ASME MFC-18M–2001

MEASUREMENT OF FLUID FLOW USING VARIABLE AREA METERS

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MEASUREMENT OF FLUID FLOW USING VARIABLE AREA METERS

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The next edition of this Standard is scheduled for publication in 2006. There will be no addenda issued to this edition.

ASME will issue written replies to inquiries concerning interpretation of technical aspects of this Standard.

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FOREWORD

This Standard is based on current industrial and research practices. It was prepared by the ASME MFC Subcommittee 10 on Variable Area Meters and approved by the ASME MFC Standards Committee on Measurement of Fluid Flow In Closed Conduits with an emphasis of definitions and specifications of variable area meters.

This Standard was approved as an American National Standard on May 25, 2001.

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Measurement of Fluid Flow In Closed Conduits

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Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry.
Edition:	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for genral understanding and use, not as a request for an approval of a proprietary design or situation. The inquirer may also include plans or drawings which are necessary to explain the question; however, they should not contain proprietary names or information.

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Nonmandatory Appendix

MEASUREMENT OF FLUID FLOW USING VARIABLE AREA METERS

1 SCOPE

This Standard describes the common variable area flowmeter. This Standard does not attempt to standardize dimensions because the commercial products differ too widely.

The variable area meter is manufactured in a variety of designs. This Standard addresses only those meters based on a vertical tapered tube of round or a modified round cross section. Specifically not addressed are the various vane type meters, meters with horizontal flow, or meters which use a spring deflection to oppose flow forces.

2 REFERENCES AND RELATED DOCUMENTS

ASME MFC-1M Glossary of Terms Used in the Measurement of Fluid Flow in Pipes
ASME MFC-2M Measurement Uncertainty for Fluid Flow in Closed Conduits
ASME Fluid Meters, 6th Ed

Publisher: The American Society of Mechanical Engineers (ASME), Three Park Avenue, New York, NY 10016; Order Department: 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300

3 SYMBOLS AND DEFINITIONS

For symbols and their definitions, see Table 1.

4 FLOW RATE EQUATIONS

The variable area flowmeter is composed of a body containing the fluid and a "float," which is free to move in the body to a position related to the flow rate. The balance of forces positions the float. Gravity pulls the float downward. The buoyancy of the float plus the velocity related dynamic fluid forces lift the float. The float rises to increase the flow area until the fluid forces lifting the float match the downward force. The meter must be oriented with flow vertically up for the analysis to be correct. Orientation substantially off the vertical will cause errors or a failure to respond. (See ASME Fluid Meters for more complete analysis of the variable area meter).

It is not practical to calculate meter capacity from physical principles for commercial variable area meters. The manufacturer's catalogs do not list the tube cross section areas, or float volumes, or weights, or inlet and exit pressure drops; all of this information is proprietary. The manufacturer supplies all of the capacity data in the form of tables. This reduces the equation for each meter flow to:

$$Q_v = C_r * \%Scale/100 \tag{1}$$

The full scale meter flow, C_r is defined and tabulated in the manufacturer's catalogs for each specific metering tube and float. Separate tables are used for liquids and compressible fluids. The industry often uses the term "normal" [typical 1.013 bar and 20°C (14.7 psia and 70°F)] conditions for compressible fluid sizing rather than "standard". The user is cautioned to define the reference conditions used. (See the manufacturer's literature for guidance on sizing and calibration.) Equation 2 shows how to correct for a float material density differing from the basis density and for a flowing fluid density differing from the basis density:

$$Q_v = C_r \bullet (\%Scale/100) \bullet \sqrt{\frac{(SG_f - SG_l) \bullet SG_{lc}}{(SG_{fc} - SG_{lc}) \bullet SG_l}} \tag{2}$$

NOTE: Use a consistent basis for SG. For compressible fluids, the negative terms above become very small and are not significant. Calculate Mass flow as the product of volumetric flow and upstream mass density.

$$Q_m = Q_v \bullet \rho_l \tag{3}$$

TABLE 1 SYMBOLS

Symbol	Description	Dimensions
%Scale	Percent of flow full scale	NA
C_r	Specific meter full scale flow capacity	L^3/T
Q_v	Volumetric flow rate	L^3/T
Q_m	Mass flow rate	M/T
SG_{fc}	Specific Gravity of float material at calibration conditions	NA
SG_l	Specific Gravity of fluid, flowing conditions	NA
SG_{lC}	Specific Gravity of fluid, at calibration conditions	NA
SG_f	Specific Gravity of float material, at flowing conditions	NA

GENERAL NOTE: *SG* is the ratio of the fluid density compared to water for liquid applications and the ratio of the fluid to air at specified conditions for compressible fluids.

5 VISCOSITY EFFECTS

For variable area meters, a fluid viscosity exceeding the limit value or "viscosity ceiling", or "viscosity immunity ceiling" as listed in the catalog tables for that specific tube and float, will affect the meter calibration. In general, float designs with a sharp edge on the maximum diameter part of the float will be less sensitive to viscosity (See the manufacturer's literature for guidance). In general, viscosity effects occur with fluids more viscous than water.

6 FLOAT STABILITY

The float may become unstable and "bob" up and down even at a constant flow (See the manufacturer's catalogs for warnings and descriptions of this phenomenon). It is normally experienced only in low pressure gas service. Special floats are used to reduce this effect. Smaller flowmeters are more likely to be affected by this problem. These instabilities may be a result of a cyclic change between laminar and turbulent flow regimes or from fluid mechanical interactions.

7 DESCRIPTION

The variable area flowmeter (see Fig. 1 through Fig. 4) as described in this Standard is composed of:

(a) float
(b) metering tube
(c) scale
(d) packing and seals
(e) upper body
(f) lower body
(g) process connections
(h) accessories

7.1 Float

The float is the body in the flowing fluid that moves in response to fluid flow. It is typically circular in cross section when viewed from the top. From the side, the float geometry may be simply a sphere, or it may be much more complex.

7.2 Metering Tube

The tube is that part of the body which surrounds and contains the float. It increases in cross section area from the bottom to the top. The simplest are circular, but some have vertical guide ribs or a central guide rod.

7.3 Scale

The scale is that part of the meter which shows the relation between the float position and the flow rate. Some have printed or engraved marks and numbers on a transparent metering tube. For metal tube meters, a magnetically coupled indicator is commonly used. This is coupled to the float, and an electronic or pneumatic device may be attached to develop a signal to be transmitted to another location (See Fig. 1 through Fig. 4).

7.4 Packing and Seals

For all but the simplest one-piece purge meters (see Fig. 4), some device is required to seal the metering tube to the upper and lower bodies. O-Rings are used in some meters, and packing is common in the larger meters. The selection of packing materials depends on the process fluid properties, including maximum and minimum pressures; and normal, maximum, and minimum temperatures.

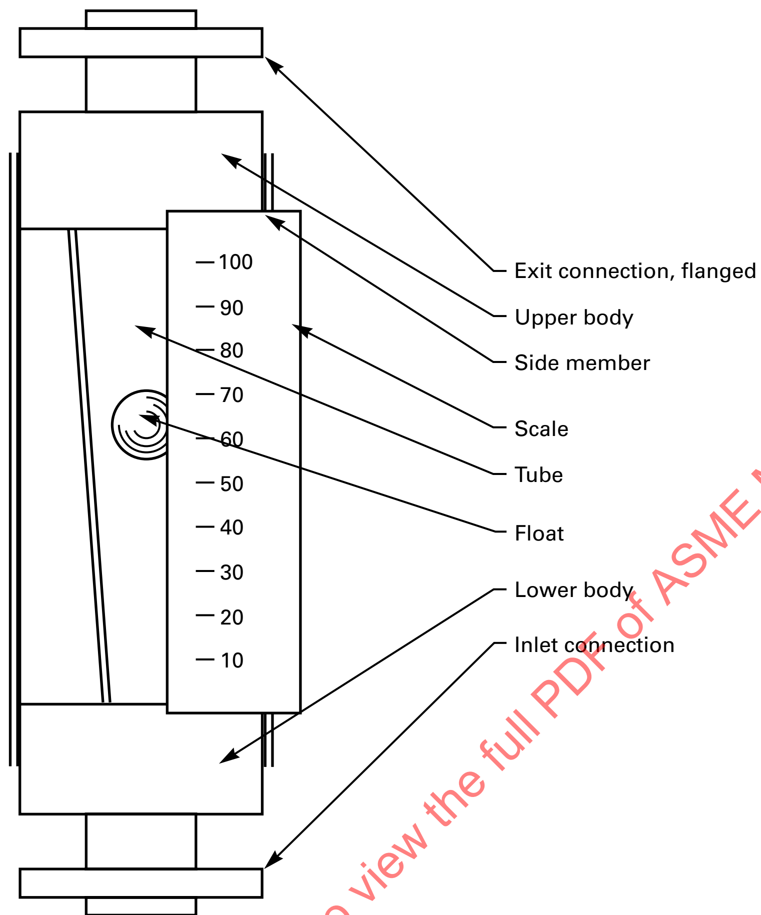

FIG. 1 NOMENCLATURE

7.5 Upper Body

The upper body supports the top or outlet of the metering tube. It usually includes a packing or sealing device. It also provides the support for the flow outlet process connection. In the simplest meters, these functions are all a part of the top of the meter body.

7.6 Lower Body

The lower body is at the bottom or inlet of the flow tube. It is similar in function and design to the upper body.

7.7 Process Connection

The process connections are used to install the meter to the associated piping system. Standard connections include standard inch and millimeter piping threads and flanges.

7.8 Accessories

Accessories include switches controlled by the float position; signal-transmitting devices, check valves to prevent reverse flow, needle valves to control flow, and constant differential relays to stabilize flow.

8 UNCERTAINTY

In most catalog and technical literature, the uncertainty is given as a percent of full scale flow and is defined only between 10% and 100% of scale. The variable area meter is not sensitive to the pipe arrangement or the flow profile entering the meter. Uncertainties can be minimized with careful application and knowledgeable use. If the sizing is based on poorly defined or varying fluid properties and operating conditions, then the accuracy will be compromised. Poor installations with high vibration or excessively non-vertical alignment will reduce accuracy. Calibration can reduce

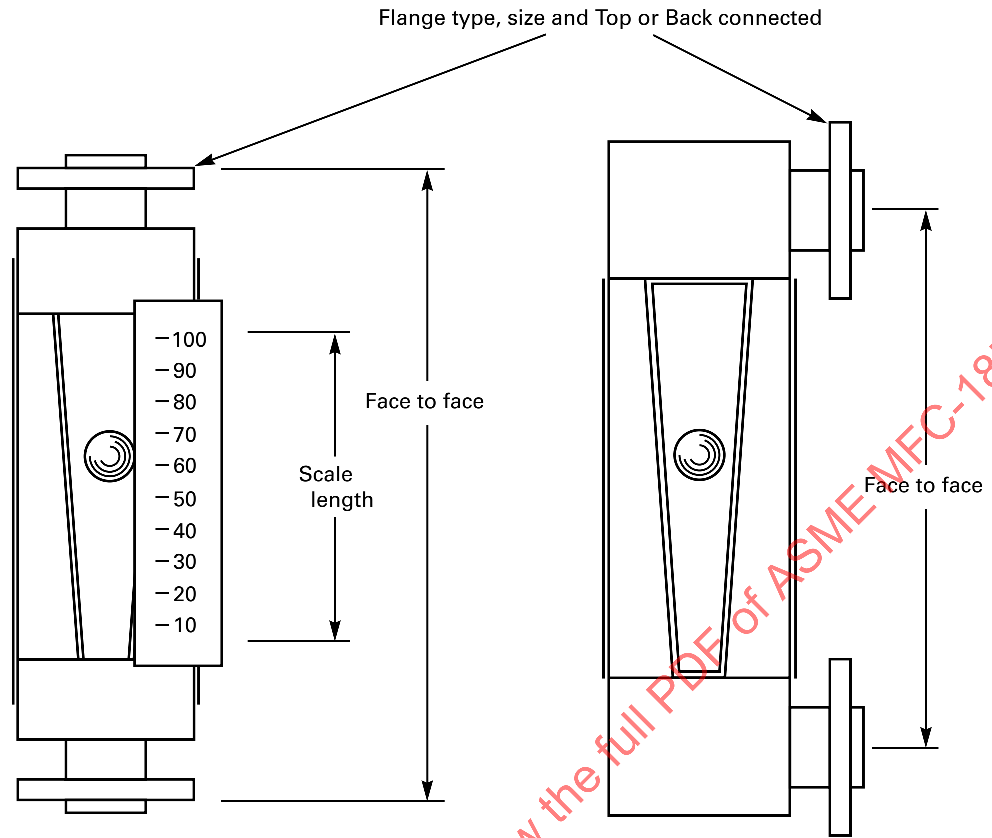

FIG. 2 DIMENSIONS

the uncertainty depending on the quality of the calibration and care in meter transport, installation, and use. Effective accuracy is also a function of the instrument scale and indicator design. An unstable float position will interfere with accurate readings.

9 CLASSES

Variable area flowmeters are of three general classes: purge or miniature meters, laboratory meters, and process flowmeters. This grouping scheme is only very general in nature.

9.1 Purge meter

Purge meters (see Fig. 4) are small and typically have $\frac{1}{4}$ NPT (6 mm) or smaller connections. Because the applications do not justify it, calibration is unlikely. Catalog claims of 2% repeatability and an uncertainty of 5% of flow rate may not always be realized in practice. Tubes vary considerably in design but are often between 50 mm and 100 mm (2 in. and 4 in.) in length.

9.2 Laboratory Meters

The laboratory meters are usually longer [300 mm to 600 mm (12 in. to 24 in.)], have longer scales, and include more graduations than other meters of the same connection size and capacity. Repeatability is advertised as $\frac{1}{2}$% and a standard accuracy of 1% is promised, which may be improved to $\frac{1}{2}$% with calibration.

9.3 Process Meter

Process meters with $\frac{1}{2}$ in. (13 mm), or smaller connections typically have standard calibration uncertainties of 2%. Meters larger than $\frac{1}{2}$ in. can often have certified uncertainty of 1% at the specified conditions if they are calibrated. Tubes are typically between 150 mm and 250 mm long.

10 SAFETY

Many users limit or prohibit the use of glass tubes in hazardous fluids in industrial service. Shields can be purchased with most glass tube meters. The user

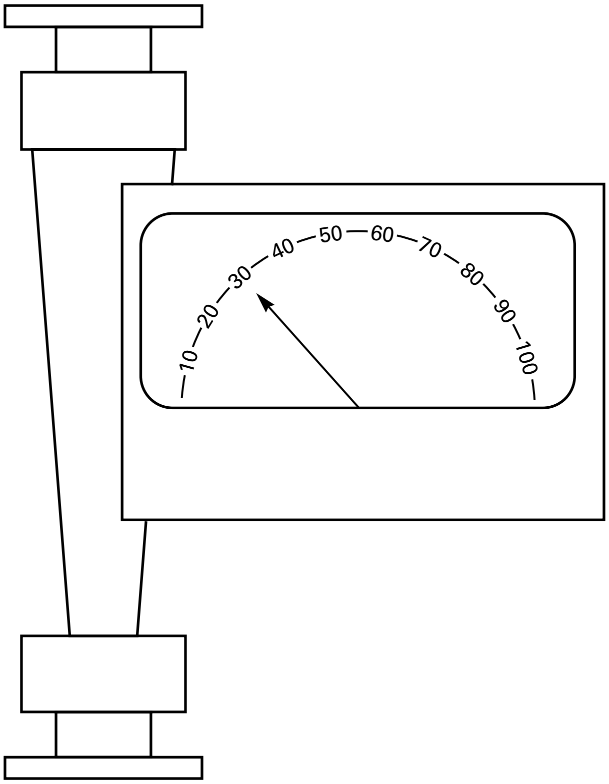

FIG. 3 METAL TUBE METER WITH INDICATOR

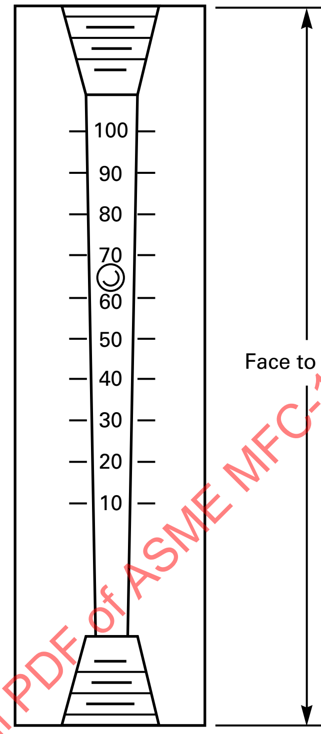

FIG. 4 PURGE METER

must determine if the level of protection provided by these shields is adequate for the application. The shield typically can deflect broken glass and flowing fluid, but is not designed to contain the fluid at the maximum pressure rating of the tube. Glass is brittle and damage to the tube can seriously weaken the tube. Ratings listed in the manufacturer's catalog are for new and undamaged meters.

Metal tube meters are available for services where the brittle nature of glass is a cause for concern.

11 VARIABLE AREA METER DEFINITIONS

11.1 Scale Length

The length of the indicating scale (see Fig. 1) is one of the factors used to classify a variable area meter.

11.2 Connections

The size, type, and orientation of the process connections (e.g., 2 in. NPT, or 2 in. Class 150 flanges) (see Fig. 2) and top or back connected are other design features used to classify variable area meters.

11.3 Maximum Working Pressure

The maximum flowmeter working pressure is the maximum pressure specified by the manufacturer for continuous operation of the flowmeter. The purchase specification should list the maximum and minimum pressures expected in service.

11.4 Maximum Temperature

The maximum flowmeter working temperature is the maximum temperature specified by the manufacturer for continuous operation of the flowmeter. The purchase specification should list the maximum and minimum temperatures expected in service.

11.5 Tube Material

Selection of the proper tube material is critical. Choices include:

(a) Corrosion resistant plastics. Limitations are: temperature and pressure ratings, and they may be harmed by certain solvents.

(b) Glass. Is corrosion resistant; limitations are brittleness, and possible damage by some low pH fluids.

(c) Metals (see Fig. 3), which may be corrosion