PROCESS INDUSTRY PRACTICES

TECHNICAL CORRECTION
May 2017

Process Control

PIP PCEFL001
Flow Measurement Guidelines

PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

In an effort to minimize the cost of process industry facilities, this Practice has been prepared from the technical requirements in the existing standards of major industrial users, contractors, or standards organizations. By harmonizing these technical requirements into a single set of Practices, administrative, application, and engineering costs to both the purchaser and the manufacturer should be reduced. While this Practice is expected to incorporate the majority of requirements of most users, individual applications may involve requirements that will be appended to and take precedence over this Practice. Determinations concerning fitness for purpose and particular matters or application of the Practice to particular project or engineering situations should not be made solely on information contained in these materials. The use of trade names from time to time should not be viewed as an expression of preference but rather recognized as normal usage in the trade. Other brands having the same specifications are equally correct and may be substituted for those named. All Practices or guidelines are intended to be consistent with applicable laws and regulations including OSHA requirements. To the extent these Practices or guidelines should conflict with OSHA or other applicable laws or regulations, such laws or regulations must be followed. Consult an appropriate professional before applying or acting on any material contained in or suggested by the Practice.

This Practice is subject to revision at any time.

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1. Scope

This Practice provides engineering guidance for the selection, design, and application of flow measurement systems.

This Practice provides guidelines, performance considerations, and preliminary recommendations for the selection of flow meters and their general application. This guideline applies to devices used to measure the flow of single phase, homogeneous liquids, vapors, and gases.

This Practice presents commonly accepted meter types but does not limit application choice. Unique or special requirements may require consideration of other meter types.

Specific custody transfer guidelines are not provided and are only mentioned with reference to other industry practices.

2. References

Applicable parts of the following Practices, industry codes and standards, and references shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles are used herein where appropriate.

2.1 Process Industry Practices (PIP)

– PIP PCCFL001 - *Flow Measurement Design Criteria*

– PIP PCCGN002 - *General Instrument Installation Criteria*

2.2 Industry Codes and Standards

- American Gas Association
  - – AGA 9 - *Measurement of Gas by Multipath Ultrasonic Meters*
- American National Standards Institute (ANSI)
  - – ANSI-2530/API-14.3/AGA-3/GPA-8185 - *Natural Gas Fluids Measurement - Concentric, Square-Edged Orifice Meters*
    Part 1 General Equations and Uncertainty Guidelines
    Part 2 Specification and Installation Requirements
    Part 3 Natural Gas Applications
    Part 4 Background, Development, Implementation Procedures and Subroutine Documentation
- American Petroleum Institute (API)
  - – API RP 551 - *Process Measurement Instrumentation*
  - – API RP 554 - *Process Instrument and Control*
  - – API *Manual of Petroleum Measurement Standards* (MPMS):
    Chapter 4 - Proving Systems
    - 4.2 Conventional Pipe Provers
    - 4.3 Small Volume Provers
    - 4.5 Master-Meter Provers
    - 4.8 Operation of Proving Systems

Chapter 5 - Metering

5.2 Measurement of Liquid Hydrocarbons by Displacement Meters

5.3 Measurement of Liquid Hydrocarbons by Turbine Meters

Chapter 6 - Metering Assemblies

Chapter 12 - Calculation of Petroleum Quantities

12.2 Calculation of Liquid Petroleum Quantities Measured by Turbine or Displacement Meters

Chapter 14 - Natural Gas Fluids Measurement

14.2 Compressibility Factors of Natural Gas and Other Related Hydrocarbon Gases (AGA Report No. 8)

14.3 Concentric, Square-Edged Orifice Meters

14.4 Converting Mass of Natural Gas Liquids and Vapors to Equivalent Liquid Volumes

14.5 Calculation of Gross Heating Value, Specific Gravity, and Compressibility of Natural Gas Mixtures from Compositional Analysis

14.6 Continuous Density Measurement

14.7 Mass Measurement of Natural Gas Liquids

14.8 Liquefied Petroleum Gas Measurement

Chapter 21 - Flow Measurement Using Electronic Metering Systems

- American Society of Mechanical Engineers (ASME)
  - ASME MFC-1M - *Glossary of Terms Used in the Measurement of Fluid Flow in Pipes*
  - ASME MFC-2M - *Measurement Uncertainty for Fluid Flow in the Closed Conduits*
  - ASME MFC-3M - *Measurement of Fluid Flow in Pipes Using Orifice, Nozzle, and Venturi*
  - ASME MFC-5M - *Measurement of Liquid Flow in Closed Conduits Using Transit-Time Ultrasonic Flow Meters*
  - ASME MFC-6M - *Measurement of Fluid Flow in Pipes Using Vortex Flow Meters*
  - ASME MFC-7M - *Measurement of Gas Flow by Means of Critical Flow Venturi Nozzles*
  - ASME MFC-8M - *Fluid Flow in Closed Conduits* - *Connections for Pressure Signal Transmissions Between Primary and Secondary Devices*
  - ASME MFC-9M - *Measurement of Liquid Flow in Closed Conduits by Weighing Method*
  - ASME MFC-10M - *Method of Establishing Installation Effects on Flow Meters*
  - ASME MFC-11M - *Measurement of Fluid Flow by Means of Coriolis Mass Flowmeters*

- ASME MFC-14M - *Measurement of Fluid Flows Using Small Bore Precision Orifice Meters*
  [Note: For ½" to 1- ½" Orifice Meters and Integral Orifice]
- ASME MFC-16M - *Measurement of Fluid Flow in Close Conduit by Means of Electromagnetic Flowmeter*
- ASME B16.5 - *Pipe Flanges and Flanged Fittings*
- ASME B16.36 - *Orifice Flanges*
- ASME PTC-6 - *Performance Test Code, Steam Turbines*

- International Organization for Standardization (ISO)
  - ISO 5167-1 - *Measurement of Fluid Flow by Means of Pressure Differential Devices*
- ISA, The International Society for Measurement and Control (ISA)
  - ISA RP16.1,2,3 - *Terminology, Dimensions and Safety Practices for Indicating Variable Area Meters*
  - ISA RP16.4 - *Nomenclature and Terminology for Extension Type Variable Area Meters*
  - ISA RP16.5 - *Installation, Operation, Maintenance Instructions for Glass Tube Variable Area Meters*
  - ISA RP16.6 - *Methods and Equipment for Calibration of Variable Area Meters*
  - ANSI/ISA RP31.1 - *Specifications, Installations, and Calibration of Turbine Flowmeters*

2.3 Other References

- Miller, R.W., *Flow Measurement Engineering Handbook*
- ISA - *Flow Measurement - Practical Guides for Measurement and Control*, Spitzer, D.W., Editor
- ASME - *Fluid Meters, Their Theory and Application*

3. General

3.1 Flow Metering Quality

3.1.1 Flow meter selection and installation are major contributors to the performance of a plant control system. During the conceptual design, performance requirements should be considered for the flow meter.

3.1.2 Figure 1 illustrates the two primary quality parameters likened to rifle marksmanship. "Repeatability" is a term meant to express the random errors in a measurement. It is the measurement of how closely a sequence of readings conforms to each other. As can be seen, a flow measurement may be repeatable without being highly accurate. Measurement repeatability is the essential requirement for many flow control loops. The minimum industry requirements and manufacturer's guidelines should be followed for the flow meter technology being applied if repeatable measurement is desired for control or general indication of flow.

3.1.3 "Accuracy" (or its inverse, inaccuracy) is a term expressing the systemic error in a measurement and is the value of how far an individual reading departs from a reference standard. A higher degree of accuracy is crucial in areas where product quality control or reporting quality is the primary reason for the measurement. More rigorous selection of meter types and installation practice must be used in these cases.

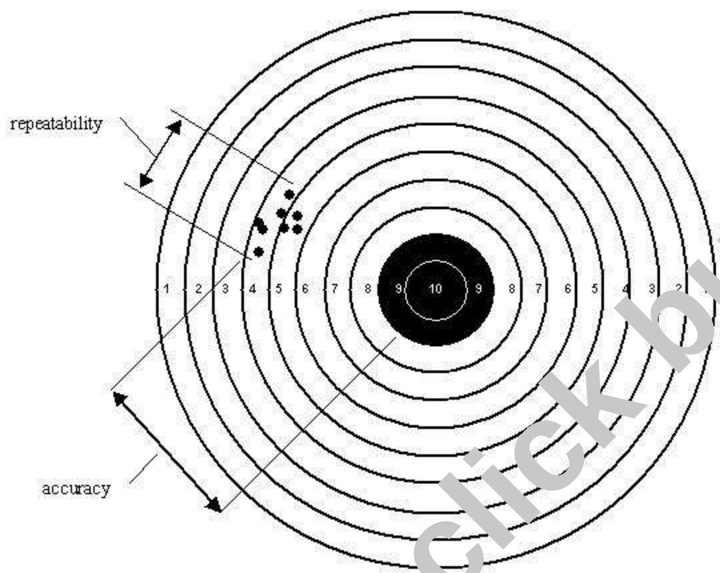

Figure 1. Target Practice Illustration of Flow Measurement

3.1.4 "Uncertainty" is the total potential error or inaccuracy from the reference standard by the two parameters expressed above. An expression of uncertainty usually represents the limit of allowable inaccuracy for a given flow measurement without distinction of its error source. A one percent uncertainty flow meter must maintain a measurement reading within one percent of the reference standard.

3.1.5 Another requirement might include periodic flow calibration as part of operation and maintenance of the meter.

3.1.6 Overall flow measurement performance can be estimated using a root-sum-of-squares technique in combining error contributions of the metering system components that make up the measurement system.

3.1.6.1 This measurement uncertainty should be applied to the daily integrated measured quantities of steady flow through the meter.

3.1.6.2 Methods for determining the measurement uncertainty are given in ISO 5167.

3.1.7 Quality flow measurement is dependent on:

a. Type of meter selected
b. Manufacturer's tolerances
c. Proper installation
d. Calibration procedures
e. Operation and maintenance procedures
f. Accounting methods

3.1.8 The following information should be obtained before selecting a meter:

a. Ranges of physical and chemical characteristics of the fluid, including composition, viscosity, flowing density, vapor pressure, corrosive, abrasive or contaminated nature, lubricating quality, and plugging or fouling tendencies
b. Acceptable materials of construction
c. Range of flow rates expected (maximum and minimum with normal expected value)
d. Process fluid temperature and pressure variations expected
e. Seasonal and daily ambient temperature changes at the meter
f. Duration of operation (continuous or intermittent)
g. Location of meter or metering station (local or remote)
h. Pressure drop allowable for the measurement
i. Maintenance accessibility
j. Meter servicing or replacement while the process is on-line
k. Required accuracy of the overall measurement
l. Plant equipment preferences and experiences with similar metering applications

3.2 Flow Element Selection

There are many types of flow metering technologies available. Appendix A, Flowchart 1 provides general information to aid in selecting primary flow elements.

3.3 Piping Arrangement

3.3.1 Many flow meters are sensitive to upstream and downstream velocity profile conditions.

3.3.2 Piping components such as fittings, reducers, expanders, elbows, strainers, branch connections, valves, pipe lengths, and spacing can affect the fluid's flowing velocity profile. Many possible configurations can make it difficult to predict changes in velocity profile.

3.3.3 Flow meters' installed performance can be adversely influenced by insufficient piping approaches and departures.

3.3.4 Straight runs before and after a primary flow element should meet established minimum upstream and downstream requirements for the specific meter.

3.3.5 Piping run length criterion for orifice meters can be applicable for other meters because they are the minimum acceptable necessary lengths to assure adequate velocity profile development.

3.3.5.1 Maximizing run lengths contributes to quality flow measurements.

3.3.5.2 Using less than minimum lengths compromises metering performance. Appendix B, Table 1 provides recommendations for the design of orifice meter runs. See *API MPMS* Chapter 14.3 for additional information.

3.3.6 The metering piping design should consider the possibility of increased flow resulting from debottlenecking or future process expansion. Maximizing meter run piping lengths based on a high beta ratio can accommodate the increase in flow without the added cost of piping revisions.

3.3.7 Temperature wells or connections should be located downstream of the primary flow elements to minimize velocity profile distortion.

3.3.7.1 In some cases, it may be necessary to insulate the piping to maintain temperature.

3.3.7.2 Pressure and temperature should be measured at or very near the meter if flow compensation is needed.

3.3.8 Piping should be arranged to ensure that liquid flow meters are always full of liquid (vapor free) and gas flow meters are always liquid free.

3.3.8.1 Turning down after a meter in a liquid horizontal run or turning up after a meter in a condensing vapor flow should be avoided.

3.3.8.2 In vertical piping runs, liquids should flow up while condensing vapors should flow down.

3.3.9 Piping layout should consider meter dimensions, tap orientation, and access for maintenance/service work. This is especially important where close-coupled transmitter installations are used.

3.4 Flow Conditioning

3.4.1 Installation of flow conditioning devices to reduce flow velocity distortion should be considered only in special cases after all other alternatives have been exhausted.

3.4.2 Flow conditioning devices introduce pressure drop and can be dislodged causing metering error or damage to downstream equipment.

3.5 Removal of Insertion Type Flow Instruments

3.5.1 Insertion flow devices should typically be used in large line sizes.

3.5.2 If a process line cannot be practically shut down, safe meter removal should be provided using flow assemblies that are fully retractable under line pressure and process temperature.

3.5.3 The packing assembly and isolation valve should be properly sized in accordance with the piping specifications.

3.5.4 Blowout prevention should be considered as part of the installation design.

3.5.5 Ensure proper clearances and accessibility to facilitate removal.

3.6 Control Valve Location

3.6.1 To avoid flow profile disturbances on the meter, the preferred location of flow and pressure control valves is downstream of the meter.

3.6.2 For liquid service, locating the valve downstream of the meter can provide adequate backpressure to avoid flashing in the meter.

3.7 Special Equipment

3.7.1 Some types of meters may require specialized testing and calibration connections and/or equipment to operate, calibrate, and maintain.

3.7.2 Installation, calibration, and operation of the special equipment (i.e., meter provers) should be considered as part of the engineering design.

4. Specific Considerations

4.1 Head-type (Differential Pressure) Flowmeters

4.1.1 Flow rangeability (ratio of full scale flow to minimum flow but not zero flow) should be considered carefully in choosing head type flow meters. Use of smart transmitters can improve turndown and accuracy for differential meters. In any case, the meter performance at the minimum flow rate should be evaluated along with the maximum flow rate.

4.1.2 Head type flow meters infer flow from measuring differential pressure, which varies as the square of actual flow, introducing a nonlinear characteristic that is especially apparent at low flows. Normally the signal is linearized, but this does not eliminate issues of low flow inaccuracy or instability. Square root operation in calculating flows from head type meters should be performed in the control system when using analog output of non-digital transmitters. Smart transmitters and multivariable transmitters with digital output may be used to provide a linearized output.

Comment: If the user wishes to use the transmitter to linearize the output signal, care must be taken to avoid the problem of multiple square root extraction.

4.1.3 Pressure and temperature compensation may be used to improve the accuracy of the flow measurement. The compensation can be done in the process control system using transmitted values or within a multivariable transmitter. Flow, pressure, and temperature values can also be used to calculate mass flow.

4.1.4 Transmitters should be located as close as practical to the primary element for differential pressure measurement applications. Impulse line length, temperature difference in the impulse lines, and long piping configurations are detrimental to the measurement.