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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 250

INFLUENCE OF THE ORIFICE ON MEASURED PRESSURES

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INFLUENCE OF THE ORIFICE ON MEASURED PRESSURES.

By Paul E. Hemke.

Summary

The influence of different orifices on the result of measuring the same pressure distributions is the subject of this note. A circular cylinder is exposed to an air stream perpendicular to its axis and its pressure distribution is repeatedly determined. The pressure on the greater part of the upstream half of the cylinder apparently increases when the orifice size increases. The pressures measured on the downstream half of the cylinder do not change for the orifice sizes used in the tests. Rounding the edge of an orifice has the same effect as increasing its size.

The maximum value of the ratio of orifice diameter to radius of curvature of the surface in the plane of motion, for which no measurable error was found, is given. Values of this ratio for orifices as used in aircraft and model airfoils were found to be much less than the maximum ratio.

Introduction

The air pressure acting on an aircraft in flight is usually measured by providing an orifice at the investigated point and

connecting this orifice to a manometer by means of a tube. When measuring pressure distributions over the surfaces of model airfoils in the wind tunnel the same method is used. In the latter case the ratio of orifice diameter to the radius of curvature of the surface at the point under investigation may be quite different than in the full-size airplane. In either case no standard size of orifice is used nor is any information available which will tell the investigator what errors he may expect when he varies the size of the orifice or in some other way changes its shape.

The present investigation deals with the effect of orifice size and shape on the pressure recorded at a designated point on a body placed in an air stream. This effect was measured by making pressure distributions over a circular cylinder placed in an air stream so that its axis is perpendicular to the direction of the stream.

Apparatus

1. The Six-Inch Wind Tunnel.

The tests were made in the six-inch wind tunnel of the Langley Memorial Aeronautical Laboratory.

A photograph of this tunnel is shown in Fig. 1. Fig. 2 is a diagrammatic sketch showing the essential features of the tunnel.

A Sturtevant multivane blower B, driven by a 3½ HP. variable speed, D.C. motor M, forces the air through the passages

P. Three sets of vanes V, turn the air stream through 90° the requisite number of times until at C_1, the entrance cone, the air moves horizontally from left to right as seen in Fig. 2. After traversing the working section A, the air enters the exit cone C_2, and thence passes into the blower B.

The passages P, are of wood construction and rectangular in cross section. The horizontal passage is constructed so that its cross sections gradually increase in area from right to left. The entrance cone C, is an aluminum casting. The section at one end is a square. This is gradually changed until it becomes a circle of much smaller cross section. The cone terminates in a cylindrical piece 8 inches long, having a circular cross section 6 inches inside diameter.

The exit cone, also an aluminum casting, has a bell-shaped mouth and for the remainder of its length is a circular cylinder of constant cross section. It is fastened to the blower by means of a sheet metal sleeve.

A honeycomb H, is placed just in front of the entrance cone. The air velocity is fairly constant and with proper alignment of the entrance and exit cones, there is very little "spilling over" at the mouth of the exit cone. The air velocity can be varied from 20 M.P.H. to 118 M.P.H.

2. Apparatus for the Orifice Tests.

A photograph of the apparatus in place in the tunnel is shown in Fig. 3. Fig. 4 is a diagrammatic sketch of the apparatus.

It consists of a brass cylinder 1 inch in diameter, and 8 inches long. The cylinder is placed symmetrically in the air stream so that its axis is at right angles to the latter. A hole coaxial with the cylinder extends from one end to the center of the cylinder. This hole is connected at one end by means of a rubber tube to a manometer. At the other end it is connected by means of a radial hole to an orifice on the surface of the cylinder.

A circular disc graduated in degrees is fastened to one end of the cylinder. The angular position of the radial hole terminating in the orifice is then known.

Method of Making Tests

The tests consisted in making pressure distributions around the cylinder for each type of orifice used. Pressures were recorded at intervals of $2\frac{1}{2}^{\circ}$ to 10°. The dynamic pressure was held as constant as possible. Its magnitude was measured by means of a static plate located on the side of the tunnel just ahead of the entrance cone. This static plate had been previously calibrated against a Pitot static tube placed in the working or test section of the tunnel.

Each orifice was tested for two dynamic pressures corresponding to 4 in. and 12 in. of water, respectively. The orifices varied in diameter from .008 in. to .250 in. There were two series of these orifices, one having sharp edges and the other rounded edges.

Results

1. Orifices with Sharp Edges.

The tests show that the measured pressure varies chiefly over the forward or upstream side of the cylinder as the orifice size is changed. If the stagnation point of the flow coincides with the zero position of the orifice, then the changes observed are limited to the 0° - 90° range of orifice positions. No appreciable change occurs in the interval 90° - 180°, even for the greatest change made in the orifice diameter. This is shown in Figs 6 and 7, where the pressure distributions are plotted for the smallest and largest orifices. The minimum values of the pressure recorded differed in this instance by 17 per cent from the dynamic pressure.

In Figs. 8 and 9 the pressures recorded at certain stations on the cylinder are plotted against orifice diameters. The pressures change slowly up to diameters of .06 in. Thereafter the changes are more rapid, particularly at the 70° station.

Let R = ratio of orifice diameter to radius of curvature of the surface at the point where the orifice is located. The air flow is assumed to be two dimensional. We assume further that the pressures measured with the smaller orifices are practically correct. It appears then from the curves in Figs. 8 and 9 that practically no error in the pressures measured occurs when $R = .06$. The experimental error was about 2 per cent of the dynamic pressure. The error increases proportionally up to

a value of $R = .12$ where it is 5 per cent of the dynamic pressure. Thereafter the errors increase rapidly.

The tests for the two Reynolds Numbers corresponding to the two velocities used show a close agreement.

2. Orifices with Rounded Edges.

The series of rounded orifices used were constructed as shown in Fig. 5. A sharp edge orifice (a), of diameter d was first tested. The edges were then rounded to a radius r, as shown in (b), and this new orifice was then tested. The next orifice in the series (c), was then made having a diameter $d + 2r$ and sharp edges.

In all cases tested the difference between the pressure distributions obtained when orifices of type (b) and the next in the series of type (c) were used, did not exceed the experimental error. Fig. 10 shows a typical curve comparing the pressure distributions obtained when using a rounded and sharp edge orifice.

Conclusions

The tests show that with the cylinder of 1 in. diameter, orifices of diameter .06 in. may be used without seriously affecting the pressure distribution over the cylinder.

If the pressure distribution obtained for the smallest orifice is considered as standard, then it is possible to make cer-

tain conclusions for the larger ones. If the ratio of orifice diameter to radius of curvature of the surface in the plane of the motion (two dimensional) is .06, the pressures are not in error by more than 2 per cent of the dynamic pressure. For values of this ratio equal to .12 the errors do not exceed 5 per cent of the dynamic pressure. With larger values of the same ratio the variations from the standard are irregular and more rapid as well as larger.

On this basis of comparison tests made on models are fairly accurate as far as orifice diameter is concerned. For the pressure distribution tests made at the Langley Memorial Aeronautical Laboratory the largest value of the ratio of orifice diameter to radius of curvature of the wing section was found to be about .005. On full-sized airplanes this ratio is considerably less.

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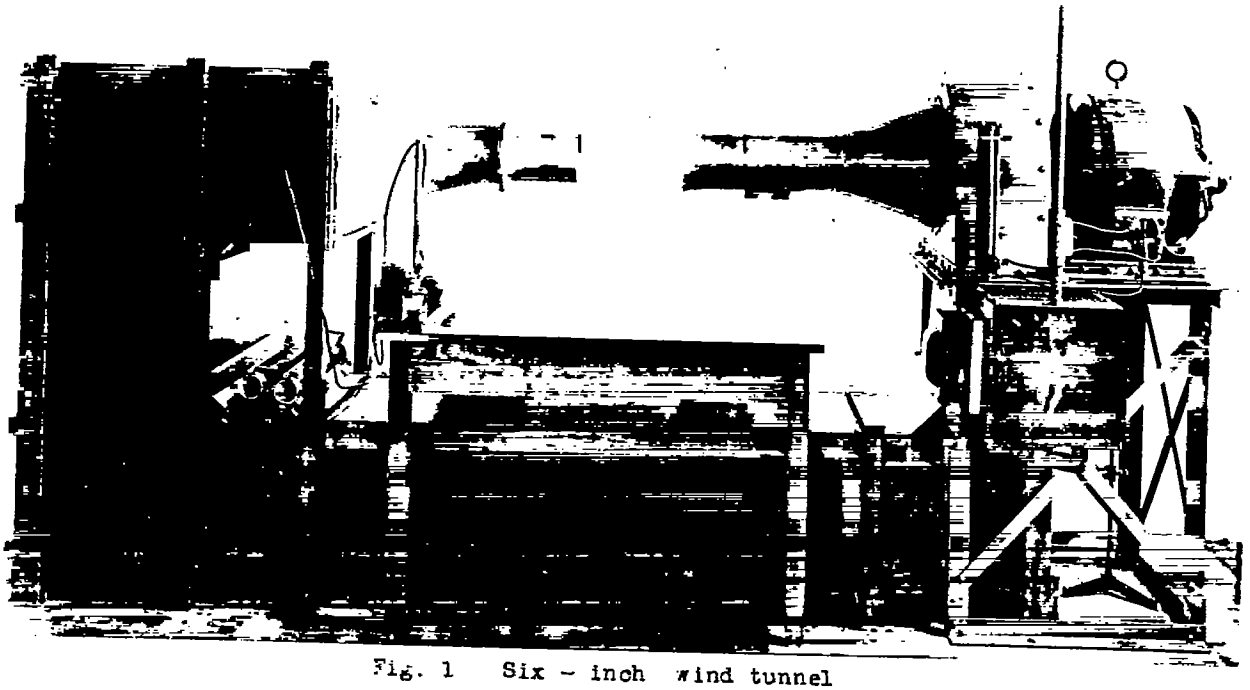

Fig. 1 Six - inch wind tunnel

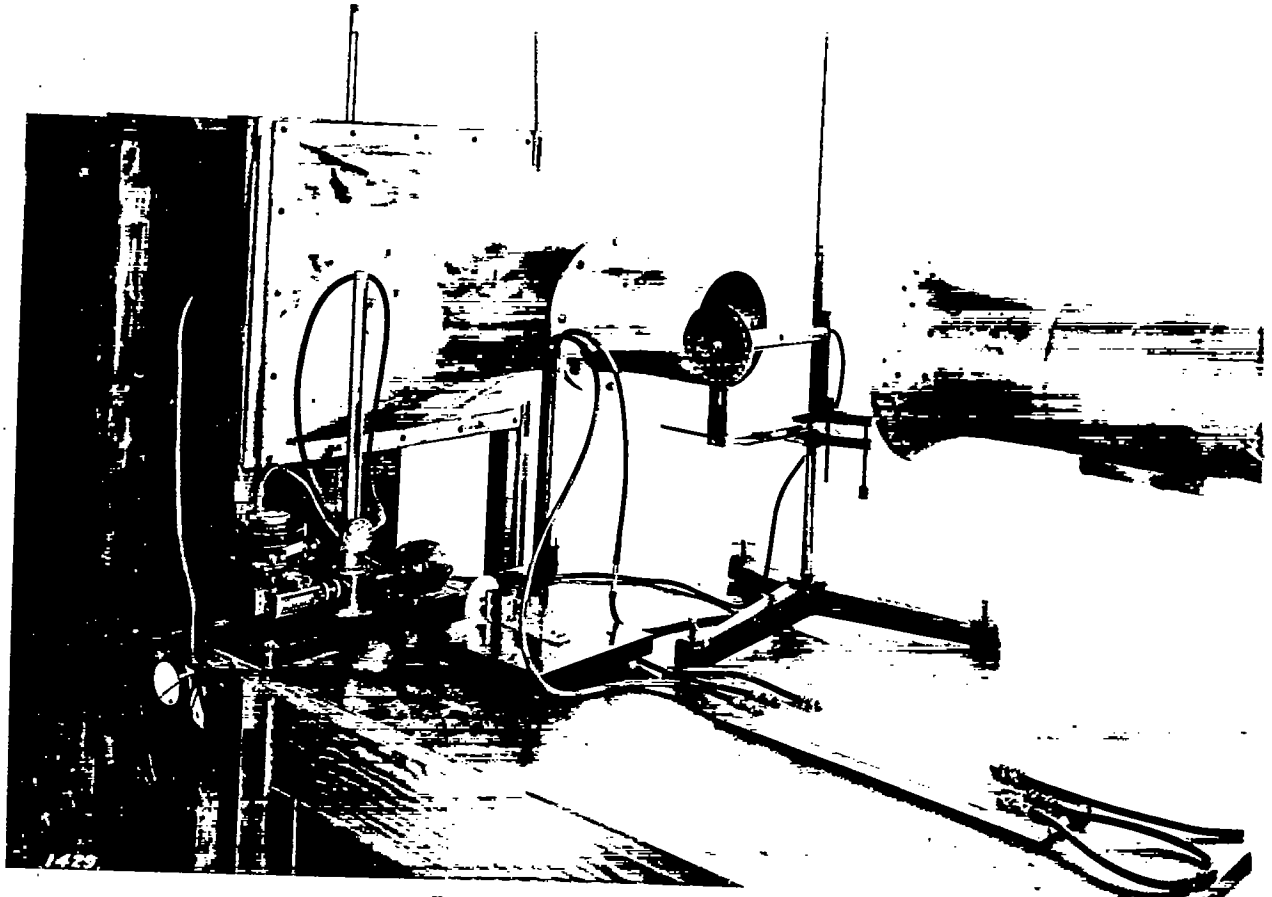

Fig. 3 Apparatus in place

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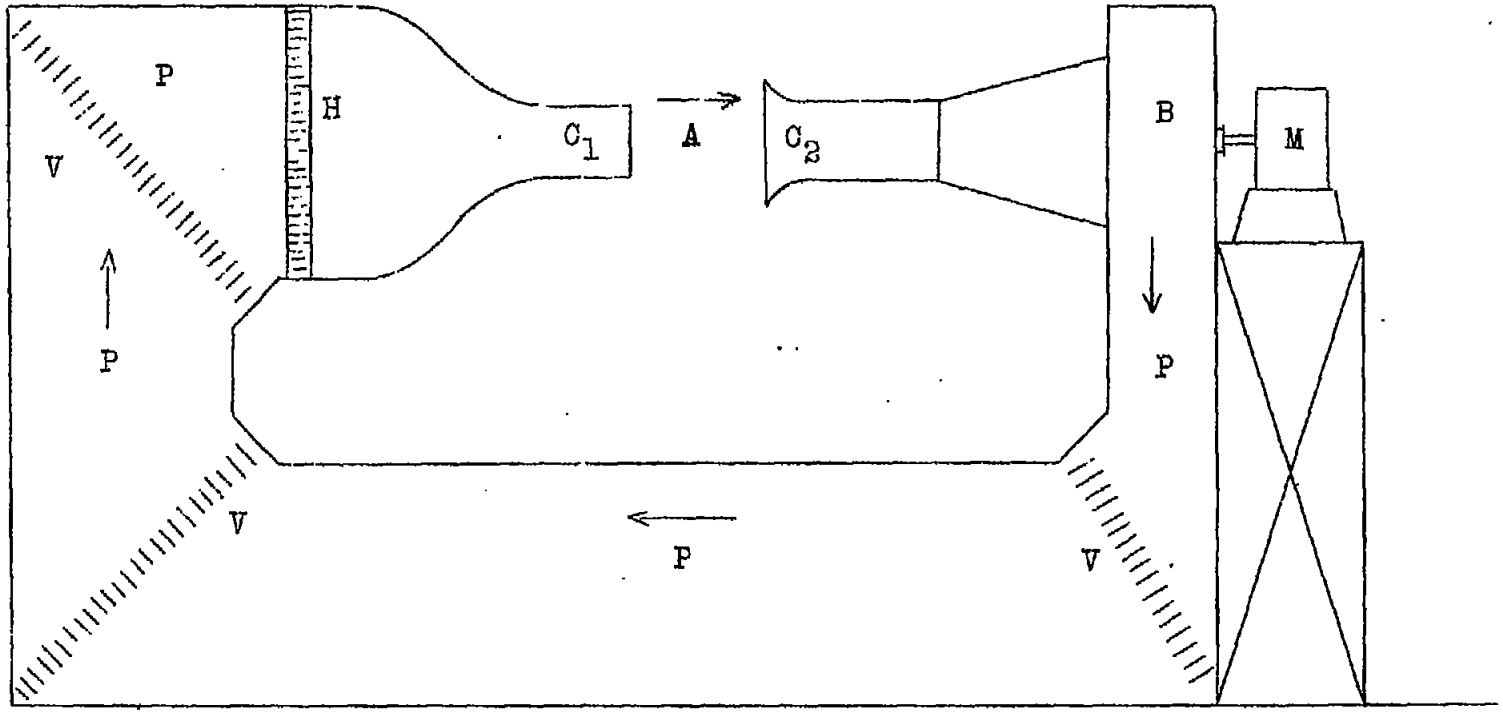

Fig.2 Sketch of N.A.C.A. six inch wind tunnel.

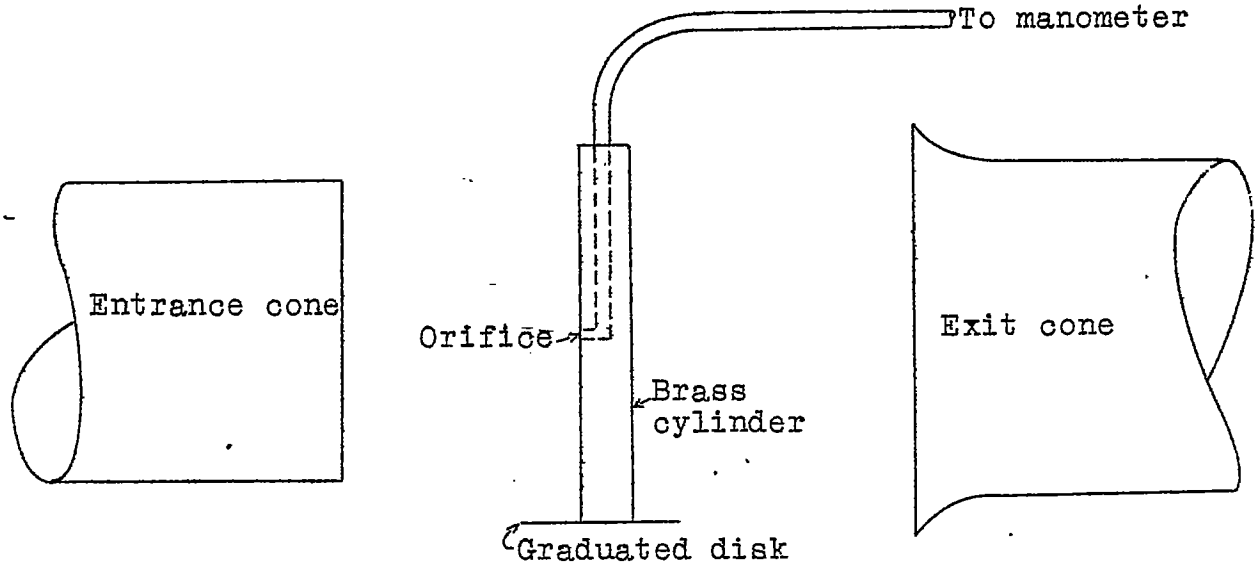

Fig.4 Cylinder and orifice in place.

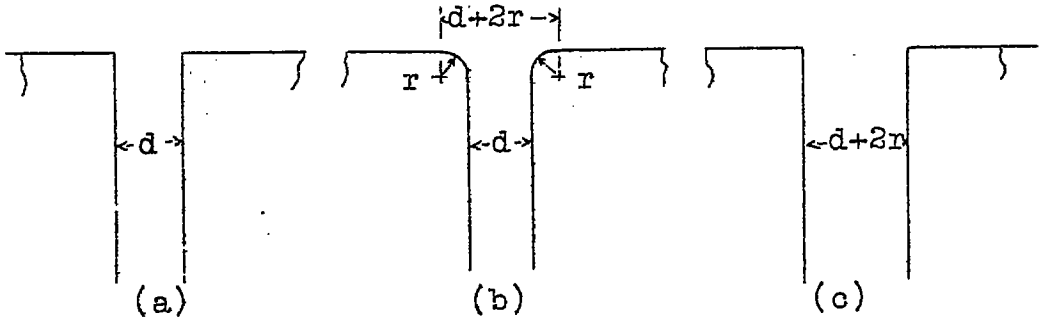

Fig.5 Orifice sections.

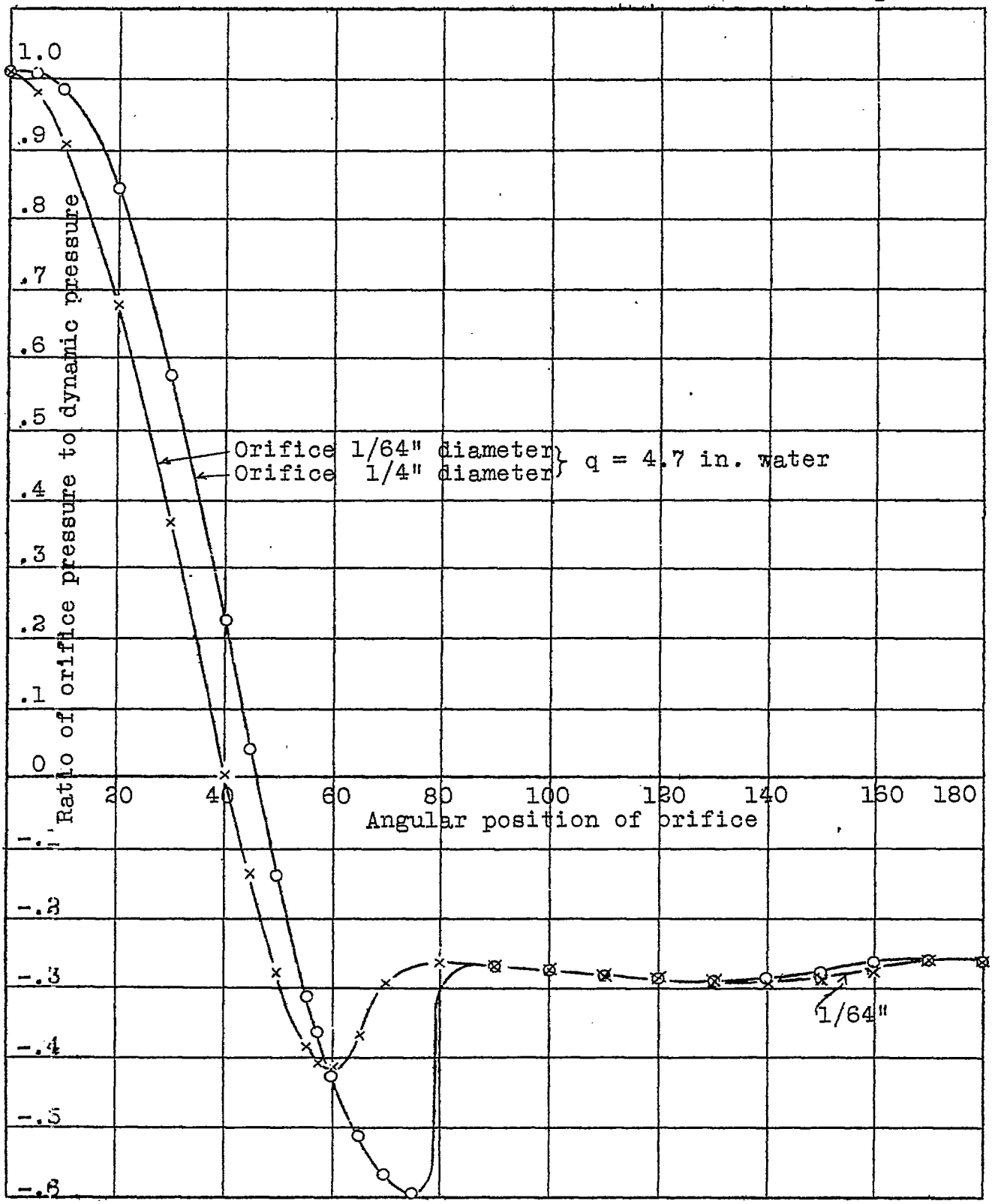

Fig.6 Pressure distribution with orifices of different diameters.

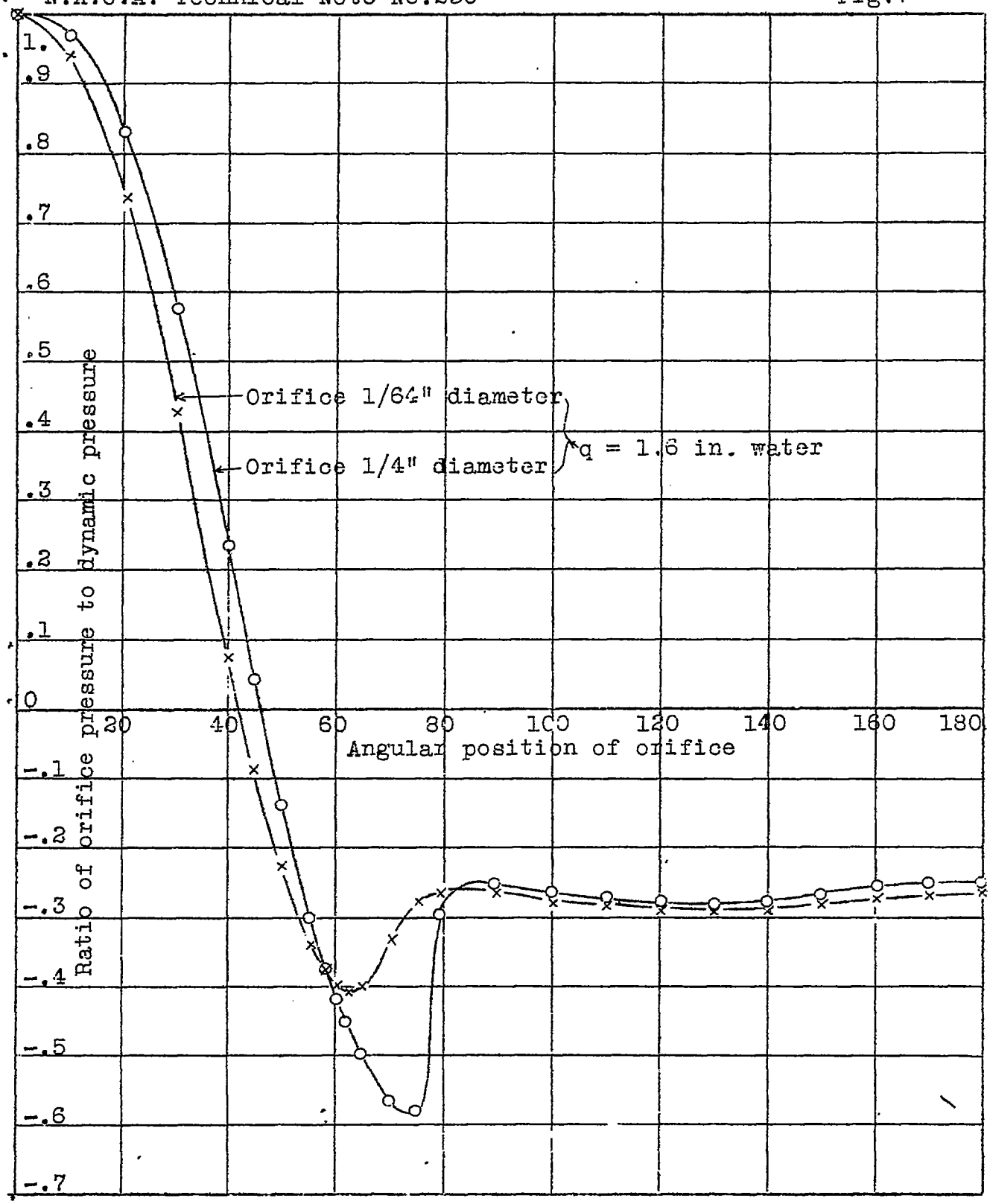

Fig.7 Pressure distribution with orifices of different diameters.

Pressure for orifice positions 90°-180° plot as horizontal lines located between two dotted lines. Dynamic pressure 5 inches of water.

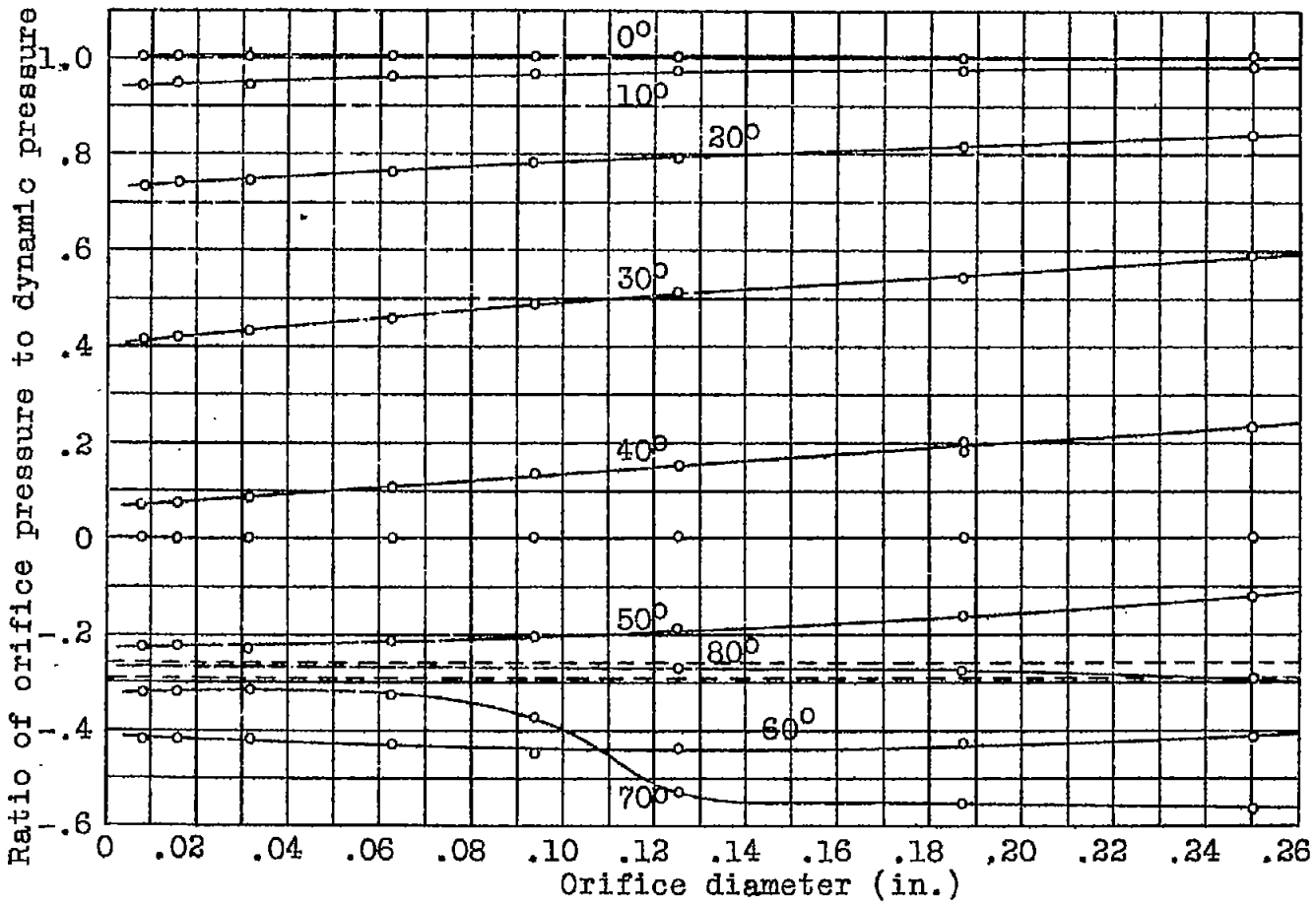

Fig.8 Pressure at various orifice positions plotted against orifice diameter.

Pressure for orifice positions 90°-180° plot as horizontal lines located between two dotted lines. Dynamic pressure 2 inches of water.

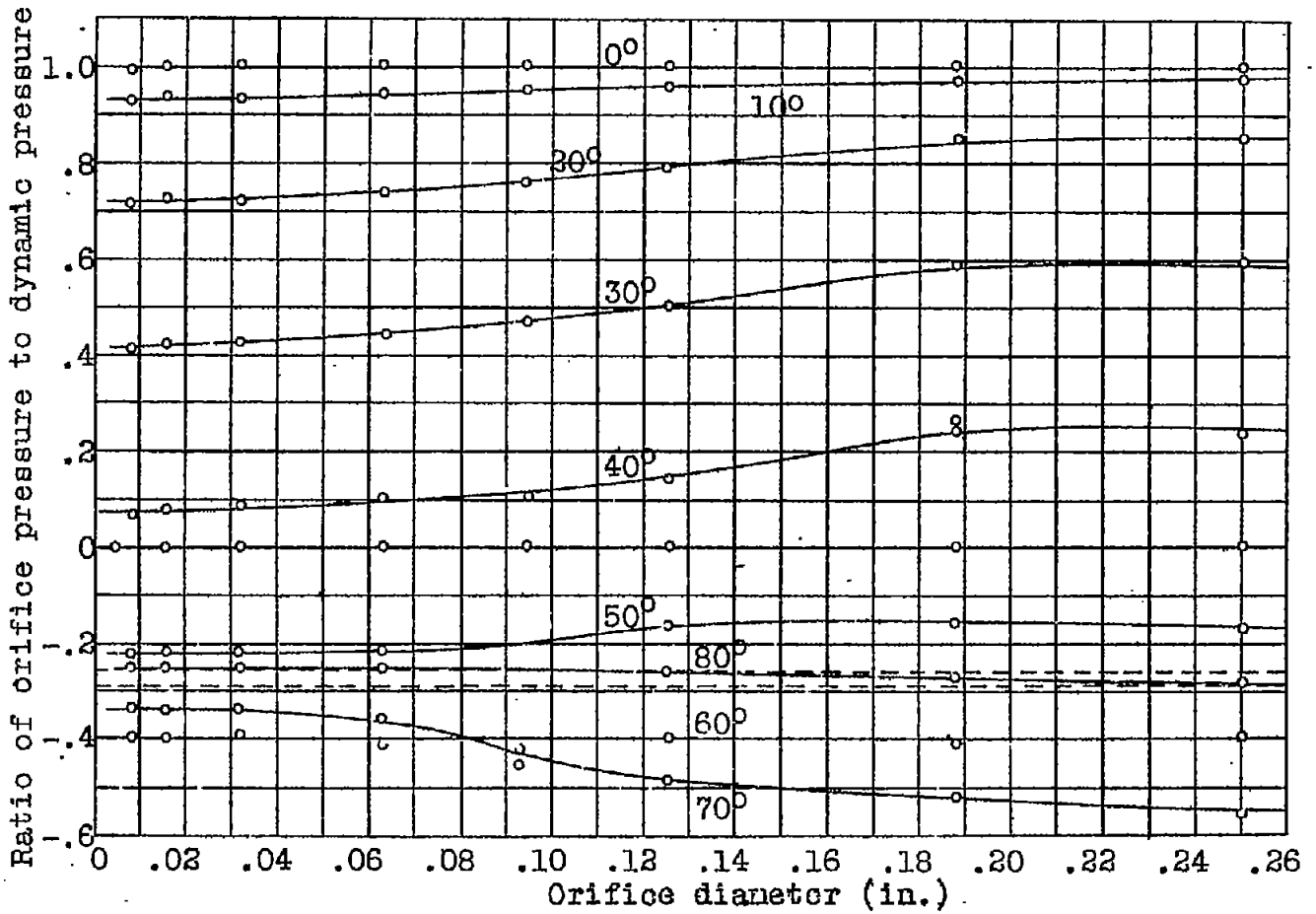

Fig.9 Pressure at various orifice positions plotted against orifice diameter.

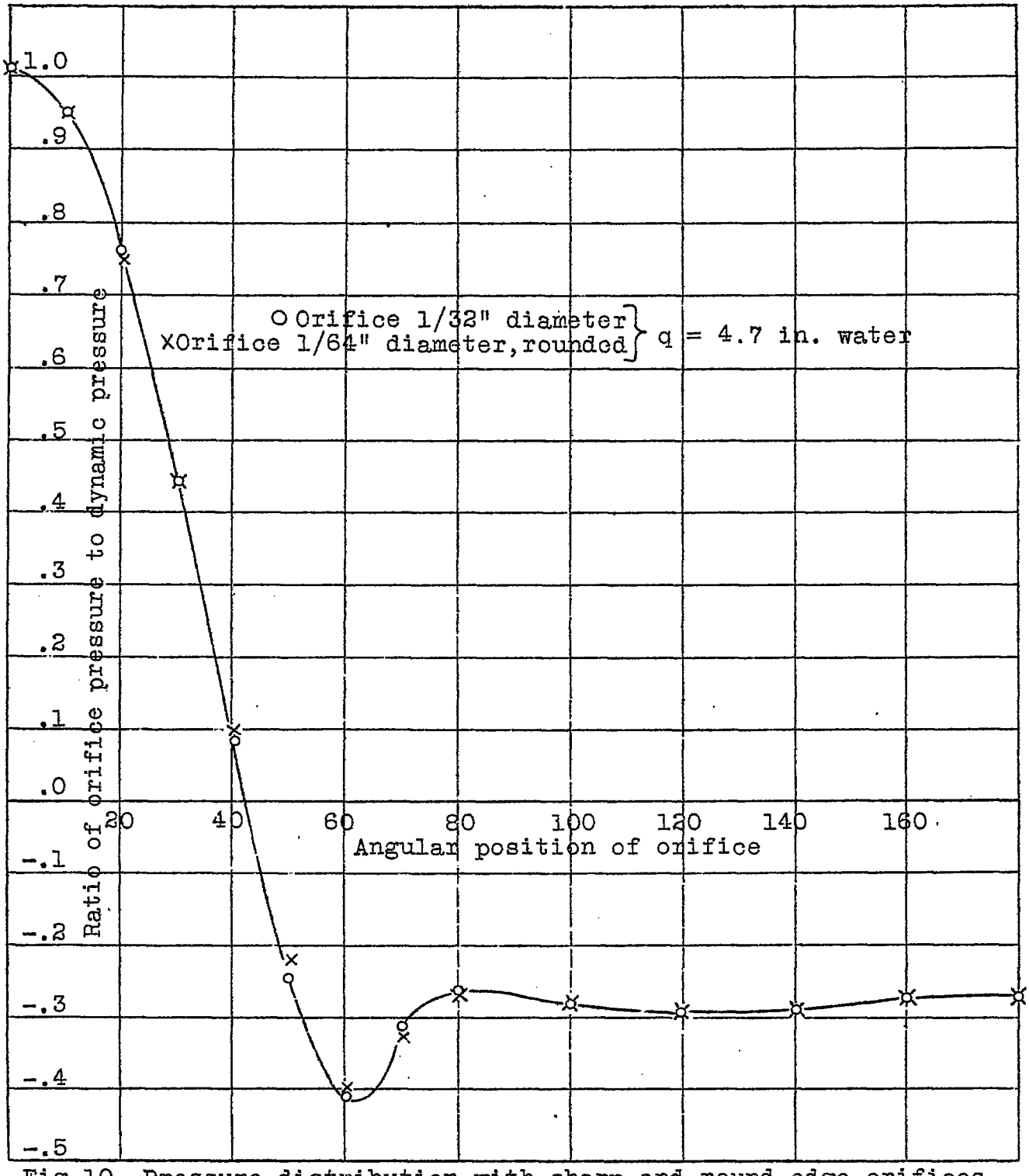

Fig.10 Pressure distribution with sharp and round edge orifices.