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Measurement of Gas Flow by Means of Capillary Tube Thermal Mass Flowmeters and Mass Flow Controllers

AN AMERICAN NATIONAL STANDARD

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FOREWORD

Capillary tube thermal mass flowmeters (MFMs) and mass flow controllers (MFCs) comprise a family of instruments for the measurement and control of the mass flow rate of gases flowing through closed conduits.

This Standard covers the capillary tube type of thermal MFM. A companion standard, ASME MFC-21.2, Measurement of Fluid Flow by Means of Thermal Dispersion Mass Flowmeters, covers the other most commonly used type of thermal MFM. Both types of instruments measure the mass flow rate of gases by means of a heated element in contact with the flowing gas, and in both types, the composition of the gas must be known.

In the case of the thermal dispersion, or immersible, type of MFM, heat is transferred to the boundary layer of the gas flowing over a heated sensor immersed in the main flow stream. The heat carried away by the gas provides the measurement of mass flow rate. Thermal dispersion MFMs are used for general industrial gas flow applications in ducts and pipes.

In the case of the capillary tube type of MFM described in this Standard, the flowing gas enters the flowmeter and passes through a laminar flow element, or bypass. This creates a pressure drop that forces a small, but proportional, fraction of the total mass flow rate through an adjacent capillary sensor tube. The capillary sensor tube measures its internal mass flow rate by means of the heat capacity of the gas that carries heat from an upstream resistance-temperature-detector winding to a downstream winding, both on the outside of the sensor tube. The difference in the electrical resistances of the two windings provides the output signal proportional to the total mass flow rate in the process.

A capillary tube thermal MFC is a capillary tube thermal MFM with an integral control valve mounted on the same flow body. The MFM portion measures the mass flow rate in the process line, the electronics compares this measurement with a set-point value, and the control valve regulates the flow to equal the set-point value. Capillary tube thermal MFMs and MFCs are used for smaller flows of clean gases flowing in tubes.

In this Standard, the term *mass flow controller* is abbreviated *MFC* and should not be confused with the name of the cognizant ASME Standards Committee, MFC, Measurement of Fluid Flow in Closed Conduits.

Suggestions for improvements in this Standard are welcome. They should be sent to the Secretary, ASME MFC Standards Committee, Two Park Avenue, New York, NY 10016-5990.

This Standard was approved as an American National Standard on May 19, 2015.

ASME MFC COMMITTEE
Measurement of Fluid Flow in Closed Conduits

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General. ASME Standards are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Standard may interact with the Committee by requesting interpretations, proposing revisions or a Case, and attending Committee meetings. Correspondence should be addressed to:

Secretary, MFC Standards Committee
The American Society of Mechanical Engineers
Two Park Avenue
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http://go.asme.org/Inquiry

Proposing Revisions. Revisions are made periodically to the Standard to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Proposing a Case. Cases may be issued for the purpose of providing alternative rules when justified, to permit early implementation of an approved revision when the need is urgent, or to provide rules not covered by existing provisions. Cases are effective immediately upon ASME approval and shall be posted on the ASME Committee Web page.

Requests for Cases shall provide a Statement of Need and Background Information. The request should identify the Standard and the paragraph, figure, or table number(s), and be written as a Question and Reply in the same format as existing Cases. Requests for Cases should also indicate the applicable edition(s) of the Standard to which the proposed Case applies.

Interpretations. Upon request, the MFC Standards Committee will render an interpretation of any requirement of the Standard. Interpretations can only be rendered in response to a written request sent to the Secretary of the MFC Standards Committee at go.asme.org/Inquiry.

The request for an interpretation should be clear and unambiguous. It is further recommended that the inquirer submit his/her request in the following format:

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 general understanding and use, not as a request for an approval of a proprietary design or situation. The inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

Request that are not in this format may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME Committee or Subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

Attending Committee Meetings. The MFC Standards Committee regularly holds meetings and/or telephone conferences that are open to the public. Persons wishing to attend any meeting and/or telephone conference should contact the Secretary of the MFC Standards Committee. Future Committee meeting dates and locations can be found on the Committee Page at go.asme.org/MFCcommittee.

MEASUREMENT OF GAS FLOW BY MEANS OF CAPILLARY TUBE THERMAL MASS FLOWMETERS AND MASS FLOW CONTROLLERS

1 SCOPE

This Standard establishes common terminology and provides guidelines for the quality, description, principle of operation, selection, operation, installation, and flow calibration of capillary tube thermal mass flowmeters and mass flow controllers for the measurement and control of the mass flow rate of gases. The content of this Standard applies to single-phase flows of pure gases and gas mixtures of known composition.

2 TERMINOLOGY, SYMBOLS, AND REFERENCES

2.1 Definitions From MFC-1M

accuracy (of measurement): the extent to which a given measurement agrees with a reference for that measurement, often used by manufacturers to express the performance characteristics of a device.

NOTE: *Accuracy* is not the same as *uncertainty* [see *uncertainty (of measurement)*].

bell prover: volumetric gaging device used for gases that consists of a stationary tank containing a sealing liquid into which is inserted a coaxial movable tank (the bell), the position of which may be determined. The volume of the gas-tight cavity produced between the movable tank and the sealing liquid may be deduced from the position of the movable tank.

calibration: the experimental determination of the relationship between the quantity being measured and the device that measures it, usually by comparison with a standard, then (typically) adjustment of the output of a device to bring it to a desired value, within a specified tolerance, for a particular value of the input.

critical flow devices: a flowmeter in which a critical flow is created through a primary differential pressure device (fluid at sonic velocity in the throat). A knowledge of the fluid conditions upstream of the primary device and of the geometric characteristics of the device and the pipe suffice for the calculation of the flow rate.

flow conditioner: general term used to describe any one of a variety of devices intended to reduce swirl and/or regulate the velocity profile.

flow rate: the quantity of fluid flowing through a cross section of a pipe per unit of time.

fully developed velocity distribution: a velocity distribution, in a straight length of pipe that has zero radial and azimuthal fluid velocity components and an axisymmetric axial velocity profile that is independent of the axial position along the pipe.

laminar flow: flow under conditions where forces due to viscosity are more significant than forces due to inertia, and where adjacent fluid particles move in essentially parallel paths.

NOTES:
(1) Laminar flow may be unsteady but is completely free from turbulent mixing.
(2) Laminar flow in a pipe follows the Poiseuille law.

Mach number: the ratio of the mean axial fluid velocity to the velocity of sound in the fluid at the considered temperature and pressure.

mass flow rate: mass of fluid-per-unit-time flowing through a cross section of a pipe.

piston prover: volumetric gaging device consisting of a straight section of pipe with a constant cross section and of known volume. The flow rate is derived from the time taken by a piston, with free or forced displacement, to travel through this section.

rangeability: the rangeability of a flowmeter is the ratio of the maximum to minimum flow rates (Reynolds numbers, velocities, etc.) in the range over which the meter meets a specified and acceptable uncertainty, also called *turndown*.

repeatability (qualitative): closeness of agreement among a series of results obtained with the same method on identical test material, under the same conditions (same operator, same apparatus, same laboratory, and short intervals of time).

NOTE: The representative parameters of the dispersion of the population that may be associated with the results are qualified by the term *repeatability*. Examples are standard deviation of repeatability and variance of repeatability.

repeatability (quantitative): closeness of the agreement between the results of successive measurements of the