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# PITOT TUBES FOR THE MEASUREMENT OF PRESSURE AND VELOCITY IN FLOWING WATER

- - -

A Translation

by

EDWARD F. WILSEY

- - -

Denver, Colorado

January 15, 1938

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# PITOT TUBES FOR THE MEASUREMENT OF PRESSURE AND VELOCITY IN FLOWING WATER

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A Translation of

Stauröhren zur Messung des
Druckes und der Geschwindigkeit
im fliessenden Wasser

by

R. Winkel

in

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- - -

Translated by

EDWARD F. WILSEY, ASSISTANT ENGINEER

- - -

Denver, Colorado,

January 15, 1938

Among the various methods for measuring the velocity and pressure at a certain point in flowing water, pitot tubes are of great importance. The behavior of such tubes when submerged and held in place in a stream depends on the fact that the kinetic energy of the water is transformed into pressure energy as a result of the resistance offered to the flow by the area of the tip of the. If a hollow tube is bent to a right angle and held in such a way that one leg is oriented against the stream and the other is held upright, water approaching with a velocity, v, pushes a column of water up the rising leg to a certain height, above the surface of the stream, this vertical distance being directly proportional to the velocity head, $\frac{V^2}{2g}$, at the opening on which the flow reacts. The height, $\triangle$, is exactly equal to $\frac{V^2}{2g}$ if the pressure on the opening is not altered by the lateral spreading of the flow lines at the rim of the opening.. In any event, the relation,

$$\triangle = f\left(\frac{V^2}{2g}\right)$$

should be determined from a calibration; after which the velocity at the opening can be computed from the observed value of $\triangle$.

Because the direct reading of $\triangle$, referred to the surface of the stream as a datum, is subject to difficulties, the vertical leg is lengthened by joining it at a certain point above the surface of the stream, or glass tube which is supplied with a stop-cock at its upper end. Then the column of water in the glass tube can be sucked up to a convenient elevation for reading. When this is done, a second tube is required. The opening at the submerged end of this tube is in a plane

parallel to the direction of the stream lines; thus no impact effect is registered in this tube and the top of the water column will stand at the same elevation as the surface of the stream. Of course, there are small disturbances at the submerged opening because water flowing past it is divided at the edge directed upstream and, therefore, eddies are set up, though they are indeed small. The net change in the height of the water column as a result of these eddies amounts to only a small fraction of the differential head and can be determined during the calibration of the pitot tube. Hence this second tube measures the hydrostatic pressure acting on the opening (assuming a constant depth of flow at the point of measurement) while the first tube measures the dynamic head. Suppose that the ~~second~~ static tube is also lengthened so that its upper end can be connected to the previously-mentioned stop-cock. Then the two water columns can be drawn up simultaneously by a partial vacuum to a convenient elevation. However, the column in the dynamic tube will still stand $\Delta$ higher than in the static tube.

The first design of such a measuring device seems to have been developed by H. Pitot in 1730. Since the differential head, is quite small for low velocities of flow (less than 0.5 feet per second), the static tube ~~was~~ has also been bent similar to the dynamic tube but was oriented in the opposite direction, that is, downstream. A suction is developed at this downstream opening which increases the differential head. However, the increase is not sufficient to be equal to $2(\frac{V^2}{2g})$; on the contrary, the differential head is little more than the velocity head $(\frac{V^2}{2g})$. New experiments and ~~experiences~~ continued use have resulted

in a continuous supply of new designs. Many of these are available and have been calibrated in the Berlin Hydraulic Laboratory.

The reading of the level in the glass tube is complicated by the meniscus; the smaller the diameter of the tube, the greater the adhesion of the water to the glass, raising the boundary of the surface above its center. Strong capillary action is a distinct disadvantage in small bore tubes and is objectionable in tubes less than about 10 millimeters in diameter. Furthermore large errors are introduced by parallax when transferring the height of the edges to the scale. If the tube is dirty, the meniscus is apt to be inclined. If the tubes are not uniform in diameter, the columns will not be of comparable heights because the capillary action in each tube is different. All of these factors introduce errors of observation which increase in relative importance the smaller the differential head. The following methods of decreasing these sources of error are used in the Berlin laboratory: A strip of mirror with suitable scales on each side, as shown in figure 1, is placed close behind each glass tube and is long enough to cover the full range of differential head. The meniscus appears in the mirror even though the column is read from the side. A reading is made when the meniscus and its image in the mirror have a common horizontal boundary line which can be easily read on either scale. Another device consists of a movable ring around a tube and vernier attachment which fits snugly to a base scale. With this arrangement, the meniscus is read in line with the top of the ring. The following example shows the effect of an error in $\Delta h$ equal to $\pm \frac{1}{2}$ millimeter arising from any of the previously-mentioned sources of

error. With $v = 0.14$ meters per second (0.45 feet per second), the the corresponding velocity head is $\frac{v^2}{2g} = h = 1$ millimeter. Assuming a coefficient, $c = 1$ obtained by calibration, for an error of 1/2 millimeter, the percentage error amounts to 50 percent and the computed velocity may be either 0.10 or 0.17 meters per second. For $v = 0.10$ meters per second corresponding to a velocity head, $\frac{v^2}{2g} = h =$ 0.51 millimeters, other conditions remaining the same, the error may amount to 100 percent, the computed velocity being either 0.14 or 0 meters second. For still smaller velocities the percentage error becomes very great. As the velocity increases the percentage error decreases and the spread of the computed velocities also becomes less.

Unfortunately, devices for magnifying the reading (for example oil on water) are not permissible for velocities less than 0.10 meters per second (0.33 feet per second) for other factors enter which produce additional errors. Therefore for velocities of about 0.1 or even 0.14 meters per second (0.33 or 0.45 feet per second) the use of Pitot tubes is not to be recommended.

Rubber tubing is used to connect the glass tubes to the two metal legs. Air can separate in the tubes when the water columns are sucked up to a height of about two meters (6.5 feet). This air usually collects in level sections of the tubes to form air bubbles or air pockets. For a given head, air bubbles create a positive reading error. It is therefore strongly recommended that the rubber tubes be freed from air pressing to a reading by squeezing the tubing from the lower end to the top.

Small differential heads can be read with greater precision

by an inclined gage. Or again, after drawing up the two water columns to eye-level using an air pump and then closing the air cock, the space above the water columns can be filled with some fluid which floats on water such as benzine. After this is done the third cock is closed (see figure 2). The apparatus now has the form shown in figure 2 to the left of the dotted line A-A. Let $\gamma$ = the specific gravity of the auxiliary fluid and assuming c = 1, then for the horizontal line r - r', we have for equilibrium:

$$p_1 = 1H$$

and

$$p_2 = \gamma H$$

Therefore

$$\Delta p = p_1 - p_2 = (1 - \gamma)\, H = 1h$$

$$H = \left(\frac{1}{1-\gamma}\right) h = nh$$

For a $\gamma = 0.9$, n = 10 and H = 10h, that is, the original differential head, $h = 1(p_1 - p_2)$ is magnified 10 times. For large velocities, however, the glass tubes must be very long and readings can no longer be made at the eye level. Therefore this device is only convenient to use for velocities less than 1.2 meters per second (4 feet per second). Velocities between 0.3 and 1.2 meters per second (1 to 4 feet per second) can be read with sufficient accuracy by this method. No great confidence can be placed on readings made by this method for velocities less than 0.1 meter per second (0.33 feet per second). Since the openings to the stream flow are small (say about 1 millimeter), and the internal diameter of the glass tubes is large (say 9 to 11 millimeters), considerable time intervals are required between readings in order that the inflow and outflow from the tubes adjust themselves. Often this

precaution is not sufficiently observed. The external forces for low velocities are not sufficient to overcome the resistance (cohesion and wall friction) which oppose the motion of the fluid through the whole system consisting of glass tubes, rubber tubing and metal legs. This is especially true with unfavorable external temperatures. Thus with v = 0.1 meters per second (0.33 feet per second), the differential head, $\frac{V^2}{2g}$ = 0.00051 meter = about 1/20 centimeter of water. On 1 square centimeter of the cross-sectional area, the force amounts to

$$F = 1 \text{ gram/cm}^3 \times 1 \text{ cm}^2 \times \frac{1}{20} \text{ cm} = 0.05 \text{ gram}$$

With v = 0.05 meters per second (0.16 feet per second), this force amounts to only 13 milligrams. It is therefore self-evident that reliable measurements cannot be anticipated for velicities of 0.05 meters per second or less unless some other method is available. This same limit applies also to reliable measurements with current meters of the present day sensitivity.

The Berlin laboratory has made systematic tests on the properties when used with water of various auxiliary fluids such as paraffin oil, anise oil, petroleum, machine oil, ethyl ether, benzine, toluene, nitrobenzine, etc.). These are divided into the following three groups:

1. Those whose specific gravity is less than 1; $\gamma < 1$
2. Those with $1 < \gamma < 2$
3. Those with $\gamma > 2$

Fluids in groups 1 and 2 increase the reading, those in group 3 decrease the reading of the differential head in the glass tubes. A U-tube is used in connection with the last two groups. In this case

$$H = \frac{1}{\gamma - 1} h = nh$$

Fluids whose specific gravity is close to 1, although theroetically they produce the greatest magnification of reading, cannot be used because they have a tendency to mix with water, forming streaks

Single space within double spaces between items

Group 1: $\gamma < 1$

1. Ethyl ether (0.74) n = 3.85; good meniscus on water; its specific gravity generally varies when it is in contact with water.

double space

2. Anise oil (0.98 - 0.99), n = 50 to 100; clings to and readily congeals on glass; has tendency to form streaks in water.
3. Benzine (0.884), n = 8.6; must be colored (for example with iodine); good meniscus; after long contact with water forms a layer of scum at the surface of separation; strongly corrosive to rubber tubing.
4. Fennel oil (0.97 ) n = 33.3; similar properties to anise oil.
5. Camphor oil (0.92) n = 12.5; is attacked by water, hence not stable.
6. Linseed oil (0.94) n = 16.7; castor oil (0.97); rape oil (0.91); olive oil (0.92); turpentine (0.87); and whale oil (0.92) n = 12.5; in contact with water some will form streaks and some cloudy emulsions.
7. Mineral oil (machine oil) (0.90 to 0.93) n = 10 to 14; adheres tenaciously to glass; some oils are not stable and others are very viscous.
8. Paraffin oil (0.868) n = 7.7; good meniscus in water; stable; adheres slightly to glass walls;
9. Petroleum (0.79 to 0.82) n = 4.8 to 5.6; clings somewhat to glass walls; forms a scum at the surface of separation after long contact with water.
10. Toluene (0.872) n = 7.5; good meniscus; stable after a month's con-

tact with water; no need to be colored because it refracts light well, therefore is well suited as an indicator.

Group II; $1 < \gamma < 2$

1. Aniline (1.02 to 1.04) n = 50 to 25; shows tendency to form streaks when in contact with water.
2. Nitrobenzine (1.15 to 1.20) n = 6.7 to 5. Freezes at +8° C. (46° F.) The vapor is dangerous to health; after sometime a grayish-white layer of scum forms at the surface of separation between the water and nitrobenzine. This floats in the water in flakes. The meniscus is not stable.
3. Carbon disulphide (1.29) n = 3.45; thin fluid; does not cling to glass and is stable; recommended as suitable (pungent odor).

Group III; $\gamma > 2$

1. Bromoform (2.9) n = 0.53; good meniscus, which is slightly convex toward the water; disagreeable odor, poisonous; becomes cloudy after standing long; appears to be slightly soluble in water.
2. Mercury (13.5 to 13.9); n = 0.08 to 0.078; stable and suitable.

Begin double space again

Many of these fluids, although their specific gravity changes only slightly when in contact with water, nevertheless may cause errors in measurements requiring a considerable period of time. Figure 2 shows a ~~[illegible]~~ scheme by H. Krey for determining the specific gravity of the auxiliary fluid while a test is in progress. For this purpose, the heights a and b are read in addition to the differential head, H. For equilibrium at

the horizontal plane passing through r - r', assuming the specific gravity of water to be unity, we have

$$(\gamma b + \gamma Z) + (ly + la) - (yZ + lb) - ly = 0$$

or

$$\gamma b + la = lb$$

and

$$\gamma = \frac{b-a}{b} = 1 - \frac{a}{b}$$

The first equation for H may now be written:

$$H = \frac{p_1 - p_2}{1-\gamma} = \frac{b}{a}(p_1 - p_2)$$

The actual specific gravity of the auxiliary fluid at the time of measurement can be computed knowing the ratio $\frac{a}{b}$. For example, if ethyl ether is employed for the auxiliary fluid, its nominal magnification value of 3.85 could be much more accurately determined.

Figures 3 to 22, inclusive, show the various types of Pitot tubes tested by the Berlin laboratory. The results of the calibrations and also special comments are included in these figures. Values of c as defined by

$$h = c\,\frac{V^2}{2g}$$

are given for various angles of flow measured from the axis of the upstream dynamic leg. However, in general, these angular flows only included deviations in the horizontal plane.

Since in practice, conditions of flow are usually present in which the stream strikes the dynamic opening from above or from below, or from one side or the other (turbulence), only those Pitot tubes are suitable whose coefficients follow the cosine law or remain constant throughout an angularity of +20 to -20 degrees. Furthermore, those Pitot tubes which are completely symmetrical with respect to the axis of the dynamic leg are to be preferred. Graphs of C in relation to the angle of incidence of

of the flow measured from the axis of the dynamic leg are shown in figure 23 for some of the Pitot tubes. Small variations in c are reflected in smaller variations of v computed from

$$v = \sqrt{c} \quad \sqrt{2gh}$$

For example, the Pitot tube in figure 6 gives the following variation in v from its value at $0^{\circ}$ for an angularity of $+20^{\circ}$ or $-20^{\circ}$.

$$\frac{\sqrt{0.985}}{\sqrt{0.941}} = 1.025 = 2.5\%$$

The same computed for the Pitot tube in figure 12 amounts to only 1.5 percent. This tube appears to be the best of those tested. In general, the coefficient of an ordinary Pitot tube does not vary appreciably with the velocity. Whether this is true for velocities less than 0.2 meters per second (0.65 feet per second) is doubtful because measurements of such velocities are not sufficiently reliable. For this reason, measurement of velocities lower than 0.65 feet per second should not be attempted with a Pitot tube. Also any Pitot tube whose coefficient varies with the velocity should not be used. The flow through the venturi pipes in figures 21 and 22 is apparently influenced by the frictional resistance. An investigation showed that c for such tubes follows Reynold's law of similitude. The investigations with venturi type Pitot tubes were continued after this paper went to press.

According to the above results, the pressure and velocity of flowing water can be measured reliably by Pitot tubes for velocities ordinarily encountered in streams or from 0.2 to 3 meters per second (0.65 to 11 feet per second) providing a Pitot tube is employed whose coefficient does not vary enough to create errors of more than 5 per-

cent in flow oscillating between an angularity of from $-20^{\circ}$ to $+20^{\circ}$. Such flow is likely to be encountered in turbulent streams (meandering streams). Pitot tubes which are symmetrical about the axis of the upstream dynamic leg are particularly suitable.

Velocities from 0.1 to 0.15 meters per second (0.33 to 0.5 feet per second) cannot be determined with sufficient accuracy unless some means of magnifying the differential head is used.

All devices for magnifying the differential head fail for velocities less than 0.1 meter per second (0.33 feet per second).

## SYNOPSIS

The action of [redacted] pitot tubes and modifications of the latter - Influence of errors of observation on the accuracy of measurements - Advantages and disadvantages of devices for magnifying the differential head, h; fluid friction in the tubes - Influence of the manometer fluid (20 kinds) on the magnitude of the head reading - Determination of the specific gravity during velocity measurements - Results of calibrating 23 types of pitot tubes in turbulent flow (inclined flow) - Variation of the coefficient, c.

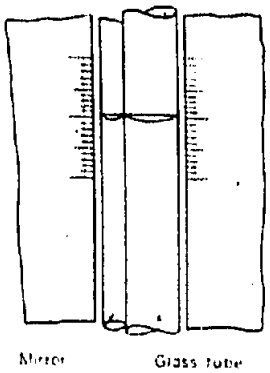


**FIGURE 1**

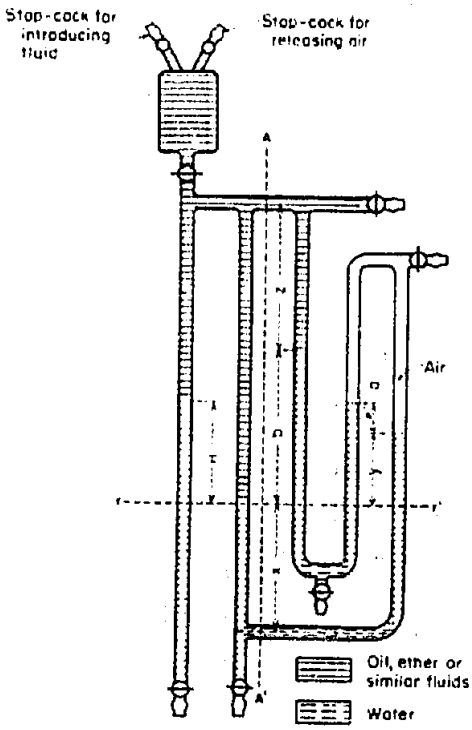


**FIGURE 2**

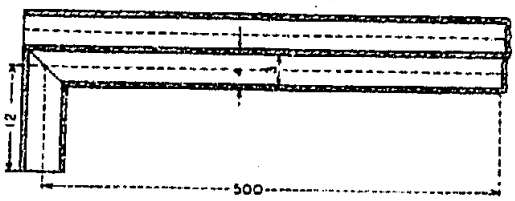


**FIGURE 3**
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 20° | 30° | 45° | 60° |
|---|---|---|---|---|---|---|---|
| C | 1.24 | 1.32 | 1.43 | 1.66 | 1.74 | 1.63 | 0.92 |

Not recommended for use near walls. It is seen to be unsatisfactory when inclined to the direction of the stream.

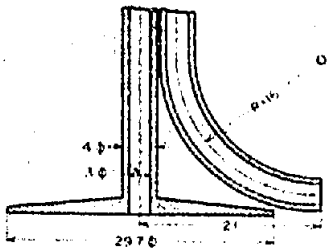


**FIGURE 4**
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 20° | 30° | 60° | 90° |
|---|---|---|---|---|---|---|---|
| C | 1.00 | 1.046 | 1.105 | 0.998 | 0.854 | −0.492 | −0.656 |

Not to be used near walls. Very sensitive to flow directed from below or above, at ±20°, C = 0.76 and 1.19 respectively.

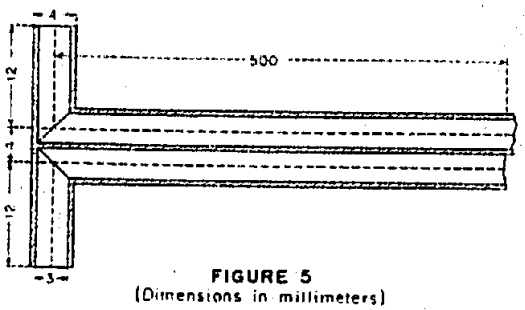


**FIGURE 5**
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 20° | 30° | 60° |
|---|---|---|---|---|---|---|
| C | 1.18 | 1.25 | 1.42 | 1.41 | 1.44 | 0.735 |

If the stream flow oscillates even a small amount, this pitot tube is not reliable, for the possible error in v is then $\frac{\sqrt{1.42}}{\sqrt{1.18}} = 1.10$, that is 10 percent.

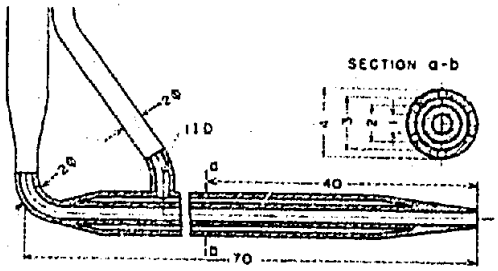


**FIGURE 6**
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 20° | 30° | 60° | 90° |
|---|---|---|---|---|---|---|---|
| C | 0.941 | 0.965 | 0.971 | 0.982 | 0.958 | 1.04 | −0.963 |

Darcy's design. Usable in narrow sections as well as near walls. Also well adapted to flow oscillating as much as 30°, when the probable error in v amounts to $\frac{\sqrt{0.958}}{\sqrt{0.941}} = 1.025$, or only 2.5 percent. A completely symmetrical pitot tube is of great advantage for turbulent flow.

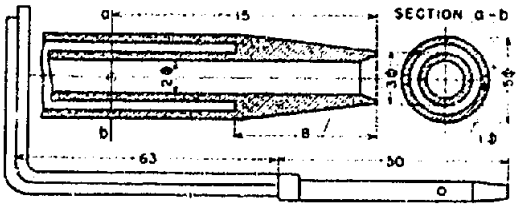


**FIGURE 7**
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 20° |
|---|---|---|---|---|
| C | 0.998 | 1.030 | 1.033 | 1.085 |

Up to 20°, its behavior is similar to that of Darcy's design.

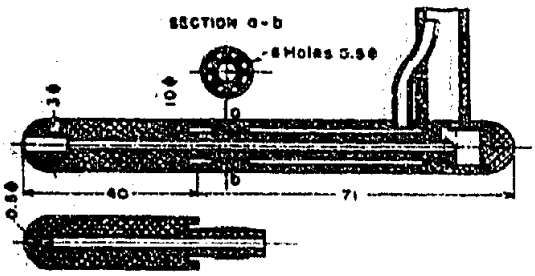


**FIGURE 8**
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 20° | 30° | 60° | 90° |
|---|---|---|---|---|---|---|---|
| C (large opening) | 0.960 | 0.985 | 0.978 | 0.965 | 0.770 | — | — |
| C (small opening) | 0.847 | — | — | — | 0.634 | −0.358 | −0.871 |

Design according to Prandtl and Rosenmüller. Behavior as far as 20° as previously given.

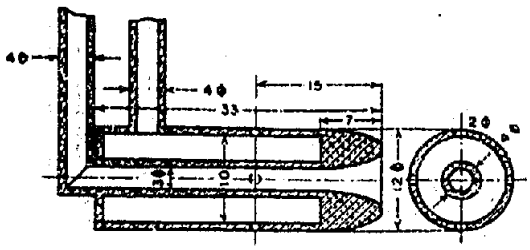

**FIGURE 11**
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 20° | 30° | 45° | 90° |
|---|---|---|---|---|---|---|---|
| C | 1.06 | 1.106 | 1.091 | 1.090 | 0.887 | 0.771 | −0.358 |

Flow oscillating as much as 20° is measured reliably.

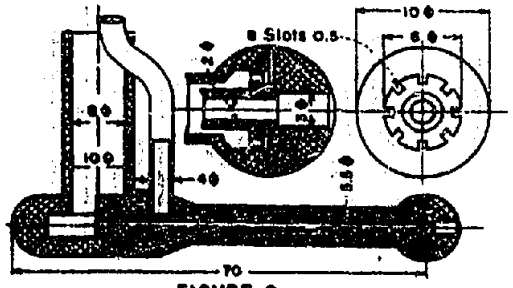


**FIGURE 9**
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 20° | 30° | 60° | 70° | 90° |
|---|---|---|---|---|---|---|---|---|
| C | 1.81 | 1.33 | 1.39 | 1.32 | 1.07 | 0.34 | 0.40 | 0.30 |

Design by Gabers. Measures very reliably flow oscillating as much as 20°.

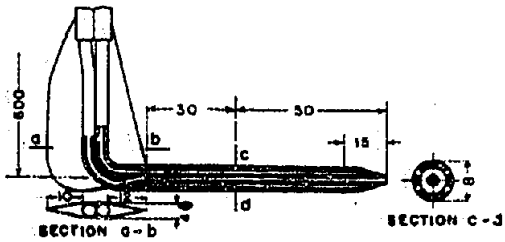


**FIGURE 12**
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 30° | 45° | 60° |
|---|---|---|---|---|---|---|
| C | 0.914 | 0.942 | 0.956 | 0.920 | 0.664 | 0.106 |

Improved Darcy pitot tube. Usable in strongly oscillating flow (up to 30°); $\sqrt{0.942}/\sqrt{0.914}=1.015$, or a probable error of 1.5 percent. The profile of the tip is rounded to a circular arc and is tangential at the transition to the cylindrical tube. The completely symmetrical design permits its use in turbulent flow.

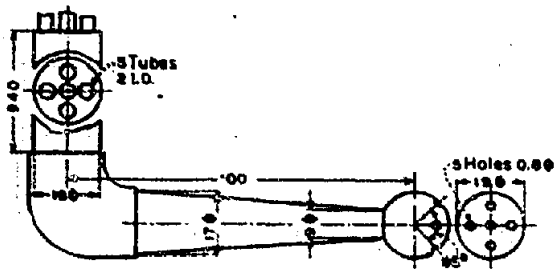


**FIGURE 10**
(Dimensions in millimeters)

| θ | 0° | 10° | 20° | 30° | 40° |
|---|---|---|---|---|---|
| $C_1$ (upper opening) | 1.044 | 1.010 | 0.906 | 0.727 | 0.550 |
| $C_2$ (lower opening) | 0.912 | 0.980 | 0.901 | 0.784 | 0.656 |
| $C_3$ (side opening) (Flow from right) | 1.070 | 1.179 | 1.171 | 0.943 | 0.600 |
| $C_3$ (side opening) (Flow from left) | 1.070 | 0.783 | 0.250 | −0.301 | −0.772 |
| $C_4$ (side opening) (Flow from right) | 1.010 | 0.883 | 0.183 | −0.329 | −0.780 |
| $C_4$ (side opening) (Flow from left) | 1.010 | 1.174 | 1.179 | 0.945 | 0.650 |

| α | PITOT TUBE SLOPED DOWNWARDS 10° | PITOT TUBE SLOPED DOWNWARDS 20° | PITOT TUBE SLOPED UPWARDS 10° | PITOT TUBE SLOPED UPWARDS 20° |
|---|---|---|---|---|
| $C_1$ | 0.723 | 0.280 | 1.211 | 1.233 |
| $C_2$ | 1.168 | 1.241 | 0.648 | 0.197 |
| $C_3$ | 0.981 | 0.908 | 0.947 | 0.850 |
| $C_4$ | 1.004 | 0.970 | 1.027 | 0.930 |

Taylor pitot sphere for finding the direction of flow; $C_3$ and $C_4$ have two values each according to whether the flow is directed from the right or left.

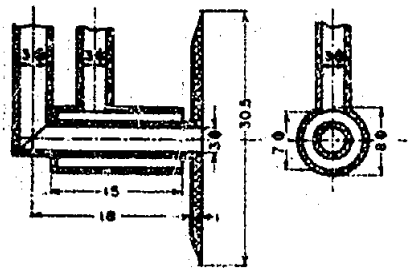

**FIGURE 13**
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 20° | 30° | 40° |
|---|---|---|---|---|---|---|
| C | 1.47 | 1.46 | 1.43 | 1.46 | 1.37 | 1.05 |

Measures reliably flow oscillating as much as 20°. Not applicable to narrow cross sections (for example, small pipes).

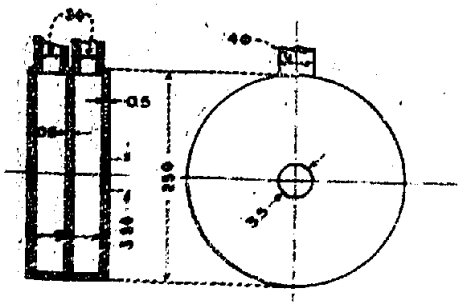

**FIGURE 14**
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 20° | 30° | 45° |
|---|---|---|---|---|---|---|
| C | 1.38 | 1.46 | 1.48 | 1.475 | 1.48 | 1.17 |

A modified design consists of a sphere 20 millimeters in diameter with openings 2 millimeters in diameter at the front and back. Such a sphere has the following coefficients.

| θ | 0° | 5° | 10° | 20° | 30° | 45° | 60° |
|---|---|---|---|---|---|---|---|
| C | 1.27 | 1.29 | 1.34 | 1.30 | 1.20 | 0.71 | 0.26 |

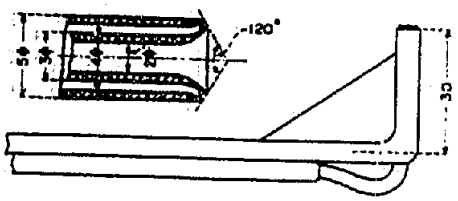

**FIGURE 17**
(Dimensions in millimeters)

| θ | 0° | 2.5° | 5° | 10° | 20° | 30° |
|---|---|---|---|---|---|---|
| C | 1.10 | 1.032 | 0.953 | 0.750 | 0.348 | 0.101 |

Pitot tube according to Beyerhaus. Very sensitive to inclined flow and hence an indicator for the direction of flow, but little suited to velocity measurements.

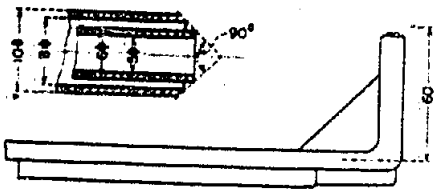

**FIGURE 18**
(Dimensions in millimeters)

| θ | 0° | 2.5° | 5° | 10° | 20° | 30° | 60° | 90° |
|---|---|---|---|---|---|---|---|---|
| C | 0.810 | 0.837 | 0.479 | 0.184 | 0.069 | 0.064 | -1.189 | -0.038 |

This design by Beyerhaus gives results similar to the previous case.

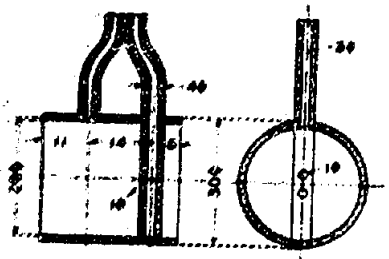

**FIGURE 15**
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 20° | 30° | 60° |
|---|---|---|---|---|---|---|
| C | 0.64 | 0.67 | 0.71 | 0.75 | 0.56 | -0.11 |

If tilted about a horizontal axis then for

| α | +20° | +10° | -10° | -20° |
|---|---|---|---|---|
| C | 0.56 | 0.60 | 0.79 | 0.92 |

Design by Blasius. Not adapted to inclined flow.

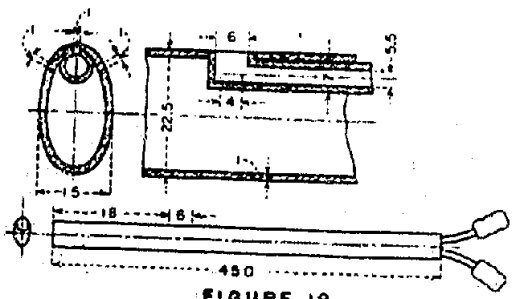

**FIGURE 19**
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 15° |
|---|---|---|---|---|
| C | 1.89 | 1.835 | 1.60 | 1.33 |

Design by Blasius (See Zentralblatt der Bauverwaltung, 1909, No. 84.)

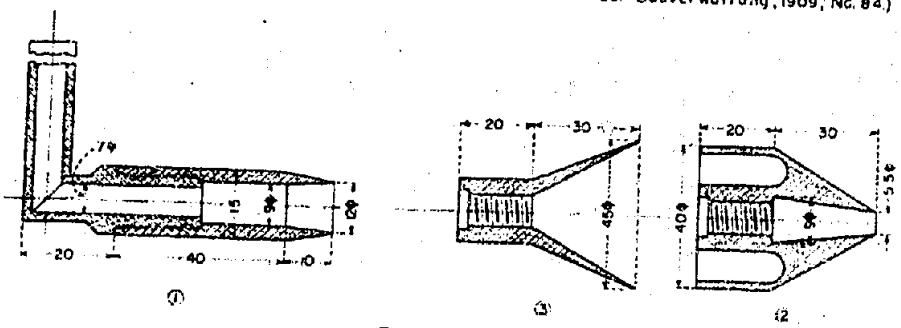

**FIGURE 16**
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 20° | 40° | 60° | 90° |
|---|---|---|---|---|---|---|---|
| $C_1$ | 0.90 | 0.897 | 0.874 | | 0.757 | 0.531 | -1.131 |
| $C_2$ | 0.934 | 0.928 | 0.925 | 0.860 | 0.172 | -0.922 | -0.787 |
| $C_3$ | 0.949 | 0.940 | 0.942 | 0.928 | 0.895 | 0.536 | -0.389 |

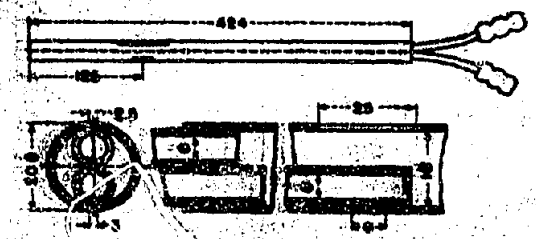

FIGURE 20
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 20° |
|---|---|---|---|---|
| C | 1.99 | 1.50 | 1.665 | 1.31 |

Design by Blasius

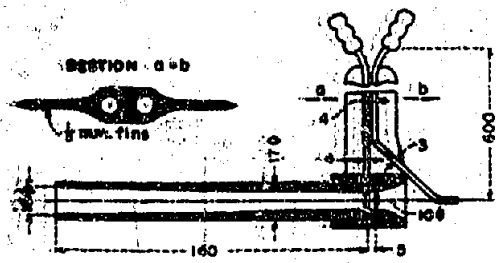


FIGURE 21
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 20° | 40° | 60° | 90° | |
|---|---|---|---|---|---|---|---|---|
| C | 2.36 | 2.37 | 2.43 | 2.39 | 2.45 | 1.16 | 1.85 | for v = 2.62 to 3.28 ft. per sec. |

Pitot tube used by the research laboratory for special purposes. Usable in rapidly oscillating flow (up to 40°). The value of c varies with the velocity thus:

| v (ft. per sec.) | 0.39 | 1.64 | 3.28 | 4.92 | 6.56 | 8.20 | 9.84 |
|---|---|---|---|---|---|---|---|
| C | 1.81 | 2.01 | 2.59 | 2.60 | 2.74 | 2.64 | 2.92 |

The coefficients for the projecting tube alone are as follows:

| v (ft. per sec.) | 0.39 | 1.64 | 3.28 | 4.92 | 6.56 | 8.20 | 9.84 |
|---|---|---|---|---|---|---|---|
| C | 0.12 | 0.67 | 0.92 | 0.96 | 0.99 | 0.99 | 0.99 |

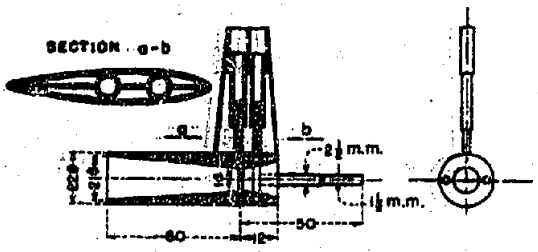


FIGURE 22
(Dimensions in millimeters)

| θ | 0° | 5° | 10° | 20° | 30° | 60° | 90° | |
|---|---|---|---|---|---|---|---|---|
| C | 3.091 | 3.096 | 3.114 | 3.224 | 3.129 | 0.922 | −0.215 | for v=1.64 to 6.56 ft. per sec. |

Conspicuous (see also figure 21) because of its high values of c. Usable for strongly oscillating flow (up to 30°). The values of c (for 0°) vary with v as follows:

| v ft. per sec. | 0.39 | 1.64 | 3.28 | 4.92 | 6.56 | 8.20 | 9.84 |
|---|---|---|---|---|---|---|---|
| C | 1.60 | 2.90 | 3.28 | 3.48 | 3.66 | 3.65 | 3.72 |

The coefficients for the projecting tubes alone are as follows:

| v (ft. per sec.) | 0.39 | 1.64 | 3.28 | 4.92 | 6.56 | 8.20 | 9.84 |
|---|---|---|---|---|---|---|---|
| C | 0.20 | 0.71 | 0.90 | 0.96 | 0.90 | 0.99 | 0.99 |

If a small vane bent in the shape of a propeller is introduced into the entrance of the constricted tube, the coefficients for the whole pitot tube are as follows.

| v (ft. per sec.) | 0.39 | 1.64 | 3.28 | 4.92 | 6.56 |
|---|---|---|---|---|---|
| C | 1.9 | 2.0 | 2.0 | 2.0 | 2.0 |

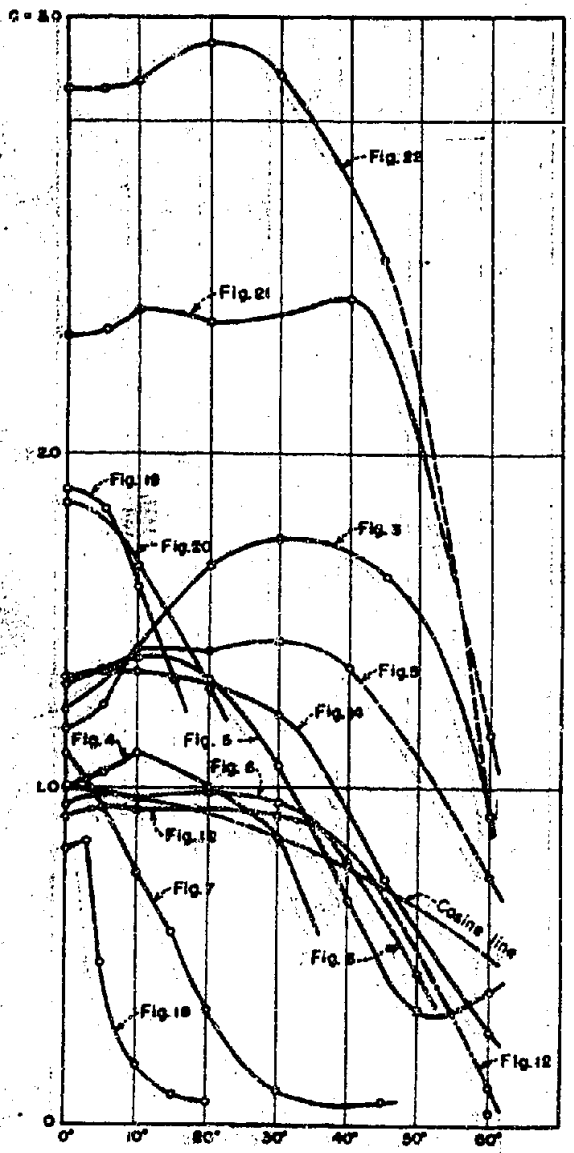


FIGURE 23-GRAPH OF THE COEFFICIENTS, C