Manual of Petroleum Measurement Standards Chapter 4—Proving Systems

Section 1—Introduction

THIRD EDITION, FEBRUARY 2005

REAFFIRMED: SEPTEMBER 2009

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Measurement Coordination

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FOREWORD

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

The information contained in this edition of Chapter 4 supersedes the information contained in the previous edition (First Edition, May 1978), which is no longer in print. It also supersedes the information on proving systems contained in API Std 1101 *Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter* (First Edition, 1960); API Std 2531 *Mechanical Displacement Meter Provers*; API Std 2533 *Metering Viscous Hydrocarbons*; and API Std 2534 *Measurement of Liquid Hydrocarbons by Turbine-Meter Systems*, which are no longer in print.

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For the purposes of business transactions, limits on error or measurement tolerance are usually set by law, regulation, or mutual agreement between contracting parties. This publication is not intended to set tolerances for such purposes; it is intended only to describe methods by which acceptable approaches to any desired accuracy can be achieved.

Chapter 4 now contains the following sections:

Section 1—“Introduction”

Section 2—“Displacement Provers”

Section 4—“Tank Provers”

Section 5—“Master-Meter Provers”

Section 6—“Pulse Interpolation”

Section 7—“Field-Standard Test Measures”

Section 8—“Operation of Proving Systems”

Section 9—“Calibration of Provers”

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Suggested revisions are invited and should be submitted to the standardization manager, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

CONTENTS

Manual of Petroleum Measurement Standards
Chapter 4—Proving Systems

SECTION 1—INTRODUCTION

1 Scope

Section 1 is a general introduction to the subject of proving. The requirements in Chapter 4 are based on customary practices that evolved for crude oils and products covered by API *MPMS* Ch. 11.1. The prover and meter uncertainties should be appropriate for the measured fluids and should be agreeable to the parties involved.

2 Referenced Publications

Several documents served as references and as a resource of information in the revision of this standard.

Manual of Petroleum Measurement Standards

Chapter 1—"Vocabulary"

Chapter 4—"Proving Systems"

Chapter 5—"Metering"

Chapter 7—"Temperature Determination"

Chapter 11.1—"Physical Properties Data"

Chapter 12—"Calculation of Petroleum Quantities"

Chapter 13—"Statistical Aspects of Measuring and Sampling"

3 Definition of Terms

Terms used in this chapter are defined in 3.1 through 3.9.

3.1 calibration: The procedure used to determine the volume of a prover.

3.2 meter proof: The multiple passes or round trips of the displacer in a prover for purposes of determining a meter factor.

3.3 meter prover: An open or closed vessel of known volume that is used as a volumetric reference standard for the calibration of meters in liquid petroleum service. Such provers are designed, fabricated, and operated within the recommendations of Chapter 4.

3.4 meter pulse: A single electrical pulse generated by flow induced effects in the meter. The flow induced effects are normally caused by movement of physical elements within the meter's primary flow element but may be caused by other flow induced effects that are proportional to flow rate. The pulses produced by the meter shall not be multiplied to increase the number of pulses to conform to the requirements of Chapter 4.

3.5 prover pass: One movement of the displacer between the detectors in a prover.

3.6 prover round trip: The forward and reverse passes in a bi-directional prover.

3.7 proving: The procedure used to determine a meter factor.

3.8 standard conditions: ***60°F and atmospheric pressure***.

4 Liquid Metering Hierarchies

4.1 OVERVIEW OF HIERARCHY

Liquid metering systems designed and operated in conformance with API's *Manual of Petroleum Measurement Standards* typically have one or more of the following levels of hierarchy as shown in Table 1.

Level 1.

Primary standards involve mass, volume, and/or density standards developed and/or maintained by National Institute of Standards and Technology (NIST) and/or other national laboratories to calibrate secondary working standards.

Level 2.

Secondary working standards include mass, volume, density, and/or weighing systems maintained by NIST and/or other national laboratories to calibrate field transfer standards conforming to Chapter 4.7. Secondary working standards may also be maintained by state and other certified metrology laboratories to calibrate field transfer standards.

These additional secondary working standards, however, increase uncertainty in the final custody transfer quantities.

Level 3.

Field transfer standards conforming to Chapter 4.7 are devices used to calibrate meter provers conforming to Chapters 4.2, 4.3, and 4.4.

Level 4.

Meter provers conforming to Chapter 4 are used to determine meter factors that correct the indicated volumes of meters.

Table 1—General Liquid Metering Hierarchy Levels

Levels	Description of Hierarchy Level
1	Primary Standards
2	Secondary Working Standards
3	Field Standard Test Measures
4	Meter Prover
5	Meter Assembly (Indicated Volume)
6	Corrections for Quality and/or Quantity
7	Custody Transfer Ticket (Net Standard Volume)

Levels 5, 6, & 7.

Compositional analyses, where appropriate, together with the meter factor, is used to make corrections in the quality and/or quantity of the indicated volume of the meter, to determine the net standard volume being metered for custody transfer purposes.

When practical, the number of levels in a hierarchy should be kept to a minimum to keep uncertainty low. Each level in the hierarchy will increase the uncertainty of subsequent levels and eventually the final custody transfer quantity.

4.2 UNCERTAINTY LIMITS WITHIN THE HIERARCHY

Each level within a hierarchy will include all the errors and uncertainties from the previous or higher levels of the hierarchy. Therefore, uncertainties will always increase throughout each level of the hierarchy. Exact, defined, and rigorous procedures must be developed and followed exactly through each level of a hierarchy so that the uncertainty in the final level of the hierarchy is not higher than specified and still tolerable for commercial purposes. For levels in the hierarchy that exhibit randomness because of the intrinsic random nature of the activity or equipment, error or uncertainty may be limited to twice or less than the uncertainty in the previous level. For levels that are performed infrequently in the hierarchy, such as primary standards, the next level in the hierarchy, such as secondary working standards, may have uncertainty limits that are up to four times the previous level in the hierarchy. In the general hierarchy shown in Table 2, uncertainty indices are used to indicate the ratio of uncertainty of one level compared to the primary standard.

The effects of time should also be included in establishing limits within a hierarchy. Most custody transfer contracts or arrangements are in effect for years between two or more parties; therefore, the effects of random uncertainties to propagate to lower average values with time should be considered. Frequently, repeated activities may have uncertainty limits that are closer to the adjacent level in the hierarchy if rigorous procedures are developed and implemented that minimize additional uncertainties. In the hierarchy of Table 2, the uncertainty index for meter indicated volume and corrections for quantity, such as the meter factors, can be lower than indicated in Table 2. An uncertainty index of 16 – 24 or lower for meter indicated volume is obtainable over the period of a year or longer. A lower uncertainty index over time for the custody transfer ticket of 32 – 48 is also obtainable from rigorous and frequently performed activities.

If the uncertainty limit for the average of custody transfer over one year is prescribed as ± 0.10%, the possible hypothetical corresponding uncertainty limits for each of the levels in the hierarchy are presented in Table 3.

Within each of the hierarchy levels there are other activities that are sources of error that must be identified and limited so that they do not disrupt the integrity of the hierarchy. These activities include procedures for calibrating the secondary working standards, field transfer standards, and meter provers. Rigorous procedures must be developed and followed so that these additional sources of uncertainties do not disrupt the uncertainty control within the hierarchy.

Table 2—Uncertainty Indices for General Liquid Metering Hierarchy

Level	Description of Hierarchy Level	Uncertainty Indices	
		Per Event	Average with Time
1	Primary Standards	1	1
2	Secondary Working Standards	2 – 4	2 – 4
3	Field Transfer Standards	4 – 16	4 – 8
4	Meter Prover Base Volume	8 – 32	8 – 16
5	Meter Indicated Volume	16 – 64	16 – 24
6	Correction for Quality and/or Quantity	32 – 128	24 – 32
7	Custody Transfer Ticket	64 – 256	32 – 48

Table 3—Hypothetical Uncertainty Limits in General Liquid Metering Hierarchy

Level	Description of Hierarchy Level	Uncertainty Limit, + or – %	
		Per Event	Per Year
1	Primary Standards	0.002	0.002
2	Secondary Working Standards	0.005	0.005
3	Field Transfer Standards	0.015	0.015
4	Meter Prover Base Volume	0.03	0.03
5	Meter Indicated Volume	0.10	0.05
6	Correction for Quality and/or Quantity	0.15	0.07
7	Custody Transfer Ticket	0.20	0.10

5 Proving and Meter Factor

The purpose of proving a meter is to determine its meter factor. The ***meter factor*** is obtained by dividing the prover volume by the indicated volume of the meter, both corrected to the standard conditions.

The purpose of a meter factor is to correct a meter's indicated volume. Obtaining a meter factor is an essential step in calculating the net standard volume of a receipt or delivery of petroleum liquids.

Because all calculations involve one or more corrections, and because the computation of numerous correction factors can lead to small differences if the computations are not carried out in a standard way, the calculations of petroleum quantities in dynamic measurement is covered in API *MPMS* Ch. 12.2. Refer to Chapter 12.2 whenever one or more of the following items must be calculated:

a. Volumes in the provers.

b. Meter factors.

c. Measurement tickets.

5.1 GENERAL CONSIDERATIONS

All meters should be proved with the liquid to be measured and at the operating flow rate, pressure, and temperature. A meter that is used to measure several different liquids should be proved with each liquid. For additional details see *API MPMS* Ch. 4.8.

Meter proving shall be performed with a high degree of precision. The many details of the meter, its auxiliary equipment, and the proving system can contribute to measurement uncertainty. Likewise, there are difficulties in determining the physical properties of the measured liquid, pressure, temperature, and the presence of trapped air. Thorough inspections of provers and their components should be made routinely to ensure the reproducibility of proving results. See API *MPMS* Ch. 12 and API *MPMS* Ch. 13 for applicable calculation methods.

5.2 OBJECTIVES

Meter proving has two general objectives depending on the type of service.

a. A meter is proved to determine its meter factor. The meter factor is applied to the indicated volume to compute the gross standard volume that is delivered through the meter. This is normal practice for pipeline and oil production operations. Results of the meter proving can be used to evaluate the performance or condition of the meter and/or prover.

b. A meter is proved to adjust its registration, if necessary, to give a meter factor as close to 1.0000 (unity) as practical. The meter's indicated volume will be the volume of liquid actually delivered (gross volume) within allowable tolerances. This is the normal practice for meters that operate on intermittent deliveries, such as tank-truck meters or loading-rack meters at terminals or bulk plants.

5.3 PROCEDURES

Meter proving can be classified according to the following procedures:

a. The running start-and-stop procedure requires that the opening and closing meter readings of the proof be obtained while the meter is in operation. If the meter-proving registration is derived from something other than the meter register, steps shall be taken to ensure that all volumes indicated by the proving counter are also reflected in the meter register.

b. The standing start-and-stop procedure uses the meter register or meter-proving counter, from which the opening and closing readings are obtained at no-flow conditions. If the flow is started too rapidly, pressure in the piping may momentarily fall below the vapor pressure of the liquid, causing some vapor to pass through the meter. This may damage the meter and result in inaccurate meter registration. Too rapid a change of liquid velocity may cause hydraulic shock.

5.4 ACCURACY

Accuracy is the ability of a measuring instrument to indicate values closely approximating the true value of the quantity measured. The accuracy of any calculated meter factor is limited by at least the following considerations:

a. Prover calibration uncertainty.

b. Meter proving procedural uncertainties.

c. Equipment performance.

d. Errors that arise from observation (spurious error).

e. Errors that are implicit in the computation used to correct a measurement to standard conditions.

Abbreviated tables, non-standardized rounding of conversion factors, or intermediate calculations (see API *MPMS* Ch. 12.2 for standardized calculations) can adversely affect the consistency of calculations. The observed and computed data for all meter proofs that are made to obtain a meter factor or another expression of meter performance shall be reported on a suitable meter-proving report form; examples are provided in API *MPMS* Ch. 12.2.

6 Types of Provers

6.1 DISPLACEMENT PROVERS

A displacement prover includes a calibrated section in which a displacer travels with the flow, activating detection devices. Proving procedure requires a resolution of one part in 10,000 (0.0001). A displacement prover may have an adequate volume to accumulate a minimum of 10,000 whole unaltered meter pulses between detector switches for each pass of the displacer. When the prover volume is inadequate to generate 10,000 whole unaltered meter pulses for each pass of the displacer, the meter factor calculation requires pulse interpolation to increase the resolution to one part in ten thousand parts (0.0001). For pulse interpolation see API *MPMS* Ch. 4, Section 6.

6.2 TANK PROVERS

A tank prover is a volumetric vessel that has a reduced cross section or neck located at both the top and bottom or, in some cases, at the top only. These necks are equipped with gauge glasses and graduated scales. Tank provers may be open to the atmosphere, or they may be closed pressurized vessels. Proving by a tank prover employs the standing start-and-stop method (that is, the flow through the meter must come to a complete stop at the beginning and end of each proving run). For more detailed information on tank provers see API *MPMS* Ch. 4, Section 4.

6.3 MASTER METER PROVERS

A master meter prover is a meter that is proved by a certified prover. A certified prover is a prover calibrated by water-draw method. The master meter is used to calibrate other provers or meters. For more detailed information on master meter provers, see API *MPMS* Ch. 4, Section 5 and Section 9.3.

7 Calibration of Provers

For procedure and calculation, refer to API *MPMS* Ch. 4, Section 9 and Ch. 12, Section 2 Parts 4 and 5.

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