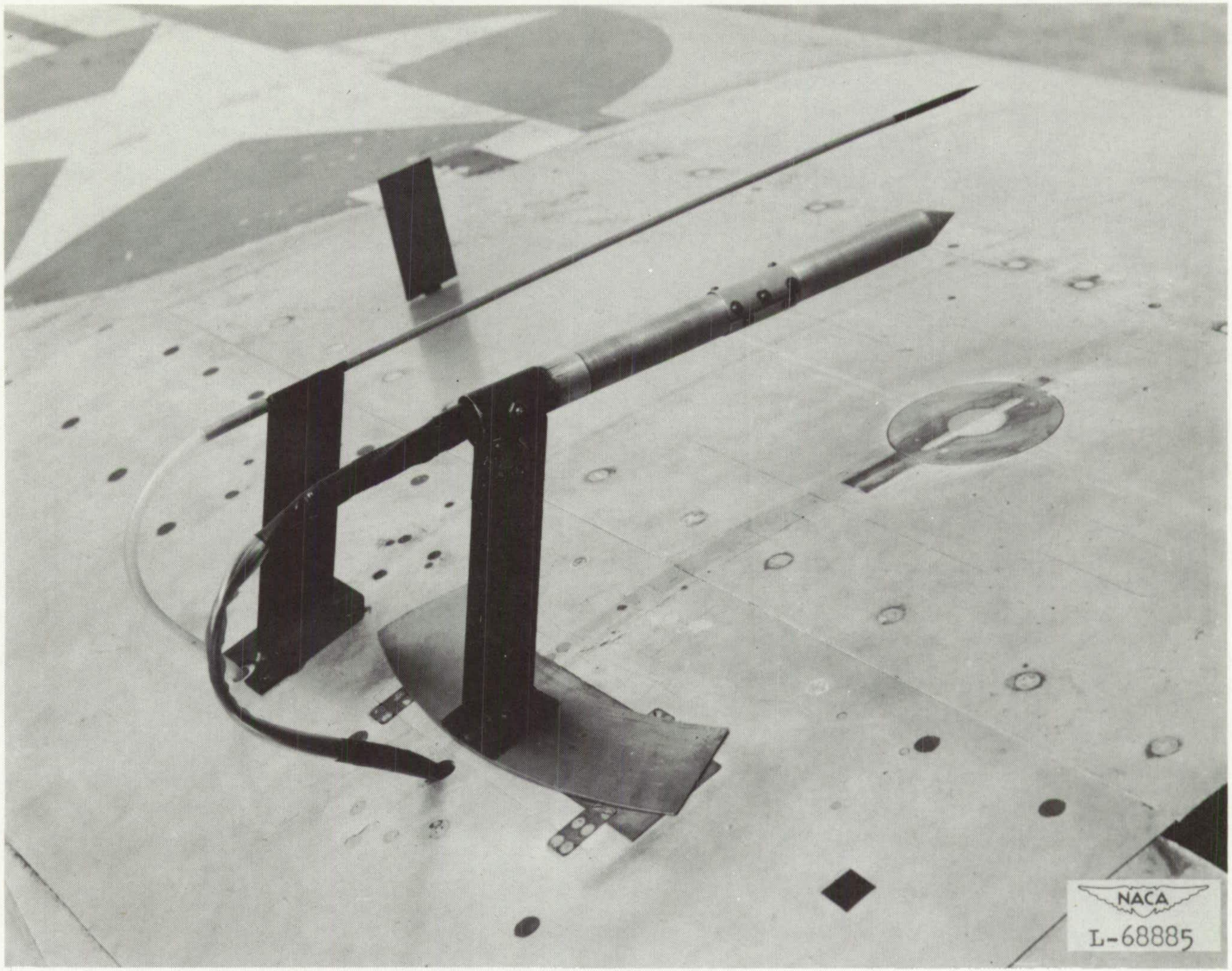

(a) -10° to 10°.

Figure 3.- Conical tube mounted on a strut for angle-of-attack range.

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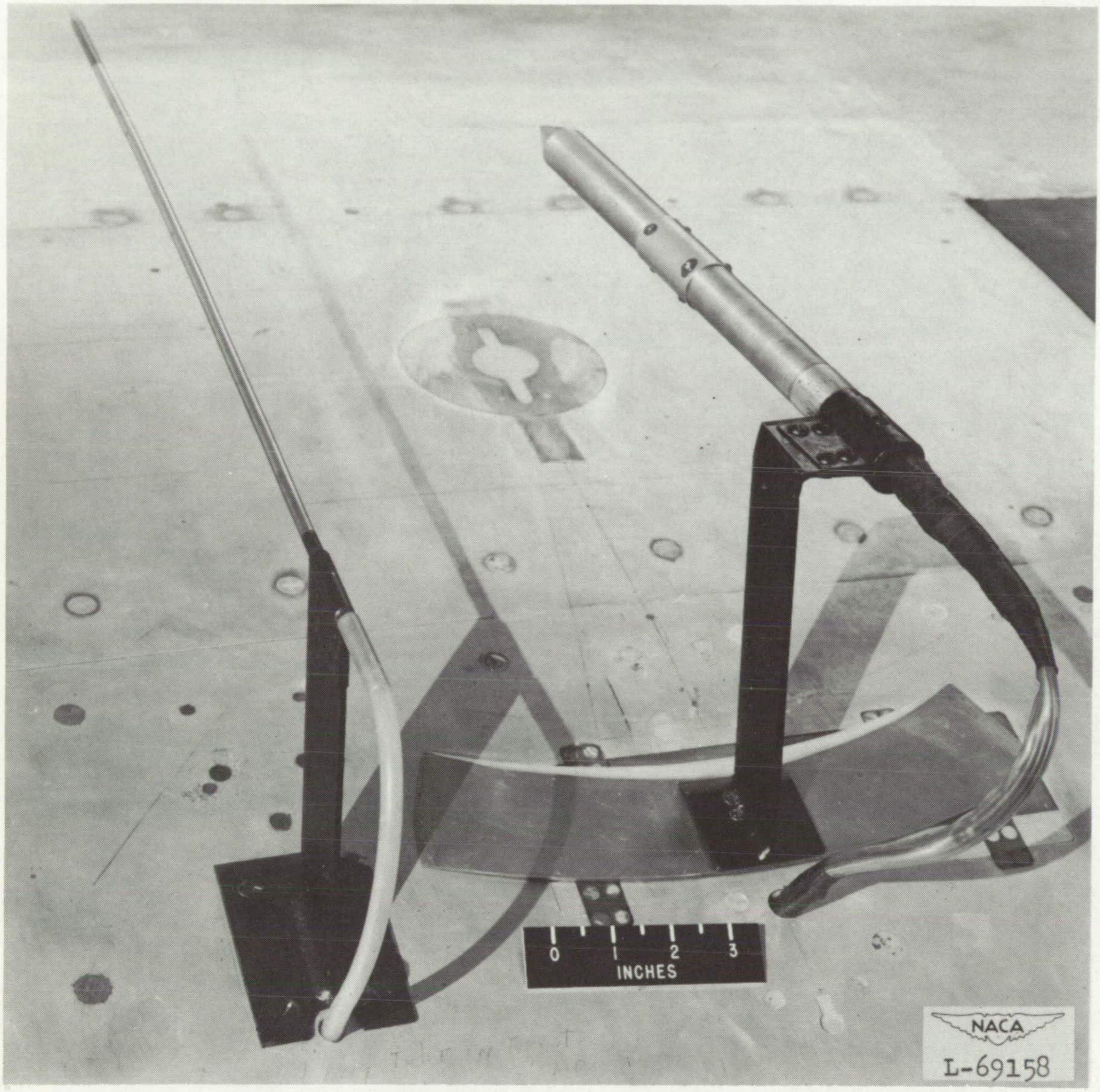

(b) 0° to 20°.

Figure 3.- Continued.

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(c) 30° to 50°.

Figure 3.- Concluded.

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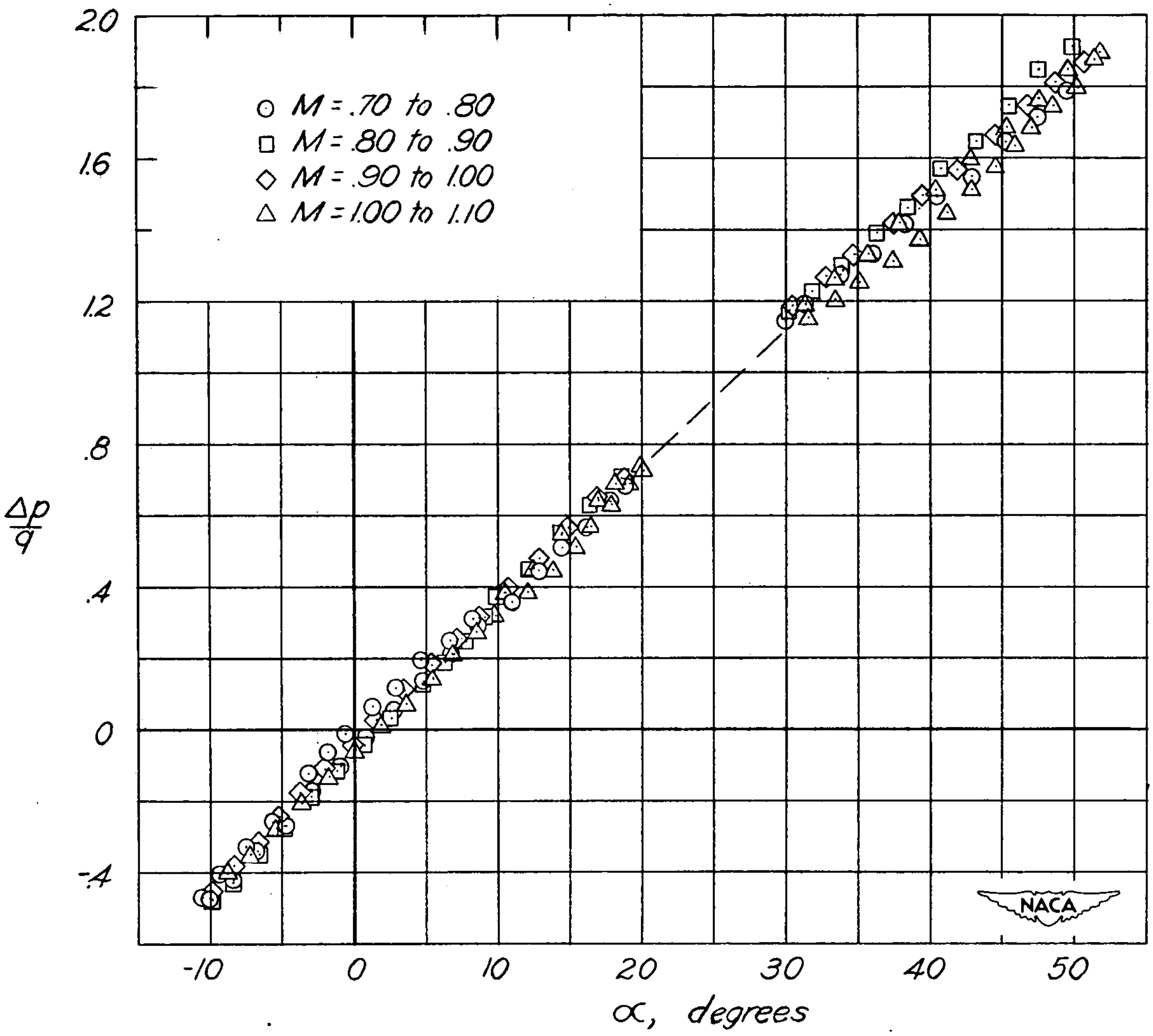

Figure 4.- Variation with angle of attack of the difference in pressure coefficient between the upper and lower meridians on the surface of a cone of 45° apex angle.