ASHRAE Standard 41.8-1989

# ASHRAE STANDARD

# Standard Methods of Measurement of Flow of Liquids in Pipes Using Orifice Flowmeters

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**This foreword is not part of this Standard but is included for information purposes only.**

## FOREWORD

This Standard has been prepared by ASHRAE for the measurement of the flow of liquids and incorporates only Inch-Pound units. In this Standard, the customary notation is used for the description of pipe size in terms of nominal internal diameter of the pipe (inches) and pipe schedule number.

This Standard is intended to be used only where orifice meters are used in connection with the control of fluids associated with heating and air-conditioning systems, and not for custody transfer or other commercial applications covered by ANSI/API 2530 Standard, *Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids.*

## 1 PURPOSE

The purpose of this Standard is to establish recommended practices for the measurement of flow of liquids in pipes. It shall also establish the standard technique to be used for the calibration of other instruments more convenient to use. This Standard is not intended to be used as a replacement for the calibration of flow meters by facilities traceable to NBS or by ASME Standard *Measurement of Fluid Flow in Pipes Using Orifice, Nozzle, and Venturi,* (ASME MFC3M-1985)[1], nor restrict the use of such facilities that do not incorporate the methods outlined below.

## 2 SCOPE

This Standard shall apply to fluids that exist in the liquid physical state and whose thermodynamic properties are such that the fluid will remain in a complete liquid state prior to, during, and following its path through the flow-measuring instrument.

## 3 DEFINITIONS

***orifice meter:*** an assembly of a meter tube, an orifice plate, and an orifice plate holder with pressure taps for connection to a pressure differential measuring instrument, such as a manometer, for the flow rate measurement of a monophase liquid with known properties.

For other definitions, refer to the ASHRAE dictionary, *Terminology of Heating, Ventilation, Air Conditioning and Refrigeration.*[2]

## 4 CLASSIFICATION

For the purpose of this Standard, any device, active or passive, that provides some type of physical or electrical analog response to a flowing liquid shall be considered a flowmeter.

## 5 REQUIREMENTS

**5.1** This Standard shall be used for the calibration of other flow meters as well as used as a measurement technique during equipment tests.

**5.2** As a calibration standard, a minimum of three separate readings shall be compared between the orifice and the instrument being calibrated at each flow point. Five readings are preferred to establish better statistical reliability.

## 6 INSTRUMENTS

**6.1 Differential Pressure.** The measurements of the differential pressure produced by the orifice shall be accomplished by a system which includes any of the following: a differential manometer, an indicator, or an electronic device such as a differential pressure transducer with associated electronic hardware. Vertical manometers shall not be used for differential pressures less than 5 in. of water. For lower differential pressures, an inclined or micromanometer shall be used.

Indicators or transducers shall be calibrated prior to use against suitable primary standards, or secondary standards traceable to an NBS standard. Where possible, instruments shall be placed well below the level of the orifice. If not, suitable means must be provided at a point highest in elevation between the pipe and instrument to vent any gases accumulating in the instrument line. All instruments shall have a resolution of at least 0.10 in. of water or better. Calibration accuracy shall be 0.10 in. of water or better.

**6.2 Inlet Pressures.** This measurement is taken primarily to determine the specific weight or density of the liquid. Manometers, bourdon tube gages, or pressure transducers may be used to make this measurement. Resolution and calibration accuracy shall be at least 0.5 psi, or better. Calibration and location requirement shall be the same as in 6.1.

**6.3** The temperature of the liquid shall be measured in all cases. This may be made either with a mercury-in-glass thermometer, a resistance thermometer, or a thermocouple. Accuracy shall be 0.20 °F or better.

## 7 APPARATUS

### 7.1 Orifice Construction

**7.1.1** The orifice plate shall be made of Monel, stainless steel, or other rust-resistant or corrosion-resistant steel alloy having a coefficient of thermal expansion which is as nearly as possible equal to that of the holding flange.

**7.1.2** The thickness of the orifice plate is specified in Table 1.

**7.1.3** If the orifice plate thickness exceeds 3/16 in., it will be necessary to machine from the outlet (downstream) side the outer portion of the plate that will be between the holding flanges, *i.e.* rim, by an amount which will give a rim thickness 3/16 in., or other methods used to ensure that the distance from the inlet face to the plate to the downstream pressure tap does not exceed 1-3/16 in. ±1/32 in. (See Fig. 1).

**7.1.4** The orifice hole shall be concentric with the metering tube.

**7.1.5** The length of the cylindrical edge of the orifice hole shall be between 0.01 D and 0.02 D. If the thickness exceeds this limit, the orifice outlet edge shall be beveled at an angle or 30 to 45 deg from the pipe axis, or recessed to a distance equal to the depth of the recess.

**Table 1**

| Pipe Size, Inches (D) | Orifice Thickness (in.) Temperature below 600 °F |
|---|---|
| Up to 3 | 3/32 ± 1/32 |
| 4 to 6 | 5/32 ± 1/32 |
| 7 to 8 | 1/4 ± 1/16 |
| 10 and over | 3/8 ± 1/8 |

**7.1.6** The inlet edge of the orifice shall be square and sharp, free from either burrs or rounding, so that when viewed without magnification a beam of light is not reflected visibly by the edge.

**7.1.7** The inlet face of the orifice plate shall be flat and remain so within 0.010 in. per inch of pipe diameter.

**7.1.8** The orifice hole diameter shall be measured in four meridian planes at 45 deg. No single diameter shall differ from the mean by more than 0.05%.

**7.1.9** The diameter ratio, $\beta$, of the hole to pipe diameter shall not be less than 25% nor greater than 70%.

**7.1.10** In nonvertical pipe, the orifice shall have a vent hole flush with the top of the pipe. The diameter of the vent hole shall be such that its area is less than 1% of the orifice, or the size may be determined from Table 2.

**7.2 Meter Tube Construction and Installation.** Refer to Fig. 1.

**7.2.1** Flange taps are selected for this Standard because of the assurance of the location of the taps and the availability of commercial flanges with pre-drilled tap holes. Style of flange is optional—raised face, female, ring joint, etc.

**7.2.2** Meter tube lengths, both upstream and downstream of the orifice, shall be accordance with Fig. 2. When in doubt, the longest section indicated should be used. The most severe case is for fittings in different planes using elbow or tube turns (Fig. 2D). Attempts at making proper straightening vanes shall not be made unless they can be purchased industrially.

**Table 2**

| Orifice Hole Diameter, In. (d) | Recommended Maximum Diameter of Vent Hole |
|---|---|
| 1.000 to 3.500 | 3/32 |
| 3.501 to 4.125 | 1/8 |
| 4.126 to 5.000 | 5/32 |
| 5.001 to 6.000 | 3/16 |
| 6.001 to 6.750 | 7/32 |
| 6.751 to 7.500 | 1/4 |
| 7.501 to 8.375 | 9/32 |
| 8.376 to 9.250 | 5/16 |
| 9.251 to 10.000 | 11/32 |
| 10.001 to 10.875 | 3/8 |
| 10.876 to 11.625 | 13/32 |
| 11.626 to 12.500 | 7/16 |
| 12.501 to 13.250 | 15/32 |
| 13.251 and larger | 1/2 |

**7.2.3** Whenever possible, the internal diameter of the pipe (D) should be machined to the diameters and to the tolerances as indicated in Table 3 for a distance of at least four pipe diameters, 4D, preceding the orifice or nozzle; and for a distance of at least two pipe diameters (2D) beyond the inlet face of the orifice or nozzle. The machined portions shall be faired into the unmachined portion at an included angle of not more than 30 deg.

**Table 3 Internal Pipe Diameters**

| Nominal Pipe Size, D, Inches | Schedule No. | Machined Diameter, Inches | Tolerance, Inches | |
|---|---|---|---|---|
| 4 | 40 | 4.065 | ±0.005 | |
| | 80 | 3.881 | ±0.005 | |
| | 120 | 3.697 | ±0.005 | |
| | 160 | 3.524 | ±0.005 | |
| 5 | 40 | 5.089 | ±0.005 | |
| | 80 | 4.874 | ±0.005 | |
| | 120 | 4.644 | ±0.005 | |
| | 160 | 4.415 | ±0.005 | |
| 6 | 40 | 6.111 | ±0.005 | |
| | 80 | 5.831 | ±0.005 | |
| | 120 | 5.592 | ±0.005 | |
| | 160 | 5.306 | ±0.005 | |
| 8 | 20 | 8.166 | +0.005 | −0.010 |
| | 30 | 8.116 | +0.005 | −0.010 |
| | 40 | 8.033 | +0.005 | −0.010 |
| | 60 | 7.879 | +0.005 | −0.010 |
| | 80 | 7.706 | +0.005 | −0.010 |
| | 100 | 7.535 | +0.005 | −0.010 |
| | 120 | 7.306 | +0.005 | −0.010 |
| | 140 | 7.133 | +0.005 | −0.010 |
| | 160 | 6.960 | +0.005 | −0.010 |
| 10 | 20 | 10.291 | +0.005 | −0.010 |
| | 30 | 10.186 | +0.005 | −0.010 |
| | 40 | 10.081 | +0.005 | −0.010 |
| | 60 | 9.831 | +0.005 | −0.010 |
| | 80 | 9.660 | +0.005 | −0.010 |
| | 100 | 9.431 | +0.005 | −0.010 |
| | 120 | 9.201 | +0.005 | −0.010 |
| | 140 | 8.931 | +0.005 | −0.010 |
| | 160 | 8.683 | +0.005 | −0.010 |
| 12 | 20 | 12.291 | +0.005 | −0.015 |
| | 30 | 12.144 | +0.005 | −0.015 |
| | 40 | 12.004 | +0.005 | −0.015 |
| | 60 | 11.717 | +0.005 | −0.015 |
| | 80 | 11.488 | +0.005 | −0.015 |
| | 100 | 11.201 | +0.005 | −0.015 |
| | 120 | 10.913 | +0.005 | −0.015 |
| | 140 | 10.683 | +0.005 | −0.015 |
| | 160 | 10.339 | +0.005 | −0.015 |
| 14 | 10 | 13.541 | +0.005 | −0.020 |
| | 20 | 13.427 | +0.005 | −0.020 |
| | 30 | 13.311 | +0.005 | −0.020 |
| | 40 | 13.197 | +0.005 | −0.020 |
| | 60 | 12.910 | +0.005 | −0.020 |
| | 80 | 12.622 | +0.005 | −0.020 |
| | 100 | 12.278 | +0.005 | −0.020 |
| | 120 | 11.992 | +0.005 | −0.020 |
| | 140 | 11.703 | +0.005 | −0.020 |
| | 160 | 11.416 | +0.005 | −0.020 |

**7.2.4** The internal pipe diameter, D, shall be measured at four or more points in the plane of inlet pressure connection and at four or more points in the plane of the outlet connection. The average of the four or more diameters in the plane of the inlet pressure connection shall be used in calculating the diameter ration, $\beta$, of the primary element.

**7.2.5** When installed in a pine line, steps must be taken to insure the center of the concentric orifice hole shall be within 3%D of the axis of the pipe.

**7.2.6** The gasket material shall be of a type and composition that does not compress more than 20% under a load of 4000 psi. For high-pressure, high-temperature service, it may be necessary to use a metallic gasket.

**7.2.7 Pressure tap holes.** The size of the pressure tap holes through the pipe wall shall not exceed the dimensions given in Table 4. There must be no burrs, wire edges, or other irregularities on the inside of the pipe at the nipple connections or along the edge of the hole through the pipe wall.

**7.2.8 Pressure hole connections.** Connections to the pressure holes shall be made by nipples, couplings, or adapters, welded or brazed, depending on pressure levels, to the outside surface of the pipe. In no case shall any fitting project beyond the inner surface of the pipe wall.

**7.2.9** Another important consideration in the making of pressure holes through pipe walls is that there should be no change in the pressure hole diameter, A (see Fig. 3), for a distance of at least 2.5A, as measured from the inner surface of the pipe. To illustrate assume the diameter, A, of the hole through the pipe wall is ¼ in. Then some means should be used whereby, in effect, a tube of ¼ in. diameter extends outward for at least 5/8 in. from the inner surface of the pipe before any change of A takes place. A distance of 3A to 5A should be used wherever possible.

**7.2.10** It should be kept in mind that the conditions under which orifices are installed may have more effect on the accuracy of the test than the degree of perfection of manufacture or the characteristics of the devices themselves. The rate of flow computed from the differential pressure produced by these elements may be in error to an unacceptable degree if the piping arrangements are such that distorted flow conditions result. Distortions of velocity traverse, helical swirls, or vortices will all endanger the flow measurement accuracy. A projecting gasket, misalignment, or a burr on a pressure tap can cause considerable error. To avoid any disturbance in the flow pattern, the preferred location of thermometers shall be 5 to 10 pipe diameters following the primary element. When this is impossible, they should be located 10 to 15 pipe diameters ahead of the primary element.

**Table 4**

| Nominal Inside Pipe Diameter, D | Maximum Diameter A (Fig. 3) |
|---|---|
| Under 2 | 1/4 |
| 2, 3 | 3/8 |
| 4 to 8 | 1/2 |
| 10 and over | 3/4 |

## 8 TEST TECHNIQUES

**8.1 Test set up.** The orifice plate and fittings to be used as the standard should be located upstream of the meter to be calibrated. Flow control should be maintained through a valve downstream of both instruments.

**8.2** Flow conditions shall be maintained in a steady-state condition while recording data. Variations greater than 1% of the differential pressure across the orifice shall be unacceptable.

**8.3** In order to assure that vapor has not formed in the lines just over the differential measurement instrument, it is desirable to have a block and bleed valve in a bypass line installed connecting the high-and-low sides of the instrument. A tight shutoff valve must be installed in this line. When readings are not being taken, this valve should be opened to allow liquid to flow from the high side to the low side, keeping the lines purged of vapors.

**8.4** Calibration of the meter in question shall be operated over the desirable flow range from low flow to high flow and back again with at least two intermediate points. This shall be repeated at least three times, preferably five. If just a single point calibration is required, then the flow must be moved off the point by at least a 10% increase and a 10% decrease before re-establishing the test point.

**8.5** The liquid shall not contain solid particles, such as sand or other process additives.

**8.6** Pressure tap holes shall be on the side of horizontal pipes.

**8.7** Differential pressure taps (flange taps) shall be located on the side of horizontal pipes. Top holes shall be piped and valved so they may be used as vents.

## 9 DATA TO BE RECORDED

**9.1 Orifice Diameter, "d"** (see 7.1.8).

**9.2 Pipe Diameter, "D".** This shall be measured at four or more points in the plane of inlet pressure connection, and their average be used in the calculation of $\beta$.

**9.3 Flow parameters:**

a. differential pressure across flange taps, inches of water
b. inlet pressure of fluid, psig
c. temperature of fluid, °F
d. temperature of manometric fluid, °F

## 10 CALCULATIONS

The following formula shall be used:

$$W_h = 359.06Kd^2F_a(h_w\gamma)^{0.5}$$

$$h_w = h_D - h_F$$

where

$W_h$ = weight rate of flow, pounds per hour

$d$ = diameter of orifice hole, inches

$F_a$ = area factor (temperature dependent)—See Fig. 4

$h_D$ = differential height of manometric fluid, inches, converted to water at 68 °F

$h_F$ = differential height of flowing fluid, inches, converted to water at 68 °F (measured height same as $h_D$)

$\gamma$ = specific weight of the flowing fluid at the inlet side of the primary element, $lb_f$ per cubic feet

$K$ = flow coefficient—See Table 5.

The flow coefficient is a function of the Reynolds number, $R_D$, and the diameter ratio $\beta$(d/D where D is the pipe diameter). It will be necessary, in determining the proper flow rate, to estimate the Reynolds Number so that the flow coefficient, K, can be selected in making the calculation. After the flow has been determined initially, a closer estimate of the Reynolds Number shall be made by determining the velocity, V, from the first value of $W_h$ by the formula:

$$V = W_h/3600\rho A$$

where

$V$ = velocity, feet per second

$W_h$ = flow rates, pounds mass per hour, calculated above

$A$ = Area, square feet (internal of pipe, calculated from D)

$\rho$ = density, pounds mass per $ft^3$

Reynolds Number can then be more accurately determined by:

$$R_D = 0.00035\ W_h/Dg_c\mu$$

where

$W_h$ = flow rate, pounds mass per hour.

$D$ = pipe diameter, feet, internal

$g_c$ = 2proportionality constant = 32.17 $lb_m \cdot ft/(lb_f \cdot sec^2)$

$\mu$ = absolute viscosity, $lb_f$ sec per $ft^2$ of flowing fluid.

After determining the value of $R_D$, check the K factor selected from Table 5 and adjust as necessary in above calculation for $W_h$. In most cases the second calculation will be sufficiently close for a final answer.

## 11 ALTERNATE TEST METHOD—WEIGH TANK

This method shall be considered a standard to be used in tests or to calibrate other flowmeters more convenient to use. It shall be preferred over the sharp-edged orifice technique particularly when data are insufficient, unavailable, or questionable regarding flow coefficients. This will be true primarily in pipe sizes smaller than 1½ in.

### 11.1 Equipment

**11.1.1 Weighing device.** This shall consist of any convenient scale or load cell having a scale or beam resolution greater than ¼ lb.

**11.1.2** The timing device shall have an accuracy of 1/10 sec or greater. Where possible, it is recommended to provide an arrangement where an electric clock is automatically tripped as the weighing begins and ends. This is commonly accomplished through the use of a low force switch tripped by the point of balance beam of a mechanical scale.

**11.1.3** The flow circuit shall have provisions to maintain a steady flow by the use of pressure regulating devices. It may be a "once through" water system (main water supply to drain) or a closed-loop system employing a pump to circulate the fluid. It also should have provisions to maintain the temperature of the fluid to ±1°F during measurements. There shall be a sufficient surge capacity in the flow circuit so that the liquid in the pump supply reservoir that is deposited in the weighing tank during the timing period will not cause aspiration at the pump inlet or some other failure.

### 11.2 Technique

**11.2.1** This method may be used for any liquid whose vapor point is well above the operating temperature at atmospheric pressure. It is not recommended for water above 150°F if flow measurements are below 1 gpm.

**11.2.2** The weighing technique shall be set up so that the timing of the selected weight (including starting or stopping of the timing device) does not occur during a valve action or diverting process.

**11.2.3** The minimum measured weight for one measurement shall be greater than 100 times the smallest division on the scale used, or 5 lb, whichever is greater.

**11.2.4** The minimum timing span for any measurement shall be 30 sec.

**11.2.5** A minimum of three (3) measurements at each flow condition shall be taken. If any reading differs by more than 1% referred to the average, the measurement must be repeated. If a fluctuating flow is present, longer measurement times must be used to insure "averaging" of the fluctuations.

### 11.3 Data to be recorded

**11.3.1** Weight of fluid, pounds (tank weight "tared")

**11.3.2** Time, seconds

**11.3.3** Temperature of fluid, °F

**11.4 Calibration.** In order to maintain the best accuracy, particularly if electronic devices are used, such as a load cell, frequent checks should be made to maintain the best possible accuracy. Commercial Class C weights can be purchased for this purpose.

## 12 REFERENCES


[1] ASME MFC-3M-1985. *Measurement of Fluid Flow in Pipes Using Orifice, Nozzle, and Venturi,* American Society of Mechanical Engineers, 345 East 47th Street, New York, NY, 1985.

[2] ASHRAE *Terminology of Heating, Ventilation, Air Conditioning and Refrigeration,* 1986.

[3] ASME PTC 19.5-72, *Application Part II of Fluid Meters Sixth Edition.* American Society of Mechanical Engineers, 345 East 47th Street, New York, NY, 1972.

[4] ANSI/API 2530, *Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids,* American Petroleum Institute, 1220 L Street, NW, Washington, D.C. 20005.

## TABLE 5* FLANGE TAPS*

**Values of the Flow Coefficient, $K$, as a Function of the Pipe Reynolds Number, $R_D$, and Diameter Ratio, $\beta$**

**For 1-1/2 In. Pipe or 1-5/8 OD Type M Copper Tube (.0409 to .0388 m I.D.)** — **Table 5A**

| $\beta$ \ $R_D$ | 1,000 | 1,500 | 2,000 | 2,500 | 3,000 | 4,000 | 5,000 | 6,000 | 8,000 | 10,000 | 15,000 | 20,000 | 25,000 | 50,000 | 100,000 | 500,000 | $10^6$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .250 | | | .6142 | .6112 | .6092 | .6068 | .6053 | .6043 | .6030 | .6023 | .6013 | .6008 | .6005 | .5999 | .5996 | .5994 | .5993 |
| .300 | | | | .6152 | .6126 | .6094 | .6075 | .6062 | .6046 | .6036 | .6023 | .6017 | .6013 | .6005 | .6001 | .5998 | .5998 |
| .350 | | | | .6245 | .6212 | .6170 | .6145 | .6129 | .6108 | .6095 | .6078 | .6070 | .6065 | .6055 | .6050 | .6046 | .6046 |
| .400 | | | | | | | .6229 | .6207 | .6179 | .6163 | .6141 | .6130 | .6124 | .6110 | .6104 | .6099 | .6098 |
| .450 | | | | | | | .6342 | .6313 | .6276 | .6254 | .6225 | .6210 | .6202 | .6184 | .6175 | .6168 | .6167 |
| .500 | | | | | | | | | .6406 | .6376 | .6336 | .6317 | .6305 | .6281 | .6269 | .6259 | .6258 |
| .550 | | | | | | | | | .6577 | .6536 | .6482 | .6456 | .6439 | .6407 | .6391 | .6378 | .6376 |
| .600 | | | | | | | | | | | .6675 | .6639 | .6617 | .6573 | .6551 | .6533 | .6531 |
| .625 | | | | | | | | | | | .6793 | .6750 | .6725 | .6674 | .6648 | .6628 | .6625 |
| .650 | | | | | | | | | | | | .6876 | .6846 | .6787 | .6757 | .6734 | .6731 |
| .675 | | | | | | | | | | | | .7018 | .6983 | .6915 | .6881 | .6853 | .6850 |
| .700 | | | | | | | | | | | | .7177 | .7137 | .7058 | .7019 | .6987 | .6983 |

**For 2 In. Pipe or 2-1/8 OD Type M Copper Tube (.0525 to .0510 m I.D.)** — **Table 5B**

| $\beta$ \ $R_D$ | 1,000 | 2,000 | 3,000 | 4,000 | 5,000 | 6,000 | 8,000 | 10,000 | 15,000 | 20,000 | 30,000 | 50,000 | 100,000 | 500,000 | $10^6$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .250 | | .6149 | .6092 | .6064 | .6047 | .6035 | .6021 | .6012 | .6001 | .5995 | .5990 | .5985 | .5982 | .5979 | .5979 |
| .300 | | | | .6113 | .6091 | .6077 | .6058 | .6047 | .6032 | .6025 | .6018 | .6012 | .6007 | .6005 | .6004 |
| .350 | | | | .6183 | .6155 | .6138 | .6110 | .6099 | .6089 | .6070 | .6061 | .6053 | .6049 | .6043 | .6042 |
| .400 | | | | | | | .6185 | .6166 | .6142 | .6129 | .6117 | .6107 | .6099 | .6095 | .6093 |
| .450 | | | | | | | .6284 | .6259 | .6225 | .6209 | .6192 | .6179 | .6169 | .6161 | .6160 |
| .500 | | | | | | | .6419 | .6384 | .6339 | .6316 | .6293 | .6275 | .6261 | .6250 | .6249 |
| .550 | | | | | | | | .6553 | .6490 | .6458 | .6426 | .6402 | .6384 | .6368 | .6366 |
| .600 | | | | | | | | | | .6644 | .6601 | .6567 | .6541 | .6521 | .6518 |
| .625 | | | | | | | | | | .6759 | .6708 | .6668 | .6638 | .6614 | .6611 |
| .650 | | | | | | | | | | | .6828 | .6781 | .6746 | .6718 | .6715 |
| .675 | | | | | | | | | | | .6962 | .6908 | .6868 | .6836 | .6832 |
| .700 | | | | | | | | | | | | .7053 | .7006 | .6968 | 6963 |

**For 3 In. Pipe or 3-1/8 OD Type M Copper Tube (.0779 to .0757 m I.D.)** — **Table 5C**

| $\beta$ \ $R_D$ | 1,000 | 2,000 | 3,000 | 4,000 | 5,000 | 6,000 | 8,000 | 10,000 | 15,000 | 20,000 | 30,000 | 40,000 | 50,000 | 100,000 | 500,000 | $10^6$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .250 | | | | | .6060 | .6045 | .6027 | .6017 | .6002 | .5994 | .5988 | .5984 | .5982 | .5978 | .5974 | .5974 |
| .300 | | | | | | .6092 | .6067 | .6055 | .6037 | .6028 | .6019 | .6014 | .6012 | .6007 | .6002 | 6002 |
| .350 | | | | | | | .6123 | .6106 | .6085 | .6073 | .6061 | .6055 | .6052 | .6045 | .6039 | .6039 |
| .400 | | | | | | | | .6178 | .6147 | .6132 | .6117 | .6109 | .6104 | .6094 | .6089 | .6088 |
| .450 | | | | | | | | | .6233 | .6213 | .6192 | .6187 | .6175 | .6163 | .6153 | 6152 |
| .500 | | | | | | | | | | .6322 | .6294 | .6280 | .6271 | .6254 | .6241 | .6239 |
| .550 | | | | | | | | | | .6471 | .6427 | .6410 | .6398 | .6369 | .6354 | .6352 |
| .600 | | | | | | | | | | | .6610 | .6583 | .6566 | .6532 | .6506 | 6502 |
| .625 | | | | | | | | | | | .6719 | .6686 | .6667 | .6628 | .6596 | .6592 |
| .650 | | | | | | | | | | | .6845 | .6805 | .6782 | .6737 | .6700 | .6695 |
| .675 | | | | | | | | | | | | .6938 | .6911 | .6858 | .6815 | .6809 |
| .700 | | | | | | | | | | | | .7091 | .7058 | .6996 | .6946 | .6939 |

**For 4 In. Pipe or 4-1/8 Type M Copper Tube (.102 to .1 m I.D.)** — **Table 5D**

| $\beta$ \ $R_D$ | 1,000 | 2,000 | 3,000 | 4,000 | 5,000 | 6,000 | 8,000 | 10,000 | 15,000 | 20,000 | 30,000 | 40,000 | 50,000 | 100,000 | 500,000 | $10^6$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .250 | | | | | | .6059 | .6038 | .6025 | .6006 | .5995 | .5989 | .5987 | .5984 | .5979 | .5975 | .5974 |
| .300 | | | | | | | .6081 | .6065 | .6044 | .6034 | .6023 | .6018 | .6015 | .6008 | .6003 | .6002 |
| .350 | | | | | | | | .6116 | .6090 | .6076 | .6064 | .6057 | .6053 | .6045 | .6039 | .6038 |
| .400 | | | | | | | | | .6152 | .6135 | .6119 | .6110 | .6105 | .6094 | .6086 | .6085 |
| .450 | | | | | | | | | | .6218 | .6194 | .6182 | .6175 | .6161 | .6150 | .6148 |
| .500 | | | | | | | | | | | .6296 | .6281 | .6271 | .6251 | .6235 | .6233 |
| .550 | | | | | | | | | | | .6439 | .6413 | .6400 | .6371 | .6350 | .6347 |
| .600 | | | | | | | | | | | | .6590 | .6569 | .6530 | .6498 | .6494 |
| .625 | | | | | | | | | | | | .6698 | .6674 | .6626 | .6588 | .6584 |
| .650 | | | | | | | | | | | | | .6790 | .6735 | .6690 | .6684 |
| .675 | | | | | | | | | | | | | .6923 | .6857 | .6804 | .6797 |
| .700 | | | | | | | | | | | | | .7071 | .6994 | .6932 | .6925 |
| .725 | | | | | | | | | | | | | .7253 | .7163 | .7081 | .7072 |
| .750 | | | | | | | | | | | | | .7461 | .7356 | .7272 | .7262 |

*Reprinted from ASME Flow Measurement PTC-19.5. 1959. Table 4, pp. 20-23, by permission of ASME.

For 6 In. Pipe or 6-1/8 Type M Copper Tube (.154 to .149 m I.D.) — Table 5E

| $\beta \backslash R_D$ | 2,000 | 3,000 | 4,000 | 5,000 | 6,000 | 8,000 | 10,000 | 15,000 | 20,000 | 30,000 | 50,000 | 100,000 | 500,000 | $10^6$ | $10^7$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .250 | | | | | | | .6042 | .6020 | .6009 | .5998 | .5990 | .5982 | .5977 | .5976 | .5975 |
| .300 | | | | | | | | .6055 | .6041 | .6028 | .6018 | .6012 | .6003 | .6002 | .6001 |
| .350 | | | | | | | | | .6087 | .6071 | .6058 | .6048 | .6040 | .6039 | .6038 |
| .400 | | | | | | | | | | .6124 | .6107 | .6095 | .6085 | .6083 | .6082 |
| .450 | | | | | | | | | | .6202 | .6179 | .6161 | .6148 | .6146 | .6144 |
| .500 | | | | | | | | | | | .6276 | .6250 | .6231 | .6228 | .6226 |
| .550 | | | | | | | | | | | .6410 | .6372 | .6343 | .6339 | .6336 |
| .600 | | | | | | | | | | | .6587 | .6533 | .6490 | .6484 | .6481 |
| .625 | | | | | | | | | | | | .6632 | .6580 | .6573 | .6568 |
| .650 | | | | | | | | | | | | .6741 | .6681 | .6673 | .6666 |
| .675 | | | | | | | | | | | | .6857 | .6795 | .6786 | .6778 |
| .700 | | | | | | | | | | | | .7003 | .6919 | .6908 | .6898 |
| .725 | | | | | | | | | | | | .7163 | .7067 | .7053 | .7041 |
| .750 | | | | | | | | | | | | .7361 | .7246 | .7231 | .7219 |

For 8 In. Pipe or 8-1/8 Type M Copper Tube (.203 to .198 m I.D.) — Table 5F

| $\beta \backslash R_D$ | 4,000 | 5,000 | 6,000 | 8,000 | 10,000 | 15,000 | 20,000 | 30,000 | 40,000 | 50,000 | 75,000 | 100,000 | 500,000 | $10^6$ | $10^7$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .250 | | | | | | .6029 | .6016 | .6003 | .5996 | .5992 | .5987 | .5984 | .5978 | .5977 | .5976 |
| .300 | | | | | | | .6049 | .6034 | .6027 | .6022 | .6016 | .6013 | .6005 | .6004 | .6003 |
| .350 | | | | | | | | .6073 | .6064 | .6059 | .6051 | .6047 | .6038 | .6037 | .6036 |
| .400 | | | | | | | | | .6118 | .6110 | .6100 | .6095 | .6084 | .6083 | .6081 |
| .450 | | | | | | | | | | .6181 | .6168 | .6161 | .6146 | .6143 | .6142 |
| .500 | | | | | | | | | | | .6262 | .6252 | .6229 | .6226 | .6223 |
| .550 | | | | | | | | | | | .6391 | .6376 | .6341 | .6336 | .6332 |
| .600 | | | | | | | | | | | .6561 | .6539 | .6486 | .6480 | .6474 |
| .625 | | | | | | | | | | | | .6640 | .6575 | .6567 | .6560 |
| .650 | | | | | | | | | | | | .6751 | .6676 | .6667 | .6658 |
| .675 | | | | | | | | | | | | .6880 | .6790 | .6779 | .6768 |
| .700 | | | | | | | | | | | | .7023 | .6918 | .6904 | .6892 |
| .725 | | | | | | | | | | | | .7185 | .7062 | .7046 | .7032 |
| .750 | | | | | | | | | | | | | .7272 | .7218 | .7202 |

For 10 In. Pipe or 10-1/8 Type M Copper Tube (.255 to .245 m I.D.) — Table 5G

| $\beta \backslash R_D$ | 4,000 | 5,000 | 6,000 | 8,000 | 10,000 | 15,000 | 20,000 | 30,000 | 40,000 | 50,000 | 75,000 | 100,000 | 200,000 | 500,000 | $10^6$ | $10^7$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .250 | | | | | | .6042 | .6027 | .6012 | .6004 | .6000 | .5991 | .5988 | .5983 | .5980 | .5979 | .5978 |
| .300 | | | | | | | | .6039 | .6039 | .6025 | .6019 | .6015 | .6010 | .6007 | .6006 | .6005 |
| .350 | | | | | | | | .6079 | .6069 | .6063 | .6054 | .6050 | .6044 | .6040 | .6039 | .6038 |
| .400 | | | | | | | | | .6122 | .6115 | .6102 | .6097 | .6089 | .6084 | .6083 | .6081 |
| .450 | | | | | | | | | .6199 | .6187 | .6171 | .6163 | .6152 | .6144 | .6142 | .6140 |
| .500 | | | | | | | | | | | .6268 | .6257 | .6239 | .6229 | .6226 | .6223 |
| .550 | | | | | | | | | | | .6399 | .6381 | .6355 | .6339 | .6334 | .6329 |
| .600 | | | | | | | | | | | | .6548 | .6509 | .6486 | .6478 | .6471 |
| .625 | | | | | | | | | | | | .6649 | .6602 | .6575 | .6566 | .6657 |
| .650 | | | | | | | | | | | | .6766 | .6710 | .6676 | .6665 | .6655 |
| .675 | | | | | | | | | | | | .6895 | .6828 | .6788 | .6775 | .6762 |
| .700 | | | | | | | | | | | | | .6963 | .6915 | .6899 | .6885 |
| .725 | | | | | | | | | | | | | .7116 | .7060 | .7055 | .7024 |
| .750 | | | | | | | | | | | | | .7245 | .7213 | .7202 | .7190 |

For 14.14 In. ID Pipe (.359 m I.D.) — Table 5H

| $\beta \backslash R_D$ | 4,000 | 5,000 | 6,000 | 8,000 | 10,000 | 15,000 | 20,000 | 30,000 | 40,000 | 50,000 | 75,000 | 100,000 | 200,000 | 500,000 | $10^6$ | $10^7$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .250 | | | | | | | .6038 | .6019 | .6009 | .6004 | .5996 | .5992 | .5986 | .5983 | .5982 | .5981 |
| .300 | | | | | | | | .6047 | .6036 | .6030 | .6021 | .6017 | .6010 | .6006 | .6005 | .6003 |
| .350 | | | | | | | | | .6074 | .6066 | .6056 | .6051 | .6041 | .6039 | .6037 | .6036 |
| .400 | | | | | | | | | | .6120 | .6107 | .6101 | .6091 | .6085 | .6083 | .6081 |
| .450 | | | | | | | | | | | .6178 | .6168 | .6155 | .6145 | .6143 | .6140 |
| .500 | | | | | | | | | | | | .6263 | .6241 | .6228 | .6224 | .6220 |
| .550 | | | | | | | | | | | | .6394 | .6361 | .6340 | .6333 | .6327 |
| .600 | | | | | | | | | | | | | .6518 | .6487 | .6477 | .6468 |
| .625 | | | | | | | | | | | | | .6615 | .6577 | .6564 | .6553 |
| .650 | | | | | | | | | | | | | .6722 | .6678 | .6663 | .6650 |
| .675 | | | | | | | | | | | | | .6844 | .6790 | .6772 | .6756 |
| .700 | | | | | | | | | | | | | .6982 | .6918 | .6897 | .6878 |
| .725 | | | | | | | | | | | | | | .7062 | .7036 | .7014 |
| .750 | | | | | | | | | | | | | | .7236 | .7205 | .7177 |

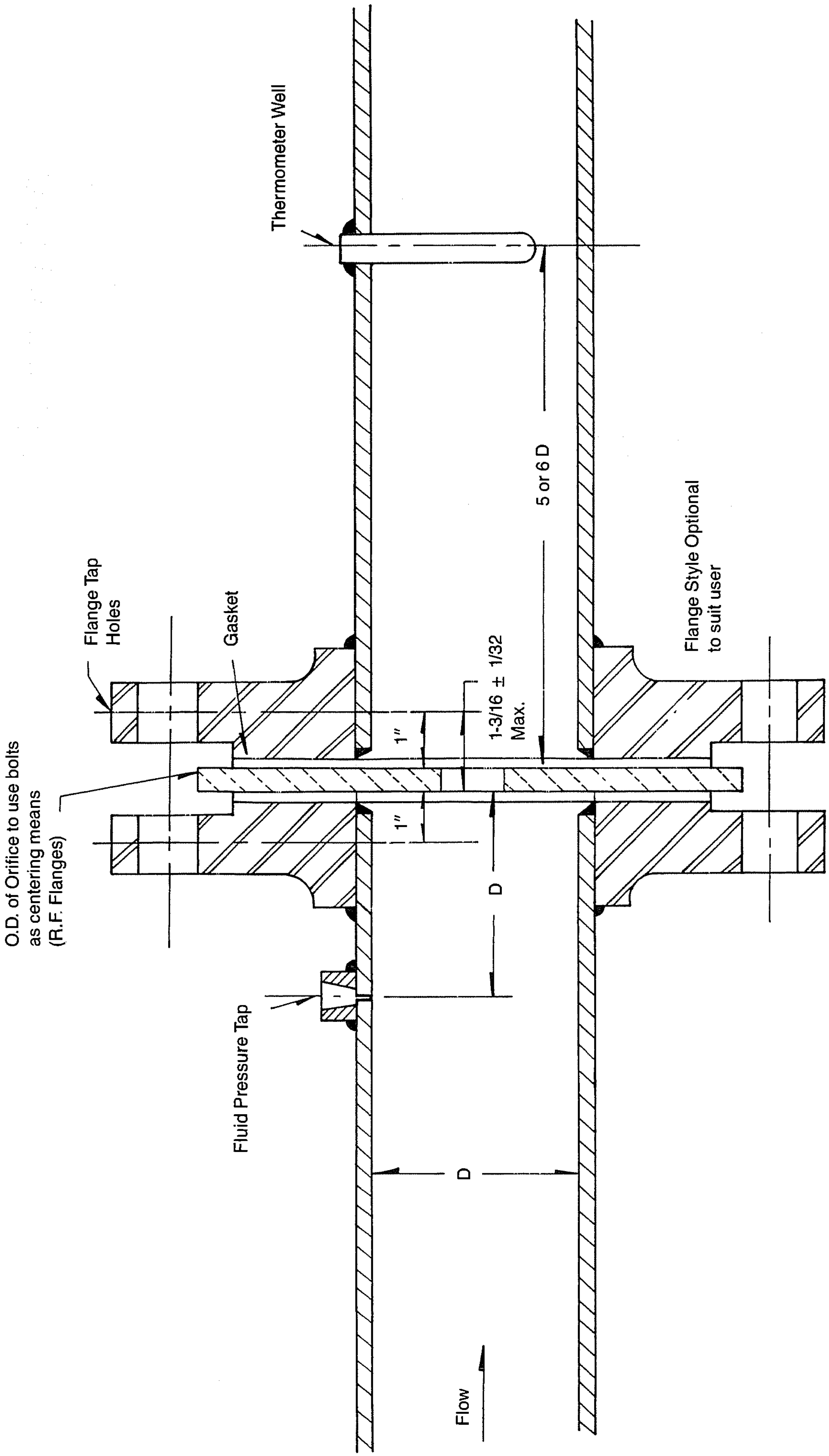
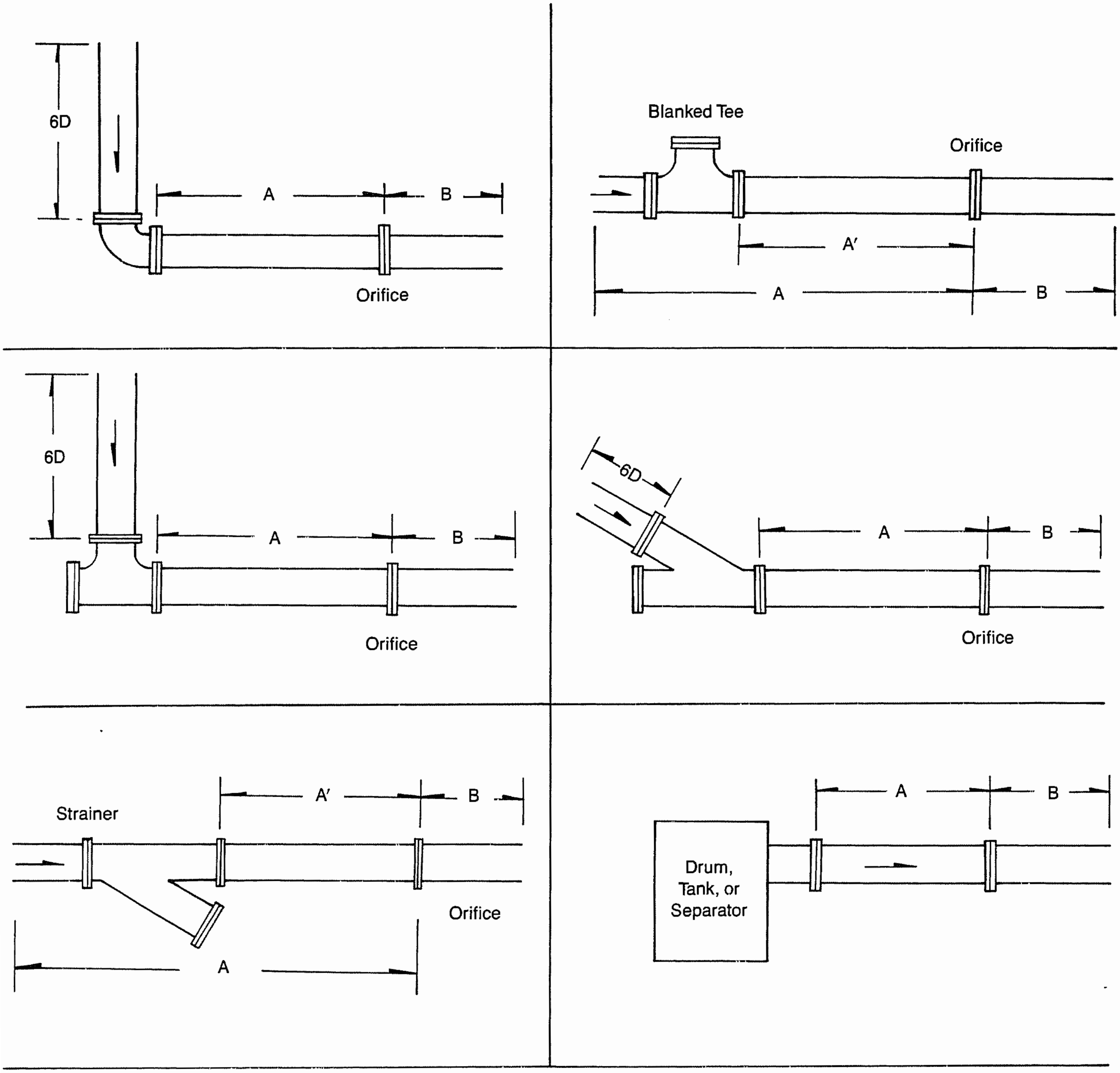
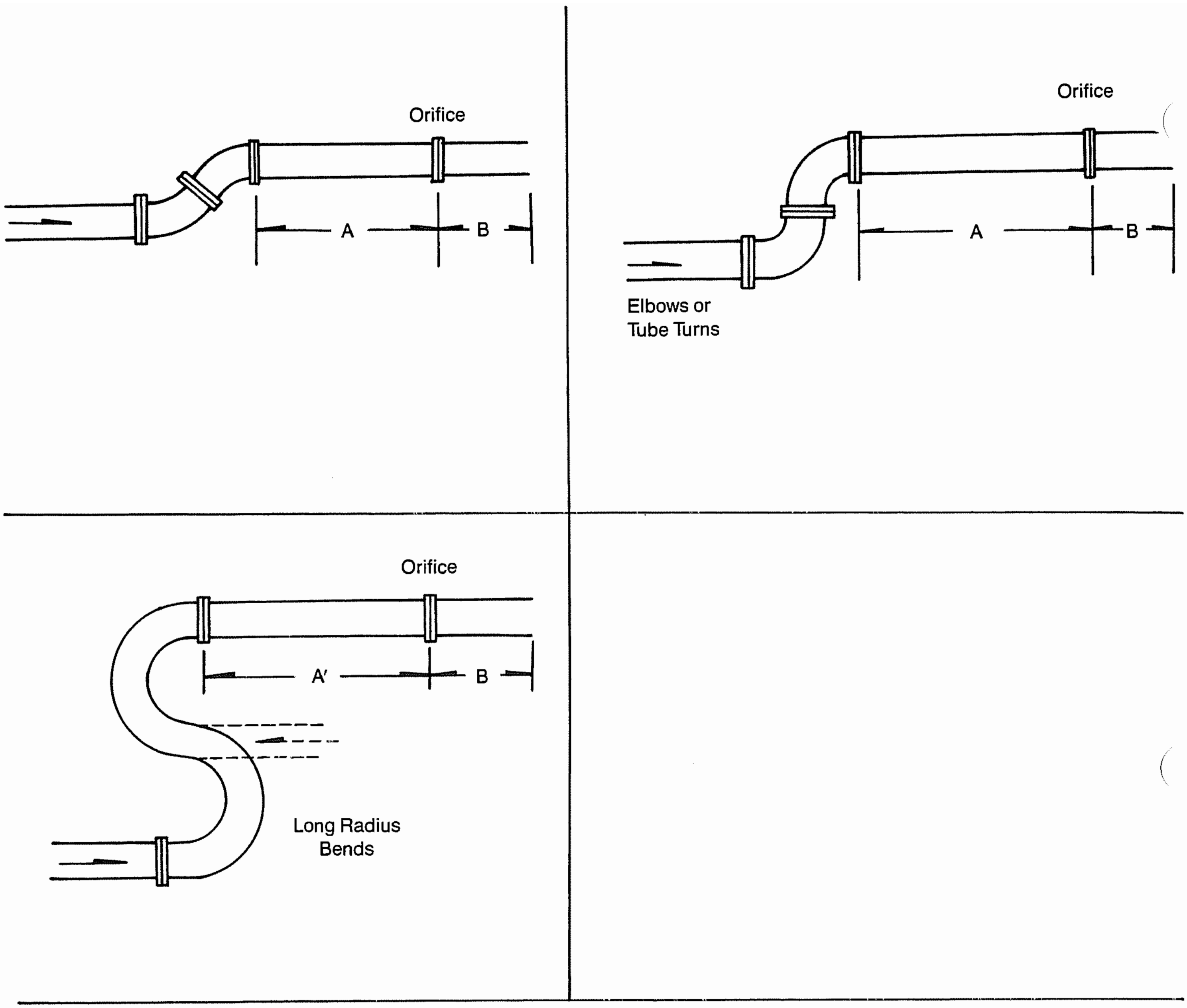



**Fig. 1 Orifice Holder Apparatus—General Arrangment**



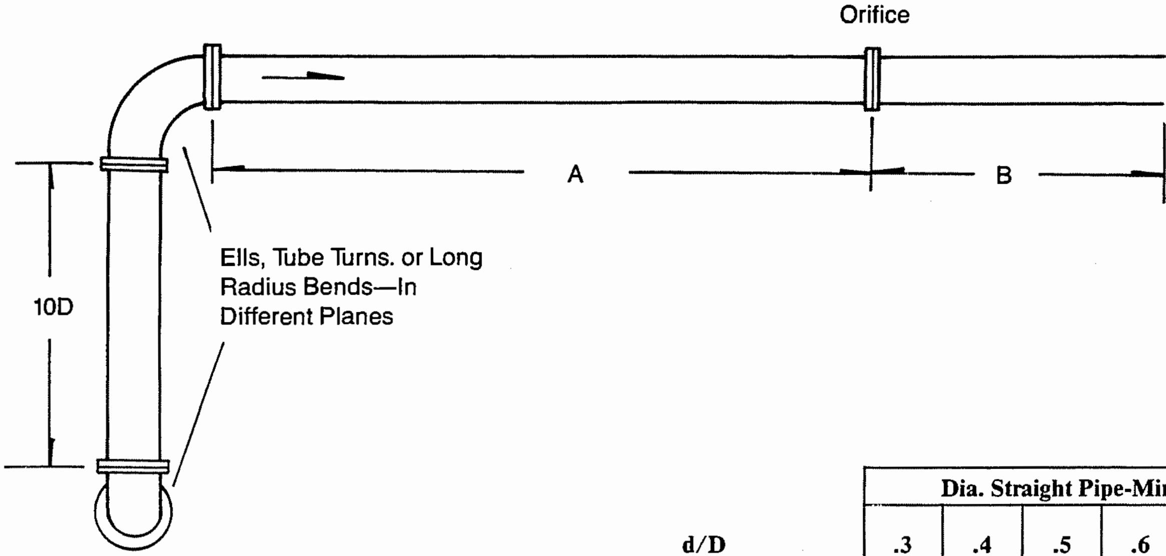

| | Dia. Straight Pipe-Min. | | | | |
|---|---|---|---|---|---|
| d/D | .3 | .4 | .5 | .6 | .7 |
| A | 6 | 7 | 7 | 9 | 13 |
| A′ | 6 | 7 | 7 | 9 | 11 |
| B | 3 | 3 | 3 | 4 | 4 |

**Fig. 2 Meter Tube Lengths**

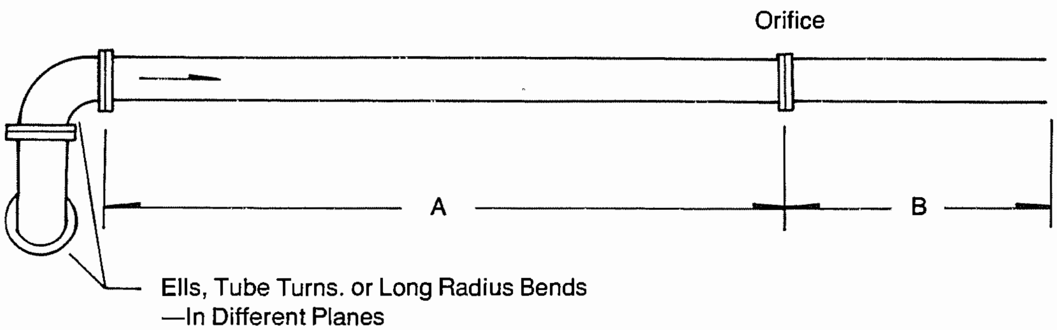



| | Dia. Straight Pipe-Min. | | | | |
|---|---|---|---|---|---|
| **d/D** | **.3** | **.4** | **.5** | **.6** | **.7** |
| **A** | 8 | 9 | 10 | 13 | 18 |
| **A′** | 6 | 6 | 8 | 11 | 15 |
| **B** | 3 | 3 | 4 | 4 | 4 |

**Fig. 2 Meter Tube Lengths (*Continued*)**

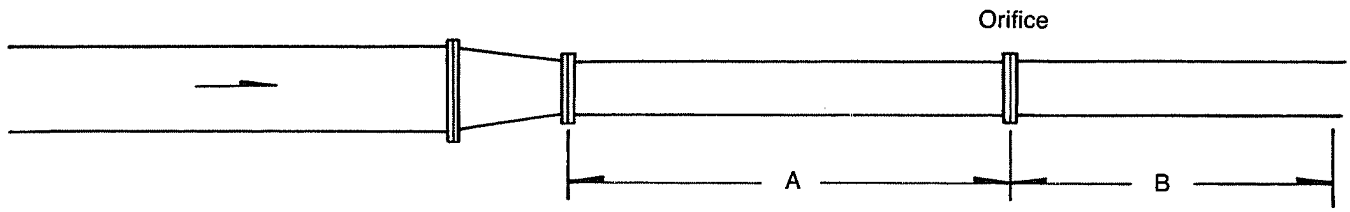


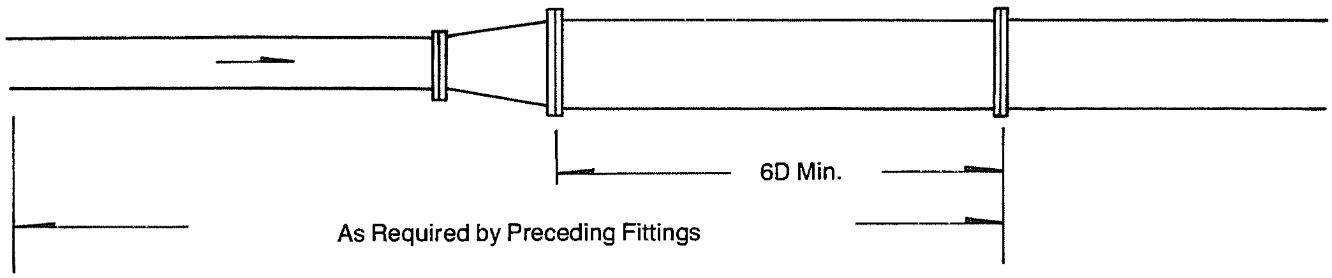

| d/D | Dia. Straight Pipe-Min. .3 | .4 | .5 | .6 | .7 |
|---|---|---|---|---|---|
| A—Elbows or Tube Turns | 14 | 14 | 16 | 19 | 24 |
| A′—Long Radius Bends | 6 | 7 | 9 | 11 | 15 |
| B | 2 | 3 | 3 | 3 | 4 |



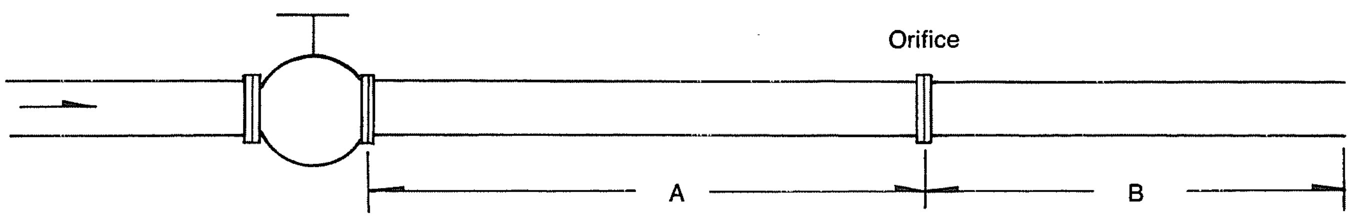

| d/D | Dia. Straight Pipe-Min. .3 | .4 | .5 | .6 | .7 |
|---|---|---|---|---|---|
| A—Elbows or Tube Turns | 16 | 18 | 20 | 24 | 30 |
| A′—Long Radius Bends | 8 | 10 | 12 | 16 | 22 |
| B | 3 | 3 | 3 | 3 | 4 |

**Fig. 2 Meter Tube Lengths (*Continued*)**



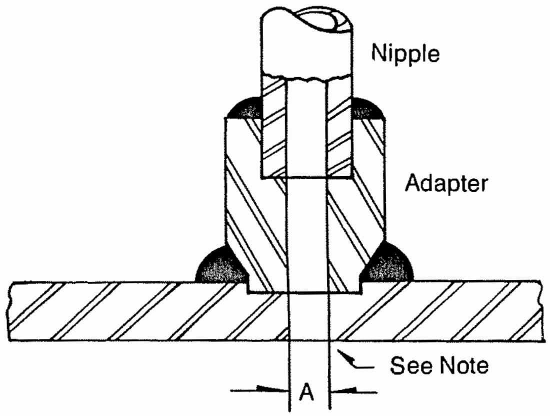




| | Dia. Straight Pipe-Min. | | | | |
|---|---|---|---|---|---|
| **d/D** | **.3** | **.4** | **.5** | **.6** | **.7** |
| **A** | 8 | 9 | 10 | 11 | 13 |
| **B** | 3 | 3 | 3 | 4 | 4 |



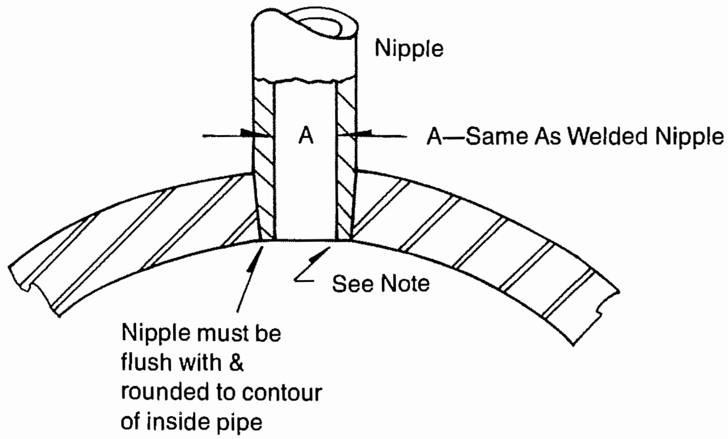

| | Dia. Straight Pipe-Min. | | | | |
|---|---|---|---|---|---|
| **d/D** | **.3** | **.4** | **.5** | **.6** | **.7** |
| **A—Globe & Stop Check Valves** | 9 | 10 | 11 | 13 | 15 |
| **A—Gate Valve Wide Open** | 6 | 6 | 7 | 8 | 10 |
| **B** | 3 | 3 | 4 | 4 | 4 |

**Fig. 2 Meter Tube Lengths (*Continued*)**

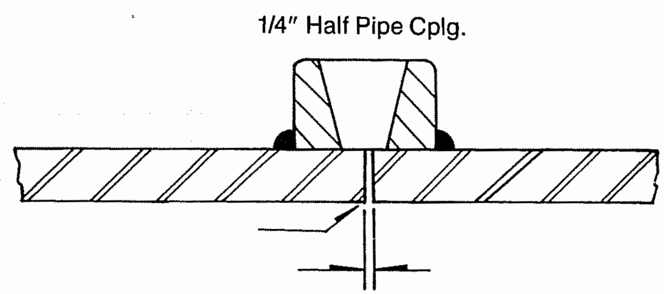



| Pipe Size | A—Max. |
|---|---|
| Under 2 | 1/4 |
| 2—3 | 3/8 |
| 4—8 | 1/2 |
| 10 & Over | 3/4 |

**WELDED NIPPLE CONSTRUCTION**




**SCREWED NIPPLE CONSTRUCTION**




**PIPE COUPLING CONSTRUCTION**

| Pipe Size | A—Max. |
|---|---|
| 2 | 3/64 |
| 2-1/2 | 1/16 |
| 3—5 | 5/64 |
| 6 | 3/32 |
| 8 | 7/64 |
| 10 Up | 1/8 |

NOTE: Edge of hole must be clean & sharp or slightly rounded, free from burrs, wire edges, or other irregularities.

**Fig. 3 Pressure Hole Constructions**

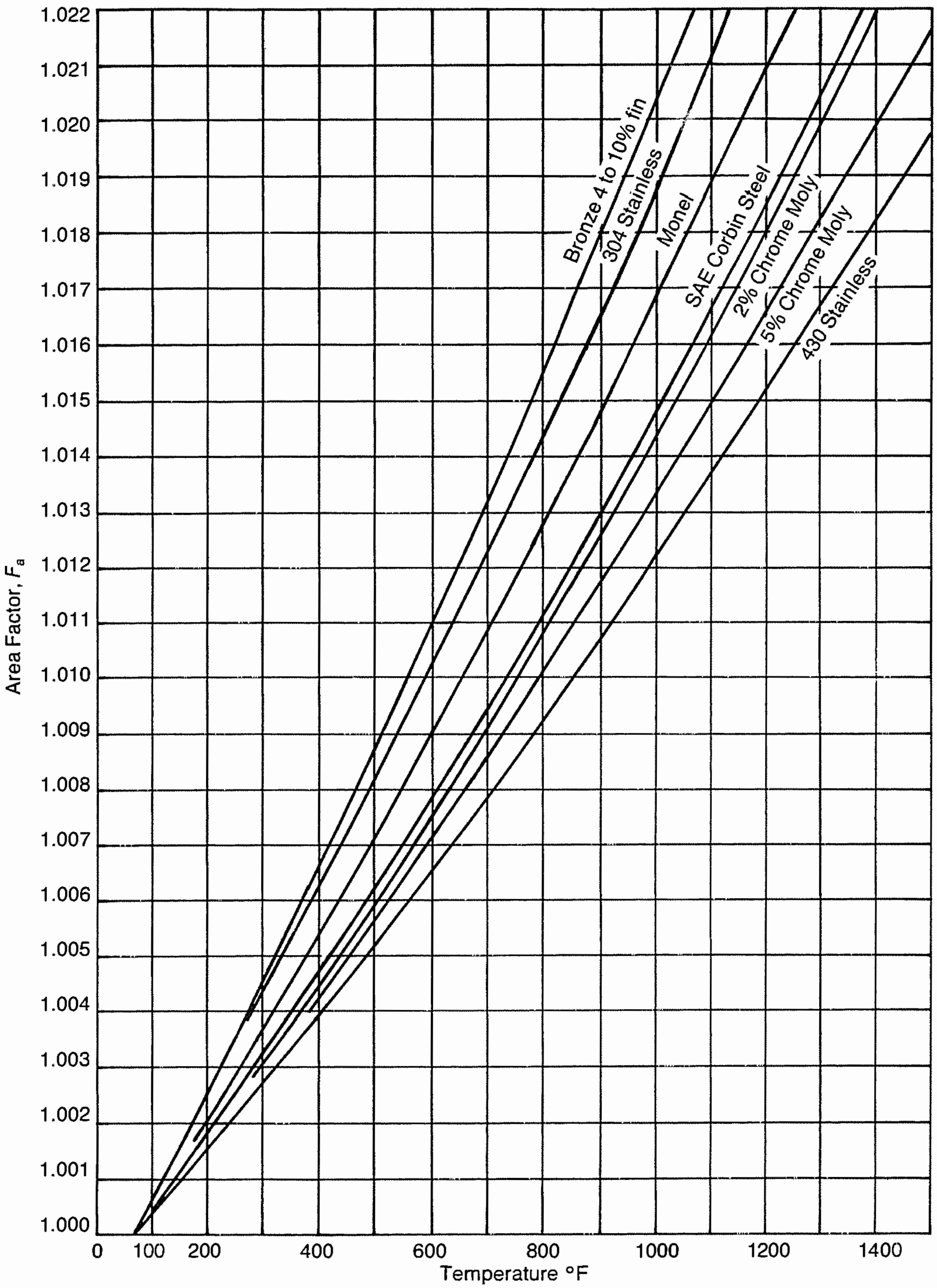



**Fig. 4 Orifice Area Factor**

## POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effects on the indoor and outdoor environment of the systems and components in their responsibility, while maximizing the beneficial effects which these systems provide, consistent with the accepted standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor or outdoor environment to a greater extent than specified by the standards as established by itself and other responsible bodies.

As an on-going goal, ASHRAE will, through its Standards Committee and extensive technical committee structure, continue to generate up-to-date standards where appropriate and adopt, recommend and promote those new and revised standards developed by other responsible organizations.

Through its Handbook, appropriate chapters will contain up-to-date standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with research and dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations which is pertinent, as guides to updating standards.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use, and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.