# Manual of Petroleum Measurement Standards Chapter 4.8

## Operation of Proving Systems

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## Introduction

This guide is intended to provide essential information on the operation of the various meter proving systems used in the petroleum industry.

In the petroleum industry, the term proving is used to refer to the testing of liquid petroleum meters. A meter is proved by comparing a known prover volume (mass) to an indicated meter volume (mass). For volume proving, the meter and prover volumes are subjected to a series of calculations using correction factors to convert volumes to standard conditions for the effects of temperature and pressure to establish a meter factor. For mass proving, the prover volume is converted to prover mass by the measurement or calculation of density at the prover in order to compare the meter mass to the prover mass, or by the use of a Coriolis master meter, to establish a meter factor.

Liquid petroleum meters used for custody transfer measurement require periodic proving to verify accuracy and repeatability and to establish valid meter factors.

Displacement, master meter, and tank provers vary in size and may be permanently installed or mobile. These prover types are described in their respective section API *Manual of Petroleum Measurement Standards* Chapter 4, *Proving Systems*.

# Operation of Proving Systems

## 1 Scope

This guide provides information for operating meter provers on single-phase liquid hydrocarbons. It is intended for use as a reference manual for operating proving systems.

The requirements of this chapter are based on customary practices for single-phase liquids. This standard is primarily written for hydrocarbons, but much of the information in this chapter may be applicable to other liquids. Specific requirements for other liquids should be agreeable to the parties involved.

## 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 4.2, *Displacement Provers*

API *MPMS* Chapter 4.4, *Tank Provers*

API *MPMS* Chapter 4.5, *Master-Meter Provers*

API *MPMS* Chapter 4.6, *Pulse Interpolation*

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 5.4, *Accessory Equipment for Liquid Meters*

API *MPMS* Chapter 5.5, *Fidelity and Security of Flow Measurement Pulsed-Data Transmission Systems*

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 7.2, *Dynamic Temperature Determination*

API *MPMS* Chapter 12. 2, (all parts) *Calculation of Petroleum Quantities Using Dynamic Measurement Methods and Volumetric Correction Factors*

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

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

## 3 Terms and Definitions

No definitions are unique to this document.

## 4 Basic Principles

The object of proving meters with a prover is to provide a number with a defined discrimination level, which can be used to convert the meter indication to an accurate quantity of fluid passed through the meter. Refer to API *MPMS* Ch. 12.2 for volume discrimination levels and calculations or API *MPMS* Ch. 5.6 for mass discrimination levels and calculations.

## 5 The Need to Prove

A meter in service should be periodically proved to confirm its accuracy. The previously determined meter factor may no longer be applicable because of changes in fluid characteristics, operating conditions, and meter wear. Specific reasons for proving meters include the following:

a) minimize financial impact of potential undetected accuracy changes;

b) contractual requirements exist, such as scheduled meter maintenance based on throughput and/or elapsed time;

c) the mechanical or electrical components of the meter have been opened, changed, repaired, removed, exchanged, or reprogrammed;

d) changes in operating conditions have occurred, such as fluid type, density, viscosity, temperature, pressure, or flow rate.

## 6 Frequency of Meter Proving

The frequency required for proving varies from several times a day to twice a year or even longer depending upon the reasons listed in Section 5. Other reasons are:

a) value of the liquid,

b) cost/benefit to prove,

c) meter proving history,

d) meter system stability,

e) variations of operating systems.

The actual proving frequency is dependent upon the contract or procedures established by the operator of the metering system. This standard does not define proving frequency of meters.

In general, the proving frequency for a new system starts with short intervals and may be extended to longer intervals as confidence increases in the system. The operator should specify the interval of time or a quantity of throughput, after which the meter should be proved again.

In a situation where custody transfer accuracy is not required, and where viscosity and temperature do not vary too widely, it may be sufficient for meters to be re-proved at specified intervals, such as every month or two when the metering system is new, extending to once in 6 or perhaps 12 months when the reliability of the meter system has been established.

# 7 General Considerations for Meters and Provers

## 7.1 General

The meter should be operated within its performance curve, and the prover should be operated within its flow rate limitations. The meter should be proved as close as practical to the same conditions under which it normally operates. Meter performance is dependent upon process conditions. Therefore, during proving it is essential that flow rate be maintained within the normal operating flow range of the meter.

## 7.2 Data Recording

Manually recording data during the prove limits the ability to track changes in operating conditions over the proving and may increase the uncertainty of the meter factor. For manual data recording, it is necessary to prove under the following conditions to minimize meter factor uncertainty:

a) stable fluid composition,

b) stable fluid temperature and pressure,

c) stable fluid flow rate.

The use of automated data recording and computational software (proving computer) reduces the uncertainty of the meter factor by averaging the changes in operating conditions and taking a greater number of data points over the proving. The amount of variation that can be tolerated before affecting the repeatability requirement and/or uncertainty varies by liquid hydrocarbon type and actual operating conditions.

## 7.3 Temperature and Pressure Measurements

### 7.3.1 General

Accurate temperature and pressure measurements are necessary for all types of proving, except direct mass proving. Proving systems with automated (computerized) recording of the required meter and prover data reduces proving uncertainty as compared to manual measurements. These two operating conditions should be stabilized (in equilibrium) for best proving results. Stability of these conditions during the proving reduces meter factor uncertainty.

### 7.3.2 Location

Prover temperature and pressure measurement shall be taken at locations as described in API *MPMS* Ch. 4.2, API *MPMS* Ch. 4.4, and API *MPMS* Ch. 4.5 as applicable.

Meter temperature and pressure measurement shall be taken at locations as described in API *MPMS* Ch. 5.1 as applicable.

### 7.3.3 Accuracy

Temperature and pressure values shall be within the ranges of the appropriate volume correction equations/tables (API, GPA).

Thermometers or temperature transducers used for proving shall be the highest practical resolution as recommended in API *MPMS* Ch. 7.

Pressure gauges or pressure transducers shall be selected with a resolution that enables the recording of pressure values as required in API *MPMS* Ch. 12.2.

#### 7.3.4 Discrimination

The proving temperature and pressure values shall be recorded as required in API *MPMS* Ch. 12.2.

### 7.4 Operating Pressure

It is essential that both the prover and meter pressures be higher than the equilibrium vapor pressure of the liquid during proving. In lieu of an actual test, or test data to determine back pressure requirements, the minimum back pressure should be 2 times the pressure drop through the flow meter plus 1.25 times the equilibrium vapor pressure (reference API *MPMS* Ch. 5 meters—various sections for minimum back pressure requirements).

### 7.5 Density

There are various ways to determine density. For proving calculations, it is important to distinguish between flowing, observed, and base density, how each is determined, and when and where each might be applied to a proving. Density measurements may be made online or off-line via a representative sample. Density may be calculated from composition or published equations. API *MPMS* Ch. 4.9, API *MPMS* Ch. 11.1, and API *MPMS* Ch. 14.6 should be referenced for more information on density determination and calculation. Density values shall be recorded as recommended in API *MPMS* Ch. 12.2 and API *MPMS* Ch. 5.6.

### 7.6 Proving Meters with Pulse Output

#### 7.6.1 General

Pulse-generating meters are the most commonly used devices. The output is pulses per unit quantity (pulses/cubic meter, pulses/gallon, pulses/barrel, pulses/pound, etc.). The electronic pulses from the meter should be continuous and produce a nonintermittent (nonburst type) signal.

#### 7.6.2 Noncomputational Technologies

Some meter technologies use the energy of the fluid stream to produce electronic pulses that are proportional to the rate of flow. Typical noncomputational meters are displacement meters and turbine meters.

#### 7.6.3 Computational Technologies

Electronic flow meter technologies use sampling methodologies to determine flow rate. The meter pulse output is a result of computations from the electronic sampling. At any instant in time the meter pulse output will represent flow (or quantity throughput) that has already occurred (i.e. the flow pulses lag the measured flow). Computational technologies include Coriolis and ultrasonic meters, and any meter using computing electronics to generate a pulse.

These meters can be proved using the techniques described by this chapter, but because of the computer calculations involved in producing pulses from such meters, it may be difficult to obtain repeatability.

### 7.7 Proving Meters Utilizing Totalizers

Meters can be equipped with electronic or mechanical totalizers that read directly in quantity units (cubic meters, gallons, barrels, pounds, etc.). When utilizing mechanical and electronic totalizers for proving, the indication shall have a discrimination level (1 part in 10,000) as outlined in API *MPMS* Ch. 12.2. For example:

a) the meter totalizer is incrementing in whole gallons (1 gallon) then the proof run shall be a minimum of 10,000 increments (10,000 gallons)

b) the meter totalizer is incrementing in tenths of a gallon (0.1 gallon) then the proof run shall be a minimum of 10,000 increments (1000 gallon)

# 8 Proving Locations

## 8.1 General

The proving location and method will depend not only on regulatory and contractual requirements but also on the meter installation and fluid properties.

Proving conditions shall be as close to the actual metering conditions as practical. Meter performance may be affected by the following conditions:

a) flow rates;

b) piping configurations/flow conditions;

c) fluid pressure and temperature;

d) ambient temperature;

e) fluid type, density, viscosity, and composition/contaminants;

f) mechanical stress on the meter.

There are three types of proving locations—in situ, laboratory, and ex situ. These three proving locations can produce different results and have different measurement uncertainties.

## 8.2 In Situ Proving

In situ proving is preferred because it is conducted on the meter's actual operating fluid under the meter's operating conditions.

## 8.3 Laboratory Proving

Laboratory proving may provide an alternative to field proving. Laboratory proving is not preferred because laboratory conditions generally do not duplicate the actual operating conditions, the impact of fluid properties, and piping effects, which leads to greater measurement uncertainties.

## 8.4 Ex Situ Proving

Ex situ proving may provide an alternative to field proving. Ex situ proving is performed in the field with the meter proved at a different location from the operating installation. Typically the ex situ proving is performed on the same or similar fluid as the operating fluid. It is not preferred because conditions generally do not duplicate the actual operating conditions, the impact of fluid properties, and piping effects, which leads to greater measurement uncertainties than in situ proving.

# 9 Types of Provers

## 9.1 General

Prover types are divided into three types: displacement, tank, and master meters. Displacement provers include both the bidirectional and unidirectional type. Tank provers include both the open and closed type. Master meters provers include the use of all meter types covered in API *MPMS* Ch. 4.5.

## 9.2 Displacement Provers

### 9.2.1 General

Both types of displacement provers may have one of two types of displacers, a sphere (ball) or piston. See API *MPMS* Ch. 4.2.

### 9.2.2 Principle of Operation

A displacer is installed inside a specially prepared length of pipe. When the prover is connected in series with a meter, the displacer moves through the pipe and forms a sliding seal against the inner wall of the pipe, traveling at the same speed as the liquid flowing through the pipe.

At two points attached along the pipe there are devices known as detectors. These detectors emit an electric signal when the displacer reaches and activates them. The signal from the first detector is used by a proving computer to start accumulating pulses from the meter. When the displacer reaches the second detector, its signal stops the proving counter. The number of pulses shown on the proving counter is the total pulses generated by the meter while the displacer was traveling between the two detectors.

A minimum number of pulses are needed for proving. The number is dependent upon several items including detector activation accuracy and meter pulse stability. The actual number will vary by prover and meter type. To estimate the minimum number of pulses required per pass and the prover volume required to achieve that number of pulses, API *MPMS* Ch. 4.2 should be consulted. The estimated number of pulses shall be collected as a minimum even if it is greater than 10,000 pulses per pass.

Pulses are accumulated by one of two methods, whole pulse counting and pulse interpolation. API *MPMS* Ch. 4.6 should be referenced for more information on pulse interpolation and the electronic requirements. If 10,000 pulses or more are accumulated per pass, either collection method may be used. For proving passes that generate less than 10,000 pulses per pass, pulse interpolation shall be used.

### 9.2.3 Equipment Description

#### 9.2.3.1 General

For detailed equipment descriptions and design requirements for displacement provers reference API *MPMS* Ch. 4.2.

#### 9.2.3.2 Bidirectional Prover

A bidirectional prover displacer operates and measures in two directions in the pipe (forward and reverse). A sphere or a piston as a displacer can be used. The calibrated base prover volume (BPV) of the prover is the sum of both the forward and reverse one-way volumes between the detector switches.

Spheres are used because they will travel around pipe bends. The prover can be built with numerous bends in the measuring sections of the pipe. See API *MPMS* Ch. 4.2. Piston-type bidirectional provers require a straight length of pipe for the pre-run and measurement section.

A four-way valve is normally used to change the direction of travel of the displacer through the prover. The sphere will start to travel on its return pass when the four-way valve reverses the flow, but it will not reach its full speed until the movement of the four-way valve is complete and the valve is closed. Caution should be taken to ensure the four-way is closed before the displacer reaches the first switch. Provers should not be operated at flow rates beyond the maximum rated flow rate.

### 9.2.3.3 Unidirectional Prover

Unidirectional prover displacers measure in only one direction. See API *MPMS* Ch. 4.2. Flow is not reversed or disrupted as with bidirectional provers. They can use either a sphere or a piston as a displacer. The calibrated BPV of the prover is the one-way volume between the detector switches.

Spheres are used because they will go around pipe bends, and the prover can be built with numerous bends in the measurement section of the pipe. Piston-type unidirectional provers require straight lengths of pipe for the pre-run and measurement section.

A unidirectional sphere prover uses a sphere displacer with a sphere interchange. The interchange is for receiving, holding, and launching the sphere. After falling through the interchange, the sphere enters the flowing stream of liquid and is swept around the loop of pipe. At the end of its pass, the sphere enters the sphere transfer valve, where it is held until the next proving pass.

Unidirectional piston provers have historically been referred to as “small volume provers.” The volume of these provers is normally much smaller than sphere types. Externally mounted precision optical detectors on these provers enable them to have smaller volumes. These type provers provide a mechanical means to retract the piston to its original starting position with minimal disruption to the flow.

### 9.2.3.4 Pre-run Requirements

A pre-run length of pipe is essential for all displacement provers. This length of pipe is the distance between the entry or release of the displacer into the fluid path and the first detector. The length of pre-run varies by prover type. It shall be of sufficient length to give the valve (four-way or poppet) time to close and seal before the displacer activates a detector. Provers should never be used at more than its rated flow rate because this pre-run length may not be adequate. Reference API *MPMS* Ch. 4.2 for more information on pre-runs.

### 9.2.3.5 Detectors

The detectors (switches) for any type of displacement prover are highly sensitive devices. There are three types of switches presently used in displacement provers (mechanical, proximity, and optical). The most common type of detector for sphere provers is a mechanical ball-end steel plunger. Precision optical detectors are common on unidirectional captive piston provers.

Replacing a detector may change the prover volume. Procedures for replacing detectors should conform to manufacturers’ recommendations. When the replacement or repair of detectors occurs, care should be taken to ensure that the neither the linear position, actuation depth, nor electrical components are altered or changed in a way that would affect (change) the prover’s calibrated volume. The linear distance between detector activations should remain the same in order not to change the prover volume.

Detector repair or replacement on bidirectional provers may be less critical than on unidirectional provers. The individual forward and reverse volumes might change but the sum of those volumes could remain the same because of the round trip travel of the displacer.

API *MPMS* Ch. 4.2 provides guidance on how to estimate prover volume changes for changes in detector mounting. When disassembly of the measuring section or removal, adjustment, repair, or replacement of a detector changes the volume of a prover by more than 0.01 %, recalibration is required. If there is doubt about or an indication that the prover volume has changed, recalibrate the prover. Records should be kept for the replacement, repair, or adjustment of detectors.

Some detector designs may make the replacement of detectors less critical (no volume change). There is no definitive guidance with regard to detector replacement that is applicable to all types, designs, and installation situations.

#### 9.2.3.6 Prover Displacers

##### 9.2.3.6.1 Spheres

The most common type of sphere is an inflatable elastomer. The type of elastomer chosen should be selected carefully to obtain the best performance for the operating conditions and fluid's chemical characteristics.

These spheres are fitted with an inflation valve, or valves, and are intended to be inflated with water or glycol, or a mixture of water and glycol, to a diameter larger than the internal diameter of the pipe. Inflation maintains an effective seal with the pipe wall without creating excessive sliding friction. Industry practice has shown that inflation greater than the pipe internal diameter in the range of 2 % to 5 % forms a tight leak-proof seal to the pipe wall. Determination of the sphere diameter is difficult because the sphere deforms under its own weight. Small bore (internal diameter) provers may employ a sphere made of solid elastomer. (See API *MPMS* Ch. 4.9.1 for sphere sizing.)

Overinflation can cause increased pressure drop, sticking of the sphere, and excessive wear of the sphere. Underinflation can result in leaking around the sphere seal and inaccuracies on proving.

Records should be maintained on sphere sizing, maintenance, and the number of prover runs in order to estimate frequency of verification and inspection needed. Spheres should be inspected for wear and damage and resized if it has changed. Wear of the sphere is a function of lubrication properties of the fluid, sphere material, and the number of prover runs.

Spheres should not be stored in an inflated condition on a flat surface. They should either be suspended in a net or supported by a hollowed-out bed of sand to prevent the development of a flat spot.

##### 9.2.3.6.2 Pistons

Piston displacers and seals vary according to the prover manufacturer. They use a variety of lip seals, cup seals, O-rings, and wear rings of different elastomers to ensure compatibility with the chemical properties of the fluid and operating conditions. They prevent leakage around the piston and should protect the measurement area pipe wall from wear by the metal parts of the piston.

Piston seals should be verified periodically for wear and damage. Wear of the seals is a function of lubrication properties of the fluid, seal material, and the number of prover runs. Periodic rotation of the piston may extend seal life by relocating the portion of the seal bearing the weight of the piston. Records should be maintained on piston maintenance, inspection, and the number of prove runs in order to estimate frequency of inspection.

## 9.3 Tank Prover

### 9.3.1 General

A tank prover is used to compare a known volume in a tank to the indicated volume that passes through a meter. Refer to API *MPMS* Ch. 4.4.

### 9.3.2 Principle of Operation

A tank prover is a calibrated vessel used to measure the volume of liquid passed through a meter. The known volume of the tank prover is compared to the meter indicated volume to determine the meter factor or meter accuracy factor. Tank provers are not recommended for viscous fluids. It is suggested that either a displacement master meter or Coriolis master meter or a displacement prover be used with viscous products.

### 9.3.3 Equipment Description

A tank prover is an open or closed volumetric measure that generally has a graduated top neck and may have a graduated bottom neck. See API *MPMS* Ch. 4.4. The volume is established between a shutoff valve or bottom-neck graduation and an upper-neck graduation.

The two basic types of tank provers are the open type (atmospheric pressure) and the closed type (pressure containing). Both of these come in a variety of configurations to meet the needs of the service required.

## 9.4 Master Meter Prover

### 9.4.1 General

Master meter proving is used when proving by a direct method (tank or displacement prover) cannot be accomplished because of meter characteristics, logistics, time, space, safety, or cost considerations. A master meter proving is a way of transferring the master meter calibration to the line meter by simultaneously measuring the flow through the master meter and the line meter to establish a meter factor.

### 9.4.2 Principle of Operation

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 factor by proving the master meter on 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. Refer to API *MPMS* Ch. 4.5 for the selection and proving of the master meter. This method may have more uncertainty than the direct proving method.

Direct master meter proving is 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 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.

Indirect master meter proving is the method in which the proving of a line meter is performed by means of a master meter in series only. The line meter is proved by comparison to the master meter whose meter factor 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.

A selected portable meter or a meter at a test station, meeting appropriate custody transfer recommendations, 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 buildup 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.

### 9.4.3 Equipment Description

The master meter output/registration shall not be compensated for liquid properties—temperature, pressure, or viscosity.

The master meter shall not have a mechanical adjustor or calibrator between the primary element and the output/registration. When proving a meter with a master meter, the same meter output and instrumentation accessories shall be connected to the master meter as were used when the master meter was proved to establish its meter factor.

For turbine and ultrasonic master meters, the master meter run includes the upstream flow-conditioning section, the meter, and the downstream flow section. The run should remain intact from the proving of the master meter until the proving of the line meter. Disassembly of the master meter run will introduce additional uncertainty.

A Coriolis master meter can be proven in volume or mass units. A Coriolis master meter can only be used to prove a line meter which measures in the same flow units (e.g. mass to mass or volume to volume).

Refer to API *MPMS* Ch. 4.5, Figure 1 (November 2011), which 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.

# 10 Prover Calibration Frequency

## 10.1 Displacement and Tank Provers

The original BPV may be determined at the manufacturers' or field site by an API *MPMS* Ch. 4.9 method. Provers that have been shipped complete may not require a field certification after field acceptance testing.

The BPV determined at the manufacturers' site certification is void and a field certification is required if any of the following are found:

— shipping damage or dents,

— alignment issues,

— change of the distance between the switches,

— loose or damaged or reinstalled detector switches.

A prover volume may change over time as the result of wear or other reasons. Prover displacers, switches, and the inside surface of a prover should be inspected periodically. A prover certification is required whenever a change in BPV could have occurred.

Reasons for prover volume change include:

— worn or faulty detector switches;

— switch repairs or replacement;

— the reduction or loss of internal coating;

— loss of internal pipe material due to oxidization, abrasion (change in wall thickness);

— accumulation of foreign material (such as wax) buildup;

— inspection indicates scored or wear internally;

— alterations or repairs that affect the BPV.

A new certification of a displacement or tank prover shall occur before its next intended use when any one of the following conditions exists:

a) the calibration frequency (time period) calculated in Annex B is met or exceeded;

b) the maximum time interval indicated below has elapsed:

   1) 60 months (5 years) for stationary provers,

   2) 36 months (3 years) for portable provers.

Additional considerations that may determine prover calibration frequency are, but not limited to:

a) the fiscal value of the metered liquids;

b) contractual or regulatory requirements;

c) usage, time, wear;

d) certification history.

### 10.2 Master Meter Provers

A master meter prover is certified (proven) and a meter factor(s) is established per API *MPMS* Ch. 4.5 and API *MPMS* Ch. 12.2.

The master meter factors from a proving may change over time and for numerous reasons. Reasons for change can be the result of:

— worn or faulty meter parts;

— damaged meter parts;

— changes in fluid characteristics (including temperature, pressure, viscosity, and density);

— loss of internal material, abrasion;

— accumulation of foreign material (such as wax) buildup in the meter;

— reprogramming of electronic based meters;

— seasonal temperature changes.

A new certification of a master meter prover shall occur before its next intended use when any one of the following conditions exists:

a) if the calibration frequency (time period) calculated in Annex B is met or exceeded,

b) the maximum time interval of 12 months (1 year) has elapsed.

The master meter prover should be inspected periodically for general conditions. Numerous considerations determine how frequently a master meter prover should be recertified. They include but not limited to:

a) the value (fiscal) of the metered liquids;

b) contractual or regulatory requirements;

c) usage, time, wear;

d) certification history;

e) alterations, repairs, or changes in operating conditions that affect the master meter factor.

NOTE Section 10.2 is applicable to master meters used for custody transfer applications. This section is not intended to define frequency for certification of master meters used for allocation applications.

# 11 Proving Methods

## 11.1 Volumetric Proving

With volumetric proving, the volume of fluid in the prover (reference quantity) is compared to the meter indicated volume to generate a meter factor. Common provers are:

a) displacement prover,

b) volumetric master meter prover,

c) volumetric tank prover,

d) gravimetric tank prover (inferred volume).

## 11.2 Direct Mass Proving

In direct mass proving, the mass of liquid in the prover (reference quantity) is physically measured by weight. The mass measured by the prover is then compared to the mass measured by the meter to generate a mass meter factor (prover mass/meter mass). The common methods used are as follows.

a) *Gravimetric*—The reference quantity of liquid is weighed on a scale and compared to a meter's indication of mass.

   1) A mass meter is proved against a gravimetric tank and scale system. The scale shall be traceable to a national metrology institute with a lower uncertainty than the meter.

   2) The test liquid flows through the mass meter and is collected in a tank on a weigh scale.

   3) The mass readout from the mass meter is compared to the weigh scale mass indication, corrected for buoyancy effect.

b) *Mass Master Meter*—The reference quantity of liquid is obtained from a mass master meter and compared to a meter indication of mass. Refer to API *MPMS* Ch. 4.5 or API *MPMS* Ch. 5.6.

   1) A mass meter proved against a mass master meter. The mass master meter has been proved against a direct or inferred mass proving system traceable to a national metrology institute with a lower uncertainty than the meter. The test liquid flows through the mass meter and the mass master meter.

2) The mass readout from the mass meter is compared to the mass master meter indication to compute a mass meter factor.

### 11.3 Inferred Mass Proving

In an inferred mass proving, the mass of the fluid in the prover (reference quantity) is calculated rather than physically measured as in 11.2. The mass of the fluid in the prover is calculated by multiplying the prover volume and the fluid density at prover conditions. The BPV is corrected using $CTS_P$ and $CPS_P$ to flowing conditions. ($CTL_P$ and $CPL_P$ are not used.) The prover mass is compared to the meter indicated mass to generate a mass meter factor. The accuracy of this method is equally dependent upon the accuracy of both the prover volume and the prover density measurement.

The volume for inferred mass proving should be determined by one of the provers in 11.1.

The selection of a method to determine the fluid density in the prover is critical to calculating the correct meter factor. Several methods to determine density can be used. Refer to 7.5 for methods of measuring flowing density. These methods should be closely reviewed as to their accuracy and ability to measure the density under the conditions (pressure and temperature) present at the prover. For inferred mass proving, the preferred method for determining the fluid density at the prover is to use an online density meter on the prover. The density meter should be installed, operated, and calibrated per API *MPMS* Ch. 14.6. The resulting output of the density meter should be averaged during each prover run or pass.

When the density varies during a proving, it shall be averaged for each prover run or pass (averaged between the prover switches). The sampling frequency and the density averaging method also influence the overall accuracy of this method.

## 12 Assessment of Proving Results

### 12.1 The Number of Runs

The estimated random uncertainty of a proving (meter factors or meter pulses) is the primary criteria for an acceptable proving. A minimum of three consecutive proving runs is required. Any number of consecutive runs from 3 to 30 can be used.

The preferred proving run uncertainty for custody transfer applications is ±0.027 % or less. Annex A or API *MPMS* Ch. 13.1 can be referenced for the uncertainty calculation at a 95 % level of statistical confidence. API *MPMS* Ch. 13.1 also states that in certain limited circumstances, a different degree of (statistical) confidence may be required.

The method of determining the actual number of proving runs and the uncertainty for a proving shall be the decision of the operating company. The values selected can be based upon many factors, some of which are installed equipment, prover design, customer requirements, corporate measurement policy, pipeline tariffs, contracts, etc.

An alternative method to determine acceptable proving runs using repeatability in place of uncertainty as the criteria is described in Annex A.

### 12.2 Meter Factor

Meter factor reproducibility is defined as the ability of a meter and prover system to generate results over a period of time where the range of variation of (change in) pressure, temperature, flow rate, and physical properties of the liquid is negligibly small. The expected reproducibility is generally determined by financial risk and experience with each individual meter and proving system or upon a meter's linearity as determined by its manufacture.

Determining acceptable meter factor reproducibility is an operating company decision. Common practice for custody transfer applications is to accept new meter factors within 0.10 % to 0.50 % of the previous meter factor.

Industry practice is to allow a greater combined reproducibility tolerance for inferred mass measurement systems that include both volume meter (turbine) and density meter factors. The tolerance is the sum of the volume and density meters' acceptable meter reproducibility. This greater tolerance should be extended to an inferred mass proving that incorporates density determination to calculate the prover mass.

For inferred mass proving where density is to be determined at the prover, the random uncertainty and reproducibility of the mass meter factor is affected by the meter performance, the choice of prover density determination, its sampling frequency, and the density meter calibration. Assessment of the mass meter factor should include evaluating the density uncertainty.

Where operating conditions are consistent, the statistical practices of API *MPMS* Ch. 13.1 can be used to evaluate meter factor reproducibility. A common practice is to compare the new meter factor against a 2 sigma limit of previously determined meter factors.

Statistical records of the meter factor should be maintained in accordance with API *MPMS* Ch. 13.2. Meter factor data should be plotted in a "control chart" and reviewed to evaluate trending. An excessive trend in one direction may be an indication of a problem.

Any of these methods for evaluating reproducibility are based upon the assumption that the liquid and operating conditions are the same as the previous (negligibly small changes). For more specific evaluation, separate control charts should be used where meter factors are tracked based on physical properties, flow rates, individual fluids, etc.

### 12.3 Application of Meter factors

Methods to apply meter factors are dependent upon the contract or procedures established by the operators of the metering systems. This standard does not define the application of meter factors. See C.8.6.3 for guidance.

## 13 Proving Concerns

### 13.1 Flow Conditioning

An unstable fluid velocity profile upstream of the meter will have little or no effect on the performance of displacement and Coriolis meters. However, it can seriously affect velocity meter performance [turbine and ultrasonic flow meters (UFMs)].

Velocity profile during proving should be the same as during normal operation. Care should be taken to not change the velocity profile. Common sources of velocity profile distortion are:

a) partially opened valve or a pipe fitting,

b) partially blocked flow conditioning element,

c) loose flow conditioning element,

d) strainer basket buildup,

e) improperly installed gaskets,

f) provers installed upstream of the meter.

## 13.2 Temperature and Pressure Variations

Temperature and pressure differences between the prover and meter should also be minimized. When a prover has been off line, more time flowing through the prover is required to minimize temperature differences before starting a prove.

If temperature and pressure measurements are read manually, minimizing variations during proving is critical. Variations during a prove result in meter factors with more bias/uncertainty. To ensure less uncertainty, temperature and pressure should be measured and averaged automatically for each proving pass/run.

Temperature and/or pressure changes from one proving to the next can have a mechanical impact on meter and proving equipment that may result in meter factor changes.

Proving calculations account for the changes on the liquid and prover body due to temperature and pressure. Proving calculations do not account for the temperature and pressure effects on the meter.

## 13.3 Viscosity Variation

The viscosity of a liquid depends upon both its composition and its temperature. Whether the viscosity change is due to a composition change or a temperature change or both of these, all meters are affected to some degree by changes in the viscosity of the liquid being metered, although some are affected more significantly than others. The effect of viscosity change is different for different metering technologies and generalizations can lead to unexpected results. Therefore, it may be necessary for the meter to be re-proved when the viscosity of the liquid being metered changes. Whether it is necessary or not will depend upon:

a) the type of meter and how much viscosity affects it accuracy,

b) the accuracy required,

c) the amount by which the viscosity has changed.

## 13.4 Valve(s) Leakage

During proving, it is essential that only liquid flowing through the meter flows through the prover. Every valve between the meter and the prover shall seal leak tight when closed. Any leakage through the valves will cause an error in proving. It is preferred to use double block-and-bleed type valves. Other valves or valving configurations can be used, but these configurations shall have a method to ensure seal integrity. All valves to the prover from other meter runs including drain, vents, and relief valves between any meter and the prover should be isolated (verified leak free) during proving.

Seal integrity should be checked periodically. Seal integrity can be verified in many ways. The space between the seals on a double block-and-bleed valve or valving configuration can be verified by:

a) bleed valve,

b) pressure gauge,

c) pressure switch (differential pressure switch).

## 13.5 Displacer Slippage

It is important that the displacer makes a perfect seal with the pipe bore in displacement provers. If it does not, then the meter being proved will measure not only the correct calibrated volume but all the volume of liquid that slips past the displacer during the proving pass. This results in a decrease in the meter factor.

Potential causes of displacer slippage are:

a) undersize or irregularities of the sphere/displacer or prover wall;

b) bad sphere seal (longitudinal seam raised areas or gouges in the prover pipe wall, lateral gap(s) in flanges, detector insertion causing sphere damage);

c) bad piston seal;

d) bad poppet seal.

## 13.6 Meter Wear

The meter and all of its associated equipment (such as gear trains, registers, compensators, transmitters, and counters) that are not maintained in good working order, both mechanically and electrically, will cause issues with proving repeatability and meter factor reproducibility. All meter types should also be inspected whenever their performance is in question, if mechanical or electrical problems exist, or as required by contract or regulations.

As a meter wears, its factor will change. A meter is proved at regular intervals to account for wear.

If a meter is removed for inspection or dismantled for repair it shall be proved before being placed back in service. Accidental damage during repair/inspection is likely to alter the meter factor.

## 13.7 Effect of Electrical Disturbance

Meter proving requires the collection of meters pulses. Poor signal to noise ratios on pulse transmission lines can cause erratic registration. Electrical noise can produce spurious pulses and cause nonrepeatability.

Refer to API *MPMS* Ch. 5.5 for detailed recommended practices.

## 13.8 Flow Rate Variation

Meter performance is dependent upon flow rate; thus, flow rate during proving shall be maintained at or near the normal operating flow rate(s). Flow stability is important from two distinct perspectives; intraproof stability and the maintenance of gross flow rate at comparable levels run to run or pass to pass.

## 13.9 Meter Registration (Head) Check

A mechanical or software fault may cause a matching error between the meter totalizer and proving counter (pulse based) indication. A comparison of a meter's totalizer (indicated quantity) to a proving-counter indication is referred to as a head check. The meter totalizer shall be verified on new installations and any time the meter totalizer is repaired, inspected, or changed. See API *MPMS* Ch. 5.5 and API *MPMS* Ch. 12.2 for discrimination levels for totalizers.

## 13.10 Meter and Prover Design

Meters and provers have range limitations. The range limitations may include maximums and minimums for parameters such as flow rate, pressure, temperature, viscosity, density, and fluid type. Using the equipment outside of its intended ranges often will manifest as erratic repeatability or reproducibility.

Some meters may be designed to correct for changes in the liquid temperature. Failure to recognize meters with temperature-corrected output will result in an erroneous meter factor.

## 13.11 Meter and Prover Combinations

An improper pairing of a prover to a meter may result in proving issues. Proper pairing requires consideration of repeatability and its effects on prover volume requirements. Meter response time also affects prover pre-run requirements. Failure to properly pair a prover to a meter may result in reproducible and repeatable meter factors which are inaccurate. See API *MPMS* Ch. 4.2, API *MPMS* Ch. 4.4, API *MPMS* Ch. 4.5, and API *MPMS* Ch. 4.6.

## 13.12 Air/Vapor in the Proving System

Any air/vapor pockets between the meter and the prover will cause proving repeatability and reproducibility issues. When air is observed (physically found) during the proving, it shall be eliminated from the system and the meter should then be proved.

## 13.13 Cavitation

Cavitation is not an introduction of air/vapor. As fluid passes through restrictions in piping, such as flow conditioners, meters, valves, and provers, the velocity of the fluid for that brief moment is increased. The increase in velocity also causes a decrease in pressure that is inversely related. The higher velocity causes the pressure to be lower. If it falls below the bubble point of the fluid, then it will flash, as bubbles. When the fluid passes the restriction, the velocity will decrease and the pressure will increase. The increase in pressure then causes the gas bubbles to collapse. This collapse is often accompanied by a noise similar to sand hitting metal.

If cavitation occurs at a meter, then the introduction of a gas phase in the middle of its measurement will affect its results. The same can be said of a prover. Cavitation may cause errors which appear as both repeatability and reproducibility issues.

See API *MPMS* Ch. 5 Metering sections for the appropriate pressure requirements.

## 13.14 Debris and Coating

Meters and provers are susceptible to the deposits of foreign material. Coating of the meter internals may cause a shift in the meter factor. If the meter performance shifts out of tolerance, the meter should be inspected, cleaned, and then re-proved.

Coating of the prover internals may change the prover volume, which will result in an incorrect meter factor.

## 13.15 Physical Damage

Externally visible dents in the calibrated section of the prover will likely affect the calibrated volume. External prover surfaces should be periodically inspected for damage. Prior damage shall be noted on the prover calibration report.

## 13.16 Computational Master Meter Provers Zero

Computational meters can indicate flow at no flow conditions. They have to be given a reference point for no flow (zero value). Zeroing a computational meter is a procedure that involves verifying the meter's flow indication while the meter is blocked in (not flowing) and adjusting it to indicate a flow value as close to zero as possible. Under a no flow condition, if the meter's flow indication is not close to zero, then the manufacturer's (re)zeroing procedure shall be followed. Errors contributed by an incorrect zero value can be calculated from Equation (2) in API *MPMS* Ch. 5.6 (October 2002).

Computational meters selected as a master meter prover should have stable zero value capabilities. Normally, most do not require frequent rezeroing. However, numerous items can cause a zero shift and those items vary by technology.

Items that may affect the zero and require a UFM to be zeroed are:

— replacement of transducers,

— electronics replacement,

— transducer cables replacement,

— reprogramming.

Items that may affect the zero and require a Coriolis meter to be zeroed are:

— pipe stress,

— large temperature changes,

— transmitter replacement.

The meter factor determined during a master meter proving includes any error the zero value may be contributing. That observed zero value should be as close to zero as possible to minimize any error it might contribute. The master meter zero value should be included in the proving documentation for the master meter.

Prior to proving a line meter, but at the operating conditions (full of fluid and at pressure and temperature) of the line meter, the master meter zero value should be observed and 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 rezeroed. See API *MPMS* Ch. 4.5, Annex E (November 2011) for examples.

After rezeroing, the new zero value should be observed and 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. The cause of the zero offset condition shall be determined and corrected if the proving is to proceed. After correction, if a zero value within the limit can be obtained; the master meter can be used in this application.

# Annex A
(normative)

# Evaluating Meter Proving Data

## A.1 Introduction

API *MPMS* Ch. 13.1 states that the 95 % level of statistical confidence is recommended for evaluating uncertainties associated with commercial applications of petroleum measurement. It is also stated that in certain limited circumstances, a different degree of (statistical) confidence may be required. The random uncertainty of the average value of a set of meter proving runs can be estimated in accordance with API *MPMS* Ch. 13.1 at the 95 % confidence level as follows:

$$a(\mathrm{MF}) = \frac{[t(95, n-i)][w_{(\mathrm{n})}]}{[\sqrt{n}][D_{(\mathrm{n})}]}$$

where

$a(\mathrm{MF})$ is the random uncertainty of the average of a set of meter proving runs;

$t(95, n-i)$ is the student "$t$" distribution factor for 95 % confidence level and $n$ – 1 degrees of freedom (see Table 2 of API *MPMS* Ch. 13.1);

$w_{(\mathrm{n})}$ is the range of values (high minus low) in the meter proving set;

$D_{(\mathrm{n})}$ is the conversion factor for estimating standard deviation for $n$ data points

[See Table 1 of API *MPMS* Ch. 13.1 (June 1985).]

For the common practice of five proving runs ($n$ = 5) that agree within a range of 0.0005, the random uncertainty of the average of this set can be estimated as follows:

$$a(\mathrm{MF}) = \frac{(2.776)(0.0005)}{(\sqrt{5})(2.326)} = \pm 0.00027$$

## A.2 Estimating Random Uncertainty Through the Use of the Standard Deviation

An alternate means of calculating random uncertainty may be desirable where large groups of data are considered (greater than the range of runs given in Table A.1). In such cases, an estimate of random uncertainty in the data may be calculated as the standard uncertainty of the average (standard deviation) of the data set for any family of data. The calculation for standard deviation may be found in API *MPMS* Ch. 13.

## A.3 Alternate Method

Common practice has been to achieve five consecutive proving runs that agree within a repeatability of 0.05 % or less. The random uncertainty of a five run proving at 0.05 % is estimated as ±0.027 %.

As an alternative to evaluating proving based upon uncertainty, repeatability can be used. Proving runs of 3 to 20 can be used to achieve the equivalent uncertainty (±0.027 %) by varying the repeatability requirement for the total number of runs. The repeatability limits listed below maintain the same random uncertainty as five runs that repeat at 0.05 %. These variable repeatability limits are as shown in Table A.1.

**Table A.1—Repeatability Criteria for 0.027 % Uncertainty (Preferred Uncertainty) For ±0.00027 Random Uncertainty in Average Meter Factor**

| Number of Proving Runs | Moving (Variable) Repeatability Limit |
|---|---|
| 3 | 0.0002 |
| 4 | 0.0003 |
| 5 | 0.0005 |
| 6 | 0.0006 |
| 7 | 0.0008 |
| 8 | 0.0009 |
| 9 | 0.0010 |
| 10 | 0.0012 |
| 11 | 0.0013 |
| 12 | 0.0014 |
| 13 | 0.0015 |
| 14 | 0.0016 |
| 15 | 0.0017 |
| 16 | 0.0018 |
| 17 | 0.0019 |
| 18 | 0.0020 |
| 19 | 0.0021 |
| 20 | 0.0022 |

## A.4 Limited Volume Proving Applications

In some applications there is limited volume (quantity) available to prove the meter. Typical applications would be LACT units loading trucks or units that have small tanks supplying the LACT. Achieving five consecutive runs within 0.05 % repeatability may not be achievable or practical in these applications. In these situations three consecutive runs with a repeatability of 0.05 % might be practiced as an alternative, but the uncertainty will increase. The random uncertainty of three proving runs with a repeatability of 0.05 % (0.0005) is ±0.073 % (0.00073).

For additional meter proving runs of 4 to 15, a variable repeatability limit can be calculated that maintains the same random uncertainty of three runs with a repeatability of 0.05 %. These variable repeatability limits are as shown in Table A.2.

## A.5 Multiple Passes per Run

Single passes per run is the preferred method of data collection. For proves with erratic data that will not meet the uncertainty or repeatability criteria for single pass runs, the scatter in data may be normalized by summing the results of several meter proving passes (called a multipass run). Multiple passes per run ignores any limits of repeatability of the subset and the resulting impact on overall uncertainty and is not the preferred data collection method.

Passes shall be consecutive in a multipass proving method. Summing passes for a run is the recommended practice. The repeatability of multipass runs may be compared to see if they meet the repeatability deviation limits of Table A.1 or Table A.2.

**Table A.2—Repeatability Criteria for 0.073 % Uncertainty (Limited Volume Proving)**
**For ±0.00073 Random Uncertainty in Average Meter Factor**

| Number of Proving Runs | Moving (Variable) Repeatability Limit |
|---|---|
| 3 | 0.0005 |
| 4 | 0.0009 |
| 5 | 0.0014 |
| 6 | 0.0017 |
| 7 | 0.0021 |
| 8 | 0.0025 |
| 9 | 0.0028 |
| 10 | 0.0032 |
| 11 | 0.0034 |
| 12 | 0.0037 |
| 13 | 0.0040 |
| 14 | 0.0043 |
| 15 | 0.0046 |

Averaging passes may be used as an alternate method to summing. It has been an industry practice to average a number of passes utilizing the resultant average as representing a proving run for comparison to similar runs to determine repeatability.

Common examples of pass, run, and repeatability combinations are:

— 3 passes per run, 5 runs at 0.05 % repeatability (15 passes);

— 3 passes per run, 3 runs at 0.02 % repeatability (9 passes);

— 5 passes per run, 5 runs at 0.05 % repeatability (25 passes);

— 10 passes per run, 3 runs at 0.02 % repeatability (30 passes).

# Annex B
(normative)

# Method for Determining the Frequency of Calibrating Provers

## B.1 Introduction

This method recognizes that each prover is an individual unit, which has its own amount of use over time, its own severity of conditions during use, and its own specific wear patterns. Therefore, it is reasonable to expect that each prover should have a unique frequency of calibration. However, the important question is how well is the prover holding to its present calibration.

The maximum calibration frequencies are set in Section 10. This method sets the benchmark in successive prover calibration change to be 0.06 % or less. If 0.06 % tolerance is exceed then more frequent calibration are necessary. To calculate the months to next calibration (MNC), three variables are utilized. They are:

— percent change ($P_f$) in prover volume between two calibrations;

— number of months ($Mn$) between calibrations;

— benchmark (0.06 % or less).

$$MNC = \left[\frac{(Mn \times 0.06)}{(P_f)}\right]$$

Calculation Notes:

— discrimination levels:

  — $MNC$ whole month,

  — $Mn$ whole months,

  — $P_f$ is X.XX;

— $MNC$ should be round up, to the next whole month if the result is a partial month (50.1 = 51);

— $MNC$ shall not be less than one (1) month;

— a month is defined as a calendar month and not 30 days;

— $P_f$ should be truncated not rounded (0.067 % = 0.06 %).

## B.2 Additional Requirements

The following guidelines should be adhered to with regard to the use of the above calculation for displacement and tank provers:

Under no circumstances should the projected time to the next calibration exceed:

— 60 months (5 years) for stationary provers or

— 36 months (3 years) for new or portable provers.

If mechanical repairs, alterations, or changes that affect the calibrated volume are made to the prover before the next projected calibration date, then:

— calibrate the prover immediately after completion of this work; and

— determine the difference from the previous volume;

  — for volume changes of 0.03 % or less, schedule next calibration at the same frequency as the last calibration;

  — for volume changes greater than 0.03 %, refer to the calculation above.

The following guidelines should be adhered to with regard to the use of the above calculation for master meter provers.

— Under no circumstances should the projected time to the next calibration exceed 12 months.

— For new meters or if mechanical repairs, alterations, or changes are made to the meter that affect the calibration, then calibrate the master meter immediately after completion of this work. Schedule another calibration for three (3) months from this date.

## B.3 Example Calculation [1]

To use this method determine the number of months between the most recent calibration and the previous prover calibration, together with the amount of volume change, as a percentage, between the two calibrations. Using this data and the allowable change of 0.06 %, calculate the projected number of months until the next calibration will be required.

**Table B.1—Prover Calibration Frequency Example**

| **Date of Calibration** | **Months Between Calibrations** | **Prover Volume** bbl | **Volume Change Percentage** | **Calculation** | **Months to Next Calibration (MNC)** |
|---|---|---|---|---|---|
| 7/02/2004 | 13 | 11.9958 | 0.026 % | $\frac{(13)(0.06)}{(0.026)}$ | 30 |
| 6/01/2003 | 0 | 11.9927 | New | | |
| **Date of Calibration** | **Months Between Calibrations** | **Master Meter Factors** | **Volume Change Percentage** | **Calculation** | **MNC** |
| 3/02/2004 | 9 | 1.0006 | 0.05 % | $\frac{(9)(0.06)}{(0.05)}$ | 11 |
| 6/01/2003 | 0 | 1.0001 | New | | |

1 These examples are merely examples for illustration purposes only. (Each company should develop its own approach.) They are not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied for reliance on or any omissions from the information contained in this document.

## Table B.2—Example Table—Dynamic or Tank Prover Calibration Frequency For 0.06 % Volume Change Benchmark

| Months Between Calibrations (Mn) | Months to Next Calibration (MNC) Based Upon Actual % Volume Change ($P_f$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **0.02 %** | **0.03 %** | **0.04 %** | **0.05 %** | **0.06 %** | **0.07 %** | **0.08 %** | **0.09 %** |
| 60 | — | — | — | — | 60 | 52 | 45 | 40 |
| 48 | — | — | 60 | 58 | 48 | 42 | 36 | 32 |
| 36 | | 60 | 54 | 43 | 36 | 30 | 27 | 24 |
| 24 | 60 | 48 | 36 | 29 | 24 | 21 | 18 | 16 |
| 12 | 36 | 24 | 18 | 14 | 12 | 11 | 9 | 8 |

## Table B.3—Determining the Frequency of Prover Calibration

**Date: 4/7/2010**

**Prover Information:**

| | |
|---|---|
| **Owner:** | USA Oil Company |
| **Brand:** | Shock Provers |
| **Model:** | Prv-09123 |
| **Serial:** | 92084512 |
| **ID:** | Swamp A50 |

**Calculation of Next Calibration:**

$$\mathrm{MNC} = \left[\frac{(\mathrm{Mn} \times \mathrm{Change}\ \%)}{(\mathrm{P_f})}\right]$$

where

| | |
|---|---|
| MNC | is months until next calibration; |
| Mn | is months since last calibration; |
| Change % (Benchmark) | is allowable change in prover volume; |
| $P_f$ | is percent change in prover volume since last calibration. |

EXAMPLE 1:

| | |
|---|---|
| **Allowable Change %:** | 0.06 |

| Date of Previous Calibration | Date of Current Calibration | Months Between Calibrations |
|---|---|---|
| 3/11/2009 | 4/6/2010 | 13 |

| Previous Volume bbl | Current Volume bbl | Volume Change % |
|---|---|---|
| 29.9907 | 30.0003 | 0.032 |

MNC = 25

**25 Months Until Next Calibration**

# Annex C
(informative)

# Meter Prover Operation

## C.1 Meter Prover Operation

The proving process consists of system inspection, system preparation, operation of meter and prover, and assessment of results.

## C.2 Inspection

### C.2.1 General

Prior to initial use or when the prover is out of service for maintenance, the metering system and the prover should be inspected to ensure proper operation.

### C.2.2 Displacement Prover

The internal surfaces should be inspected for coating failures, adhesions (any foreign material buildup on the internal surface), or corrosion that would change the calibrated volume of the prover. If the prover is internally coated, the lining should be checked for coating wear or failure that would cause the calibrated volume to change. The most likely location for such failures will be in the elbows.

The displacer should be removed from the prover and examined at the intervals prescribed by the manufacturer or by the operating company. The sphere or seals should be inspected and replaced if there is any sign of mechanical damage or change in the durometer (hardness) by chemical action. Spheres should also be inspected for roundness and proper inflation. This is done with either a sizing ring or a tape measure.

### C.2.3 Tank Prover

Inspect the prover tank for any dents that are not recorded on the calibration certificate, any foreign objects or clingage inside the tank, or failure of an internal coating that would have an effect on the calibrated volume of the prover tank. Verify that the gauge scales, drain valves, and thermowells are sealed. Also check for a current and valid calibration certificate.

### C.2.4 Master Meter

Prior to the meter-proving operation the master meter prover and line meter to be proved shall be inspected to ensure proper operation. This inspection shall include, but not be limited to, the following steps.

1) Verify that all temperature, pressure, and density measurement devices to be used during the proving operation are properly installed, recently calibrated or verified, and operating within acceptable tolerances as stated in API *MPMS* Ch. 7 and API *MPMS* Ch. 12.2.

2) All electronic instrumentation such as counters, switches, and interconnecting wiring shall be inspected for proper installation and operation. Care should be taken to ensure that all electrical pulse transmission cables are properly shielded and grounded.

3) Check for current and valid master meter factor documentation. See API *MPMS* Ch. 4.5.

4) Verify that the master meter has been proved within the applicable flow rates fluid properties. See API *MPMS* Ch. 4.5.

## C.3 Considerations

### C.3.1 General

The meter and all of its associated equipment (such as gear trains, registers, compensators, and counters) should be maintained in good working order, both mechanically and electrically. The meter should also be inspected whenever its performance is in question, if mechanical or electrical problems exist, or as required by contract or regulations.

The meter should be operated in the linear portion of its performance curve, and the prover should be operated within its flow rate limitations. The meter should be proved as close as practical to the same conditions under which it normally operates. Meter performance is dependent upon flow rate. Therefore, during proving it is essential that flow rate be maintained as steady as possible within the normal operating flow range of the meter.

The conditions under which a meter is proven are:

a) stable product composition,

b) stable product temperature and pressure,

c) stable flow rate,

d) system valves and seals have been checked to ensure there is no leakage,

e) trial runs have been conducted to evacuate any air/gas from the system.

### C.3.2 Computational Meters

Meter proving requires counting flow meter pulses that represent the actual volume that passed between the detector switches of the prover. Because some meters use an electronic sampling methodology to determine flow rate, the manufactured pulse train obtained at any instant in time will represent flow (or volume throughput) that has already occurred (i.e., the manufactured flow pulses lag the measured flow). In normal operation, delay between flow pulses and the actual measured flow has little impact on measurement accuracy if the correct meter factor has been used. However, during the proving process, delayed flow pulses may cause poor run to run repeatability and/or introduce a bias error in the calculated meter factor.

Poor repeatability and/or meter factor bias error can be the result of:

a) flow instability during the prover run,

b) flow disturbances that occur immediately before the displacer activates either of the detector switches.

Excessive time delay between the measured flow and the manufactured flow pulses can make the proving process more sensitive to flow rate changes that occur shortly before the displacer passes by the detector switches. While the time lag between manufactured pulses and actual measured volume is constant, the linear velocity of, and volume displaced by the prover displacer as it activates each of the detector switches, is “not” constant if the flow rate is not identical.

To minimize any meter factor bias error, and/or to obtain the best possible span of repeatability results, it is important to ensure that:

1) the flow rate remains constant just before the first detector and throughout each prove run,

2) the time delay between the manufactured pulses and the actual measured flow is minimized in accordance with the manufacturer’s recommendations,

3) the duration of the proving runs be increased either by using larger volume provers or larger master meter proving runs.

Because flow and pressure disturbances can occur with some prover types when the displacer is launched or the four-way valve is cycled, it may be necessary to derate the prover maximum flow rate specification to attain item 1) above. Derating the prover should increase the pre-run travel time to the first detector sufficiently to allow all manufactured pulses representing flow that occurred during the period of flow pulsation, caused by the displacer launch disturbance, to be output by the meter before the first detector switch is activated.

To minimize meter factor bias errors that can be introduced during proving, it is important that the flow pulse respond as quickly as possible to changes in flow rate. The configuration settings of the computational meter can be adjusted to improve the responsiveness to changes in flow rate. These configuration settings vary between manufacturers but typically fall into three categories:

a) sample interval—the time period between flow rate samples;

b) number of samples—the number of samples processed for each flow measurement update;

c) pulse output adjustment—amount of damping or filtering of the flow measurements that produce the pulse output signal.

NOTE Not all manufacturers provide Item a), Item b), and Item c).

It is recommended that Item a) and/or Item b) above be set to the minimum as recommended by the manufacturer. Item c) above should be set to zero or minimum as recommended by the manufacturer.

When changes are made that affect the computational meter speed of response to flow rate changes (i.e. by modifying the sample rate, sample time period, pulse output filtering, or damping), the meter shall be re-proved.

### C.3.3 Valve(s) Leakage

All valves to the prover from other meter runs are to be isolated without leakage during proving. Any leakage through the valves will cause an error in proving. These valves should be of a double block-and-bleed type or of a similar configuration to ensure seal integrity. Drains, vents, and relief valves are to seal during proving.

The space between the seals on a double block-and-bleed valve or valving configuration is connected to a small bleed valve, pressure gauge, or pressure switch to verify seal integrity. Seal integrity should be checked each time a valve is closed.

### C.3.4 Displacer Slippage

It is important that the displacer makes a perfect seal with the pipe bore in displacement provers. If it does not, then the meter being proved will measure not only the correct calibrated volume but all the volume of liquid that slips past the displacer during the proving pass. This results in a decrease in the meter factor.

If a meter factor is lower than expected, displacer leakage is one possible reason. The displacer may be removed from the prover and examined. If there is any sign of mechanical damage or change in the durometer (hardness) by chemical reaction, the sphere or piston seals may need to be replaced. In addition, the piston while still in the prover could be subjected to a leak test by momentarily opening a bleed valve so as to reduce the pressure between the seals and seeing if it rises again or by any other means recommended by the manufacturer. Spheres should also be inspected visually, and the diameter should be verified/confirmed.

### C.3.5 Displacer Durometer

The durometer (hardness) and composition of the sphere should be considered as part of prover design. Different hardness and materials can have an effect on both normal operations and calibration, so these should be considered in the design to accommodate both. Because of the lower lubricity of water and greatly reduced flow rates encountered during waterdraw calibrations, a softer durometer sphere usually has a better performance during calibrations. Harder durometer spheres have a difficult time creating a capillary seal inside a prover with anything less than excellent interior coating and round pipe. Conversely, caution should be taken to ensure that the durometer of the sphere is not too soft, otherwise it might have a hard time compressing the spring on the detector switch probe.

## C.4 Coriolis Considerations

### C.4.1 Inferred Mass Proving

Variations in flowing density and errors in the determination of density are the greatest source of errors when performing an inferred mass proving. The accuracy of the meter factor determination will be a direct reflection of the accuracy and precision of the density measurement. As an illustration: if the density measurement error is 2 kg/m$^3$, then the meter factor determination will be offset by 0.20 % (based on a density of 1000 kg/m$^3$). As stated in 11.3, the preferred method for inferred mass provings is to use an online density meter that has been installed, operated and calibrated per API *MPMS* Ch. 14.6. For the best accuracy, a density factor should be determined and applied to the density measurement prior to proving in the inferred mass method.

Stabilizing the density before making proving runs minimizes variations in density between the prover, meter and the density determination used in the calculation. Any difference in the measured density and the true flowing density during the proving will result in an error in the meter factor. Therefore, to minimize errors, it is extremely important that the density remains stable during the proving. See 11.3 regarding averaging and sampling frequency for the density measurement at the prover.

If there are density variations during the proving, it is likely that additional proving runs will be required to obtain an acceptable meter factor. Often, allowing density and flow to stabilize between proving runs will improve results. The proving data should be reviewed for outliers. Any outlying points should be scrutinized to determine if they were caused by density variations during proving. These points may not be valid and may result in an incorrect meter factor if used in the average.

Reproducibility of a Coriolis meter factor that has been calculated using a density factor determined by the calibration of an online density meter includes the change in the density factor. Meter factor charts or history of both the Coriolis meter factor and any density meter factor used in the proving of the Coriolis meter are needed to isolate the Coriolis meter factor reproducibility from the density meter factor reproducibility.

### C.4.2 Volumetric Proving (Coriolis Meter)

Determination of a separate Coriolis meter density factor is not needed if the Coriolis meter is configured to measure volume and is being proved against a volumetric prover. (The exception would be if the Coriolis meter's volume measurement and the Coriolis meter's density measurement were used as separate measurements to calculate inferred mass in a flow computer.) The Coriolis meter's volume meter factor includes the combined errors for the mass flow measurement and the density measurement, which are made internally within the meter's electronics to arrive at volume flow. The only purpose of determining a density factor (note exception above) would be to identify what portion of the meter factor can be attributed to each component: the mass flow and the density measurement.

## C.5 Verification

Verify that the prover has a valid calibration certificate and that the certificate is for the prover being used, by verifying the prover serial number with the serial number on the certificate.

The prover pressure, temperature, and material compatibility rating should be verified before use to ensure suitability. Hydrotest results may be necessary to evaluate compliance. This also should be done for any hoses or attached devices.

If a displacement prover is being used, check to ensure that the prover volume between detectors is sufficient to accumulate a minimum of 10,000 pulses. If not, pulse interpolation techniques are required. Since some provers have more than one calibrated volume, verify that the proper calibration certificate is being used.

If a tank prover is used, verify that the prover volume is equal to a minimum of one minute of the maximum operating flow rate. See API *MPMS* Ch. 4.4.

If a master meter is used, all data that is used to develop the master meter factor(s), including the prover calibration report, certificate, and master meter factor(s) reports are current and available.

As described in Section 6 of API *MPMS* Ch. 5.6 (October 2002), manufacturer calibration factors are entered into the Coriolis transmitter that is unique to each particular sensor. If the sensor, transmitter, or calibration factors have been changed since the last prove, a shift in meter factor may occur. To ensure that no unexplained meter factor shift can occur, it is advisable that the operator confirms that there has been no changes in the manufacturer calibration factors since the last prove. These values should be documented as part of each proving report.

## C.6 Preparations for Proving

### C.6.1 General

Examples of meter proving forms are shown in Annex D. Other forms or documents may be required before proving is started. Refer to API *MPMS* Ch. 12.2 for meter factor calculation requirements.

### C.6.2 Preparation for Proving Pressurized Provers

#### C.6.2.1 General

This section refers to displacement and master meter provers. This section does not pertain to tank provers, which are covered in C.6.4.

#### C.6.2.2 Filling Pressurized Provers

After checking that end closures and any fittings that could be opened are properly fastened and that all vent and drain valves are closed, proceed with filling the prover in the following sequence.

a) Fill the prover with liquid and eliminate vapor.

b) Ensure that all liquid flowing through the meter under test, and only that liquid, passes through the prover with no leakage or diversion.

c) Cycle the displacer or circulate fluid through the prover and continue to eliminate vapor from the high points until no vapor is observed.

d) Verify the seal integrity of all vents, drains, reliefs, and double block-and-bleed valves between the meter and the outlet of the prover.

### C.6.3 Preparation for Proving with Mobile Prover

The specification of the mobile prover should be reviewed to ensure that the prover is suitable for the flow rate, pressure, and the temperature of the metering facility. Pressure and temperature ratings are to satisfy all regulations and standards. Prover materials should be compatible with the metered liquids. Elastomers are especially susceptible to damage from incompatibility. The elastomers of the sphere/piston, flange O-rings and gaskets, valve seals/seats, hoses, swivel fittings, etc. should be compatible with the liquid.

Check that the product in the prover is compatible with the current product to prevent contamination. If incompatible, it may be necessary to drain and flush the prover.

### C.6.4 Preparation for Proving with Tank Prover

Check that all connections are properly made and isolation/diverter valves are properly aligned. Verify the integrity of all vents, drains, reliefs, and double block-and-bleed valves between the meter and the prover. Proceed with the preparations as follows.

a) The initial step prior to the first proof run is to wet down the prover tank. This is done instead of circulating fluid. Fill the tank with metered liquid. Check the level indicators on the tank. Then empty the tank.

b) If the tank is equipped with a lower-gauge glass, close the main drain valve just prior to the liquid level reaching the zero mark on the glass. Allow the time stated on the calibration report before closing the small drain valve when the liquid level reaches the zero mark. Whatever drain time is allowed after closing the main drain valve and drawing the liquid down to zero should be used on all subsequent proof runs.

c) If the tank is not equipped with a lower-gauge glass, leave the drain valve open until continuous flow ceases and dripping starts. The drip should be allowed to continue for a minimum of 30 seconds (or that which is stated on the calibration report) before closing the drain valve. Whatever drip time allowed between flow cessation and closing the drain valve should be used on all subsequent proof runs.

d) When reading gauge glasses, read the bottom of the meniscus for transparent liquids and the top of the meniscus for opaque liquids.

e) If the system has vapor recovery, the vapor recovery should have makeup gas or should be disconnected prior to emptying the prover so that air can enter the prover and prevent a vacuum that could damage the prover.

### C.6.5 Preparation for Proving with Master Meter Prover

The master meter should be installed as close as possible to the meter under test to minimize temperature and pressure differences between the meters. The master meter normally is installed downstream of the meter under test. The following steps should be taken.

a) If the master meter has an electrical output, care should be taken to ensure all electrical equipment is properly grounded to prevent errors from electrical noise.

b) If the master meter is permanently piped in a manifold with the meter under test, the isolation valves should be opened and the flow directed through both meters.

c) Before the meter proving is made, the two meters shall be operated at the desired flow rate for a period of time sufficient to purge the system of vapor and to achieve steady temperature, pressure, and flow rate.

## C.7 Operating Procedures

### C.7.1 General

This section outlines the steps that are taken in the field during the meter-proving operation.

### C.7.2 Displacement Prover

Maintain the flow through the proving system until stable conditions of pressure, temperature, and flow rate exist. Once stability is achieved, proving operations may proceed. Determine the flow rate on the first pass of the displacer and make spot checks thereafter.

If the prover is equipped with both inlet and outlet temperature and pressure devices, determine the average prover inlet and outlet temperature and pressure during each pass. The average prover temperature and pressure is recorded on a round trip basis in the case of a bidirectional prover.

If the prover is equipped with only one temperature and pressure device, the devices should be located at the prover outlet. Determine the prover temperature and pressure during each pass of the displacer and record the average during each pass of a bidirectional prover.

If using a bidirectional prover, record the reading of the prover counter at the end of each pass and the round trip of the displacer. For a unidirectional prover, record the reading of the prover counter at the end of each pass of the displacer.

Repeat the proving operation until the required minimum number of acceptable proving runs (per agreement between parties) is attained. If suitable range is not obtained, discontinue the proving operation and refer to Annex A.

### C.7.3 Tank Prover

There are two unique features of an open tank prover. The first is that vapor is allowed to escape (evaporate) from within the tank during the proving. If a vapor recovery system is used during normal metering operations, consideration should be given to not operating the vapor recovery system during the meter proving if allowed.

The second unique feature is that the meter is operated from as start-run-stop condition. Thus the meter experiences a static-to-dynamic and back-to-static cycle of operation. This method of operation depicts similar operating conditions of the prover/meter system; the greater the difference of the prover volume is in relation to the quantity loaded, the greater the potential errors.

It is important to use consistent tank prover operating techniques without interruption to obtain satisfactory repeatability between consecutive proof runs. Operating conditions at the meter during the proof runs should replicate the conditions during normal use.

a) Using a tank prover report or worksheet, record the appropriate meter, tank, and flow data as indicated in the meter factor calculation section of API *MPMS* Ch. 12.2.3.

b) Record the meter register or zero the proving counter if one is being used. Record the reading of the prover tank's bottom gauge glass, if so equipped. These become the opening readings for this proving run.

c) Start the flow through the meter into the tank.

d) While the tank is filling, record the average meter temperature and verify that the meter is operating at the desired proving rate.

e) Stop the meter flow when the liquid level is within the upper gauge scale range.

f) Record the prover tank temperature. If the tank has more than one thermometer, the recorded temperature is the average of all thermometer readings.

g) Record the meter register or the proving counter reading and the prover tank's upper gauge glass reading. These are the closing readings for this proving run.

h) Calculate the meter factor for this run as outlined in API *MPMS* Ch. 12.2. This completes one proving run. The next proving run is initiated by draining down and zeroing the tank as described in C.6.3 of this annex and then starting over with the steps described previously.

i) At least three consecutive proving runs in which the meter factors agree within the required uncertainty (as specified in 12.1). The average of these meter factors is the final meter factor. If an adjustment to the meter factor is made mechanically with a calibrator, additional runs typically are made to confirm that the meter factor is correct.

j) Upon conclusion of the proving operation, if a prover tank is a portable unit, isolate the prover from the flow stream; drain down; remove all connections made; and prepare the tank for removal from the site. If the tank is permanently located, isolate the prover from the flow stream; drain down; and place the tank in a protected idle mode.

### C.7.4 Master Meter Prover

Each proving run shall be of sufficient quantity to discriminate to 1 part in 10,000. In many cases, load rack meters are proved incorporating the start up, shutdown, and interim flow patterns of loading. If one flow rate is used for the proving, the proving should be done at the maximum loading rate.

Once the proving operation is started, it should be carried to conclusion in a continuous process, with only minimal delays. The following steps should be taken.

a) With flow through the meters, a proving run is initiated by simultaneously gating both meter counters on. Meter temperature and pressure are recorded for both meters during the proving run. Flow rate through the meters during the proving operation should be within the calibrated range of the master meter (see API *MPMS* Ch. 4.5). The flow rate is to remain relatively stable for all proving runs entered in the meter factor calculation.

b) Record the appropriate meter and flow data as indicated in the factor calculations section of API *MPMS* Ch. 12.2 using a worksheet or master meter proving report.

c) Checks should be made during the proving to ensure all equipment is functioning properly and all test parameters are remaining within their constraints. After sufficient quantity has passed through the meters or the batch is completed, the counters are simultaneously gated off. The indicated counter readings for the run are recorded. This completes one proving run.

d) Check the uncertainty of consecutive runs per 12.1.

e) Meter factor calculations shall be made as detailed in API *MPMS* Ch. 12.2.

f) After completion of the proving operation, the master meter should be isolated from the flow stream if the meter is permanently installed, or disconnected if the meter is portable.

g) Thermometers, pressure gauges, counters, and any other proving equipment that is not a permanent part of the manifolding should be removed and stored until the next proving.

## C.8 Assessment of Results

### C.8.1 General

It is important to note that an acceptable uncertainty or repeatability does not prove that the results are correct. Something could have gone wrong that throws all the results out by the same amount, in which case the successive tests could merely be repeating an incorrect result. Lower uncertainty or repeatability values indicate higher probabilities that the meter factor is correct, while higher values indicate that a investigation is need to determine the reason for the undesirable result.

### C.8.2 Meter Performance Curves

A meter performance curve is a graph of K-factor or meter factor versus flow rate, covering the working range of the meter. The shape of such a curve provides a useful check that the performance of the meter is being maintained. If the shape of the curve has changed, it may indicate a problem with the meter.

### C.8.3 Control Charts

Control charts are used to provide operators with valuable historical information about the meter or metering system. This is covered in detail in API *MPMS* Ch. 13.2.

### C.8.4 Proving Runs

The required number of test runs for each proving may vary depending on:

a) type of proving method being employed,

b) meter type and size,

c) operating flow rate and quantity of fluid accumulated during each proving run.

Experience with the meter/proving system will ultimately establish the number of runs required. Typical examples of the number of runs required are given in Table A.1 and Table A.2. API *MPMS* Ch. 4.2, Appendix C (September 2003) and API *MPMS* Ch. 13.1 provide more details regarding the number of runs required to achieve 0.027 % uncertainty.

The number of runs required to achieve the desired tolerance for meter factor uncertainty should be defined and agreed to by all contractual parties. Once established, the same procedure should be followed consistently in order to better track the performance of the meter. These requirements should not differ from other custody transfer meters for similar applications.

### C.8.5 Evaluation of Results

Historically repeatability has been used to estimate the uncertainty of the proving data and thus evaluate the results. Two methods of calculating the repeatability: one associated with the average data method and the other associated with the average meter factor method are described in API *MPMS* Ch. 12.2.

The average meter factor method is recommended because it incorporates changes in operating conditions between runs into the results. This method uses the meter factor from each run as the basis for the uncertainty or repeatability calculations.

The average data method uses only the meter pulses as the basis for the uncertainty or repeatability calculations. Achieving uncertainty or repeatability with this method normally requires more stable operating conditions.

If repeatability or uncertainty values are unacceptable or remain unacceptable after numerous attempts, it is necessary to stop proving and look for the cause of the problem. Operating conditions such as flow rate, temperature, pressure, or density that vary from run to run will cause the data to be erratic. Erratic operating conditions are the most common cause of nonrepeatability. For alternate data collection or evaluation methods for this type of situation, see Annex A.

## C.8.6 Meter Factor Reproducibility

### C.8.6.1 General

Reproducibility is defined as the ability of a meter and prover system to reproduce similar results over a period of time in a service where the range of variation of pressure, temperature, flow rate, and physical properties of the metered fluid are negligibly small. The amount of variation that might produce unacceptable results differs by meters type, fluid properties, and operating conditions. An expected reproducibility value for a meter is generally determined from experience with each individual proving and metering system.

A common practice is to limit the change in consecutive meter factors to within ±0.10 % to ±0.50 %. A single value for all metering and proving systems may lead to excessive investigations of nonreproducibility. Reproducibility is determined as follows:

$$\text{Range of Reproducibility} = (\text{New Meter Factor} - \text{Old Meter Factor})/(\text{Old Meter Factor}) \times 100$$

Historical meter factor data should be maintained and is easily assessed by keeping a control chart, which is a graph of meter factor plotted against each test date. Control charts are valuable in analyzing the reproducibility of meter factors and determining the desired proving frequency. Control charting meter factors with operational conditions can provide additional insight proving problems. A meter factor control chart figure is shown API *MPMS* Ch. 13.2.

### C.8.6.2 Additional Guidance for UFM Performance

Verifying the performance of a UFM is not unlike verifying mechanical systems. However, because UFMs employ sampling methodology, they produce a greater degree of data scatter because of their ability to measure minute variations in velocity. UFMs may produce wider repeatability ranges for existing provers designed in accordance with industry standards than are typical for a mechanical device. Failure to be mindful of the evenly distributed nature of the data points about the mean meter factor will lead to errors in evaluation. A range exceeding 0.05 % in five runs does not mean that a UFM is defective or that its meter factor cannot be established with the required uncertainty.

UFM performance verification can be ascertained by conventional means and to a level consistent with Table A.1 (shown below as Table C.1).

**Table C.1—Repeatability Criteria for 0.027 % Uncertainty**
**For ±0.00027 Random Uncertainty in Average Meter Factor**

| Number of Proving Runs | Moving (Variable) Repeatability Limit |
|---|---|
| 3 | 0.0002 |
| 4 | 0.0003 |
| 5 | 0.0005 |
| 6 | 0.0006 |
| 7 | 0.0008 |
| 8 | 0.0009 |
| 9 | 0.0010 |
| 10 | 0.0012 |

**Table C.1—Repeatability Criteria for 0.027 % Uncertainty**
**For ±0.00027 Random Uncertainty in Average Meter Factor**

| Number of Proving Runs | Moving (Variable) Repeatability Limit |
|---|---|
| 11 | 0.0013 |
| 12 | 0.0014 |
| 13 | 0.0015 |
| 14 | 0.0016 |
| 15 | 0.0017 |
| 16 | 0.0018 |
| 17 | 0.0019 |
| 18 | 0.0020 |
| 19 | 0.0021 |
| 20 | 0.0022 |

The most conservative approach to accomplishing this level of repeatability relies on determining an acceptable prover volume. For instance, turbine meters can usually be successfully proven in five consecutive runs to within 0.05 % span of repeatability, which demonstrates ±0.027 % or better meter factor uncertainty at a 95 % confidence level. Based on field data, UFMs may require a larger prover volume to achieve this same level of meter factor uncertainty. Table C.2 below, is derived from actual UFM data and illustrates typical prover volumes required as a function of pipe size to obtain ±0.027 % meter factor uncertainty at a 95 % confidence level.

Given the larger prover volume that may be needed to verify a UFM to ±0.027 % uncertainty, it follows that more than five proving runs may be required to verify the meter's performance. Table C.2 provides the guidance for obtaining these results. Any of the number of runs chosen from the tabulation below will produce results that verify meter performance to ±0.027 % uncertainty. There is no difference, in this regard, in a repeatability range of 0.05 % in 5 runs vs a range of 0.12 % in 10 runs—they are the same. The operator is advised to select the appropriate number of runs, and span of repeatability, suitable for the prover volume available.

**Table C.2—Suggested Minimum Prover Volume for ±0.027 % Uncertainty of Meter Factor when Proving Ultrasonic Flow Meters**

| Prover Volume vs Meter Size | | | |
|---|---|---|---|
| Meter Size in. | 5 Runs 0.05 % | 8 Runs 0.09 % | 10 Runs 0.12 % |
| | Prover Size bbl | | |
| 4 | 33 | 15 | 10 |
| 6 | 73 | 34 | 22 |
| 8 | 130 | 60 | 40 |
| 10 | 203 | 94 | 62 |
| 12 | 293 | 135 | 89 |
| 14 | 399 | 184 | 121 |
| 16 | 521 | 241 | 158 |

Alternatively, the operator may simply increase the number of proof runs incrementally until the repeatability range falls within the limits of Table C.1. Experience with UFMs of several manufacturers using ball provers shows that the required meter factor accuracy is typically achieved with fewer than 10 to 12 runs or with a prover volume 2 to 3 times larger than current industry standards. Larger numbers of runs may be necessary if small volume provers are employed. Small volume provers that create flow disturbances can create nonrepeatable proving results. Care shall be exercised when selecting and using small volume provers.

#### C.8.6.3 Application of Meter Factor Examples

When metering a single or similar liquid, the meter factor is normally applied forward to the meter's indicated volume until the meter is re-proved. The factor can be applied in the flow computer or after the fact to the transaction statement (ticket). As described above an operator normally prescribes a deviation limit between consecutive meter factors on the same or similar liquid. If the deviation limit is consistently exceeded, it may be appropriate to increase the frequency of meter proving. It may also be appropriate to inspect and repair the meter and the proving system. Refer to API *MPMS* Ch. 13.2 for statistical evaluation of meter proving data.

# Annex D
(informative)

# Proving Form Examples [2]

[2] The following examples are merely examples for illustration purposes only. (Each company should develop its own approach.) They are not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied for reliance on or any omissions from the information contained in this document. Users of forms should not rely exclusively on the information contained in this document. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein.

**PROVER INFORMATION**

CERTIFICATION DATE: ____________ (YY/MM/DD) PROVER COMPANY ____________

BASE PROVER VOLUME ____________ (BARRELS) PROVER UNIT SERIAL NO. ____________

**METER INFORMATION**

SERIAL NO. ____________ MANUFACTURER ____________

METER ID ____________ MODEL ____________

LOCATION ____________

MANUFACTURER FLOW CALIBRATION FACTOR(S) ____________

PULSE SCALING FACTOR ____________ (PULSES/LB) KF (In Associated Equipment) ____________ (PULSES/LB)

**PROCESS CONDITIONS**

FLOW RATE ____________ (LB/MIN) ____________ (BBL/HR) FLUID TYPE ____________

DENSITY SOURCE ____________ (DEVICE/LOCATION)

**PROVE INFORMATION**

PREVIOUS METER FACTOR ____________ (DATE OF PROVE YY/MM/DD) ____________ (FACTOR)

| RUN NUMBER | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| TOTAL METER PULSES | | | | | |
| PROVER DENSITY (kg/m$^3$) | | | | | |
| PROVER TEMPERATURE (°F) | | | | | |
| $CTS_p$ | | | | | |
| PROVER PRESSURE (psig) | | | | | |
| $CPS_p$ | | | | | |
| PROVER VOLUME (bbl)= (Base Prover Volume * $CTS_p$ * $CPS_p$) | | | | | |
| PROVER MASS (lb)= (Prover Volume * Prover Density * 0.3505071) | | | | | |
| CORIOLIS METER MASS (lb)= (Pulses/Mass K-Factor) | | | | | |
| METER FACTOR= (Prover Mass/Coriolis Meter Mass) | | | | | |

AVERAGE METER FACTOR $\boxed{\phantom{xxxxxx}}$ LOCATION OF ENTRY (of Meter Factor) ____________ TRANSMITTER/CALC. DEVICE

PERCENT REPEATABILITY ____________ [(MAX – MIN)/MIN]* 100 ZERO VERIFIED? ______ YES/NO ______ AS FOUND ______ AS LEFT

PROVER ____________ (SIGN) ____________ (DATE) WITNESS ____________ (SIGN) ____________ (DATE)

**Figure D.1—Proving Example—Inferred Mass Proving**

**PROVER INFORMATION**

CERTIFICATION DATE: ______ (YY/MM/DD) PROVER COMPANY ______

MASTER METER K-FACTOR ______ (PULSES/LB) MANUFACTURER ______

SERIAL NO. MODEL

**METER INFORMATION**

SERIAL NO. ______ MANUFACTURER ______

METER ID ______ MODEL ______

LOCATION ______

MANUFACTURER FLOW CALIBRATION FACTOR(S) ______

PULSE SCALING FACTOR ______ (PULSES/LB) KF (In Associated Equipment) ______ (PULSES/LB)

**PROCESS CONDITIONS**

FLOW RATE ______ (LB/MIN) ______ (BBL/HR) FLUID TYPE ______

DENSITY SOURCE ______ (DEVICE/LOCATION)

**PROVE INFORMATION**

PREVIOUS METER FACTOR ______ (DATE OF PROVE YY/MM/DD) ______ (FACTOR)

| RUN NUMBER | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| TOTAL MASTER METER PULSES | | | | | |
| TOTAL METER PULSES | | | | | |
| TEST TIME (sec) | | | | | |
| MASTER METER DENSITY (kg/$m^3$) | | | | | |
| MASTER METER MASS (lb)= (Pulses/Mass K-Factor or Visual Totalizer Display) | | | | | |
| METER MASS (lb)= (Pulses/Mass K-Factor or Visual Totalizer Display) | | | | | |
| METER FACTOR= (Master Meter Mass/Meter Mass) | | | | | |

AVERAGE METER FACTOR ______ LOCATION OF ENTRY (of Meter Factor) ______ TRANSMITTER/CALC. DEVICE

PERCENT REPEATABILITY ______ [(MAX – MIN)/MIN] * 100 ZERO VERIFIED? ______ YES/NO ______ AS FOUND ______ AS LEFT

PROVER ______ (SIGN) ______ (DATE) WITNESS ______ (SIGN) ______ (DATE)

**Figure D.2—Proving Example—Direct Mass Proving**

**PROVER INFORMATION**

CERTIFICATION DATE: ____________ (YY/MM/DD) PROVER COMPANY ____________

BASE PROVER VOLUME ____________ (BARRELS) PROVER UNIT SERIAL NO. ____________

**METER INFORMATION**

SERIAL NO. ____________ MANUFACTURER ____________

METER ID ____________ MODEL ____________

LOCATION ____________

____________

K-FACTOR ____________ (PULSES/BBL) ____________

**PROCESS CONDITIONS**

FLOW RATE ____________ (BBL/HR) ____________ ____________

Product Table ____________ (DEVICE/LOCATION) DENSITY ____________ (kg/m$^3$ @ 60 ºF) FLUID TYPE ____________

**PROVE INFORMATION**

PREVIOUS METER FACTOR ____________ (DATE OF PROVE YY/MM/DD) ____________ (FACTOR)

| RUN NUMBER | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| TOTAL METER PULSES | | | | | |
| PROVER TEMPERATURE (˚F) | | | | | |
| $CTS_p$ | | | | | |
| $CTL_p$ | | | | | |
| PROVER PRESSURE (psig) | | | | | |
| $CPS_p$ | | | | | |
| $CPL_p$ | | | | | |
| METER TEMPERATURE (˚F) | | | | | |
| $CTL_m$ | | | | | |
| METER PRESSURE (psig) | | | | | |
| $CPL_m$ | | | | | |
| PROVER VOLUME (Bbl.)= [(BaseVol * $CTS_p$ * $CPS_p$) * $CTL_p$ * $CPL_p$] | | | | | |
| METER VOLUME (Bbl.)= [(Pulses/Vol. K-Factor) * CTLm * CPLm] | | | | | |
| METER FACTOR= (Prover Volume/Meter Volume) | | | | | |

AVERAGE METER FACTOR ☐

PERCENT REPEATABILITY ____________ [(MAX – MIN)/MIN] * 100 PERCENT UNCERTAINTY ____________ ____________ ____________

PROVER ____________ (SIGN) ____________ (DATE) WITNESS ____________ (SIGN) ____________ (DATE)

**Figure D.3—Proving Example—Volumetric Proving**

# Bibliography

[1] API *MPMS* Ch. 4.9, (all parts) *Methods of Calibration for Displacement and Volumetric Tank Provers*

[2] API *MPMS* Ch. 11.1, *Volume Correction Factors*

[3] API *MPMS* Ch. 13.1, *Statistical Concepts and Procedures in Measurement*

[4] API *MPMS* Ch. 14.6, *Continuous Density Measurement*

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