Manual of Petroleum Measurement Standards Chapter 5—Metering

Section 1—General Considerations for Measurement by Meters

FOURTH EDITION, SEPTEMBER 2005

ERRATA, JUNE 12, 2008
ERRATA 2, JUNE 27, 2011

REAFFIRMED, MARCH 2011

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AMERICAN PETROLEUM INSTITUTE

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Measurement Coordination

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Date of Issue: June 27, 2011
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ERRATA 2

(This errata contains changes made in an Errata published June 12, 2008)

Remove Paragraph **5.1.6.3 i**

Paragraph **5.1.9.4.2**, *the reference at the end of the paragraph should read:*

(see 5.1.9.5)

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ERRATA

Paragraph 5.1.9.4.2, the reference at the end of the paragraph should read:

(see 5.1.9.5)

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FOREWORD

Chapter 5 of the API *Manual of Petroleum Measurement Standards* (API *MPMS*) provides recommendations, based on best industry practice, for the custody transfer metering of liquid hydrocarbons. The various sections of this Chapter are intended to be used in conjunction with API *MPMS* Chapter 6 to provide design criteria for custody transfer metering encountered in most aircraft, marine, pipeline, and terminal applications. The information contained in this chapter may also be applied to non-custody transfer metering.

The chapter deals with the principal types of meters currently in use: displacement meters, turbine meters and Coriolis meters. If other types of meters gain wide acceptance for the measurement of liquid hydrocarbon custody transfers, they will be included in subsequent sections of this chapter.

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Suggested revisions are invited and should be submitted to the Standards and Publications Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

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Manual of Petroleum Measurements Standards

Chapter 5—Metering

Section 1—General Considerations for Measurement by Meters

5.1.1 Introduction

API *MPMS* Chapter 5 covers the general installation and operation of meters and accessory equipment, without respect to the arrangements necessary to meet special problems. The guidelines are common to all metering systems, but appropriate precautions should be taken when they are used for specialized metering systems, as discussed in API *MPMS* Chapter 6, "Metering Assemblies," and for mass measurement, as discussed in API *MPMS* Chapter 14.8, "Liquefied Petroleum Gas Measurement."

Some of the advantages of metering are as follows:

a. Metering can increase the availability of tanks, since no tank needs to be isolated for the sole purpose of measurement.
b. Metering lends itself to the calculation, indication, and display of instantaneous flow rate and volume.
c. Metering can deliver a measured volume taken from several sources at the same time into a single receiver, or it can deliver a measured volume taken from a single source into several receivers.
d. Metering accuracy can be readily checked by the use of standard references.
e. Metering allows dynamic volume averaging of temperatures and samples to be applied to volumes.

This publication does not endorse or advocate the preferential use of any specific type of equipment or systems, nor is it intended to restrict future development of such equipment.

5.1.2 Scope

API *MPMS* Chapter 5 is intended to be a guide for the proper specification, installation, and operation of meter runs designed to dynamically measure liquid hydrocarbons so that acceptable accuracy, service life, safety, reliability, and quality control can be achieved. API *MPMS* Chapter 5 also includes information that will assist in troubleshooting and improving the performance of meters.

5.1.2.1 FIELD OF APPLICATION

The field of application of API *MPMS* Chapter 5 is the measurement of liquid hydrocarbons and chemicals by meter, at the temperature and pressure conditions that prevail inside a meter during flowing conditions. API *MPMS* Chapter 5 is also concerned with the metering of hydrocarbons that can, by heating, cooling, and/or compressing, be made and kept liquid by maintaining the proper temperature and pressure.

The chapter does not apply to the metering of two-phase fluids.

5.1.3 Referenced Publications

As stated in the foreword, this edition of API *MPMS* Chapter 5 contains six main sections; others may be added if the need arises. The current editions of the following API *MPMS* Standards contain information applicable to this chapter:

API *Manual of Petroleum Measurement Standards*

Chapter 1	"Vocabulary"
Chapter 4	"Proving Systems"
Chapter 6	"Metering Assemblies"
Chapter 7	"Temperature"
Chapter 8	"Sampling"
Chapter 9	"Density"
Chapter 11	"Physical Properties Data"
Chapter 12	"Statistical Aspects of Measuring and Sampling"
Chapter 13	"Application of Statistical Methods"
Chapter 14	"Natural Gas Fluids Measurement"
Chapter 20.1	"Allocation Measurement"
Chapter 21.2	"Flow Measurement Using Electronic Metering Systems"

5.1.4 Considerations for the Design of Meter Installations

The design of meter installations should take into account the following considerations:

a. The installation should be capable of satisfying the required performance characteristics for the application between the maximum and minimum flow rates, at the maximum operating pressure, and over the temperature range and liquid types to be measured. If necessary, the installation should include protective devices that keep the operation of the meter within design limits.
b. The installation should ensure a maximum, dependable operating life. Strainers, filters, air/vapor eliminators, or other protective devices may be provided upstream of the meter to remove solids and/or gases that could cause meter damage, premature meter wear and/or measurement error.
c. The installation should maintain adequate pressure on the liquid in the metering system at all temperatures to ensure

that the fluid being measured will be in the liquid state at all times.

d. The installation should provide for proving each meter and should be capable of duplicating normal operating conditions at the time of proving.

e. The installation should ensure, where necessary, appropriate flow conditioning both upstream and downstream of the meter or meters.

f. The installation should comply with all applicable regulations and codes.

5.1.5 Factors to Consider in Selecting Meters and Meter Accessory Equipment

API *MPMS* Chapter 5.4 provides information that will assist in selecting the appropriate meter accessory equipment. In addition, the manufacturer should be consulted and detailed consideration should be given to the following items:

a. The properties of the metered liquids, including viscosity, density, vapor pressure, toxicity, corrosiveness, abrasiveness and lubricating ability. Toxic and environmentally controlled fluids must receive special consideration to prevent and control potential leaks or spills.

b. The operating flow rates and whether the flow is continuous, intermittent, fluctuating, bidirectional, and/or reversible.

c. The performance specifications (e.g., meter linearity and repeatability) that are required for the application (e.g., see Figure 1).

d. The class and type of piping connections and materials and the dimensions of the equipment to be used.

e. The space required for the meter installation and the proving facility.

f. The range of operating pressures (including surges), acceptable pressure losses through the meter, and whether pressure on the liquid is adequate to prevent vaporization.

g. The operating temperature range and the applicability of automatic temperature compensation.

h. The effects of corrosive contaminants on the meter.

i. The quantity and size of foreign matter, including abrasive particles, carried in the liquid stream.

j. The types of readout and printout devices or systems to be used, signal preamplification (see API *MPMS* Chapter 5.4), and the standard units of volume or mass that are required.

k. The type, method, and frequency of proving (see API *MPMS* Chapter 4).

l. The method by which a meter can be proved at its normal operating rate and the method by which a meter in a bank of meters can be put on or taken off line as the total rate changes.

m. Whether volume or mass registration is required.

n. The method of factoring a meter's registration.

o. The need for accessory equipment, such as totalizers, pulsers, additive injection apparatus, combinators, and devices for controlling delivery of a predetermined quantity. When meter-driven mechanical accessory devices are used, caution must be taken to limit the total torque applied to the metering element (see API *MPMS* Chapter 5.4).

p. Valves in the meter installation. Valves require special consideration since their performance can affect measurement accuracy. The flow or pressure control valves on the main-stream meter run should be capable of smooth opening and closing to prevent shocks and surges. Other valves, particularly those between the meter or meters and the prover (for example, the stream diversion valves, drains, and vents), require leak-proof shutoff, which may be provided by a double block-and-bleed valve with telltale bleed or by another similarly effective method of verifying shut off integrity.

q. Maintenance methods/costs and spare parts required.

r. Requirements and suitability for security sealing.

s. Power supply requirements for continuous or intermittent meter readout (see API *MPMS* Chapter 5.4).

t. The fidelity and security of pulse-data transmission systems (see API *MPMS* Chapter 5.5).

5.1.6 Guidelines for Selecting Type of Meter

Displacement, turbine or Coriolis meters are normally used to meter custody transfers of liquid hydrocarbons. In many situations one type of meter is preferred, but in some cases, any of these types of meters is satisfactory.

Although factors such as pressure, temperature, viscosity, flow range and fluid contamination may influence the type of meter selected, viscosity, flow rate and fluid contamination should be considered first.

Because Coriolis meters are less affected by severe fluid contamination they are often selected over the other two types of meters.

Figure 1 depicts guidelines for selecting a displacement meter or a turbine meter in terms of viscosity and flow rate. It illustrates that displacement meters perform better with high-viscosity liquids and that turbine meters perform better with low-viscosity liquids. Turbine meters perform best in fully developed turbulent flow (that is, when the Reynolds number is above 10,000). Thus at higher flow rates turbine meters can be used on higher viscosity liquids. Two-bladed helical rotor type turbine meters will typically operate satisfactorily at lower Reynolds Numbers than conventional, multi-bladed turbine meters.

Both displacement meters and turbine meters may experience performance variations when used with liquids that have changing viscosities. This effect with displacement meters is greatest on very low viscosity liquids. On turbine meters it is greatest on high viscosity liquids. Since the effect on turbine meters is directly related to the Reynolds Number, smaller turbine meters experience this problem at lower viscosities than do larger turbine meters. The effect of changing viscosity on two-bladed helical rotor type turbine meters is typically

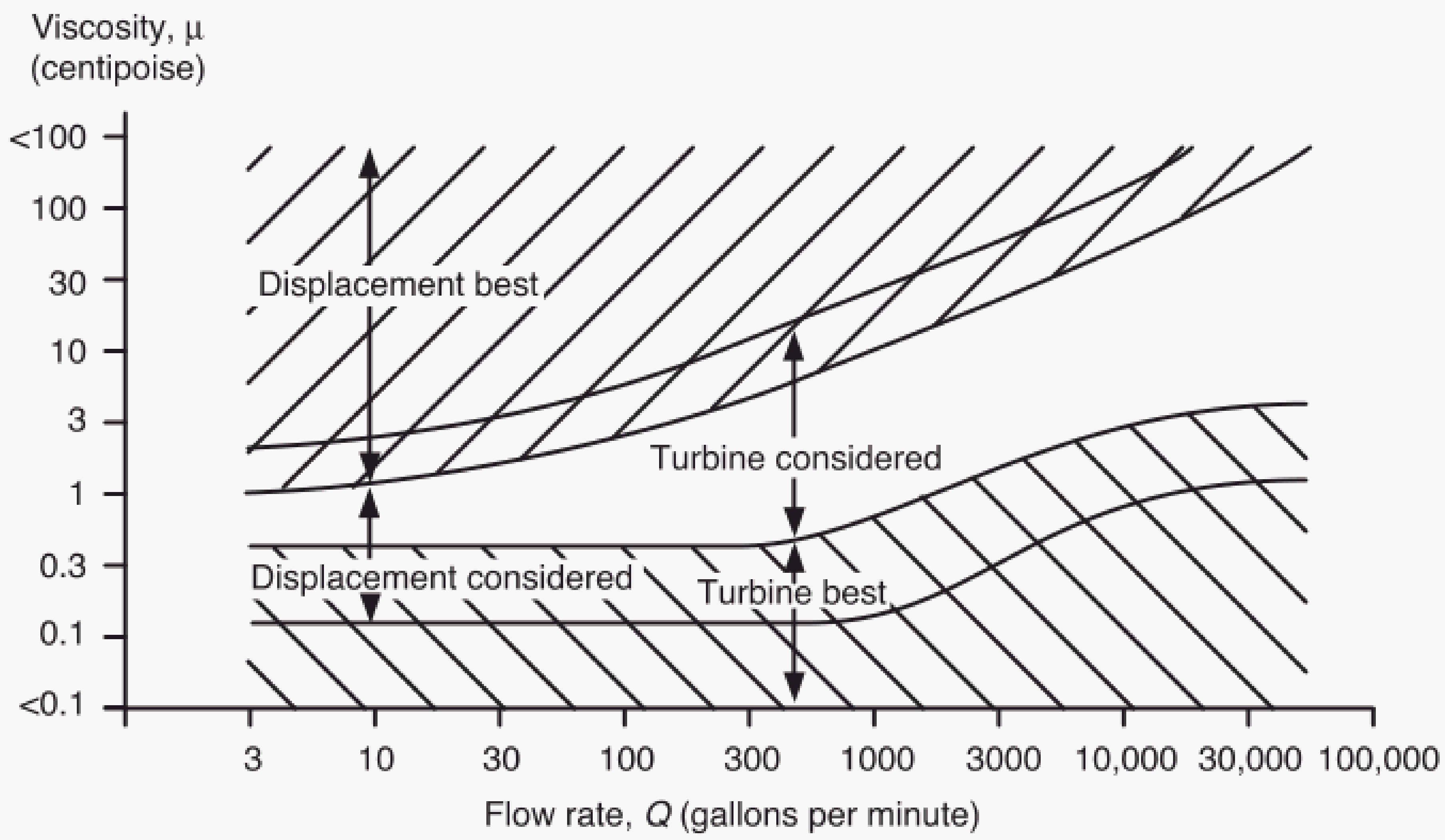


Figure 1—Selection Guide for Displacement and Turbine Meters

less than on conventional, multi-bladed turbine meters. Coriolis meter performance is generally unaffected by changing viscosity. However higher viscosities may result in excessive pressure drops.

Turbine meters are normally preferred over displacement meters on pipelines used for refined products, such as propane, gasoline, kerosene, or diesel oil. In terms of continuous-duty operation, they have a longer service life than displacement meters, and they are as accurate or more accurate in measuring these types of products.

Generally turbine meters should not be used on liquids that contain substances that may collect on the surfaces of the meter and affect its cross-sectional flow area, and possibly some of its other performance factors. Proving frequency and operational and maintenance procedures must also be considered when applications of this kind are evaluated. Because of fewer blades, this effect is less pronounced on two-bladed helical rotor type turbine meters.

When mass registration is required the use of Coriolis meters should be considered because they measure mass flow directly; whereas displacement and turbine meters, require an accurate density measurement to convert their volume measurements to mass measurements.

After a meter has been selected, proper system design, operation, and maintenance must be provided to obtain accurate measurements.

5.1.6.1 DISPLACEMENT METERS

Displacement meters have the following relative strengths:

a. Capability to measure viscous liquids.
b. Capability to function without external power.
c. Capability to register near-zero flow rate.
d. Conceptual simplicity of design and operation.
e. Flow conditioning is not required.
f. Less back pressure required.

Displacement meters have the following relative weaknesses:

g. Susceptibility to damage by flow surges and gas slugging.
h. Susceptibility to corrosion and erosion.
i. Severe reduction in flow if meter is jammed.
j. Increased maintenance requirements.
k. Sensitivity to viscosity changes at lower viscosities.

5.1.6.2 TURBINE METERS

Turbine meters have the following relative strengths:

a. Wide flow range for low viscosity liquids.
b. Small size and weight.
c. Long-bearing life.
d. Wide temperature and pressure range.

Turbine meters have the following relative weaknesses:

e. Necessity for flow conditioning.
f. Need for back pressure control to prevent flashing and/or cavitation and error.
g. Difficulty in metering high-viscosity liquids (especially conventional multi-bladed turbine meters).
h. Susceptibility to fouling or deposits.
i. Sensitivity to viscosity changes at higher viscosities (lower Reynolds Numbers).
j. Susceptibility to damage by gas slugging or flow surges

5.1.6.3 CORIOLIS METERS

Coriolis meters have the following relative strengths:

a. Low maintenance—minimally affected by abrasive and corrosive substances
b. Not susceptible to damage by gas slugging
c. Capability of registering near-zero flow rate
d. Minimally affected by viscosity changes
e. Direct mass and density measurements (providing indirect volume measurement)
f. Flow conditioning is not normally required.

Coriolis meters have the following relative weaknesses:

g. Sensitivity to installation conditions, including shock and vibration
h. Accumulation of internal deposits can affect accuracy
i. Sizes larger than six inches are not typically used for volumetric custody transfer applications.
j. Sometimes difficult to prove due to time lag of manufactured pulse output
k. Meter requires periodic re-zeroing under pressure, with no flow.
l. Needs back pressure control.
m. High pressure drop

5.1.7 Installation

Meters shall be installed according to the manufacturer's instructions and shall not be subjected to piping strain and vibration beyond their recommended limits. Flow conditioning is required for all turbine meters, but is not required for displacement meters and most Coriolis meters.

5.1.7.1 VALVES

5.1.7.1.1 If a bypass is permitted around a meter or a battery of meters, it should be provided with a blind or positive-shutoff double block-and-bleed valve with a telltale bleed.

5.1.7.1.2 In general, all valves, especially spring-loaded or self-closing valves, should be designed so that they will not admit air when they are subjected to vacuum conditions.

5.1.7.1.3 Valves for intermittent flow control should be fast acting and shock free to minimize the adverse effects of starting and stopping liquid movement.

5.1.7.1.4 A flow-limiting device, such as a flow rate control valve or a restricting orifice, should preferably be installed downstream of the meter and prover. The device should be selected or adjusted so that sufficient pressure will be maintained to prevent vaporization. An alarm may be desirable to signal that flow rates have fallen below the design minimum. If a pressure-reducing device, or other restrictive device (e.g., check valve, isolating butterfly valve, etc.) is used on the inlet side of the meter, it shall be installed as far upstream of the meter as possible. The device shall be installed so that sufficient pressure will be maintained on the outlet side of the meter installation to prevent any vaporization of the metered liquid.

5.1.7.1.5 A back-pressure valve may be required to maintain the pressure on the meter and the prover above the fluid vapor pressure. In general, displacement meters do not accelerate fluid velocity and are not normally subject to the resulting pressure reduction that can cause vaporization (cavitation) in other types of meters.

5.1.7.2 PIPING INSTALLATION

5.1.7.2.1 Meters are normally installed in a horizontal position. The manufacturer shall be consulted if space limitations dictate a different position. For example, Coriolis meters are sometimes installed vertically.

5.1.7.2.2 Where the flow range is too great for any one meter, where shutting down the metering system is impractical, or where frequent service is needed, a bank of meters may be installed in parallel. Each meter in the bank shall be operated within its minimum and maximum flow rates. A means shall be provided to balance flow through each meter.

5.1.7.2.3 Meters should be installed and operated to have a maximum, dependable service life. This may require that protective devices be installed to remove from the liquid abrasives or other entrained substances which could stop the metering mechanism or cause premature wear. Strainers, filters, sediment traps, settling tanks, water separators, a combination of these items, or any other suitable devices, can be used. They should be properly sized and installed to not adversely affect the operation of the meter or the overall system. Protective devices may be installed singly or in an interchangeable battery, depending on the importance of continuous service. Monitoring devices should be installed to determine when the protective device needs to be cleaned.

5.1.7.2.4 Meters shall be installed and operated to perform satisfactorily within the viscosity, pressure, temperature, and flow ranges that will be encountered.

5.1.7.2.5 Meters shall be adequately protected from pressure pulsations, from excessive flow surges and from excessive pressure caused by thermal expansion of the liquid. This kind of protection may require the installation of surge tanks, expansion chambers, pressure-limiting valves, relief valves, or other protective devices. When pressure relief valves are located between the meter and the prover, a means of detecting leakage from the valves shall be provided.

5.1.7.2.6 Any condition that contributes to the release of vapor from the liquid stream shall be avoided through suitable system design and through operation of the meter and prover within the flow range specified by the manufacturer.

The release of vapor can be minimized or eliminated by maintaining sufficient back-pressure downstream of the meter. This can be achieved by installing the appropriate type of valve (back-pressure, throttling, or reducing) downstream of the meter and prover.

The meter manufacturer may be consulted for recommendations on the minimum acceptable operating pressure for specific applications.

5.1.7.2.7 Each meter shall be installed to prevent air or vapor from passing through it. If necessary, air/vapor elimination equipment shall be installed as close as possible to the upstream side of the meter run. The vapor vent lines on air/vapor eliminators shall be of adequate size. The safety of the venting system should be given special design consideration. Air eliminators cannot vent when they are operating below atmospheric pressure. Under adverse conditions, they may even draw air into the system. A tight-closing check valve in the vent line will prevent air from being drawn into the system under these conditions.

5.1.7.2.8 Meters and piping shall be installed to avoid accidental drainage and vaporization of liquid. The piping shall have no unvented high points or pockets where air or vapor may accumulate and later be carried through the meter by the added turbulence that results from increased flow rate. The installation shall prevent air from being introduced into the system through leaky valves, piping, glands of pump shafts, separators, connecting lines, and so forth.

5.1.7.2.9 Lines from the meter to the prover shall be installed to minimize the possibility of air or vapor being trapped. Manual bleed valves should be installed at high points to allow air to be bled off, when necessary, before proving. The distance between the meter and its prover shall be minimized. The diameter of the connecting lines shall be large enough to prevent a significant decrease in flow rate during proving. In multi-meter stations, throttling valves may be installed downstream of the meters to regulate flow through the prover while each meter is being proved.

5.1.7.2.10 Piping shall be designed to prevent the loss or gain of liquid between the meter and the prover during proving.

5.1.7.2.11 Special consideration should be given to the location of each meter, its accessory equipment, and its piping manifold to minimize the mixing of dissimilar liquids.

5.1.7.2.12 For meters designed to flow in one direction only, provision shall be made to prevent flow in the opposite direction.

5.1.7.2.13 A means of measuring temperature shall be provided to enable correction of thermal effects on the stream or meter. The capability to obtain the stream temperature inside the meter body is desirable. Some displacement meters and double case turbine meters allow for installation of a temperature-measuring device in the meter body. However, this is impractical with most other types of meters because of the way they are constructed or because of the type of temperature-measuring device that is selected.

If it is impractical to mount the temperature-measuring device in the meter, the device should be installed either immediately downstream (preferable, especially for turbine meters) or upstream of the meter run. Where several meters are operated in parallel on a common stream, one temperature-measuring device in the total stream, located sufficiently close to the meter inlets or outlets, is acceptable if the stream temperatures at each meter and at the sensing location agree within the tolerance specified in Chapter 7. Test thermowell(s) should be provided downstream of each meter, or downstream of all the meter runs, to verify that the stream temperatures are identical and the upstream temperature is representative of the temperature at the meters. Refer to API *MPMS* Chapter 7 for additional information.

5.1.7.2.14 To determine meter pressure, a gauge, recorder, or transmitter of suitable range and accuracy shall be installed near the outlet of each meter run. Near the inlet is acceptable for displacement and Coriolis meters.

5.1.7.2.15 A heat-traced manifold that maintains a heavy hydrocarbon in a sufficiently liquid state to permit measurement by a meter shall be designed to meet the following objectives:

a. An excessively high temperature (e.g., exceeding equipment manufacturers' maximum temperature specification), cannot occur.
b. The temperature cannot fall below the level at which the viscosity of the liquid becomes too great for the meter at the required flow rates.
c. Temperature control is especially important when the meter is not operating. The meter manufacturer should be consulted about high and low limits for viscosity and temperature.

5.1.7.3 ELECTRICAL INSTALLATIONS

Meter systems may include a variety of electrical or electronic accessories, as discussed in Chapter 5.4. The electrical systems shall be designed and installed to meet the manufacturer's recommendations and the applicable hazardous area classifications, to preclude signal and noise interference from nearby electrical equipment, and to minimize the possibility of mechanical damage to the components.

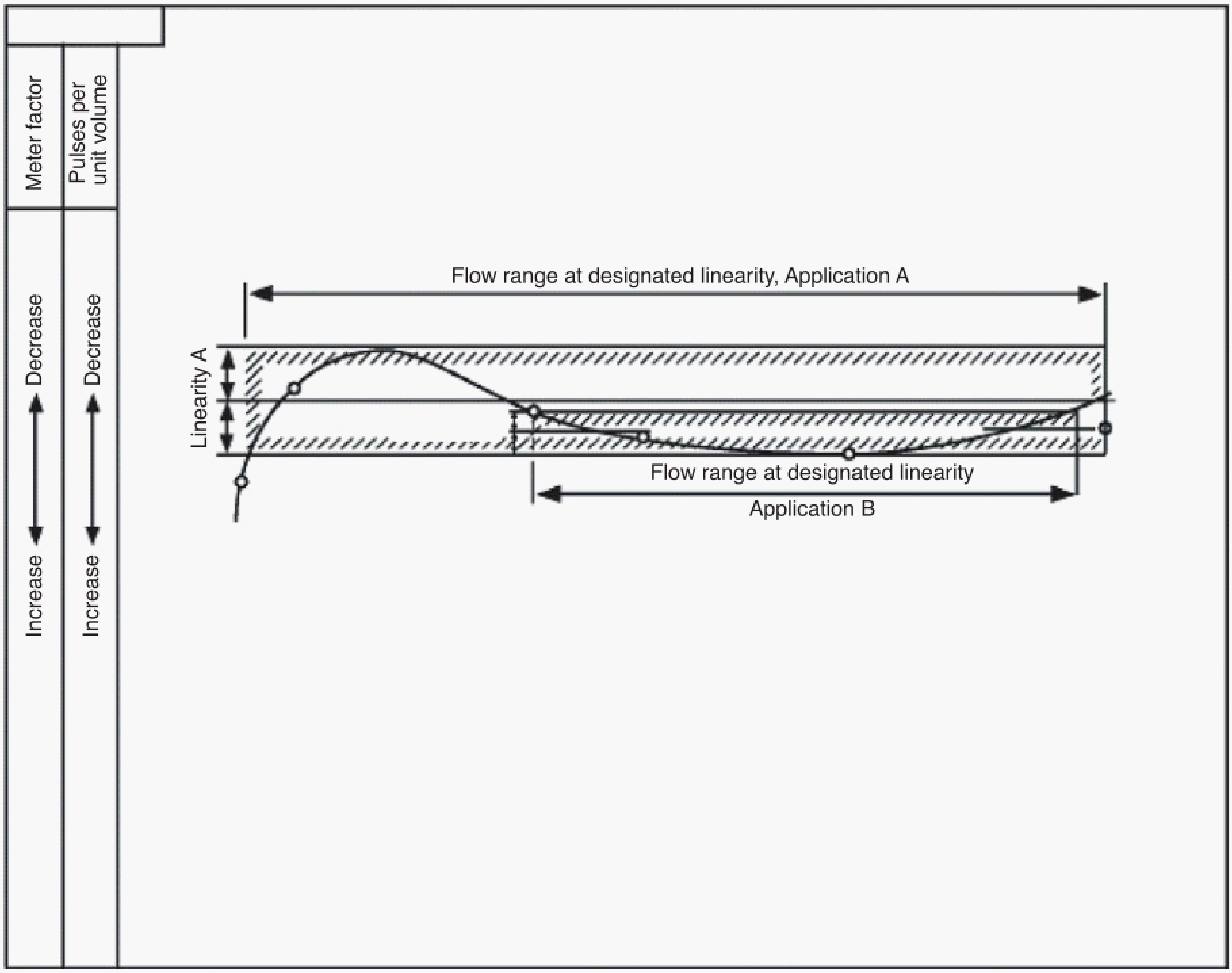
5.1.8 Meter Performance

The overall performance of measurement by a meter depends on the condition of the meter and its accessories, the temperature and pressure corrections, the proving system, the frequency of proving, and the variations between operating and proving conditions. The inherent accuracy of a meter is often published in the manufacturer's specification, and may be expressed as repeatability and/or linearity. In other words, accuracy is based on how repeatable and how linear the meter can stay within the manufacturer's performance specifications. Manufacturers' specifications are based on meter operation within recommended flow ranges, within a narrow range of pressures, temperatures, and fluid viscosities. For custody transfer applications, meters with the highest inherent accuracy should be used and should be proved on site. The meters should operate within the manufacturer's specifications.

An excellent indicator of how well a meter performs is the development of, and history of, its meter factor from proving the meter. A meter factor obtained for one set of conditions will not necessarily apply to a changed set of conditions. Meter performance curves can be developed from a set of proving results. The curve in Figure 2 is called a meter linearity curve.

The following conditions may affect the meter factor:

a. Flow rate.
b. Viscosity of the liquid.
c. Temperature of the liquid.
d. Density of the liquid.
e. Pressure of the flowing liquid.
f. Cleanliness and lubricating qualities of the liquid.
g. Foreign material lodged in the meter, strainer or flow-conditioning element.
h. Changes in mechanical clearances or internal geometry due to wear or damage.
i. Changes in piping, valves, or valve positions that affect fluid profile or swirl into a turbine meter.
j. Conditions of the prover (see API *MPMS* Chapter 4).



Note: This figure is illustrative only and should not be construed as representing the likely performance of any given model or size of turbine meter. The curve represents the characteristic performance of a turbine meter under stable operating conditions for flow rates within the manufacturer's capacity rating.

Figure 2—Turbine Meter Performance Characteristics

5.1.9 Meter Operation and Maintenance

This section covers recommended operating practices for meter installations. All operating data that pertain to measurement, including the meter factor control charts, should be accessible to interested parties.

5.1.9.1 CONDITIONS THAT AFFECT OPERATIONS

5.1.9.1.1 The overall accuracy of measurement depends on the condition of the meter and its accessories, the temperature and pressure corrections, the proving system, the frequency of proving, and the variations, if any, between operating and proving conditions. A meter factor obtained for one set of conditions will not necessarily apply to a changed set of conditions.

5.1.9.1.2 Meters should be operated with the manufacturer's recommended accessory equipment and within the range of flow rates specified by the manufacturer. Meters should be operated only with liquids whose properties are consistent with the design of the installation.

5.1.9.1.3 If a meter is to be used for bidirectional flow, meter factors shall be obtained for flow in each direction.

5.1.9.1.4 Failure to remove foreign matter upstream of a meter run may result in mismeasurement and/or meter damage. Strainers, filters, or other protective devices should be placed upstream of the meter run.

5.1.9.2 PRECAUTIONS FOR OPERATING NEWLY INSTALLED METERS

When a new meter installation is placed in service, particularly on newly installed lines, foreign matter can be carried to the metering mechanism during the initial passage of liquid. Protection should be provided from malfunction or damage by foreign matter, such as air or vapor, slag, debris, welding splatter, thread cuttings, pipe compound, etc. Following are suggested means of protecting the meter from foreign matter:

a. Temporarily replace the meter with a spool.
b. Put a bypass around the meter.
c. Remove the metering element.
d. Install a protective device upstream of the meter.

5.1.9.3 INSTRUCTIONS FOR OPERATING METER SYSTEMS

Procedures, both for operating metering systems and for calculating measured quantities, should be furnished to personnel at meter stations. Following is a list of items which these procedures should include, along with chapters of the API Manual of Petroleum Measurement Standards that can be used for reference and assistance in developing these operating guidelines:

a. A standard procedure for meter proving (Chapter 4).
b. Instructions for operating standby or spare meters.
c. Minimum and maximum meter flow rates and other operating information, such as pressure and temperature.
d. Instructions for applying pressure and temperature correction factors (Chapter 12.2).
e. A procedure for recording and reporting corrected meter quantities and other observed data.
f. A procedure for estimating the quantity passed, in the event of meter failure or mismeasurement.
g. Instructions in the use of control charts and the action to be taken when the meter factor exceeds the established acceptable limits (Chapter 13).
h. Instructions regarding who should witness meter provings and repairs.
i. Instructions for reporting breaks in security seals.
j. Instructions in the use of all forms and tables necessary to record the data that supports proving reports and meter tickets.
k. Instructions for routine maintenance.
l. Instructions for taking samples (Chapter 8).
m. Details of the general policy regarding frequency of meter proving and reproving when changes of flow rate or other variables affect meter accuracy (Chapters 4 and 5).
n. Procedures for operations that are not included in this list but that may be important in an individual installation.
o. Documentation of all meter and associated instrument spans and ranges.

5.1.9.4 METER PROVING

5.1.9.4.1 Each meter run should be connected to a permanent prover or connections should be provided for a portable prover or master meter to obtain and demonstrate the use of meter factors that represent current operations. The proving methods selected shall be acceptable to all parties involved (see Chapter 4).

5.1.9.4.2 The optimum frequency of proving depends on so many operating conditions that it is unwise to establish a fixed time or throughput interval for all conditions. In clean fluid service at substantially uniform rates and temperatures, meter factors tend to vary little, necessitating less frequent meter proving. More frequent proving is required with fluids that contain abrasive materials, in LP gas service where meter wear may be significant, or in any service where flow rates and /or viscosities vary substantially. Likewise, frequent changes in product types necessitate more frequent provings. In seasons of rapid ambient temperature change, meter factors vary accordingly, and proving should be more frequent. Study of the meter factor control chart, which should include data on liquid temperature and rate, will aid determinations of the optimum frequency of proving (see 5.1.10.5).

5.1.9.4.3 Provings should be frequent (e.g., every tender or every day) when a meter is initially installed. After frequent proving has shown that the meter factors for any given liquid are being reproduced within narrow limits, the frequency of proving can be reduced if the factors are under control and the overall repeatability of measurement is satisfactory to the parties involved.

5.1.9.4.4 A meter should always be proved after maintenance that could affect measurement. If the maintenance has shifted the meter factor values, the period of relatively frequent proving should be repeated to set up a new factor data base by which meter performance can be monitored.

When the values have stabilized, the frequency of proving can again be reduced.

5.1.9.5 METHODS OF CONTROLLING METER FACTORS

5.1.9.5.1 Meter factors can be analyzed with a suitable statistical control method. Chapter 13.2 addresses meter measurement control methods and other methods of analysis that use historical comparison of meter factor data to monitor meter performance.

5.1.9.5.2 Meter factor control charts are essentially plots of successive meter factor values along the abscissa at the appopirate ordinate value, with parallel abscissae representing $X \pm 1\sigma$, $X \pm 2\sigma$, and $X \pm 3\sigma$, where X is the arithmetic mean meter-factor value and σ is the standard deviation or other tolerance-level criterion (for example, (0.0025 or (0.0050). A control chart can be maintained for each meter in each product or grade of crude at a specified rate or range of rates for which the meter is to be used.

5.1.9.5.3 Meter factor control methods can be used to provide a warning of measurement trouble and to show when and to what extent results may have deviated from accepted norms. The methods can be used to detect trouble, but they will not define the nature of the trouble. When trouble is encountered or suspected, the measurement system should be systematically checked. The following problems commonly occur in meter systems:

a. The physical properties of the liquid change.
b. The operating conditions (e.g., flow rate, product, etc.) have changed
c. The moving parts or internal surfaces of the meter become worn or fouled with foreign matter.
d. Isolation and diversion valves leak.
e. The proving system and its components require maintenance (see Chapter 4).
f. Air becomes trapped somewhere in the manifolding. (This possibility must be remedied by either procedure or equipment.)
g. The calibration of pressure-, temperature-, and density-sensing devices has to be checked.
h. When a tank prover is used, the act of opening and closing the diversion valve is unduly slow. (Opening and closing should be smooth and rapid.)

5.1.9.6 METER MAINTENANCE

5.1.9.6.1 For maintenance purposes, a distinction should be made between parts of the system that can be checked by operating personnel (parts such as pressure gauges and mercury thermometers) and more complex components that may require the services of technical personnel. Meters and associated equipment can normally be expected to perform well for long periods. Indiscriminate adjustment of the more complex parts and disassembly of equipment is neither necessary nor recommended. The manufacturer's standard maintenance instructions should be followed.

5.1.9.6.2 Meters stored for a long period shall be kept under cover and shall have protection to minimize corrosion.

5.1.9.6.3 Establishing a definite schedule for meter maintenance is difficult, in terms of both time and throughput, because of the many different sizes, services, and liquids measured. Scheduling repair or inspection of a meter may best be accomplished by monitoring the meter factor history for each product or grade of crude oil. Small random changes in meter factor will naturally occur in normal operation, but if the value of these changes exceeds the established deviation limits of the control method, the cause of the change should be investigated, and any necessary maintenance should be provided. Using deviation limits to determine acceptable normal variation strikes a balance between looking for trouble that does not exist and not looking for trouble that does exist.

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