Manual of Petroleum Measurement Standards Chapter 12—Calculation of Petroleum Quantities

Section 2—Calculation of Petroleum Quantities Using Dynamic Measurement Methods and Volumetric Correction Factors

Part 5—Calculation of Base Prover Volume by Master Meter Method

FIRST EDITION, SEPTEMBER 2001

ERRATA, JULY 2009

REAFFIRMED, AUGUST 2016

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Measurement Coordination

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FOREWORD

This multi-part publication consolidates and presents standard calculations for the measurement of petroleum liquids using turbine or displacement meters. Units of measure in this publication are in International System (SI) and United States Customary (US Customary) units consistent with North American industry practices.

This standard has been developed through the cooperative efforts of many individuals from industry under the sponsorship of the American Petroleum Institute and the Gas Processors Association.

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PART 5—CALCULATION OF BASE PROVER VOLUMES BY MASTER METER METHOD

1 Purpose

1.1 When most of the older standards were written, mechanical desk calculators were widely used for calculating measurement documentation, and tabulated values were used more widely than is the case today. Rules for rounding and the choice of how many figures to enter in each calculation step were often made on the spot. As a result, different operators obtained different results from the same data.

1.2 This multi-part publication consolidates and standardizes calculations pertaining to metering petroleum liquids using turbine or displacement meters and clarifies terms and expressions by eliminating local variations of such terms. The purpose of standardizing calculations is to produce the same unbiased answer from the given data. For different operators to obtain identical results from the same data, the rules for sequence, rounding and discrimination of figures (or decimal places) must be defined.

2 Scope

2.1 This part provides standardized calculation methods for the quantification of liquids and the determination of base prover volumes under defined conditions, regardless of the point of origin or destination or units of measure required by governmental customs or statute. The criteria contained in this document allows different entities using various computer languages on different computer hardware (or manual calculations) to arrive at identical results using the same standardized input data.

2.2 This document also specifies the equations for computing correction factors, rules for rounding, including the calculational sequence, and discrimination levels to be employed in the calculations. No deviations from these specified equations are permitted, since the intent of this document is to establish a rigorous standard.

3 Organization of Standard

This standard is organized into five separate parts. Part 1 contains a complete general introduction to dynamic measurement calculations. Part 2 focuses on the calculation of metered quantities for measurement tickets. Part 3 applies to the calculation of meter factors in proving operations and proving reports. Part 4 applies to the determination of base prover volumes by the water draw method, and Part 5 explains the calculation steps required to determine base prover volume by the master meter method.

3.1 PART 1—INTRODUCTION

3.1.1 The base (reference or standard) volumetric determination of metered quantities is discussed, along with the general terms required for solution of equations.

3.1.2 General rules for rounding of numbers, including field data and intermediate calculational numbers and discrimination levels, are specified.

3.1.3 For the proper use of this standard, prediction of the density of the liquid in both flowing and base conditions is discussed.

3.1.4 An explanation of the principal correction factors associated with dynamic measurement is presented.

3.2 PART 2—CALCULATION OF METERED QUANTITIES

3.2.1 The application of this standard to the calculation of metered quantities is presented, for base volumetric calculations in conformance with North American industry practices.

3.2.2 Recording of field data, rules for rounding, discrimination levels, calculational sequences, along with a detailed explanation of the calculation steps, are all specified, together with appropriate flow charts and a set of example calculations. These examples can be used as an aid in checking out the procedures for any computer calculation routines that are developed on the basis of the requirements stated in this standard.

3.3 PART 3—PROVING REPORTS

3.3.1 The application of this standard to the calculation of proving reports is presented for base volumetric calculations in conformance with North American industry practices. Proving reports are utilized to calculate meter correction factors and/or performance indicators. The determination of the appropriate terms is based on both the hardware and the preferences of the users.

3.3.2 Recording of field data, rules for rounding, calculation sequence and discrimination levels are specified, along with a set of example calculations. The examples are designed to aid in checkout procedures for any computer routines that are developed using the requirements stated in this part.

3.4 PART 4—CALCULATION OF BASE PROVER VOLUMES BY WATERDRAW METHOD

3.4.1 The waterdraw method uses the displacement (or drawing) of water from the prover into certified volumetric field standard test measures. Alternatively, for open tank provers, the waterdraw method may also use the displacement (or drawing) of water from field standard test measures into the open tank prover. Certification of the field standard measures must be traceable to an appropriate national weights and measures organization.

3.4.2 Recording of field data, rules for rounding, calculation sequence and discrimination levels are specified, along with a set of example calculations. The examples are designed to aid in checkout procedures for any routines that are developed using the requirements stated in this part.

3.5 PART 5—CALCULATION OF BASE PROVER VOLUMES BY MASTER METER METHOD

3.5.1 The master meter method uses a transfer meter (or transfer standard). This transfer meter is proved under actual operating conditions, by a prover which has been previously calibrated by the waterdraw method and is designated the master meter. This master meter is then used to determine the calibrated volume of a field displacement prover.

3.5.2 Recording of field data, rules for rounding, calculation sequence and discrimination levels are specified, along with a set of example calculations. The examples are designed to aid in checkout procedures for any routines that are developed using the requirements stated in this section.

4 References

Several documents served as references for the revisions of this standard. In particular, previous editions of *API MPMS* Chapter 12.2 (ANSI/API 12.2) provided a wealth of information. Other publications served as a resource of information:

API

Manual of Petroleum Measurement Standards (MPMS)
- Chapter 4—“Proving Systems”
- Chapter 5—“Metering”
- Chapter 6—“Metering Assemblies”
- Chapter 7—“Temperature Determination”
- Chapter 9—“Density Determination”
- Chapter 10—“Sediment and Water”
- Chapter 11—“Physical Properties Data”
- Chapter 13—“Statistical Aspects of Measuring and Sampling”

ASTM[1]

- D1250 *Petroleum Measurement Tables*, Current Edition
- D1250 *Petroleum Measurement Tables*, Historical Edition, 1952
- D1550 *ASTM Butadiene Measurement Tables*
- D1555 *Calculation of Volume And Weight of Industrial Aromatic Hydrogens*

NIST[2]

- Handbook 105-3 *Specifications and Tolerances for Reference Standards and Field Standards*
- Handbook 105-7 *Small Volume Provers*

5 Terms and Symbols

Terms and symbols described below are acceptable and in common use for the calibration of flow meters.

5.1 DEFINITION OF TERMS

5.1.1 barrel (Bbl): A unit volume equal to 9,702.0 cubic inches, or 42.0 U.S. gallons.

5.1.2 base prover volume (*BPV*): The volume of the prover at base conditions, as shown on the calibration certificate, and obtained by arithmetically averaging an acceptable number of consecutive calibrated prover volume (*CPV*) determinations.

5.1.3 calibrated prover volume (*CPV*): The volume at base conditions between the detectors in a unidirectional prover, or the volume of a prover tank between specified “empty” and “full” levels as determined by a single calibration run. The calibrated volume (*CPV*) of a bidirectional prover is the sum of the two volumes swept out between detectors during a calibration round-trip.

5.1.4 cubic meter (m^3): A unit of volume equal to 1,000,000.0 milliliters (ml), or 1,000.0 liters. One cubic meter equals 6.28981 barrels.

5.1.5 calibration certificate: A document stating the base prover volume (*BPV*) and the physical data used to calculate that base prover volume e.g. *E, Gc, Ga, Gl*).

[1]American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428.
[2]U.S. Department of Commerce, National Institute of Standards and Technology (formerly the National Bureau of Standards), Washington, D.C. 20234.

5.1.6 calibration run set: A series of events that involve making multiple consecutive runs of a master prover, that has been previously water drawn, to prove a master meter to determine a start master meter factor (*MMFstart*). Multiple consecutive runs are then made with the master meter to calibrate the field prover to collect the run data. Then more multiple consecutive runs are made with the master prover to prove the master meter to determine a stop master meter factor (*MMFstop*). The average of the *MMFstart*, and the *MMFstop* is then used with the collected run data to determine a calibrated prover volume (*CPV*) for that Calibration Run Set.

5.1.7 certified: As it refers to a pressure or temperature device, pertains to documentation that an instrument has been calibrated over the operating range against an appropriate standard traceable to a national standard.

5.1.8 field prover: Refers to the volumetric standard (displacement prover) that is to be proved by using the master meter method.

5.1.9 gross standard volume (*GSV*): The metered volume corrected to base conditions and also corrected for the performance of the meter (*MF, MMF*).

5.1.10 indicated volume (*IV*): The change in the meter register head volume that occurs during a proving run (*MRo-MRc*). The word **registration**, though not preferred, often has the same meaning. Alternately, indicated volume (*IV*) may also be determined by dividing the meter pulse output, (*N*) or (*Ni*), during a proving pass, by the nominal K-factor (*NKF*).

5.1.11 indicated standard volume (ISV): The indicated volume (*IV*) corrected to base conditions.

5.1.12 K-factor (*KF*): Defined as the number of pulses generated by the meter per unit volume. A new K-factor may be determined during each proving to correct the indicated volume. If, however, a new K-factor is not used, then the nominal K-factor may be utilized to generate a new meter factor, which will then correct the indicated volume of the meter to a gross volume.

5.1.13 liter (l): A unit of volume equal to 1,000.0 milliliters (ml) or 0.001 cubic meters.

5.1.14 master meter: A transfer device (meter) that is proved using a certified prover (called the master prover) and can then be used to calibrate other meter provers or to prove other flow meters. A master meter is either a positive displacement or turbine meter with no mechanical or built-in temperature or gravity corrections, which is described and discussed in Chapter 4.

5.1.15 master meter factor (*MMF*): A dimensionless term obtained by dividing the gross standard volume of the liquid passed through the master prover (during the proving of the master meter) by the indicated standard volume.

5.1.16 master prover: Refers to the volumetric standard (displacement prover or open tank prover) that was calibrated by the waterdraw method with test measures traceable to a national standards organization, and then used to calibrate a master meter.

5.1.17 nominal K-factor (*NKF*): Used to determine the meter factor. It is a K-factor generated by the manufacturer, retained as a fixed value, and used to convert meter pulses (*N*) or (*Ni*) into an indicated volume (*IV*) during meter proving. Many installations retain this fixed value of the nominal K-factor throughout the life of the installation to provide an audit trail for meter proving.

5.1.18 pass: A single movement of the displacer between detectors which define the calibrated section of a prover.

5.1.19 round-trip: The combined forward (out) and reverse (back) passes of the displacer in a bidirectional prover.

5.1.20 run, meter proving: One pass of a unidirectional prover or one round-trip of a bidirectional prover, or one empty or filling of a volumetric prover tank, the result of which is deemed acceptable to provide a single test value of the master meter factor (*MMF*) when using the average meter factor method of calculation.

5.1.21 run, prover calibration: One pass of a unidirectional prover or one roundtrip of a bidirectional prover, or one empty or filling of a volumetric prover tank, the result of which is deemed acceptable to provide a single test value of the calibrated prover volume (*CPV*).

5.1.22 U.S. gallon (gal): A unit volume equal to 231.0 cubic inches.

5.2 DEFINITION OF SYMBOLS

A combination of upper and lower case notation is used for symbols and formulas in this publication. Subscripted notation is often difficult to use for computers and other word processing documents, and therefore has not been used in this publication, but may, however, be employed if the interested parties wish. Upper case notation is usually preferred for computer programming and other documents as deemed appropriate.

Symbols have been defined to aid in the clarity and specificity of the mathematical treatments. Some examples of the symbol notation are as follows: *CTL* = **C**orrection for effect of **T**emperature on the **L**iquid; *GSV* = **G**ross **S**tandard **V**olume; *MMF* = **M**aster **M**eter **F**actor; *CPS* = **C**orrection for **P**ressure on the **S**teel. In many cases the symbols have additional letters added at the end to help clarify their meaning and application. Some of these additional letters are defined as follows: "mm" always refers to the master meter, "p" always refers to the prover, "mp" always refers to the master prover, "b" implies base conditions (*DENb*), "obs" implies observed conditions (*RHOobs*), and "avg" defines the average (mean) of the readings [*Tp(avg)*]. Where occasionally other additional letters have been used, they should be just as easy to interpret.

5.2.1 Units

SI	International System of units (pascal, cubic meter, kilogram, metric system).
USC	US Customary units (inch, pound, cubic inch, traditional system).

5.2.2 Pipe Dimensions

ID	Inside diameter of the prover.
OD	Outside diameter of the prover.
WT	Wall thickness of prover.

5.2.3 Liquid Density

API	Density of liquid in degree API gravity units.
APIb	Base density in degree API gravity units.
APIobs	Observed density at base pressure in degree API gravity units.
DEN	Density of liquid in kilogram per cubic meter (kg/m^3) units.
DENb	Base density of liquid in kilogram per cubic meter (kg/m^3) units.
DENobs	Observed density of liquid at base pressure in kilogram per cubic meter (kg/m^3) units.
RD	Relative density of the liquid.
RDb	Base relative density of the liquid.
RDobs	Observed relative density of the liquid at base pressure.
RHO	Density of liquid (SI or USC) in mass per unit volume.
RHOb	Base density of liquid in mass per unit volume.
RHOobs	Observed density of liquid at base pressure in mass per unit volume.
RHOp	Density of liquid in the prover (for master meter calculations) in mass per unit volume.
RHOtp	Density of the liquid at operating temperature and pressure in mass per unit volume.

5.2.4 Liquid Viscosity

VISb	Base liquid viscosity in cP units (if needed).

5.2.5 Temperature

°C	Celsius temperature scale.
°F	Fahrenheit temperature scale.
T	Temperature in °F or °C units.
Tb	Base temperature, in °F or °C units.
Td	Temperature of detector mounting shaft on SVP with external detectors.
Tmm	Temperature of master meter, in °F or °C units.
Tmp	Temperature of master prover, in °F or °C units.
Tp	Temperature of field prover, in °F or °C units.
Tobs	Observed temperature to determine *RHOb* (i.e., hydrometer temperature) in °F or °C units.

5.2.6 Pressure

kPa	Kilopascals (SI) in absolute pressure units.
kPag	Kilopascals (SI) in gauge pressure units.
psi	Pounds per square inch (USC) pressure units.
psia	Pounds per square inch (USC) in absolute pressure units.
psig	Pounds per square inch (USC) in gauge pressure units.
P	Operating pressure in gauge pressure units.
Pb	Base pressure, in psi or kPa pressure units.
Pba	Base pressure, in absolute pressure units.
Pbg	Base pressure, in gauge pressure units.
Pmm	Pressure of liquid in the master meter, in gauge pressure units.
Pp	Pressure of liquid in field prover, in gauge pressure units.
Pmp	Pressure of liquid in the master prover, in gauge pressure units.
Pg	Internal operating pressure of prover, in gauge pressure units.
Pe	Equilibrium vapor pressure of liquid at normal operating conditions, in absolute pressure units.
Peb	Equilibrium vapor pressure of liquid at base temperature, in absolute pressure units.
Pem	Equilibrium vapor pressure of liquid in meter, in absolute pressure units.
Pemm	Equilibrium vapor pressure of liquid in master meter, in absolute pressure units.
Pemp	Equilibrium vapor pressure of liquid in master prover, in absolute pressure units.

5.2.7 Correction Factors

CCFmm	Combined correction factor for master meter at proving conditions.
CCFp	Combined correction factor for field prover at proving conditions.

CCFmp Combined correction factor for master prover at proving conditions.

CPL Basic correction for the compressibility of a liquid.

CPLp Correction for the Compressibility of liquid in the field prover at operating conditions.

CPLmp Correction for the Compressibility of liquid in the master prover at operating conditions.

CPLmm Correction for the Compressibility of liquid in the master meter at operating conditions.

CPS Basic correction for the effect of pressure on steel.

CPSp Correction for the effect of pressure on steel field prover.

CPSmp Correction for the effect of pressure on steel master prover.

CTL Basic correction for effect of temperature on a liquid.

CTLp Correction for the effect of temperature on a liquid in field prover.

CTLmp Correction for the effect of temperature on a liquid in master prover.

CTLmm Correction for the effect of temperature on a liquid in the master meter.

CTS Basic correction for the effect of temperature on steel.

CTSp Correction for the effect of temperature on steel in field prover.

CTSmp Correction for the effect of temperature on steel master prover.

E Modulus of elasticity of the steel prover.

F Compressibility factor of liquid in meter (for *CMF* and ticket calculations).

Fp Compressibility factor of liquid in field prover.

Fmp Compressibility factor of liquid in master prover.

Fmm Compressibility factor of liquid in master meter.

Gl Linear coefficient of thermal expansion on displacer shaft or detector mounting.

Ga Area coefficient of thermal expansion of prover.

Gc Cubical coefficient of thermal expansion of prover.

Gmp Cubical coefficient of thermal expansion of master prover.

MMF Master meter factor.

MMFstart Master meter factor determined at the start of a prover calibration run for one calibration run set.

MMFstop Master meter factor determined at the stop of a prover calibration run for one calibration run set.

MMFavg The average of *MMFstart* and *MMFstop*.

IMMF Intermediate master meter factor as derived in the average meter factor method.

KF K-factor, pulses per unit volume.

NKF Nominal K-factor, pulses per unit volume.

5.2.8 Volumes

CPV Calibrated prover volume.

CPVn Calibrated prover volume for a single prover calibration run (round trip for bidirectional prover).

BPV Base prover volume of a displacement prover.

BPV*amp* Adjusted base prover volume for master tank prover.

GSV Gross standard volume.

GSVp Gross standard volume of field prover for proving operations.

GSVmp Gross standard volume of master prover for proving operations.

GSVmm Gross standard volume when using a master meter for proving operations.

IV Indicated volume.

IVmm Indicated volume of master meter for proving operations.

ISV Indicated standard volume.

ISVmm Indicated standard volume of the master meter.

MMRo Opening master meter reading.

MMRc Closing master meter reading.

N Number of whole meter pulses for a single proving pass or round-trip.

Ni Number of interpolated meter pulses for a single proving pass or round-trip.

N(avg) Average number of pulses or interpolated meter pulses for the proving runs that satisfy the repeatability requirements.

V Volume.

Vb Base volume of each pass of the field prover.

Vb(out) Base volume of "out" pass of a bidirectional field prover.

Vb(back) Base volume of "back" pass of a bidirectional field prover.

SRu Upper scale reading of atmospheric tank prover.

SRl Lower scale reading of atmospheric tank prover.

6 Application of Chapter 12.2, Part 5

6.1 For fiscal and custody transfer applications, provers are transfer standards which are used to calibrate flowmeters.

6.2 The purpose of calibrating a prover is to determine its volume at reference conditions (base prover volume).

6.3 The base prover volume (*BPV*) of a prover may be determined by one of two methods—water draw or master meter. The master meter method refers to a volumetric calibration procedure whereby the base volume of a displacement prover is determined by using a master meter. The volume element (field prover) to be calibrated is piped in series with the master meter and the master prover. The master prover shall have been previously calibrated by the water draw method. Liquid is then passed through all three devices and the volume determined from the master meter, corrected to reference conditions, is regarded as the reference volume. The volume of liquid collected is then corrected for pressure and/or temperature differences between the test volume and the master meter. The corrected volume is then designated the base volume of the test element (field prover). See Figures 1, 2, and 3 for drawings of typical configurations.

6.4 The master meter method of determining the base volume of a prover is an indirect method of calibrating a prover. The function of the master meter is to serve as an intermediate link between the prover and the volumetric standard.

6.5 The purpose of standardizing terms and arithmetical procedures employed in calculating the *BPV* is to avoid disagreement between the parties involved in the facility. The purpose of Part 5—"Calculation of Prover Base Volume by Master Meter Method" is to obtain the unbiased answer from the same measurement data, regardless of who or what does the computing. The result of these efforts is the production of the prover's calibration certificate.

6.6 A calibration certificate serves as document stating the base volume of the prover (*BPV*) and also reports the physical data used to calculate that base prover volume.

6.7 Recording of field data, rules for rounding, calculational sequence and discrimination levels are specified, along with a set of example calculations. The examples are designed to aid in checkout procedures for any routines that are developed using the requirements stated in this part.

6.8 The operational procedures employed to calibrate a prover are specified in *API MPMS* Chapter 4—"Proving Systems".

7 Field of Application

7.1 APPLICABLE LIQUIDS

7.1.1 This standard applies to liquids that, for all practical purposes, are considered to be clean, single-phase, homogeneous, and Newtonian at metering conditions. Most liquids and dense phase liquids associated with the petroleum and petrochemical industries are usually considered to be Newtonian.

7.1.2 The application of this standard is limited to liquids which utilize tables and/or implementation procedures to correct metered volumes at flowing temperatures and pressures to corresponding volumes at base (reference or standard) conditions. To accomplish this, the density of a liquid shall be determined by the appropriate technical standard, or, alternatively, by use of the proper density correlation, or, if necessary, by use of the correct equations of state. If multiple parties are involved in the measurement, the method selected for determining the density of the liquid shall be mutually agreed upon by all concerned.

7.2 BASE CONDITIONS

7.2.1 Historically, the measurement of some liquids for custody transfer and process control, have been stated in volume units at base (reference or standard) conditions.

7.2.2 The base conditions for the measurement of liquids, such as crude petroleum and its liquid products, having a vapor pressure equal to or less than atmospheric at base temperature are:

United States Customary (USC) Units:

Pressure	14.696 psia	(101.325 kPa)
Temperature	60.0°F	(15.56°C)

International System (SI) Units:

Pressure	101.325 kPa	(14.696 psia)
Temperature	15.00°C	(59.00°F)

7.2.3 For fluids, such as liquid hydrocarbons, having a vapor pressure greater than atmospheric pressure at base temperature, the base pressure shall be the equilibrium vapor pressure at base temperature.

7.2.4 For liquid applications, base conditions may change from one country to the next due to governmental regulations. Therefore, it is necessary that the base conditions be identified and specified for standardized volumetric flow measurement by all parties involved in the measurement.

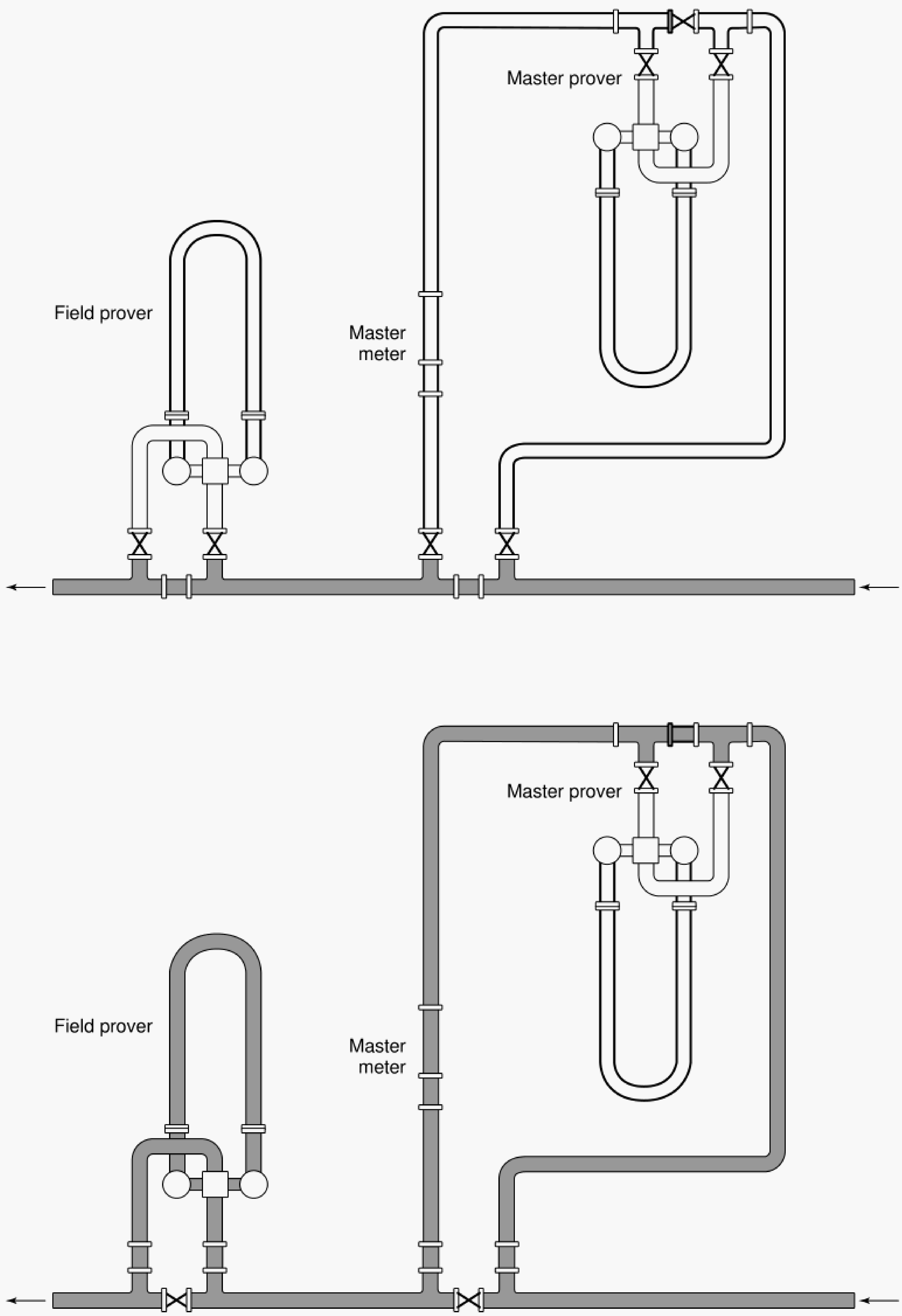

Figure 1—Typical Pipeline Construction

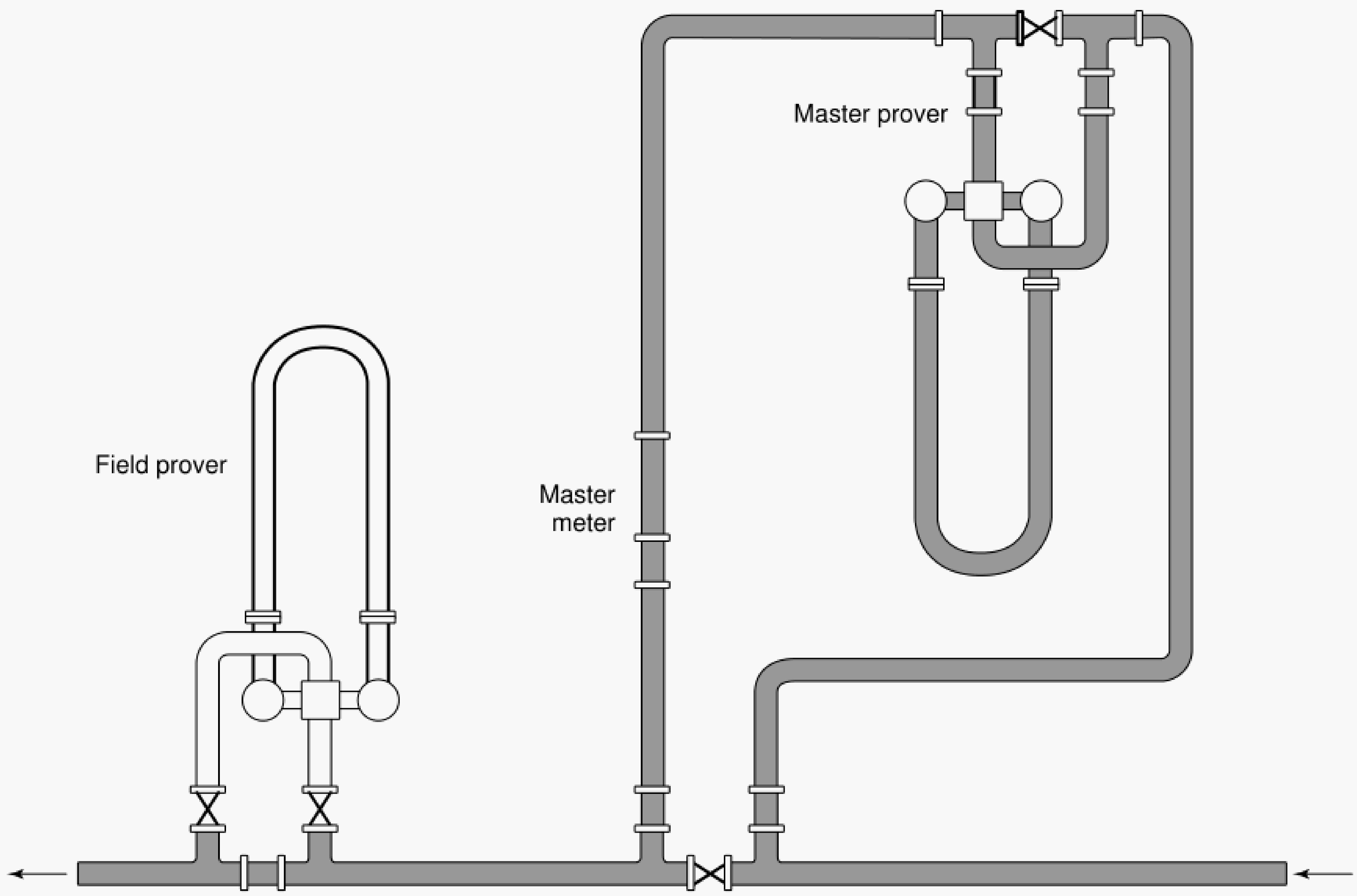

Figure 2—Master Meter Calibration

8 Precision, Rounding, and Discrimination Levels

The minimum precision of the computing hardware must be equal to or greater than a ten digit calculator to obtain the same answer in all calculations.

The general rounding rules and discrimination levels are described in the following subsections.

8.1 ROUNDING OF NUMBERS

When a number is to be rounded to a specific number of decimals, it shall always be rounded off in one step to the number of figures that are to be recorded, and shall not be rounded in two or more steps of successive rounding. The rounding procedure shall be in accordance with the following:

a. When the figure to the right of last place to be retained is 5 or greater, the figure in the last place to be retained should be increased by 1.

b. If the figure to the right of the last place to be retained is less than 5, the figure in the last place retained should be unchanged.

8.2 DISCRIMINATION LEVELS

8.2.1 For field measurements of temperature and pressure the levels specified in the various tables are maximum discrimination levels.

8.2.2 For example, if the parties agree to use a thermometer graduated in whole °F or $^1/_2$°C increments, then the device is normally read to levels of 0.5°F or 0.25°C resolution.

8.2.3 Likewise, if the parties agree to use a "smart" temperature transmitter which can indicate temperatures to 0.01°F or 0.005°C, then the reading shall be rounded to the nearest 0.1°F, or 0.05°C, prior to recording for calculation purposes.

9 Calibration Requirements

The calculation of base prover volume (*BPV*) by master meter method requires first that the master meter be proved against a master prover with the liquid selected for field prover calibration. The master meter is then used as the reference standard in the calibration of the field prover.

There are two general classes of liquid provers: displacement provers and open tank provers.

Subclasses of displacement provers are unidirectional and bidirectional flow designs, as well as small volume provers

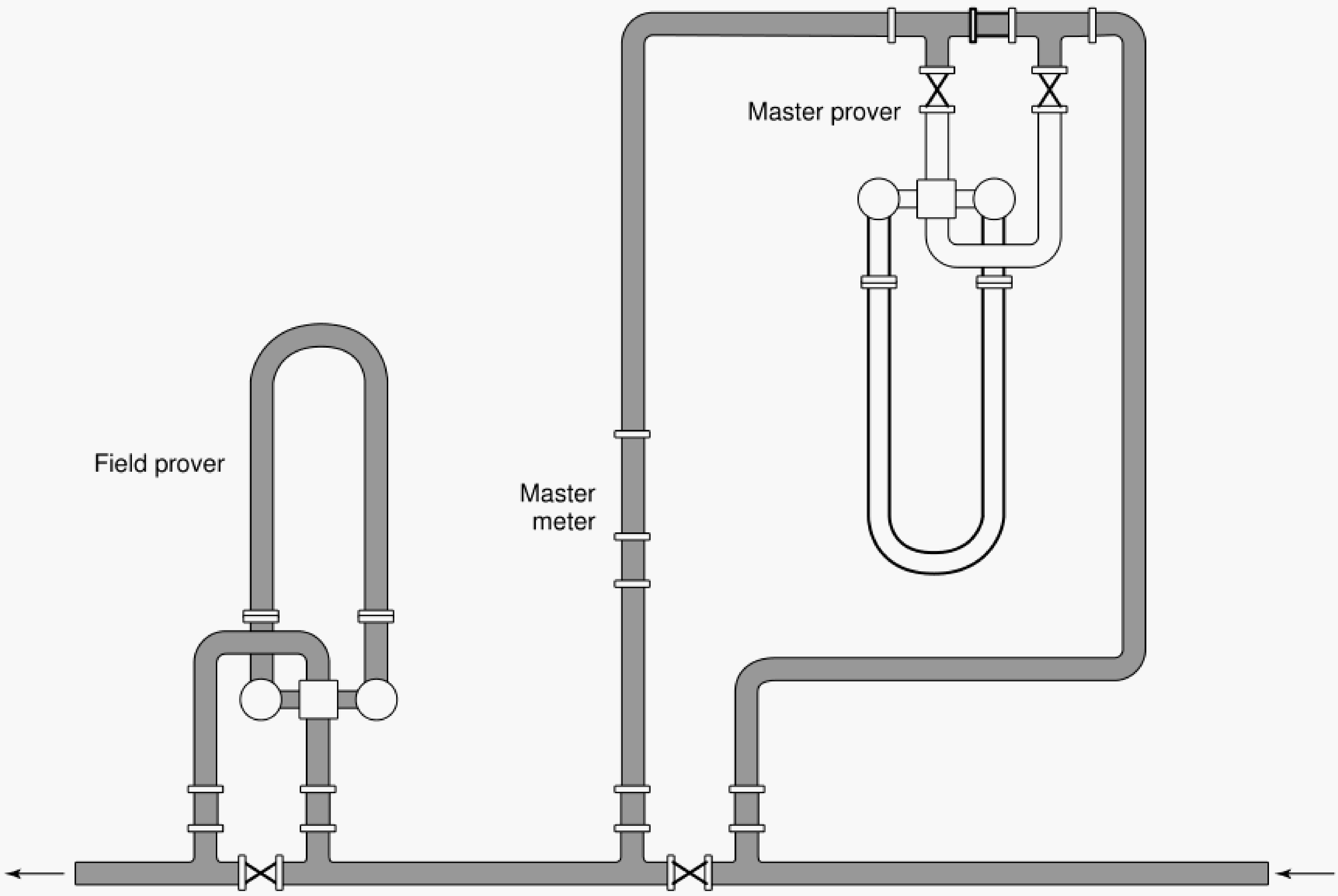

Figure 3—Field Prover Calibration

with external detectors which may also be of the unidirectional or bidirectional construction.

Subclasses of open tank provers are top filling or bottom filling designs.

9.1 UNIDIRECTIONAL DISPLACEMENT FIELD PROVERS

9.1.1 For unidirectional displacement field provers, three or more consecutive calibration run sets of the field prover are required for a calibration which shall meet the following criteria:

a. The calibration run set average calibrated prover volume (*CPVavg*) at reference conditions for three or more consecutive passes shall exhibit a range of 0.020% or less.

b. The flow rate between consecutive calibration run sets shall be changed by at least 25% or more.

9.1.2 Each calibration run set shall consist of the following sequence and meet the following criteria:

a. Do five or more consecutive out of a maximum of ten consecutive master meter proving runs against the master prover to determine *MMFstart*. These *MMFstarts* shall agree within a range of 0.020% or less.

b. Do three or more consecutive out of a maximum of six consecutive field prover calibration runs with the master meter to determine the calibrated prover volume (*CPVn*). These volumes at reference conditions shall exhibit a range of 0.020% or less.

c. Do five or more consecutive out of a maximum of ten consecutive master meter proving runs against the master prover to determine *MMFstop*. These *MMFstops* shall agree within a range of 0.020% or less.

d. The flow rate during a calibration run set shall be maintained within a range of 2.5%.

e. The delta % between the average of the five consecutive or more out of ten consecutive *MMFstarts* and the average of the five consecutive or more out of ten consecutive *MMFstops* in each calibration run set shall agree within 0.020%.

$$\text{Delta } \% = (MMFstart - MMFstop) \times 100$$

9.2 BIDIRECTIONAL DISPLACEMENT FIELD PROVERS

9.2.1 For bidirectional displacement field provers, three or more consecutive calibration run sets of the field prover are required for a calibration which shall meet the following criteria:

Note: Having no range criteria on the "out" and "back" run set average volumes reduces the statical rigor of this method.

a. The calibration run set average "round-trip" calibrated prover volume (*CPVavg*) at reference conditions for three or more consecutive calibration run sets shall exhibit a range of 0.020% or less.

b. The flow rate between consecutive calibration run sets shall be changed by at least 25% or more.

9.2.2 Each calibration run set shall consist of the following sequence and meet the following criteria:

a. Do five or more consecutive out of a maximum of ten consecutive master meter proving runs against the master prover to determine *MMFstart*. These *MMFstarts* shall agree within a range of 0.020% or less.

b. Do three or more consecutive out of a maximum of six consecutive field prover round-trip calibration runs with the master meter to determine the average "out" pass volume *Vb(out)*, average "back" pass volume *Vb(back)* and average "round-trip" volume (*CPVavg*). The three or more consecutive round-trip calibrated prover volumes (*CPVn*) at reference conditions shall exhibit a range of 0.020% or less.

c. Do five or more consecutive out of a maximum of ten consecutive master meter proving runs against the master prover to determine *MMFstop*. These *MMFstops* shall agree within a range of 0.020% or less.

d. The flow rate during each calibration run set shall be maintained within a range of 2.5%.

e. The delta % between the average of the five consecutive or more out of ten consecutive *MMFstarts* and the average of the five or more out of ten consecutive *MMFstops* in each calibration run set shall agree within 0.020%.

$$\text{Delta } \% = (MMFstart - MMFstop) \times 100$$

9.3 OPEN TANK MASTER PROVERS

9.3.1 The use of open tank provers, in this standard, are restricted to master provers only and shall not be calibrated by the master meter method.

9.3.2 For open tank master provers, the calibration sequence is the same as for the unidirectional displacement provers, see 9.1.

9.4 REPEATABILITY

As a measure of repeatability, the following equation shall be utilized to calculate and verify the range results:

$$\text{Repeatability } \% = [(\text{Max} - \text{Min})/(\text{Min})] \times 100$$

9.5 CALCULATION METHODS FOR PROVING THE MASTER METER

Two different meter factor calculation methods are in common use and described in this text. The two methods have been designated, the *Average Meter Factor Method*, and the *Average Data Method*.

9.5.1 Average Meter Factor Method

9.5.1.1 The Average Meter Factor method calculates an Intermediate Master Meter Factor (*IMMF*) for each selected run based on the individual (*Tp*), (*Tmm*), (*Pp*), (*Pmm*), (*N*), (*Ni*) values. The average (mean) of these separately calculated intermediate master meter factors is used as the Master Meter Factors (*MMFstart*) and (*MMFstop*) to calculate the Average Master Meter Factor (*MMFavg*) for a calibration run set.

$$R\% = [\text{High}(IMMF) - \text{Low}(IMMF)/\text{Low}(IMMF)] \times 100$$

9.5.1.2 The range of the intermediate master meter factors, for a calibration run set, is used to determine that the required repeatability requirement (< 0.020 percent) has been satisfied.

9.5.2 Average Data Method

9.5.2.1 The Average Data Method calculates the Master Meter Factor (*MMFstart*) and (*MMFstop*) using *Tp(avg)*, *Tmm(avg)*, *Pp(avg)*, *Pmm(avg)*, *N(avg)* values, from all the selected runs which satisfy the repeatability requirement stated in 9.3.

$$R\% = [(\text{High}(N) - \text{Low}(N))/\text{Low}(N)] \times 100$$

9.5.2.2 The range of the pulses (*N*), or interpolated (*Ni*), for the selected runs, is used to determine that the required repeatability requirement (< 0.020 percent) has been satisfied.

9.5.3 Alternate Calibration Procedure Method

9.5.3.1 If all parties agree, a meter proving may be performed *between* each field prover calibration run within the calibration run set. In that case, there would be an *MMFstop* and *MMFstart* between each field prover calibration run. Each master meter proving would consist of five consecutive runs within a range of 0.020% out of a maximum of five consecutive runs. Each calibration set consists of three field prover consecutive calibration runs within 0.020% out of a maximum of six consecutive runs. The *MMFstop* at the end of each calibration run may be designated the *MMFstart* for the next calibration run.

9.5.3.2 Under certain conditions, even though the repeatability criteria for individual provings of the master meter are more stringent, the alternate method may be advantageous for the following reasons

a. Proving the meter between each field prover calibration run allows for early detection of meter factor drift. On a large prover it might be good to know that *MMFstop* (*MMF2*) does not agree with *MMFstart* (*MMF1*) before making up to six consecutive calibration runs.

b. Proving the meter between each field prover calibration run allows for some drift in the master meter factor when making up to six consecutive calibration runs. This could be beneficial when calibrating large provers in flowing conditions that change over a period of time. While the *MMFstart* and *MMFstop* around each calibration run must be within a range of 0.020%, the first *MMFstart* does not necessarily have to agree with the last *MMF stop*. For comparison of standard versus alternate methods, see Table 12.

10 Correction Factors

In the master meter calibration procedure, the volume indicated by the master meter must be subjected to certain corrections in order to determine the base volume of the prover.

Calculations in this publication are based on determining a prover's base volume by master meter. Corrections are made for:

a. The effects of thermal expansion of the liquid in the master meter and the prover under calibration.

b. The effect of thermal expansion of the steel in the prover under calibration.

c. The compressibility of the liquid in the prover under calibration.

d. The elastic distortion of the prover under calibration due to pressure.

Correction for the temperature effects on the steel prover are combined and discussed in the following sections.

10.1 LIQUID DENSITY CORRECTION FACTORS

10.1.1 General

10.1.1.1 The liquid's density shall be determined by appropriate technical standards or if necessary proper correlations or equations of state.

10.1.1.2 If multiple parties are involved in the measurement, the method selected for determining the liquid's densities shall be mutually agreed upon by all concerned.

10.1.1.3 Appendix A, contains a list of recommended liquid versus API correlations in accordance with API's position paper dated 1981. Where an API correlation doesn't currently exist, the appropriate ASTM standard has been provided to assist the user community.

10.1.1.4 Liquid density correction factors are employed to account for changes in density due to the effects of temperature and pressure upon the liquid. These correction factors are:

a. *CTL*—corrects for the effect of temperature on the liquid density.

b. *CPL*—corrects for the effect of pressure on the liquid density.

10.1.2 Correction for Effect of Temperature on Liquid (*CTL*)

10.1.2.1 If a volume of petroleum liquid is subjected to a change in temperature, its density will decrease as the temperature rises, or increase as the temperature falls. This density change is proportional to the thermal coefficient of expansion of the liquid and the liquid temperature.

10.1.2.2 The correction factor for the effect of temperature on the liquid's density is called *CTL*. The *CTL* factor is a function of the liquid's base density (*RHOb*) and the liquid's temperature (*T*).

10.1.2.3 Appendix A contains assistance in determining an appropriate reference, to enable the correct (*CTL*) for the liquid involved to be determined.

10.1.3 Correction for Compressibility on the Liquid (*CPL*)

10.1.3.1 If a volume of petroleum liquid is subjected to a change in pressure, it's density will increase as the pressure increases, and decrease as the pressure decreases. This density change is proportional to the compressibility factor (*F*) of the liquid, which depends upon its base density and the liquid temperature. The correction factor for the effect of compressibility on liquid density is called (*CPL*). References to the appropriate standards for the compressibility factor (*F*), may be found in *API MPMS* Chapter 11.2.1, *API MPMS* Chapter 11.2.2 and Appendix A of this standard. *CPL* can be expressed as follows:

$$CPL = \frac{Ve}{Vo} = \frac{1}{1-[(P-Pe)\times F]}$$

where

Ve = volume at equilibrium pressure (Pe) at operating temperature,

Vo = volume at operating pressure (P) at operating temperature.

a. When the operating pressure is in gauge pressure units:

$$CPL = \frac{1}{1-[(Pg+Pba-Pe)\times F]}$$

where

Pg = operating pressure of the liquid in gauge pressure units,

Pba = base pressure in absolute pressure units,

Pe = equilibrium vapor pressure at the temperature of the liquid being measured, in absolute pressure units,

F = compressibility factor for the liquid.

b. When the operating pressure is in absolute pressure units:

$$CPL = \frac{1}{1 - [(Pa - Pe) \times F]}$$

where

Pa = $Pg + Pba$,

Pa = operating pressure of the liquid in absolute pressure units,

Pe = equilibrium vapor pressure at the temperature of the liquid being measured, in absolute pressure units,

F = compressibility factor for the liquid.

The liquid equilibrium vapor pressure (*Pe*) is considered to be equal to the base pressure (*Pb*) for liquids which have an equilibrium vapor pressure less than or equal to atmospheric pressure at flowing temperature, e.g. water.

Tank provers are calibrated using the master meter method at reference (or atmospheric) pressure. As a result, no *CPL* corrections are required for open tank prover calculations, except for on the master meter itself.

10.2 PROVER CORRECTION FACTORS

10.2.1 General

Prover correction factors are employed to account for changes in the prover volume due to the effects of temperature and pressure upon the steel. These correction factors are:

a. *CTS*—corrects for thermal expansion and/or contraction of the steel in the prover shell due to the average prover liquid temperature.

b. *CPS*—corrects for pressure expansion and/or contraction of the steel in the prover shell due to the average prover liquid pressure.

10.2.2 Correction for the Effect of Temperature on Steel (*CTS*)

Any metal container, be it a displacement prover, a tank prover when subjected to a change in temperature will change its volume accordingly. The volume change, regardless of prover shape, is normally proportional to the coefficient of thermal expansion of the material. The cubical coefficient of thermal expansion is normally proportional when the calibrated section and its detector switch mountings are constructed of a single material (displacement provers, and tank provers).

The coefficients of expansion (*Gc, Ga, Gl, Gmp*) for the prover should be the ones for the materials used in the construction of the calibrated section; however, the values contained in Table 6 shall be used if the coefficients of expansion are unknown.

10.2.2.1 *CTS* for Displacement and Open Tank Provers

10.2.2.1.1 The *CTS* for displacement provers and open tank provers assumes a singular construction material, and may be calculated from:

$$CTS = 1 + [(T - Tb) \times Gc]$$

where

Gc = mean coefficient of cubical expansion per degree temperature of the material of which the container is made between Tb and T,

Tb = base temperature,

T = mean liquid temperature in the container.

10.2.2.1.2 The cubical coefficient of expansion (*Gc*) for a displacement prover or open tank prover shall be the one for the materials used in the construction of its calibrated section; however, should the coefficient of expansion be unknown, then the *Gc* values contained in Table 6 shall be used.

10.2.2.2 Corrections for Small Volume Provers with External Detectors

10.2.2.2.1 The cubical coefficient of expansion used to calculate *CTS* for some displacement pipe provers has to be modified due to their design. In this special case, where the detector(s) are mounted externally and not on the prover barrel itself, the volume changes that occur due to temperature are defined in terms of the area change in the prover barrel, and s distance change between the detector positions. While occasionally these detector positions may be on a carbon or stainless steel mounting shaft, it is much more likely that they will be on a mounting of a special alloy (e.g., Invar) that has a very small linear coefficient of expansion.

10.2.2.2.2 For displacement pipe provers, which utilize detectors, not mounted in the calibrated section of the pipe but attached to a separate shaft (for example, small volume provers), the correction factor for the effect of temperature (*CTS*) may be calculated as follows:

$$CTS = \{1 + [(Tp - Tb) \times (Ga)]\} \times \{1 + [(Td - Tb) \times (Gl)]\}$$

where

Ga = area thermal coefficient of expansion for prover chamber,

Gl = linear thermal coefficient of expansion on displacer shaft,

Tb = base temperature,

Td = temperature of the detector mounting shaft or displacer shaft with external detectors,

Tp = temperature of the prover chamber.

10.2.2.2.3 The linear and area thermal coefficients of expansion used shall be the ones for the materials used in the construction of the prover; however, the values contained in Table 6 shall be used if the coefficients are unknown.

10.2.3 Correction for the Effect of Pressure on Steel, *CPS*

If a metal container such as a pipe or a tank prover is subjected to an internal pressure, the walls of the container will stretch elastically and the volume of the container will change accordingly.

The modulus of elasticity (E) for a displacement prover, preferably, should be based on data for the materials used in the construction of the calibrated section; however, the values contained in Table 7 shall be used if the modulus of elasticity (E) is unknown.

Tank provers are calibrated using the master meter at reference (or atmospheric) pressure. As a result, no *CPS* corrections are required for the open tank prover calculations.

10.2.3.1 Corrections for Single-Walled Container or Prover

10.2.3.1.1 While it is recognized that simplifying assumptions enter the equations below, for practical purposes the correction factor for the effect of internal pressure on the volume of a cylindrical container, called *CPS*, may be calculated from:

$$CPS = 1 + [(P - Pbg) \times (ID)] / (E \times WT)$$

Since Pbg, gauge pressure, is equal to zero, the equation simplifies to:

$$CPS = 1 + [(P \times ID) / (E \times WT)]$$

and,

$$ID = OD - (2 \times WT)$$

where

Pg = internal operating pressure of prover, in gauge pressure units,

Pbg = base pressure, in gauge pressure units,

ID = internal diameter of container,

E = modulus of elasticity of the metal in the calibrated section of the prover,

OD = outside diameter of the prover,

WT = wall thickness of the prover.

10.2.3.1.2 The modulus of elasticity (E) for a pipe prover or open tank prover, shall be the one for the materials used in the construction of the calibrated section; however, the values contained in Table 7 shall be used if the modulus of elasticity (E) is unknown.

10.2.3.2 Corrections for Double-Walled Container or Prover

For double-walled provers, the inner measuring section of the prover is not subjected to a net internal pressure, and the walls of this inner chamber do not stretch elastically. Therefore, in this special case:

$$CPS = 1.000000$$

10.3 COMBINED CORRECTION FACTORS

For the purpose of calculation, the corrections for the temperature and pressure effects on the prover and the temperature and pressure effects on the liquid can be combined. Errors can occur in mathematical calculations due to the sequencing and rounding between different machines and/or programs. To minimize these errors, a method was selected by the industry which combines correction factors in a specified sequence and discrimination level. The method for combining two or more correction factors is to first obtain a combined correction factor (*CCF*) by serial multiplication in the order given of the individual correction factors and rounding the *CCF* to the required number of decimal places. Therefore, for master meter proving the combined corrections factors are as follows:

a. The master meter combined correction factor, *CCFmm* is:

$$CCFmm = (CTLmm \times CPLmm \times MMF)^1$$

[1](for proving field prover using master meter)

$$CCFmm = (CTLmm \times CPLmm)^2$$

[2](for master meter calibration using master prover)

b. The master prover combined correction factor, *CCFmp* is:

$$CCFmp = CTSmp \times CPSmp \times CTLmp \times CPLmp$$

c. The field prover combined correction factor, *CCFp* is:

$$CCFp = CTSp \times CPSp \times CTLp \times CPLp$$

10.4 NOMINAL K-FACTORS (*NKF*)

Nominal K-factors (*NKF*) are utilized to determine the master meter factor (*MMF*). The original nominal K-factor (*NKF*) is a fixed value for a specific meter, determined by the manufacturer of the device and supplied with the new meter. This original nominal K-factor is established at the time of installation of the flow meter, and if unchanged can be used to calculate the meter factor. Using a constant unchanging nominal K-factor provides an audit trail through the meter proving system, establishes meter factor control charts and allows meter factor control of the system.

11 Recording of Field Data

All required field data shall be recorded and rounded in accordance with the discrimination levels specified in this section. In addition, see 7.2.

Field data discrimination levels *less than* those specified are not permitted in the calculation procedures for determining base prover volume.

Field data discrimination levels *greater than* those specified are not in agreement with the intent of this standard and should not be used in the calculation procedure.

11.1 SPECIFIED DISCRIMINATION LEVELS FOR FIELD DATA

Specified discrimination levels for field data are listed in the tables indicated below:

11.1.1 Liquid Data

RHOobs, RHOb	Table 1
Tobs, Tb	Table 3
VISb (if needed)	Table 11

11.1.2 Prover Data

OD, WT, ID	Table 2
Tp	Table 3
Pp	Table 4
Gc	Table 6
Ga	Table 6
Gl	Table 6
Gmp	Table 6
E	Table 7

11.1.3 Master Meter Data

KF	Table 8
MMRo	Table 8
MMRc	Table 8
Tmm	Table 3
Pmm	Table 4
Pem	Table 4
N, Ni, N(avg)	Table 10

11.2 DISCRIMINATION TABLES

11.2.1 In all tables that follow, the number of digits shown as (X) *in front of the decimal point* are illustrative purposes only, and may have a value more or less than the number (X) illustrated.

11.2.2 The number of digits shown as (**x**) *after the decimal point* are very specific as they define the required discrimination level for each value described.

11.2.3 Tables 8 and 9 have letters, such as ABCD.**xx**, to the left of the decimal point, in this case the letters do give the actual size of the value before the decimal and are intended to be specific, not illustrative.

11.2.4 In cases where a value is shown with the number 5 in the last decimal place, such as XX.x5, this is intended to signify that the last decimal place in the value must be rounded to either 0 or 5, no other value is permitted.

Table 1—Liquid Density Discrimination Levels

	API	DEN (kg/m^3)	RD
Observed Density (*RHOobs*)	XXX.**x**	XXX.5	X.**xxx5**
Base Density (*RHOb*)	XXX.**x**	XXXX.**x**	X.**xxxx**

Table 2—Dimensional Discrimination Levels—Prover Pipe Dimensions

	USC Units (in.)	SI Units (mm)
Outside Dimension (*OD*)	XX.**xxx**	XXX.**xx**
Wall Thickness (*WT*)	X.**xxx**	XX.**xx**
Inside Dimension (*ID*)	XX.**xxx**	XXX.**xx**

Table 3—Temperature Discrimination Levels

	USC Units (°F)	SI Units (°C)
Base Temperature (*Tb*)	60.0	15.00
Prover Temperature [*Tp, Tp(avg), Tmp, Tmp(avg)*]	XX.**x**	XX.**x5**
Master Meter Temperature [*Tmm, Tmm(avg)*]	XX.**x**	XX.**x5**
Detector Mounting Shaft Temperatures [*Td, Td(avg)*]	XX.**x**	XX.**x5**
Observed Temperature *(Tobs)*	XX.**x**	XX.**x5**

Table 4—Pressure Discrimination Levels

	USC Units		SI Units	
	(psia)	(psig)	(bar)	(kPa)
Base Pressure (*Pb*)	14.696	0.0	1.01325	101.325
Prover Pressure (*Pp*) [*Pp, Pp(avg), Pmp, Pmp(avg)*]	XX.**x**	XX.0	XX.**x**	XX.0
Master Meter Pressure [*Pmm, Pmm(avg)*]	XX.**x**	XX.0	XX.**x**	XX.0
Eq Vapor Pressure (*Pe*)	XX.**x**	XX.0	XX.**x**	XX.0

Table 5—Compressibility Factor Discrimination Levels

	USC Units	SI Units	
	(psi)	(bar)	(kPa)
Compressibility Factor	0.00000**xxx**	0.0000**xxx**	0.000000**xxx**
[*F, Fp, Fm, Fmp, Fmm*]	0.0000**xxxx**	0.000**xxxx**	0.00000**xxxx**
	0.000**xxxxx**	0.00**xxxxx**	0.0000**xxxxx**

Table 6—Coefficients of Thermal Expansion for Steel (*Gc, Ga, Gl, Gmp*)

Type of Steel	Thermal Expansion Coefficient	
	(per °F)	(per °C)
A. Cubical Coefficient (*Gc, Gmp*)		
Mild Carbon	0.0000186	0.0000335
304 Stainless	0.0000288	0.0000518
316 Stainless	0.0000265	0.0000477
17-4PH Stainless	0.0000180	0.0000324
B. Area Coefficient, (*Ga*)		
Mild Carbon	0.0000124	0.0000223
304 Stainless	0.0000192	0.0000346
316 Stainless	0.0000177	0.0000318
17-4PH Stainless	0.0000120	0.0000216
C. Linear Coefficient, (*Gl*)		
Mild Carbon	0.00000620	0.0000112
304 Stainless	0.00000960	0.0000173
316 Stainless	0.00000883	0.0000159
17-4PH Stainless	0.00000600	0.0000108
Invar Rod	0.00000080	0.0000014

Table 7—Modulus of Elasticity Discrimination Levels

	Modulus of Elasticity (*E*)		
Type of Steel	(psi)	(bar)	(kPa)
Mild Carbon	30,000,000	2,068,000	206,800,000
304 Stainless	28,000,000	1,931,000	193,100,000
316 Stainless	28,000,000	1,931,000	193,100,000
17-4PH Stainless	28,500,000	1,965,500	196,500,000

Table 8—Correction Factor Discrimination Levels

Correction Factors	
CTL	X.**xxxxxx**[a]
CPL	X.**xxxxxx**[a,b]
CPS	X.**xxxxxx**
CTS	X.**xxxxxx**
CTLp	X.**xxxxxx**
CPLp	X.**xxxxxx**
CPSp	X.**xxxxxx**
CTSp	X.**xxxxxx**
CTLmm	X.**xxxxxx**
CPLmm	X.**xxxxxx**
CTLmp	X.**xxxxxx**
CPLmp	X.**xxxxxx**
CPSmp	X.**xxxxxx**
CTSmp	X.**xxxxxx**
CCFp	X.**xxxxxx**
CCFmp	X.**xxxxxx**
CCFmm	X.**xxxxxx**
MMF	X.**xxxxxx**
IMMF	X.**xxxxxx**
MMFstart	X.**xxxxxx**
MMFstop	X.**xxxxxx**
MMFavg	X.**xxxxxx**
KF	AB.**xxx** or ABC.**xx** or ABCD.**x** or ABCDE.0
NKF	Value recorded as determined by Manufacturer

Notes on specific uses of *CPL* and *CTL*:

[a,b]*CPL* and *CTL* are calculated using *PWA, TWA*, and the average density [*RHO(avg)*], as determined for the whole metered delivery of the liquid, when used to calculate the *CCF* for a measurement ticket. *CCF* is derived from *CTL* x *CPL* x *MF*, which can also be defined as the meter factor at base conditions.

[a]*CPL* is required to calculate a *CMF* or *CKF*, and is calculated using an assumed average pressure, average temperature, and average density, for the whole delivery at the time of proving.

Table 9—Volume Discrimination Levels

	USC Units		SI Units	
	(Bbl)	(gal)	(M^3)	(L)
Meter Readings (*MMRo, MMRc*)	XX.**xx**	XX.**x**	XX.**xxx**	XX.**xx**
Scale Reading (*SRu, SRl*)	X.**xxxx**	X.**xx**	—	X.**xx**
Volume Discrimination Levels (*BPV, BPVmp, CPV, CPVn, ISVm, ISVmm, BPVamp, IVm, IVmm, GSV, Vbout, Vbback, GSVm, GSVmm, GSVmp, and GSVp*)	ABC.**xxxx**	ABCDE.**x**	AB.**xxxxx**	ABCDE.**x**
	AB.**xxxx**	ABCD.**xx**	A.**xxxxx**	ABCD.**xx**
	A.**xxxxx**	ABC.**xxx**	0.**xxxxxx**	ABC.**xxx**
	0.**xxxxxx**	AB.**xxxx**	0.0**xxxxxx**	AB.**xxxx**

Table 10—Pulse Discrimination Levels

	(*N*)	(*Ni*)	[*N(avg)*]
Whole Pulse Applications	XX.0	—	XX.**x**
Pulse Interpolation Applications	—	XX.**xxx**	XX.**xxxx**

Table 11—Liquid Viscosity Discrimination Levels

	(*cP*)
Liquid Viscosity	XXX.**x**

Table 12—Summary of the Standard Method vs. Alternate Calibration Method(s)

Standard Method (Average *MF* or Average Data Method)	Alternate Calibration Method (A)	Alternate Calibration Method (B) (uses *MMFstop* as the *MMFstart* of the next run)
Calibration Run Set I	Calibration Run Set I	Calibration Run Set I
MMFstart (MMF1)	*MMFstart (MMF1)*	*MMFstart (MMF1)*
Calibration Run 1st consecutive	Calibration Run 1st consecutive *MMFstop(MMF2)*	Calibration Run 1st consecutive *MMFstop (MMF2)*
Calibration Run 2rd consecutive	*MMFstart(MMF3)*	*MMFstart (same as MMF2)*
Calibration Run 3rd consecutive *MMFstop* (*MMF2*)	Calibration Run 2nd consecutive *MMFstop(MMF4)* *MMFstart(MMF5)*	Calibration Run 2nd consecutive *MMFstop (MMF3)* *MMFstart (same as MMF3)*
Above pattern can be continued up to a maximum of six consecutive Calibration Runs.	Calibration Run 3rd consecutive *MMFstop(MMF6)*	Calibration Run 3rd consecutive *MMFstop (MMF4)*
Allowable for Calibration Runs: Three consecutive runs, within a range of 0.020%, out of a maximum of six consecutive calibration runs.	Above pattern can be continued up to a maximum of six consecutive Calibration Runs.	Above pattern can be continued up to a maximum of six consecutive Calibration Runs.
Allowable for each *MMF*: Five consecutive runs, within a range of 0.020%, out of a maximum of ten consecutive proving runs.	Allowable for Calibration Runs: Three consecutive runs, within a range of 0.020%, out of a maximum of six consecutive calibration runs.	Allowable for Calibration Runs: Three consecutive runs, within a range of 0.020%, out of a maximum of six consecutive calibration runs.
MMF1 must be within 0.020% of *MMF2*.	Allowable for each *MMF*: Five consecutive runs, within a range of 0.020%, out of a maximum of five consecutive proving runs.	Allowable for each *MMF*: Five consecutive runs, within a range of 0.020%, out of a maximum of five consecutive proving runs.
	MMF1 must be within 0.020% of *MMF2*. *MMF3* must be within 0.020% of *MMF4*. *MMF5* must be within 0.020% of *MMF6*.	*MMF1* must be within 0.020% of *MMF2*. *MMF2* must be within 0.020% of *MMF3*. *MMF3* must be within 0.020% of *MMF4*.
Calibration Run Set II	Calibration Run Set II	Calibration Run Set II
Conduct the same as Calibration Run Set I except at different flow rate.	Conduct the same as Calibration Run Set I except at different flow rate.	Conduct the same as Calibration Run Set I except at different flow rate.
Calibration Run Set III	Calibration Run Set III	Calibration Run Set III
Conduct the same as Calibration Run Set II except at different flow rate. Standard allows 3 or more Calibration Run Sets within 0.020% or less to calculate for *CPV.*	Conduct the same as Calibration Run Set II except at different flow rate. Standard allows 3 or more Calibration Run Sets within 0.020% or less to calculate for *CPV.*	Conduct the same as Calibration Run Set II except at different flow rate. Standard allows 3 or more Calibration Run Sets within 0.020% or less to calculate for *CPV.*

12 Calculation Sequence, Discrimination Levels, and Rules for Rounding

The following section describes the steps required to obtain a calculated value for a master meter factor, based on standardized input data and exact calculation procedures. This will ensure that all interested parties will arrive at the same answer. Note that after the *first eleven steps*, which are common to the average meter factor method, the average data method and the alternate calibration method in determining the master meter factor value, the methods diverge. They are described separately in the following steps.

12.1 DISPLACEMENT PROVERS

This section rigorously specifies the rounding, calculation sequence, and discrimination levels required to determine a base prover volume.

The procedures outlined below do not include the requirements for the calculations associated with *RHOb, CTL* and *F.* The rounding, calculation sequence and discrimination levels for these terms are, for the most part, contained in the references listed in Appendix A. When a reference does not contain an implementation procedure, Appendix A contains a suggested method of implementation.

The following rules for rounding, calculation sequence and discrimination levels are applicable for volumetric master meter calibration of displacement provers (displacement pipe, small volume, and volumetric tank provers).

Flow Charts (Figures 4 and 5) have been prepared to graphically explain the calculation sequences.

a. Step 1—Obtain General Data.

Obtain, round and record the following general data:

- Proving report no.
- Date.
- Time.
- Liquid type.
- API gravity/relative density at base conditions.
- Viscosity (if needed).
- Flow rate tolerance.
- Operator's name.
- Witness.

b. Step 2—Obtain Master Meter Data.

Obtain and record the following data for the master meter:

- Manufacturer.
- Meter type.
- Model number.
- Meter size.
- Nominal K-factor (*NKF*).
- Serial number.

c. Step 3—Obtain Master and Field Prover Data.

1. Obtain, round and record the following data from a previous calibration certificate or from the prover manufacturer:
   - Prover type and size.
   - Type of steel.
   - Manufacturer.
   - Serial number.
   - Location.
   - Coefficients of thermal expansion (*Gc, Ga, Gl, Gmp*).
   - Modulus of elasticity for prover (*E*).
   - Displacer type and size.
   - Outside diameter of the prover pipe (*OD*).
   - Wall thickness of the prover pipe (*WT*).
2. Round the values for *Gc, Ga, G1,* and *Gmp* in accordance with Table 6.
3. Round the value for *E* in accordance with Table 7.
4. Round the values for *OD* and *WT* in accordance with Table 2.
5. Calculate the prover's *ID* using the following equation:

$$ID = OD - (2 \times WT)$$

6. Round the value for the prover's *ID* in accordance with Table 2.

d. Step 4—Master Meter Calibration Sequence.

Connect the master meter, master prover and the field prover together so that the liquid flows through all three devices. See Figures 1 and 2. Ensure that the air has been eliminated by venting at the highest point in the provers. This may require running the displacers several times to ensure the complete elimination of air from the proving system.

e. Step 5—Set the Flowrate for the Calibration Run Set #1.

Set the flow rate for the Calibration Run Set #1. When the flowrate and temperature are stabilized, the calibration run set should be initiated.

f. Step 6—Master Meter Prover Run to Determine MMFstart.

Begin the run sequence with the master prover. Go to *MMFstart* Subroutine. Determine the *MMFstart* from the following:

g. Step 7—Make an "Out" Pass Proving Run on the Master Meter.

h. Step 8—Record Master Meter and Master Prover Run Data.

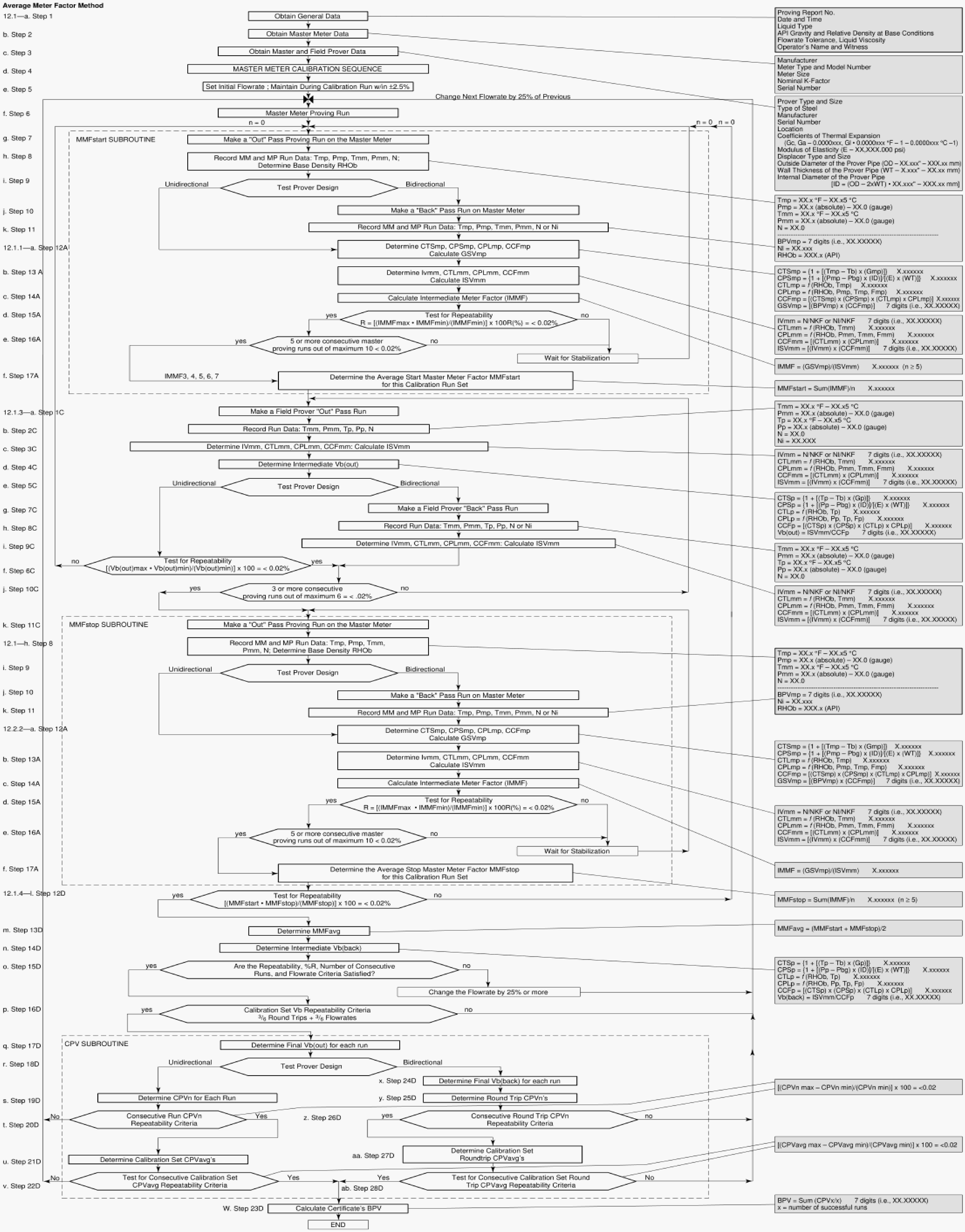

Figure 4—Flow Chart for Master Meter Calibration of Provers—Average Meter Factor Method

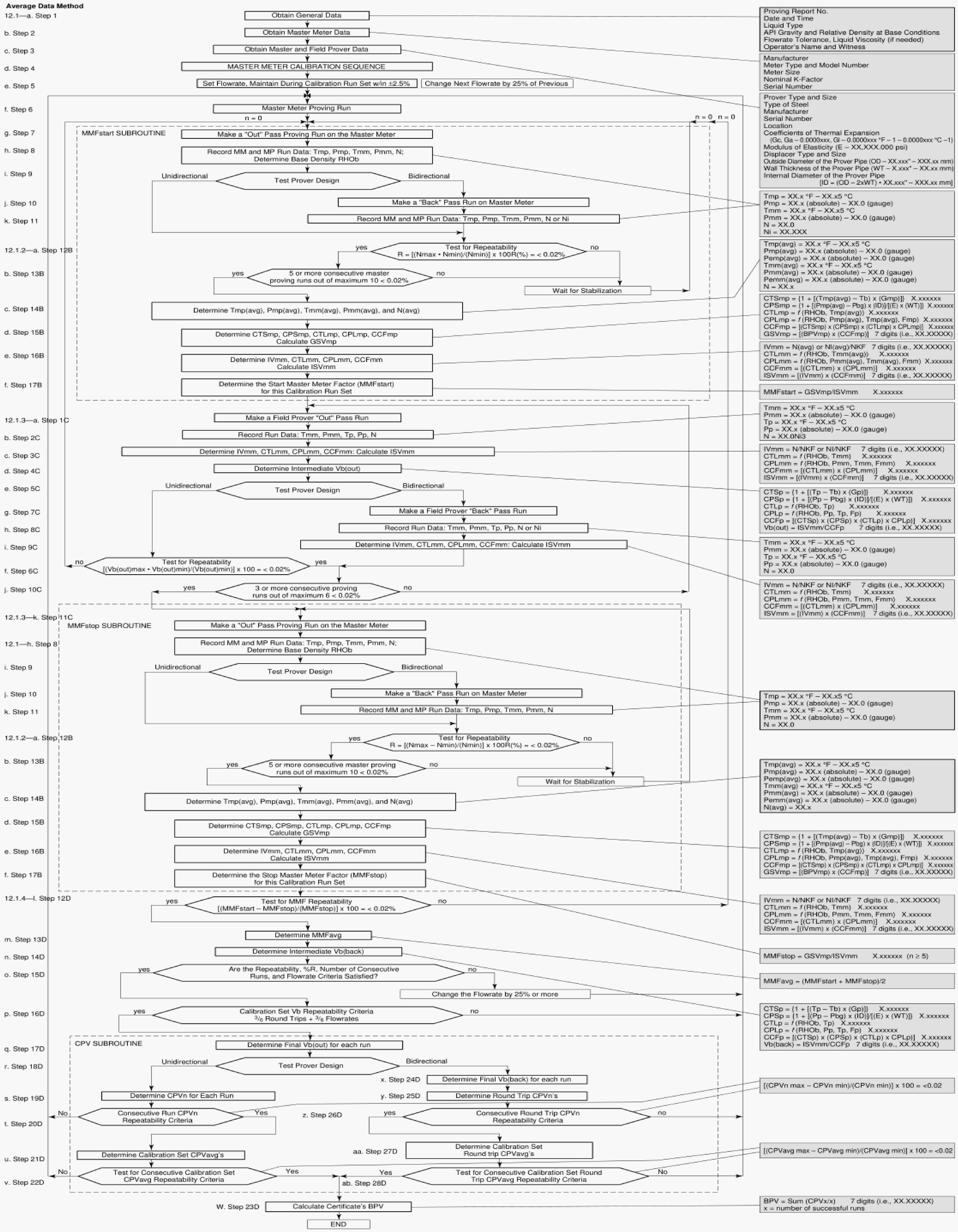

Figure 5—Flow Chart for Master Meter Calibration of Provers—Average Data Method

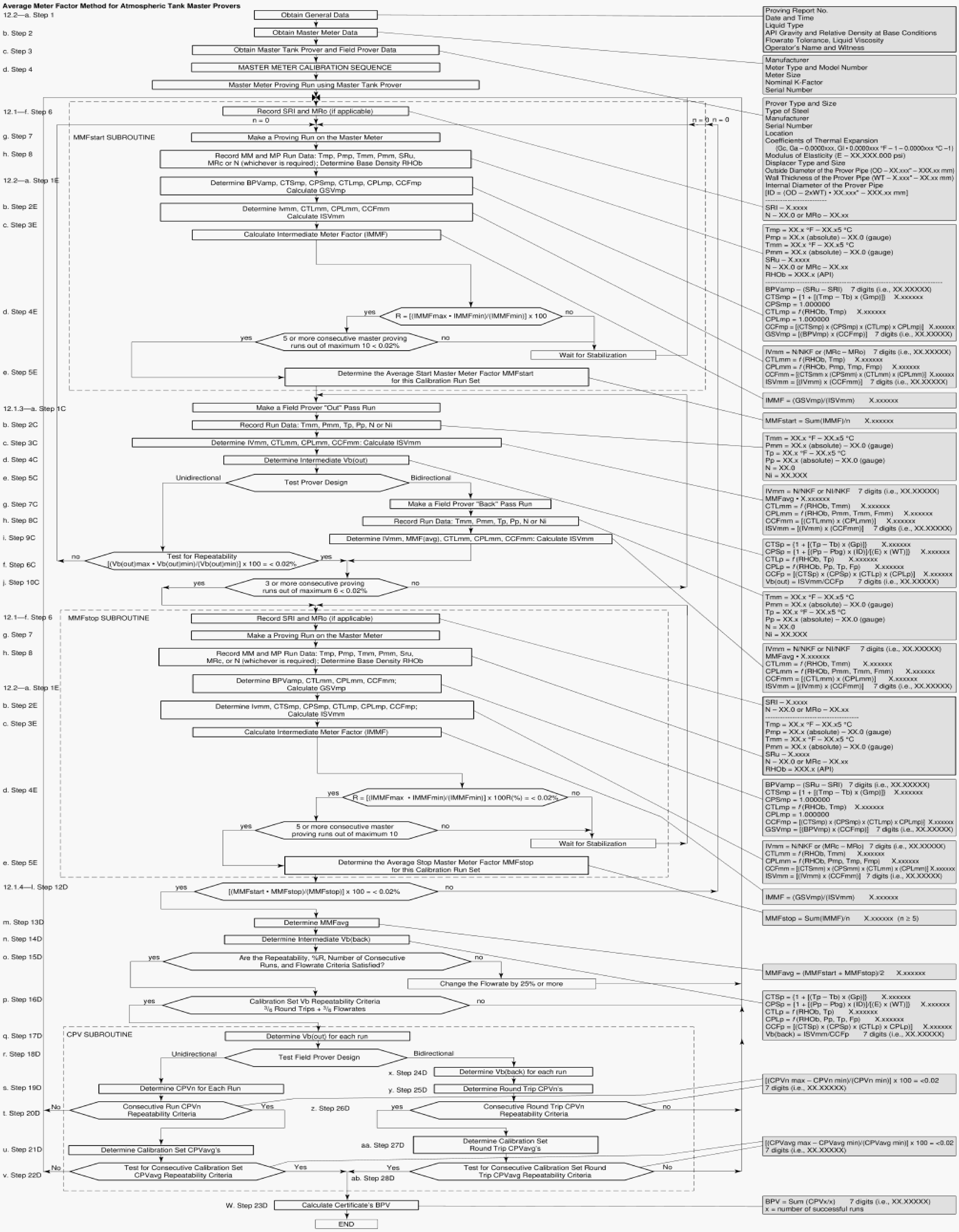

Figure 6—Flow Chart for Master Meter Calibration of Atmospheric Tank—Average Meter Factor Method

1. For every proving pass or run of the master meter against the master prover, record the following data:

Master Prover Data	Discrimination Levels
Tmp (for displacement and tank provers)	Table 3
Pmp (for displacement provers)	Table 4
BPVmp (for displacement provers)	Table 9
BPVamp (for tank provers)	Table 9
SRu (for tank provers)	Table 9
SRl (for tank provers)	Table 9

Master Meter Data	Discrimination Levels
Tmm	Table 3
Pmm	Table 4
Ni	Table 10
N	Table 10
MMRc	Table 9
MMRo	Table 9

2. Using a certified temperature device (certificate should be available for inspection), record the temperature of the liquid in the master meter (*Tmm*) and master prover (*Tmp*). Round the value in accordance with Table 3.
3. Using a certified pressure device (certificate should be available for inspection), measure and record the pressure of the liquid in the master meter (*Pmm*) and field prover (*Pp*). Round the value in accordance with Table 4.

4. Determine base density by using the observed density (*RHOobs, DENobs, APIobs, or RDobs*) and observed temperature (*Tobs*), calculate the base density (*RHOb, DENb, APIb, RDb*) by either the appropriate technical standards, the proper density correlations, of the relevant equations of state. Round the density value in accordance with specifications given in Table 1.

Note: At some metering facilities, an online density meter (densitometer) is installed to continuously monitor and determine density in real time. The user should refer to the Appendix A—Liquid Density Correlation, for information on these special calculation requirements.

5. Collect the master meter pulses, *MMRo* and *MMRc*, between switch closures during a single pass of the master prover.

i. Step 9—Test for Prover Design

1. If unidirectional prover—jump to calculate *GSVmp*, a. Step 12a, 12.1.1.
2. If bidirectional prover—proceed to make a "back" pass run on master meter, j. Step 10.

j. Step 10—Make a "Back" Pass Run on Master Meter.

k. Step 11—Record Master Meter and Master Prover Run Data.

For every proving pass or run of the master meter against the master prover, record the following data:

Master Prover Data	Discrimination Levels
Tmp (for displacement and tank provers)	Table 3
Pmp (for displacement provers)	Table 4

Master Meter Data	Discrimination Levels
Tmm	Table 3
Pmm	Table 4
Ni	Table 10
N	Table 10
MMRc	Table 9
MMRo	Table 9

If using the average data method, go to 12.1.3. If not, continue to 12.1.1.

12.1.1 Determination of the Master Meter Factor Using the Average Meter Factor Method

See Figure 4 for a flowchart of this method.

a. Step 12A—Calculate *GSVmp*.

The gross standard volume (*GSVmp*) of the master prover, that is the "true" volume of liquid passing through the prover during the proving run, is calculated from the following equation:

$$GSVmp = BPVmp \times CCFmp$$

The base prover volume (*BPVmp*) is determined from the prover calibration certificate.

To calculate the combined correction factor (*CCFmp*) requires that all four individual correction factor values, *CTSmp, CPSmp, CTLmp, CPLmp*, are calculated and then sequentially multiplied together, in the order specified, for each selected proving run, to obtain the combined correction factor (*CCFmp*) for the prover volume.

1. *CTSmp* determination:

The *CTSmp* value corrects for the thermal expansion of the steel in the prover calibrated section using the average prover liquid temperature *Tmp(avg)*, from all the selected proving runs.

For displacement master provers with detectors mounted internally in the calibrated section, the following formula shall be used:

$$CTSmp = 1 + [(Tmp - Tb) \times (Gmp)]$$

For displacement master provers, usually small volume provers, which utilize detectors that are mounted externally on a shaft, then this modified formula shall be used:

$$CTSmp = \{1 + [(Tmp - Tb) \times (Ga)]\} \times \{1 + [(Td - Tb) \times (Gl)]\}$$

The *CTSmp* value shall be rounded in accordance with Table 8 discrimination level requirements.

2. *CPSmp* determination:

The *CTSmp* value corrects for the expansion of the steel in the prover calibrated section using the average liquid pressure of the master prover, *Pmp(avg)*, from all of the selected proving runs.

The *CPSmp* for a single wall pipe master prover shall be calculated using the following formula:

$$CPSmp = \frac{1 + [(Pmp - Pbg) \times ID]}{E \times WT}$$

where

$$ID = [OD - (2 \times WT)] \text{ and } Pbg = 0 \text{ psi}$$

For a double wall displacement master prover the value of *CPSmp* = 1.000000.

The *CPSmp* value shall be rounded in accordance with Table 8 discrimination level requirements.

3. *CTLmp* determination:

Using the base density (*RHOb, APIb, RDb*, and *DENb*) and the temperature of the liquid (*Tmp*) in the master prover, together with the appropriate standards or computer routines, a value for *CTLmp* can be obtained for each of the selected proving runs. Round the values according to the discrimination level requirements specified in Table 8.

4. *CPLmp* Determination

Using the density value (*RHOb, APIb, RDb*, and *DENb*), the master prover pressure (*Pmp*), and the master prover temperature (*Tmp*), calculate the value of *Fmp* using the appropriate technical standards for each of the selected proving runs. Round the values according to the discrimination level requirements specified in Table 5.

Using this compressibility factor (*Fmp*), determined in the preceding step, together with the pressure in the master prover calibrated section (*Pmp*), the equilibrium vapor pressure of the liquid in the master prover (*Pemp*), and the base pressure (*Pba*), calculate the (*CPLmp*) value using the following expression:

$$CPLmp = \frac{1}{1 - \{[Pmp + Pba - Pemp] \times Fmp\}}$$

Round this value according to the requirements specified in Table 8.

Note: If the vapor pressure of the liquid is less than atmospheric pressure at normal temperature then *Pemp* is considered to be 0 psig.

5. *CCFmp* determination:

Having determined the four above described correction factors, the combined correction factor of the master prover (*CCFmp*) can now be calculated, by serial multiplication of the correction factors, in the exact order specified, using the equation shown below and rounding at the end of the multiplication. This value shall be rounded according to the requirements specified in Table 8.

$$CCFmp = CTSmp \times CPSmp \times CTLmp \times CPLmp$$

As stated above, the *GSVmp* is now calculated for each of the selected master proving runs by the following equation, and rounded to the discrimination level requirements contained in Table 9:

$$GSVmp = BPVmp \times CCFmp$$

Round the value for *GSVmp* according to Table 9.

b. Step 13A—Calculate *ISVmm*.

The indicated standard volume (*ISVmm*) of the master meter is the volume of the liquid passing through the meter for the selected runs, with no correction for meter inaccuracies, calculated by the following equation:

$$ISVmm = IVmm \times CCFmm$$

The indicated volume (*IVmm*) through the master meter is calculated as shown below.

To calculate the combined correction factor (*CCFmm*) requires that two individual correction factor values, *CTLmm* and *CPLmm*, are calculated and then sequentially multiplied together, in order specified, to obtain the combined correction factor (*CCFmm*) for the master meter.

1. *IVmm* determination:

Using a digital pulse train, the indicated volume (*IVmm*) of liquid passing through the master meter shall be calculated by dividing the pulses (*N*) or the interpolated pulses (*Ni*) for each selected proving run by the nominal K-factor (*NKF*) as shown below. Round and record the value of *IVmm* in accordance with the discrimination levels specified in Table 9.

$$IVmm = \frac{N}{NKF} \quad \text{or} \quad IVmm = \frac{Ni}{NKF}$$

2. *CTLmm* determination:

By using a base density (*RHob, APIb, RDb, DENb*), and the temperature (*Tmm*) of the master meter, together with the relevant standards or computer routines, a value for *CTLmm* can be obtained for each of the selected proving runs. Round this value according to the discrimination level requirements specified in Table 8.

3. *CPLmm* determination:

Using the density value (*RHOb, APIb, RDb*, and *DENb*), the master meter pressure (*Pmm*), and the master meter temperature (*Tmm*) for each of the selected proving runs, calculate the value of *Fmm* using the appropriate technical standards. Round this value according to the discrimination level requirements specified in Table 5.

Using the compressibility factor (*Fmm*) determined in the preceding step, together with the pressure in the master meter (*Pmm*), the equilibrium vapor pressure of the liquid in the master meter (*Pemm*), and the base pressure (*Pba*), for each of the selected proving runs, calculate the *CPLmm* value using the following expression.

$$CPLmm = \frac{1}{1 - \{[Pmm + Pba - Pemm] \times Fmm\}}$$

Round this value according to the requirements specified in Table 8.

Note: If the vapor pressure of the liquid is less than atmospheric pressure at normal temperature then *Pemm* is considered to be 0 psig.

4. *CCFmm* determination:

Having determined the two above described correction factors, the combined correction factor of the master meter (*CCFmm*) can now be calculated, by serial multiplication of the correction factors, in the exact order specified, using the equation shown below and rounding at the end of the multiplication. This value shall be rounded according to the requirements specified in Table 8.

$$CCFmm = CTLmm \times CPLmm$$

The *ISVmm* shall now be calculated by the following equation:

$$ISVmm = IVmm \times CCFmm$$

Round this value according to the requirements specified in Table 9.

c. Step 14A—Calculate *IMMF*.

Intermediate master meter factors (*IMMF*) are determined at the time of proving, for each of the acceptable consecutive proving runs, by the formula:

$$IMMF = \frac{GSVmp}{ISVmm}$$

Record and round the values of the *IMMF* according to the discrimination level requirements specified in Table 8.

d. Step 15A—Test for Repeatability Criteria.

See 9.1, 9.2, and 9.3 for the repeatability criteria.

To judge the acceptability of each of the selected run data, the repeatability for the average master meter factor method (*MMFavg*) is calculated as follows:

Intermediate master meter factors (*IMMF*) are calculated for each selected pass or round trip of the prover. The range of these intermediate meter factors, for all the acceptable consecutive proving runs, is now calculated, and used as the measure of acceptability for the master meter proving. In the method, the complete calculation steps to determine an intermediate master meter factor have to be performed for every selected pass or round trip, and then comparing all these intermediate master meter factors for acceptable repeatability.

For a master meter proving using a displacement master prover the range percent *R*% of the acceptable consecutive intermediate master meter factors (*IMMF*) shall not exceed 0.020%. This range is calculated using the following formula:

$$R\% = \frac{IMMFmax - IMMFmin}{IMMFmin} \times 100$$

An example of this repeatability check is shown at the bottom of this page:

e. Step 16A—Test Runs for Repeatability Criteria.

Master meter factor determination shall consist of five or more consecutive master proving runs out of maximum 10 consecutive master proving runs which exhibit a range of 0.02% or less.

- Yes—Proceed to determine average *MMFstart* for this calibration run set, f. Step 17A.
- No—Wait for stabilization then return back to *MMFstart* subroutine: make an "out" pass proving run on the master meter, g. Step 7, 12.1. to collect additional run data.

f. Step 17A—Determine Average *MMFstart* for this Calibration Run Set.

The master meter start factor (*MMFstart*) is a value used to adjust for any small inaccuracies associated with the performance of the master meter as determined at the time of proving. Having established that the range (repeatability) of the intermediate master meter factors (*IMMF*) meets the acceptability criteria, then a master meter start factor shall be calculated as follows:

$$MMstart = \frac{\sum IMMF}{n}$$

Where:

n = the number of *IMMF*, where $n \geq 5$, from the selected proving runs.

Round and record this value to the discrimination level requirements as specified in Table 8.

12.1.2 Calculating a Master Meter Factor Using the Average Data Method

Having made the selected number of proving runs to collect run data for the "Out" pass, record the results of the data for *Tmm, Pmm, Pmp*, and *N* or *Ni* as described in k. Step 11, 12.1.—Record Master Meter and Master Prover Run Data, proceed to the following step:

a. Step 12B—Determine Repeatability.

Using the average data method, requires that the range of the pulse generated for each selected pass or round trip, be calculated, and used to measure acceptable repeatability. Acceptable repeatability *R*(%) for a master meter proving with a master proving with a master prover shall not exceed a range of 0.02%. To determine the range, examine the pulses generated for each of the selected proving runs, and use the following formula to calculate the repeatability:

$$R\% = \frac{Highest\ Pulse - Lowest\ Pulse}{Lowest\ Pulse} \times 100$$

Example of Repeatability Check

Run	Total Pulses	Prover Temperature	Meter Temperature	Prover Pressure	Meter Pressure	GSVmp	ISVmm	IMMF
1	12,234	72.5	73.0	23.0	23.0	22.3356	22.4883	0.993210
2	12,232	72.0	73.0	23.0	23.0	22.3348	22.4855	0.993298
3	12,237	72.0	72.5	22.0	23.0	22.3363	22.4854	0.993369
4	12,237	72.0	72.5	23.0	23.0	22.3360	22.4892	0.993188
5	12,233	72.5	73.0	23.0	23.0	22.3340	22.4856	0.993258
					Average Master Meter Factor (IMMF)			0.993265

$$R\% = \frac{IMMFmax - IMMFmin}{IMMFmin} \times 100$$

$$R\% = \frac{0.993369 - 0.993188}{0.993188} \times 100 = 0.018\%$$

An example of this repeatability check is shown below:

Run	Prover Temp.	Meter Temp.	Prover Pressure	Meter Pressure	Total Pulses
1	72.5	73.0	23.0	23.0	12,234
2	72.0	73.0	23.0	23.0	12,232
3	72.0	72.5	22.0	22.0	12,234
4	72.0	72.5	23.0	23.0	12,234
5	72.5	73.0	23.0	23.0	12,233
Avg.	72.2	72.8	22.8	22.8	12,233.4

$$R\% = \frac{Highest\ Pulse - Lowest\ Pulse}{Lowest\ Pulse} \times 100$$

$$R\% = \frac{12{,}234 - 12{,}232}{12{,}232} \times 100 = 0.014\%$$

Once the selected proving runs satisfy the repeatability requirement by not exceeding 0.02%, the following data shall be calculated:

Prover Data	Discrimination Levels
Tmp(avg)	Table 3
Pmp(avg)	Table 4
Pemp(avg)	Table 4

Meter Data	Discrimination Levels
Tmm(avg)	Table 3
Pmm(avg)	Table 4
Pemm(avg)	Table 4
N(avg)	Table 10

b. Step 13B—Test Runs for Repeatability Criteria.

Master meter factor determination shall consist of five or more consecutive master proving runs out of maximum 10 consecutive master proving runs which exhibit a range of 0.02% or less.

- Yes—proceed to determine average *Tmp, Pmp, Tmm, Pmm, N(MMFstart)*, c. Step 14B for this calibration run set.
- No—wait for stabilization then return back to *MMF-start* subroutine: make an "out" pass proving run on the master meter, g. Step 7, 12.1. to collect additional run data.

c. Step 14B—Determine Average *Tmp, Pmp, Tmm, Pmm, N.*

Calculate the average *Tmp, Pmp, Tmm, Pmm, N* for the calibration run set.

d. Step 15B—Calculate *GSVmp.*

The gross standard volume (*GSVmp*) of the master prover, that is the "true" volume of liquid passing through the prover during the proving run, is calculated from the following equation:

$$GSVmp = BPVmp \times CCFmp$$

The base prover volume (*BPVmp*) is determined from the prover calibration certificate.

To calculate the combined correction factor (*CCFmp*) requires that all four individual correction factor values, *CTSmp, CPSmp, CTLmp, CPLmp*, are calculated and then sequentially multiplied together, in the order specified rounding at the end of the multiplication to obtain the combined correction factor (*CCFmp*) for the master prover.

1. *CTSmp* determination:

The *CTSmp* value corrects for the thermal expansion of the steel in the prover calibrated section using the average prover liquid temperature [*Tmp(avg)*] from all the selected proving runs.

For displacement master provers with detectors mounted internally in the calibrated section, the following formula shall be used:

$$CTSmp = 1 + \{[Tmp(avg) - Tb] \times Gmp\}$$

For displacement master provers, usually small volume provers, which utilize detectors that are mounted externally on a shaft, then this modified formula shall be used:

$$CTSmp = \{1 + [(Tmp(avg) - Tb) \times Ga]\} \times \{1 + [(Td(avg) - Tb) \times Gl]\}$$

The *CTSmp* value shall be rounded in accordance with Table 8 discrimination level requirements.

2. *CPSmp* determination:

The *CTSmp* value corrects for the expansion of the steel in the prover calibrated section using the average liquid pressure of the master prover [*Pmp(avg)*] from all of the selected proving runs.

The *CPSmp* for a single-wall pipe master prover shall be calculated using the following formula:

$$CPSmp = 1 + \frac{[Pmp(avg) - Pbg] \times ID}{E \times WT}$$

where

$ID = OD - (2 \times WT)$,

$Pbg = 0$ psig.

For a double-wall displacement master prover the value of *CPSmp* = 1.000000.

The *CPSmp* value shall be rounded in accordance with Table 8 discrimination level requirements.

3. *CTLmp* determination:

By using an average base density (*RHOb, APIb, RDb*, and *DENb*) and the average temperature of the liquid [*Tmp(avg)*] in the master prover, together with the relevant standards or computer routines, a value for *CTLmp* can be obtained. Round this value according to the discrimination level requirements specified in Table 8.

4. *CPLmp* determination:

Using an average density value (*RHOb, APIb, RDb*, and *DENb*), the master prover pressure [*Pmp(avg)*], and the average master prover temperature [*Tmp(avg)*], calculate the value of *Fmp* using the appropriate technical standards. Round this value according to the discrimination level requirements specified in Table 5.

Using this compressibility factor (*Fmp*), determined in the preceding step, together with the average pressure in the master prover calibrated section [*Pmp(avg)*], the equilibrium vapor pressure of the liquid in the master prover [*Pemp(avg)*], and the base pressure (*Pba*), calculate the *CPLmp* value using the following expression.

$$CPLmp = \frac{1}{1 - [Pmp(avg) + Pba - Pemp(avg) \times Fmp]}$$

Round this value according to the discrimination level requirements specified in Table 8.

Note: If the vapor pressure of the liquid is less than atmospheric pressure at normal temperature then *Pemp(avg)* is considered to be 0 psig.

5. *CCFmp* determination:

Having determined the four previously described correction factors, the combined correction factor of the master prover (*CCFmp*) can now be calculated, by serial multiplication of the correction factors, in the exact order specified, using the equation shown below and rounding at the end of the multiplication. This value shall be rounded according to the requirements specified in Table 8.

$$CCFmp = CTSmp \times CPSmp \times CTLmp \times CPLmp$$

6. Calculate *GSVmp*:

The *GSVmp* is now calculated for each of the selected master proving runs by the following equation, and rounded to the discrimination level requirements contained in Table 9:

$$GSVmp = BPVmp \times CCFmp$$

Round the value for *GSVmp* according to Table 9.

e. Step 16B—Calculate *ISVmm*.

The indicated standard volume (*ISVmm*) of the master meter is the volume of the liquid passing through the meter for the selected runs, with no correction for meter inaccuracies, calculated by the following equation:

$$ISVmm = IVmm \times CCFmm$$

The indicated volume (*IVmm*) through the master meter is calculated as shown below.

To calculate the combined correction factor (*CCFmm*) requires that two individual correction factor values, *CTLmm* and *CPLmm*, are calculated and then sequentially multiplied together, in order specified, to obtain the *CCFmm* for the master meter.

1. *IVmm* determination:

Using a digital pulse train, the indicated volume (*IVmm*) of liquid passing through the master meter to be calculated by dividing the average of all the pulses, *N(avg)*, for all the selected proving runs, by the nominal K-factor (*NKF*) as shown below. Round and record the value of *IVmm* in accordance with the discrimination levels specified in Table 9.

$$IVmm = \frac{N(avg)}{NKF}$$

2. *CTLmm* determination:

By using a average base density (*RHOb, APIb, RDb DENb*), and the average temperature [*Tmm(avg)*] of the liquid in the master meter, together with the relevant standards or computer routines, a value for *CTLmm* can be obtained. Round this value according to the discrimination level requirements specified in Table 8.

3. *CPLmm* determination:

Using an average density value (*RHOb, APIb, RDb*, and *DENb*), the average master meter pressure [*Pmm(avg)*], and average the master meter temperature [*Tmm(avg)*], from all of the selected proving runs, calculate the value of *Fmm* using the appropriate technical standards. Round this value according to the discrimination level requirements specified in Table 5.

Using this compressibility factor (*Fmm*) determined in the preceding step, together with the average pressure in the master meter [*Pmm(avg)*], the average equilibrium vapor pressure of the liquid in the master meter [*Pemm(avg)*], and the base pressure (*Pba*), calculate the *CPLmm* value using the following expression:

$$CPLmm = \frac{1}{1 - \{[Pmm(avg) + Pba - Pemm(avg)]XFmm\}}$$

Round this value according to the requirements specified in Table 8.

Note: If the vapor pressure of the liquid is less than atmospheric pressure at normal temperature then *Pemm(avg)* is considered to be 0 psig.

4. *CCFmm* determination:

Having determined the two above described correction factors, the combined correction factor of the master meter (*CCFmm*) shall now be calculated, by serial multiplication of the correction factors, in the exact order specified, rounding at the end of the multiplication, using the equation shown below. Round this value according to the requirements specified in Table 8.

$$CCFmm = CTLmm \times CPLmm$$

The *ISVmm* shall now be calculated by the following equation:

$$ISVmm = IVmm \times CCFmm$$

Round this value according to the requirements specified in Table 9.

f. Step 17B—Determine MMFstart.

The master meter factor (*MMFstart*) is determined at the time of proving by the formula:

$$MMFstart = \frac{GSVmp}{ISVmm}$$

Round this value according to the discrimination level requirements as specified in Table 8.

12.1.3 Start Making Runs on the Field Prover

a. Step 1C—Make a Field Prover "Out" Pass Run.

b. Step 2C—Record Run Data For "Out" Pass.

Record *Tmm, Pmm, Tp, Pp,* and *N. or N1*. Round values per appropriate table.

c. Step 3C—Determine Indicated Standard Volume (*ISVmm*).

Calculate *IVmm, CTLmm, CPLmm,* and *CCFmm*.

Determine indicated standard volume (*ISVmm*) from the following:

$$ISVmm = IVmm \times CCFmm$$

Round the value for *ISVmm* according to Table 8.

d. Step 4C—Determine *Vbout* for the "Out" Pass.

Determine the base volume of each "out" pass of the field prover. See *CPV* subroutine for an explanation of calculating each pass *Vb.*

Determine the indicated standard volume of the master meter for a given directional pass.

Calculate *CTSp, CPSp, CTLp, Fp, CPLp, CCFp,* and round per the appropriate table.

Determine the estimated *Vb* for an "out" pass from the following:

$$Vb(out) = \frac{ISVmm}{CCFp}$$

Round the value for *Vb* according to Table 9.

e. Step 5C—Test for Prover Design.

- If Unidirectional Prover—proceed to field prover "out" pass sequence termination, f. Step 6C.
- If Bidirectional Prover—jump to make a field prover "back" pass run, g. Step 7C.

f. Step 6C—Unidirectional Field Prover Run Sequence Termination.

Test for unidirectional field prover run sequence termination. The individual run volumes at reference conditions for three or more consecutive directional runs out of maximum six consecutive directional runs shall exhibit a range of 0.02% or less.

Round the results in accordance with the requirements specified in Table 9.

- If no—return back to *MMFstart* subroutine: make a "out" pass proving run on the master meter, g. Step 7, 12.1. to collect additional run data.
- If yes—jump to bidirectional field prover "back" pass sequence termination, j. Step 10C.

g. Step 7C—Make a Field Prover "Back" Pass Run.

h. Step 8C—Record Run Data.

Record *Tmm, Pmm, Tp, Pp,* and *N.*

Collect master meter pulses, *MMRo* and *MMRc*, between switch closures during a single pass of the master prover.

Calculate *IVmm, MMF, CTLmm, Fmm, CPLmm, CCFmm,* and round the values at each step per the appropriate table.

i. Step 9C—Calculate Master Meter Indicated Standard Volume (*ISVmm*).

Calculate the indicated standard volume (*ISVmm*) from the following:

$$ISVmm = IVmm \times CCFmm$$

Round the value for *ISVmm* according to Table 9.

j. Step 10C—Bidirectional Field Prover "Back" Pass Sequence Termination.

Test for bidirectional field prover round trip sequence termination. The round trip volumes at reference conditions for three or more consecutive round trips out of maximum six consecutive directional passes shall exhibit a range of 0.02% or less.

Note: For a bidirectional prover, since there is no requirement to satisfy a range criteria on the "Out" and "Back" pass volumes, *Vb(out)* and *Vb(back)*, of each roundtrip, an early check can be performed in the calibration exercise to detect a possible repeatability problem before getting to the end of the calibration. After each roundtrip, check the repeatability of the average "out" pass volumes [*Vb(out)*] of each roundtrip to determine if they repeat within a range for example 0.03% or less. Do the same for the "back" pass volumes [*Vb(back)s*].

Round the results in accordance with the requirements specified in Table 8.

- If no—return back to make a field prover "out" pass run, a. Step 1C, 12.1.3.
- If yes—proceed to *MMFstop* subroutine: make an "out" pass proving run on the master meter, k. Step 11C.

k. Step 11C—*MMFstop* Subroutine: Make an "Out" Pass Proving Run on the Master Meter.

For the average meter factor method, determine the stop master meter factor (*MMFstop*) using master meter and master prover data from the same sequence of steps as in the *MMFstart* subroutine. See f. Steps 6, 12.1. through f. 17A, 12.1.1.

For the average data method, determine the stop master meter factor (*MMFstop*) using master meter and master prover data from the same sequence of steps as in the *MMFstart* subroutine. See f. Steps 6, 12.1 through f. 17B, 12.1.2.

$$MMFstop = \frac{\sum IMMF}{n}$$

for 5 or more acceptable consecutive runs out of maximum 10 consecutive acceptable runs.

where

n = number of acceptable consecutive runs.

Round the results in accordance with the requirements specified in Table 8.

12.1.4 Test Start and Stop Master Meter Factor

l. Step 12D—Test for Master Meter Factor Repeatability.

The start and stop master meter factors shall exhibit range of 0.02% or less.

- If yes—proceed to determine *MMFavg*, m. Step 13D.
- If no—return back to master meter prover run to determine *MMFstart*, f. Step 6, 12.1. and repeat the run.

m. Step 13D—Determine *MMFavg*.

Determine the average meter factor (*MMFavg*) from the following:

$$MMFavg = \frac{MMFstart + MMFstop}{2}$$

Round the results in accordance with the requirements specified in Table 8.

n. Step 14D—Determine *Vb(back)* for "Back" Pass.

Determine the base volume of each "back" pass of the field prover. See *CPV* subroutine for an explanation of calculating each pass *Vb*.

Determine the indicated standard volume of the master meter for a given directional pass.

Calculate *CTSp, CPSp, CTLp, Fp, CPLp, CCFp*, and round per the appropriate table.

Determine the estimated *Vb* for a "back" pass from the following:

$$Vb(back) = ISVmm \,/\, CCFp$$

Round the value for *Vb* according to Table 9.

o. Step 15D—Test for Flow Rate Sequence Termination.

Determine that an average *Vb* for the field prover has been obtained for each of the three or more consecutive runs out of maximum six consecutive runs and they shall agree within a range of 0.02% or less. The change in flow rate between each calibration run set shall be at least 25% or more.

- If yes—proceed to test each run set for *Vb* repeatability criteria, p. Step 16D.
- If no—return back to f. Step 6, 12.1. and continue to run until the criteria is met.

p. Step 16D—Test Each Round Trip for *Vb* Repeatability Criteria.

Determine if the range of 0.02% or less has been satisfied between at least three consecutive roundtrip runs out of a maximum six consecutive roundtrip runs with the flow rate between each Calibration Run Set changed by at least 25%.

- Yes—proceed to determine *Vb(out)* for each run, q. Step 17D.
- No—Initiate another run sequence by returning back to f. Step 6,12.1.

q. Step 17D—Initiate *CPV* Subroutine: Determine *Vb(out)* for Each Run.

The following shows the determination of *Vb(out)*:

Pass 1 *Vb* reference volume
Pass 2 *Vb* reference volume
Pass 3 *Vb* reference volume
" " " " "
Pass 6 *Vb* reference volume

Vb(out), Pass Avg

r. Step 18D—Test for Prover Design?

- If Unidirectional Prover—proceed to determine *CPVn* for each run, s. Step 19D.
- If Bidirectional Prover—jump to determine *Vb(back)* for each run, x. Step 24D.

s. Step 19D—For Unidirectional Provers: Determine *CPVn* for Each Run.

For the unidirectional field prover calibration run, the *Vb(out)* for each run now becomes the *CPVn* for each run.

Round the value for *CPVn* according to Table 9.

t. Step 20D—Consecutive Run *CPVn* Repeatability Criteria.

For unidirectional provers, the individual pass volume at reference conditions for three or more consecutive directional passes of a prover calibration run out of maximum six consecutive directional passes shall exhibit a range of 0.020% or less.

- If yes—proceed to determine calibration set *CPVavgs*, u. Step 21D.
- If no—return back to f. Step 6, 12.1. and continue to run until the criteria is met.

u. Step 21D—Determine Calibration Set CPVavgs.

Pass 1 *CPVn* reference volume
Pass 2 *CPVn* reference volume
Pass 3 *CPVn* reference volume
" " " " "
Pass 6 *CPVn* reference volume

CPVn, Avg

The consecutive pass *CPVns* shall exhibit a range of 0.020% or less.

v. Step 22D—Consecutive Calibration Set *CPVavg* Repeatability Criteria.

For unidirectional provers, the average corrected prover volumes (*CPVavg*) at reference conditions for three or more consecutive field prover calibration runs out of maximum six consecutive runs shall exhibit a range of 0.020% or less.

- If yes—proceed to calculate certificate's *BPV*, w. Step 23D.
- If no—return back to f. Step 6, 12.1 and continue to run until the criteria is met.

w. Step 23D—Calculate Certificate's *BPV*.

Determine the field prover roundtrip *CPVavg* Sequence Termination.

Average the *CPV* values for the acceptable consecutive sets to determine the base prover volume (*BPV*).

$$BPV = \frac{\sum CPVx}{x}$$

where

$CPVx$ = Run 1 *CPV* + Run 2 *CPV* + Run 3 *CPV* +.... + Run × *CPV*,

x = number of consecutive successful runs.

Round the results in accordance with the requirements specified in Table 9.

x. Step 24D—For Bidirectional Provers: Determine *Vb(back)* for Each Run.

Determine the base volume of each "back" pass of the field prover.

Determine the indicated standard volume of the master meter for a given directional pass.

Calculate *CTSp, CPSp, CTLp, Fp, CPLp, CCFp,* and round per the appropriate table.

Determine the *Vb* for a "back" pass from the following:

$$Vb(out) = \frac{ISVmm}{CCFp}$$

Round the value for *Vb* according to Table 9.

y. Step 25D—Determine Roundtrip Corrected Prover Volumes *CPVns*.

Determine the round trip *CPVn* for each consecutive round trip of the field prover from the following:

$$CPVn = \frac{Vb(out) + Vb(back)}{2}$$

Round the value for *CPVn* according to Table 9.

z. Step 26D—Consecutive Roundtrip *CPVn* Repeatability Criteria.

For bidirectional provers, the consecutive roundtrip volumes at reference conditions for three or more consecutive roundtrip volumes of a prover calibration run out of a maximum six consecutive runs shall exhibit a range of 0.020% or less.

Round the results in accordance with the requirements specified in Table 9.

- If yes—proceed to determine calibration set roundtrip *CPVavgs*, a. Step 27D.
- If no—return back to f. Step 6, 12.1. and continue to run until the criteria is met.

aa. Step 27D—Determine Calibration Set Roundtrip *CPVavgs*.

For the Bidirectional Field Prover Calibration Run

			Repeatability Criteria required for Column 3
Calibration Set	Column 1 Out Pass *Vb(out)*	Column 2 Back Pass *Vb(back)*	Column 3 Round Trip *CPVn*
I	Pass 1 Vb	Pass 2 *Vb*	Run 1 *CPVn*
II	Pass 3 Vb	Pass 4 *Vb*	Run 2 *CPVn*
III	Pass 5 Vb	Pass 6 *Vb*	Run 3 *CPVn*
"	"	"	"
VI	Pass 11 Vb	Pass 12 *Vb*	Run 6 *CPVn*
	Vb(out), Pass Avg.	*Vb(back)*, Pass Avg.	*CPVavg*, Run Avg.

The average "out" pass volume is determined by:

$$Vb(out) = \frac{Pass\ 1\ Vb + Pass\ 3\ Vb + Pass\ 5\ Vb + \ldots + Pass\ 11\ Vb}{n}$$

where

n = number of consecutive successful passes.

and,

The average "back" pass volume is determined by:

$$Vb(out) = \frac{Pass\ 2\ Vb + Pass\ 4\ Vb + Pass\ 6\ Vb + \ldots + Pass\ 12\ Vb}{n}$$

where

n = number of consecutive successful passes.

The average "round" trip volume is determined by:

$$CPVavg = \frac{Run\ 1\ CPV + Run\ 2\ CPV + Run\ 3\ CPV + \ldots + Run\ x\ CPV}{x}$$

where

x = number of consecutive successful runs.

ab. Step 28D—Consecutive Calibration Set Roundtrip *CPVavg* Repeatability Criteria.

For bidirectional provers, the average consecutive roundtrip volume at reference conditions for three or more consecutive roundtrip volumes of a prover calibration run out of maximum six consecutive volumes shall exhibit a range of 0.020% or less.

- If yes—proceed back to calculate certificate's *BPV*, w. Step 23D.
- If no—return back to f. Step 6, 12.1. and continue to run until the criteria is met.

12.2 ATMOSPHERIC TANK PROVERS

Normal industry practices use the average meter factor method to calculate master meter factors when proving a master meter with an open tank prover as the master prover. Normal proving technique allows flow through the master meter to be proved into the empty open master tank prover until filled. This constitutes a proving run.

Complete a. Step 1, 12.1 through h. Step 8, 12.1 as shown at the start of section 12.1. then proceed to the following step. Flow chart (Figure 6) has been prepared to graphically explain the calculational sequence.

a. Step 1E—Determine *GSVmp*.

The gross standard volume (*GSVmp*) of the tank prover, that is the "true" volume of liquid contained in the prover between the nominal "empty" and "full" levels. The *GSVmp* is calculated from the following equation:

$$GSVmp = BPVamp \times CCFmp$$

where

$BPVamp = SRu - SRl$

The adjusted base prover volume (*BPVamp*) for the master tank prover is determined by the difference between the upper and lower scale readings during each proving run. To determine the lower (*SRl*) scale reading of the open master tank prover, it should first be filled with the liquid, then drained to empty for the prescribed draining time, refilled up to the lower scale and the lower scale reading taken prior to the proving run commencing. The proving run is then initiated and where the master tank prover is filled to the upper scale, the flow is shut off, and the upper (*SRu*) scale reading is taken signaling the completion of proving run. The scale readings should be recorded as indicated in the discrimination levels in Table 9.

To calculate the combined correction factor for the master tank prover (*CCFmp*), however, the *CTSmp, CPSmp, CTLmp*, and *CPLmp* values are required, as discussed in the previous section on displacement provers.

1. *CTSmp* determination:

The *CTSmp* for a master tank prover may be calculated from the formula:

$$CTSmp = 1 + [(Tmp - Tb) \times Gmp]$$

The *CTSmp* value shall be rounded in accordance with Table 8 discrimination level requirements.

2. *CPSmp* determination:

Since an open tank prover is under atmospheric conditions, the *CPSmp* value is set to equal 1.000000.

$$CPSmp = 1.000000$$

3. *CTLmp* determination:

By using a base density (*RHOb, APIb, RDb*, and *DENb*) and the temperature of the liquid (*Tmp*) in the master tank prover, together with the appropriate standards or computer routines, a value for *CTLmp* can be determined. Round the values according to the discrimination level requirements specified in Table 8.

4. *CPLmp* determination:

Since an open tank prover is under atmospheric conditions, the *CPSmp* value is set to equal 1.000000.

$$CPLmp = 1.000000$$

5. *CCFmp* determination:

Having determined the four above described correction factors, the combined correction factor of the master prover (*CCFmp*) can now be calculated, by serial multiplication of the correction factors, in the exact order specified, using the equation shown below and rounding at the end of the multiplication. This value shall be rounded according to the requirements specified in Table 8.

$$CCFmp = CTSmp \times CPSmp \times CTLmp \times CPLmp$$

$$CCFmp = CTSmp \times 1.000000 \times CTLmp \times 1.000000$$

$$CCFmp = CTSmp \times CTLmp$$

6. Determine *GSVmp* Final Calculation:

The *GSVmp* is calculated by the following equation and rounded to the discrimination requirements contained in Table 9:

$$\mathrm{GSVmp} = (SRu - SRl) \times CCFmp$$

SRu and *SRl* determination was previously described. Round and record the value of *GSVmp* as indicated in Table 9.

b. Step 2E—Determine *ISVmm*.

The indicated standard volume (*ISVmm*) of the master meter is the volume of the liquid passing through the meter for the selected runs, with no correction for meter inaccuracies, calculated by the following equation:

$$ISVmm = IVmm \times CCFmm$$

The indicated volume (*IVmm*) through the master meter is calculated as shown below.

To calculate the combined correction factor (*CCFmm*) for the master meter requires that two individual correction factor values, *CTLmm* and *CPLmm*, are calculated and then sequentially multiplied together, in order specified, to obtain the combined correction factor (*CCFmm*) for the master meter.

1. *IVmm* determination:

If using a digital pulse train, then the indicated volume (*IVmm*) of through the master meter shall be calculated by dividing the pulses (*N*) from each run by the nominal K-factor (*NKF*) as shown below. Round and record the value of *IVmm* in accordance with the discrimination levels specified in Table 9.

$$IVMM = \frac{N}{NKF}$$

If using a master meter register head, then the indicated volume (*IVmm*) shall be calculated using the opening and closing master meter readings (*MMRo, MMRc*) for each run. Round and record the value of *IVmm* in accordance with the discrimination levels specified in Table 9.

$$IVmm = MMRc - MMRo$$

2. *CTLmm* determination:

By using a base density (*RHOb, APIb, RDb, DENb*), and the temperature (*Tmm*) of the liquid in the master meter, together with the relevant standards or computer routines, a value for *CTLmm* can be obtained. Round this value according to the discrimination level requirements specified in Table 8.

3. *CPLmm* determination:

Using an density value (*RHOb, APIb, RDb*, and *DENb*), the master meter pressure (*Pmm*), and the master meter temperature (*Tmm*), calculate the value of *Fmm* using the appropriate technical standards. Round this value according to the discrimination level requirements specified in Table 5.

Using this compressibility factor (*Fmm*) determined in the preceding step, together with the pressure in the master meter (*Pmm*), the average equilibrium vapor pressure of the liquid in the master meter (*Pemm*), and the base pressure (*Pba*), calculate the *CPLmm* value using the following expression.

$$CPLmm = \frac{1}{1 - [(Pmm + Pba - Pemm) \times Fmm]}$$

Round this value according to the requirements specified in Table 8.

Note: If the vapor pressure of the liquid is less than atmospheric pressure at normal temperature then *Pemm* is considered to be 0 psig.

4. *CCFmm* determination:

Having determined the two above-described correction factors, the combined correction factor of the master meter (*CCFmm*) shall now be calculated, by serial multiplication of the correction factors, in the exact order specified, rounding at the end of the multiplication, using the equation shown below. Round this value according to the requirements specified in Table 8.

$$CCFmm = CTLmm \times CPLmm$$

The *ISVmm* shall now be calculated by the following equation:

$$ISVmm = IVmm \times CCFmm$$

Round this value according to the requirements specified in Table 9.

c. Step 3E—Determine *IMMF*.

Intermediate master meter factors (*IMMF*) are determined at the time of proving, for each of the selected proving runs, by the formula:

$$IMMF = \frac{GSVmp}{ISVmm}$$

Record and round the values of the *IMMF* according to the discrimination level requirements specified in Table 8.

d. Step 4E—Test Runs for Repeatability Criteria.

See 9.1, 9.2, and 9.3 for the repeatability criteria.

To judge the acceptability of each of the selected consecutive run data, the repeatability for the average master meter factor method (*MMFavg*) is calculated as follows:

Intermediate master meter factors (*IMMF*) are calculated for each filling of the master tank prover. The range of these intermediate meter factors, for all the acceptable master proving runs, is now calculated, and used as the measure of acceptability for the master meter proving. In this method, the complete calculation steps to determine an intermediate master meter factor have to be performed for every master prover filling and then comparing all these intermediate master meter factors for acceptable repeatability.

Acceptable repeatability (%*R*) is defined as all the intermediate master meter factors within a range of 0.020%.

This repeatability check is made using the following formula:

$$R\% = \frac{IMMFmax - IMMFmin}{IMMFmin} X100$$

An example of this repeatability check is shown in the table on this page:

e. Step 5E—Determine *MMFstart*.

The master meter start factor (*MMFstart*) is a value used to adjust for any small inaccuracies associated with the performance of the master meter as determined at the time of proving. Having established that the range (repeatability) of the intermediate master meter factors (*IMMF*) meets the acceptability criteria, then a master meter start factor shall be calculated as follows:

$$MMstart = \frac{\sum IMMF}{n}$$

Where n = the number of *IMMFs*, where $n > 5$, from the selected proving runs. Round and record this value to the discrimination level requirements as specified in Table 8.

Proceed back to 12.1.4 test start and stop master meter factor section and proceed with l. Step 12D test for master meter factor repeatability.

Example of Repeatability Check

Run	Total Pulses	Prover Temperature	Meter Temperature	Prover Pressure	Meter Pressure	*GSVmp*	*ISVmm*	*IMMF*
1	12,234	72.5	73.0	23.0	23.0	22.3356	22.4883	0.993210
2	12,232	72.0	73.0	23.0	23.0	22.3348	22.4855	0.993298
3	12,237	72.0	72.5	22.0	23.0	22.3363	22.4854	0.993369
4	12,237	72.0	72.5	23.0	23.0	22.3360	22.4892	0.993188
5	12,233	72.5	73.0	23.0	23.0	22.3340	22.4856	0.993258
						Average Meter Factor (*IMMF*)		0.993265

$$R\% = \frac{IMMFmax - IMMFmin}{IMMFmin} \times 100$$

$$R\% = \frac{0.993369 - 0.993188}{0.993188} \times 100 = 0.018\%$$

13 Base Prover Volume Calculation Examples

13.1 EXAMPLE 1—DISPLACEMENT PROVER—UNIDIRECTIONAL PIPE DESIGN

The following example depicts the calculations using the average meter factor method and required documentation for a complete unidirectional field prover calibration by the master meter method.

Field Prover:	Unidirectional Displacement Pipe Prover	
Master Prover:	Bi-directional Displacement Pipe Prover	
Master Meter:	Displacement Flow Meter Sliding Vane Displacement Type	
Proving Method:	Average Meter Factor Method	
Liquid Medium:	Crude Oil	
Calibration Set I	Cover Sheet for Calibration Set I	1 page
	MMFstart	1 page
	Calibration Runs and Set Summary	1 page
	MMFstop	1 page
Calibration Set II	Cover Sheet for Calibration Set II	1 page
	MMFstart	1 page
	Calibration Runs and Set Summary	1 page
	MMFstop	1 page
Calibration Set III	Cover Sheet for Calibration Set III	1 page
	MMFstart	1 page
	Calibration Runs and Set Summary	1 page
	MMFstop	1 page
Calibration Summary	Calibration Summary Sheet	1 page

13.1.1 Example 1—Calibration Set I

13.1.1.1 Master Meter Type Calibration of Field Prover

13.1.1.1.1 *MMFstart* for this Calibration Set

a. See first data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of eight consecutive proving runs.
f. First three runs did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 4, 5, 6, 7, and 8) within a range of 0.02%.

13.1.1.1.2 Calibration Runs on Field Prover for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Conducted calibration runs on field prover using master meter.
c. Criteria: three consecutive calibration runs within a range of 0.02%.
d. Maximum of six runs allowed to complete this exercise.
e. Made a total of six consecutive calibrations runs.
f. First three runs did not repeat within 0.02% (temperature instability etc.).
g. Used last three runs (runs 4, 5, and 6) within a range of 0.02%.
h. Trial calculations can be performed to test repeatability using *MMFstart*.
i. Final calculations can be made only after completion of *MMFstop*.
j. Example shows final calculations only with using average of *MMFstart* and *MMFstop*.

13.1.1.1.3 *MMFstop* for this Calibration Set

a. See third data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of six consecutive proving runs.
f. First run did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 2, 3, 4, 5, and 6) within a range of 0.02%.

13.1.1.1.4 *MMFavg* and Final Calculations for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Compared *MMFstart* to *MMFstop*.
c. Criteria: *MMFstart* and *MMFstop* must be within a range of 0.02%.
d. Calculated the average of *MMFstart* and *MMFstop*.
e. Used *MMFavg* for field prover calibration runs.

13.1.1.1.5 Go to Calibration Set II

Example 1—Calibration Set I
PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION
Method: Average MF method
Master Prover: Bi-directional Displacement Pipe Prover
Master Meter: Displacement 4" (sliding vane type)

MMFstart I
Report #_________
Date:____________
S/N_____________
S/N_____________

****

Run Number	4	5	6	7	8
Medium	Crude Oil	Crude Oil	Crude Oil	Crude Oil	Crude Oil
Steel	316 S.S.	316 S.S.	316 S.S.	316 S.S.	316 S.S.
Gc	0.0000265	0.0000265	0.0000265	0.0000265	0.0000265
OD	10.750	10.750	10.750	10.750	10.750
WT	0.365	0.365	0.365	0.365	0.365
ID	10.020	10.020	10.020	10.020	10.020
E	28000000	28000000	28000000	28000000	28000000
APIobs	42.0	42.0	42.0	42.0	42.0
Tobs	75.0	75.0	75.0	75.0	75.0
APIb	40.7	40.7	40.7	40.7	40.7
Seconds	20.29	20.29	20.29	20.29	20.29
Flow (BPH)	600	600	600	600	600
Tmp	71.1	71.1	71.2	71.3	71.3
Pmp	94	94	94	94	94
Fmp	0.00000568	0.00000568	0.00000568	0.00000569	0.00000569
BPVmp	3.38126	3.38126	3.38126	3.38126	3.38126
CTSmp	1.000294	1.000294	1.000297	1.000299	1.000299
CPSmp	1.000092	1.000092	1.000092	1.000092	1.000092
CTLmp	0.994372	0.994372	0.994321	0.994270	0.994270
CPLmp	1.000534	1.000534	1.000534	1.000535	1.000535
CCFmp	0.995287	0.995287	0.995239	0.995191	0.995191
GSVmp	3.36532	3.36532	3.36516	3.36500	3.36500
N(half trip)	14206	14209	14206	14208	14207
N	28402	28405	28404	28404	28403
NKF	8400	8400	8400	8400	8400
IVmm	3.38119	3.38155	3.38143	3.38143	3.38131
Tmm	71.2	71.2	71.3	71.3	71.3
Pmm	100	100	100	100	100
Fmm	0.00000568	0.00000568	0.00000569	0.00000569	0.00000569
CTLmm	0.994321	0.994321	0.994270	0.994270	0.994270
CPLmm	1.000568	1.000568	1.000569	1.000569	1.000569
CCFmm	0.994886	0.994886	0.994836	0.994836	0.994836
ISVmm	3.36390	3.36426	3.36397	3.36397	3.36385
IMMF	1.000422	1.000315	1.000354	1.000306	1.000342

****

Average of Five Consecutive Runs =	1.000348	*MMFstart* I
Calculated Range Percent =	0.012	((MAX-MIN)/(MIN))*(100)
Allowable Range Percent =	0.020	%
Formulae for Proving the Master Meter:	(witnesses)	

IMMF = (*GSVmp* / *ISVmm*) ________________________

GSVmp = (*BPVmp* * *CCFmp*)

ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________

CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)

CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 1—Calibration	Set I	UNIDIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Displacement Unidirectional Pipe Prover
Master Prover Type...	Displacement Bi-directional Pipe Prover
Master Meter Type...	Displacement 4", (sliding vane type)
Liquid Medium Type...	Crude Oil 40.7 degrees API @ 60 degrees F

Calibration Report No.	____________	____________	*MMFstart*	1.000348
Calibration Date	____________	____________	*MMFstop*	1.000197
Field Prover S/N	____________	____________	*MMFaverage*	1.000273
Master Prover S/N	____________	____________	Delta%	0.015

****

Medium = Crude Oil	Run No.	4	5	6
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	20.000	20.000	20.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	19.250	19.250	19.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	42.0	42.0	42.0
Temperature Observed	*Tobs*	75.0	75.0	75.0
API @ 60 F	*APIb*	40.7	40.7	40.7
Time of Pass/Run	*Seconds*	187.56	187.54	187.55
Flow Rate in Bbls/Hour	*BPH*	600	600	600
Master Meter Pulses	*N*	262612	262590	262604
Nominal K Factor	*NKF*	8400	8400	8400
Indicated Meter Volume	*IVmm*	31.2633	31.2607	31.2624
Temp (F) Master Meter	*Tmm*	71.4	71.6	71.8
Press. (psig) Mstr Meter	*Pmm*	100	100	100
Compressibility Factor	*Fmm*	0.00000569	0.00000569	0.00000570
Master Meter Factor	*MMFavg*	1.000273	1.000273	1.000273
Corr.Temp. Liq. M.Meter	*CTLmm*	0.994219	0.994118	0.994016
Corr.Press.Liq. M.Meter	*CPLmm*	1.000569	1.000569	1.000570
Comb.Corr.Fact. M.Meter	*CCFmm*	0.995056	0.994955	0.994854
Indicated Std Volume MM	*ISVmm*	31.1087	31.1030	31.1015
Temp. Deg. F in Prover	*Tp*	71.2	71.4	71.6
Press. (psig) in Prover	*Pp*	88	88	88
Compressibility Factor	*Fp*	0.00000568	0.00000569	0.00000569
Corr Temp Steel Prover	*CTSp*	1.000208	1.000212	1.000216
Corr Press Steel Prover	*CPSp*	1.000151	1.000151	1.000151
Corr Temp Liquid Prover	*CTLp*	0.994321	0.994219	0.994118
Corr Press Liq'd Prover	*CPLp*	1.000500	1.000501	1.000501
Comb.Corr.Factor Prover	*CCFp*	0.995175	0.995078	0.994981
Prover Vol. @ Tb & Pb =	*CPVn*	31.2595	31.2568	31.2584

****

CPVn Range (allowed) =		< or = 0.02%	0.009% (actual)	
CPVn	=	(*ISVmm* / *CCFp*)		
ISVmm	=	(*IVmm* * *CCFmm*)	________________________	
IVmm	=	(*N* / *NKF*)	(witnesses)	
CCFmm	=	(*MMFav* * *CTLmm* * *CPLmm*)	________________________	
CCFp	=	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)		
CPVavg	=	(Average *CPV* of Set)	>>>>>>>>>>>>	31.2582

****

Example 1—Calibration Set I *MMFstop* I

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #________
Method: Average MF method Date:___________
Master Prover: Bi-directional Displacement Pipe Prover S/N____________
Master Meter: Displacement 4" (sliding vane type) S/N____________

****

Run Number	2	3	4	5	6
Medium	Crude Oil	Crude Oil	Crude Oil	Crude Oil	Crude Oil
Steel	316 S.S.	316 S.S.	316 S.S.	316 S.S.	316 S.S.
Gc	0.0000265	0.0000265	0.0000265	0.0000265	0.0000265
OD	10.750	10.750	10.750	10.750	10.750
WT	0.365	0.365	0.365	0.365	0.365
ID	10.020	10.020	10.020	10.020	10.020
E	28000000	28000000	28000000	28000000	28000000
APIobs	42.0	42.0	42.0	42.0	42.0
Tobs	75.0	75.0	75.0	75.0	75.0
APIb	40.7	40.7	40.7	40.7	40.7
Seconds	20.29	20.29	20.29	20.29	20.29
Flow (BPH)	600	600	600	600	600
Tmp	71.6	71.7	71.7	71.8	71.8
Pmp	94	94	94	94	94
Fmp	0.00000569	0.00000569	0.00000569	0.00000570	0.00000570
BPVmp	3.38126	3.38126	3.38126	3.38126	3.38126
CTSmp	1.000307	1.000310	1.000310	1.000313	1.000313
CPSmp	1.000092	1.000092	1.000092	1.000092	1.000092
CTLmp	0.994118	0.994067	0.994067	0.994016	0.994016
CPLmp	1.000535	1.000535	1.000535	1.000536	1.000536
CCFmp	0.995047	0.994999	0.994999	0.994952	0.994952
GSVmp	3.36451	3.36435	3.36435	3.36419	3.36419
N(half trip)	14210	14209	14209	14211	14209
N	28410	28406	28409	28410	28408
NKF	8400	8400	8400	8400	8400
IVmm	3.38214	3.38167	3.38202	3.38214	3.38190
Tmm	71.7	71.8	71.8	71.8	71.9
Pmm	100	100	100	100	100
Fmm	0.00000569	0.00000570	0.00000570	0.00000570	0.00000570
CTLmm	0.994067	0.994016	0.994016	0.994016	0.993965
CPLmm	1.000569	1.000570	1.000570	1.000570	1.000570
CCFmm	0.994633	0.994583	0.994583	0.994583	0.994532
ISVmm	3.36399	3.36335	3.36370	3.36382	3.36341
IMMF	1.000155	1.000297	1.000193	1.000110	1.000232

****

Average of Five Consecutive Runs = 1.000197 *MMFstop* I
Calculated Range Percent = 0.019 ((MAX-MIN)/(MIN))*(100)
Allowable Range Percent = 0.020 %

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________
GSVmp = (*BPVmp* * *CCFmp*)
ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________
CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)
CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

13.1.2 Example 1—Calibration Set II

13.1.2.1 Master Meter Type Calibration of Field Prover

13.1.2.1.1 *MMFstart* for this Calibration Set

a. See first data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of ten consecutive proving runs.
f. First five runs did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 6, 7, 8, 9, and 10) within a range of 0.02%.

13.1.2.1.2 Calibration Runs on Field Prover for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Conducted calibration runs on field prover using master meter.
c. Criteria: three consecutive calibration runs within a range of 0.02%.
d. Maximum of six runs allowed to complete this exercise.
e. Made a total of three consecutive calibrations runs.
f. No additional runs were necessary.
g. Used these three consecutive runs (runs 1, 2, and 3) within a range of 0.02%.
h. Trial calculations can be performed to test repeatability using *MMFstart*.
i. Final calculations can be made only after completion of *MMFstop*.
j. Example shows final calculations only with using average of *MMFstart* and *MMFstop*.

13.1.2.1.3 *MMFstop* for this Calibration Set

a. See third data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of nine consecutive proving runs.
f. First four runs did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 5, 6, 7, 8, and 9) within a range of 0.02%.

13.1.2.1.4 *MMFavg* and Final Calculations for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Compared *MMFstart* to *MMFstop*.
c. Criteria: *MMFstart* and *MMFstop* must be within a range of 0.02%.
d. Calculated the average of *MMFstart* and *MMFstop*.
e. Used *MMFavg* for field prover calibration runs.

13.1.2.1.5 Go to Calibration Set III

Example 1—Calibration Set II *MMFstart*

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #________
Method: Average MF method Date:___________
Master Prover: Bi-directional Displacement Pipe Prover S/N____________
Master Meter: Displacement 4" (sliding vane type) S/N____________

****

Run Number	6	7	8	9	10
Medium	Crude Oil	Crude Oil	Crude Oil	Crude Oil	Crude Oil
Steel	316 S.S.	316 S.S.	316 S.S.	316 S.S.	316 S.S.
Gc	0.0000265	0.0000265	0.0000265	0.0000265	0.0000265
OD	10.750	10.750	10.750	10.750	10.750
WT	0.365	0.365	0.365	0.365	0.365
ID	10.020	10.020	10.020	10.020	10.020
E	28000000	28000000	28000000	28000000	28000000
APIobs	42.0	2.0	42.0	42.0	42.0
Tobs	75.0	75.0	75.0	75.0	75.0
APIb	40.7	40.7	40.7	40.7	40.7
Seconds	30.43	30.43	30.43	30.43	30.43
Flow (BPH)	400	400	400	400	400
Tmp	72.0	72.0	72.0	72.0	72.0
Pmp	96	96	96	96	96
Fmp	0.00000570	0.00000570	0.00000570	0.00000570	0.00000570
BPVmp	3.38126	3.38126	3.38126	3.38126	3.38126
CTSmp	1.000318	1.000318	1.000318	1.000318	1.000318
CPSmp	1.000094	1.000094	1.000094	1.000094	1.000094
CTLmp	0.993915	0.993915	0.993915	0.993915	0.993915
CPLmp	1.000547	1.000547	1.000547	1.000547	1.000547
CCFmp	0.994868	0.994868	0.994868	0.994868	0.994868
GSVmp	3.36391	3.36391	3.36391	3.36391	3.36391
N(half trip)	14217	14220	14217	14218	14219
N	28424	28427	28426	28424	28427
NKF	8400	8400	8400	8400	8400
IVmm	3.38381	3.38417	3.38405	3.38381	3.38417
Tmm	72.0	72.0	72.0	72.0	72.0
Pmm	100	100	100	100	100
Fmm	0.00000570	0.00000570	0.00000570	0.00000570	0.00000570
CTLmm	0.993915	0.993915	0.993915	0.993915	0.993915
CPLmm	1.000570	1.000570	1.000570	1.000570	1.000570
CCFmm	0.994482	0.994482	0.994482	0.994482	0.994482
ISVmm	3.36514	3.36550	3.36538	3.36514	3.36550
IMMF	0.999634	0.999528	0.999563	0.999634	0.999528

****

Average of Five Consecutive Runs = 0.999577 *MMFstart* II
Calculated Range Percent = 0.011 ((MAX-MIN)/(MIN))*(100)
Allowable Range Percent = 0.020 %

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________
GSVmp = (*BPVmp* * *CCFmp*)
ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________
CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)
CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 1—Calibration Set II UNIDIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Displacement Unidirectional Pipe Prover
Master Prover Type...	Displacement Bi-directional Pipe Prover
Master Meter Type...	Displacement 4", (sliding vane type)
Liquid Medium Type...	Crude Oil 40.7 degrees API @ 60 degrees F

Calibration Report No.	____________	____________	*MMFstart*	0.999577
Calibration Date	____________	____________	*MMFstop*	0.999668
Field Prover S/N	____________	____________	*MMFaverage*	0.999623
Master Prover S/N	____________	____________	Delta%	0.009

****

Medium = Crude Oil	Run No.	1	2	3
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	20.000	20.000	20.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	19.250	19.250	19.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	42.0	42.0	42.0
Temperature Observed	*Tobs*	75.0	75.0	75.0
API @ 60 F	*APIb*	40.7	40.7	40.7
Time of Pass/Run	*Seconds*	281.31	281.31	281.32
Flow Rate in Bbls/Hour	*BPH*	400	400	400
Master Meter Pulses	*N*	262755	262758	262767
Nominal K Factor	*NKF*	8400	8400	8400
Indicated Meter Volume	*IVmm*	31.2804	31.2807	31.2818
Temp (F) Master Meter	*Tmm*	72.0	72.2	72.4
Press. (psig) Mstr Meter	*Pmm*	100	100	100
Compressibility Factor	*Fmm*	0.00000570	0.00000570	0.00000571
Master Meter Factor	*MMFavg*	0.999623	0.999623	0.999623
Corr.Temp. Liq. M.Meter	*CTLmm*	0.993915	0.993813	0.993711
Corr.Press.Liq. M.Meter	*CPLmm*	1.000570	1.000570	1.000570
Comb.Corr.Fact. M.Meter	*CCFmm*	0.994107	0.994005	0.993903
Indicated Std Volume MM	*ISVmm*	31.0961	31.0932	31.0911
Temp. Deg. F in Prover	*Tp*	71.9	72.1	72.3
Press. (psig) in Prover	*Pp*	92	92	92
Compressibility Factor	*Fp*	0.00000570	0.00000570	0.00000571
Corr Temp Steel Prover	*CTSp*	1.000221	1.000225	1.000229
Corr Press Steel Prover	*CPSp*	1.000157	1.000157	1.000157
Corr Temp Liquid Prover	*CTLp*	0.993965	0.993864	0.993762
Corr Press Liq'd Prover	*CPLp*	1.000525	1.000525	1.000526
Comb.Corr.Factor Prover	*CCFp*	0.994863	0.994766	0.994669
Prover Vol. @ Tb & Pb =	*CPVn*	31.2567	31.2568	31.2577

****

CPVn Range (allowed) = < or = 0.02% 0.003 % (actual)

CPVn	=	(*ISVmm* / *CCFp*)		
ISVmm	=	(*IVmm* * *CCFmm*)	________________________	
IVmm	=	(*N* / *NKF*)	(witnesses)	
CCFmm	=	(*MMFavg* * *CTLmm* * *CPLmm*)	________________________	
CCFp	=	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)		
CPVavg	=	(Average *CPV* of Set)	>>>>>>>>>>>>	31.2571

****

Example 1—Calibration Set II *MMFstop* II

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #_______
Method: Average MF method Date:__________
Master Prover: Bi-directional Displacement Pipe Prover S/N___________
Master Meter: Displacement 4" (sliding vane type) S/N___________

****

Run Number	5	6	7	8	9
Medium	Crude Oil	Crude Oil	Crude Oil	Crude Oil	Crude Oil
Steel	316 S.S.	316 S.S.	316 S.S.	316 S.S.	316 S.S.
Gc	0.0000265	0.0000265	0.0000265	0.0000265	0.0000265
OD	10.750	10.750	10.750	10.750	10.750
WT	0.365	0.365	0.365	0.365	0.365
ID	10.020	10.020	10.020	10.020	10.020
E	28000000	28000000	28000000	28000000	28000000
APIobs	42.0	42.0	42.0	42.0	42.0
Tobs	75.0	75.0	75.0	75.0	75.0
APIb	40.7	40.7	40.7	40.7	40.7
Seconds	30.43	30.43	30.43	30.43	30.43
*Flow (*BPH*)*	400	400	400	400	400
Tmp	72.4	72.4	72.4	72.4	72.4
Pmp	96	96	96	96	96
Fmp	0.00000571	0.00000571	0.00000571	0.00000571	0.00000571
BPVmp	3.38126	3.38126	3.38126	3.38126	3.38126
CTSmp	1.000329	1.000329	1.000329	1.000329	1.000329
CPSmp	1.000094	1.000094	1.000094	1.000094	1.000094
CTLmp	0.993711	0.993711	0.993711	0.993711	0.993711
CPLmp	1.000548	1.000548	1.000548	1.000548	1.000548
CCFmp	0.994676	0.994676	0.994676	0.994676	0.994676
GSVmp	3.36326	3.36326	3.36326	3.36326	3.36326
N(half trip)	14218	14217	14216	14219	14216
N	28425	28422	28423	28425	28422
NKF	8400	8400	8400	8400	8400
IVmm	3.38393	3.38357	3.38369	3.38393	3.38357
Tmm	72.4	72.4	72.4	72.4	72.4
Pmm	100	100	100	100	100
Fmm	0.00000571	0.00000571	0.00000571	0.00000571	0.00000571
CTLmm	0.993711	0.993711	0.993711	0.993711	0.993711
CPLmm	1.000571	1.000571	1.000571	1.000571	1.000571
CCFmm	0.994278	0.994278	0.994278	0.994278	0.994278
ISVmm	3.36457	3.36421	3.36433	3.36457	3.36421
IMMF	0.999611	0.999718	0.999682	0.999611	0.999718

****

Average of Five Consecutive Runs = 0.999668 *MMFstop* II
Calculated Range Percent = 0.011 ((MAX-MIN)/(MIN))*(100)
Allowable Range Percent = 0.020 %

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________
GSVmp = (*BPVmp* * *CCFmp*)
ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________
CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)
CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

13.1.3 Example 1—Calibration Set III

13.1.3.1 Master Meter Type Calibration of Field Prover

13.1.3.1.1 *MMFstart* for this Calibration Set

a. See first data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of six consecutive proving runs.
f. First run did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 2, 3, 4, 5, and 6) within a range of 0.02%.

13.1.3.1.2 Calibration Runs on Field Prover for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Conducted calibration runs on field prover using master meter.
c. Criteria: three consecutive calibration runs within a range of 0.02%.
d. Maximum of six runs allowed to complete this exercise.
e. Made a total of four consecutive calibrations runs.
f. First run did not repeat within 0.02% (temperature instability etc.).
g. Used last three runs (runs 2, 3, and 4) within a range of 0.02%.
h. Trial calculations can be performed to test repeatability using *MMFstart*.
i. Final calculations can be made only after completion of *MMFstop*.
j. Example shows final calculations only with using average of *MMFstart* and *MMFstop*.

13.1.3.1.3 *MMFstop* for this Calibration Set

a. See third data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of eight consecutive proving runs.
f. First three runs did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 4, 5, 6, 7, and 8) within a range of 0.02%.

13.1.3.1.4 *MMFavg* and Final Calculations for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Compared *MMFstart* to *MMFstop*.
c. Criteria: *MMFstart* and *MMFstop* must be within a range of 0.02%.
d. Calculated the average of *MMFstart* and *MMFstop*.
e. Used *MMFavg* for field prover calibration runs.

13.1.3.1.5 Go to Calibration Summary at End of this Example

Example 1—Calibration Set III *MMFstart* III

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #_______
Method: Average MF method Date:__________
Master Prover: Bi-directional Displacement Pipe Prover S/N___________
Master Meter: Displacement 4" (sliding vane type) S/N___________
****

Run Number	2	3	4	5	6
Medium	Crude Oil	Crude Oil	Crude Oil	Crude Oil	Crude Oil
Steel	316 S.S.	316 S.S.	316 S.S.	316 S.S.	316 S.S.
Gc	0.0000265	0.0000265	0.0000265	0.0000265	0.0000265
OD	10.750	10.750	10.750	10.750	10.750
WT	0.365	0.365	0.365	0.365	0.365
ID	10.020	10.020	10.020	10.020	10.020
E	28000000	28000000	28000000	28000000	28000000
APIobs	42.0	42.0	42.0	42.0	42.0
Tobs	75.0	75.0	75.0	75.0	75.0
APIb	40.7	40.7	40.7	40.7	40.7
Seconds	15.22	15.22	15.22	15.22	15.22
*Flow (*BPH*)*	800	800	800	800	800
Tmp	72.7	72.7	72.7	72.8	72.8
Pmp	92	92	92	92	92
Fmp	0.00000571	0.00000571	0.00000571	0.00000572	0.00000572
BPVmp	3.38126	3.38126	3.38126	3.38126	3.38126
CTSmp	1.000337	1.000337	1.000337	1.000339	1.000339
CPSmp	1.000090	1.000090	1.000090	1.000090	1.000090
CTLmp	0.993559	0.993559	0.993559	0.993508	0.993508
CPLmp	1.000526	1.000526	1.000526	1.000527	1.000527
CCFmp	0.994506	0.994506	0.994506	0.994458	0.994458
GSVmp	3.36268	3.36268	3.36268	3.36252	3.36252
N(half trip)	14201	14204	14201	14204	14202
N	28392	28395	28394	28395	28394
NKF	8400	8400	8400	8400	8400
IVmm	3.38000	3.38036	3.38024	3.38036	3.38024
Tmm	72.9	72.9	73.0	73.0	73.0
Pmm	100	100	100	100	100
Fmm	0.00000572	0.00000572	0.00000572	0.00000572	0.00000572
CTLmm	0.993457	0.993457	0.993407	0.993407	0.993407
CPLmm	1.000572	1.000572	1.000572	1.000572	1.000572
CCFmm	0.994025	0.994025	0.993975	0.993975	0.993975
ISVmm	3.35980	3.36016	3.35987	3.35999	3.35987
IMMF	1.000857	1.000750	1.000836	1.000753	1.000789

****

Average of Five Consecutive Runs = 1.000797 *MMFstart* III
Calculated Range Percent = 0.011 ((MAX-MIN)/(MIN))*(100)
Allowable Range Percent = 0.020 %
Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________
GSVmp = (*BPVmp* * *CCFmp*)
ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________
CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)
CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 1—Calibration Set III UNIDIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Displacement Unidirectional Pipe Prover
Master Prover Type...	Displacement Bi-directional Pipe Prover
Master Meter Type...	Displacement 4", (sliding vane type)
Liquid Medium Type...	Crude Oil 40.7 degrees API @ 60 degrees F

Calibration Report No.	____________	____________	*MMFstart*	1.000797
Calibration Date	____________	____________	*MMFstop*	1.000698
Field Prover S/N	____________	____________	*MMFaverage*	1.000748
Master Prover S/N	____________	____________	Delta%	0.010

****

Medium = Crude Oil	Run No.	2	3	4
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	20.000	20.000	20.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	19.250	19.250	19.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	42.0	42.0	42.0
Temperature Observed	*Tobs*	75.0	75.0	75.0
API @ 60 F	*APIb*	40.7	40.7	40.7
Time of Pass/Run	*Seconds*	140.66	140.66	140.68
Flow Rate in Bbls/Hour	*BPH*	800	800	800
Master Meter Pulses	*N*	262452	262476	262488
Nominal K Factor	*NKF*	8400	8400	8400
Indicated Meter Volume	*IVmm*	31.2443	31.2471	31.2486
Temp (F) Master Meter	*Tmm*	73.0	73.2	73.2
Press. (psig) Mstr Meter	*Pmm*	100	100	100
Compressibility Factor	*Fmm*	0.00000572	0.00000572	0.00000572
Master Meter Factor	*MMFavg*	1.000748	1.000748	1.000748
Corr.Temp. Liq. M.Meter	*CTLmm*	0.993407	0.993305	0.993305
Corr.Press.Liq. M.Meter	*CPLmm*	1.000572	1.000572	1.000572
Comb.Corr.Fact. M.Meter	*CCFmm*	0.994719	0.994617	0.994617
Indicated Std Volume MM	*ISVmm*	31.0793	31.0789	31.0804
Temp. Deg. F in Prover	*Tp*	73.0	73.0	73.2
Press. (psig) in Prover	*Pp*	84	84	84
Compressibility Factor	*Fp*	0.00000572	0.00000572	0.00000572
Corr Temp Steel Prover	*CTSp*	1.000242	1.000242	1.000246
Corr Press Steel Prover	*CPSp*	1.000144	1.000144	1.000144
Corr Temp Liquid Prover	*CTLp*	0.993407	0.993407	0.993305
Corr Press Liq'd Prover	*CPLp*	1.000481	1.000481	1.000481
Comb.Corr.Factor Prover	*CCFp*	0.994269	0.994269	0.994170
Prover Vol. @ Tb & Pb =	*CPVn*	31.2584	31.2580	31.2627

****

CPVn Range (allowed) = < or = 0.02% 0.015 % (actual)

CPVn	=	(*ISVmm* / *CCFp*)	
ISVmm	=	(*IVmm* * *CCFmm*)	________________________
IVmm	=	(*N* / *NKF*)	(witnesses)
CCFmm	=	(*MMFavg* * *CTLmm* * *CPLmm*)	________________________
CCFp	=	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)	
CPVavg	=	(Average *CPV* of Set)	>>>>>>>>>>>> 31.2597

****

Example 1—Calibration Set III *MMFstop* III

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION
Method: Average MF method
Master Prover: Bi-directional Displacement Pipe Prover
Master Meter: Displacement 4" (sliding vane type)

Report #_______
Date:__________
S/N___________
S/N___________

****

Run Number	4	5	6	7	8
Medium	Crude Oil	Crude Oil	Crude Oil	Crude Oil	Crude Oil
Steel	316 S.S.	316 S.S.	316 S.S.	316 S.S.	316 S.S.
Gc	0.0000265	0.0000265	0.0000265	0.0000265	0.0000265
OD	10.750	10.750	10.750	10.750	10.750
WT	0.365	0.365	0.365	0.365	0.365
ID	10.020	10.020	10.020	10.020	10.020
E	28000000	28000000	28000000	28000000	28000000
APIobs	42.0	42.0	42.0	42.0	42.0
Tobs	75.0	75.0	75.0	75.0	75.0
APIb	40.7	40.7	40.7	40.7	40.7
Seconds	15.22	15.22	15.22	15.22	15.22
*Flow (*BPH*)*	800	800	800	800	800
Tmp	73.3	73.4	73.4	73.4	73.5
Pmp	92	92	92	92	92
Fmp	0.00000573	0.00000573	0.00000573	0.00000573	0.00000573
BPVmp	3.38126	3.38126	3.38126	3.38126	3.38126
CTSmp	1.000352	1.000355	1.000355	1.000355	1.000358
CPSmp	1.000090	1.000090	1.000090	1.000090	1.000090
CTLmp	0.993254	0.993203	0.993203	0.993203	0.993152
CPLmp	1.000527	1.000527	1.000527	1.000527	1.000527
CCFmp	0.994217	0.994169	0.994169	0.994169	0.994121
GSVmp	3.36171	3.36154	3.36154	3.36154	3.36138
N(half trip)	14203	14204	14201	14206	14204
N	28396	28395	28394	28399	28398
NKF	8400	8400	8400	8400	8400
IVmm	3.38048	3.38036	3.38024	3.38083	3.38071
Tmm	73.4	73.5	73.6	73.6	73.7
Pmm	100	100	100	100	100
Fmm	0.00000573	0.00000573	0.00000573	0.00000573	0.00000573
CTLmm	0.993203	0.993152	0.993102	0.993102	0.993051
CPLmm	1.000573	1.000573	1.000573	1.000573	1.000573
CCFmm	0.993772	0.993721	0.993671	0.993671	0.993620
ISVmm	3.35943	3.35913	3.35885	3.35943	3.35914
IMMF	1.000679	1.000717	1.000801	1.000628	1.000667

****

Average of Five Consecutive Runs	=	1.000698	*MMFstop* III
Calculated Range Percent	=	0.017	((MAX-MIN)/(MIN))*(100)
Allowable Range Percent	=	0.020	%

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________

GSVmp = (*BPVmp* * *CCFmp*)

ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________

CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)

CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 1—Calibration Summary UNIDIRECTIONAL DISPLACEMENT PROVER

Date of Calibration:	______________________________
Calibration Report Number:	______________________________
Summary Sheet of a Total of:	______________________________
Time of Calibration (begin/end):	______________________________
Weather During Calibration:	______________________________
Owner / Operator of Prover:	______________________________
Site of Meter Prover Calibration:	______________________________
Service Location of Field Prover:	______________________________
Service Identification of Prover:	______________________________
Volume Identification of Prover:	______________________________
Manufacturer of Field Prover:	______________________________
Serial Number of Field Prover:	______________________________
Serial Number of Master Prover:	______________________________
Serial Number of Master Meter:	______________________________
Description/Type of Field Prover:	Displacement Unidir. Pipe Prover
Description & Type Master Prover:	Displacement Bi-dir. Pipe Prover
Description & Type Master Meter:	Displacement 4" (sliding vane type)
Material of Construction of Prover:	______________________________
Cubical Coefficient per Degree F:	______________________________
Square Coefficient per Degree F:	______________________________
Linear Coefficient per Degree F:	______________________________
Modulus of Elasticity per psi:	______________________________
Outside Diameter of Prover Pipe:	______________________________
Wall Thickness of Prover Pipe:	______________________________
Inside Diameter of Prover Pipe:	______________________________
Calibration Liquid Description:	Crude Oil 40.7 deg API @ 60 deg F

****

MASTER METER CALIBRATION SUMMARY

UNIDIRECTIONAL DISPLACEMENT PIPE PROVER

Calibration Set I	= *CPVavg* @	600 BPH	=	31.2582 Barrels
Calibration Set II	= *CPVavg* @	400 BPH	=	31.2571 Barrels
Calibration Set III	= *CPVavg* @	800 BPH	=	31.2597 Barrels

[(MAX - MIN) / (MIN)] * [100] = 0.008% Range

Allowable Tolerance = 0.020% Range

Calculate average CPVavg:
Base Prover Volume @ 60 Degrees F & 0 psig = 31.2583 Barrels

Previous Base Prover Volume:	______________________________
Percentage change in volume:	______________________________
Diameter of displacer in inches:	______________________________

Calibrator's Name & Company Name ______________________________

****

13.2 EXAMPLE 2—DISPLACEMENT PROVER—BI-DIRECTIONAL PIPE DESIGN

The following example depicts the calculations using the average meter factor method and required documentation for a complete bi-directional displacement prover calibration by the master meter method.

Field Prover:	Bi-directional Displacement Pipe Prover
Master Prover:	Small Volume Prover – Unidirectional Displacement Type Prover – Equipped With External Detectors
Master Meter:	Turbine Flow Meter
Proving Method:	Average Meter Factor Method
Liquid Medium:	Gasoline

Calibration Set I	Cover Sheet for Calibration Set I	1 page
	MMFstart	1 page
	Calibration Runs	3 pages
	MMFstop	1 page
	Summary Sheet for Calibration Set I	1 page
Calibration Set II	Cover Sheet for Calibration Set II	1 page
	MMFstart	1 page
	Calibration Runs	3 pages
	MMFstop	1 page
	Summary Sheet for Calibration Set II	1 page
Calibration Set III	Cover Sheet for Calibration Set III	1 page
	MMFstart	1 page
	Calibration Runs	3 pages
	MMFstop	1 page
	Summary Sheet for Calibration Set III	1 page
Calibration Summary	Calibration Summary Sheet	1 page

13.2.1 Example 2—Calibration Set I

13.2.1.1 Master Meter Type Calibration of Field Prover

13.2.1.1.1 *MMFstart* for this Calibration Set

a. See first data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of ten consecutive proving runs.
f. First five runs did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 6, 7, 8, 9, and 10) within a range of 0.02%.

13.2.1.1.2 Calibration Runs on Field Prover for this Calibration Set

a. See second, third and fourth data/calculations pages of this calibration set.
b. Conducted calibration runs (round trips) on field prover using master meter.
c. Criteria: three consecutive calibration runs (round trips) within a range of 0.02%.
d. Maximum of six runs (round trips) allowed to complete this exercise.
e. Made a total of six consecutive calibration runs (round trips).
f. First three runs (round trips) did not repeat within 0.02% (temperature instability etc.).

g. Used last three runs (round trips 4, 5, and 6) within a range of 0.02%.
h. Trial calculations can be performed to test repeatability using *MMFstart*.
i. Final calculations can be made only after completion of *MMFstop*.
j. Example shows final calculations only with using average of *MMFstart* and *MMFstop*.

13.2.1.1.3 *MMFstop* for this Calibration Set

a. See fifth data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of six consecutive proving runs.
f. First run did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 2, 3, 4, 5, and 6) within a range of 0.02%.

13.2.1.1.4 *MMFavg* and Final Calculations for this Calibration Set

a. See second, third and fourth data/calculations pages of this calibration set.
b. Compared *MMFstart* to *MMFstop*.
c. Criteria: *MMFstart* and *MMFstop* must be within a range of 0.02%.
d. Calculated the average of *MMFstart* and *MMFstop*.
e. Used *MMFavg* for field prover calibration runs.

See sixth data/calculations page of this calibration set for summary of this calibration set.

13.2.1.1.5 Go to Calibration Set II

Example 2—Calibration Set I *MMFstart* I

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION
Method: Average MF method
Master Prover: Small Vol. Displacement w/ External Detectors
Master Meter: Turbine 3" Flow Meter

Report #_______
Date:__________
S/N___________
S/N___________

****

Run Number	6	7	8	9	10
Medium	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline
Steel	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.	7-4PH S.S.	17-4PH S.S.
Ga	0.0000120	0.0000120	0.0000120	0.0000120	0.0000120
Gl	0.0000008	0.0000008	0.0000008	0.0000008	0.0000008
WT	0.875	0.875	0.875	0.875	0.875
ID	12.250	12.250	12.250	12.250	12.250
E	28500000	28500000	28500000	28500000	28500000
APIobs	57.4	57.4	57.4	57.4	57.4
Tobs	62.0	62.0	62.0	62.0	62.0
APIb	57.2	57.2	57.2	57.2	57.2
Seconds	1.6076	1.6076	1.6076	1.6076	1.6076
Flow (BPH)	800	800	800	800	800
Tmp	52.0	52.0	52.0	52.0	52.0
Td	57.0	57.0	57.0	57.0	57.0
Pmp	95	95	95	95	95
Fmp	0.00000697	0.00000697	0.00000697	0.00000697	0.00000697
BPVmp	0.357249	0.357249	0.357249	0.357249	0.357249
CTSmp	0.999902	0.999902	0.999902	0.999902	0.999902
CPSmp	1.000047	1.000047	1.000047	1.000047	1.000047
CTLmp	1.005339	1.005339	1.005339	1.005339	1.005339
CPLmp	1.000663	1.000663	1.000663	1.000663	1.000663
CCFmp	1.005954	1.005954	1.005954	1.005954	1.005954
GSVmp	0.359376	0.359376	0.359376	0.359376	0.359376
Ni	749.965	750.003	749.986	749.969	750.010
NKF	2100	2100	2100	2100	2100
IVmm	0.357126	0.357144	0.357136	0.357128	0.357148
Tmm	52.2	52.2	52.2	52.2	52.2
Pmm	100	100	100	100	100
Fmm	0.00000697	0.00000697	0.00000697	0.00000697	0.00000697
CTLmm	1.005205	1.005205	1.005205	1.005205	1.005205
CPLmm	1.000697	1.000697	1.000697	1.000697	1.000697
CCFmm	1.005906	1.005906	1.005906	1.005906	1.005906
ISVmm	0.359235	0.359253	0.359245	0.359237	0.359257
IMMF	1.000393	1.000342	1.000365	1.000387	1.000331

****

Average of Five Consecutive Runs	=	1.000364	*MMFstart* I
Calculated Range Percent	=	0.006	((Max-Min)/(Min))*(100)
Allowable Range Percent	=	0.020	%

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________

GSVmp = (*BPVmp* * *CCFmp*)

ISVmm = (*Ni* / *NKF*) * (*CCFmm*) ________________________

CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)

CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 2—Calibration Set I BI-DIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Bi-directional Displacement Pipe Prover
Master Prover Type...	Small Volume Displacement w/External Detectors
Master Meter Type...	Turbine 3" Flow Meter
Liquid Medium Type...	Gasoline 57.2 degrees API @ 60 degrees F

Calibration Report No.	___________	___________	*MMFstart*	1.000364
Calibration Date	___________	___________	*MMFstop*	1.000297
Field Prover S/N	___________	___________	*MMFavg*	1.000331
Master Prover S/N	___________	___________	Delta %	0.007

****

Calibration Medium:	Gasoline	OUT Pass	BACK Pass	Round Trip 4
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	30.000	30.000	30.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	29.250	29.250	29.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	57.4	57.4	n/a
Temperature Observed	*Tobs*	62.0	62.0	n/a
API @ 60 F	*APIb*	57.2	57.2	n/a
Time of Pass/Run	*Seconds*	375.16	375.39	n/a
Flow Rate in Bbls/Hour	*BPH*	600	600	n/a
Master Meter Pulses	*N*	131283	131365	n/a
Nominal K Factor	*NKF*	2100	2100	n/a
Indicated Meter Volume	*IVmm*	62.5157	62.5548	n/a
Temp (F) Master Meter	*Tmm*	52.4	52.6	n/a
Press. (psig) Mstr Meter	*Pmm*	100	100	n/a
Compressibility Factor	*Fmm*	0.00000699	0.00000699	n/a
Master Meter Factor	*MMFavg*	1.000331	1.000331	n/a
Corr.Temp. Liq. M.Meter	*CTLmm*	1.005072	1.004939	n/a
Corr.Press.Liq. M.Meter	*CPLmm*	1.000699	1.000699	n/a
Comb.Corr.Fact. M.Meter	*CCFmm*	1.006107	1.005974	n/a
Indicated Std Volume MM	*ISVmm*	62.8975	62.9285	n/a
Temp. Deg. F in Prover	*Tp*	52.2	52.4	n/a
Press. (psig) in Prover	*Pp*	90	90	n/a
Compressibility Factor	*Fp*	0.00000697	0.00000699	n/a
Corr Temp Steel Prover	*CTSp*	0.999855	0.999859	n/a
Corr Press Steel Prover	*CPSp*	1.000234	1.000234	n/a
Corr Temp Liquid Prover	*CTLp*	1.005205	1.005072	n/a
Corr Press Liq'd Prover	*CPLp*	1.000628	1.000629	n/a
Comb.Corr.Factor Prover	*CCFp*	1.005926	1.005798	n/a
Vb(out) + Vb(back) = CPV	n >>>>>>>>>>	62.5270	62.5657	125.0927

****

Formulae for Master Meter Calibration: (witnesses)

Vb(out) or Vb(back) =	(*ISVmm* / *CCFp*)	
ISVmm =	(*IVmm* * *CCFmm*)	________________________
IVmm =	(*N* / *NKF*)	
CCFmm =	(*MMF* * *CTLmm* * *CPLmm*)	________________________
CCFp =	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)	
CPVn =	Vb(out) + Vb(back)	________________________

****

Example 2—Calibration Set I — BI-DIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Bi-directional Displacement Pipe Prover
Master Prover Type...	Small Volume Displacement w/External Detectors
Master Meter Type...	Turbine 3" Flow Meter
Liquid Medium Type...	Gasoline 57.2 degrees API @ 60 degrees F

Calibration Report No.	___________	___________	*MMFstart*	1.000364
Calibration Date	___________	___________	*MMFstop*	1.000297
Field Prover S/N	___________	___________	*MMFaverage*	1.000331
Master Prover S/N	___________	___________	Delta %	0.007

****

Calibration Medium:	Gasoline	OUT Pass	BACK Pass	Round Trip 5
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	30.000	30.000	30.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	29.250	29.250	29.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	57.4	57.4	n/a
Temperature Observed	*Tobs*	62.0	62.0	n/a
API @ 60 F	*APIb*	57.2	57.2	n/a
Time of Pass/Run	*Seconds*	375.15	375.40	n/a
Flow Rate in Bbls/Hour	*BPH*	600	600	n/a
Master Meter Pulses	*N*	131278	131367	n/a
Nominal K Factor	*NKF*	2100	2100	n/a
Indicated Meter Volume	*IVmm*	62.5133	62.5557	n/a
Temp (F) Master Meter	*Tmm*	52.6	52.6	n/a
Press. (psig) Mstr Meter	*Pmm*	100	100	n/a
Compressibility Factor	*Fmm*	0.00000699	0.00000699	n/a
Master Meter Factor	*MMFavg*	1.000331	1.000331	n/a
Corr.Temp. Liq. M.Meter	*CTLmm*	1.004939	1.004939	n/a
Corr.Press.Liq. M.Meter	*CPLmm*	1.000699	1.000699	n/a
Comb.Corr.Fact. M.Meter	*CCFmm*	1.005974	1.005974	n/a
Indicated Std Volume MM	*ISVmm*	62.8868	62.9294	n/a
Temp. Deg. F in Prover	*Tp*	52.4	52.4	n/a
Press. (psig) in Prover	*Pp*	90	90	n/a
Compressibility Factor	*Fp*	0.00000699	0.00000699	n/a
Corr Temp Steel Prover	*CTSp*	0.999859	0.999859	n/a
Corr Press Steel Prover	*CPSp*	1.000234	1.000234	n/a
Corr Temp Liquid Prover	*CTLp*	1.005072	1.005072	n/a
Corr Press Liq'd Prover	*CPLp*	1.000629	1.000629	n/a
Comb.Corr.Factor Prover	*CCFp*	1.005798	1.005798	n/a
Vb(out) + Vb(back) = CPV	n >>>>>>>>>>	62.5243	62.5666	125.0909

****

Formulae for Master Meter Calibration: (witnesses)

Vb(out) or Vb(back) =	(*ISVmm* / *CCFp*)	
ISVmm =	(*IVmm* * *CCFmm*)	________________________
IVmm =	(*N* / *NKF*)	
CCFmm =	(*MMF* * *CTLmm* * *CPLmm*)	________________________
CCFp =	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)	
CPVn =	Vb(out) + Vb(back)	________________________

****

Example 2—Calibration Set I BI-DIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Bi-directional Displacement Pipe Prover
Master Prover Type...	Small Volume Displacement w/External Detectors
Master Meter Type...	Turbine 3" Flow Meter
Liquid Medium Type...	Gasoline 57.2 degrees API @ 60 degrees F

Calibration Report No.	___________	___________	MMFstart	1.000364
Calibration Date	___________	___________	MMFstop	1.000297
Field Prover S/N	___________	___________	MMFaverage	1.000331
Master Prover S/N	___________	___________	Delta %	0.007

****

Calibration Medium:	Gasoline	OUT Pass	BACK Pass	Round Trip 6
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	30.000	30.000	30.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	29.250	29.250	29.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	57.4	57.4	n/a
Temperature Observed	*Tobs*	62.0	62.0	n/a
API @ 60 F	*APIb*	57.2	57.2	n/a
Time of Pass/Run	*Seconds*	375.15	375.41	n/a
Flow Rate in Bbls/Hour	*BPH*	600	600	n/a
Master Meter Pulses	*N*	131286	131370	n/a
Nominal K Factor	*NKF*	2100	2100	n/a
Indicated Meter Volume	*IVmm*	62.5171	62.5571	n/a
Temp (F) Master Meter	*Tmm*	52.5	52.6	n/a
Press. (psig) Mstr Meter	*Pmm*	100	100	n/a
Compressibility Factor	*Fmm*	0.00000699	0.00000699	n/a
Master Meter Factor	*MMFavg*	1.000331	1.000331	n/a
Corr.Temp. Liq. M.Meter	*CTLmm*	1.005005	1.004939	n/a
Corr.Press.Liq. M.Meter	*CPLmm*	1.000699	1.000699	n/a
Comb.Corr.Fact. M.Meter	*CCFmm*	1.006040	1.005974	n/a
Indicated Std Volume MM	*ISVmm*	62.8947	62.9308	n/a
Temp. Deg. F in Prover	*Tp*	52.2	52.4	n/a
Press. (psig) in Prover	*Pp*	90	90	n/a
Compressibility Factor	*Fp*	0.00000697	0.00000699	n/a
Corr Temp Steel Prover	*CTSp*	0.999855	0.999859	n/a
Corr Press Steel Prover	*CPSp*	1.000234	1.000234	n/a
Corr Temp Liquid Prover	*CTLp*	1.005205	1.005072	n/a
Corr Press Liq'd Prover	*CPLp*	1.000628	1.000629	n/a
Comb.Corr.Factor Prover	*CCFp*	1.005926	1.005798	n/a
Vb(out) + Vb(back) = CPV	n >>>>>>>>>>	62.5242	62.5680	125.0922

****

Formulae for Master Meter Calibration: (witnesses)

Vb(out) or Vb(back) =	(*ISVmm* / *CCFp*)	
ISVmm =	(*IVmm* * *CCFmm*)	________________________
IVmm =	(*N* / *NKF*)	
CCFmm =	(*MMF* * *CTLmm* * *CPLmm*)	________________________
CCFp =	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)	
CPVn =	Vb(out) + Vb(back)	________________________

****

Example 2—Calibration Set I *MMFstop* I

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #______
Method: Average MF method Date:_________
Master Prover: Small Vol. Displacement w/External Detectors S/N__________
Master Meter: Turbine 3" Flow Meter S/N__________

****

Run Number	2	3	4	5	6
Medium	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline
Steel	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.
Ga	0.0000120	0.0000120	0.0000120	0.0000120	0.0000120
Gl	0.0000008	0.0000008	0.0000008	0.0000008	0.0000008
WT	0.875	0.875	0.875	0.875	0.875
ID	12.250	12.250	12.250	12.250	12.250
E	28500000	28500000	28500000	28500000	28500000
APIobs	57.4	57.4	57.4	57.4	57.4
Tobs	62.0	62.0	62.0	62.0	62.0
APIb	57.2	57.2	57.2	57.2	57.2
Seconds	1.6076	1.6076	1.6076	1.6076	1.6076
*Flow (*BPH*)*	800	800	800	800	800
Tmp	52.6	52.6	52.6	52.6	52.6
Td	57.0	57.0	57.0	57.0	57.0
Pmp	95	95	95	95	95
Fmp	0.00000699	0.00000699	0.00000699	0.00000699	0.00000699
BPVmp	0.357249	0.357249	0.357249	0.357249	0.357249
CTSmp	0.999909	0.999909	0.999909	0.999909	0.999909
CPSmp	1.000047	1.000047	1.000047	1.000047	1.000047
CTLmp	1.004939	1.004939	1.004939	1.004939	1.004939
CPLmp	1.000664	1.000664	1.000664	1.000664	1.000664
CCFmp	1.005562	1.005562	1.005562	1.005562	1.005562
GSVmp	0.359236	0.359236	0.359236	0.359236	0.359236
Ni	750.041	750.114	750.042	749.972	750.035
NKF	2100	2100	2100	2100	2100
IVmm	0.357162	0.357197	0.357163	0.357130	0.357160
Tmm	52.8	52.8	52.8	52.8	52.8
Pmm	100	100	100	100	100
Fmm	0.00000700	0.00000700	0.00000700	0.00000700	0.00000700
CTLmm	1.004805	1.004805	1.004805	1.004805	1.004805
CPLmm	1.000700	1.000700	1.000700	1.000700	1.000700
CCFmm	1.005508	1.005508	1.005508	1.005508	1.005508
ISVmm	0.359129	0.359164	0.359130	0.359097	0.359127
IMMF	1.000298	1.000200	1.000295	1.000387	1.000304

****

Average of Five Consecutive Runs = 1.000297 *MMFstop* I
Calculated Range Percent = 0.019 ((Max-Min)/(Min))*(100)
Allowable Range Percent = 0.020 %

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________
GSVmp = (*BPVmp* * *CCFmp*)
ISVmm = (*Ni* / *NKF*) * (*CCFmm*) ________________________
CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)
CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 2—Calibration Summary I BI-DIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Bi-directional Displacement Pipe Prover
Master Prover Type...	Small Volume Displacement w/External Detectors
Master Meter Type...	Turbine 3" Flow Meter
Liquid Medium Type...	Gasoline 57.2 degrees API @ 60 degrees F

Calibration Report No.	___________	___________	*MMFstart*	1.000364
Calibration Date	___________	___________	*MMFstop*	1.000297
Field Prover S/N	___________	___________	*MMFaverage*	1.000331
Master Prover S/N	___________	___________	Delta %	0.007

****

SUMMARY OF CALIBRATION RUNS FOR THIS SET

CALIBRATION SET I

@ 600 BPH

BI-DIRECTIONAL DISPLACEMENT PIPE PROVER

		OUT Pass *Vb(out)*	BACK Pass + *Vb(back)*	Round Trip = *CPVn*
Round Trip No. 4	=	62.5270	62.5657	125.0927
Round Trip No. 5	=	62.5243	62.5666	125.0909
Round Trip No. 6	=	62.5242	62.5680	125.0922
[(MAX-MIN) / (MIN)] * [100]	=	N/A	N/A	0.001
Allowable Range %	=	N/A	N/A	0.020
		Average *Vb(out)*	Average *Vb(back)*	*CPVavg*
Averages for this Set CPVavg	=	62.5252	62.5668	125.0919

Notes:
1. Round trips used in the calibration must be consecutive.
.2. No more than 6 round trips can be run in any one set in order to obtain the required 3 consecutive round trips.

13.2.2 Example 2—Calibration Set II

13.2.2.1 Master Meter Type Calibration of Field Prover

13.2.2.1.1 *MMFstart* for this Calibration Set

a. See first data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a six consecutive proving runs.
f. First run did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 2, 3, 4, 5, and 6) within a range of 0.02%.

13.2.2.1.2 Calibration Runs on Field Prover for this Calibration Set

a. See second, third and fourth data/calculations pages of this calibration set.
b. Conducted calibration runs (round trips) on field prover using master meter.
c. Criteria: three consecutive calibration runs (round trips) within a range of 0.02%.
d. Maximum of six runs (round trips) allowed to complete this exercise.
e. Made a total of three consecutive calibrations runs (round trips).
f. First three runs (round trips) repeated within a range of 0.02%.
g. Used these three consecutive runs (round Trips 1, 2, and 3) within a range of 0.02%.
h. Trial calculations can be performed to test repeatability using *MMFstart*.
i. Final calculations can be made only after completion of *MMFstop*.
j. Example shows final calculations only with using average of *MMFstart* and *MMFstop*.

13.2.2.1.3 *MMFstop* for this Calibration Set

a. See fifth data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of five consecutive proving runs.
f. First five runs repeated within a range of 0.02%.
g. Used these five consecutive runs (runs 1, 2, 3, 4, and 5) within a range of 0.02%.

13.2.2.1.4 *MMFavg* and Final Calculations for this Calibration Set

a. See second, third and fourth data/calculations pages of this calibration set.
b. Compared *MMFstart* to *MMFstop*.
c. Criteria: *MMFstart* and *MMFstop* must be within a range of 0.02%.
d. Calculated the average of *MMFstart* and *MMFstop*.
e. Used *MMFavg* for field prover calibration runs.

See sixth data/calculations page of this calibration set for summary of this calibration set.

13.2.2.1.5 Go to Calibration Set III

Example 2—Calibration Set II *MMFstart* II

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #_______
Method: Average MF method Date:_________
Master Prover: Small Vol. Displacement w/External Detectors S/N___________
Master Meter: Turbine 3" Flow Meter S/N___________

****

Run Number	2	3	4	5	6
Medium	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline
Steel	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.
Ga	0.0000120	0.0000120	0.0000120	0.0000120	0.0000120
Gl	0.0000008	0.0000008	0.0000008	0.0000008	0.0000008
WT	0.875	0.875	0.875	0.875	0.875
ID	12.250	12.250	12.250	12.250	12.250
E	28500000	28500000	28500000	28500000	28500000
APIobs	57.4	57.4	57.4	57.4	57.4
Tobs	62.0	62.0	62.0	62.0	62.0
APIb	57.2	57.2	57.2	57.2	57.2
Seconds	3.2152	3.2152	3.2152	3.2152	3.2152
*Flow (*BPH*)*	400	400	400	400	400
Tmp	53.3	53.3	53.3	53.3	53.3
Td	57.0	57.0	57.0	57.0	57.0
Pmp	97	97	97	97	97
Fmp	0.00000702	0.00000702	0.00000702	0.00000702	0.00000702
BPVmp	0.357249	0.357249	0.357249	0.357249	0.357249
CTSmp	0.999917	0.999917	0.999917	0.999917	0.999917
CPSmp	1.000048	1.000048	1.000048	1.000048	1.000048
CTLmp	1.004472	1.004472	1.004472	1.004472	1.004472
CPLmp	1.000681	1.000681	1.000681	1.000681	1.000681
CCFmp	1.005121	1.005121	1.005121	1.005121	1.005121
GSVmp	0.359078	0.359078	0.359078	0.359078	0.359078
Ni	750.472	750.402	750.508	750.434	750.458
NKF	2100	2100	2100	2100	2100
IVmm	0.357368	0.357334	0.357385	0.357350	0.357361
Tmm	53.4	53.4	53.4	53.4	53.4
Pmm	100	100	100	100	100
Fmm	0.00000702	0.00000702	0.00000702	0.00000702	0.00000702
CTLmm	1.004405	1.004405	1.004405	1.004405	1.004405
CPLmm	1.000702	1.000702	1.000702	1.000702	1.000702
CCFmm	1.005110	1.005110	1.005110	1.005110	1.005110
ISVmm	0.359194	0.359160	0.359211	0.359176	0.359187
IMMF	0.999677	0.999772	0.999630	0.999727	0.999697

****

Average of Five Consecutive Runs = 0.999701 *MMFstart* II
Calculated Range Percent = 0.014 ((Max-Min)/(Min))*(100)
Allowable Range Percent = 0.020 %

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________
GSVmp = (*BPVmp* * *CCFmp*)
ISVmm = (*Ni* / *NKF*) * (*CCFmm*) ________________________
CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)
CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 2—Calibration Set II BI-DIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Bi-directional Displacement Pipe Prover
Master Prover Type...	Small Volume Displacement w/External Detectors
Master Meter Type...	Turbine 3" Flow Meter
Liquid Medium Type...	Gasoline 57.2 degrees API @ 60 degrees F

Calibration Report No.	___________	___________	MMFstart	0.999701
Calibration Date	___________	___________	MMFstop	0.999751
Field Prover S/N	___________	___________	MMFaverage	0.999726
Master Prover S/N	___________	___________	Delta%	0.005

****

Calibration Medium:	Gasoline	OUT Pass	BACK Pass	Round Trip 1
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	30.000	30.000	30.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	29.250	29.250	29.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	57.4	57.4	n/a
Temperature Observed	*Tobs*	62.0	62.0	n/a
API @ 60 F	*APIb*	57.2	57.2	n/a
Time of Pass/Run	*Seconds*	562.78	563.03	n/a
Flow Rate in Bbls/Hour	*BPH*	400	400	n/a
Master Meter Pulses	*N*	131381	131440	n/a
Nominal K Factor	*NKF*	2100	2100	n/a
Indicated Meter Volume	*IVmm*	62.5624	62.5905	n/a
Temp (F) Master Meter	*Tmm*	53.6	53.8	n/a
Press. (psig) Mstr Meter	*Pmm*	100	100	n/a
Compressibility Factor	*Fmm*	0.00000702	0.00000703	n/a
Master Meter Factor	*MMFavg*	0.999726	0.999726	n/a
Corr.Temp. Liq. M.Meter	*CTLmm*	1.004272	1.004139	n/a
Corr.Press.Liq. M.Meter	*CPLmm*	1.000702	1.000703	n/a
Comb.Corr.Fact. M.Meter	*CCFmm*	1.004702	1.004570	n/a
Indicated Std Volume MM	*ISVmm*	62.8566	62.8765	n/a
Temp. Deg. F in Prover	*Tp*	53.4	53.6	n/a
Press. (psig) in Prover	*Pp*	95	95	n/a
Compressibility Factor	*Fp*	0.00000702	0.00000702	n/a
Corr Temp Steel Prover	*CTSp*	0.999877	0.999881	n/a
Corr Press Steel Prover	*CPSp*	1.000247	1.000247	n/a
Corr Temp Liquid Prover	*CTLp*	1.004405	1.004272	n/a
Corr Press Liq'd Prover	*CPLp*	1.000667	1.000667	n/a
Comb.Corr.Factor Prover	*CCFp*	1.0052	1.00507	n/a
Vb(out) + Vb(back) = CPV	n >>>>>>>>>>	62.5314	62.5593	125.0907

****

Formulae for Master Meter Calibration: (witnesses)

Vb(out) or *Vb(back)* =	(*ISVmm* / *CCFp*)	
ISVmm =	(*IVmm* * *CCFmm*)	________________________
IVmm =	(*N* / *NKF*)	
CCFmm =	(*MMF* * *CTLmm* * *CPLmm*)	________________________
CCFp =	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)	
CPVn =	*Vb(out)* + *Vb(back)*	________________________

****

Example 2—Calibration Set II BI-DIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Bi-directional Displacement Pipe Prover
Master Prover Type...	Small Volume Displacement w/External Detectors
Master Meter Type...	Turbine 3" Flow Meter
Liquid Medium Type...	Gasoline 57.2 degrees API @ 60 degrees F

Calibration Report No.	___________	___________	MMFstart	0.999701
Calibration Date	___________	___________	MMFstop	0.999751
Field Prover S/N	___________	___________	MMFaverage	0.999726
Master Prover S/N	___________	___________	Delta %	0.005

****

Calibration Medium:	Gasoline	OUT Pass	BACK Pass	Round Trip 2
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	30.000	30.000	30.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	29.250	29.250	29.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	57.4	57.4	n/a
Temperature Observed	*Tobs*	62.0	62.0	n/a
API @ 60 F	*APIb*	57.2	57.2	n/a
Time of Pass/Run	*Seconds*	562.72	562.98	n/a
Flow Rate in Bbls/Hour	*BPH*	400	400	n/a
Master Meter Pulses	*N*	131376	131435	n/a
Nominal K Factor	*NKF*	2100	2100	n/a
Indicated Meter Volume	*IVmm*	62.5600	62.5881	n/a
Temp (F) Master Meter	*Tmm*	53.7	53.8	n/a
Press. (psig) Mstr Meter	*Pmm*	100	100	n/a
Compressibility Factor	*Fmm*	0.00000702	0.00000703	n/a
Master Meter Factor	*MMFavg*	0.999726	0.999726	n/a
Corr.Temp. Liq. M.Meter	*CTLmm*	1.004206	1.004139	n/a
Corr.Press.Liq. M.Meter	*CPLmm*	1.000702	1.000703	n/a
Comb.Corr.Fact. M.Meter	*CCFmm*	1.004636	1.004570	n/a
Indicated Std Volume MM	*ISVmm*	62.8500	62.8741	n/a
Temp. Deg. F in Prover	*Tp*	53.4	53.5	n/a
Press. (psig) in Prover	*Pp*	95	95	n/a
Compressibility Factor	*Fp*	0.00000702	0.00000702	n/a
Corr Temp Steel Prover	*CTSp*	0.999877	0.999879	n/a
Corr Press Steel Prover	*CPSp*	1.000247	1.000247	n/a
Corr Temp Liquid Prover	*CTLp*	1.004405	1.004339	n/a
Corr Press Liq'd Prover	*CPLp*	1.000667	1.000667	n/a
Comb.Corr.Factor Prover	*CCFp*	1.0052	1.005135	n/a
Vb(out) + Vb(back) = CPV	n >>>>>>>>>>	62.5249	62.5529	125.0778

****

Formulae for Master Meter Calibration: (witnesses)

Vb(out) or *Vb(back)* =		(*ISVmm* / *CCFp*)	
ISVmm	=	(*IVmm* * *CCFmm*)	______________________
IVmm	=	(*N* / *NKF*)	
CCFmm	=	(*MMF* * *CTLmm* * *CPLmm*)	______________________
CCFp	=	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)	
CPVn	=	*Vb(out)* + *Vb(back)*	______________________

****

Example 2—Calibration Set II BI-DIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Bi-directional Displacement Pipe Prover
Master Prover Type...	Small Volume Displacement w/External Detectors
Master Meter Type...	Turbine 3" Flow Meter
Liquid Medium Type...	Gasoline 57.2 degrees API @ 60 degrees F

Calibration Report No.	___________	___________	MMFstart	0.999701
Calibration Date	___________	___________	MMFstop	0.999751
Field Prover S/N	___________	___________	MMFaverage	0.999726
Master Prover S/N	___________	___________	Delta %	0.005

****

Calibration Medium:	Gasoline	OUT Pass	BACK Pass	Round Trip 3
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	30.000	30.000	30.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	29.250	29.250	29.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	57.4	57.4	n/a
Temperature Observed	*Tobs*	62.0	62.0	n/a
API @ 60 F	*APIb*	57.2	57.2	n/a
Time of Pass/Run	*Seconds*	562.77	563.06	n/a
Flow Rate in Bbls/Hour	*BPH*	400	400	n/a
Master Meter Pulses	*N*	131386	131446	n/a
Nominal K Factor	*NKF*	2100	2100	n/a
Indicated Meter Volume	*IVmm*	62.5648	62.5933	n/a
Temp (F) Master Meter	*Tmm*	53.8	53.8	n/a
Press. (psig) Mstr Meter	*Pmm*	100	100	n/a
Compressibility Factor	*Fmm*	0.00000703	0.00000703	n/a
Master Meter Factor	*MMFavg*	0.999726	0.999726	n/a
Corr.Temp. Liq. M.Meter	*CTLmm*	1.004139	1.004139	n/a
Corr.Press.Liq. M.Meter	*CPLmm*	1.000703	1.000703	n/a
Comb.Corr.Fact. M.Meter	*CCFmm*	1.004570	1.004570	n/a
Indicated Std Volume MM	*ISVmm*	62.8507	62.8794	n/a
Temp. Deg. F in Prover	*Tp*	53.5	53.6	n/a
Press. (psig) in Prover	*Pp*	95	95	n/a
Compressibility Factor	*Fp*	0.00000702	0.00000702	n/a
Corr Temp Steel Prover	*CTSp*	0.999879	0.999881	n/a
Corr Press Steel Prover	*CPSp*	1.000247	1.000247	n/a
Corr Temp Liquid Prover	*CTLp*	1.004339	1.004272	n/a
Corr Press Liq'd Prover	*CPLp*	1.000667	1.000667	n/a
Comb.Corr.Factor Prover	*CCFp*	1.005135	1.00507	n/a
Vb(out) + Vb(back) = CPV	n >>>>>>>>>>	62.5296	62.5622	125.0918

****

Formulae for Master Meter Calibration: (witnesses)

Vb(out) or *Vb(back)* =		(*ISVmm* / *CCFp*)	
ISVmm	=	(*IVmm* * *CCFmm*)	______________________
IVmm	=	(*N* / *NKF*)	
CCFmm	=	(*MMF* * *CTLmm* * *CPLmm*)	______________________
CCFp	=	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)	
CPVn	=	*Vb(out)* + *Vb(back)*	______________________

****

Example 2—Calibration Set II *MMFstop* II

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #_______
Method: Average MF method Date:__________
Master Prover: Small Vol. Displacement w/External Detectors S/N___________
Master Meter: Turbine 3" Flow Meter S/N___________

****

Run Number	1	2	3	4	5
Medium	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline
Steel	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.
Ga	0.0000120	0.0000120	0.0000120	0.0000120	0.0000120
Gl	0.0000008	0.0000008	0.0000008	0.0000008	0.0000008
WT	0.875	0.875	0.875	0.875	0.875
ID	12.250	12.250	12.250	12.250	12.250
E	28500000	28500000	28500000	28500000	28500000
APIobs	57.4	57.4	57.4	57.4	57.4
Tobs	62.0	62.0	62.0	62.0	62.0
APIb	57.2	57.2	57.2	57.2	57.2
Seconds	3.2152	3.2152	3.2152	3.2152	3.2152
Flow (BPH)	400	400	400	400	400
Tmp	54.0	54.0	54.0	54.0	54.0
Td	57.0	57.0	57.0	57.0	57.0
Pmp	97	97	97	97	97
Fmp	0.00000703	0.00000703	0.00000703	0.00000703	0.00000703
BPVmp	0.357249	0.357249	0.357249	0.357249	0.357249
CTSmp	0.999926	0.999926	0.999926	0.999926	0.999926
CPSmp	1.000048	1.000048	1.000048	1.000048	1.000048
CTLmp	1.004006	1.004006	1.004006	1.004006	1.004006
CPLmp	1.000682	1.000682	1.000682	1.000682	1.000682
CCFmp	1.004665	1.004665	1.004665	1.004665	1.004665
GSVmp	0.358916	0.358916	0.358916	0.358916	0.358916
Ni	750.436	750.407	750.432	750.398	750.451
NKF	2100	2100	2100	2100	2100
IVmm	0.357350	0.357337	0.357349	0.357332	0.357358
Tmm	54.1	54.1	54.1	54.1	54.1
Pmm	100	100	100	100	100
Fmm	0.00000703	0.00000703	0.00000703	0.00000703	0.00000703
CTLmm	1.003939	1.003939	1.003939	1.003939	1.003939
CPLmm	1.000703	1.000703	1.000703	1.000703	1.000703
CCFmm	1.004645	1.004645	1.004645	1.004645	1.004645
ISVmm	0.359010	0.358997	0.359009	0.358992	0.359018
IMMF	0.999738	0.999774	0.999741	0.999788	0.999716

****

Average of Five Consecutive Runs	=	0.999751	*MMFstop* II
Calculated Range Percent	=	0.007	((Max-Min)/(Min))*(100)
Allowable Range Percent	=	0.020	%

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________

GSVmp = (*BPVmp* * *CCFmp*)

ISVmm = (*Ni* / *NKF*) * (*CCFmm*) ________________________

CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)

CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 2—Calibration Summary II

BI-DIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Bi-directional Displacement Pipe Prover
Master Prover Type...	Small Volume Displacement w/External Detectors
Master Meter Type...	Turbine 3" Flow Meter
Liquid Medium Type...	Gasoline 57.2 degrees API @ 60 degrees F

Calibration Report No.	___________	___________	*MMFstart*	0.999701
Calibration Date	___________	___________	*MMFstop*	0.999751
Field Prover S/N	___________	___________	*MMFaverage*	0.999726
Master Prover S/N	___________	___________	Delta%	0.005

****

SUMMARY OF CALIBRATION RUNS FOR THIS SET

CALIBRATION SET II

@ 400 BPH

BI-DIRECTIONAL DISPLACEMENT PIPE PROVER

		OUT Pass *Vb(out)*	BACK Pass + *Vb(back)*	Round Trip = *CPVn*
Round Trip No. 1	=	62.5314	62.5593	125.0907
Round Trip No. 2	=	62.5249	62.5529	125.0778
Round Trip No. 3	=	62.5296	62.5622	125.0918
[(MAX-MIN) / (MIN)] * [100]	=	N/A	N/A	0.011
Allowable Range %	=	N/A	N/A	0.020
		Average *Vb(out)*	Average *Vb(back)*	*CPVavg*
Averages for this Set *CPVavg*	=	62.5286	62.5581	125.0868

Note:
1. Round trips used in the calibration must be consecutive.
2. No more than 6 round trips can be run in any one set in order to obtain the required 3 consecutive round trips.

13.2.3 Example 2—Calibration Set III

13.2.3.1 Master Meter Type Calibration of Field Prover

13.2.3.1.1 *MMFstart* for this Calibration Set

a. See first data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of seven (7) consecutive proving runs.
f. First two runs did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 3, 4, 5, 6, and 7) within a range of 0.02%.

13.2.3.1.2 Calibration Runs on Field Prover for this Calibration Set

a. See second, third and fourth data/calculations pages of this calibration set.
b. Conducted calibration runs (round trips) on field prover using master meter.
c. Criteria: three consecutive calibration runs (round trips) within a range of 0.02%.
d. Maximum of six runs (round trips) allowed to complete this exercise.
e. Made a total of five consecutive calibrations runs (round trips).
f. First two runs (round trips) did not repeat within 0.02% (temperature instability etc.).
g. Used last three runs (round trips 3, 4, and 5) within a range of 0.02%.
h. Trial calculations can be performed to test repeatability using *MMFstart*.
i. Final calculations can be made only after completion of *MMFstop*.
j. Example shows final calculations only with using average of *MMFstart* and *MMFstop*.

13.2.3.1.3 *MMFstop* for this Calibration Set

a. See fifth data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of six consecutive proving runs.
f. First run did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 2, 3, 4, 5, and 6) within a range of 0.02%.

13.2.3.1.4 *MMFavg* and Final Calculations for this Calibration Set

h. See second, third and fourth data/calculations pages of this calibration set.
i. Compared *MMFstart* to *MMFstop*.
j. Criteria: *MMFstart* and *MMFstop* must be within a range of 0.02%.
k. Calculated the average of *MMFstart* and *MMFstop*.
l. Used *MMFavg* for field prover calibration runs.

See sixth data/calculations page of this calibration set for summary of this calibration set.

13.2.3.1.5 Go to Calibration Summary at End of this Example

Example 2—Calibration Set III *MMFstart* III

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #_______
Method: Average MF method Date:__________
Master Prover: Small Vol. Displacement w/ External Detectors S/N___________
Master Meter: Turbine 3" Flow Meter S/N___________

****

Run Number	3	4	5	6	7
Medium	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline
Steel	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.
Ga	0.0000120	0.0000120	0.0000120	0.0000120	0.0000120
Gl	0.0000008	0.0000008	0.0000008	0.0000008	0.0000008
WT	0.875	0.875	0.875	0.875	0.875
ID	12.250	12.250	12.250	12.250	12.250
E	28500000	28500000	28500000	28500000	28500000
APIobs	57.4	57.4	57.4	57.4	57.4
Tobs	62.0	62.0	62.0	62.0	62.0
APIb	57.2	57.2	57.2	57.2	57.2
Seconds	2.1435	2.1435	2.1435	2.1435	2.1435
*Flow (*BPH*)*	600	600	600	600	600
Tmp	54.2	54.2	54.2	54.2	54.2
Td	57.0	57.0	57.0	57.0	57.0
Pmp	93	93	93	93	93
Fmp	0.00000703	0.00000703	0.00000703	0.00000703	0.00000703
BPVmp	0.357249	0.357249	0.357249	0.357249	0.357249
CTSmp	0.999928	0.999928	0.999928	0.999928	0.999928
CPSmp	1.000046	1.000046	1.000046	1.000046	1.000046
CTLmp	1.003872	1.003872	1.003872	1.003872	1.003872
CPLmp	1.000654	1.000654	1.000654	1.000654	1.000654
CCFmp	1.004502	1.004502	1.004502	1.004502	1.004502
GSVmp	0.358857	0.358857	0.358857	0.358857	0.358857
Ni	749.502	749.486	749.460	749.552	749.498
NKF	2100	2100	2100	2100	2100
IVmm	0.356906	0.356898	0.356886	0.356930	0.356904
Tmm	54.4	54.4	54.4	54.4	54.4
Pmm	100	100	100	100	100
Fmm	0.00000705	0.00000705	0.00000705	0.00000705	0.00000705
CTLmm	1.003739	1.003739	1.003739	1.003739	1.003739
CPLmm	1.000705	1.000705	1.000705	1.000705	1.000705
CCFmm	1.004447	1.004447	1.004447	1.004447	1.004447
ISVmm	0.358493	0.358485	0.358473	0.358517	0.358491
IMMF	1.001015	1.001038	1.001071	1.000948	1.001021

****

Average of Five Consecutive Runs = 1.001019 *MMFstart* III
Calculated Range Percent = 0.012 ((Max-Min)/(Min))*(100)
Allowable Range Percent = 0.020 %

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________
GSVmp = (*BPVmp* * *CCFmp*)
ISVmm = (*Ni* / *NKF*) * (*CCFmm*) ________________________
CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)
CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 2—Calibration Set III BI-DIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Bi-directional Displacement Pipe Prover
Master Prover Type...	Small Volume Displacement w/External Detectors
Master Meter Type...	Turbine 3" Flow Meter
Liquid Medium Type...	Gasoline 57.2 degrees API @ 60 degrees F

Calibration Report No.	___________	___________	*MMFstart*	1.001019
Calibration Date	___________	___________	*MMFstop*	1.001157
Field Prover S/N	___________	___________	*MMFaverage*	1.001088
Master Prover S/N	___________	___________	Delta%	0.014

****

Calibration Medium:	Gasoline	OUT Pass	BACK Pass	Round Trip 3
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	30.000	30.000	30.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	29.250	29.250	29.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	57.4	57.4	n/a
Temperature Observed	*Tobs*	62.0	62.0	n/a
API @ 60 F	*APIb*	57.2	57.2	n/a
Time of Pass/Run	*Seconds*	281.38	281.52	n/a
Flow Rate in Bbls/Hour	*BPH*	800	800	n/a
Master Meter Pulses	*N*	131186	131251	n/a
Nominal K Factor	*NKF*	2100	2100	n/a
Indicated Meter Volume	*IVmm*	62.4695	62.5005	n/a
Temp (F) Master Meter	*Tmm*	54.7	54.8	n/a
Press. (psig) Mstr Meter	*Pmm*	100	100	n/a
Compressibility Factor	*Fmm*	0.00000705	0.00000706	n/a
Master Meter Factor	*MMFavg*	1.001088	1.001088	n/a
Corr.Temp. Liq. M.Meter	*CTLmm*	1.003539	1.003472	n/a
Corr.Press.Liq. M.Meter	*CPLmm*	1.000705	1.000706	n/a
Comb.Corr.Fact. M.Meter	*CCFmm*	1.005339	1.005273	n/a
Indicated Std Volume MM	*ISVmm*	62.8030	62.8301	n/a
Temp. Deg. F in Prover	*Tp*	54.5	54.6	n/a
Press. (psig) in Prover	*Pp*	85	85	n/a
Compressibility Factor	*Fp*	0.00000705	0.00000705	n/a
Corr Temp Steel Prover	*CTSp*	0.999898	0.9999	n/a
Corr Press Steel Prover	*CPSp*	1.000221	1.000221	n/a
Corr Temp Liquid Prover	*CTLp*	1.003672	1.003605	n/a
Corr Press Liq'd Prover	*CPLp*	1.000600	1.000600	n/a
Comb.Corr.Factor Prover	*CCFp*	1.004394	1.004329	n/a
Vb(out) + Vb(back) = CPV	n >>>>>>>>>>	62.5283	62.5593	125.0876

****

Formulae for Master Meter Calibration: (witnesses)

Vb(out) or *Vb(back)* =		(*ISVmm* / *CCFp*)	
ISVmm	=	(*IVmm* * *CCFmm*)	________________________
IVmm	=	(*N* / *NKF*)	
CCFmm	=	(*MMF* * *CTLmm* * *CPLmm*)	________________________
CCFp	=	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)	
CPVn	=	*Vb(out)* + *Vb(back)*	________________________

****

Example 2—Calibration Set III

BI-DIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Bi-directional Displacement Pipe Prover
Master Prover Type...	Small Volume Displacement w/External Detectors
Master Meter Type...	Turbine 3" Flow Meter
Liquid Medium Type...	Gasoline 57.2 degrees API @ 60 degrees F

Calibration Report No.	___________	___________	*MMFstart*	1.001019
Calibration Date	___________	___________	*MMFstop*	1.001157
Field Prover S/N	___________	___________	*MMFaverage*	1.001088
Master Prover S/N	___________	___________	Delta%	.014

****

Calibration Medium:	Gasoline	OUT Pass	BACK Pass	Round Trip 4
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	30.000	30.000	30.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	29.250	29.250	29.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	57.4	57.4	n/a
Temperature Observed	*Tobs*	62.0	62.0	n/a
API @ 60 F	*APIb*	57.2	57.2	n/a
Time of Pass/Run	*Seconds*	281.36	281.51	n/a
Flow Rate in Bbls/Hour	*BPH*	800	800	n/a
Master Meter Pulses	*N*	131177	131246	n/a
Nominal K Factor	*NKF*	2100	2100	n/a
Indicated Meter Volume	*IVmm*	62.4652	62.4981	n/a
Temp (F) Master Meter	*Tmm*	54.6	54.8	n/a
Press. (psig) Mstr Meter	*Pmm*	100	100	n/a
Compressibility Factor	*Fmm*	0.00000705	0.00000706	n/a
Master Meter Factor	*MMFavg*	1.001088	1.001088	n/a
Corr.Temp. Liq. M.Meter	*CTLmm*	1.003605	1.003472	n/a
Corr.Press.Liq. M.Meter	*CPLmm*	1.000705	1.000706	n/a
Comb.Corr.Fact. M.Meter	*CCFmm*	1.005405	1.005273	n/a
Indicated Std Volume MM	*ISVmm*	62.8028	62.8277	n/a
Temp. Deg. F in Prover	*Tp*	54.4	54.6	n/a
Press. (psig) in Prover	*Pp*	85	85	n/a
Compressibility Factor	*Fp*	0.00000705	0.00000705	n/a
Corr Temp Steel Prover	*CTSp*	0.999896	0.9999	n/a
Corr Press Steel Prover	*CPSp*	1.000221	1.000221	n/a
Corr Temp Liquid Prover	*CTLp*	1.003739	1.003605	n/a
Corr Press Liq'd Prover	*CPLp*	1.000600	1.000600	n/a
Comb.Corr.Factor Prover	*CCFp*	1.004459	1.004329	n/a
Vb(out) + Vb(back) = CPV	n >>>>>>>>>>	62.5240	62.5569	125.0809

****

Formulae for Master Meter Calibration: (witnesses)

Vb(out) or *Vb(back)* =	(*ISVmm* / *CCFp*)	
ISVmm =	(*IVmm* * *CCFmm*)	________________________
IVmm =	(*N* / *NKF*)	
CCFmm =	(*MMF* * *CTLmm* * *CPLmm*)	________________________
CCFp =	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)	
CPVn =	*Vb(out)* + *Vb(back)*	________________________

****

Example 2—Calibration Set III BI-DIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Bi-directional Displacement Pipe Prover
Master Prover Type...	Small Volume Displacement w/External Detectors
Master Meter Type...	Turbine 3" Flow Meter
Liquid Medium Type...	Gasoline 57.2 degrees API @ 60 degrees F

Calibration Report No.	___________	___________	*MMFstart*	1.001019
Calibration Date	___________	___________	*MMFstop*	1.001157
Field Prover S/N	___________	___________	*MMFaverage*	1.001088
Master Prover S/N	___________	___________	Delta%	0.014

****

Calibration Medium:	Gasoline	OUT Pass	BACK Pass	Round Trip 5
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	30.000	30.000	30.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	29.250	29.250	29.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	57.4	57.4	n/a
Temperature Observed	*Tobs*	62.0	62.0	n/a
API @ 60 F	*APIb*	57.2	57.2	n/a
Time of Pass/Run	*Seconds*	281.36	281.54	n/a
Flow Rate in Bbls/Hour	*BPH*	800	800	n/a
Master Meter Pulses	*N*	131187	131253	n/a
Nominal K Factor	*NKF*	2100	2100	n/a
Indicated Meter Volume	*IVmm*	62.4700	62.5014	n/a
Temp (F) Master Meter	*Tmm*	54.7	54.7	n/a
Press. (psig) Mstr Meter	*Pmm*	100	100	n/a
Compressibility Factor	*Fmm*	0.00000705	0.00000705	n/a
Master Meter Factor	*MMFavg*	1.001088	1.001088	n/a
Corr.Temp. Liq. M.Meter	*CTLmm*	1.003539	1.003539	n/a
Corr.Press.Liq. M.Meter	*CPLmm*	1.000705	1.000705	n/a
Comb.Corr.Fact. M.Meter	*CCFmm*	1.005339	1.005339	n/a
Indicated Std Volume MM	*ISVmm*	62.8035	62.8351	n/a
Temp. Deg. F in Prover	*Tp*	54.4	54.6	n/a
Press. (psig) in Prover	*Pp*	85	85	n/a
Compressibility Factor	*Fp*	0.00000705	0.00000705	n/a
Corr Temp Steel Prover	*CTSp*	0.999896	0.9999	n/a
Corr Press Steel Prover	*CPSp*	1.000221	1.000221	n/a
Corr Temp Liquid Prover	*CTLp*	1.003739	1.003605	n/a
Corr Press Liq'd Prover	*CPLp*	1.000600	1.000600	n/a
Comb.Corr.Factor Prover	*CCFp*	1.004459	1.004329	n/a
Vb(out) + Vb(back) = CPV	n >>>>>>>>>>	62.5247	62.5643	125.0890

****

Formulae for Master Meter Calibration: (witnesses)

Vb(out) or *Vb(back)* = (*ISVmm* / *CCFp*)

ISVmm = (*IVmm* * *CCFmm*) ________________________

IVmm = (*N* / *NKF*)

CCFmm = (*MMF* * *CTLmm* * *CPLmm*) ________________________

CCFp = (*CTSp* * *CPSp* * *CTLp* * *CPLp*)

CPVn = *Vb(out)* + *Vb(back)* ________________________

****

Example 2—Calibration Set III *MMFstop* III

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #_______

Method: Average MF method Date:__________

Master Prover: Small Vol. Displacement w/External Detectors S/N___________

Master Meter: Turbine 3" Flow Meter S/N___________

****

Run Number	2	3	4	5	6
Medium	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline
Steel	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.	17-4PH S.S.
Ga	0.0000120	0.0000120	0.0000120	0.0000120	0.0000120
Gl	0.0000008	0.0000008	0.0000008	0.0000008	0.0000008
WT	0.875	0.875	0.875	0.875	0.875
ID	12.250	12.250	12.250	12.250	12.250
E	28500000	28500000	28500000	28500000	28500000
APIobs	57.4	57.4	57.4	57.4	57.4
Tobs	62.0	62.0	62.0	62.0	62.0
APIb	57.2	57.2	57.2	57.2	57.2
Seconds	2.1435	2.1435	2.1435	2.1435	2.1435
*Flow (*BPH*)*	600	600	600	600	600
Tmp	54.9	54.9	54.9	54.9	54.9
Td	57.0	57.0	57.0	57.0	57.0
Pmp	93	93	93	93	93
Fmp	0.00000706	0.00000706	0.00000706	0.00000706	0.00000706
BPVmp	0.357249	0.357249	0.357249	0.357249	0.357249
CTSmp	0.999936	0.999936	0.999936	0.999936	0.999936
CPSmp	1.000046	1.000046	1.000046	1.000046	1.000046
CTLmp	1.003405	1.003405	1.003405	1.003405	1.003405
CPLmp	1.000657	1.000657	1.000657	1.000657	1.000657
CCFmp	1.004046	1.004046	1.004046	1.004046	1.004046
GSVmp	0.358694	0.358694	0.358694	0.358694	0.358694
Ni	749.425	749.428	749.372	749.405	749.395
NKF	2100	2100	2100	2100	2100
IVmm	0.356869	0.356870	0.356844	0.356860	0.356855
Tmm	55.1	55.1	55.1	5.1	55.1
Pmm	100	100	100	100	100
Fmm	0.00000706	0.00000706	0.00000706	0.00000706	0.00000706
CTLmm	1.003272	1.003272	1.003272	1.003272	1.003272
CPLmm	1.000706	1.000706	1.000706	1.000706	1.000706
CCFmm	1.003980	1.003980	1.003980	1.003980	1.003980
ISVmm	0.358289	0.358290	0.358264	0.358280	0.358275
IMMF	1.001130	1.001128	1.001200	1.001156	1.001169

****

Average of Five Consecutive Runs = 1.001157 *MMFstop* III

Calculated Range Percent = 0.007 ((Max-Min)/(Min))*(100)

Allowable Range Percent = 0.020 %

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________

GSVmp = (*BPVmp* * *CCFmp*)

ISVmm = (*Ni* / *NKF*) * (*CCFmm*) ________________________

CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)

CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 2—Calibration Summary III BI-DIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Bi-directional Displacement Pipe Prover
Master Prover Type...	Small Volume Displacement w/External Detectors
Master Meter Type...	Turbine 3" Flow Meter
Liquid Medium Type...	Gasoline 57.2 degrees API @ 60 degrees F

Calibration Report No.	___________	___________	*MMFstart*	1.001019
Calibration Date	___________	___________	*MMFstop*	1.001157
Field Prover S/N	___________	___________	*MMFaverage*	1.001088
Master Prover S/N	___________	___________	Delta%	0.014

****

SUMMARY OF CALIBRATION RUNS FOR THIS SET

CALIBRATION SET III

@ 800 BPH

BI-DIRECTIONAL DISPLACEMENT PIPE PROVER

		OUT Pass *Vb(out)*	BACK Pass + *Vb(back)*	Round Trip = *CPVn*
Round Trip No. 3	=	62.5283	62.5593	125.0876
Round Trip No. 4	=	62.5240	62.5569	125.0809
Round Trip No. 5	=	62.5247	62.5643	125.0890
[(MAX-MIN) / (MIN)] * [100]	=	N/A	N/A	0.006
Allowable Range %	=	N/A	N/A	0.020

		Average *Vb(out)*	Average *Vb(back)*	*CPVavg*
Averages for this Set CPVavg	=	62.5257	62.5602	125.0858

Note:
1. Round trips used in the calibration must be consecutive.
2. No more than 6 round trips can be run in any one set in order to obtain the required 3 consecutive round trips.

Example 2—Calibration Summary BI-DIRECTIONAL DISPLACEMENT PROVER

Date of Calibration:	____________________
Calibration Report Number:	____________________
Summary Sheet of a Total of:	____________________
Time of Calibration (begin/end):	____________________
Weather During Calibration:	____________________
Owner / Operator of Prover:	____________________
Site of Meter Prover Calibration:	____________________
Service Location of Field Prover:	____________________
Service Identification of Prover:	____________________
Volume Identification of Prover:	____________________
Manufacturer of Field Prover:	____________________
Serial Number of Field Prover:	____________________
Serial Number of Master Prover:	____________________
Serial Number of Master Meter:	____________________
Description/Type of Field Prover:	Bi-directional Displacement Prover
Description & Type Master Prover:	Small Volume Prover w/ Ext. Det'rs
Description & Type Master Meter:	Turbine (3") Flow Meter
Material of Construction of Prover:	____________________
Cubical Coefficient per Degree F:	____________________
Square Coefficient per Degree F:	____________________
Linear Coefficient per Degree F:	____________________
Modulus of Elasticity per psi:	____________________
Outside Diameter of Prover Pipe:	____________________
Wall Thickness of Prover Pipe:	____________________
Inside Diameter of Prover Pipe:	____________________
Calibration Liquid Description:	Gasoline 57.2 deg API @ 60 deg F

****

MASTER METER CALIBRATION SUMMARY

BI-DIRECTIONAL DISPLACEMENT PROVER		OUT Pass *Avg Vb(out)*	BACK Pass *+ Avg Vb(back)*	Round Trip *= CPVavg*
Calib. Set I @ 600 BPH	=	62.5252	62.5668	125.0919
Calib. Set II @ 400 BPH	=	62.5286	62.5581	125.0868
Calib. Set III @ 800 BPH	=	62.5257	62.5602	125.0858
[(MAX-MIN) / (MIN)] * [100]	=	N/A	N/A	0.005
Allowable Range %	=	N/A	N/A	0.020

Average CPV from Calibration Sets I, II & III for Base Prover Volume:

Base Prover Volume @ 60 Degrees F & 0 psig: 125.0882 Barrels

Previous Base Prover Volume:	____________________
Percentage change in volume:	____________________
Diameter of displacer in inches:	____________________
Calibrator's Name & Company Name:	____________________

****

13.3 EXAMPLE 3—DISPLACEMENT PIPE PROVER—UNIDIRECTIONAL DESIGN

The following example depicts the calculations using the average meter factor method and required documentation for a complete unidirectional displacement prover calibration by the master meter method.

Field Prover:	Unidirectional Displacement Pipe Prover
Master Prover:	Volumetric Tank Prover
Master Meter:	Displacement Flow Meter Sliding Vane Displacement Type
Proving Method:	Average Meter Factor Method
Liquid Medium:	Water

Calibration Set I	Cover Sheet for Calibration Set I	1 page
	MMFstart	1 page
	Calibration Runs & Set Summary	1 page
	MMFstop	1 page
Calibration Set II	Cover Sheet for Calibration Set II	1 page
	MMFstart	1 page
	Calibration Runs & Set Summary	1 page
	MMFstop	1 page
Calibration Set III	Cover Sheet for Calibration Set II	1 page
	MMFstart	1 page
	Calibration Runs & Set Summary	1 page
	MMFstop	1 page
Calibration Summary	Calibration Summary Sheet	1 page

13.3.1 Example 3—Calibration Set I

13.3.1.1 Master Meter Type Calibration of Field Prover

13.3.1.1.1 *MMFstart* for this Calibration Set

a. See first data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of six consecutive proving runs.
f. First run did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 2, 3, 4, 5, and 6) within a range of 0.02%.

13.3.1.1.2 Calibration Runs on Field Prover for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Conducted calibration runs on field prover using master meter.
c. Criteria: three consecutive calibration runs within a range of 0.02%.
d. Maximum of six runs allowed to complete this exercise.
e. Made a total of six consecutive calibrations runs.
f. First three runs did not repeat within 0.02% (temperature instability etc.).

g. Used last three runs (runs 4, 5, and 6) within a range of 0.02%.
h. Trial calculations can be performed to test repeatability using *MMFstart*.
i. Final calculations can be made only after completion of *MMFstop*.
j. Example shows final calculations only with using average of *MMFstart* and *MMFstop*.

13.3.1.1.3 *MMFstop* for this Calibration Set

a. See third data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of six consecutive proving runs.
f. First run did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 2, 3, 4, 5, and 6) within a range of 0.02%.

13.3.1.1.4 *MMFavg* and Final Calculations for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Compared *MMFstart* to *MMFstop*.
c. Criteria: *MMFstart* and *MMFstop* must be within a range of 0.02%.
d. Calculated the average of *MMFstart* and *MMFstop*.
e. Used *MMFavg* for field prover calibration runs.

13.3.1.1.5 Go to Calibration Set II

Example 3—Calibration Set I *MMFstart* I

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #_______
Method: Average MF method Date:__________
Master Prover: Atmospheric Volumetric Tank Prover S/N___________
Master Meter: Displacement 4" (sliding vane type) S/N___________

****

Run Number	2	3	4	5	6
Medium	Water	Water	Water	Water	Water
Steel	Mild Carbon	Mild Carbon	Mild Carbon	Mild Carbon	Mild Carbon
Gc	0.0000186	0.0000186	0.0000186	0.0000186	0.0000186
WT	0.250	0.250	0.250	0.250	0.250
ID	95.500	95.500	95.500	95.500	95.500
E	30000000	30000000	30000000	30000000	30000000
APIobs	10.0	10.0	10.0	10.0	10.0
Tobs	60.0	60.0	60.0	60.0	60.0
APIb	10.0	10.0	10.0	10.0	10.0
Seconds	142.86	142.86	142.86	142.86	142.86
Flow (BPH)	600	600	600	600	600
Tmp	71.1	71.1	71.2	71.3	71.3
Pmp	0	0	0	0	0
Fmp	0.00000320	0.00000320	0.00000320	0.00000320	0.00000320
SRu	23.8095	23.7595	23.8095	23.9095	23.8095
SRl	0.0000	–0.0500	0.0000	0.1000	0.0000
BPVamp	23.8095	23.8095	23.8095	23.8095	23.8095
CTSmp	1.000206	1.000206	1.000208	1.000210	1.000210
CPSmp	1.000000	1.000000	1.000000	1.000000	1.000000
CTLmp	1.000000	1.000000	1.000000	1.000000	1.000000
CPLmp	1.000000	1.000000	1.000000	1.000000	1.000000
CCFmp	1.000206	1.000206	1.000208	1.000210	1.000210
GSVmp	23.8144	23.8144	23.8145	23.8145	23.8145
N	200014	200035	200028	200028	200021
NKF	8400	8400	8400	8400	8400
IVmm	23.8112	23.8137	23.8129	23.8129	23.8120
Tmm	71.2	71.2	71.3	71.3	71.3
Pmm	35	35	35	35	35
Fmm	0.00000320	0.00000320	0.00000320	0.00000320	0.00000320
CTDW	0.999988	0.999988	0.999987	1.000000	1.000000
CPLmm	1.000112	1.000112	1.000112	1.000112	1.000112
CCFmm	1.000100	1.000100	1.000099	1.000112	1.000112
ISVmm	23.8136	23.8161	23.8153	23.8156	23.8147
IMMF	1.000034	0.999929	0.999966	0.999954	0.999992

****

Average of Five Consecutive Runs	=	0.999975	*MMFstart* I
Calculated Range Percent	=	0.011	((MAX-MIN)/(MIN))*(100)
Allowable Range Percent	=	0.020	%

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________
GSVmp = (*BPVamp* * *CCFmp*)
ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________
CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)
CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 3—Calibration	Set I	UNIDIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Displacement Unidirectional Pipe Prover
Master Prover Type...	Atmospheric Tank Prover
Master Meter Type...	Displacement 4", (sliding vane type)
Liquid Medium Type...	WATER

Calibration Report No.	____________	____________	*MMFstart*	0.999975
Calibration Date	____________	____________	*MMFstop*	0.999812
Field Prover S/N	____________	____________	*MMFaverage*	0.999894
Master Prover S/N	____________	____________	Delta%	0.016

****

Medium = Crude Oil	Run No.	4	5	6
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	20.000	20.000	20.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	19.250	19.250	19.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	10.0	10.0	10.0
Temperature Observed	*Tobs*	60.0	60.0	60.0
API @ 60 F	*APIb*	10.0	10.0	10.0
Time of Pass/Run	*Seconds*	187.50	187.48	187.49
Flow Rate in Bbls/Hour	*BPH*	600	600	600
Master Meter Pulses	*N*	262612	262590	262604
Nominal K Factor	*NKF*	8400	8400	8400
Indicated MMeter Volume	*IVmm*	31.2633	31.2607	31.2624
Temp (F) Master Meter	*Tmm*	71.4	71.6	71.8
Press. (psig) Mstr Meter	*Pmm*	100	100	100
Compressibility Factor	*Fmm*	0.00000320	0.00000320	0.00000320
Master Meter Factor	*MMFavg*	0.999894	0.999894	0.999894
Corr.Temp. Liq. M.Meter	*CTDW*	0.999975	0.999975	0.999975
Corr.Press.Liq. M.Meter	*CPLmm*	1.000320	1.000320	1.000320
Comb.Corr.Fact. M.Meter	*CCFmm*	1.000189	1.000189	1.000189
Indicated Std Volume MM	*ISVmm*	31.2692	31.2666	31.2683
Temp. Deg. F in Prover	*Tp*	71.2	71.4	71.6
Press. (psig) in Prover	*Pp*	88	88	88
Compressibility Factor	*Fp*	0.00000320	0.00000320	0.00000320
Corr Temp Steel Prover	*CTSp*	1.000208	1.000212	1.000216
Corr Press Steel Prover	*CPSp*	1.000151	1.000151	1.000151
Corr Temp Liquid Prover	*CTLp*	1.000000	1.000000	1.000000
Corr Press Liq'd Prover	*CPLp*	1.000282	1.000282	1.000282
Comb.Corr.Factor Prover	*CCFp*	1.000641	1.000645	1.000649
Prover Vol. @ Tb & Pb =	*CPVn*	31.2492	31.2464	31.2480

****

CPVn Range (allowed) =	< or = 0.02%	0.009	% (actual)
CPVn =	(*ISVmm* / *CCFp*)		
ISVmm =	(*IVmm* * *CCFmm*)	____________________	
IVmm =	(*N* / *NKF*)	(witnesses)	
CCFmm =	(*MMFavg* * *CTLmm* * *CPLmm*)	____________________	
CCFp =	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)		
CPVavg =	(Average *CPV* of Set)	>>>>>>>>>>>>	31.2479

****

Example 3—Calibration Set I *MMFstop* I

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #_______
Method: Average MF method Date:_________
Master Prover: Atmospheric Volumetric Tank Prover S/N___________
Master Meter: Displacement 4" (sliding vane type) S/N___________

****

Run Number	2	3	4	5	6
Medium	Water	Water	Water	Water	Water
Steel	Mild Carbon	Mild Carbon	Mild Carbon	Mild Carbon	Mild Carbon
Gc	0.0000186	0.0000186	0.0000186	0.0000186	0.0000186
WT	0.250	0.250	0.250	0.250	0.250
ID	95.500	95.500	95.500	95.500	95.500
E	30000000	30000000	30000000	30000000	30000000
APIobs	10.0	10.0	10.0	10.0	10.0
Tobs	60.0	60.0	60.0	60.0	60.0
APIb	10.0	10.0	10.0	10.0	10.0
Seconds	142.86	142.86	142.86	142.86	142.86
Flow (BPH)	600	600	600	600	600
Tmp	71.6	71.7	71.7	71.8	71.8
Pmp	0	0	0	0	0
Fmp	0.00000320	0.00000320	0.00000320	0.00000320	0.00000320
SRu	23.8095	23.8295	23.8095	23.8095	23.6595
SRl	0.0000	0.0200	0.0000	0.0000	–0.1500
BPVamp	23.8095	23.8095	23.8095	23.8095	23.8095
CTSmp	1.000216	1.000218	1.000218	1.000219	1.000219
CPSmp	1.000000	1.000000	1.000000	1.000000	1.000000
CTLmp	1.000000	1.000000	1.000000	1.000000	1.000000
CPLmp	1.000000	1.000000	1.000000	1.000000	1.000000
CCFmp	1.000216	1.000218	1.000218	1.000219	1.000219
GSVmp	23.8146	23.8147	23.8147	23.8147	23.8147
N	200070	200042	200063	200070	200056
NKF	8400	8400	8400	8400	8400
IVmm	23.8179	23.8145	23.8170	23.8179	23.8162
Tmm	71.7	71.8	71.8	71.8	71.9
Pmm	35	35	35	35	35
Fmm	0.00000320	0.00000320	0.00000320	0.00000320	0.00000320
CTDW	0.999987	0.999987	0.999987	1.000000	0.999987
CPLmm	1.000112	1.000112	1.000112	1.000112	1.000112
CCFmm	1.000099	1.000099	1.000099	1.000112	1.000099
ISVmm	23.8203	23.8169	23.8194	23.8206	23.8186
IMMF	0.999761	0.999908	0.999803	0.999752	0.999836

****

Average of Five Consecutive Runs = 0.999812 *MMFstop* I
Calculated Range Percent = 0.016 ((MAX-MIN)/(MIN))*(100)
Allowable Range Percent = 0.020 %

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________
GSVmp = (*BPVamp* * *CCFmp*)
ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________
CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)
CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

13.3.2 Example 3—Calibration Set II

13.3.2.1 Master Meter Type Calibration of Field Prover

13.3.2.1.1 *MMFstart* for this Calibration Set

a. See first data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of seven (7) consecutive proving runs.
f. First two runs did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 3, 4, 5, 6, and 7) within a range of 0.02%.

13.3.2.1.2 Calibration Runs on Field Prover for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Conducted calibration runs on field prover using master meter.
c. Criteria: three consecutive calibration runs within a range of 0.02%.
d. Maximum of six runs allowed to complete this exercise.
e. Made a total of three consecutive calibrations runs.
f. No additional runs were necessary.
g. Used these three consecutive runs (runs 1, 2, and 3) within a range of 0.02%.
h. Trial calculations can be performed to test repeatability using *MMFstart*.
i. Final calculations can be made only after completion of *MMFstop*.
j. Example shows final calculations only with using average of *MMFstart* and *MMFstop*.

13.3.2.1.3 *MMFstop* for this Calibration Set

a. See third data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of six consecutive proving runs.
f. First run did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 2, 3, 4, 5, and 6) within a range of 0.02%.

13.3.2.1.4 *MMFavg* and Final Calculations for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Compared *MMFstart* to *MMFstop*.
c. Criteria: *MMFstart* and *MMFstop* must be within a range of 0.02%.
d. Calculated the average of *MMFstart* and *MMFstop*.
e. Used *MMFavg* for field prover calibration runs.

13.3.2.1.5 Go to Calibration Set III

Example 3—Calibration Set II *MMFstart* II

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #_______
Method: Average MF method Date:__________
Master Prover: Atmospheric Volumetric Tank Prover S/N___________
Master Meter: Displacement 4" (sliding vane type) S/N___________

****

Run Number	3	4	5	6	7
Medium	Water	Water	Water	Water	Water
Steel	Mild Carbon	Mild Carbon	Mild Carbon	Mild Carbon	Mild Carbon
Gc	0.0000186	0.0000186	0.0000186	0.0000186	0.0000186
WT	0.250	0.250	0.250	0.250	0.250
ID	95.500	95.500	95.500	95.500	95.500
E	30000000	30000000	30000000	30000000	30000000
APIobs	10.0	10.0	10.0	10.0	10.0
Tobs	60.0	60.0	60.0	60.0	60.0
APIb	10.0	10.0	10.0	10.0	10.0
Seconds	214.29	214.29	214.29	214.29	214.29
*Flow (*BPH*)*	400	400	400	400	400
Tmp	72.0	72.0	72.0	72.0	72.0
Pmp	0	0	0	0	0
Fmp	0.00000320	0.00000320	0.00000320	0.00000320	0.00000320
SRu	23.8095	23.8095	23.8095	23.8095	23.8095
SRl	0.0000	0.0000	0.0000	0.0000	0.0000
BPVamp	23.8095	23.8095	23.8095	23.8095	23.8095
CTSmp	1.000223	1.000223	1.000223	1.000223	1.000223
CPSmp	1.000000	1.000000	1.000000	1.000000	1.000000
CTLmp	1.000000	1.000000	1.000000	1.000000	1.000000
CPLmp	1.000000	1.000000	1.000000	1.000000	1.000000
CCFmp	1.000223	1.000223	1.000223	1.000223	1.000223
GSVmp	23.8148	23.8148	23.8148	23.8148	23.8148
N	200169	200190	200183	200169	200190
NKF	8400	8400	8400	8400	8400
IVmm	23.8296	23.8321	23.8313	23.8296	23.8321
Tmm	72.0	72.0	72.0	72.0	72.0
Pmm	30	30	30	30	30
Fmm	0.00000320	0.00000320	0.00000320	0.00000320	0.00000320
CTDW	1.000000	1.000000	1.000000	1.000000	1.000000
CPLmm	1.000096	1.000096	1.000096	1.000096	1.000096
CCFmm	1.000096	1.000096	1.000096	1.000096	1.000096
ISVmm	23.8319	23.8344	23.8336	23.8319	23.8344
IMMF	0.999282	0.999178	0.999211	0.999282	0.999178

****

Average of Five Consecutive Runs	=	0.999226	*MMFstart* II
Calculated Range Percent	=	0.010	((MAX-MIN)/(MIN))*(100)
Allowable Range Percent	=	0.020	%

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________

GSVmp = (*BPVamp* * *CCFmp*)

ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________

CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)

CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 3—Calibration	Set II		UNIDIRECTIONAL DISPLACEMENT PROVER
Field Prover Type...	Displacement Unidirectional Pipe Prover		
Master Prover Type...	Atmospheric Tank Prover		
Master Meter Type...	Displacement 4", (sliding vane type)		
Liquid Medium Type...	WATER		

Calibration Report No.	____________	____________	MMFstart	0.999226
Calibration Date	____________	____________	MMFstop	0.999312
Field Prover S/N	____________	____________	MMFaverage	0.999269
Master Prover S/N	____________	____________	Delta%	0.009

****

Medium = Crude Oil	Run No.	1	2	3
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	20.000	20.000	20.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	19.250	19.250	19.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	10.0	10.0	10.0
Temperature Observed	*Tobs*	60.0	60.0	60.0
API @ 60 F	*APIb*	10.0	10.0	10.0
Time of Pass/Run	*Seconds*	281.21	281.22	281.23
Flow Rate in Bbls/Hour	*BPH*	400	400	400
Master Meter Pulses	*N*	262755	262758	262767
Nominal K Factor	*NKF*	8400	8400	8400
Indicated Meter Volume	*IVmm*	31.2804	31.2807	31.2818
Temp (F) Master Meter	*Tmm*	72.0	72.2	72.4
Press. (psig) Mstr Meter	*Pmm*	100	100	100
Compressibility Factor	*Fmm*	0.00000320	0.00000320	0.00000320
Master Meter Factor	*MMFavg*	0.999269	0.999269	0.999269
Corr.Temp. Liq. M.Meter	*CTDW*	0.999987	0.999987	0.999987
Corr.Press.Liq. M.Meter	*CPLmm*	1.000320	1.000320	1.000320
Comb.Corr.Fact. M.Meter	*CCFmm*	0.999576	0.999576	0.999576
Indicated Std Volume MM	*ISVmm*	31.2671	31.2674	31.2685
Temp. Deg. F in Prover	*Tp*	71.9	72.1	72.3
Press. (psig) in Prover	*Pp*	92	92	92
Compressibility Factor	*Fp*	0.00000320	0.00000320	0.00000320
Corr Temp Steel Prover	*CTSp*	1.000221	1.000225	1.000229
Corr Press Steel Prover	*CPSp*	1.000157	1.000157	1.000157
Corr Temp Liquid Prover	*CTLp*	1.000000	1.000000	1.000000
Corr Press Liq'd Prover	*CPLp*	1.000294	1.000294	1.000294
Comb.Corr.Factor Prover	*CCFp*	1.000672	1.000676	1.000680
Prover Vol. @ Tb & Pb =	*CPVn*	31.2461	31.2463	31.2473

****

CPVn Range (allowed) =	< or = 0.02%	0.004 % (actual)	
CPVn =	(*ISVmm* / *CCFp*)		
ISVmm =	(*IVmm* * *CCFmm*)	________________________	
IVmm =	(*N* / *NKF*)	(witnesses)	
CCFmm =	(*MMFavg* * *CTLmm* * *CPLmm*)	________________________	
CCFp =	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)		
CPVavg =	(Average *CPV* of Set)	>>>>>>>>>>>>	31.2466

****

Example 3—Calibration Set II *MMFstop* II

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #_______
Method: Average MF method Date:__________
Master Prover: Atmospheric Volumetric Tank Prover S/N___________
Master Meter: Displacement 4" (sliding vane type) S/N___________

****

Run Number	2	3	4	5	6
Medium	Water	Water	Water	Water	Water
Steel	Mild Carbon	Mild Carbon	Mild Carbon	Mild Carbon	Mild Carbon
Gc	0.0000186	0.0000186	0.0000186	0.0000186	0.0000186
WT	0.250	0.250	0.250	0.250	0.250
ID	95.500	95.500	95.500	95.500	95.500
E	30000000	30000000	30000000	30000000	30000000
APIobs	10.0	10.0	10.0	10.0	10.0
Tobs	60.0	60.0	60.0	60.0	60.0
APIb	10.0	10.0	10.0	10.0	10.0
Seconds	214.29	214.29	214.29	214.29	214.29
Flow (BPH)	400	400	400	400	400
Tmp	72.4	72.4	72.4	72.4	72.4
Pmp	0	0	0	0	0
Fmp	0.00000320	0.00000320	0.00000320	0.00000320	0.00000320
SRu	23.8095	23.8095	23.8095	23.8095	23.8095
SRl	0.0000	0.0000	0.0000	0.0000	0.0000
BPVamp	23.8095	23.8095	23.8095	23.8095	23.8095
CTSmp	1.000231	1.000231	1.000231	1.000231	1.000231
CPSmp	1.000000	1.000000	1.000000	1.000000	1.000000
CTLmp	1.000000	1.000000	1.000000	1.000000	1.000000
CPLmp	1.000000	1.000000	1.000000	1.000000	1.000000
CCFmp	1.000231	1.000231	1.000231	1.000231	1.000231
GSVmp	23.8150	23.8150	23.8150	23.8150	23.8150
N	200176	200154	200161	200176	200154
NKF	8400	8400	8400	8400	8400
IVmm	23.8305	23.8279	23.8287	23.8305	23.8279
Tmm	72.4	72.4	72.4	72.4	72.4
Pmm	30	30	30	30	30
Fmm	0.00000320	0.00000320	0.00000320	0.00000320	0.00000320
CTDW	1.000000	1.000000	1.000000	1.000000	1.000000
CPLmm	1.000096	1.000096	1.000096	1.000096	1.000096
CCFmm	1.000096	1.000096	1.000096	1.000096	1.000096
ISVmm	23.8328	23.8302	23.8310	23.8328	23.8302
IMMF	0.999253	0.999362	0.999329	0.999253	0.999362

****

Average of Five Consecutive Runs = 0.999312 *MMFstop* II
Calculated Range Percent = 0.011 ((MAX-MIN)/(MIN))*(100)
Allowable Range Percent = 0.020 %

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________
GSVmp = (*BPVamp* * *CCFmp*)
ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________
CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)
CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

13.3.3 Example 3—Calibration Set III

13.3.3.1 Master Meter Type Calibration of Field Prover

13.3.3.1.1 *MMFstart* for this Calibration Set

a. See first data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of five consecutive proving runs.
f. No additional runs were necessary.
g. Used these five consecutive runs (runs 1, 2, 3, 4, and 5) within a range of 0.02%.

13.3.3.1.2 Calibration Runs on Field Prover for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Conducted calibration runs on field prover using master meter.
c. Criteria: three consecutive calibration runs within a range of 0.02%.
d. Maximum of six runs allowed to complete this exercise.
e. Made a total of four consecutive calibrations runs.
f. First run did not repeat within 0.02% (temperature instability etc.).
g. Used last three runs (runs 2, 3, and 4) within a range of 0.02%.
h. Trial calculations can be performed to test repeatability using *MMFstart*.
i. Final calculations can be made only after completion of *MMFstop*.
j. Example shows final calculations only with using average of *MMFstart* and *MMFstop*.

13.3.3.1.3 *MMFstop* for this Calibration Set

a. See third data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of six consecutive proving runs.
f. First run did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 2, 3, 4, 5, and 6) within a range of 0.02%.

13.3.3.1.4 *MMFavg* and Final Calculations for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Compared *MMFstart* to *MMFstop*.
c. Criteria: *MMFstart* and *MMFstop* must be within a range of 0.02%.
d. Calculated the average of *MMFstart* and *MMFstop*.
e. Used *MMFavg* for field prover calibration runs.

13.3.3.1.5 Go to Calibration Summary at End of this Example

Example 3—Calibration Set III *MMFstart* III

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #______

Method: Average MF method Date:_________

Master Prover: Atmospheric Volumetric Tank Prover S/N__________

Master Meter: Displacement 4" (sliding vane type) S/N__________

****

Run Number	1	2	3	4	5
Medium	Water	Water	Water	Water	Water
Steel	Mild Carbon	Mild Carbon	Mild Carbon	Mild Carbon	Mild Carbon
Gc	0.0000186	0.0000186	0.0000186	0.0000186	0.0000186
WT	0.250	0.250	0.250	0.250	0.250
ID	95.500	95.500	95.500	95.500	95.500
E	30000000	30000000	30000000	30000000	30000000
APIobs	10.0	10.0	10.0	10.0	10.0
Tobs	60.0	60.0	60.0	60.0	60.0
APIb	10.0	10.0	10.0	10.0	10.0
Seconds	107.14	107.14	107.14	107.14	107.14
Flow (BPH)	800	800	800	800	800
Tmp	72.7	72.7	72.7	72.8	72.8
Pmp	0	0	0	0	0
Fmp	0.00000320	0.00000320	0.00000320	0.00000320	0.00000320
SRu	23.8095	23.8095	23.8095	23.8095	23.8095
SRl	0.0000	0.0000	0.0000	0.0000	0.0000
BPVamp	23.8095	23.8095	23.8095	23.8095	23.8095
CTSmp	1.000236	1.000236	1.000236	1.000238	1.000238
CPSmp	1.000000	1.000000	1.000000	1.000000	1.000000
CTLmp	1.000000	1.000000	1.000000	1.000000	1.000000
CPLmp	1.000000	1.000000	1.000000	1.000000	1.000000
CCFmp	1.000236	1.000236	1.000236	1.000238	1.000238
GSVmp	23.8151	23.8151	23.8151	23.8152	23.8152
N	199943	199964	199957	199964	199957
NKF	8400	8400	8400	8400	8400
IVmm	23.8027	23.8052	23.8044	23.8052	23.8044
Tmm	72.9	72.9	73.0	73.0	73.0
Pmm	40	40	40	40	40
Fmm	0.00000320	0.00000320	0.00000320	0.00000320	0.00000320
CTDW	0.999974	0.999974	0.999961	0.999974	0.999974
CPLmm	1.000128	1.000128	1.000128	1.000128	1.000128
CCFmm	1.000102	1.000102	1.000089	1.000102	1.000102
ISVmm	23.8051	23.8076	23.8065	23.8076	23.8068
IMMF	1.000420	1.000315	1.000361	1.000319	1.000353

****

Average of Five Consecutive Runs	=	1.000354	*MMFstart* III
Calculated Range Percent	=	0.011	((MAX-MIN)/(MIN))*(100)
Allowable Range Percent	=	0.020	%

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________

GSVmp = (*BPVamp* * *CCFmp*)

ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________

CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)

CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 3—Calibration	Set III	UNIDIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Displacement Unidirectional Pipe Prover
Master Prover Type...	Atmospheric Tank Prover
Master Meter Type...	Displacement 4", (sliding vane type)
Liquid Medium Type...	WATER

Calibration Report No.	____________	____________	MMFstart	1.000354
Calibration Date	____________	____________	MMFstop	1.000273
Field Prover S/N	____________	____________	MMFaverage	1.000314
Master Prover S/N	____________	____________	Delta%	0.008

****

Medium = Crude Oil	Run No.	2	3	4
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	20.000	20.000	20.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	19.250	19.250	19.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	10.0	10.0	10.0
Temperature Observed	*Tobs*	60.0	60.0	60.0
API @ 60 F	*APIb*	10.0	10.0	10.0
Time of Pass/Run	*Seconds*	140.60	140.61	140.62
Flow Rate in Bbls/Hour	*BPH*	800	800	800
Master Meter Pulses	*N*	262452	262476	262488
Nominal K Factor	*NKF*	8400	8400	8400
Indicated Meter Volume	*IVmm*	31.2443	31.2471	31.2486
Temp (F) Master Meter	*Tmm*	73.0	73.2	73.2
Press. (psig) Mstr Meter	*Pmm*	100	100	100
Compressibility Factor	*Fmm*	0.00000320	0.00000320	0.00000320
Master Meter Factor	*MMFavg*	1.000314	1.000314	1.000314
Corr.Temp. Liq. M.Meter	*CTDW*	1.000000	0.999974	1.000000
Corr.Press.Liq. M.Meter	*CPLmm*	1.000320	1.000320	1.000320
Comb.Corr.Fact. M.Meter	*CCFmm*	1.000634	1.000608	1.000634
Indicated Std Volume MM	*ISVmm*	31.2641	31.2661	31.2684
Temp. Deg. F in Prover	*Tp*	73.0	73.0	73.2
Press. (psig) in Prover	*Pp*	84	84	84
Compressibility Factor	*Fp*	0.00000320	0.00000320	0.00000320
Corr Temp Steel Prover	*CTSp*	1.000242	1.000242	1.000246
Corr Press Steel Prover	*CPSp*	1.000144	1.000144	1.000144
Corr Temp Liquid Prover	*CTLp*	1.000000	1.000000	1.000000
Corr Press Liq'd Prover	*CPLp*	1.000269	1.000269	1.000269
Comb.Corr.Factor Prover	*CCFp*	1.000655	1.000655	1.000659
Prover Vol. @ Tb & Pb =	*CPVn*	31.2436	31.2456	31.2478

****

CPVn Range (allowed) =	< or = 0.02%		0.013	% (actual)
CPVn =	(*ISVmm* / *CCFp*)			
ISVmm =	(*IVmm* * *CCFmm*)	________________________		
IVmm =	(*N* / *NKF*)	(witnesses)		
CCFmm =	(*MMFavg* * *CTLmm* * *CPLmm*)	________________________		
CCFp =	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)			
CPVavg =	(Average *CPV* of Set)	>>>>>>>>>>>>		31.2457

****

Example 3—Calibration Set III *MMFstop* III

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #_______
Method: Average MF method Date:__________
Master Prover: Atmospheric Volumetric Tank Prover S/N___________
Master Meter: Displacement 4" (sliding vane type) S/N___________

****

Run Number	2	3	4	5	6
Medium	Water	Water	Water	Water	Water
Steel	Mild Carbon	Mild Carbon	Mild Carbon	Mild Carbon	Mild Carbon
Gc	0.0000186	0.0000186	0.0000186	0.0000186	0.0000186
WT	0.250	0.250	0.250	0.250	0.250
ID	95.500	95.500	95.500	95.500	95.500
E	30000000	30000000	30000000	30000000	30000000
APIobs	10.0	10.0	10.0	10.0	10.0
Tobs	60.0	60.0	60.0	60.0	60.0
APIb	10.0	10.0	10.0	10.0	10.0
Seconds	107.14	107.14	107.14	107.14	107.14
Flow (BPH)	800	800	800	800	800
Tmp	73.3	73.4	73.4	73.4	73.5
Pmp	0	0	0	0	0
Fmp	0.00000320	0.00000320	0.00000320	0.00000320	0.00000320
SRu	23.8095	23.8095	23.8095	23.8095	23.8095
SRl	0.0000	0.0000	0.0000	0.0000	0.0000
BPVamp	23.8095	23.8095	23.8095	23.8095	23.8095
CTSmp	1.000247	1.000249	1.000249	1.000249	1.000251
CPSmp	1.000000	1.000000	1.000000	1.000000	1.000000
CTLmp	1.000000	1.000000	1.000000	1.000000	1.000000
CPLmp	1.000000	1.000000	1.000000	1.000000	1.000000
CCFmp	1.000247	1.000249	1.000249	1.000249	1.000251
GSVmp	23.8154	23.8154	23.8154	23.8154	23.8155
N	199971	199964	199957	199992	199985
NKF	8400	8400	8400	8400	8400
IVmm	23.8061	23.8052	23.8044	23.8086	23.8077
Tmm	73.4	73.5	73.6	73.6	73.7
Pmm	40	40	40	40	40
Fmm	0.00000320	0.00000320	0.00000320	0.00000320	0.00000320
CTDW	0.999987	0.999987	0.999974	0.999974	0.999973
CPLmm	1.000128	1.000128	1.000128	1.000128	1.000128
CCFmm	1.000115	1.000115	1.000102	1.000102	1.000101
ISVmm	23.8088	23.8079	23.8068	23.8110	23.8101
IMMF	1.000277	1.000315	1.000361	1.000185	1.000227

****

Average of Five Consecutive Runs	=	1.000273	*MMFstop* III
Calculated Range Percent	=	0.018	((MAX-MIN)/(MIN))*(100)
Allowable Range Percent	=	0.020	%

Formulae for Proving the Master Meter: (witnesses)

IMMF = (*GSVmp* / *ISVmm*) ________________________

GSVmp = (*BPVamp* * *CCFmp*)

ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________

CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)

CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 3—Calibration Summary UNIDIRECTIONAL DISPLACEMENT PROVER

Date of Calibration:	______________________________
Calibration Report Number:	______________________________
Summary Sheet of a Total of:	______________________________
Time of Calibration (begin/end):	______________________________
Weather During Calibration:	______________________________
Owner/Operator of Prover:	______________________________
Site of Meter Prover Calibration:	______________________________
Service Location of Field Prover:	______________________________
Service Identification of Prover:	______________________________
Volume Identification of Prover:	______________________________
Manufacturer of Field Prover:	______________________________
Serial Number of Field Prover:	______________________________
Serial Number of Master Prover:	______________________________
Serial Number of Master Meter:	______________________________
Description/Type of Field Prover:	Unidirectional Displacement Prover
Description & Type Master Prover:	Atmospheric Volumetric Tank Prover
Description & Type Master Meter:	Displacement 4" (sliding vane type)
Material of Construction of Prover:	______________________________
Cubical Coefficient per Degree F:	______________________________
Square Coefficient per Degree F:	______________________________
Linear Coefficient per Degree F:	______________________________
Modulus of Elasticity per psi:	______________________________
Outside Diameter of Prover Pipe:	______________________________
Wall Thickness of Prover Pipe:	______________________________
Inside Diameter of Prover Pipe:	______________________________
Calibration Liquid Description:	WATER

****

MASTER METER CALIBRATION SUMMARY

UNIDIRECTIONAL DISPLACEMENT PIPE PROVER

Calibration Set I	= *CPVavg* @	600 BPH =	31.2479	Barrels
Calibration Set II	= *CPVavg* @	400 BPH =	31.2466	Barrels
Calibration Set III	= *CPVavg* @	800 BPH =	31.2457	Barrels
	[(MAX - MIN) / (MIN)] * [100] =		0.007	% Range
	Allowable Tolerance	=	0.020	% Range

Calculate average *CPVavg*:
Base Prover Volume @ 60 Degrees F & 0 psig = 31.2467 Barrels

Previous Base Prover Volume:	______________________________
Percentage change in volume:	______________________________
Diameter of displacer in inches:	______________________________
Calibrator's Name & Company Name	______________________________

****

13.4 EXAMPLE 4—DISPLACEMENT PIPE PROVER—UNIDIRECTIONAL DESIGN

The following example depicts the calculations using the average data method and required documentation for a complete unidirectional displacement prover calibration by the master meter method.

Field Prover:	Unidirectional Displacement Pipe Prover
Master Prover:	Bi-directional Displacement Pipe Prover
Master Meter:	Displacement Flow Meter Sliding Vane Displacement Type
Proving Method:	Average Data Method
Liquid Medium:	Crude Oil

Calibration Set I	Cover Sheet for Calibration Set I	1 page
	MMFstart	1 page
	Calibration Runs & Set Summary	1 page
	MMFstop	1 page
Calibration Set II	Cover Sheet for Calibration Set II	1 page
	MMFstart	1 page
	Calibration Runs & Set Summary	1 page
	MMFstop	1 page
Calibration Set III	Cover Sheet for Calibration Set II	1 page
	MMFstart	1 page
	Calibration Runs & Set Summary	1 page
	MMFstop	1 page
Calibration Summary	Calibration Summary Sheet	1 page

13.4.1 Example 4—Calibration Set I

13.4.1.1 Master Meter Type Calibration of Field Prover

13.4.1.1.1 *MMFstart* for this Calibration Set

a. See first data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of eight consecutive proving runs.
f. First three runs did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 4, 5, 6, 7, and 8) within a range of 0.02%.

13.4.1.1.2 Calibration Runs on Field Prover for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Conducted calibration runs on field prover using master meter.
c. Criteria: three consecutive calibration runs within a range of 0.02%.
d. Maximum of six runs allowed to complete this exercise.
e. Made a total of six consecutive calibrations runs.
f. First three runs did not repeat within 0.02% (temperature instability etc.).
g. Used last three runs (Runs 4, 5, and 6) within a range of 0.02%.

h. Trial calculations can be performed to test repeatability using *MMFstart*.
i. Final calculations can be made only after completion of *MMFstop*.
j. Example shows final calculations only with using average of *MMFstart* and *MMFstop*.

13.4.1.1.3 *MMFstop* for this Calibration Set

a. See third data/calculations page of this Calibration Set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of six consecutive proving runs.
f. First run did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 2, 3, 4, 5, and 6) within a range of 0.02%.

13.4.1.1.4 *MMFavg* and Final Calculations for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Compared *MMFstart* to *MMFstop*.
c. Criteria: *MMFstart* and *MMFstop* must be within a range of 0.02%.
d. Calculated the average of *MMFstart* and *MMFstop*.
e. Used *MMFavg* for field prover calibration runs.

13.4.1.1.5 Go to Calibration Set II

Example 4 - Calibration Set I   MMFstart I

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION — Report #________
Method: Average data method — Date:___________
Master Prover: Bi-directional Displacement Pipe Prover — S/N____________
Master Meter: Displacement 4" (sliding vane type) — S/N____________

****

5 Runs	Average Data	Run Numbers 4, 5, 6, 7 and 8		
Medium	Crude Oil			
Steel	316 S.S.			
Gc	0.0000265			
OD	10.750		AVERAGE DATA METHOD	
WT	0.365			
ID	10.020		AVERAGE DATA METHOD	
E	28000000			
APIobs	42.0		AVERAGE DATA METHOD	
Tobs	75.0			
APIb	40.7			
Seconds	20.29	Run data: 20.29 on each of the 5 runs		
Flow (BPH)	600	Run data: 600 on each of the 5 runs		
Tmp	71.2	Run data: 71.1, 71.1, 71.2, 71.3 and 71.3		
Pmp	94	Run data: 94 on each of the 5 runs		
Fmp	0.00000568			
BPVmp	3.38126			
CTSmp	1.000297			
CPSmp	1.000092			
CTLmp	0.994321			
CPLmp	1.000534			
CCFmp	0.995239			
GSVmp	3.36516			
N(1/2 trip)	n/a	Run data: 14206, 14209, 14206, 14208 and 14207		
N(avg)	28403.6	Run data: 28402, 28405, 28404, 28404 and 28403		
NKF	8400		MAX =	28405 PULSES
IVmm	3.38138		MIN =	28402 PULSES
Tmm	71.3	Run data: 71.2, 71.2, 71.3, 71.3 and 71.3		
Pmm	100	Run data: 100 on each of the 5 runs		
Fmm	0.00000569			
CTLmm	0.994270			
CPLmm	1.000569			
CCFmm	0.994836			
ISVmm	3.36392			
MMF	1.000369			

****

Average of Five Consecutive Runs	=	1.000369	*MMFstart* I
Calculated Range Percent	=	0.011	((MAX-MIN)/(MIN))*(100)
Allowable Range Percent	=	0.020	%

Formulae for Proving the Master Meter: (witnesses)

MMF = (*GSVmp* / *ISVmm*)   ______________________

GSVmp = (*BPVmp* * *CCFmp*)

ISVmm = (*N* / *NKF*) * (*CCFmm*)   ______________________

CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)

CCFmm = (*CTLmm* * *CPLmm*)   ______________________

****

Example 4—Calibration	Set I	UNIDIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Displacement Unidirectional Pipe Prover
Master Prover Type...	Displacement Bi-directional Pipe Prover
Master Meter Type...	Displacement 4", (sliding vane type)
Liquid Medium Type...	Crude Oil 40.7 degrees API @ 60 degrees F

Calibration Report No.	____________	____________	MMFstart	1.000369
Calibration Date	____________	____________	MMFstop	1.000205
Field Prover S/N	____________	____________	MMFaverage	1.000287
Master Prover S/N	____________	____________	Delta%	0.016

****

Medium = Crude Oil	Run No.	4	5	6
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	20.000	20.000	20.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	19.250	19.250	19.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	42.0	42.0	42.0
Temperature Observed	*Tobs*	75.0	75.0	75.0
API @ 60 F	*APIb*	40.7	40.7	40.7
Time of Pass/Run	*Seconds*	187.56	187.54	187.55
Flow Rate in Bbls/Hour	*BPH*	600	600	600
Master Meter Pulses	*N*	262612	262590	262604
Nominal K Factor	*NKF*	8400	8400	8400
Indicated MMeter Volume	*IVmm*	31.2633	31.2607	31.2624
Temp (F) Master Meter	*Tmm*	71.4	71.6	71.8
Press. (psig) Mstr Meter	*Pmm*	100	100	100
Compressibility Factor	*Fmm*	0.00000569	0.00000569	0.00000570
Master Meter Factor	*MMFavg*	1.000287	1.000287	1.000287
Corr.Temp. Liq. M.Meter	*CTLmm*	0.994219	0.994118	0.994016
Corr.Press.Liq. M.Meter	*CPLmm*	1.000569	1.000569	1.000570
Comb.Corr.Fact. M.Meter	*CCFmm*	0.995070	0.994969	0.994868
Indicated Std Volume MM	*ISVmm*	31.1092	31.1034	31.1020
Temp. Deg. F in Prover	*Tp*	71.2	71.4	71.6
Press. (psig) in Prover	*Pp*	88	88	88
Compressibility Factor	*Fp*	0.00000568	0.00000569	0.00000569
Corr Temp Steel Prover	*CTSp*	1.000208	1.000212	1.000216
Corr Press Steel Prover	*CPSp*	1.000151	1.000151	1.000151
Corr Temp Liquid Prover	*CTLp*	0.994321	0.994219	0.994118
Corr Press Liq'd Prover	*CPLp*	1.000500	1.000501	1.000501
Comb.Corr.Factor Prover	*CCFp*	0.995175	0.995078	0.994981
Prover Vol. @ Tb & Pb =	*CPVn*	31.2600	31.2572	31.2589

****

CPVn Range (allowed) =	< or = 0.02%	0.009 % (actual)	
CPVn =	(*ISVmm* / *CCFp*)		
ISVmm =	(*IVmm* * *CCFmm*)	________________________	
IVmm =	(*N* / *NKF*)	(witnesses)	
CCFmm =	(*MMFavg* * *CTLmm* * *CPLmm*)	________________________	
CCFp =	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)		
CPVavg =	(Average *CPV* of Set)	>>>>>>>>>>>>	31.2587

****

Example 4—Calibration Set I *MMFstop* I

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION
Method: Average data method
Master Prover: Bi-directional Displacement Pipe Prover
Master Meter: Displacement 4" (sliding vane type)

Report #_______
Date:__________
S/N___________
S/N___________

****

5 Runs	Average Data	Run Numbers 2, 3, 4, 5 and 6		
Medium	Crude Oil			
Steel	316 S.S.			
Gc	0.0000265			
OD	10.750		AVERAGE DATA METHOD	
WT	0.365			
ID	10.020		AVERAGE DATA METHOD	
E	28000000			
APIobs	42.0		AVERAGE DATA METHOD	
Tobs	75.0			
APIb	40.7			
Seconds	20.29	Run data: 20.29 on each of the 5 runs		
Flow (BPH)	600	Run data: 600 on each of the 5 runs		
Tmp	71.7	Run data: 71.6, 71.7, 71.7, 71.8 and 71.8		
Pmp	94	Run data: 94 on each of the 5 runs		
Fmp	0.00000569			
BPVmp	3.38126			
CTSmp	1.000310			
CPSmp	1.000092			
CTLmp	0.994067			
CPLmp	1.000535			
CCFmp	0.994999			
GSVmp	3.36435			
N(half trip)	n/a	Run data: 14210, 14209, 14209, 14211 and 14209		
N(avg)	28408.6	Run data: 28410, 28406, 28409, 28410 and 28408		
NKF	8400		MAX =	28410 PULSES
IVmm	3.38198		MIN =	28406 PULSES
Tmm	71.8	Run data: 71.7, 71.8, 71.8, 71.8 and 71.9		
Pmm	100	Run data: 100 on each of the 5 runs		
Fmm	0.00000570			
CTLmm	0.994016			
CPLmm	1.000570			
CCFmm	0.994583			
ISVmm	3.36366			
MMF	1.000205			

****

Average of Five Consecutive Runs	=	1.000205	*MMFstop* I
Calculated Range Percent	=	0.014	((MAX-MIN)/(MIN))*(100)
Allowable Range Percent	=	0.020	%

Formulae for Proving the Master Meter: (witnesses)

MMF = (*GSVmp* / *ISVmm*) ________________________

GSVmp = (*BPVmp* * *CCFmp*)

ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________

CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)

CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

13.4.2 Example 4—Calibration Set II

13.4.2.1 Master Meter Type Calibration of Field Prover

13.4.2.1.1 *MMFstart* for this Calibration Set

a. See first data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of ten consecutive proving runs.
f. First five runs did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 6, 7, 8, 9, and 10) within a range of 0.02%.

13.4.2.1.2 Calibration Runs on Field Prover for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Conducted calibration runs on field prover using master meter.
c. Criteria: three consecutive calibration runs within a range of 0.02%.
d. Maximum of six runs allowed to complete this exercise.
e. Made a total of three consecutive calibrations runs.
f. No additional runs were necessary.
g. Used these three consecutive runs (runs 1, 2, and 3) within a range of 0.02%.
h. Trial calculations can be performed to test repeatability using *MMFstart*.
i. Final calculations can be made only after completion of *MMFstop*.
j. Example shows final calculations only with using average of *MMFstart* and *MMFstop*.

13.4.2.1.3 *MMFstop* for this Calibration Set

a. See third data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of nine consecutive proving runs.
f. First four runs did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 5, 6, 7, 8, and 9) within a range of 0.02%.

13.4.2.1.4 *MMFavg* and Final Calculations for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Compared *MMFstart* to *MMFstop*.
c. Criteria: *MMFstart* and *MMFstop* must be within a range of 0.02%.
d. Calculated the average of *MMFstart* and *MMFstop*.
e. Used *MMFavg* for field prover calibration runs.

13.4.2.1.5 Go to Calibration Set III

Example 4—Calibration Set II *MMFstart* II

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #_______
Method: Average data method Date:__________
Master Prover: Bi-directional Displacement Pipe Prover S/N___________
Master Meter: Displacement 4" (sliding vane type) S/N___________

****

5 Runs	Average Data	Run Numbers 6, 7, 8, 9 and 10	
Medium	Crude Oil		
Steel	316 S.S.		
Gc	0.0000265		
OD	10.750	AVERAGE DATA METHOD	
WT	0.365		
ID	10.020	AVERAGE DATA METHOD	
E	28000000		
APIobs	42.0	AVERAGE DATA METHOD	
Tobs	75.0		
APIb	40.7		
Seconds	30.43	Run data: 30.43 on each of the 5 runs	
Flow (BPH)	400	Run data: 400 on each of the 5 runs	
Tmp	72.0	Run data: 72.0 on each of the 5 runs	
Pmp	96	Run data: 96 on each of the 5 runs	
Fmp	0.00000570		
BPVmp	3.38126		
CTSmp	1.000318		
CPSmp	1.000094		
CTLmp	0.993915		
CPLmp	1.000547		
CCFmp	0.994868		
GSVmp	3.36391		
N(half trip)	n/a	Run data: 14217, 14220, 14217, 14218 and 14219	
N(avg)	28425.6	Run data: 28424, 28427, 28426, 28424 and 28427	
NKF	8400	MAX =	28427 PULSES
IVmm	3.38400	MIN =	28424 PULSES
Tmm	72.0	Run data: 72.0 on each of the 5 runs	
Pmm	100	Run data: 100 on each of the 5 runs	
Fmm	0.00000570		
CTLmm	0.993915		
CPLmm	1.000570		
CCFmm	0.994482		
ISVmm	3.36533		
MMF	0.999578		

****

Average of Five Consecutive Runs = 0.999578 *MMFstart* II
Calculated Range Percent = 0.011 ((MAX-MIN)/(MIN))*(100)
Allowable Range Percent = 0.020 %

Formulae for Proving the Master Meter: (witnesses)

MMF = (*GSVmp* / *ISVmm*) ________________________
GSVmp = (*BPVmp* * *CCFmp*)
ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________
CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)
CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 4—Calibration	Set II	UNIDIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Displacement Unidirectional Pipe Prover
Master Prover Type...	Displacement Bi-directional Pipe Prover
Master Meter Type...	Displacement 4", (sliding vane type)
Liquid Medium Type...	Crude Oil 40.7 degrees API @ 60 degrees F

Calibration Report No.	____________	____________	MMFstart	0.999578
Calibration Date	____________	____________	MMFstop	0.999667
Field Prover S/N	____________	____________	MMFaverage	0.999623
Master Prover S/N	____________	____________	Delta%	0.009

****

Medium = Crude Oil	Run No.	1	2	3
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	20.000	20.000	20.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	19.250	19.250	19.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	42.0	42.0	42.0
Temperature Observed	*Tobs*	75.0	75.0	75.0
API @ 60 F	*APIb*	40.7	40.7	40.7
Time of Pass/Run	*Seconds*	281.31	281.31	281.32
Flow Rate in Bbls/Hour	*BPH*	400	400	400
Master Meter Pulses	*N*	262755	262758	262767
Nominal K Factor	*NKF*	8400	8400	8400
Indicated Meter Volume	*IVmm*	31.2804	31.2807	31.2818
Temp (F) Master Meter	*Tmm*	72.0	72.2	72.4
Press. (psig) Mstr Meter	*Pmm*	100	100	100
Compressibility Factor	*Fmm*	0.00000570	0.00000570	0.00000571
Master Meter Factor	*MMFavg*	0.999623	0.999623	0.999623
Corr.Temp. Liq. M.Meter	*CTLmm*	0.993915	0.993813	0.993711
Corr.Press.Liq. M.Meter	*CPLmm*	1.000570	1.000570	1.000570
Comb.Corr.Fact. M.Meter	*CCFmm*	0.994107	0.994005	0.993903
Indicated Std Volume MM	*ISVmm*	31.0961	31.0932	31.0911
Temp. Deg. F in Prover	*Tp*	71.9	72.1	72.3
Press. (psig) in Prover	*Pp*	92	92	92
Compressibility Factor	*Fp*	0.00000570	0.00000570	0.00000571
Corr Temp Steel Prover	*CTSp*	1.000221	1.000225	1.000229
Corr Press Steel Prover	*CPSp*	1.000157	1.000157	1.000157
Corr Temp Liquid Prover	*CTLp*	0.993965	0.993864	0.993762
Corr Press Liq'd Prover	*CPLp*	1.000525	1.000525	1.000526
Comb.Corr.Factor Prover	*CCFp*	0.994863	0.994766	0.994669
Prover Vol. @ Tb & Pb =	*CPVn*	31.2567	31.2568	31.2577

****

CPVn Range (allowed) = < or = 0.02%   0.003 % (actual)

CPVn	=	(*ISVmm* / *CCFp*)		
ISVmm	=	(*IVmm* * *CCFmm*)	________________________	
IVmm	=	(*N* / *NKF*)	(witnesses)	
CCFmm	=	(*MMFavg* * *CTLmm* * *CPLmm*)	________________________	
CCFp	=	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)		
CPVavg	=	(Average *CPV* of Set)	>>>>>>>>>>>>	31.2571

****

Example 4—Calibration Set II | *MMFstop* II

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION
Method: Average data method
Master Prover: Bi-directional Displacement Pipe Prover
Master Meter: Displacement 4" (sliding vane type)

Report #_______
Date:__________
S/N___________
S/N___________

****

5 Runs	Average Data	Run Numbers 5, 6, 7, 8 and 9		
Medium	Crude Oil			
Steel	316 S.S.			
Gc	0.0000265			
OD	10.750		AVERAGE DATA METHOD	
WT	0.365			
ID	10.020		AVERAGE DATA METHOD	
E	28000000			
APIobs	42.0		AVERAGE DATA METHOD	
Tobs	75.0			
APIb	40.7			
Seconds	30.43	Run data: 30.43 on each of the 5 runs		
*Flow (*BPH*)*	400	Run data: 400 on each of the 5 runs		
Tmp	72.4	Run data: 72.4 on each of the 5 runs		
Pmp	96	Run data: 96 on each of the 5 runs		
Fmp	0.00000571			
BPVmp	3.38126			
CTSmp	1.000329			
CPSmp	1.000094			
CTLmp	0.993711			
CPLmp	1.000548			
CCFmp	0.994676			
GSVmp	3.36326			
N(half trip)	n/a	Run data: 14218, 14217, 14216, 14219 and 14216		
N(avg)	28423.4	Run data: 28425, 28422, 28423, 28425 and 28422		
NKF	8400		MAX =	28425 PULSES
IVmm	3.38374		MIN =	28422 PULSES
Tmm	72.4	Run data: 72.4 on each of the 5 runs		
Pmm	100	Run data: 100 on each of the 5 runs		
Fmm	0.00000571			
CTLmm	0.993711			
CPLmm	1.000571			
CCFmm	0.994278			
ISVmm	3.36438			
MMF	0.999667			

****

Average of Five Consecutive Runs	=	0.999667	*MMFstop* II
Calculated Range Percent	=	0.011	((MAX-MIN)/(MIN))*(100)
Allowable Range Percent	=	0.020	%

Formulae for Proving the Master Meter: (witnesses)

MMF = (*GSVmp* / *ISVmm*) ________________________

GSVmp = (*BPVmp* * *CCFmp*)

ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________

CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)

CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

13.4.3 Example 4—Calibration Set III

13.4.3.1 Master Meter Type Calibration of Field Prover

13.4.3.1.1 *MMFstart* for this Calibration Set

a. See first data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of six consecutive proving runs.
f. First run did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 2, 3, 4, 5, and 6) within a range of 0.02%.

13.4.3.1.2 Calibration Runs on Field Prover for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Conducted calibration runs on field prover using master meter.
c. Criteria: three consecutive calibration runs within a range of 0.02%.
d. Maximum of six runs allowed to complete this exercise.
e. Made a total of four consecutive calibrations runs.
f. First run did not repeat within 0.02% (temperature instability etc.).
g. Used last three runs (runs 2, 3, and 4) within a range of 0.02%.
h. Trial calculations can be performed to test repeatability using *MMFstart*.
i. Final calculations can be made only after completion of *MMFstop*.
j. Example shows final calculations only with using average of *MMFstart* and *MMFstop*.

13.4.3.1.3 *MMFstop* for this Calibration Set

a. See third data/calculations page of this calibration set.
b. Conducted proving runs on master meter using master prover.
c. Criteria: five consecutive proving runs within a range of 0.02%.
d. Maximum of ten runs allowed to complete this exercise.
e. Made a total of eight consecutive proving runs.
f. First three runs did not repeat within 0.02% (temperature instability etc.).
g. Used last five consecutive runs (runs 4, 5, 6, 7, and 8) within a range of 0.02%.

13.4.3.1.4 *MMFavg* and Final Calculations for this Calibration Set

a. See second data/calculations page of this calibration set.
b. Compared *MMFstart* to *MMFstop*.
c. Criteria: *MMFstart* and *MMFstop* must be within a range of 0.02%.
d. Calculated the average of *MMFstart* and *MMFstop*.
e. Used *MMFavg* for field prover calibration runs.

13.4.3.1.5 Go to Calibration Summary at End of this Example

Example 4—Calibration Set III *MMFstart* III

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION Report #_______
Method: Average data method Date:__________
Master Prover: Bi-directional Displacement Pipe Prover S/N___________
Master Meter: Displacement 4" (sliding vane type) S/N___________

****

5 Runs	Average Data	Run Numbers 2, 3, 4, 5 and 6		
Medium	Crude Oil			
Steel	316 S.S.			
Gc	0.0000265			
OD	10.750		AVERAGE DATA METHOD	
WT	0.365			
ID	10.020		AVERAGE DATA METHOD	
E	28000000			
APIobs	42.0		AVERAGE DATA METHOD	
Tobs	75.0			
APIb	40.7			
Seconds	15.22	Run data: 15.22 on each of the 5 runs		
Flow (BPH)	800	Run data: 800 on each of the 5 runs		
Tmp	72.7	Run data: 72.7, 72.7, 72.7, 72.8 and 72.8		
Pmp	92	Run data: 92 on each of the 5 runs		
Fmp	0.00000571			
BPVmp	3.38126			
CTSmp	1.000337			
CPSmp	1.000090			
CTLmp	0.993559			
CPLmp	1.000526			
CCFmp	0.994506			
GSVmp	3.36268			
N(half trip)	n/a	Run data: 14201, 14204, 14201, 14204 and 14202		
N(avg)	28394.0	Run data: 28392, 28395, 28394, 28395 and 28394		
NKF	8400		MAX =	28395 PULSES
IVmm	3.38024		MIN =	28392 PULSES
Tmm	73.0	Run data: 72,9, 72.9, 73.0, 73.0 and 73.0		
Pmm	100	Run data: 100 on each of the 5 runs		
Fmm	0.00000572			
CTLmm	0.993407			
CPLmm	1.000572			
CCFmm	0.993975			
ISVmm	3.35987			
MMF	1.000836			

****

Average of Five Consecutive Runs	=	1.000836	*MMFstart* III
Calculated Range Percent	=	0.011	((MAX-MIN)/(MIN))*(100)
Allowable Range Percent	=	0.020	%

Formulae for Proving the Master Meter: (witnesses)

MMF = (*GSVmp* / *ISVmm*) ________________________

GSVmp = (*BPVmp* * *CCFmp*)

ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________

CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)

CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 4—Calibration Set III UNIDIRECTIONAL DISPLACEMENT PROVER

Field Prover Type...	Displacement Unidirectional Pipe Prover
Master Prover Type...	Displacement Bi-directional Pipe Prover
Master Meter Type...	Displacement 4", (sliding vane type)
Liquid Medium Type...	Crude Oil 40.7 degrees API @ 60 degrees F

Calibration Report No.	____________	____________	MMFstart	1.000836
Calibration Date	____________	____________	MMFstop	1.000720
Field Prover S/N	____________	____________	MMFaverage	1.000778
Master Prover S/N	____________	____________	Delta%	0.012

****

Medium = Crude Oil	Run No.	2	3	4
Steel Type for Prover	Steel	Mild Carbon	Mild Carbon	Mild Carbon
Cubical Coefficient	*Gc*	0.0000186	0.0000186	0.0000186
Outside Diameter	*OD*	20.000	20.000	20.000
Wall Thickness	*WT*	0.375	0.375	0.375
Inside Diameter	*ID*	19.250	19.250	19.250
Modulus of Elasticity	*E*	30000000	30000000	30000000
API Gravity @ Tobs	*APIobs*	42.0	42.0	42.0
Temperature Observed	*Tobs*	75.0	75.0	75.0
API @ 60 F	*APIb*	40.7	40.7	40.7
Time of Pass/Run	*Seconds*	140.67	140.67	140.69
Flow Rate in Bbls/Hour	*BPH*	800	800	800
Master Meter Pulses	*N*	262452	262476	262488
Nominal K Factor	*NKF*	8400	8400	8400
Indicated Meter Volume	*IVmm*	31.2443	31.2471	31.2486
Temp (F) Master Meter	*Tmm*	73.0	73.2	73.2
Press. (psig) Mstr Meter	*Pmm*	100	100	100
Compressibility Factor	*Fmm*	0.00000572	0.00000572	0.00000572
Master Meter Factor	*MMFavg*	1.000778	1.000778	1.000778
Corr.Temp. Liq. M.Meter	*CTLmm*	0.993407	0.993305	0.993305
Corr.Press.Liq. M.Meter	*CPLmm*	1.000572	1.000572	1.000572
Comb.Corr.Fact. M.Meter	*CCFmm*	0.994749	0.994646	0.994646
Indicated Std Volume MM	*ISVmm*	31.0802	31.0798	31.0813
Temp. Deg. F in Prover	*Tp*	73.0	73.0	73.2
Press. (psig) in Prover	*Pp*	84	84	84
Compressibility Factor	*Fp*	0.00000572	0.00000572	0.00000572
Corr Temp Steel Prover	*CTSp*	1.000242	1.000242	1.000246
Corr Press Steel Prover	*CPSp*	1.000144	1.000144	1.000144
Corr Temp Liquid Prover	*CTLp*	0.993407	0.993407	0.993305
Corr Press Liq'd Prover	*CPLp*	1.000481	1.000481	1.000481
Comb.Corr.Factor Prover	*CCFp*	0.994269	0.994269	0.994170
Prover Vol. @ Tb & Pb =	*CPVn*	31.2593	31.2589	31.2636

****

CPVn Range (allowed) =	< or = 0.02%	0.015	% (actual)
CPVn =	(*ISVmm* / *CCFp*)		
ISVmm =	(*IVmm* * *CCFmm*)	________________________	
IVmm =	(*N* / *NKF*)	(witnesses)	
CCFmm =	(*MMFavg* * *CTLmm* * *CPLmm*)	________________________	
CCFp =	(*CTSp* * *CPSp* * *CTLp* * *CPLp*)		
CPVavg =	(Average *CPV* of Set)	>>>>>>>>>>>>	31.2606

****

Example 4—Calibration Set III MMFstop III

PROVING THE MASTER METER FOR A FIELD PROVER CALIBRATION
Method: Average data method
Master Prover: Bi-directional Displacement Pipe Prover
Master Meter: Displacement 4" (sliding vane type)

Report #_______
Date:__________
S/N___________
S/N___________

****

5 Runs	Average Data	Run Numbers 4, 5, 6, 7 and 8		
Medium	Crude Oil			
Steel	316 S.S.			
Gc	0.0000265			
OD	10.750		AVERAGE DATA METHOD	
WT	0.365			
ID	10.020		AVERAGE DATA METHOD	
E	28000000			
APIobs	42.0		AVERAGE DATA METHOD	
Tobs	75.0			
APIb	40.7			
Seconds	15.22	Run data: 15.22 on each of the 5 runs		
Flow (BPH)	800	Run data: 800 on each of the 5 runs		
Tmp	73.4	Run data: 73.3, 73.4, 73.4, 73.4 and 73.5		
Pmp	92	Run data: 92 on each of the 5 runs		
Fmp	0.00000573			
BPVmp	3.38126			
CTSmp	1.000355			
CPSmp	1.000090			
CTLmp	0.993203			
CPLmp	1.000527			
CCFmp	0.994169			
GSVmp	3.36154			
N(half trip)	n/a	Run data: 14203, 14204, 14201, 14206 and 14204		
N(avg)	28396.4	Run data: 28396, 28395, 28394, 28399 and 28398		
NKF	8400		MAX =	28399 PULSES
IVmm	3.38052		MIN =	28394 PULSES
Tmm	73.6	Run data: 73.4, 73.5, 73.6, 73.6 and 73.7		
Pmm	100	Run data: 100 on each of the 5 runs		
Fmm	0.00000573			
CTLmm	0.993102			
CPLmm	1.000573			
CCFmm	0.993671			
ISVmm	3.35912			
MMF	1.000720			

****

Average of Five Consecutive Runs	=	1.000720	*MMFstop* III
Calculated Range Percent	=	0.018	((MAX-MIN)/(MIN))*(100)
Allowable Range Percent	=	0.020	%

Formulae for Proving the Master Meter: (witnesses)

MMF = (*GSVmp* / *ISVmm*) ________________________
GSVmp = (*BPVmp* * *CCFmp*)
ISVmm = (*N* / *NKF*) * (*CCFmm*) ________________________
CCFmp = (*CTSmp* * *CPSmp* * *CTLmp* * *CPLmp*)
CCFmm = (*CTLmm* * *CPLmm*) ________________________

****

Example 4—Calibration Summary UNIDIRECTIONAL DISPLACEMENT PROVER

Date of Calibration:	______________________
Calibration Report Number:	______________________
Summary Sheet of a Total of:	______________________
Time of Calibration (begin/end):	______________________
Weather During Calibration:	______________________
Owner / Operator of Prover:	______________________
Site of Meter Prover Calibration:	______________________
Service Location of Field Prover:	______________________
Service Identification of Prover:	______________________
Volume Identification of Prover:	______________________
Manufacturer of Field Prover:	______________________
Serial Number of Field Prover:	______________________
Serial Number of Master Prover:	______________________
Serial Number of Master Meter:	______________________
Description/Type of Field Prover:	Displacement Unidir. Pipe Prover
Description & Type Master Prover:	Displacement Bi-dir. Pipe Prover
Description & Type Master Meter:	Displacement 4" (sliding vane type)
Material of Construction of Prover:	______________________
Cubical Coefficient per Degree F:	______________________
Square Coefficient per Degree F:	______________________
Linear Coefficient per Degree F:	______________________
Modulus of Elasticity per psi:	______________________
Outside Diameter of Prover Pipe:	______________________
Wall Thickness of Prover Pipe:	______________________
Inside Diameter of Prover Pipe:	______________________
Calibration Liquid Description:	Crude Oil 40.7 deg API @ 60 deg F

****

MASTER METER CALIBRATION SUMMARY

UNIDIRECTIONAL DISPLACEMENT PIPE PROVER

Calibration Set I	= *CPVavg* @	600 BPH	=	31.2587	Barrels
Calibration Set II	= *CPVavg* @	400 BPH	=	31.2571	Barrels
Calibration Set III	= *CPVavg* @	800 BPH	=	31.2606	Barrels

[(MAX - MIN) / (MIN)] * [100] = 0.011 % Range

Allowable Tolerance = 0.020 % Range

Calculate average CPVavg:
Base Prover Volume @ 60 Degrees F & 0 psig = 31.2588 Barrels

Previous Base Prover Volume:	______________________
Percentage change in volume:	______________________
Diameter of displacer in inches:	______________________

Calibrator's Name & Company Name ______________________

****

APPENDIX A—FLUID DENSITIES, VOLUMES AND COMPRESSIBILITY CORRELATIONS

A.1 General Information

A.1.1 Table A-1, provides a guide to the appropriate references (*RHOb, CTL, F*) for most of the liquids associated with the petroleum and petrochemical industry.

A.1.2 The following text, which is applicable to the Table A-1, describes these recommended references. The expertise of a physical properties specialist should be consulted before adopting the recommendations contained in the table.

A.1.3 For some of the older references, the table values for *RHOb* and *CTL* cannot be curve fit. Therefore, it is recommended that linear interpolation of these tables (between columns and values within a column) be utilized for intermediate calculations.

A.1.4 Density Meter (Densitometer) Calculations:

When using an on-line density meter (densitometer), the base density of a liquid (*RHOb*) is determined by the following expression:

$$RHOb = \frac{RHOtp}{CTL \times CPL}$$

A.1.5 It is important to note that the density under flowing conditions (*RHOtp*), must be known to accurately calculate the base density (*RHOb*). Also, for low pressure applications, *CPL* may be assumed to be 1.0000, if a sensitivity analysis indicates an acceptable level of uncertainty.

A.1.6 For some liquids, computer subroutines exist to correct the observed density to base density, using the *API MPMS* Chapter 11.1, Volume X, implementation procedures; however, for elevated pressures, an iterative procedure to solve for base density is required for custody transfer purposes. The manufacturer of the densitometer should be contacted for consultation on the density calculation requirements at elevated pressures.

A.1.7 The computation for correcting from density at flowing conditions (*RHOtp*) to density at base conditions (*RHOb*) may be carried out continuously, if mutually agreed between all the parties concerned with the transaction.

A.2 Base Density (*RHOb*) Determination

The standards to convert liquid density at observed conditions (*RHOobs*) to base density (*RHOb*) are as follows:

A.2.1 *API MPMS* Chapter 11.1, Volume X (ANSI/ASTM D1250-1980), Tables 5A, 53A, and 23A cover generalized crude oils and jet fuel (JP4). The document specifies the implementation procedures, together with rounding and truncating, to determine the base density (*RHOb*) from the observed density (*RHOobs*) and observed temperature (*Tobs*) at base pressure (*Pb*).

a. Table 5A, used for a base temperature of 60°F, covers generalized crude oils and jet fuel (JP4) over an API@60°F gravity range of 0° to 100°API. For natural or drip gasolines with API@60°F gravity greater than 100°API, use Table 23 of ASTM D1250 (Historical Edition—1952).

b. Table 53A, used for base temperature of 15°C, covers generalized crude oils and jet fuel (JP4) over a *DENb*@15°C range of 610 to 1075 kg/m^3.

c. Table 23A, used for base temperature of 60°F, covers generalized crude oils and jet fuel (JP4) over a RD@60°F range of 0.6110 to 1.0760.

A.2.2 *API MPMS* Chapter 11.1, Volume X (ANSI/ASTM D1250-1980), Tables 5B, 53B, and 23B cover generalized products. The document specifies the implementation procedures, together with rounding and truncating, to determine the base density (*RHOb*) from the observed density (*RHOobs*) and observed temperature (*Tobs*) at base pressure (*Pb*).

a. Table 5B, used for base temperature of 60°F, covers generalized products (excluding JP4) over an API@60°C gravity range of 0° to 85°API.

b. Table 53B, used for base temperature of 15°C, covers generalized products over a *DENb*@15°C range of 653 to 1075 kg/m^3.

c. Table 23B, used for base temperature of 60°F, covers generalized products over a RD@60°F range of 0.6535 to 1.0760.

A.2.3 *API MPMS* Chapter 11.1, Volume X (ANSI/ASTM D1250-1980), Tables 5D and 53D cover lubricating oils. The document specifies the implementation procedures, together with rounding and truncating, to determine the base density (*RHOb*) from the observed density (*RHOobs*) and observed temperature (*Tobs*) at base pressure (*Pb*).

a. Table 5D, used for base temperature of 60°F, covers lubricating oils over an API@60°F gravity range of –10° to 40°API.

b. Table 53D, used for base temperature of 15°C, covers lubricating oils over a *DENb*@15°C range of 825 to 1164 kg/m^3.

A.2.4 ASTM D1250 (Table 23—Historical Edition, 1952) covers a relative density at 60°F (RD@60°F) range of 0.500 to 1.100. Table 23 converts the observed relative density at the observed temperature and equilibrium vapor pressure to the RD@60°F.

Table A-1—Reference Guide for *RHOb, CTS, F*

Liquid Type	RHOb	CTL	F
Crude Oils			
Crude Oils	(R1)	(C1)	(F1)
Natural Gasolines	(R1)	(C1)	(F1)
Drip Gasolines	(R1)	(C1)	(F1)
Refined Products			
JP4	(R1)	(C1)	(F1)
Gasoline	(R2)	(C2)	(F1)
Naphthenes	(R2)	(C2)	(F1)
Jet Fuels	(R2)	(C2)	(F1)
Aviation Fuels	(R2)	(C2)	(F1)
Kerosine	(R2)	(C2)	(F1)
Diesel	(R2)	(C2)	(F1)
Heating Oils	(R2)	(C2)	(F1)
Fuel Oils	(R2)	(C2)	(F1)
Furnace Oils	(R2)	(C2)	(F1)
Lube Oils	(R3)	(C3)	(F1)
Propane	(R4)	(C4)	(F1)
Butane	(R4)	(C4)	(F1)
Propane Mixes	(R4)	(C4)	(F1)
Butane Mixes	(R4)	(C4)	(F1)
Isopentane	(R4)	(C4)	(F1)
Asphalt	NA	(C5)	(F1)
Solvents			
Benzene	NA	(C6)	(F1)
Toluene	NA	(C6)	(F1)
Stoddard Solvent	NA	(C6)	(F1)
Xylene	NA	(C6)	(F1)
Styrene	NA	(C6)	(F1)
Orthoxylene	NA	(C6)	(F1)
Metaxylene	NA	(C6)	(F1)
Paraxylene	NA	(C6)	(F1)
Cyclohexane	NA	(C6)	(F1)
Acetone	NA	(C6)	(F1)
Butadiene			
Butadiene	(R5)	(C7)	(F1)
Butadiene Mixtures	(R5)	(C7)	(F1)
Water			
For Volumetric Provers	NA	(C8)	(F2)

A.2.5 ASTM D1550, used for base temperature of 60°F, is applicable to both butadiene and butadiene concentrates that contain at least 60 percent butadiene.

A.3 *CTL* Determination

The standards that have been developed to determine the *CTL* values for various liquids are as follows:

A.3.1 *API MPMS* Chapter 11.1, Volume X (ANSI/ASTM D1250-1980), Tables 6A, 54A, and 24A cover generalized crude oils and jet fuel (JP4). The document specifies the implementation procedures, together with rounding and truncating, to determine the *CTL* from base density (*RHOb*) and flowing temperature (*T*).

a. Table 6A, used for base temperature of 60°F, covers generalized crude oils and jet fuel (JP4), over an API@60°F gravity range of 0° to 100°API. For natural or drip gasolines and condensates with API@60°F gravity greater than 100°API, use Table 24 of ASTM D1250 (Historical Edition—1952).

b. Table 54A, used for base temperature of 15°C, covers generalized crude oils and jet fuel (JP4) over a *DENb*@15°C range of 610.5 to 1075.0 kg/m^3.

c. Table 24A, used for base temperature of 60°F, covers generalized crude oils and jet fuel (JP4) over a *RD*@60°F range of 0.6110 to 1.0760.

A.3.2 *API MPMS* Chapter 11.1, Volume X (ANSI/ASTM D1250-1980), Tables 6B, 54B, and 24B cover generalized products. The document specifies the implementation procedures and the rounding and truncating procedures to determine the *CTL* from base density (*RHOb*) and flowing temperature (*T*).

a. Table 6B, used for base temperature of 60°F, covers generalized products (excluding JP4) over an API@60°F gravity range of 0° – 100°API.

b. Table 54B, used for base temperature of 15°C, covers generalized products (excluding JP4) over a *DENb*@15°C range of 653.0 to 1075.0 kg/m^3.

c. Table 24B, used for base temperature of 60°F, covers generalized products over a *RD*@60°F range of 0.6535 to 1.0760.

A.3.3 *API MPMS* Chapter 11.1, Volume X (ANSI/ASTM D1250-1980), Tables 6D and 54D cover lubricating oils. The document specifies the implementation procedures and the rounding and truncating procedures to determine the *CTL* from the base density (*RHOb*) and flowing temperature (*T*).

a. Table 6D, used for base temperature of 60°F, covers lubricating oils over an API@60°F gravity range of –10° to 40°API.

b. Table 54D, used for base temperature of 15°C, covers lubricating oils over a *DENb*@15°C range of 825 to 1164 kg/m^3.

A.3.4 ASTM D1250 (Table 24—Historical Edition, 1952) covers a relative density at 60°F (*RD*@60°F) range of 0.500 to 1.100 for liquefied petroleum gases (LPG). Table 24 calculates the *CTL* from the *RD*@ 60°F and the flowing temperature (*T*).

A.3.5 ASTM D1250 (Table 6— covers the gravity range for asphalt. Table 6 is recommended by the API and Asphalt Institute for *CTL* determinations on asphalt and asphalt products.

A.3.6 ASTM D1555, used for base temperature of 60°F, is the industry reference for *CTL* values associated with certain liquid aromatic hydrocarbons.

A.3.7 ASTM D1550, used for base temperature of 60°F, is the industry reference for *CTL* values associated with butadiene and butadiene concentrates that contain at least 60 percent butadiene.

A.3.8 *API MPMS* Chapters 11.2.3 and 11.2.3M cover *CTDW* values utilized in water calibration of volumetric provers.

a. Chapter 11.2.3, used for a base temperature of 60°F, calculates the *CTDW* for the temperature of the water flowing from the prover (*Tp*) and the temperature of the water in the test measure (*Ttm*).

b. Chapter 11.2.3M, used for a base temperature of 15°C, calculates the *CTDW* for the temperature of the water flowing from the prover (*Tp*) and the temperature of the water in the test measure (*Ttm*).

A.3.9 Fixed or Small-Variant Liquid Composition:

There are numerous specification solvents, resins, chemicals, and specialty hydrocarbons that are used or manufactured by companies are not compatible with existing industry *CTL* tables. For these materials, interested parties may wish to utilize proprietary liquid property tables, that have often been used for years, and that remain in use today for many applications. In applications where Table 6C of *API MPMS*, Chapter 11.1 is used, then laboratory testing or fluid property tables can be used to determine the desired alpha (coefficient of expansion) value. These alpha values can be used where existing commercial requirements permit.

A.3.10 Table 6C of *API MPMS*, Chapter 11.1 calculates the *CTL* for a liquid with a chemical composition that is fixed, or does not vary significantly, and whose coefficient of expansion may be easily determined.

A.3.11 Since *RHOb* is constant, no correction or determination of observed gravity is necessary. The *API MPMS* Chapter 11.1, Table 6C, is commonly used for specialized products with coefficients of thermal expansion that do not follow Tables 6A, 6B, or 6D of *API MPMS*, Chapter 11.1.

A.3.12 Use of Table 6C requires an equation of state and/or extensive data on the metered liquid.

A.4 Compressibility Factor Determination (*F*)

The density of the liquid shall be determined by the appropriate technical standards, or, alternatively, by the use of the proper density correlations, or, if necessary, by the use of the correct equations of state. If multiple parties are involved in the custody transfer measurement, the method selected for determining the density of the liquid shall be mutually agreed upon by all concerned. To assist in selecting which methods to utilize, the following information has been assembled for clarity.

A.4.1 *API MPMS* Chapters 11.2.1, 11.2.1M, 11.2.2, and 11.2.2M provide values for compressibility factors (*F*) for hydrocarbon fluids. The documents specify the implementation procedures, together with rounding and truncating, to determine *F* from base density (*RHOb*), the flowing temperature (*T*), and flowing pressure (*P*).

a. Chapter 11.2.1, used for base temperature of 60°F, covers hydrocarbon liquids over an API@60°F range of 0 to 90°API.
b. Chapter 11.2.1M, used for base temperature of 15°C, covers hydrocarbon liquids over a *DEN*@15°C range of 638 to 1074 kg/m^3.
c. Chapter 11.2.2, used for base temperature of 60°F, covers hydrocarbon liquids over a *RD*@60°F range of 0.350 to 0.637.
d. Chapter 11.2.2M, used for base temperature of 15°C, covers hydrocarbon liquids over a *DEN*@15°C range of 350 to 637 kg/m^3.

A.4.2 The compressibility factor (*F*) for water utilized in the calibration of volumetric provers is defined as follows:

a. For USC units, a constant *F* value 0.00000320 (3.20E-06) per psi for water shall be utilized in the calculations.
b. For SI units, a constant *F* value 0.000000464 (4.64E-07) per kPa, or 0.0000464 (4.64E-05) per bar, for water shall be utilized in the calculations.

Date of Issue: July 2009
Affected Publications: API *Manual of Petroleum Measurement Standards* Chapter 12.2, *Calculation of Petroleum Quantities Using Dynamic Measurement Methods and Volumetric Correction Factors*
Part 1, *Introduction*, Second Edition, May 1995
Part 4, *Calculation of Base Prover Volumes by Waterdraw Method*, First Edition, December 1997
Part 5, *Calculation of Base Prover Volume by Master Meter Method*, First Edition, September 2001

ERRATA

Chapter 12.2.1—Introduction

Appendix B, paragraph C8, references API *MPMS* Chapters 11.2.3 and 11.2.3M to determine *CTDW* values utilized in water calibration of volumetric provers.

API *MPMS* Chapter 11.4.1-2003 *Properties of Reference Materials Part 1—Density of Water and Water Volumetric Correction Factors for Water Calibration of Volumetric Provers*, has replaced these chapters.

Chapter 12.2.4—Calculation of Base Prover Volumes by Waterdraw Method

Section 10.1.1 references API *MPMS* Chapters 11.2.3 and 11.2.3M to determine *CTDW* values utilized in water calibration of volumetric provers.

API *MPMS* Chapter 11.4.1-2003 *Properties of Reference Materials Part 1—Density of Water and Water Volumetric Correction Factors for Water Calibration of Volumetric Provers*, has replaced these chapters.

Section 10.1.2 provides an equation for the calculation of a correction for compressibility of water (*CPL*). Chapter 11.4.1-2003 provides a different equation in Appendix E. Some users are uncertain as to which to use. As stated in Addendum 1 to Chapter 12 issued in August 2007, Chapter 12 is the primary standard for calculation of volume quantities. As such, the CPL equation in Chapter 11.4.1-2003, Appendix E, should not be used unless specifically required by Chapter 12.

Section 13.1, example 1 (page 32):

"Liters = 1000 cubic meters"

should be changed to

"Liters = 1000 cubic centimeters"

Section 13.2, example 2 (page 42):

"Liters = 1000 cubic meters"

should be changed to

"Liters = 1000 cubic centimeters"

Chapter 12.2.4—Calculation of Base Prover Volumes by Waterdraw Method

Section 13.3, example 3 (page 49):

"Liters = 1000 cubic meters"

should be changed to

"Liters = 1000 cubic centimeters"

Chapter 12.2.5—Calculation of Base Prover Volume by Master Meter Method

Appendix A, paragraph A.3.8, references API *MPMS* Chapter 11.2.3 and 11.2.3M to determine *CTDW* values utilized in water calibration of volumetric provers.

API MPMS Chapter 11.4.1-2003 *Properties of Reference Materials Part 1—Density of Water and Water Volumetric Correction Factors for Water Calibration of Volumetric Provers*, has replaced these chapters.

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