

Manual of Petroleum Measurement Standards Chapter 4.8

Operation of Proving Systems

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Contents

	Page
1 Scope.....	1
2 Normative References	1
3 Terms and Definitions	1
4 Basic Principles	1
5 The Need to Prove.....	1
6 Frequency of Meter Proving	2
7 General Considerations for Meters and Provers	2
7.1 General	2
7.2 Data Recording	2
7.3 Temperature and Pressure Measurements	3
7.4 Operating Pressure.....	3
7.5 Density	3
7.6 Proving Meters with Pulse Output	4
7.7 Proving Meters Using Totalizers	4
8 Proving Locations	4
8.1 General	4
8.2 In Situ Proving	5
8.3 Laboratory Proving	5
8.4 Ex Situ Proving	5
9 Types of Provers	5
9.1 General	5
9.2 Displacement Provers.....	5
9.3 Tank Prover.....	8
9.4 Master Meter Prover	8
10 Prover Calibration Frequency	9
10.1 Displacement and Tank Provers	9
10.2 Master Meter Provers	10
11 Proving Methods	11
11.1 Volumetric Proving	11
11.2 Direct Mass Proving.....	11
11.3 Inferred Mass Proving.....	12
12 Assessment of Proving Results	12
12.1 The Number of Runs	12
12.2 Meter Factor	13
12.3 Application of Meter factors	13
13 Proving Concerns	13
13.1 Flow Conditioning	13
13.2 Temperature and Pressure Variations.....	14
13.3 Viscosity Variation.....	14

Contents

	Page
13.4 Valve(s) Leakage	14
13.5 Displacer Slippage	15
13.6 Meter Wear	15
13.7 Effect of Electrical Disturbance	15
13.8 Flow Rate Variation	15
13.9 Meter Registration (Head) Check	15
13.10 Meter and Prover Design	15
13.11 Meter and Prover Combinations	16
13.12 Air/Vapor in the Proving System	16
13.13 Cavitation	16
13.14 Debris and Coating	16
13.15 Physical Damage	16
13.16 Computational Master Meter Provers Zero	16
Annex A (normative) Evaluating Meter Proving Data	18
Annex B (normative) Method for Determining the Frequency of Calibrating Provers	21
Annex C (informative) Meter Prover Operation	24
Annex D (informative) Proving Form Examples	36
Bibliography	39

Figures

B.1 Determining the Frequency of Prover Calibration	23
D.1 Proving Example—Inferred Mass Proving	36
D.2 Proving Example—Direct Mass Proving	37
D.3 Proving Example—Volumetric Proving	38

Tables

A.1 Repeatability Criteria for 0.027 % Uncertainty (Preferred Uncertainty) for ± 0.00027 Random Uncertainty in Average Meter Factor	19
A.2 Repeatability Criteria for 0.073 % Uncertainty (Limited Volume Proving) for ± 0.00073 Random Uncertainty in Average Meter Factor	20
B.1 Prover Calibration Frequency Example	22
B.2 Example Table—Dynamic or Tank Prover Calibration Frequency for 0.06 % Volume Change Benchmark	23
C.1 Repeatability Criteria for 0.027 % Uncertainty for ± 0.00027 Random Uncertainty in Average Meter Factor	34
C.2 Repeatability Criteria for 0.027 % Uncertainty for ± 0.00027 Random Uncertainty in Average Meter Factor	34
C.3 Suggested Minimum Prover Volume for ± 0.027 % Uncertainty of Meter Factor when Proving Ultrasonic Flow Meters	35

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 5.1, *General Considerations for Measurement by Meters*

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

API MPMS Chapter 12.2, *Calculation of Petroleum Quantities Using Dynamic Measurement Methods and Volumetric Correction Factors*

3 Terms and Definitions

There are no definitions unique to this document. Terms of more general use may be found in the API MPMS Chapter 1—Online Terms and Definitions Database.

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 or elapsed time, or both;

- 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 six 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 samples.

over the proving. The amount of variation that can be tolerated before affecting the repeatability requirement or uncertainty, or both, 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 with 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 ^[10].

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* Chapter 5—*Metering* ^[3]—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 ^[2], API *MPMS* Ch. 11.1 ^[13], and API *MPMS* Ch. 14.6 ^[17] 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 (non-burst 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 Using Totalizers

Meters can be equipped with electronic or mechanical totalizers that read directly in quantity units (cubic meters, gallons, barrels, pounds, etc.). When using 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 gallons).

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 ^[1] 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 ^[2] 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 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 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 with 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. 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 consecutively). 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 or conditions, or both. 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 adjuster 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 ^[2] 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,