Manual of Petroleum Measurement Standards Chapter 4.5

Master Meter Provers

FOURTH EDITION, JUNE 2016

AMERICAN PETROLEUM INSTITUTE

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Measurement Coordination Department

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Foreword

Chapter 4 of the Manual of Petroleum Measurement Standards was prepared as a guide for the design, installation, calibration, and operation of meter proving systems commonly used by the majority of petroleum operators. The devices and practices covered in this chapter may not be applicable to all liquid hydrocarbons under all operating conditions. Other types of proving devices that are not covered in this chapter may be appropriate for use if agreed upon by the parties involved.

This publication is primarily intended for use in the United States and is related to the standards, specifications, and procedures of the National Institute of Standards and Technology (NIST). When the information provided herein is used in other countries, the specifications and procedures of the appropriate national standards organizations may apply. Where appropriate, other test codes and procedures for checking pressure and electrical equipment may be used.

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API *MPMS* Chapter 4 now contains the following sections:

Section 1, *Introduction*

Section 2, *Displacement Provers*

Section 4, *Tank Provers*

Section 5, *Master Meter Provers*

Section 6, *Pulse Interpolation*

Section 7, *Field-Standard Test Measures*

Section 8, *Operation of Proving Systems*

Section 9.1, *Introduction to Determination of the Volume of Displacement and Tank Provers*

Section 9.2, *Determination of the Volume of Displacement and Tank Provers by the Waterdraw Method of Calibration*

Section 9.3, *Determination of the Volume of Displacement Provers by the Master Meter Method of Calibration*

Section 9.4, *Determination of the Volume of Displacement and Tank Provers by the Gravimetric Method of Calibration*

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

Contents

Master Meter Provers

1 Scope

This standard covers the use of displacement, turbine, Coriolis, and ultrasonic meters as master meters.

The requirements in this standard are intended for single-phase liquid hydrocarbons. Meter proving requirements for other fluids should be appropriate for the overall custody transfer accuracy and should be agreeable to the parties involved. This document does not cover master meters to be used for the calibration of provers. For information concerning master meter calibration of provers, see API *MPMS* Chapter 4.9.3.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API *MPMS* Chapter 4.8, *Operation of Proving Systems*

API *MPMS* Chapter 4.9.2, *Determination of the Volume of Displacement and Tank Provers by the Waterdraw Method of Calibration*

API *MPMS* Chapter 4.9.3, *Determination of the Volume of Displacement Provers by the Master Meter Method of Calibration*

API *MPMS* Chapter 5.1, *General Considerations for Measurement by Meters*

API *MPMS* Chapter 5.2, *Measurement of Liquid Hydrocarbons by Displacement Meters*

API *MPMS* Chapter 5.3, *Measurement of Liquid Hydrocarbons by Turbine Meters*

API *MPMS* Chapter 5.6, *Measurement of Liquid Hydrocarbons by Coriolis Meters*

API *MPMS* Chapter 5.8, *Measurement of Liquid Hydrocarbons by Ultrasonic Flow meters Using Transit Time Technology*

API *MPMS* Chapter 12.2.3, *Calculation of Petroleum Quantities Using Dynamic Measurement Methods and Volumetric Correction Factors, Part 3—Proving Reports*

API *MPMS* Chapter 13.1, *Statistical Concepts and Procedures in Measurement*

API *MPMS* Chapter 13.2, *Statistical Methods of Evaluating Meter Proving Data*

API *MPMS* Chapter 20.1, *Allocation Measurement*

ISO 4185, *Measurement of Liquid Flow in Closed Conduits—Weighing Method*

NOTE For additional information regarding gravimetric proving systems.

3 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1
direct proving method
A proving operation is considered a direct proving when a line meter is proved against:

— a displacement prover, with a ball or piston type free displacer;

— a displacement prover, captive displacer (piston and shaft) type, with external detectors;

— an atmospheric volumetric prover.

Using this method, there is no meter other than the line meter in series with the prover.

3.2
direct master meter proving method
The method in which the proving of a line meter is performed indirectly by means of a prover in series with the master meter and the line meter. Both meters are proved using a common flowing stream at essentially the same time (either simultaneously or "back-to-back"). This method has a higher uncertainty than a direct method, simply by the introduction of a direct master meter into the procedures. However, it closely approximates the direct method because all of the testing is conducted using a common flowing stream at essentially the same time and conditions.

3.3
indirect master meter proving method
This proving method requires that the line meter and a master meter be in series. The line meter is proved by comparison to the master meter whose meter factor (MF) was determined by a previous direct proving on a different flow stream and/or conditions. This method has a significantly higher uncertainty than the other methods because a displacement prover is not in series with the master meter and the line meter.

4 Applications

Master meter proving is the method used to prove a line meter with a master meter. In order to minimize the uncertainties of this method, every attempt should be made to determine the master meter's meter factor (MMF) by proving the master meter in the same fluid and flowing conditions that will be experienced by both the line meter and the master meter at the time of the line meter proving. In principle this method may have greater uncertainty than the direct proving method.

Master meter proving is used when proving by the direct method can not be accomplished because of meter characteristics, logistics, time, space, safety, and cost considerations.

For master meter proving of flow meters in allocation measurement applications, refer to API *MPMS* Chapter 20.1 for proving procedures.

This standard does not endorse nor advocate the preferential use of any type of meter described in API *MPMS* Chapter 5, nor does it intend to restrict the development or use of other types of master meter provers. However all technologies used as master meters shall have a standard in API *MPMS* Chapter 5.

5 Equipment

Master meters shall meet current industry standard requirements for custody transfer measurement. Master meters shall be properly sized to prove a line meter such that the operating range of the line meter falls within the proven operating range of the master meter. The master meter shall display very good reproducibility and repeatability throughout its operating range. Suggested acceptable performance of a master meter is that a flow variation of ±10 % results in no greater than 0.1 % change in meter factor and at any flow rate used in the calibration. Master meters shall be selected to minimize the effects of variances in flow rate and viscosity.

A selected portable meter or a meter at a test station meeting appropriate custody transfer recommendation can be assigned as a master meter. The meter selected should be known, from proven performance, to be reliable and consistent, and capable of calibration to specified accuracy tolerances. In the absence of an in-situ prover, a master meter shall not be used for another function other than proving meters and shall not be in service when no meters are being proved.

Master meters shall be properly maintained to minimize wear, corrosion, and build-up of material that may occur as a result of draining down lines and during periods of inactivity, especially if the meter is in portable service. If the master meter is in portable service, the inlet and outlet connections should be capped to protect against damage from corrosion and intrusion of foreign objects during storage. Care shall be taken to protect the meter during transportation, handling and installation.

6 Master Meter Factor (MMF) Proving the Meter

6.1 General

Prior to proving with a master meter, a MMF shall be determined by the Direct Proving Method in accordance with applicable API standards. The prover shall be manufactured and calibrated to applicable API standards.

The master meter shall not have been proved by another master meter. A volumetric master meter is proven utilizing a volumetric tank or displacement prover. A mass master meter is proven utilizing either a gravimetric tank prover or an inferred mass method. For additional information regarding gravimetric proving see Annex D.

For master meters used on multiple fluid types, such as different grades of petroleum products or crude oils of different viscosities, a series of unique MMFs or MMF curves shall be determined as required for each fluid to achieve the required uncertainty. Proving data point criteria will include the full range of flow rates over which the line meter will be operated. Dissimilar meter sizes or design ranges are not necessarily exclusionary when determining master meter size.

It is generally assumed when establishing a master meter factor, the uncertainty will be minimized. The tolerances shown in Section 6 are typical for pipeline applications. However, depending upon the application, alternative tolerances shown in Annex B may be used.

6.2 Single Operating Flow Rate

6.2.1 Direct Master Meter Proving

When a master meter is used to prove a line meter in the direct master meter proving mode (sometimes referred to as transfer master meter proving) on a single liquid type, and for a single target flow rate under stable conditions (i.e. viscosity, gravity, temperature and pressure), a single point proving of the master meter is sufficient. The flow rate at the line meter proving may vary up to ±5 % from the flow rate at which the master meter was proven. If the flow rate varies more than ±5 %, the master meter shall be reproved within ±5 % of the line meter flow rate.

6.2.2 Indirect Master Meter Proving

When a master meter is used to prove a line meter in the indirect master meter proving mode, a single point proving of the master meter is not sufficient. It must be assumed there will be some variation in the flow rates encountered. A minimum of 2 points should be determined within ±10 % of the expected operating flow rate of the line meter. If the two master meter factors do not agree within 0.1 %, prove the master meter at a narrower flow range until the two master meter factors agree within 0.1 %. The MMF can only be used within the range of the flow rates used to determine it.

The average of the two MMFs should be used within the range of the flow rates used to determine it. Linear interpolation of a MMF between these two points is the preferred method of determining the MMF to be used for line meter proving.

6.3 Multiple Operating Flow Rates

When a master meter is used to prove a line meter over a range of flow rates, a series of MMFs shall be determined spanning the range of flows anticipated. The procedure is as follows.

Prove the master meter at the maximum and minimum expected flow rates to be encountered by the line meter(s).

1) If the above two flow rates differ by less than 20 % of the expected maximum flow rate of the master meter (MM) and the difference of two MMFs is 0.1 % or less, use the average of the two MMFs for proving the line meter.

2) If the above two flow rates differ by more than 20 % of the expected maximum flow rate of the MM, prove the MM at additional flow rates between the maximum and minimum flow rates until the flow rate variation between any two adjacent points does not exceed 20 % of the maximum expected flow rate of the MM.

3) If the difference of any two adjacent MMFs is more than 0.1 %, prove the MM at flow rates between the adjacent rates until the difference between any two adjacent MMFs is 0.1 % or less.

4) The MMF to be used for the line meter proving should be the average of two MMFs adjacent to the line meter flow rate that are within 0.1 % of each other.

The procedure above uses averaging to determine a MMF between two flow rate points. It does not preclude using computing methods which employ linear interpolation to determine the MMF. Linear interpolation is the preferred method to determine a MMF between proving flow rates.

6.4 Master Meters used in Load Racks

Master meters proved with prover tanks shall establish the master meter factor with a minimum of three proving runs with a repeatability per Annex A. The proving rate shall be representative of the typical loading rate for the line meter to be proved and use the standing start-stop proving method. When a master meter is proved with the standing start-stop method, the same method shall be used to prove the line meter.

6.5 Establishing the Master Meter Factor (MMF)

To establish a MMF, a proving shall be performed with a repeatability that results in a demonstrated random uncertainty of 0.029 % or better at a 95 % confidence level. Any combination of consecutive runs (minimum of 3 runs to be statistically significant) and repeatability requirements that results in an uncertainty of 0.029 % or lower will meet the requirements of this standard. Increasing the number of proving runs, while maintaining the same repeatability requirements will decrease the uncertainty of the MMF.

API *MPMS* Chapter 13.1 outlines calculations to determine the uncertainty of a MF or MMF based on the number of proving runs and the range of repeatability results obtained.

Table 1 shows the random uncertainty at a 95 % confidence level as calculated for the average of 3 to 5 runs with a repeatability range limit of 0.02 % to 0.05 % that results in an uncertainly of 0.029 % or less (see API *MPMS* Chapter 12.2.3 for repeatability calculations). Annex A provides alternatives to the examples in Table 1 that will achieve the same or lesser uncertainty as 0.029 %.

Table 1—Random Uncertainty of Master Meter Factor [a]

Number of Runs	Repeatability of Runs (%)	Uncertainty of the Average of Runs at a 95 % Confidence Level
3	0.02	± 0.029
4	0.03	± 0.023
5	0.05	± 0.027

[a] For more runs see Annex A.

6.6 Considerations Regarding Uncertainty

Master meter proving normally has the highest total uncertainty of all meter proving methods. The technique used to prove the master meter and the process to prove the line meter introduce various levels of uncertainty into the petroleum measurement hierarchy. Some of the factors that can contribute to a higher uncertainty include the following.

a) Installation conditions where the master meter is not proven in-situ.

b) Differences between the viscosity and density of the liquid used to prove the master meter and the liquid used during proving.

c) Differences between the temperature, pressure, flow conditions and flow rates used to prove the master meter and those present during line meter proving.

d) The reproducibility of the MMF (the interval between proving, severity of service, meter damage, transportation and storage, use, corrosion, etc.).

e) Using the “standing start-stop” method of proving versus “running start-stop”.

f) Flow rate changes during proving of the master meter that result in poor repeatability and/or bias errors due to delay in response time of the master meter pulse output. Larger prover volumes may reduce the effect because it increases the proving time.

7 Master Meter Operational Guidelines

7.1 General

The master meter shall be used with flow in the same direction and orientation as when it was proved.

For meters with mechanical and electronic registers the discrimination level shall be sufficient to resolve the meter factor to within 1 part in 10,000.

Adequate back pressure shall be maintained to prevent cavitation or flashing. Reference appropriate section of API *MPMS* Chapter 5 for technology used.

Before proving, the master meter and the line meter shall be operated at the desired flow rate (proving flow rate) long enough to achieve stable operating conditions.

The proving run volume of the line meter shall be equal to or greater than the run volume used to determine the MMF. If proving runs of this volume are not repeatable, larger proof volumes may be used to achieve repeatability.

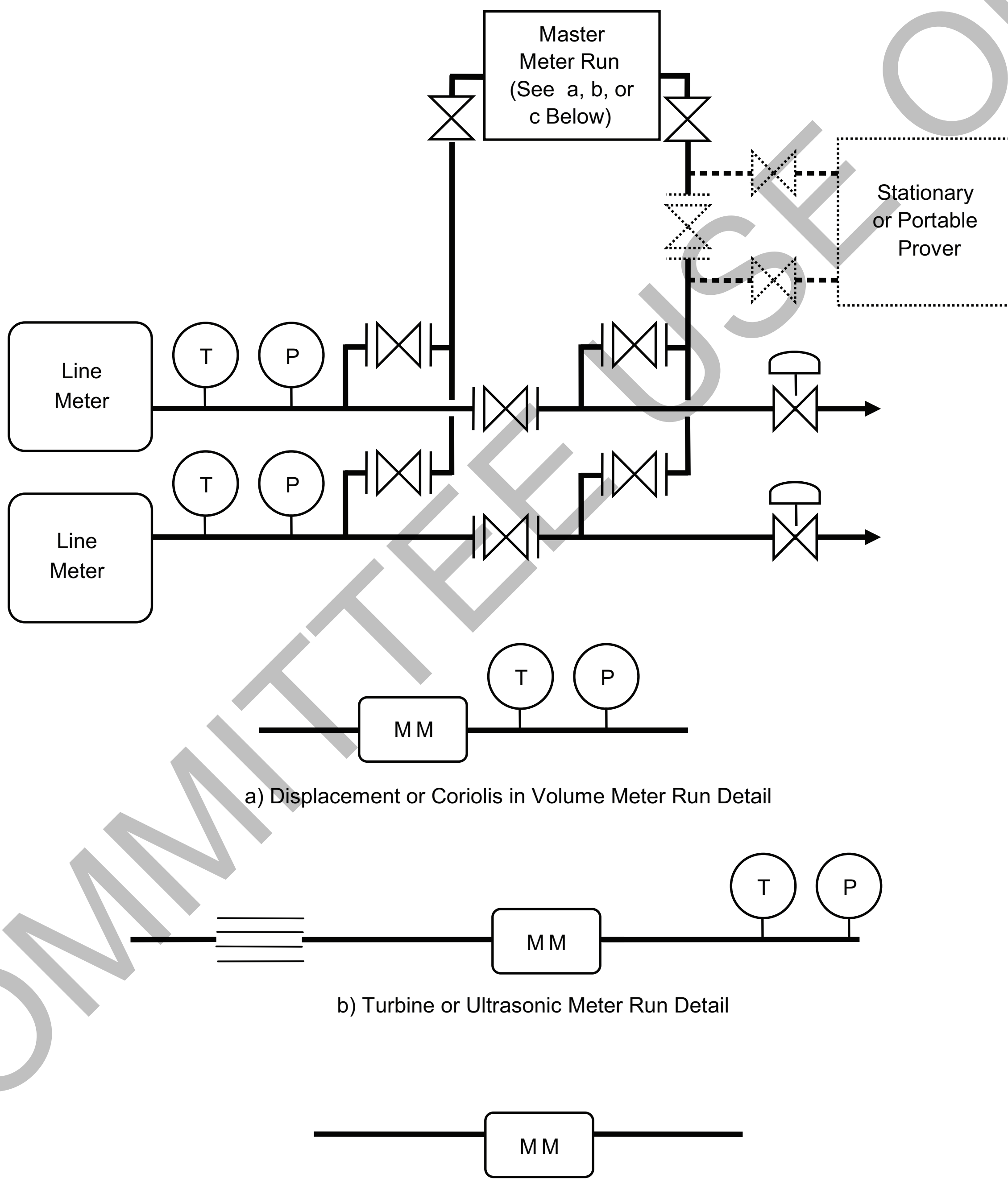
The master meter proving frequency shall be as defined in API *MPMS* Chapter 4.8.

Figure 1 shows three typical configurations using a master meter to prove a line meter:

— master meter (proven off site);

— stationary master meter with portable or stationary prover;

— portable master meter and prover.



a) Displacement or Coriolis in Volume Meter Run Detail

b) Turbine or Ultrasonic Meter Run Detail

c) Coriolis in Mass

Figure 1—Master Meter Configurations

7.2 Displacement Meters as a Master Meter

When using a displacement meter the following requirements shall be met:

— For meters that mechanically drive accessories such as counters, printers, and pulse transmitters that produce drag on the meter, adding or removing these accessories may affect the meter factor and require reproving of the master meter.

— Displacement meters shall comply with API *MPMS* Chapter 5.2.

7.3 Turbine Meter as a Master Meter

When using a turbine meter the following requirements shall be met:

— A master meter assembly is comprised of an upstream pipe, flow-conditioning element (if used), the meter, and downstream pipe. The assembly should remain intact from the proving of the master meter until the proving of the line meter. Disassembly of the master meter assembly can introduce additional uncertainty.

— If master meter assembly is disassembled, care shall be taken to reassemble it in the exact orientation and alignment as when proven.

— Turbine meters shall comply with API *MPMS* Chapter 5.3.

7.4 Coriolis Meter as a Master Meter

When using a Coriolis meter the following requirements shall be met:

— The Coriolis master meter can be proven in volume or mass units. Mass provings can be gravimetric or inferred mass. Separate meter factors are required for mass and volume measurements.

— A master meter can only be used to prove a line meter which measures in the same flow units (example: mass to mass or volume to volume).

— Coriolis meters have a zero value (a flow indication at zero flow). The observed zero value should be as close to zero as possible and should be included in the documentation for the master meter. The meter factor that is determined during proving includes any error the zero value may be contributing.

— Prior to proving the line meter, but at the operating conditions (pressure and temperature) of the line meter, the master meter observed zero value should be verified. The difference in this zero value and the documented zero value from the master meter proving is the zero offset. If the zero offset has changed beyond the user's specification, the master meter shall be re-zeroed. Error contributed by the zero value can be calculated from Equation 2 in API *MPMS* Chapter 5.6-2002 (R2008). See Annex E for examples.

— After re-zeroing, the new observed zero value shall be within the offset limit. If this zero value is within the offset limit, the master meter factor is valid. If an observed value within the offset limit cannot be obtained, then the master meter shall not be used for this proving until the cause of the zero offset condition can be determined and corrected.

— Coriolis meters shall comply with API *MPMS* Chapter 5.6.

7.5 Ultrasonic Meter as a Master Meter

When using an Ultrasonic meter the following requirements shall be met:

— A master meter assembly is comprised of an upstream pipe, flow-conditioning element (if used), the meter, and downstream pipe. The assembly should remain intact from the proving of the master meter until the proving of the line meter. Disassembly of the master meter assembly can introduce additional uncertainty.

— If master meter assembly is disassembled, it shall be reassembled in the exact orientation and alignment as when proven.

— Ultrasonic meters shall comply with API *MPMS* Chapter 5.8.

8 Master Meter Factor Documentation

Complete records of all data pertaining to the MMF determination shall be retained. Historical proving records may increase confidence and provide evidence of the reliability of the master meter. The operator shall have a documentation package available upon request containing the following:

— the master meter proving report/s showing the MMF to be used, the degree of random uncertainty obtained for this MMF (see Annex B) and the proof volume;

— the method the MM was proved (see 3.2 and 3.3);

— the method the MMF was determined (see Section 6);

— the MM proving run volume;

— the certification package of the prover used to determine the MMF [see API *MPMS* Ch. 4.9 (all sections)];

— if a density meter is used in the mass proving of a Coriolis meter in the mass mode, the certification package of the pycnometer used to prove the density meter is required;

— zero value of the Coriolis master meter at time of proving;

— flow direction when the master meter was proven (forward or reverse).

Annex A
(normative)

Random Uncertainty Master Meter Factor

Table A.1—Random Uncertainty Master Meter Factor

No. Proving Runs	Uncertainty of the Average of the Proving Runs at a 95 % Confidence Level Depending Upon the Proving Run Range of Repeatability Percent [a]							
	Repeatability (%)	Uncert. (%)	Repeatability (%)	Uncert. (%)	Repeatability (%)	Uncert. (%)	Repeatability (%)	Uncert. (%)
3	0.02	± 0.029	0.03	± 0.044	0.04	± 0.059	0.05	± 0.073
4	0.02	± 0.016	0.03	± 0.023	0.04	± 0.031	0.05	± 0.039
5	0.02	± 0.011	0.03	± 0.016	0.04	± 0.021	0.05	± 0.027
6	—	—	0.03	± 0.012	0.04	± 0.017	0.05	± 0.021
7	—	—	0.03	± 0.010	0.04	± 0.014	0.05	± 0.017
8	—	—	—	—	0.04	± 0.012	0.05	± 0.015
9	—	—	—	—	0.04	± 0.010	0.05	± 0.013
10	—	—	—	—	—	—	0.05	± 0.012

[a] API *MPMS* Chapter 13.1 outlines calculations to determine the uncertainty of a MF or MMF based on the number of proving runs and the range of repeatability results obtained.

Annex B
(informative)

MMF Combined Uncertainty

The combined MMF proving uncertainty is the combination of the Random Uncertainty (RU) as determined from the repeatability test and the uncertainty of the Master Meter Factor (MMF) range.

The equation for determining combined MMF uncertainty is:

$$\text{MMF Uncertainty} = \sqrt{RU_1^{\,2} + RU_2^{\,2}} + (\dot{0}.5 \times \text{ MMF Range})$$

where

RU_1 is the random uncertainty of test point 1;

RU_2 is the random uncertainty of the adjacent test point 2;

MMF the maximum deviation (spread) in meter factor between adjacent test points (RU_1 and RU_2) as defined in Section 6.2.2.

Random Uncertainty for different repeatability ranges and number of runs is defined in Annex A. The criteria for two-point MMF variation criteria are defined in 6.2 and 6.3, as both methods establish multiple MMFs around expected or known operating flow rate(s).

Examples of random uncertainty are demonstrated in Table B.1.

The standard is based on Random Uncertainty (repeatability) ±0.029 % and an MMF Range 0.10 %, but other accuracy criteria may be used based on the user requirements. See API *MPMS* Chapter 13.2, Appendix A, for estimating random uncertainty.

A – Meets the repeatability requirements as defined in 6.5.

B – Meets the repeatability requirements as defined in 6.5.

C – Does not meet the repeatability requirements as defined in 6.5.

Table B.1—Examples of Random Uncertainty

Example	Range of Repeatability	Number of Runs	Random Uncertainty
A	0.02 %	5	±0.011%
B	0.05 %	5	±0.027%
C	0.05 %	3	±0.073%

Table B.2 illustrates the uncertainty of the MMF with four examples using the results of two proves and calculating the combined uncertainty with the equation above. For example, the B+B combination shown in Table B.2 (both proves were five runs that repeated within 0.05 %) shows a calculated combined uncertainty of 0.063 % for the MMF because the MMF was obtained from the average of the two factors that were within 0.05 % (MMF Range) and 0.027 % was the uncertainty of both factors.

Combining MMF uncertainties should be used when master meter proving via the indirect method or multiple operating flow rate method due to the need for multiple MMFs to be established.

Table B.2—Examples of Combined Random Uncertainty of an MMF

Combinations	**Random Uncertainty (RU1)** Value of First Meter	**Random Uncertainty (RU2)** Value of Second	**MMF Range (spread)** Defined in 6.2 and 6.3	**Combined Uncertainty** $\text{MMF Uncertainty} = \sqrt{RU_1^2 + RU_2^2 + (0.5 \times \text{MMF Range})}$
A+B	0.011 %	0.027 %	0.05 %	0.054 %
A+C	0.011 %	0.073 %	0.10 %	0.124 %
C+B	0.073 %	0.027 %	0.15 %	0.153 %
B+B	0.027 %	0.027 %	0.05 %	0.063 %

Annex C
(informative)

Master Meter Factor Validation

C.1 General

Comparing the MMF(s) or MMF curves periodically against a user-defined tolerance will ensure that the master meter proving was representative and that the master meter performance did not change.

In establishing the tolerance for comparing MMFs in a validation process, it should be understood that the tolerance should not be set at less than twice the random uncertainty of the MMF uncertainty as shown previously in Table 1 and Annex A.

C.2 Single Flow Rate

Repeating the proving at the same flow rate and operating conditions will show if there is a shift in MMF that could have resulted from damage or wear.

C.3 Multiple Flow Rates

For master meters proven at multiple discrete flow rates, repeating a proving at one or more flow rates may show if there is shift in the MMFs that could have resulted from damage or wear. To further investigate a meter factor shift, the preferred method is to reprove in the original sequence of flow rates, e.g. 1, 2 and then repeat flow rates 1, 2, rather than prove at flow rates 1, 1 then 2, 2.

C.4 Master Meter Factor Curve

If a MMF curve is generated as a result of the master meter proving, repeating a proving at one or more flow rates may aid in the detection of any problems with the MMF curve. A repeated proving can be performed at any flow rate within the range of flow rates used to develop the original curve.

Annex D
(informative)

Gravimetric Proving

D.1 General

Gravimetric proving is a common technique applicable to liquid flow direct mass measuring devices.

D.2 Equipment

A gravimetric proving system utilizes a liquid source tank with a pipe configuration which includes a pump, a flow meter test section and a batching valve to deliver the liquid to a tank on a scale. Water is used as the proving liquid. The scale is calibrated with mass standards traceable to a national metrology institute.

Commonly, the piping configuration is arranged in a manner such that the proving process is described as a “standing start-stop” method or a “running start-stop” method (or “flying start-stop” method). The “standing start-stop” method uses a static type weighing method. The flow through the flow meter is started, the test flow rate is established and the flow is stopped. All the liquid which has flowed through the flow meter is weighed. The “running start-stop” method uses a dynamic type weighing method. The flow through the flow meter is started and the test flow rate is established in a recirculation line. A valve, downstream of the flow meter, diverts the flow into the tank on the scale. Once enough liquid is in the tank, the flow is diverted back into the recirculation line. The liquid which has flowed through the flow meter at the test flow rate is captured in the tank on the scale and is weighed.

D.3 Applicable References

Coriolis mass flow meters are proved on gravimetric systems. The proving of Coriolis mass flow meters using the gravimetric method is described in the API *MPMS* Ch. 5.6-2002 (R2008), *Measurement of Liquid Hydrocarbons by Coriolis Meters,* Appendix B.

Additionally, a standard reference by many Coriolis mass flow meter manufacturers is ISO 4185, *Measurement of Liquid Flow in Closed Conduits—Weighing Method.*

Annex E
(informative)

Coriolis Meter Zeroing Examples

This Annex provides examples of when a Coriolis master meter should be re-zeroed and/or re-proved. As a part of the master meter proving process, the observed zero value should be recorded. This zero value should be determined at the conditions under which the meter factor is determined. At line meter proving, a zero value of the master meter should again be observed. (The master meter shall be installed and brought to line conditions prior to evaluating the meter zero value. Failure to properly purge the flowmeter prior to evaluating the zero may lead to an incorrect evaluation. Once the MM is at line meter conditions, block the MM in and verify the observed zero value.) Equation (E.1) can be used to determine the amount of shift in the MM factor created by the difference in the above two zero values. The need for re-zeroing is based on the acceptable amount of shift in MM factor.

$$\%\ \text{Flow Error} = ((ZV_{LM} - ZV)/(FR)) \times 100 \qquad \text{(E.1)}$$

where

ZV is the recorded zero value at master meter factor determination;

ZV_{LM} is the observed zero value of master meter at line meter proving location;

FR is the flow rate of the line meter.

If it is determined that the master meter needs to be re-zeroed, the new observed zero value, after re-zero, should be compared to the recorded zero value from the original proving of the master meter. Equation (E.2) can be used to determine the amount of shift in the MM factor created by the difference in zero values. If the "new zero value" is within an acceptable limit, the proving of the line meter can proceed.

$$\%\ \text{Flow Error} = ((ZV_{NEW} - ZV)/(FR)) \times 100 \qquad \text{(E.2)}$$

where

ZV is the recorded zero value at master meter factor determination;

ZV_{NEW} is the new zero value of master meter at line meter proving location after re-zeroing;

FR is the flow rate of the line meter.

If a new zero value within acceptable tolerance cannot be achieved, the proving of the line meter should not proceed. An investigation into the cause of the zero shift should occur. Normally, a zero shift can be resolved by properly installing the meter, purging the line and bringing the master meter to line conditions. Reproving the master meter alone may not resolve a zero shift problem when the meter requires maintenance or repair.

Example 1: Master Meter re-zeroing required, but not reproving:

A master meter was initially proved at a flow rate of 5000 lb/min with a +2.5 lb/min zero value, and a meter factor of 0.9998 was generated.

The observed zero value of the master meter at a line meter proving has changed to +7.5 lb/min. The difference in the observed zero and the recorded zero value at MM proving is 5 lb/min. If the line meter is flowing at 5005 lb/min, then:

$$0.10\ \% = ((7.5 - 2.5)/5005) \times 10 \text{ as found}$$

The master meter should be re-zeroed because this zero shift could generate a 0.0010 shift in the MM factor at this operating flow rate. After re-zeroing the new observed zero value was +3 lb/min. This new zero value should be acceptable because the 0.5 lb/min difference between the recorded zero value and the new observed zero value after re-zeroing only generates a 0.0001 shift in MM factor. Then:

$$0.01\ \% = ((3 - 2.5)/5005) \times 100 \text{ as left}$$

Example 2: Master Meter no re-zeroing required:

A master meter was initially proved at a flow rate of 7000 lb/min with a +2.5 lb/min zero value, the meter factor of 0.9999 was generated.

The observed zero value of the master meter at a line meter proving was +3.5 lb/min. The difference in the observed zero and the recorded zero value at MM proving is 1 lb/min. If the flow rate for the line meter proving is 7005 lb/min, then at this flow rate the MM does not need to be re-zeroed because this zero shift only generates a 0.00014 shift in the MM factor.

$$0.014\ \% = ((3.5 - 2.5)/7005) \times 100 \text{ as found, as left}$$

Example 3: Master Meter repair and re-proving may be required:

A master meter was initially proved at a flow rate of 6000 lb/min with a +2.5 lb/min zero value, the meter factor of 0.9998 was generated.

If the observed zero value of the master meter at a line meter proving flow rate of 6006 lb/min was +25 lb/min. The difference in the observed zero and the recorded zero value at MM proving is 22.5 lb/min. The MM should be re-zeroed because this zero shift generates a 0.0037 MM factor shift at this flow rate. After re-zeroing a new observed zero value was 20 lb/min. This zero shift generates a 0.0029 shift in the MM factor at this flow rate and the MM should not be used. The MM should be inspected or possibly re-proved and possibly repaired to resolve the reason for the zero shift. Reproving the MM alone may not resolve a zero shift problem when the meter requires maintenance or repair.

$$0.37\ \% = ((25 - 2.5)/6006) \times 100 \text{ as found}$$

$$0.29\ \% = ((20 - 2.5)/6006) \times 10 \text{ as left;}$$

Master Meter NOT to be used

Example 4: Zero Error contribution to a MMF curve:

A master meter was initially proved at several flow rates to determine a MMF curve with a +2.5 lb/min zero value.

The observed zero value of the master meter at a line meter proving has changed to 7.5 lb/min. The difference in the observed zero and the recorded zero value at MM proving is 5 lb/min. If the MM is used but not re-zeroed, then Equation (E.1) can be used to estimate errors at any flow rate over the range of the MMF curve as shown below.

Flow Rate (lb/min)	5005	3754	2503	1251
Zero at Certification (ZV)	2.5	2.5	2.5	2.5
Obs Zero at Line (ZVLM)	7.5	7.5	7.5	7.5
% Shift	0.0999	0.1332	0.1998	0.3996

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