

ENGINEERING STANDARD
FOR
FLOW INSTRUMENTS

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1. SCOPE

This Standard covers recommended practices for the design and engineering aspects of different types of flow measurement instruments. These meters are commonly used to indicate, record, transmit, and control fluid flow.

Flow measurement falls into two broad classifications: process flow measurement and custody transfer. This standard is primarily concerned with process flow measurement. Liquid custody transfer is normally done with positive displacement meters or turbine meters, usually combined with meter proving equipment.

In this regard reference to be made to IPS-E-IN-240.

It is intended to be used in oil, gas, and petrochemical industries.

2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the vendor/consultant.

- 1) API Manual of Petroleum Measurement Standards, Chapter 5.2, "Measurement of Liquid Hydrocarbons By Displacement Meter Systems," First Edition, 1977.
- 2) API Manual of Petroleum Measurement Standards, Chapter 5.3, "Turbine Meters," First Edition, 1976.
- 3) API Manual of Petroleum Measurement Standards, Chapter 4, "Proving Systems," First Edition, 1978.
- 4) Spink, L.K., Principles and Practice of Flow Meter Engineering, The Foxboro Co., Foxboro, Massachusetts, Ninth Edition, 1967.
- 5) Lansford, W.M., The Use of an Elbow in a Pipe Line for Determining the Rate of Flow in the Pipe, University of Illinois, Urbana, Illinois, Bulletin No. 289, 1936.
- 6) Murdock, J.W., Holtz, C.J., Gregory, C., "Performance Characteristics of Elbow Flow Meters," ASME Paper 63-WA-17.
- 7) ANSI / API 2530, Orifice Metering of Natural Gas, and Other Related Hydrocarbon Fluids, AGA Report No.3, American Gas Association, New York, New York, Second Edition, 1985.
- 8) PTC 19.5.4, Instruments and Apparatus, supplement to ASME Power Test Codes, American Society of Mechanical Engineers, New York, New York, February, 1959.
- 9) Fluid Meters: Their Theory and Application, report of ASME Research Committee on Fluid Meters, 6th edition, American Society of Mechanical Engineers, New York, New York, 1971.
- 10) Beitler, S.R., and Mason, D.J., "Calibration of Eccentric and Segmental Orifices in 4 and 6 inch Pipe Lines," ASME Transactions, 71, American Society of Mechanical Engineers, October, 1949.
- 11) Bogema, M., Spring, B. and Ramamoorthy, M.V., "Quadrant Edge Orifice Performance-Effect of Upstream Velocity Distribution," ASME Transactions, Journal of Basic Engineering 84 Ser. D. [1], December, 1962.
- 12) Sprinkle, R.E., and Courtright, N.S., "Straightening Vanes for Flow Measurement," Mechanical Engineering 80 [5], February, 1958.
- 13) Landstra, J.A., "Quarter-Circle Orifices," Transactions, Institute Chemical Engineering, 38 [4], pp. 26-32, 1960.

- 14) Bogema, M., and Monkmeyer, P.L., "The Quadrant Edge Orifice-A Fluid Meter for Low Reynolds Numbers," ASME Transactions, Journal of Basic Engineering 82 Series D [6], September, 1960.
- 15) Miller, R.W., Flow Measurement Engineering Handbook, McGraw-Hill, New York, New York, 1983.
- 16) Filban, T.J., and Griffin, W.A., "Small-Diameter-Orifice Metering," ASME Transactions, Journal of Basic Engineering 82, Series D [6], September, 1960.
- 17) Miner, L.O., "The Dall Flow Tube," ASME Transactions 78, April, 1956.
- 18) Hopper, L.J., "Calibration of Six Beth Flow Meters at Alden Hydraulic Laboratory," ASME Transactions 72, November, 1950.
- 19) Hopper, L.J., "Design and Calibration of the Lo-Loss Tube," ASME Transactions 84, Part II, December 1962.
- 20) Computation of Orifice Bores Using Corner Connections, Barton Instrument Corporation, Monterey Park, California, 1954.
- 21) Sprengle, R.E., "Piping Arrangements for Acceptable Flow Meter Accuracy," ASME Transactions 67, July 1945.
- 22) API Standard 2534, Method of Measuring the Temperature of Petroleum and Petroleum Products, 1965, (ANSI / ASTM D 1086).
- 23) ISA Instrument Society of America
 - RP3.2 "Flanged Mounted, Sharp Edged Orifice Plates for Flow Measurement".
 - RP16.1, 2, 3 "Terminology, Dimensions, and Safety Practices for Indicating Variable Area Meters (Rotameters, Glass Tube, Metal Tube, Extrusion Type Glass Tube)".
 - RP16.4 "Nomenclature and Terminology for Extension Type Variable Area Meters (Rotameters)".
 - RP31.1 "Specification, Installation, and Calibration of Turbine Flowmeters".

24) IPS Iranian Petroleum Standards

IPS-E-GN-100	Units
IPS-M-IN-130	Material standard of flow instruments
IPS-E-IN-240	Engineering standard of Liquid custody transfer
IPS-M-IN-240	Material Standard of Liquid Custody Transfer

3. UNITS

All dimensions and ratings shall be metric to SI. (see: IPS-E-GN-100 units). Except for the temperatures, which shall be in degrees celcius instead of kelvin, and for pipes and fittings threads, which shall be in inches of NPT.

4. GENERAL

4.1 Differential Pressure Instruments

The differential-head type of instrument measures flow inferentially from the differential pressure caused by flow through a primary element. This differential pressure is sensed by diaphragms, bellows, or manometers. Transmitters of the force or motion type are either pneumatic or electronic. Electronic transmitters use strain gages, capacitance detectors, or other solid state detectors to provide output with minimal sensing element displacement.

Primary elements are generally one of the types described in 4.1.1 through 4.1.6

4.1.1 Orifice

Orifices are usually thin concentric plates, but they may be eccentric, segmental, quadrant edge, or some other special form, depending upon their application.

4.1.2 Flow nozzle

Flow nozzles are used in installations where higher velocity and moderately better pressure recovery are required than are obtainable with an orifice plate.

4.1.3 Venturi tube

Venturi tubes are used in installations where high capacity and good pressure recovery are required or where the measured stream contains some solids.

4.1.4 Flow tube

Flow tubes are used in installations where low pressure loss is a major consideration or where piping configurations are restrictive.

4.1.5 Pitot tube

Generally, pitot tubes are used in installations where no appreciable pressure drop can be tolerated on high-volume flows, such as on cooling water. The accuracy of the measurement depends upon the determination of the average velocity from the velocity profile. An averaging pitot tube is also available.

4.1.6 Elbow taps

Elbow taps are used in installations where the velocity is sufficient and where high accuracy is not required [4]*. Although they are less accurate than other differential pressure instruments, elbow taps possess good repeatability. A water velocity of 17 feet per second (5 meters per second) will produce a water differential of approximately 100 inches (2500 millimeters). Some test data are available [5,6]*.

* Bracketed numbers indicate references which are listed in para. 2.2.

4.2 Variable Area Flowmeters

Variable area flowmeters are normally used when local indication only is required.

4.3 Force or Target Flowmeters

Force or target flowmeters measure flow inferentially by measuring the force developed at a disk-shaped target suspended in the flow path.

4.4 Turbine Flowmeters

Turbine meters measure flow from the rotation produced by the flow past a turbine or propeller.

4.5 Electromagnetic Flowmeters

If a fluid has some degree of electrical conductivity, an electromagnetic flowmeter can measure its average flow velocity inferentially from the voltage generated by the fluid as it moves through a magnetic field.

4.6 Positive Displacement Meters

This meter measures flow by isolating, counting, and totaling segments of known volume as they are displaced through its body [1]*.

4.7 Vortex Flowmeters

Vortex meters are oscillatory flowmeters that utilize the vortex train generated by an obstruction placed in a fluid stream. They measure flow by counting the vortices.

* Bracketed numbers indicate references which are listed in para. 2.2.

4.8 Sonic Flowmeters

There are two main classes of sonic flowmeters. Contrapropagating meters measure the difference in the transit times of sounds transmitted upstream and downstream. Doppler or reflection meters measure the frequency shift of sound reflected back from particles or bubbles in the flow stream.

4.9 Mass Flowmeters

These meters use the principle of coriolis acceleration which allow true mass flow rate measurements of fluids to be made directly, without the need for external temperature, pressure, or specific gravity measurements.

5. DIFFERENTIAL PRIMARY ELEMENTS

5.1 Thin-Plate Orifices

5.1.1 Concentric orifice plates

The sharp-edge, concentric orifice plate is the most frequently used primary element because of its low cost, adaptability, and the availability of accurate coefficients.

For most services, orifice plates are made of corrosion-resistant materials, usually type 316 stainless steel. Other materials are used for special services.

The upstream face of the orifice plate should be as flat as can be obtained commercially. It must be smooth, and its finish should be at least equivalent to that given in Fig. 1.

The thickness of the orifice plate at the orifice edge should not exceed (minimum requirements governing in all cases):

- D/50 (one-fiftieth of pipe diameter)
- d/8 (one-eighth of orifice diameter)
- (D-d)/8 (one-fourth of dam height)

* Bracketed numbers indicate references which are listed in para. 2.2.

In some cases, including large pipe diameter and high pressure and temperature, the thickness of the orifice plate will be greater than is permitted by the limitations for the thickness of the orifice edge. In such a case the downstream edge shall be counterbored or beveled at an angle of (30-45) degrees to the required thickness at the orifice edge. The word "upstream" or "inlet" should be stamped on the orifice tab on the square-edge side of the plate. Dimensions for orifice plates are shown in Fig. 1.

Bores must be round and concentric. Practical tolerances for orifice diameters, as given in ANSI / API 2530 [7]*, are shown in Table 1.

The upstream edge of sharp edge orifice should be square and sharp. It is usually considered sharp if the reflection of a beam of light from its edge cannot be seen without magnification. The edge radius should not exceed 0.0004 times the bore diameter. It should be maintained in this condition at all times. For two-way flow, both edges must be square. Orifice plate details and schedule of thicknesses are shown in Fig. 1. Detailed tolerances are discussed in ANSI / API 2530 and American Society of Mechanical Engineers Publications [8.9]*.

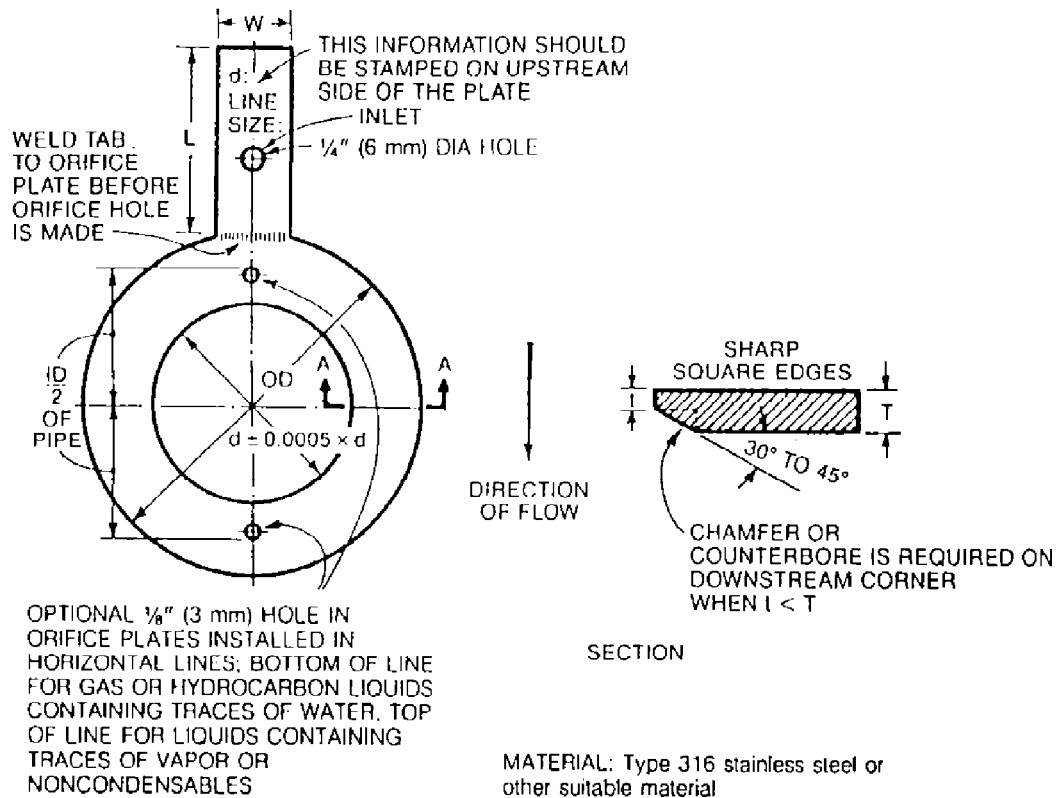
In wet-gas or wet-steam services, where the volume of condensate is small, a weep hole flush at the bottom of the orifice run may be used to prevent a build-up of condensate in horizontal lines. The weep hole serves as a drain to prevent freeze-up during shutdown periods. A weep hole flush with the top of the pipe can also be used to pass small quantities of gas in liquid streams. If the diameter of the hole is less than one-tenth of the orifice bore diameter, the maximum flow through the drain hole is less than 1 percent of the total flow.

Because more test information is available for thin-plate orifices than for other primary devices, it is possible to design orifice installations to acceptable accuracies. Sometimes the layout of equipment precludes the use of the most accurate design. A lower order of accuracy is often acceptable in installations used only for control purposes than in installations used for accounting, material balance, or custody transfer.

* Bracketed numbers indicate references which are listed in para. 2.2.

TABLE 1
PRACTICAL TOLERANCES FOR ORIFICE DIAMETERS
DIMENSIONS IN INCHES AND MM

ORIFICE SIZE, d		TOLERANCE PLUS OR MINUS	
		MM	INCH
	MM	INCH	
	6.350	0.250	0.00762
	9.525	0.375	0.01016
	12.700	0.500	0.0127
	15.875	0.625	0.0127
	19.050	0.750	0.0127
	22.225	0.875	0.0127
	25.400	1.000	0.0127
	Over 25.400	1.000	0.0127
			0.0003
			0.0004
			0.0005
			0.0005
			0.0005
			0.0005
			0.0005
			0.0005
			0.0005
			per 25.4 mm (1 in) of diameter



ORIFICE PLATE OUTSIDE DIAMETERS TO FIT ANSI SERVICE RATED FLANGE UNIONS

NOMINAL			CLASS						
PIPE SIZE DN	T	t	300	600	900	1500	2500	I	TAB
									w
50 (2)	3 (1/8)	0.8 (1/32)	110 (4 3/8)	110 (4 3/8)	143 (5 5/8)	143 (5 5/8)	146 (5 ¾)	100 (4)	20 (¾)
80 (3)	3 (1/8)	0.8 (1/32)	150 (5 7/8)	150 (4 7/8)	168 (6 5/8)	175 (6 7/8)	197 (7 ¾)	100 (4)	20 (¾)
100 (4)	3 (1/8)	1.6 (1/16)	181 (7 1/8)	194 (7 5/8)	305 (8 1/8)	210 (8 ¼)	235 (9 ¼)	150 (6)	25 (1)
150 (6)	3 (1/8)	2.4 (3/32)	251 (9 7/8)	267 (10 ½)	289 (11 3/8)	283 (11 1/8)	317 (12 ½)	150 (6)	25 (1)
200 (8)	3 (1/8)	3 (1/8)	308 (12 1/8)	321 (12 5/8)	359 (14 1/8)	352 (13 7/8)	387 (15 ¼)	150 (6)	25 (1)
250 (10)	6 (¼)	4.8 (3/16)	362 (14 ¼)	400 (15 ¾)	435 (17 1/8)	435 (17 1/8)	476 (18 ¾)	150 (6)	25 (1)
300 (12)	6 (¼)	5.6 (7/32)	422 (16 5/8)	457 (18)	498 (19 5/8)	521 (20 ½)	549 (21 5/8)	150 (6)	25 (1)
350 (14)	6 (¼)	5.6 (7/32)	486 (19 1/8)	492 (19 3/8)	521 (20 ½)	578 (22 ¾)		150 (6)	25 (1)
400 (16)	9 (3/8)	7.2 (9/32)	540 (21 ¼)	565 (22 ¼)	575 (22 5/8)	641 (25 ¼)		150 (6)	25 (1)
450 (18)	9 (3/8)	7.2 (9/32)	597 (23 ½)	613 (24 1/8)	638 (25 1/8)	705 (27 ¾)		150 (6)	25 (1)
500 (20)	9 (3/8)	9 (3/8)	654 (25 ¾)	683 (26 7/8)	698 (27 ½)	756 (29 ¾)		180 (7)	25 (1)
600 (24)	9 (3/8)	9 (3/8)	775 (30 ½)	790 (31 1/8)	838 (33)	902 (35 ½)		180 (7)	25 (1)

CONCENTRIC ORIFICE PLATE
Fig. 1

Notes: (Related to Fig. 1)

- 1) All measurements inside parenthesis are in inches and the rest are in mm.
- 2) The outside diameter (OD) of the orifice plate is that required to fit inside the bolts of standard ANSI flanges. The outside diameter is equal to the diameter of bolt circle minus the nominal diameter of bolt, within a manufacturing tolerance of +0 millimeters, -0.8 millimeters (+0 inches, -1/32 inch).
- 3) For orifice plate outside diameters in flange sizes and ratings not listed above, refer to gasket OD dimensions given under Fig. 3, Table 1, Appendix E in ANSI B 16.5-1981, "Steel Pipe Flanges and Flanged Fittings", available from the American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.
- 4) The upstream face of the orifice plate shall be as flat as can be obtained commercially; any plate departing from flatness along any diameter more than 0.25 millimeters (0.010 per inch) of dam height, $(D-d)/2$, shall be unacceptable. Surface roughness shall not exceed 1.3 microns (50 microinches) in a band at least 0.25 diameter wide around the orifice bore.
- 5) All seating surfaces for spiral-wound gaskets should be clean and free of rust, burrs, nicks, and so forth. Any surface not meeting the following tolerances should be relapped:
 - a) Roughness

Should not exceed 2 microns (80 microinches) root mean square with 1.6 microns (63 microinches) root mean square or better as optimum.

- b) Flatness

Out-of-plane tolerances must not exceed 0.06 millimeter (0.0025 inch). The cumulative out-of-flatness for two mating surfaces shall not exceed 0.1 millimeter (0.0040 inch).

5.1.2 d/D (β) Ratio

Orifice diameters should be selected so that the ratio of orifice diameter to actual internal pipe diameter, d/D , does not exceed the limits as shown on ANSI / API 2530, as follows:

- 1) With meters using flange taps, β shall be between 0.15 and 0.70.
- 2) With meters using pipe taps, β shall be between 0.20 and 0.67.

With either type of pressure taps, diameter ratios as low as 0.10 may be used while ratios as high as 0.75 may be used with flange taps and as high as 0.70 may be used with pipe taps. The flow constants, F_b , for these extreme values of β are subject to higher tolerances, and it is recommended that the use of these extreme ratios be avoided (see ANSI / API 2530).

When using small bores, care should be exercised to prevent plugging by pipe scale or other foreign material.

5.1.3 Other orifice plates

Eccentric or segmental orifices may be used in horizontal runs for special services where concentric orifices cannot be used. In some installations, the fluid stream possesses a large quantity of undissolved gas or a gas containing condensables, which may be carried along the pipe. This type of plate can produce full venting or full drainage, whichever is required, if the orifice opening is properly located.

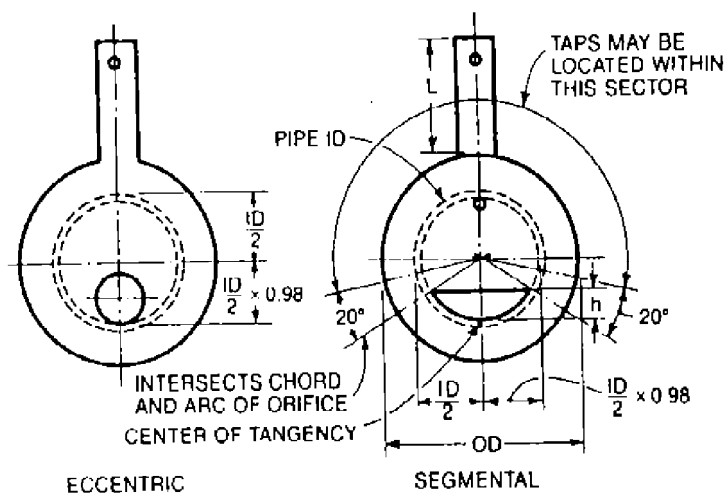
Segmental orifices are recommended for slurry services because of their insensitivity to changes in the liquid-solid ratio and their relatively satisfactory accuracy (approximately 2.2 percent for plate calculations) [10]*.

* Bracketed numbers indicate references which are listed in para. 2.2.

The eccentric orifice usually is placed with its edge tangent to a circle having a diameter 0.98 of that of the pipe. The point of tangency is at the top, vertical centerline for liquids containing some vapor, and at the bottom, vertical centerline for vapors containing some liquids. Coefficients are also available for differential pressure taps at 90 or 180 degrees

from the point of tangency. Eccentric and segmental orifice plates are shown in Fig. 2. Segmental orifices are usually constructed with a circle diameter (D) between 0.97 and 0.98 percent of the inside pipe diameter (ID). They are generally used in services which require that the orifice be placed at the bottom of the line. For best accuracy, the tap location should be 180 degrees from the center of tangency. However, to avoid gas bubbles in the taps, the location may be anywhere within the sector shown in Fig. 2.

The quadrant-edge, or quarter-circle, orifice is a device in which the upstream edge is rounded to form a quarter circle. The thickness of the plate near the orifice is equal to the radius of the quarter circle. See typical drawing No. 9 of IPS-M-IN-130.



ECCENTRIC AND SEGMENTAL ORIFICE PLATES
Fig. 2

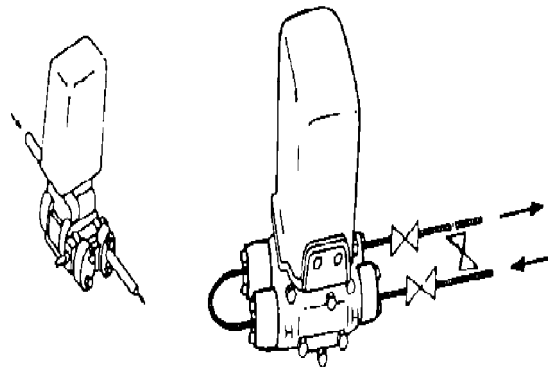
The quadrant-edge orifice is used for the flow measurement of viscous streams because of its relatively constant coefficient over a wide range of low Reynolds numbers. It is especially valuable where the viscosity is high and variable. In contrast, the square-edge orifice coefficients show increasing dependence on orifice Reynolds number⁽¹⁾, R_d , below 100,000. Square-edge orifice coefficient correction factors are available for R_d down to approximately 25,000.

(1) In some data, R_D (The Reynolds number for the pipe) is given; in other data, R_d , (the Reynolds number for the restriction) is given. The difference between these two numbers is shown in the following equation $RD = \beta R_d$

The quadrant-edge orifice may be used when the line Reynolds numbers (R_D) range from 100,000 down to 3000 to 5000, depending upon the β ratio. It has a standard deviation of ± 1 percent for β from 0.3 to 0.6 and ± 1.25 percent for β from 0.25 to 0.3. It is recommended for measurement of flows when the Reynolds number, based on pipe diameter, is less than 10,000. When R_D is below the 3000 to 5000 range, the coefficient curve shows a hump, which is proportionally higher for longer upstream runs. The hump may be suppressed, even at values of RD below 1000, by taking the flow straight out of a vessel nozzle through a meter run of only a few pipe diameters ahead of the orifice. The hump may also be suppressed by using a screen, such as a multiplate flow straightener, a few diameters upstream [11-14]*.

Readings for flows exceeding the maximum Reynolds number limits may be very inaccurate. High-quality machining of quadrant orifice plates is important because the dimensions, shape, and smoothness of the edges can affect the accuracy of its readings.

A very small orifice plate or capillary that is an integral part of a diaphragm pressure transmitter is sometimes used for the measurement of very small flows. Flows as low as 0.04 cubic centimeters per minute of water equivalent or 0.027 standard cubic feet per minute of air may be measured using this method (see Fig. 3).



INTEGRAL ORIFICE FLOWMETER-LIQUID AND GAS

Fig. 3

Notes:

- 1) Upstream strainers or filters are optional, but highly desirable.
- 2) For continuous services, provide block and bypass valves to allow meter calibration.
- 3) Provide breakout unions where piping cannot be spread to remove meter body.

* Bracketed numbers indicate references which are listed in para. 2.2.

5.1.4 Sizing orifices

It is common to size the orifice for a 2500 millimeter (100 inch) water column (dry calibration) at maximum flow. This permits either an increase or decrease in maximum flow, without changing the orifice bore, by an adjustment of the differential transmitter range. Smaller differentials, 1250 millimeters (50 inches) or 500 millimeters (20 inches), are now commonly used to save energy. For gas or steam flow, a good rule of thumb is that the meter range, in mm of water (inches of water), should not exceed the flowing pressure, in m bar absolute (pounds per square inch absolute).

The procedures for computing orifice sizes and flow through orifices are given in various publications [4,7,9,15,16]. Special slide rules are specially valuable for checking longhand or computer computations and for preliminary orifice sizing.

Programs and softwares to size orifices are also available for various computers and programmable calculators. Orifice calculations can be purchased from the manufacturers of orifice plates or flowmeters. Occasionally, only approximate physical properties of the flowing fluid are known before startup; in such cases a flow slide rule may be used to determine orifice size. Computations can be made later using actual flow conditions, or corrections can be applied to preliminary computations made with the approximate values. See plant calculations equations for liquid, steam and gases in appendix A, page 70 through 74, which are extracted from chapter 29 of [4]*.

Note:

Meter range shall be selected in accordance with the following:

- a) for orifice meters, normal flow rate shall be between 70% and 80% of capacity, provided anticipated minimum and maximum flow rates will be between 30% and 95% of capacity;
- b) if rangeability larger than 30% to 95% is required, two differential pressure transmitters connected to the same orifice taps shall be used.

* Bracketed numbers indicate references which are listed in para. 2.2.

5.2 Flow Nozzles

Flow nozzles are used less frequently than orifice plates. Their principal advantages are better pressure recovery and approximately 65 percent higher flow capacity for a given diameter than can be obtained under the same conditions with orifice plates. Flow nozzles may be used in light slurry service; however, accuracy is poor below certain Reynolds numbers [1,5,6]. Meter run requirements, flange ratings, and tap requirements are generally the same as for orifice installations. However, because the d/D ratio for the same flow and line size is smaller, a shorter meter run may be used where the run length is based on the minimum run for the actual d/D ratio.

A typical flow nozzle is shown in Fig. 4. There are several forms of flow nozzles, one of the most common being the American Society of Mechanical Engineers' long-radius form [4,9]. Properly installed and calibrated, flow nozzles are nearly equal in accuracy to sharp-edge orifices. Calculation procedures and coefficients for flow nozzles have been published [4,7,8]*.

5.3 Venturi Tubes and Flow Tubes (Lo-Loss, Dall and Gentile Tubes)

5.3.1 General

Venturi tubes and flow tubes are frequently used in petroleum industries. Permanent head loss for these devices is lower than for other constricting primary elements. Venturi and flow tubes should be considered for all applications where minimizing head loss is an important factor. These primary devices are more costly than orifice or flow nozzle installations, and the long-form venture is the most expensive. The venture tube and flow tubes are shown in Fig. 4.

* Bracketed numbers indicate references which are listed in para. 2.2.

5.3.2 Venturi tubes

Venturi Tubes (see Fig. 4) give a much lower permanent head loss than orifices or flow nozzles. For a long-form venture tube, the approximate head loss will be between 10 and 14 percent of the measured differential, dependent upon the d/D ratio. Minimum runs are usually shorter for these tubes than for orifice plates or flow nozzles. As a rule, the manufacturer of the venture tube can supply the minimum length meter run data.

Although coefficients are available for the calculation of flow through venture tubes [4,8,9]*, the manufacturer may specify the flow for a given differential. Venturi tubes usually give an accuracy nearly equal to that of a thin-plate orifice. Venturi tube flow coefficients are relatively stable over a wider range of Reynolds numbers than are the coefficients of sharp-edge orifices.

When properly purged, venture tubes are suitable for metering streams that contain solids. An increase in the solid liquid ratio will cause a higher reading.

5.3.3 Dall tubes

The dall tube [17]* is available as a fabricated line insert, approximately 2 diameters long. The static pressure tap is in a linesize section followed by a sharp shoulder and a steep, conical entrance to a short, cylindrical section, which has an annular slot, followed by a 15-degree conical diffuser, terminating with a shoulder (see Fig. 4).

Upon examination, the Dall tube gives the impression that a fluid flowing through it would be subject to a very high permanent head loss. Actually, the Dall tube head loss is only about 2½ to 6 percent of the measured differential as compared to 10 to 14 percent for the same flow in a long-form venture. The coefficient may vary for line Reynolds numbers below 500,000. Rounding of the sharp edges will cause slight variations in the coefficients.

Unless it is purged, the Dall tube should not be used for slurries or fluids that contain suspended solids because the annular throat slot is subject to plugging. Dall tubes require longer minimum meter runs than venture tubes.

*** Bracketed numbers indicate references which are listed in para. 2.2.**

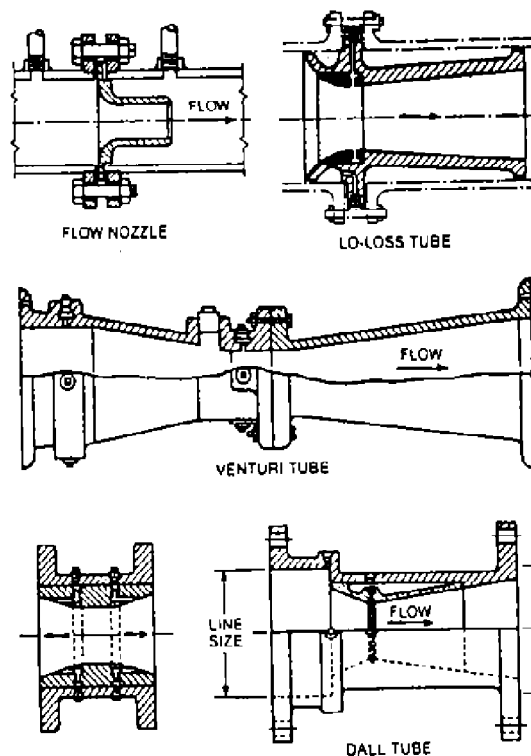
5.3.4 Gentile tubes

The Gentile tube has impact- and suction-type piezometer openings to increase the measured differential. The Gentile tube is short and gives a good differential with a relatively small amount of constriction (approximately 1½ diameters) (see Fig. 4). Its coefficients are the same for flow in either direction, and it is less expensive than a venture tube. However, Gentile tubes are very susceptible to line roughness.

Until sufficient data has been accumulated on the effect of manufacturing tolerances and upstream piping configurations on its accuracy, a Gentile tube should be calibrated for any application where accuracy is important [18]*.

5.3.5 Lo-loss tubes

The Lo-Loss tube [19]* is another type of differential producer designed for very high-pressure recovery. Its installation requires much less length than the venture tube, but its use should be restricted to relatively clean services (see Fig. 4).



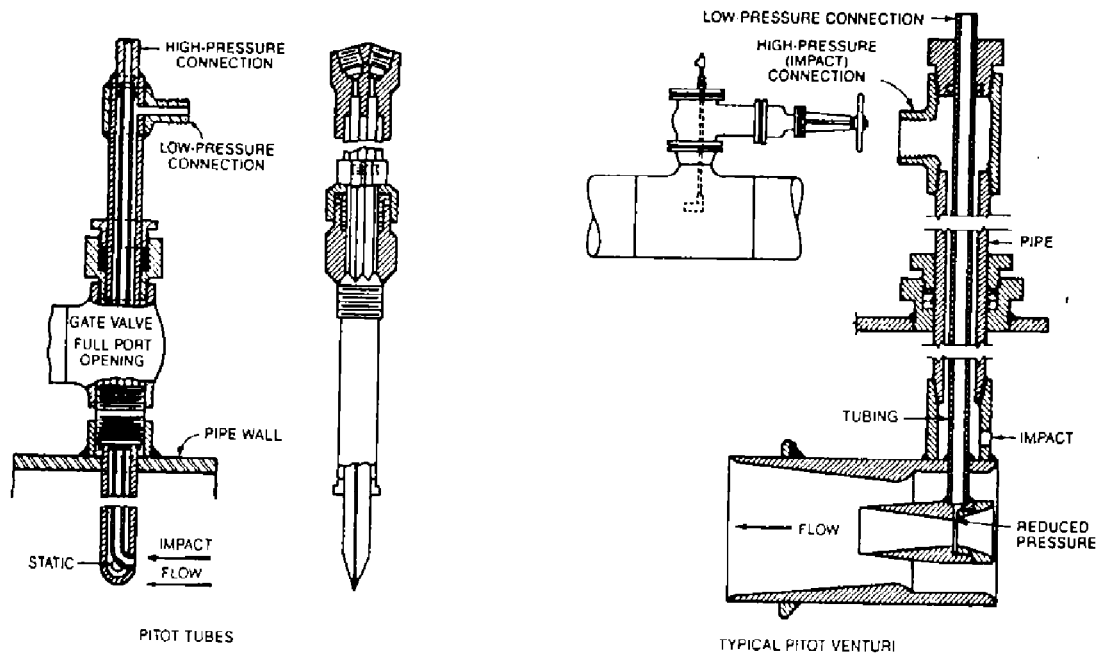
FLOW NOZZLE, VENTURI TUBE, AND FLOW TUBES
Fig. 4

* Bracketed numbers indicate references which are listed in para. 2.2.

5.4 Pitot Tubes and Pitot Venturis

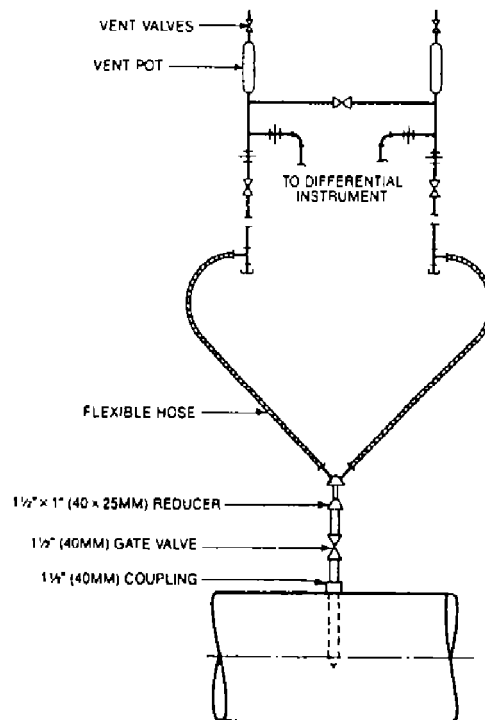
Pitot tubes and pitot venturis are used where the pressure drop or power loss through other devices cannot be tolerated where accuracy is not of prime concern and where the pipe diameter is too large for acceptable orifice plate design (see Fig. 5). Frequently, these devices are used to measure high air and water flow rates. Pitot venturis are useful in applications where an ordinary pitot tube does not give satisfactory differential. However, they require a larger tap size. Pitot venturis should not be used in a liquid service of greater than 2.7 m (9 feet) per second if dissolved gases are present. Higher velocities cause cavitation, and gas bubbles collect in the meter connecting lines. A traverse is required for good measurement unless there is sufficient straight upstream run to obtain a uniform velocity profile, except in cases where an averaging type of pitot tube is used.

Proper design will permit the installation or removal of pitot tubes and pitot venturis from lines that are in service. Care should be exercised when considering their use in hot oil or other hazardous service except in fixed installations designed to be leakproof. As the line size increases, the cost of pitot tubes and pitot venturis decreases in relation to other primary elements. A typical pitot tube installation is shown in Fig. 6.



PITOT TUBES AND PITOT VENTURI

Fig. 5



PITOT TUBE INSTALLATION

Fig. 6

5.5 Elbow Taps

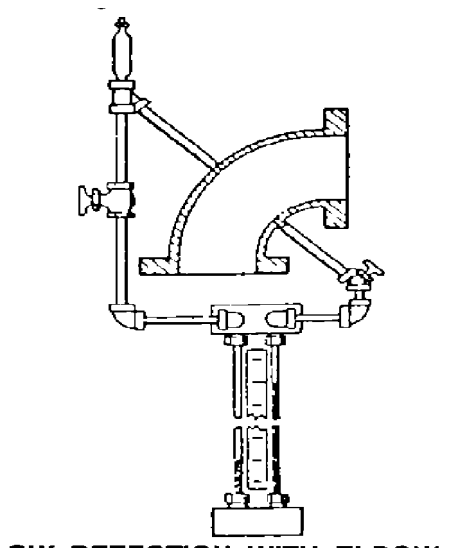
Flow measurement using elbow taps depends on a measurement of the differential pressure developed by centrifugal force as the direction of fluid flow is changed in a pipe elbow. Taps are located at opposite ends of a diameter in the plane of the elbow; the diameter which passes through the taps is at either 45 degrees or 22½ degrees from the inlet face of the elbow (Figure 7).

Elbow taps have an advantage in that most piping configurations already contain elbows in which taps can be located. This allows economical installation and results in no added pressure loss. The measurement introduces no obstructions in the line. With normal precaution against accumulation of extraneous material in the differential pressure connections, elbow taps may be used to measure flow of almost any fluid.

As with other head-type primary flow measurement devices, the differential pressure developed by a given flow is precisely repeatable. However, the coefficient of an elbow tap calculated from the physical dimensions is generally considered reliable to only ± 5 to ± 10 percent. This is quite satisfactory for many flow control applications, where repeatability is the primary consideration.

If absolute accuracy is essential, a more precise type of meter is recommended, or an actual flow calibration of the system can be performed, preferably in place and using the working fluid. Data on elbow tap measurement is insufficient to establish precise correction factors for effects of upstream disturbances, viscosity, and roughness in pipe, elbow surfaces, etc.

Elbow taps develop a relatively low differential pressure. For this reason, their use is questionable for measurement of streams with low velocity. Typically, water flowing at an average velocity of 5 feet per second (roughly 200 gpm in a 4 inch pipe or 1.5 meters per second roughly 45 cubic meters per hour in a 100 mm pipe) through a conventional elbow with a center line radius equal to the pipe diameter develops about 10 inches of water differential pressure. This approaches minimum full scale value recommended for reliable measurement. Taps in long radius pipe or tube bends do not develop sufficient differential pressure for good flow measurement at low flow velocities.



FLOW DETECTION WITH ELBOW TAPS

Fig. 7

Care in installation of elbow taps is required, as it is with other head-type meters. Straight runs of pipe at least 25 pipe diameters upstream and 10 diameters downstream are recommended. The tap holes should be perpendicular to the surface of the elbow and slightly rounded at the pipe surface with no burrs or protrusions. Tap hole diameter should not exceed 1/8 of the pipe diameter. Elbows should be of the flange type with the elbow diameter equal to the pipe diameter. An elbow of smaller diameter than the pipe with a reducer between pipe and elbow has the advantage of higher differen-

tial for a given flow. Threaded elbows with the flow section larger than the pipe develop less differential pressure and introduce major uncertainty in calculated coefficient. Best results, particularly as to reliability of coefficient, are obtained with elbows with smooth inside surfaces. The elbow should be precisely aligned with the pipe with no projecting surfaces or gaskets protruding into the flowing stream either at the inlet or outlet of the elbow.

5.6 Metering Runs

5.6.1 Orifice taps

Orifice taps may be of several types, as shown in Fig. 8. Flange taps usually are preferred. Vena contracta taps and pipe taps sometimes are used. However, vena contracta taps cannot be used with some sizes and pressure ratings of welding-neck flanges because one or both taps may fall in an undesirable location in the flange hub or weld. Also, when changing orifice bore, the downstream tap must be changed.

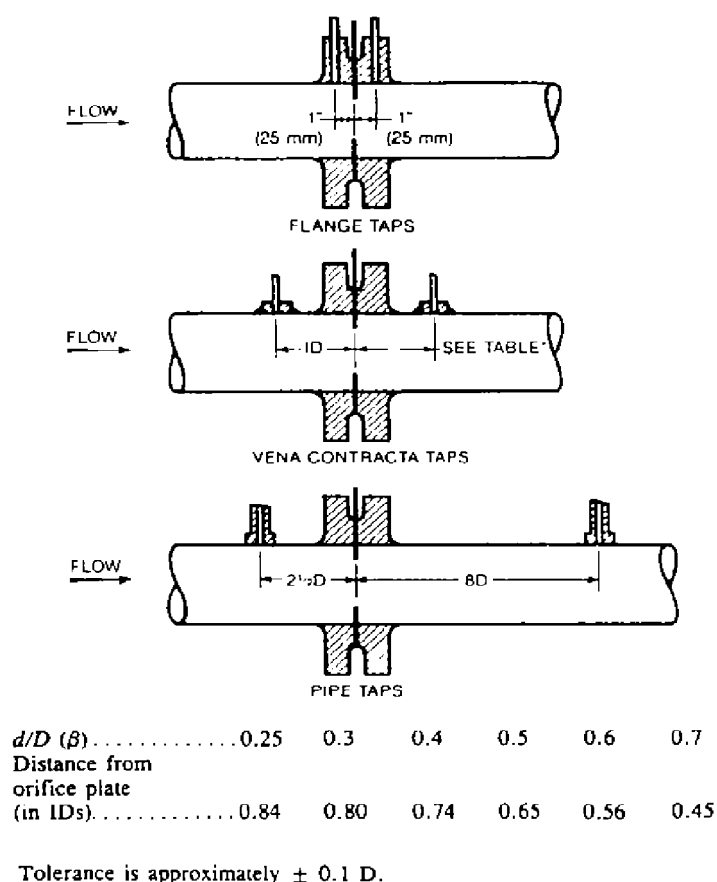
Radius or throat taps (those located 1 pipe inside diameter upstream and $\frac{1}{2}$ pipe inside diameter downstream) can be used for some services. The downstream tap for the radius or throat tap sometimes falls either fully or partially into the flange hub.

Corner taps [20]* are used sometimes, particularly on small lines where flange taps may be at the wrong location in the pressure profile. One type of corner tap orifice flange arrangement is shown in Fig. 9.

Pipe taps or full-flow taps, located $2\frac{1}{2}$ diameters upstream and 9 diameters downstream, measure the permanent pressure loss. These can measure higher flow rates for a given meter differential than can flange, vena contracta, radius, or corner taps.

Orifice flanges with flange taps, as shown in Fig. 9 are generally used. These flanges have a minimum thickness of 40 millimeters ($1\frac{1}{2}$ inches). In the smaller sizes, they are thicker than the standard class 300 flange. Each tap should be positioned 25 millimeters (1 inch) from the nearest face of the orifice plate. It is important to allow for compressed gasket thickness.

* Bracketed numbers indicate references which are listed in para. 2.2.



FLANGE TAPS, VENA CONTRACTA TAPS, AND PIPE TAPS

Fig. 8

Curves on allowable variations in pressure tap hole location versus β ratio can be found in ANSI / API 2530. It is recommended that the tolerances for β ratio of 0.70 minimum be used.

For pipes smaller than 100 millimeters (4 inches), the tolerance is 0.6 millimeters (0.025 inches). This tolerance increases to 2 millimeters (0.065 inches) at a β of 0.40 or smaller.

If 20 millimeter ($3/4$ inch) taps are used, minimum flange thickness should be 40 millimeters ($1\frac{5}{8}$ inches). Where piping specifications exclude threaded joints in primary piping, socket or fillet-weld-taps may be used with socket-weld block valves. If secondary piping may be screwed, the block valves may be socket-weld on one end and threaded on the other. Screwed taps may be seal-welded to minimize leakage. It is recommended that nipples to the first block valves be at least Schedule 160.

Between adjacent lines sufficient space should be provided for orifice taps, block valves, and connecting piping. Consideration should be given to room requirements for rodding or drilling out taps.

Special orifice plate holding fittings are available that make it easier to change orifice plates. With some of these devices, changing orifice plates is possible while the line is under pressure. These types are considerably larger, most costly, and require regular lubrication and maintenance. (see: 5.7)

5.6.2 Minimum length of meter runs

Meter runs [21,22]* should be designed with not less than a minimum length (usually given in nominal pipe diameters) of straight pipe preceding and following the orifice (see details 1 through 13 in Fig. 10 and Table 2). It should be noted that these show minimum lengths of run; these runs should be increased if practicable [4, 7, 9, 15, 21]*. If straightening vanes are used, refer to ANSI / API 2530 for run requirements. Where pipe taps are used, the upstream run should be increased by 2 pipe diameters and the downstream run increased by 8 pipe diameters. The meter run length shown in Table 2, based on a minimum d/D ratio of 0.70, is recommended wherever practical, even if the actual d/D ratio is smaller. If other reasons make it necessary to use runs designed for less than 0.70 d/D , a future increase in d/D requirements should be considered. Straightening vanes should be avoided because of the possibility of their fouling or loosening.

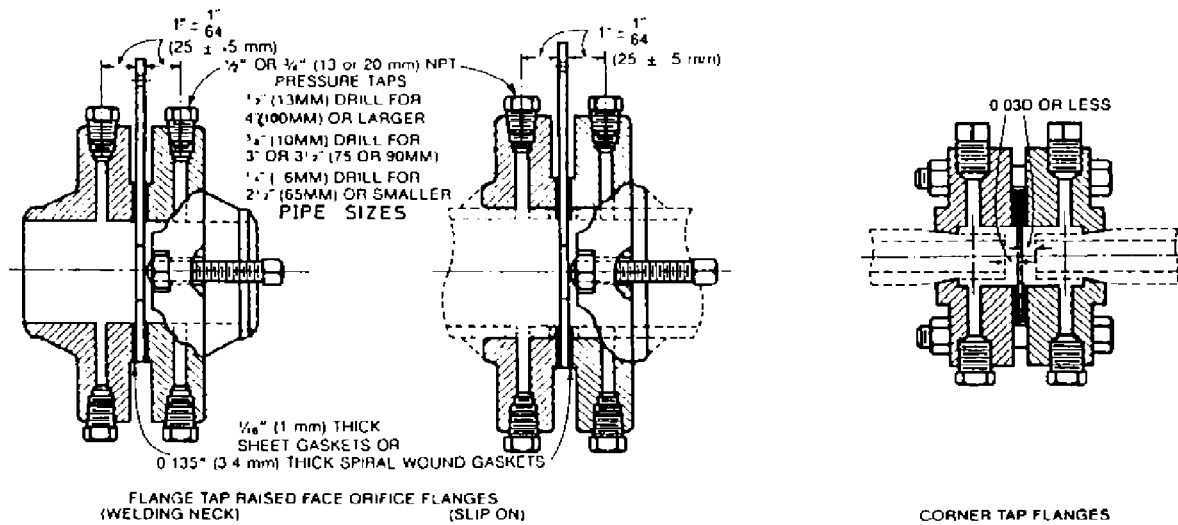
5.6.3 Orientation of meter runs

Vertical orifice runs, in liquid service and with widely separated pressure taps, may have a head error due to temperature differences. Although horizontal orifice runs avoid this head error, vertical orifice runs are often preferable for gas or steam flows containing appreciable amounts of condensate and for liquids containing vapor. Vertical flows should be upward for liquids; downward for wet gases and steam. The potential for error in vertical lines can be minimized by proper manifolding, as shown in Figs. 11 to 14, or by using seals or purges. For steam, the condensate pots must be at the same level as shown in Figs. 12 and 14.

* Bracketed numbers indicate references which are listed in para. 2.2.

5.6.4 Minimum diameter of metering runs

Metering runs for orifices should preferably be 50 millimeters (2 inches) or larger. In lines smaller than 2 inches, it is advisable to swage the line up to the 2 inch size for the metering run or to use rotameters, calibrated meter runs, or other special devices. Errors caused by the roughness of pipe walls become more pronounced in smaller-sized orifice runs. Small-size orifices are subject to plugging in all but the cleanest service.



ORIFICE FLANGES
Fig. 9

Note:

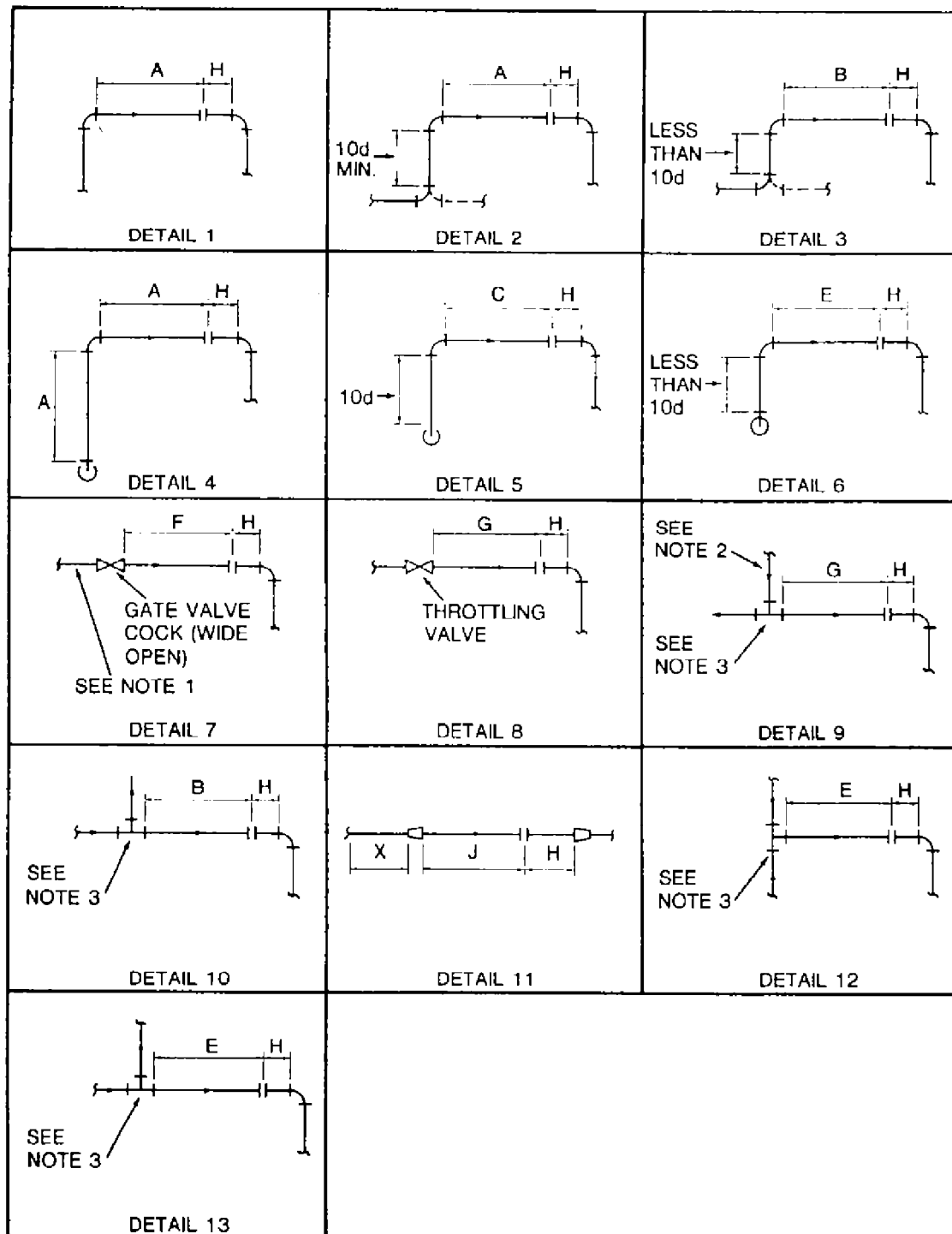
To provide adequate clearance in 40 millimeters (1½ inch) and smaller pipe sizes, the pipe end is often made flush with the face of the raised face flange. In this arrangement, clearance to the plate is the thickness of the compressed gasket.

TABLE 2
d/D RATIO vs. STRAIGHT RUN REQUIREMENTS
FOR ORIFICE MEASUREMENT

d/D Ratio	Straight Run Requirement (In Nominal Pipe Diameters) See Fig. 10							
	A	B	C	E	F	G	H	J
0.80	20	25	33	40	14	50	5	15
0.75	17	21	27	35	11	44	5	14
0.70	14	19	23	31	9	39	5	13
0.65	12	15	21	28	8	34	5	11
0.60	10	14	19	25	8	31	5	10
0.55	9	12	18	22	7	28	5	9
0.50	8	10	17	21	7	25	5	8
0.45	7	9	16	20	5	24	5	7
0.40	7	9	15	18	5	22	5	7
0.35	6	9	14	17	5	21	5	6
0.30	6	9	14	16	5	20	5	6
0.25	6	9	14	16	5	19	5	6

Notes:

- 1) When the valve is preceded by fittings, the straight run must be sufficient to cover their requirements.
- 2) If this line contains fittings in another plane, use Dimension C or E as required by Detail 5 or 6 in Fig. 10.
- 3) Double entry fittings may be considered as single bends when the line is normally blocked off, such as at spare pumps.
- 4) In fig. 9 Detail 11, X + J must be equal to the number of diameters required by previous fittings.



STRAIGHT RUN REQUIRED
Fig. 10

Note:

See Table 2 for d/D values, run requirements, and detail notes.

5.6.5 Static pressure and temperature measurement locations

When metering gases, a static pressure tap should be installed in the main line near the primary measuring device. Either an upstream or a downstream pressure tap can be used, but the appropriate expansion factor must be employed for the type of tap selected. Pressure measurement from the downstream tap is recommended. This method is more commonly used because a given change in differential pressure causes less variation, based on downstream pressure, in the value of the expansion factor. However, the upstream tap may be used if variations in the expansion factor are to be neglected. The tap location is sometimes specified in some custody transfer installations by contractual requirements. A common practice is to use the downstream differential tap instead of a separate tap. Neither the upstream nor the downstream tap of flange taps gives a true measurement of line pressure, nor does the downstream tap of vena contracta taps. However, the error in flow rate is both small and predictable. Measurement of the static pressure is required to correct the apparent reading to a measurement of the actual flow.

It may also be desirable to measure the temperature of the flowing fluid, especially if the fluid is a gas, in order to make required corrections in the apparent flow value. Thermowells, if used, should be inserted in the line a sufficient distance from the primary element so that flow disturbances are prevented from affecting the measurement. On the upstream side, thermowells should precede the orifice by at least 20 pipe diameters. If straightening vanes are used, thermowells should be placed not less than 300 millimeters (12 inches) nor more than 900 millimeters (36 inches) upstream from the inlet edge of the vanes. Downstream thermowells should not be located closer than 5 pipe diameters.

5.7 Senior Retractive Orifice Fitting

This fitting provides a fast, safe and extremely simple method of changing orifice plates under pressure without interrupting the flow and eliminates costly by-passes, valves and other fittings required with conventional orifice flange installations.

The most popular senior orifice fitting, has a weldneck inlet and flanged outlet, see Fig.15.

The senior orifice fitting is composed of two independent compartments separated by a hardened stainless steel slide valve. Side sectional view (Fig.16 A) shows the slide valve in closed position and orifice plate concentric in line of flow. Slide valve cannot be closed unless orifice is concentric to bore of fitting.

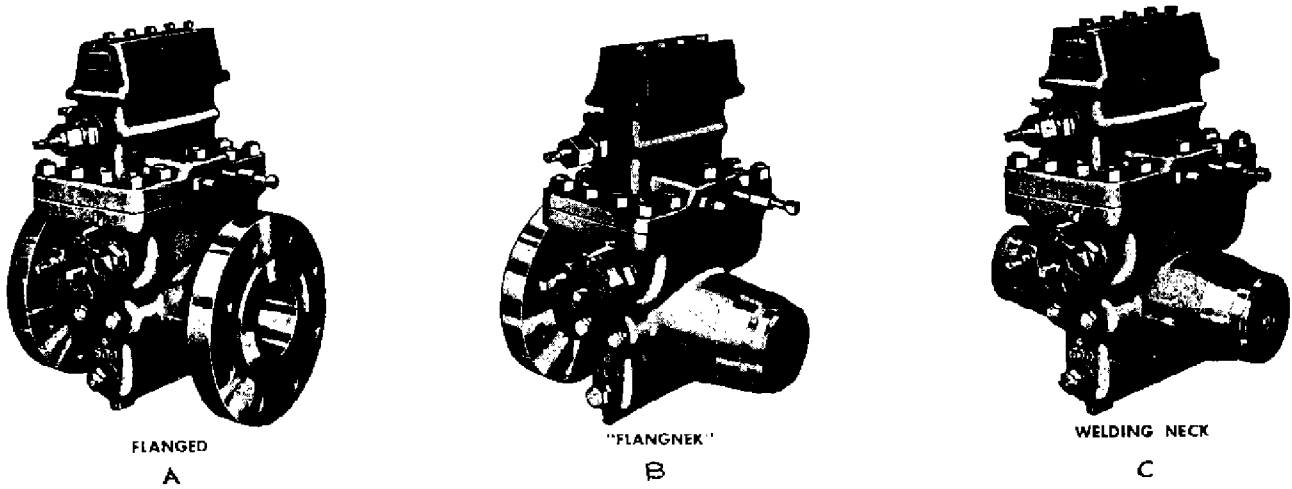
Fig: 16 B shows the top closure in opened position with plate carrier inplace for change or inspection of orifice plate. Only a few turns of the speed wrench are required to loosen screws to remove or replace clamping and sealing bars. Set screws always remain in clamping bar.

This feature adds greatly to speed and ease of operation.

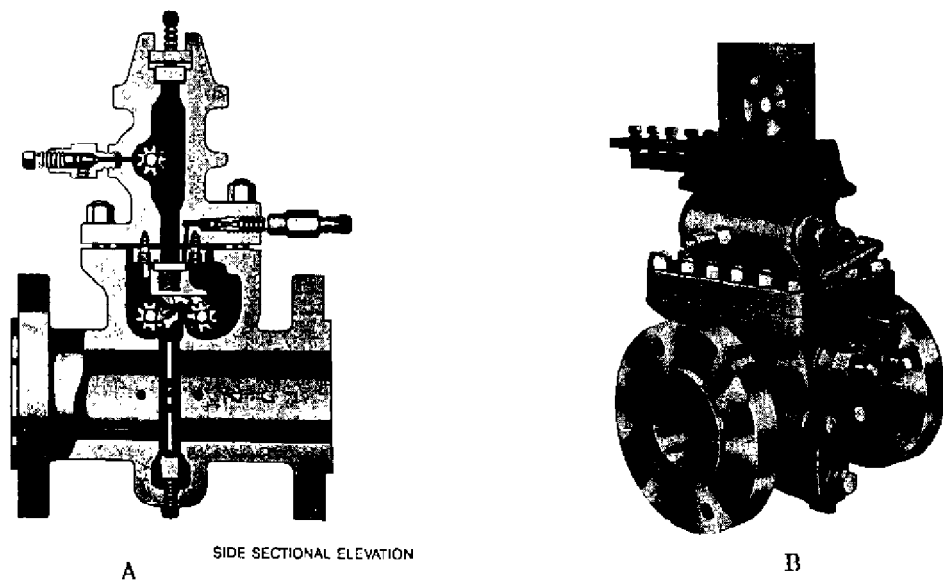
Plate carrier is raised and lowered by double rack and pinion mechanism with power applied through speed wrench.

This method provides the quickest means of operation with the least amount of effort and assures positive control of plate carrier at all times.

All parts, including the essential slide valve assembly, may be replaced or repaired without removing fitting from line-see Fig.16.

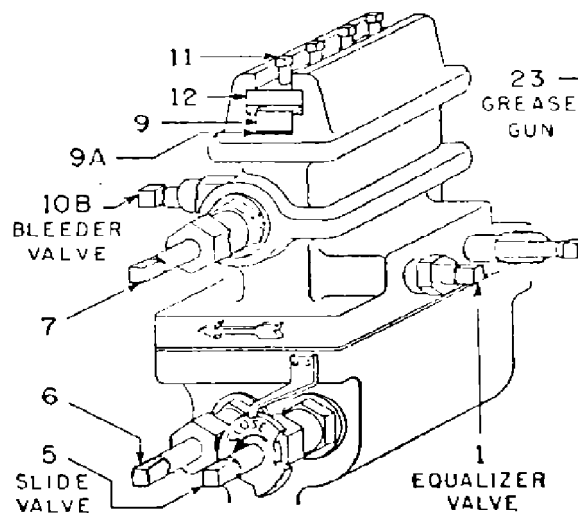


DIFFERENT TYPES OF SENIOR ORIFICE FITTING
Fig. 11



SIDE SECTIONAL VIEW OF SENIOR ORIFICE FITTING
Fig. 12

- 6) Lower plate carrier gear shaft.
- 7) upper plate carrier gear shaft.
- 9) Sealing bar
- 9A) Sealing bar gasket
- 11) Clamping bar screws
- 12) Clamping bar



ILLUSTRATING DRAWING OF SENIOR ORIFICE FITTING
Fig. 13

6. DIFFERENTIAL MEASURING DEVICES

Several types of measuring devices are used to determine the differential produced by the primary element. Flow is proportional to the square root of the differential; therefore, in order to maintain accuracy at low flow readings, a rangeability greater than three to one is not recommended.

For flow recorders, the charts most generally used are the 0 to 10 square root charts. Square root charts are available with various linear secondary scales for recording pressure, level or temperature on the same chart. A suitable meter factor is multiplied by the reading to give the actual flow.

By judicious sizing of the orifice, meter factors can be obtained in round figures. However, when the physical properties of the flowing stream change, it is much more convenient to change meter factors than it is to change the orifice plate or the meter range.

A large variety of special charts are offered as standard by various flow recorder manufacturers. Some users require direct reading charts or scales wherever practicable (or some reasonable combination of standard chart graduation with a whole number factor, preferably factors in multiples of 10).

For calibration of the flow measuring or differential device, a manometer or large multiturn test gage should be used to read the differential input. It is most convenient for the calibration devices to be graduated in the same units as the meter range (for example mm of water). Pneumatic outputs may be read on the same type of device. Electronic devices would utilize a high-quality volt or ammeter which would read these units directly, rather than on a square root or other scale

related to the read-out device. Total flow may be obtained by planimetering flow charts or by equipping the meter with an integrator. Corrections must be applied for changes in the condition of the flowing stream.

Some flow transmitters are available only as blind transmitters, without direct reading scales. An output indicator with a 0 to 10 square root or other suitable scale may be furnished with this type of transmitter. An output indicator will allow flow to be read at the transmitter or control valve location, but it should not be used to calibrate the transmitter.

Some of the devices mentioned in 5.1 through 5.3 are usually supplied as blind transmitters without direct flow scales. In this case an output indicator with a 0 to 10 square root, or other suitable scale, may be furnished so that flow can be read at the transmitter or control valve location. This device should not be used to calibrate the transmitter.

Differential pressure transmitters used for protective systems duty shall be sized such that the cut in or cut out flow rate is at least 30% of the transmitter full-scale flow.

6.1 Diaphragm Transmitters

Different types of differential pressure transmitters of the diaphragm capsule are extensively used in petroleum plants, such as pneumatic, electronic and micro-processor based transmitters, with different types of sensors, such as capacitance, resonance wire and strain gage.

To provide overrange protection and damping, the body or capsule is liquid filled. The transmission signal may be either pneumatic, electronic or digital. These instruments generally are used without a seal or condensate pot because of their low displacement and corrosion-resistant construction. Gas meters are mounted slightly above the line to allow liquids to drain back. Liquid meters are mounted below the line to allow gas bubbles to work back to the line. If leads are short enough, the transmitter may be mounted level with the center of the line. With this arrangement, it makes little difference in accuracy if the opposite legs of the connecting piping contain liquid or vapor in different amounts.

Piping arrangements for diaphragm transmitters are shown in Fig. 11. If remote rather than close-coupled mounting is necessary, the piping may be similar to that shown in Figs. 12 and 13.

6.1.1 Pneumatic transmitters

These transmitters are either force or motion-balance, with 3-15 psig output signal, and accuracy better than 1%. Usually applied when pneumatic control system is preferred.

6.1.2 Electronic transmitters

These transmitters utilize different types of sensors such as: piezoresistive, capacitance, resonance wire and strain gage, with solid state electronic, capable of transmitting a 4-20 mA output signal, via a 2 wire system. The usual accuracy is about 0.25% usually applied when electrical control system is preferred.

6.1.3 Micro-processor-based transmitters

These transmitters are called: smart, wise or intelligent transmitters up to the manufacturer.

Micro processor is partially utilized for ambient temperatures compensation. This feature is the main reason for the high accuracy of this type of transmitters.

The output signal is either 4-20 mA with accuracy of about 0.1%, and better, or digital signal with accuracy of about 0.07% or better.

These transmitters can be reranged and communicated remotely from any point of the loop through the hand held communicator, which is called hand held terminal (HHT), or smart field communicator (SFC), up to the manufacturer.

This type of transmitters is usually applied to be connected to D.C.S. system.

6.2 Bellows Meters

In the bellows-type meter, the bellows is opposed by a calibrated spring system and is filled to prevent rupturing when overpressured and to provide pulsation damping.

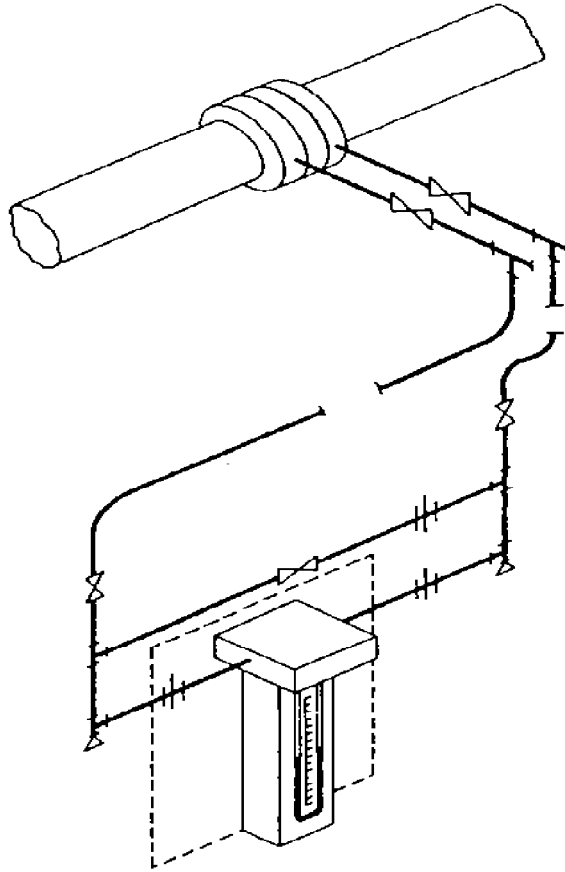
Seal chambers or condensate pots are not generally used. A 20 millimeter ($\frac{3}{4}$ inch) tee has sufficient volume for a liquid seal or as a condensate pot in steam or condensable vapor service for instruments that displace less than 16 cm^3 (1 cubic inch) with full-scale deviation. However, if the displacement is much greater than 16 cm^3 (1 cubic inch), or if the differential of the instrument is low in comparison to the column displacement, regular condensate pots should be used.

Bellows meters have both top and bottom body connections. The top connections are used for liquid flow installations, and the bottom connections are used for gas flow installations to avoid the error caused by trapping gas or liquid, respectively, in the meter body. It is desirable to use 12 millimeter ($\frac{1}{2}$ inch) connections, which may require rotating the body chambers in some cases, where both 12 millimeter and 6 millimeter ($\frac{1}{2}$ inch and $\frac{1}{4}$ inch) connections are provided. It is suggested that the alternate tapped opening can be used as a drain or vent.

Typical meter piping is shown in Figs. 13 and 14.

6.3 Manometers

The simplest measuring device is the glass manometer, which may vary in form from the simple U-tube to the more highly developed singletube devices. These are of little use in process plants, except as test devices and as indicators on nonhazardous low-pressure streams. A manometer with manifold is shown in Fig. 18.



GLASS TUBE MANOMETER

Fig. 14

7. VARIABLE AREA METERS

7.1 General

Variable area meters are often called rotameters. They work on the principle that a float within a vertical tapered tube will assume a position that is a function of the flow rate passing through the tube from the bottom. The float must have a density greater than the measured fluid. The area (annular area) through which the flow must pass is the difference between the internal area of the taper tube at the point of balance and the area of the float head. Since the internal area of the tube increases constantly and is continuously variable from bottom to top while the float head area remains constant, the term "variable area meter" is derived. At a constant differential pressure (P), flow is directly proportional to area.

7.2 Applications

Variable area meters are often used when wide rangeability, linear output, or the measurement of very low flow rates is required. When local indication only is required, their cost (especially in small sizes) is very attractive.

7.3 Features

Variable area meters have the following characteristics:

- a) wide range of flow rates (frequently 10:1 or higher);
- b) accuracy of uncalibrated meters is typically ± 2 percent of full scale; of a calibrated meter ± 1 percent of rate over 10:1 range is not uncommon;
- c) good linearity;
- d) high viscosity immunity;
- e) minimal effects of gas compressibility, since its expansion factor is near unity;
- f) common sizes are available from 3 to 50 millimeters (1/8 inch to 2 inches).

7.4 Typical Uses

Variable area meters are used in the following services:

- a) Liquified petroleum gas or other volatile liquid measurement.
- b) Freezing or congealing liquids such as waxes and asphalts. Steam-jacketed meters are available.
- c) Streams with suspended solids, within reasonable limits.
- d) Low flows, including purges.
- e) Various acids.

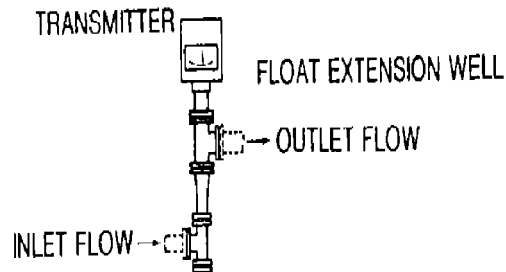
7.5 Options

Variable area meters are available as indicators, transmitters, recorders, local pneumatic controllers, totalizers, or many combinations of the above, with or without alarms. Most meters are available with the through-flow or float extension design (see Figs. 19 and 20). Protective armor and steam tracing are available in many designs.

7.6 Limitations

Variable area meters have the following limitations:

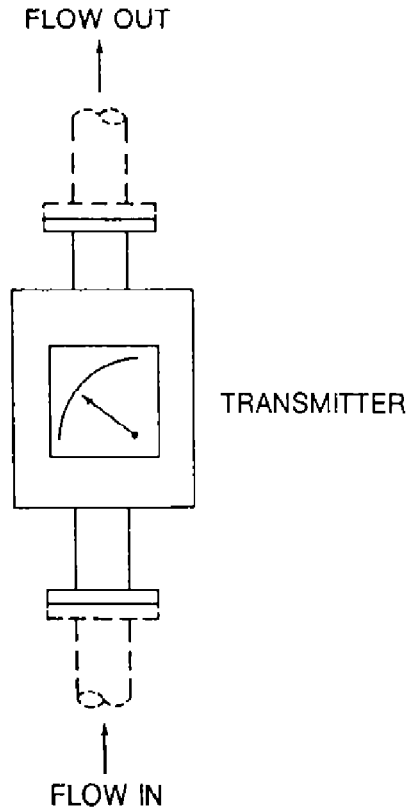
- a) In large sizes (especially when exotic materials of construction are required) rotameters become quite expensive.
- b) Glass tube meters, unless protected by suitable armor, should not be used on hazardous service. Metal tube meters as well as armored meters are available for hazardous service.
- c) The user is unable to check calibration or change range.
- d) Meters having magnetically coupled indicators or transmitters are subject to error if ferrous metal particles accumulate.



EXTENSION TYPE ROTAMETER
Fig. 15

7.7 Selected Range

For variable area meters, the maximum flow rate shall be selected to use manufacturer's standard tube and float, if possible. Normal flow rate shall be between 60% and 80% of capacity, provided anticipated minimum and maximum flow rate will be between 10% and 95% of capacity.



THROUGH-FLOW TYPE ROTAMETER

Fig. 16

8. TARGET FLOWMETERS

8.1 General

The target flowmeter is a fluid flow measuring transmitter that generates an output signal directly proportional to the force applied on a target suspended in the fluid stream.

Flow is measured as the square root of the transmitted signal. The meter is contained in a body that fits between flanges, or it may have a short pipe sections extending upstream and downstream. A square-edge circular or a shaped metal target is secured to a beam, which holds the target at the center of the flow stream. The flow path is through the annular orifice around the target. The force on the target or the deflection of it becomes the variable that is related to flow rate by the square law (see Fig. 21).

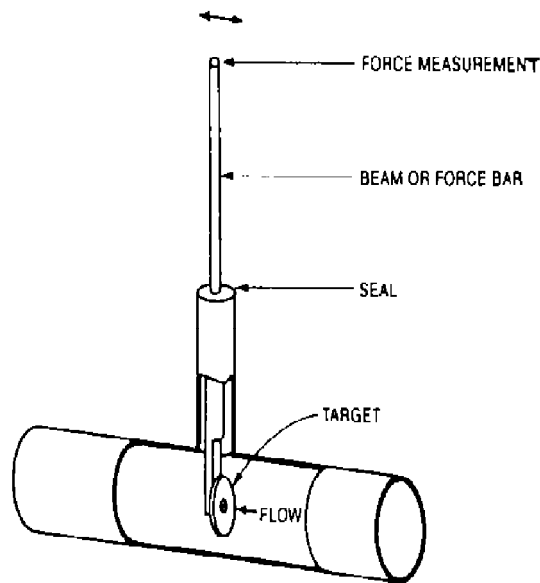
8.2 Applications

Target meters are used for measuring the flow of viscous hydrocarbon streams. They may also be used for the measurement of other liquids, gases, or vapors.

8.3 Features

Target meters have the following characteristics:

- a) Accuracy is typically ± 2 percent of full scale reading;
- b) they are available in a wide range of nominal line sizes, from 15 to 100 millimeters ($\frac{1}{2}$ inch to 4 inches);
- c) they eliminate the need for pressure taps or purging;
- d) they eliminate the need for heating when used for viscous flows.



TARGET-TYPE METER
Fig. 17

8.4 Typical Uses

Target meters are used in the following services:

- a) Viscous flows;
- b) hot asphalt;
- c) tars.

8.5 Options

Pneumatic or electronic transmission is available with either forcebalance or motion-balance transmitters.

Meters may be of either welded or flanged construction and, depending on design, may be used in relatively high pressure, 100 bar (1500 pounds per square inch), and temperature, 260°C (500°F), applications.

8.6 Limitations

Target meters are limited by the following characteristics:

- a) Relatively high pressure drop;
- b) normal usable range (3:1 as for an orifice plate);
- c) inability to calibrate in place;
- d) cost of blocks and bypasses;
- e) possible plugging of the flow stream by large pieces of foreign matter;
- f) possible damage to the meter by large pieces of foreign matter.

9. TURBINE METERS

9.1 General

The turbine meter [2]* is a volumetric, fluid flow measuring meter with a pulse train output, the frequency of which is linearly related to flowrate. A turbine (rotor) located directly in the flow stream rotates at a rate proportional to the average velocity of the fluid passing it and hence proportional to the volume of the fluid being measured. Rotation of the turbine is usually sensed either magnetically or inductively by a sensing coil located outside the flow stream (see Fig. 22).

Alternatively, the rotary motion may be mechanically extracted from the body magnetically or by a shaft through a packing gland. In some cases, the pulses generated are conditioned before transmission by a preamplifier mounted directly on or adjacent to the meter.

9.2 Applications

Turbine meters are used primarily because of their accuracy and rangeability. The major application is the custody transfer (1) of light products or light crude oils [2]*. They are also used extensively for in-line product blending in refineries. Occasionally, turbine meters are used for process flow measurement where highly accurate, wide range measurement of very small flow rates is required.

9.3 Features

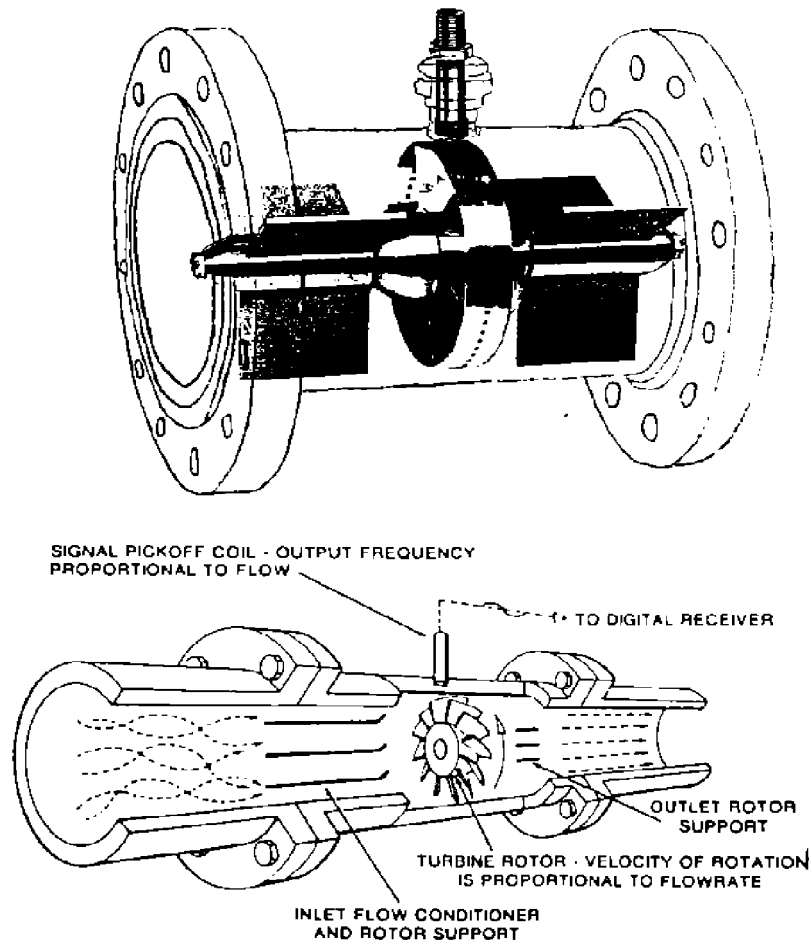
Turbine meters have the following characteristics:

- a) Accuracy of 0.25 percent of rate with repeatability of 0.10 percent is typical. To obtain the highest possible accuracies, some form of meter proving is required [3]*.
- b) Rangeability typically varies from 7:1 to 75:1, depending on meter design, fluid viscosity, and meter size.
- c) A high flow rate for a given line size is obtainable. Line velocity may be as high as 8 to 9 meters (25 to 30 feet) per second.
- d) Very low flow rate designs, as low as 0.02 liters (0.005 gallons) per minute (although normally nonlinear in these ranges) are available.
- e) Availability of very wide temperature ranges, from -255 to 540°C (-430 to 1000°F) and pressure ratings (up to 3000 bar or 50,000 pounds per square inch depending on size).
- f) Turbine meters are available for bi-directional flow (as a special design).

Note:

(1) For more details regarding custody transfer refer to IPS-E-IN-240

* Bracketed numbers indicate references which are listed in para. 2.2



TURBINE METER
Fig. 18

9.4 Typical Uses

Turbine meters are commonly used in the following services:

- a) Custody transfer of light products or crude oils;
- b) in-line product blending;
- c) very accurate volumetric totalization;
- d) low flow rates of additives.

9.5 Limitations

Turbine meters are limited by the following characteristics:

- a) Susceptible to wear or damage if process stream is dirty or nonlubricating.
- b) Require considerable maintenance. Some meters must be returned to manufacturer for recalibration after bearing change.
- c) Relatively high cost.

- d) Strainers usually are required., and air eliminators (if applicable).
- e) Turbine meters have unique relationship between accuracy, rangeability, viscosity, and meter size. Highest accuracy is obtainable with low-viscosity fluids.
- f) Susceptible to damage from overspeed.

10. ELECTROMAGNETIC FLOWMETERS (MAGMETERS)

10.1 General

A magnetic flowmeter measures the volumetric rate of flow of any liquid that has the required measure of electrical conductivity. Most petroleum hydrocarbons have insufficient conductivity to be measured with a magnetic flowmeter. For this reason, its use in the petroleum industry is restricted to certain services, such as water, acids, emulsions, and certain other solutions.

The meter consists of two parts, the magnetic flowmeter primary is stalled directly in the process line and a secondary element, the electronic transmitter. The meter generates a signal proportional to the volume of the flow.

The magnetic flowmeter operates on the principle of an electrical generator. It is based on Faraday's law of electromagnetic induction: when a conductor cuts across magnetic lines of flux, a voltage will be induced in the conductor that is directly proportional to the rate (velocity) at which the lines of flux are being cut. In the case of a magnetic flowmeter, the actual spool piece is an insulated section of pipe. An alternating magnetic field is impressed across it, and the process fluid itself becomes the moving conductor that cuts across the flux. A voltage that is proportional to the velocity of the process fluid is then induced and extracted via two metal electrodes located on opposite sides of the meter (see Fig. 23). This small alternating current (a.c.) voltage is then amplified and conditioned by the secondary transducer. Some magnetic flowmeters are excited by a pulsed direct current (d.c.) signal to eliminate noise and zero drift.

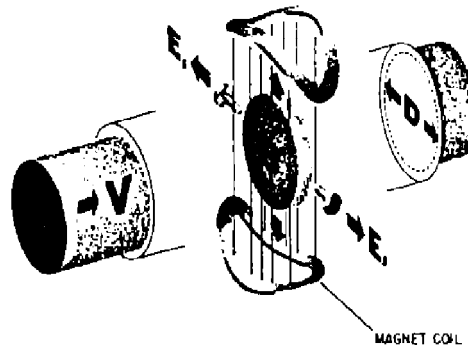
10.2 Applications

Magnetic flowmeters are widely applied on slurries, since they are obstructionless, and on corrosive fluids, since only the liner and electrodes are in contact with the process stream. They are suitable for very viscous fluids or where negligible pressure drop is desired.

10.3 Features

Magnetic flowmeters have the following characteristics:

- a) Accuracy of the magnetic flowmeter is typically 0.5 per-cent of full scale.
- b) The magnetic flowmeter responds only to the velocity of the flow stream and, therefore, is independent of density, viscosity, and static pressure.
- c) Since this type of meter tends to average the velocity profile between the electrodes, neither long runs of upstream or downstream pipe nor flow straighteners are needed, unless percent of rate accuracy is required.
- d) Rangeability is 10/1 or greater.
- e) Bi-directional flow may be measured.
- f) Temperatures from -40 to 260°C (-40 to 500°F) may be handled.
- g) Pressures from full vacuum to 2000 bar (30,000 pounds per square inch) are possible.
- h) There is a negligible pressure drop.
- i) A large variety of sizes are available, from 2.5 millimeters to 2.5 meters (1/10 inch to 96 inches), or even larger.



MAGNETIC FLOWMETERS
Fig. 19

10.4 Typical Uses

Magnetic flowmeters are commonly used to measure the following types of flows:

- a) Slurries;
- b) acid streams;
- c) very small flows;
- d) very large flows;
- e) very viscous fluids.

10.5 Options

A wide variety of options are available for recording, indicating, controlling, totalizing, or batching. Percent of rate accuracy is one option. Various electrode cleaning devices are also available.

10.6 Limitations

Magnetic flowmeters are limited by the following characteristics:

- a) The process fluid typically must have a conductivity of 2 micromhos per centimeter. Special conductivity units are available for fluids with a conductivity as low as 0.1 micromhos per centimeter.
- b) Special care is required for erosive application.
- c) Magnetic flowmeters cannot be calibrated in place.
- d) Relatively high cost.

11. POSITIVE DISPLACEMENT METERS

11.1 General

There are five main types of positive displacement meters: nutating disk, oscillating piston, fluted rotor, rotary (lobed impeller and sliding vane), and oval-shaped gear.

All positive displacement meters measure flow by mechanically trapping successive volumetric segments of the liquid passing through the meter. The number of segments is converted to shaft rotation. A gear train and a calibrator convert shaft rotation to appropriate volumetric units. The output is usually a mechanical register or ticket printer. Temperature compensators are available to correct the output as the fluid temperature changes. Pulse generators are available to provide pulse outputs for meter proving or remote read-out.

11.2 Applications

Positive displacement meters are used because they are accurate over a wide flow range. They are often used for custody transfer[1]*, particularly for heavy or viscous fluids.

Occasionally, positive displacement meters are used for heavy product blending or for refinery process flows.

11.3 Features

Positive displacement meters have the following characteristics:

- a) Typical accuracies are ± 0.05 to 0.15 percent of actual flow. Highest accuracy requires some form of meter proving [3]*. Typical repeatabilities are: 0.02 to 0.05 percent.
- b) Rangeability is typically 10:1 or more. Positive displacement meters have good rangeability and accuracy, particularly with heavy or viscous fluids.
- c) Positive displacement meters come in a range of sizes from 0.38 liter per minute (0.1 gallon per minute) to 34000 liters per minute (9000 gallons per minute).

11.4 Typical Uses

Positive displacement meters are used in the following services:

- a) Custody transfer [1];*
- b) relatively heavy, viscous hydrocarbon streams;
- c) water, caustic, or acid measurement;
- d) volumetric totalization rather than rate of flow.

* Bracketed numbers indicate references which are listed in para 2.2.

11.5 Optional Features

Positive displacement meters are available with the following options:

- a) Temperature compensators to provide read-out in 15°C (60°F) barrels or m³. Some temperature compensators include a manual adjustment to permit setting an appropriate specific gravity.
- b) Calibrators to correct the register reading after the meter is calibrated.
- c) Ticket printers, and counters.
- d) Pulse generators to provide pulse trains suitable for meter proving or remote transmission of flow data.
- e) Pressure lubrication to allow the meter to be used with nonlubricating fluids.
- f) strainers and air eliminators.

11.6 Limitations

p.d meters are limited by the following characteristics:

- a) The material selection and low internal clearances of positive displacement meters are usually designed to match a range of specific fluid properties and design conditions. Operating the meters outside of this design range may cause serious inaccuracy or premature meter failure.
- b) Susceptible to wear or damage if process stream is dirty.
- c) Require considerable maintenance.
- d) Relatively high cost.
- e) Strainers and air eliminators are usually required.
- f) Susceptible to damage from overspeed.

12. VORTEX FLOWMETERS

12.1 General

When a specially designed bluff body obstruction is placed in a liquid or gas stream, a vortex train is generated. This train of high and low-pressure areas can be measured by sensors on the body or the pipe wall. The frequency of the pressure changes is directly and linearly related to the velocity of the fluid stream. Since flow in any pipeline is a function of cross-sectional area and velocity, there is a direct relationship between frequency and flowrate.

12.2 Applications

Vortex meters are used primarily because of their wide rangeability and accuracy. In certain cases, their relatively low cost may also dictate their use.

12.3 Features

Vortex meters have the following characteristics:

- a) Wide rangeability (15:1 for liquids; 50:1 for gases);
- b) reasonable accuracy;
- c) sizes from 2.5 to 30 centimeters (1 to 12 inches) (larger sizes are insertion-type);
- d) linear output;
- e) pulse output (makes totalization easy and accurate).

12.4 Typical Uses

Vortex meters are commonly used in the following services:

- a) Steam;
- b) cooling water;
- c) process water;
- d) light hydrocarbons where large turndown is required;
- e) any gas flow where large turndown is required.

12.5 Options

Either pulse or analog output is available. Local indicators are also available. Certain manufacturers offer two-wire transmitters.

12.6 Limitations

Vortex meters have the following limitations:

- a) A limited range of construction materials is available;
- b) on liquids, vortex meters should not be used for slurries or for high-viscosity liquids;
- c) as with most flowmeters, users cannot check fluid calibration or change range without reducing rangeability;
- d) vortex meters have an upper temperature limit;
- e) bouncing ball types are limited to clean fluids;
- f) fully developed turbulent flow is required;
- g) most meters will not tolerate much greater than 50 percent overrange.

13. MASS FLOWMETERS

13.1 General

A Coriolis flow meter directly measures the mass of a fluid in motion. The basic theory behind operation of a Coriolis sensor is Newton's second law of motion:

$$\text{Force} = \text{Mass} \cdot \text{Acceleration}$$

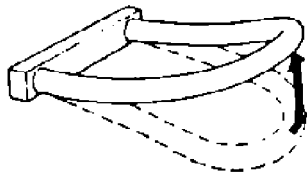
By applying a known force to an unknown mass and measuring its acceleration, mass rate can be precisely determined.

Application of this theory to actual Coriolis flow measurement is illustrated in Fig. 24. In a Coriolis flow meter, a given force is applied to a flow tube assembly causing it to vibrate. As mass is passed through the tube, it resists the perpendicular acceleration of the tube assembly causing the tube to twist slightly. The resulting tube velocity is determined by measuring the time delay between the two ends of the tube assembly as indicated by the twist angle shown in the Figure. With a known force and a measured velocity, the mass rate is directly determined. In Coriolis instruments, mass rate is measured at accuracies as high as $\pm 0.15\%$ of full scale.

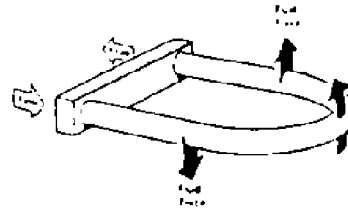
Unlike other flow measurement technologies, a Coriolis meter has the capability to directly measure density in addition to mass flowrate. The theory of direct density measurement is based on the physics of a spring and mass assembly as illustrated in Fig. 25.

Mass Flow Measurement

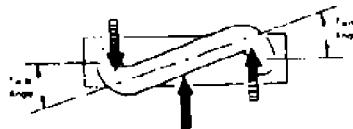
Force = Mass * Acceleration



Vibrating flow tube (single flow tube shown)



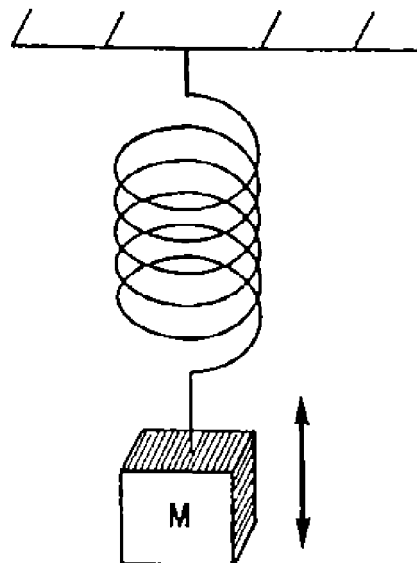
Fluid forces reacting to vibration of flow tube



End view of flow tube showing twist

DIRECT MASS FLOW MEASUREMENT IN A CORIOLIS SENSOR

Fig. 20



DENSITY MEASUREMENT IN A CORIOLIS SENSOR

Fig. 21

Spring and mass assemblies can be characterized by the following relationship:

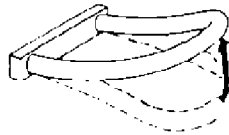
$$\text{Frequency of Oscillation} = \frac{1}{2\pi} \sqrt{\frac{K}{\text{Mass}}}$$

Here, k represents a constant which is characteristic of a given spring assembly. Once a spring has been calibrated with a known mass to determine this constant, an unknown mass can be directly determined by measuring the oscillation frequency of the spring.

In a Coriolis instrument, the flow tube acts as the vibrating spring assembly (Fig. 26) with the mass inside the tube rather than on the end of a spring. While the tube is driven to vibrate at a given amplitude, the tube is driven to vibrate at a given amplitude, the tube frequency changes as the mass of material in the tube gets heavier or lighter. Measuring the frequency of oscillation of the tube provides a direct mass measurement of a known volume of fluid (based on the tube diameter and length) and a direct density measurement is obtained. A Coriolis instrument can measure density to an accuracy of ± 0.0005 g/cc.

Density measurement

$$\text{Frequency of oscillation} = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$$

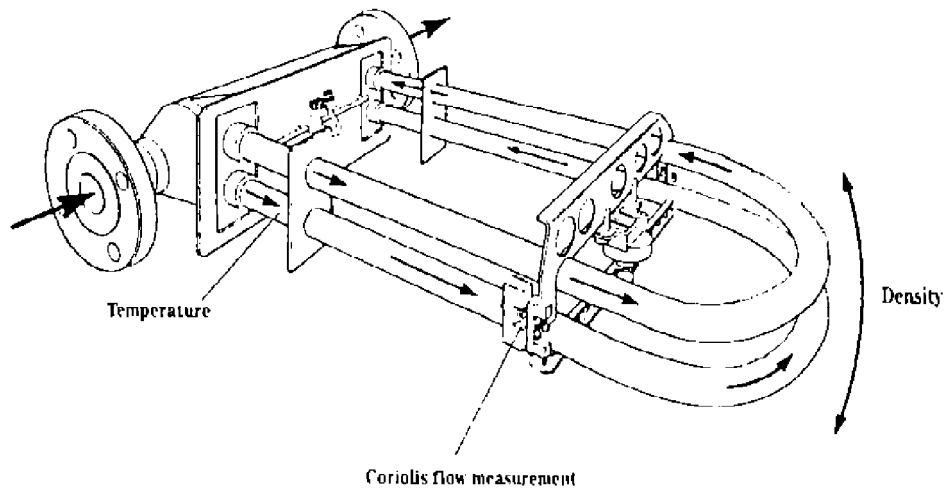


Frequency of oscillation is a function of fluid density results in 2 measurements from 1 sensor.

THE VIBRATING SPRING AND MASS ANALOGY
Fig. 22

13.2 Applications

Coriolis technology has been applied throughout the chemical industry since 1976 for precision flow and density measurement of fluids. Early sensor designs were limited to application in controlled environments due to their sensitivity to external environmental changes. In 1983, a more practical design was developed, utilizing two flow tubes to reference fluid measurement in each tube directly to the other tube (fig. 27). This design essentially eliminated problems with environmental sensitivity and greatly expanded Coriolis application.



MASS FLOWMETER WITH TWO FLOW TUBES
Fig. 23

13.3 Features

Coriolis (Mass flow) meters have the following characteristics:

- a)** Accuracy of the mass flowmeter is typically $\pm 0.2\%$ of full scale.
- b)** Rangeability is 80/1
- c)** Repeatability is as high as $\pm 0.05\%$.
- d)** Line sizes are from 6 mm to 200 mm ($\frac{1}{4}$ inch to 8 inch).
- e)** They are non-intrusive (obstructionless) meters, and without moving parts.
- f)** They eliminate the need for pressure taps or purging.
- g)** Availability of very wide temperature ranges, from -204°C to $+204^{\circ}\text{C}$ (-400°F to $+400^{\circ}\text{F}$) and pressure ratings (up to 330 barg or 5000 psig depending on size).
- h)** Coriolis technology provides direct mass measurement independent of changing fluid properties, therefore, temperature, pressure, and specific gravity compensation is not required.
- i)** Can be used to measure, the density, volumetric flow rate, %concentration (% solids) of a two component (or slurry) stream. Use of % concentration measurement with the direct mass rate also provides a device to measure and batch net materials such as catalyst slurries.
- j)** Direct, in-line coriolis mass measurement eliminates the need for expensive, high maintenance weigh scales, which have traditionally been used in batch loading applications.
- k)** Upstream / Downstream straight piping not required.

13.4 Typical Uses

Mass flowmeters are commonly used in the following services:

- a) Can be used in every process industry, from food and beverage manufacturing to oil refining and petrochemical processing.
- b) batch loading applications;
- c) material balances applications;
- d) custody transfer, light and heavy fluids;
- e) slurries;
- f) very viscous fluids;
- g) low flow rates of additives;
- h) in-line product blending;
- i) multi-phase fluids.

13.5 Options

This type of flowmeters can be provided with micro-processor based transmitters, which can supply: 4-20 mA, pulse, alarm contacts, and digital output signal.

13.6 Limitations

Mass flowmeters are limited by the following characteristics:

- a) Sensitive to external environmental changes (pressure and temperature changes).
- b) Sensivity to piping vibration.
- c) Relatively high weight (about 80 kg, for 2" size flowtubes)
- d) The maximum size available is 6 inch, and for some manufacturers is 2 inch.
- e) Relatively high pressure drop.
- f) Relatively high cost.
- g) Meters to be used in/with hazardous locations and fluids are costly.

14. METER PROVING FACILITIES

Meter proving facilities shall be available for all flow meters used for custody transfer unless otherwise agreed in writing by the user.

Depending on the location, the meter proving facilities may be owned and operated by the user, by a body recognized by the user and the local authorities and/or the customer who will purchase the measured product. Where such facilities are not already available, they shall be provided as part of the project.

Note:

Local regulations or the nature of the application may require that meter proving is carried out or witnessed by local authorities or by an independent third party.

The process engineering flow schemes and the instrument data sheets shall indicate:

- Where meter proving facilities are required;
- specifications of facilities such as master meters, mechanical displacement provers or tank provers;
- whether these facilities shall be mobile or permanently installed.

Preference shall be given to in-line meter proving under actual operating conditions and flow rates. Permanent installation (including manifolding) of proving facilities shall be fully detailed in the engineering flow schemes.

Where mobile facilities are specified, the piping shall have provisions for the insertion of a master meter or a meter prover into the line in which the meter is installed, the meters shall then be accessible with the mobile prover.

Note:

1) For more details concerning custody transfer, refer to IPS-E-IN-240.

Where master meters are used, a meter prover shall be available for their calibration.

For meter provers, preference should be given to mechanical displacement provers. Only where this is not possible or allowed by the local authorities, shall meter prover tanks be provided.

Meter provers shall comply with Chapter 4, of the API Manual of Petroleum Measurement Standards and IPS-M-IN-240

APPENDICES

APPENDIX A

ORIFICE CALCULATIONS EQUATIONS FOR LIQUID, STEAM AND GASES

METRIC UNITS SUPPLEMENT

METRIC SYMBOLS

Significance of symbols distinguished with a prime. Most of the factors in the flow equations are dimensionless: hence, they are the same regardless of the units of measurement. The following equations indicate the factors which are different for metric units by means of primes. These factors are given in subsequent tables: all others may be obtained from the regular tables and curves. (See Summary of Symbols, pp. 548-557.)

- C_n' = corrected coefficient in units corresponding to N' .
 D' = pipe diameter in millimeters.
 d' = orifice diameter in millimeters.
 E = slope of Reynolds number factor vs. $1/Ra$.
 h_m' = maximum differential, millimeters of water, dry calibrated.
 h_w' = operating differential, millimeters of water, dry calibrated.
 K_s' = conversion factor for coefficient in various metric units.
 N' = constant dependent on units (metric).
 P_f' = flowing pressure for gas flow measurement (kg./cm^2 , absolute).
 Q_h' = operating rate of flow in $\text{m}^3/\text{hr.}$ at base conditions.
 Q_m' = maximum rate of flow corresponding to full scale on the chart.
 Liquids — volume units corresponding to N' .
 Gases — cubic meters in time t .
 Q_n' = operating rate of flow, units same as Q_m' .
 T_f' = flowing absolute temperature, $^{\circ}K$.
 W_h' = actual or operating rate of flow, kg./hr. .
 W_m' = maximum rate of flow corresponding to full scale on chart, weight units corresponding to N' . In steam, vapor, or gas flow equations, $W_m' = \text{kg./hr.}$.
 W_n' = operating rate of flow, units, corresponding to N' .
 γ_f' = specific weight at flowing conditions, kg./m^3 .
 μ_p = absolute viscosity, poises.

(to be continued)

APPENDIX A (Continued)

EQUATIONS FOR PLANT CALCULATIONS FOR NONVISCIOUS
LIQUID FLOWMETRIC UNITS*

For Volume

$$\text{Bore } S = \frac{Q_m^0 G_l}{N D^2 F_a F_m \bar{p} \bar{G}_f \bar{h}_m^0} \quad \text{Eq. 92}$$

$$\text{Rate of flow } Q_n^0 = \frac{S N D^2 F_a F_m \bar{p} \bar{G}_f \bar{h}_w^0}{G_l} \quad \text{Eq. 93}$$

$$\text{Coefficient } C_n^0 = K_s^0 C_n \frac{F_a F_m \bar{p} \bar{G}_f}{G_l} \quad \text{Eq. 94}$$

$$\text{Rate of flow } Q_n^0 = C_n^0 \bar{h}_u^q \quad \text{Eq. 95}$$

For Weight

$$\text{Bore } S = \frac{W_m^0}{N D^2 F_a F_m \bar{p} \bar{G}_f \bar{h}_m^0} \quad \text{Eq. 92a}$$

$$\text{Rate of flow } W_n^0 = S N D^2 F_a F_m \bar{p} \bar{G}_f \bar{h}_w^q \quad \text{Eq. 93a}$$

$$\text{Coefficient } C_n^0 = K_s^0 C_u F_a F_m \bar{p} \bar{G}_f \quad \text{Eq. 94a}$$

$$\text{Rate of flow } W_n^0 = C_n^0 \bar{h}_u^q \quad \text{Eq. 95a}$$

(to be continued)

APPENDIX A (Continued)

Reynolds number — metric units. The basic equation for Reynolds number is

$$R_D = \frac{\text{pipe velocity, m/sec} \times \text{pipe diameter, m}}{\text{kinematic viscosity, m}^2/\text{s}} \quad (\text{Eq. 96})$$

One of the following forms may be found more convenient to use:

$$R_D = \frac{12.73 \times \text{rate of flow, g/sec}}{\text{pipe diameter, cm} \times \text{absolute viscosity, cP}} \quad (\text{Eq. 97})$$

$$R_D = \frac{3.537 \times \text{rate of flow, kg/hr}}{\text{pipe diameter, cm} \times \text{absolute viscosity, cP}} \quad (\text{Eq. 98})$$

* See pages 548 to 557 for symbols not identified with a prime.

Calculate S. Read d/D from the proper S table. Bore = $D' \times d/D$.

Warning: Conversion of R_D to R_d cannot be made in Eq. 96 by merely substituting orifice or throat diameter for pipe diameter, because velocity is affected as the reciprocal of diameter squared. To convert, use the formula $R_d = R_D \times D/d$. Eq. 97, 98, or 99 may be used to compute orifice or throat Reynolds number by merely substituting the suitable dimension in the denominator.

$$R_D = \frac{3537 \times \text{rate of flow, cu m/hr at flowing conditions}}{\text{pipe diameter, cm} \times \text{kinematic viscosity, cStokes}} \quad (\text{Eq. 99})$$

PRECISE EQUATIONS FOR LIQUID FLOWMETRIC UNITS*

For Volume

$$\text{Bore } S = \frac{Q_m^0 G_f}{N D^2 F_a F_m \frac{p}{G_f} \frac{p}{h_m^0 (F_c F_p)}} \quad \text{Eq. 100}$$

$$\text{Rate of Flow } Q_n^0 = \frac{(S N D^2 F_a F_m \frac{p}{G_f} \frac{p}{h_m^0 (F_c F_p)})}{G_f} \quad \text{Eq. 101}$$

(to be continued)

APPENDIX A (Continued)

$$\text{Coefficient} \quad C_n^0 = \frac{6}{4} K_s^0 C_w \frac{F_a F_m^p}{G_f} \frac{\overline{G}_f^3}{5} (F_c F_p) \quad \text{Eq. 102}$$

$$\text{Rate of Flow} \quad Q_n^0 = C_n^0 \overline{h}_w^q \quad \text{Eq. 103}$$

For Weight

$$\text{Bore} \quad S = \frac{W_m^p}{N D^2 F_a F_m^p \overline{G}_f^p \overline{h}_m^p (F_c F_p)} \quad \text{Eq. 100a}$$

$$\text{Rate of Flow} \quad W_n^p = (S N D^2 F_a F_m^q \overline{G}_f^q \overline{h}_w^q (F_c F_p)) \quad \text{Eq. 101a}$$

$$\text{Coefficient} \quad C_n^0 = (K_s^0 C_w F_a F_m^q \overline{G}_f (F_c F_p)) \quad \text{Eq. 102a}$$

$$\text{Rate of Flow} \quad W_n^p = C_n^0 \overline{h}_w^q \quad \text{Eq. 103a}$$

TABLE 59
VALUES OF N'

Time	Liters	Cubic Ineters	Kilograms	Grams
Second	.0001100	.0000001100	.0001099	.1099
Minute	.006598	.000006598	.006592	6.592
Hour	.3959	.0003959	.3955	395.5
24-Hour	9.501	.009501	9.492	9492.

* See pages 548 to 557 for symbols not identified with a prime.

Calculate S. Read d/D from S table for the primary device involved.

Bore = $D' \times d/D$.

(to be continued)

APPENDIX A (Continued)

Steam, Vapor, or Gas Flow Equations

UNIVERSAL EQUATIONS FOR
STEAMMETRIC UNITS*

$$\text{Bores} \quad S = \frac{W_m^0}{0.05008 D^2 F_a F_m F_c Y^p \bar{p} \bar{h}_w^0} \quad \text{Eq. 104}$$

$$\text{Rate of Flow} \quad W_h^0 = 0.05008 S D^2 F_a F_m F_c Y^p \bar{p} \bar{h}_w^0 \quad \text{Eq. 105}$$

$$\text{Rate of Flow} \quad W_h^0 = 0.09000 C_s F_a F_m F_c Y^p \bar{p} \bar{h}_w^0 \quad \text{Eq. 106}$$

UNIVERSAL EQUATIONS FOR GAS OR
VAPORMETRIC WELGHT UNITS*

$$\text{Bores} \quad S = \frac{W_m^0}{0.01251 D^2 F_a F_m F_c Y^p \bar{p} \bar{h}_w^0} \quad \text{Eq. 107}$$

$$\text{Rate of Flow} \quad W_h^0 = 0.01251 S D^2 F_a F_m F_c Y^p \bar{p} \bar{h}_w^0 \quad \text{Eq. 108}$$

$$\text{Rate of Flow} \quad W_h^0 = 0.02249 C_s F_a F_m F_c Y^p \bar{p} \bar{h}_w^0 \quad \text{Eq. 109}$$

$$\text{Density} \quad \bar{p} = \frac{m_u P_f^0}{0.08479 Z_f T_f^0} \quad \text{Eq. 110}$$

(to be continued)

APPENDIX A (Continued)

SPECIAL EQUATIONS FOR STEAM-FLANGE
TAPS ONLY*

$$\text{Bore} \quad K_{\text{R}}^{-2} = \frac{11_m^0}{0.05008 D^2 F_a F_m F_r Y_p \bar{f}^q \overline{h_f^0}} \quad \text{Eq. 111}$$

$$\text{Rate of Flow} \quad W_h^0 = 0.05008 K_{\text{R}}^{-2} D^2 F_a F_m F_r Y_p \bar{f}^q \overline{h_w^0} \quad \text{Eq. 112}$$

$$\text{Rate of Flow} \quad W_h^0 = 0.09555 F_b F_a F_m F_r Y_p \bar{f}^q \overline{h_w^0} \quad \text{Eq. 113}$$

$$\text{Orifice Reynolds number} \quad R_d = \frac{3.537 W_h^0}{d \mu_p} \quad \text{Eq. 114}$$

* See pages 548 to 557 for symbols not identified with a prime.

Calculate S. Read d/D from S table for the primary device involved.

Bore = $D' \times d/D$

SPECIAL EQUATIONS FOR VAPOR OR GAS
(METRIC WEIGHT UNITS)*

$$\text{Bore} \quad K_{\text{R}}^{-2} = \frac{W_m^0}{0.01251 D^2 F_a F_m F_r Y_p \bar{f}^q \overline{h_m^0}} \quad \text{Eq. 115}$$

$$\text{Rate of Flow} \quad W_h^0 = 0.01251 K_w^{-2} D^2 F_a F_m F_r Y_p \bar{f}^q \overline{h_w^0} \quad \text{Eq. 116}$$

(to be continued)

APPENDIX A (Continued)

$$\text{Rate of Flow } W_h^0 = 0.02387 F_b F_a F_m F_r Y^p \bar{f}^q \overline{h_w^0} \quad \text{Eq. 117}$$

$$\text{Density } \bar{f} = \frac{m_u P_f^0}{0.08479 Z_f T_f^0} \quad \text{Eq. 110}$$

EQUATIONS FOR GASES (METRIC VOLUME UNITS)

Direct Reading Orifice Bore

$$K_{\text{R}}^{-2} = \frac{Q_m^0}{0.01111 t D^2 F_r Y F_{pb} F_{tb} F_{to} F_{pa} F_{wa} F_m} \overline{h_{mp}^0} \quad \text{Eq. 118}$$

$$Q_h^0 = 0.01111 K_{\text{R}}^{-2} t D^2 F_r Y F_{pb} F_{tb} F_{to} F_{pa} F_{ua} F_m \overline{h_{wp}^0} \quad \text{Eq. 118a}$$

Flow Rate for Natural Gas

$$\text{A. G. A. Report No. 3 } Q_h^0 = 0.02119 C'^0 \overline{h_{up}^0} \quad \text{Eq. 118b}$$

Note: C' in Eq. 118b is an exception to the rule that the prime indicates metric units. This exception is made because it is a widely accepted symbol in the American gas industry for a corrected gas coefficient in cubic feet hour. See Eq. 86, page 433.

TABLE 64
PRESSURE BASE EQUIVALENTS

psia	14.4	14.65	14.7	14.73	14.9	15.025	15.4	16.4
kg./cm. ²	1.012	1.030	1.033	1.036	1.048	1.056	1.083	1.1

* See pages 548 for symbols not identified with a prime.

Calculate k_β^2 . Read d/D from tables, pages 391-92 or 397-98. Bore = $D' \times d/D$.

**APPENDIX B
FLOWMETERS SELECTION TABLE**

Group	Type	Application																	
		Liquids (see note 1)								Gases (see note 2)					Miscellaneous (see note 3)				
		A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S	T
1	Orifice Venturi Nozzle	t	?	t	t	t	t	t		t	?	t	t	t	?	t	?	?	?
		t		t	t	t	t			t	?		?	?	?	t	?	?	?
		t		t	t	t	t			t	t	?	?	t	?	t	?	?	?
2	VA Target Averaging pitot Sonic nozzle	t	t			#	?		t	t	t				?	t	?	?	?
		t				#			t	t				t	?	t	?		
		t		t	t	t	?	t		t		t	t	t		t	?	?	?
3	Sliding vane Oval gear Gas diaphragm Rotary gas	t		#			t		t							?			
		t	t	#		#	t		t							?		t	
		t	?			#	t		t	t	t					?		#	
4	Turbine Pelton Mechanical Insertion turbine	t		t	#	t	?	t	t	t		t				?	?	#	
		t	t			t		t		?	?					?	?	?	
		t													#	?			
		t		t	t	t		t		t		t	t	?		?	?		
5	Vortex Swirlmeter Insertion vortex	t				t		t	t	t		?	t	t		?			
		t								t									
		t		t	t	?		?	?	t		t	?	t		t		?	?
6	Electromagnetic Insertion electromagnetic	t	t	t	t	#	?		t						t	t	?	t	
		t		t	t	?			t						?	t	?	t	
7	Doppler Transit time	t		?	?	#			?						t	t	?	?	
		t	?	t	t	#	?	#	t	#					?	?		#	#
8	Coriolis (direct) Twin rotor (indirect)	t				#	t		t	?					?	?		#	
		t																	
9	Anemometer Thermal mase	t		?	?	#				t									
			#							t	t								
10	Tracer Laser	t	#	t	t	t	t	t		#		#	t	t		?	t	#	#
		t		?	?														

Key

t is suitable; generally applicable

? is worth considering; sometimes applicable

is worth considering, limited availability or tends to be expensive

A blank indicates unsuitable; not applicable

NOTE 1. Liquid applications are indicated by the following:

- A General liquid application (< 50 cP) (< 0.05 Pa.s)
- B Low liquid flows (< 0.12 m³/h) (< 2 L/min)
- C Large liquid flows (> 1000 m³/h) ($> 1.7 \times 10^4$ L/min)
- D Large water pipes (> 0.5 m bore)
- E Hot liquids (temperatures $> 200^\circ\text{C}$)
- F Viscous liquids (> 50 cP) (> 0.05 Pa.s)
- G Cryogenic liquids
- H Hygienic liquids

NOTE 2. Gas applications are indicated by the following:

- J General gas applications
- K Low gas flows (< 150 m³/h)
- L Large gas flows (> 5000 m³/h)
- M Hot gases (temperatures $> 200^\circ\text{C}$)
- N Steam

NOTE 3. Miscellaneous applications are indicated by following:

- P Slurries and particle flows
- Q Liquid/liquid mixtures
- R Liquid/gas mixtures
- S Corrosive liquids
- T Corrosive gases

DATA SHEETS WITH THEIR FILLING INSTRUCTIONS

		ORIFICE PLATES and FLANGES				SHEET _____ OF _____		
		No.	BY	DATE	REVISION	SPEC. No.		REV
						CONTRACT		DATE
						REQ. P.O.		
						BY	CHK'D	APPR.
ORIFICE PLATES		ORIFICE FLANGES						
1. concentric b Other _____		7. Taps: Flange b Vena Contracte b Pipe b Other _____						
2. ISA Standard b Other _____		8. Tap Size: ½ in. b Other _____						
3. Bore: Maximum Rate b Nearest 3 mm b		9. Type: Weld Neck b Slip On b Threaded b						
4. Material: 304 SS b 316 SS b Other _____		10. Material: Steel b Other _____						
5. Ring Material & Type _____		11. Flanges included b By othersb						
6. MFR. & Model No. _____		12. Flange Rating _____						
FLUID DATA	13	Tag Number						
	14	Service						
	15	Line Number						
	16	Fluid						
	17	Fluid State						
	18	Maximum Flow						
	19	Normal Flow						
	20	Pressure-bar g						
	21	Temperature °C						
	22	Specific Gravity at Base						
	23	Operating Spec. Gravity						
	24	Supercomp. Factor						
	25	Mol. Weight Cp/Cv						
	26	Operating Viscosity						
	27	Quality % or °Superheat						
	28	Base press. Base Temp.						
METER	29	Type of Meter						
	30	Diff, Range-Dry m bar						
	31	Seal sp. gr. at 15°C						
	32	Static Press. Range bar (abs)						
	33	Chart or Scale Range						
	34	Chart Multiplier						
PLATE & FLANGE	35	Beta = d/D						
	36	Orifice Bore Diameter						
	37	Line I.D.						
	38	Flange Rating						
	39	Vent or Drain Hole						
	40	Plate Thickness						
Notes:								

ORIFICE PLATES AND FLANGES

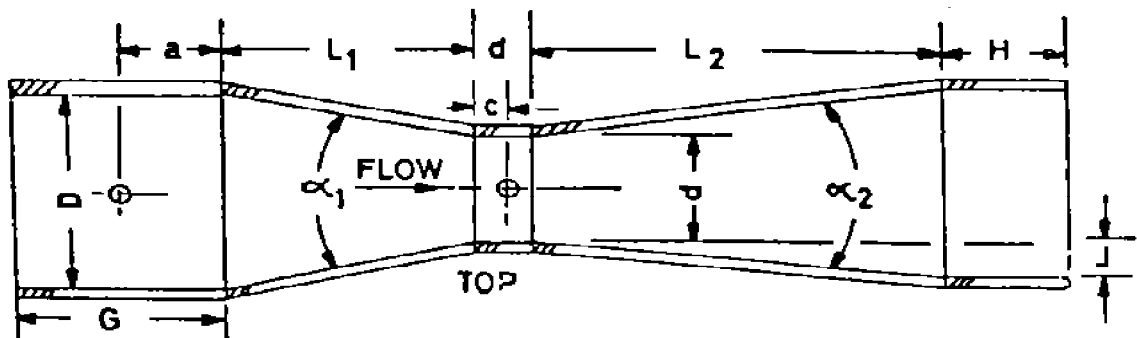
Instructions for filling IPS Form E-IN-130.1

Refer to ISA Recommended Practice RP3.2, "Flanged Mounted, Sharp Edged Orifice Plates for Flow Measurement".

- 1) Check if concentric bore, or write in eccentric, segmental, etc.
- 2) ISA Standard reference given above. This also conforms to AGA-ASME requirements.
- 3) Check whether plate is to be bored odd size for exact maximum rate, or to nearest 3 mm (1/8 in) for approximate maximum rate.
- 4) Select plate material.
- 5) If ring joint assembly is used, give ring material and configurations.
- 6) Refers to plate, not flanges.
- 7) Select one of the standard tap locations or write in other.
- 8) Select tap size.
- 9) Select flange construction.
- 10) Select flange material. If stainless steel, show type; such as, "304 SS."
- 11) Indicate whether orifice flanges are to be included with the plate, or furnished by others.
- 12) Note Flange Rating.
- 13) Tag number or other identification No.
- 14) Process service.
- 15) Line number. Include line size.
- 16) List fluid, unless classified.
- 17) Liquid, gas, or vapor.
- 18) Maximum flow assumed to be meter maximum. Give flow units.
- 19) Figure only if units given above.
- 20) Upstream operating pressure and units. This is also the contract figure unless otherwise noted.
- 21) Operating temperature, °C. See comment in 20 above.
- 22) Specific gravity at Base Temperature.
- 23) Liquid specific gravity at operating temperature given on Line 21.
- 24) Applies to gas, at operating pressure. Supercompressibility factor normally required for gases over 7 barg (100 psig) because the gas at this pressure and above does not follow the ideal gas laws.
- 25) Applies to vapor or gas. C_p specific heat at constant pressure, C_v specific heat at constant volumes - Ratio = K at the operating temperature.
- 26) Viscosity and units, at operating temperature given on line 21.
- 27) Applies to vapor or steam. Write "SAT" if saturated; otherwise give % quality degrees superheat, in F or C.

- 28)** Contract base conditions. Pressure must be given in absolute units.
- 29)** Bellows, diaphragm, mercury, etc.
- 30)** Set range and units.
- 31)** Applies to wet meters.
- 32)** Fill in if applicable.
- 33)** Full scale range and units. See comment under 18 above.
- 34)** Fill in if required.
- 35)** Fill in for final records after approved bore calculation is available.
- 36)** For final records, see comment on 35.
- 37)** In mm; or give line size and Schedule.
- 38)** ANSI Flange Rating, i.e., 4 in. 300 lb. RF.
- 39)** If desired, state whether top or bottom.
- 40)** Give plate thickness.

VENTURI FLOW METER SPECIFICATION SHEET	INSTRUMENT SPECIFICATION			SPEC. No.		REV
	PROJECT			DATE	CONT	No.
	No.	BY	DATE	REVISION		
	Δ			MANUFACTURER		
	Δ			P.O. No.		
	Δ					
	Δ			BY	CHK'D	APPR.
	Δ					



TAG No. LINE No. OR SERVICE		SERVICE CONDITIONS FLUID	
FLANGE RATING		MAX METER FLOW j BASE COND.	
CONE.. HORIZ. LENGTH L_1		NORM. FLOW j BASE COND.	
CONE.. HORIZ. LENGTH L_2		FLOW UNITS	
THROAT LENGTH d		VISCOSITY FLOW COND. cp	
PIPE I.D. D		S.D. OF SEAL OVER MERCURY	
THROAT I.D. d		FLOW TEMPERATURE °C	
THROAT TAP z $C= d/2$		FLOW PRESS j UPSTRM TAP bar (abs)	
UPSTRM TAP z a		CONTRACT BASE TEMP °C	
UPSTRM STR RUN G		CONTRACT BASE PRES bar (abs)	
DWN STRM STR. RUN H		SP HEAT RATIO CP/CV	
THROAT TO PIPE I.D. j		MW OR SP. GR.	
RADIUS 11		COMPRESSIBILT j FLOW COND.	
RADIUS 12		COMPRESSIBILT j BASE COND.	
PRESS. TAP NIPPLE SIZE		DIFFRANGE mbar	
PRESS. TAP BORE SIZE		MANOMETER TYPE	
UPSTRM ANGLE μ_1		SEAL MATERIAL	
DWNSTRM ANGLE μ_2		CHART OR SCALE RANGE	
OVERALL LENGTH mm.		MULTIPLIER	

- 1) MATERIAL : Venturi to be fabricated from ———— rolled plate Throat may be fabricated from heavier stock and bored to size.
- 2) TOLERANCES: Throat Tolerance: \pm ———— out of Roundness: 3 mm All other Dimensions : ± 1.0 %.
- 3) WELDS: All welds shall be full penetration. Grind all inside welds flush. Welds at throat inlet and outlet to be ground to provide a smooth transition between throat and cones.
- 4) PAINTING: Entire inside shall have one coat of Westem states Laoquer Co. P-31 wash coat primer (or equal). Out-side shall have one coat of rod lead and oil primer.

IPS FORM E-IN-130.2

			ORIFICE PLATES and FLANGES				SHEET _____ OF _____		
							SPEC. No.		REV
			No.	BY	DATE	REVISION			
							CONTRACT		DATE
							REQ. P.O.		
							BY	CHK'D	APPR.
GENERAL	1	Tag Number							
	2	Service							
	3	Line No./Vessel No.							
	4	Function							
	5	Mounting							
	6	Power Supply							
	7	Conn. Size Type							
	8	Inlet Dir. Outlet Dir.							
	9	Fitting Material							
	10	Packing or O-Ring Mtl.							
	11	Enclosure Type							
METER	12	Size Float Guide							
	13	Tube Mtl. Float Mtl.							
	14	Meter Scale: Length & Type							
	15	Meter Scale Range							
	16	Meter Factor							
	17	Rated Accuracy							
	18	Hydraulic Calib. Required							
FLUID DATA	19	Fluid							
	20	Color or Transparency							
	21	Maximum Flow Rate							
	22	Norm Flow Min Flow							
	23	Oper. Specific Gravity (Liq)							
	24	Max Oper. Viscosity							
	25	Oper. Press. Oper. Temp.							
	26	Oper. Density (Gases)							
	27	Std. Density Mol. Wgt.							
	28	Max. Allowable Press. Drop							
	29								
EXT	30	Extension Well Mtl.							
	31	Gasket Mtl.							
XMTR	32	Transmitter Output							
	33	Trans. Enclosure Class							
	34	Scale Range							
ALARM	35	No. of Contacts Form							
	36	Rating Housing							
	37	Action							
	38								
OPTIONS	39	Valve Size & Material							
	40	Valve Location							
	41	Const. Diff. Relay Mtl.							
	42	Purge Meter Tubing							
	43	Airset							
	43a								
	44	Manufacturer							
	45	Model Number							
	46	Tube Number							
	47	Float Number							

Notes:
IPS FORM E-IN-130.4

ROTAMETERS (VARIABLE AREA FLOWMETERS)

Instructions for filling IPS Form E-IN 130.4 (Refer to ISA RP 16.1, 2, 3, 4)

- 1) List tag number.
- 2) Refers to process applications.
- 3) Show line number, vessel number, or line specification.
- 4) Give functions such as INDICATE RECORD, CONTROL TRANSMIT, INTEGRATE, etc.
- 5) FLUSH PANEL, FRONT PANEL, PIPE, etc.
- 6) Give voltage, dc or ac, and ac frequency.
- 7) Give nominal connection size and type such as SCREWED, 150 lb. FLANGED, etc.
- 8) Select orientation of inlet and outlet and designated as RIGHT, LEFT, VERTICAL or REAR.
- 9) Select material of end fittings. Note if lining is required.
- 10) Select either packing or "O" ring design and note material.
- 11) Select type of enclosure, if any, such as SIDE PLATE, SAFETY GLASS, etc.
- 12) Give meter size. Note that this is not the same as connection size but refers to the nominal size of the tube and float combination.

Give the method of float guiding such as NONE, FLUTES, POLE, EXTENSIONS.

- 13) Select tube and float material.
- 14) Select type meter scale: NONE, ON GLASS, METAL STRIP. Select meter scale length.
- 15) Select meter scale range and flow units. Remember that rotameters' scales cannot start at zero but typically have rangeability of 10:1 or 12:1.
- 16) Meter factor if not direct reading.
- 17) Accuracy statement does not imply any specific calibration.
- 18) Note if hydraulic calibration is required and state required accuracy.
- 19) If fluid cannot be identified, state if liquid or gas.
- 20) Give fluid color or transparency which will affect float visibility in glass tube meters.
- 21) List maximum operating flow rate and units, usually the same as maximum of meter scale.
- 22) Show normal and minimum flow rates expected.
- 23) Give operating specific gravity of liquid. (Numerically equal to density in gm/cm³).
- 24) Give maximum expected viscosity and units.
- 25) Give operating pressure and temperature, with units.
- 26) For gases give operating density and units, unless molecular weight is given on Line 27.
- 27) For gases give density at standard conditions atmospheric pressure and 15°C (14.7 psia and 60°F) unless stated otherwise, and/or molecular weight if known.

- 28)** State maximum allowable pressure drop at full flow, if applicable.
- 30)** If meter has an extension well, state material of well.
- 31)** Select material of gasket on extension.
- 32)** If meter transmits, state pneumatic or electronic output such as 0.2-1 barg (3-15 psig), 4-20 mA, etc.
- 33)** Give transmitter electrical classification such as General Purpose, Class 1, Group D, etc.
- 34)** Give transmitter scale size and range. Note that this is not the meter scale but the scale of the attached instrument.
- 35)** Number of alarm contacts in case.
Form of contacts: SPDT, SPST, DPDT, etc.
- 36)** Contact electrical load rating. Contact housing-GP, Class I, GR. D, etc. Use NEMA identification.
- 37)** HIGH, LOW, DEVIATION.
- 39)** Specify needle valve if required.
- 40)** Valve may be on the inlet, outlet or separately mounted. Do not list here if valve is to be furnished by others.
- 41)** This relay may be used on purge assemblies.
- 44-47)** When manufacturer is selected fill in exact model and part numbers.

				ORIFICE PLATES and FLANGES				SHEET _____ OF _____		
								SPEC. No.		REV
				No.	BY	DATE	REVISION			
								CONTRACT		DATE
								REQ. P.O.		
								BY	CHK'D	APPR.
METERING ELEMENT	1	Meter Tag No.								
	2	Service								
	3	Location								
	4		Line Size, Sched.							
	5		Line Material							
	6		Connection Type							
	7		Connection							
	8		Tube Material							
	9		Liner Material							
	10		Electrode Type							
	11		Electrode Matl.							
	12		Meter Casing							
	13		Power Supply	Elect. Code						
	14		Grounding, Type & Matl.							
	15		Enclosure Class							
	16									
	17		Fluid							
	18		Max. Flow, Units							
	19		Max. Velocity, Units							
	20		Norm. Flow	Min. Flow						
	21		Max. Temp.	Min. Temp.						
	22		Max. Press.	Min. Press.						
	23		Min. Fluid Conductivity							
	24		Vacuum Possibility							
	25									
ASSOCIATED INSTRUMENT	26	Instrument Tag Number								
	27	Function								
	28	Mounting								
	29	Enclosure Class								
	30	Length Signal Cable								
	31	Type Span Adjustment								
	32	Power Supply								
	33	TRANS.	Transmitter Output							
	34									
	35	DISPLAY	Scale Size	Range						
	36		Chart Drive	Speed						
	37		Chart Range	Chart No.						
	38		Integrator							
	39	CONTR.	Modes	Output						
	40		Action	Auto-Man.						
	41									
42	ALARM	Contact No.	Form							
43		Rating	Elec. Code							
44		Action								
	45	Manufacturer								
	46	Meter Model Number								
	47	Instrument Model Number								

Notes:

IPS FORM E-IN-130.5

MAGNETIC FLOWMETERS

Instructions for filling IPS Form E-IN 130.5.

- 1) Tag number of meter only.
- 2) Refers to process application.
- 3) Show line number or identify associated vessel.
- 4) Give pipeline size and schedule. If reducers are used, so state.
- 5) Give material of pipe. If lined, plastic or otherwise nonconductive, so state.
- 6) Give connection type: FLANGED, DRESSER, COUPLINGS, etc.
- 7) Specify material of meter connections.
- 8) Select tube material. (Non-permeable material required if coils are outside tube).
- 9) Specify material of line
- 10) Select electrode type: STD., BULLET NOSED, ULTRASONIC CLEANED, BURN OFF, etc.
- 11) Specify electrode material.
- 12) Describe casing: STD., SPLASH PROOF, SUBMERSIBLE, SUBMERGED OPERATION, etc.
- 13) Give ac voltage and frequency, along with application NEMA or IEC identification of the electrical enclosure.
- 14) State means for grounding to fluid: GROUNDING RINGS, STRAPS, etc.
- 15) State power supply and enclosure class to meet area electrical requirements.
- 16) Meter factor if not direct reading.
- 17) State fluid by name or description
- 18) Give maximum operating flow and units; usually same as maximum of instrument scale.
- 19) Give maximum operating velocity, usually in m/s.
- 20) List normal and minimum flow rates.
- 21) List maximum and minimum fluid temperature °C.
- 22) List maximum and minimum fluid pressure.
- 23) List minimum (at lowest temp.) conductivity of fluid.
- 24) If a possibility of vacuum exists at meter, so state and give greatest value. (highest vacuum).
- 25) (Void)
- 26) List tag number of instrument used directly with meter.
- 27) Control loop function such as INDICATE, RECORD, CONTROL, etc.
- 28) Mounting: FLUSH PANEL, SURFACE INTEGRAL WITH METER, etc.
- 29) Give NEMA or IEC identification of case type.
- 30) State cable length required between meter and instrument.

- 31)** Span adjust: BLIND, ft/s DIAL, OTHER.
- 32)** Give ac supply voltage and frequency.
- 33)** If a transmitter, state analog output electrical or pneumatic range, or pulse train frequency for digital outputs, i.e., pulses per gallon.
- 34)** List scale size and range.
- 35)** List Scale Size and Range for indicating transmitter.
- 36)** Recorder chart drive-ELECT. HANDWIND, etc. and chart speed in time per revolution or inch per hour.
- 37)** List chart range and number.
- 38)** If integrator is used, state counts per hour, or value of smallest count; such as "10 GAL UNITS".
- 39)** For control modes: (Per ANSI C85.1-1963, "Terminology for Automatic Control.") Write-in PI_P , I_P , PI_S , PI_F , D_P etc.

 P = proportional (gain)
 I = integral (auto reset)
 D = derivative (rate)

Subscripts:

 f = fast
 s = slow
 n = narrow

State output signal range, pneumatic or electronic.
- 40)** Controller action in response to an increase in flowrate-INC. or DEC.

State auto-man. switch as NONE, SWITCH ONLY, BUMPLESS, etc.
- 42)** Number of alarm lights in case. Give form of contacts; SPDT, SPST, etc.
- 43)** Contact electrical load rating. Contact housing General Purpose, Class I, Group D, etc., if not in the same enclosure described in line 29.
- 44)** Action of alarms: HIGH, LOW, DEVIATION, etc.
- 45)** Fill in manufacturer and model numbers for meters
- 46)** and
- 47)** Instrument after selection.

		ORIFICE PLATES and FLANGES				SHEET _____ OF _____		
						SPEC. No.		REV
		No.	BY	DATE	REVISION			
						CONTRACT		
						DATE		
						REQ. P.O.		
						BY	CHK'D	APPR.
METER	1	Tag Number						
	2	Service						
	3	Meter Location						
	4	Line Size						
	5	End Connections						
	6	Body Rating						
	7	Nominal Flow Range						
	8	Accuracy						
	9	Linearity						
	10	K Factor, Cycles per vol. Unit						
	11	Excitation						
	12	Materials: Body						
	13	Support						
	14	Shaft						
	15	Flanges						
	16	Rotor						
	17	Bearings: type						
	18	Bearing Material						
	19	Max. Speed						
	20	Min. Output Voltage						
	21	Pickoff Type						
	22	Enclosure Class						
	23							
FLUID DATA	24	Fluid						
	25	Flow Rate: Min. Max.						
	26	Normal Flow						
	27	Operating Pressure						
	28	Back Pressure						
	29	Operating Temp. Max. Min.						
	30	Operating Specific Gravity						
	31	Viscosity Range						
	32	Percent Solids & Type						
	33							
	SECONDARY INSTR.	34	Secondary Instr. Tag No.					
35		Preamplifier						
36		Function						
37		Mounting						
38		Power Supply						
39		Scale Range						
40		Output Range						
OPTIONS	41	Totalizer Type						
	42	Compensation						
	43	Preset Counter						
	44	Enclosure class						
	45	Strainer Size & Mesh						
	46							
	47							
	48							
	49	Manufacturer						
	50	Meter Model No.						
	51	Secondary Instr. Model No.						

Notes:

IPS FORM E-IN- 130.6

TURBINE FLOWMETERS

Instruction for filling IPS Form E-IN 130.6.

Refer to ISA Standard S31, "Specification, Installation, and Calibration of Turbine Flowmeters"

- 1) Show meter tag number. Quantity is assumed to be one unless otherwise noted.
- 2) Refers to process service applications.
- 3) Give line number or process area.
- 5) Specify size and style of connections, such as "1 in. NPT", "2 in. 150 lb. ANSI", etc.
- 6) Pressure and temperature design rating required.
- 7) Nominal flow range is obtained from manufacturer's data. This usually defines linear range of selected meter.
- 8) Turbine meter accuracy figures are in terms of percent of instantaneous flow rate.
- 9) Degree of linearity over nominal flow range.
- 10) K factor relates cycles per second to volume units. Enter this figure after selection is made.
- 11) Excitation modulating type only expressed as Volts _____ at _____ Hertz.
- 12-16) Specify materials of construction or write in "MFR STD".
- 17) Specify sleeve or ball bearings, or none if floating rotor design.
- 18) Bearing material - will be MFG STD if not stated otherwise.
- 19) Maximum speed or frequency which the meter can produce without physical damage.
- 20) _____
- 21) Pick-off may be standard hi-temp., radio-frequency type (RF) or explosion proof. Minimum output voltage volts _____ peak to peak.
- 22) Specify electrical classification of enclosure such as General Purpose, Weather Proof, Class 1, Group D, etc.
- 23) Specify fluid data as indicated, using line 28 for additional item if required.
- 24-32) _____
- 34) Give Tag No. of secondary instrument if different from meter Tag No.
- 35) Pre-amplifier if used.
- 36) Specify function of instrument, such as rate indicator, totalizer or batch control.
- 37) Flush, surface or rack.
- 38) Power supply, i.e., 110 Vac.
- 39) Applies to rate indicator.
- 40) Give output range such as "4-20 mA", 0.2-1 barg (3-15 psig), etc.
- 41) May be used for number of digits, and to state whether counter is reset or non-reset type.
- 42) Specify range of compensation, if required, in pressure and/or temperature units or viscosity units.
- 43) Pre-set counter.

- 44)** Specify NEMA or IEC classification of enclosure.
- 45)** Specify strainer size and mesh size. Request vendor's recommendation if not known.
- 49, 50 & 51)** Fill in after selection is made.

			ORIFICE PLATES and FLANGES				SHEET _____ OF _____		
							SPEC. No.		REV
			No.	BY	DATE	REVISION			
							CONTRACT		DATE
							REQ. P.O.		
							BY	CHK'D	APPR.
	1	Tag Number							
	2	Service							
	3	Line No./Vessel No.							
METER	4	Type of Element							
	5	Size							
	6	End Connections							
	7	Temp. & Press. Rating							
	8	Fow Rate Range							
	9	Totalized Units							
	10	Enclosure Class							
	11	Power Supply							
	12	Materials: Outer Housing							
	13	Main Body Cover							
	14	Roating Element							
	15	Shaft							
	16	Blades							
	17	Bearlings: Type & Material							
	18	Packing							
	19	Type of Coupling							
	20								
COUNTER	21	Register Type							
	22	Totalizer							
	23	Reset							
	24	Capacity							
	25	Set-Stop							
	26								
FLUID DATA	27	Fluid							
	28	Flow Rate: Min. Max.							
	29	Normal Flow							
	30	Oper. Press. Oper. Temp.							
	31	Oper. Specific Gravity							
	32	Oper. Viscosity							
	33	Coef. of Expansion							
OPTIONS	34	Flow Units							
	35	Shut-Off Valve							
	36	Switch: Single or 2-Stage							
	37	Temp. Compensator							
	38	Transmitter Type							
	39	Transmitter output							
	40	Air Eliminator							
	41	Strainer: Size & mesh							
	42								
	43								
	44								
	45	Manufacturer							
	46	Model Number							

Notes:
130.7

IPS FORM E-IN-

POSITIVE DISPLACEMENT METERS

Instructions for filling IPS Form E-IN-130.7.

- 1) Tag No. of instrument.
- 2) Process service.
- 3) Pipe line or vessel identification.
- 4) Write in type of rotating element, such as, disc, piston, vane, helical, rotors, etc.
- 5) Show connection pipe size.
- 6) Specify end connections type and ANSI rating such as 300 lb R. F.
- 7) Specify the manufacturer's recommended body pressure and temperature rating, such as 20 bar at 90°C.
- 8) Write in manufacturer's recommended normal operating range.
- 9) Specify smallest totalized unit, as "Tens of Gallons", "Pounds", "Barrels".
- 10) Specify enclosure electrical classification, if applicable, such as "Class 1, Group D., Div. 2", "General Purpose", etc.
- 11) Specify power supply, if applicable.
- 12) Specify materials of construction. If no preference, write in, MFR. STD. (Manufacturer's Standard).
- 13-18) Specify materials of construction, if no preference, write in, Manufacturer's Standard (MFG-STD).
- 19) Specify type of coupling.
- 20) Specify coupling such as "Magnetic", or MFR. STD.
- 21) Specify register type such as horizontal, vertical, inclined, in-line reading, dial reading, print, etc.
- 22) Specify number of figures such as 6 digit, 5 digit, or 099, 999, etc.
- 23) If totalizer reset required, write in type. If reset is not required, write in "none".
- 24) Write in number of figures or maximum quantity (in flow units) that can be held in counter.
- 25) Specify by writing in "yes" if a set-stop is required to operate shutoff valve, switch, etc.
- 27-34) Specify fluid data as completely as possible, note at operating conditions. Be sure to note if liquid is at saturation conditions.
- 35) Specify by writing in "yes" if a shut-off valve is required. Valve to be manufacturer's standard construction unless otherwise noted.
- 36) Specify by writing in "yes" if a switch is required. Two switches are required for 2-stage shut-off control.
- 37) Write in "yes" if manufacturer's standard temperature compensator is required. Write in "no" if not required.
- 38) Specify, if transmitter is required, by writing in type such as pulse, rate of flow, etc.
- 39) Give transmitter output in pulse per gallon, 4.20 mA, etc.
- 40) Write in "yes" if air eliminator is required, otherwise write in "no".
- 41) Specify, if strainer is required, by writing in type such as "Y", "Basket", etc. Strainer to have same pressure and temperature rating, end connections and material as meter body unless otherwise noted.
- 45-46) Identify manufacturer's name and model number after selection is made.