

# **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 2—Measurement Tickets**

THIRD EDITION, JUNE 2003

REAFFIRMED, SEPTEMBER 2010



AMERICAN PETROLEUM INSTITUTE



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Using Dynamic Measurement Methods  
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**Measurement Coordination**

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## FOREWORD

This five-part publication consolidates and presents standard calculations for metering petroleum liquids using turbine or displacement meters. Units of measure in this publication are in International System (SI) and United States Customary (USC) 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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# Chapter 12—Calculation of Petroleum Quantities

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

### Part 2—Measurement Tickets

#### 1 Purpose

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.

This five-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. So that different operators can obtain identical results from the same data, the rules for sequence, rounding, and discrimination of figures (or decimal places) have been defined.

#### 2 Scope

This document 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 the units of measure required by governmental customs or statute. The criteria contained in this document allow different entities using various computer languages on different computer hardware (or manual calculations) to arrive at identical results using the same standardized input data.

The publication rigorously specifies the equations for computing correction factors, rules for rounding, calculational sequence, and discrimination levels to be employed in the calculations. No deviations from these specifications are permitted since the intent of this document is to serve as a rigorous standard.

#### 3 Application of Part 2

The purpose of standardizing the terms and arithmetical procedures employed in calculating the amount of petroleum liquid on a measurement ticket is to avoid disagreement between the parties involved. The purpose of Part 2, “Measurement Tickets,” is to obtain the same unbiased answer from the same measurement data, regardless of who or what does the computing.

Calculations of correction factors and volumes may be done using continuous online integration techniques if agreed between the parties. The results of these calculations may not agree with the methods contained in this standard due to the variability in obtaining flowing parameters. However, the equations for computing correction factors and the rules for rounding, calculation sequence, and discrimination levels for any continuous online integration methods shall be identical to the specifications contained in this standard.

A measurement ticket is a written acknowledgment of a transfer of petroleum liquids and is the legal document of transfer. In addition, it serves as an agreement between the authorized representatives of the parties concerned as to the measured quantities and quality of the liquid. The measurement ticket shall contain all field data required to calculate the metered quantities.

Care must be taken to ensure that all copies of a measurement ticket are legible. Proper fiscal procedures forbid making corrections or erasures on a measurement ticket unless the interested parties agree to do so and initial the ticket to that effect. Should a mistake be made, the ticket should be marked “VOID” and a new ticket prepared. The voided ticket should be attached to the new one to support the validity of the corrected ticket.

#### 4 Organization of Standard

The standard is organized into five separate parts. Part 1 contains a general introduction for dynamic calculations. Part 2 focuses on the calculation of metered quantities for fiscal purposes or measurement tickets. Part 3 applies to meter proving calculations for field operations or proving reports. Parts 4 and 5 apply to the determination of base prover volumes (BPVs).

##### 4.1 PART 1—INTRODUCTION

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

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

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

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

#### 4.2 PART 2—MEASUREMENT TICKETS

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

Recording of field data, rules for rounding, discrimination levels, calculation sequences, along with a detailed explanation with appropriate flow charts and a set of example calculations. The examples can be used to aid in checkout procedures for any computer calculation routines that are developed on the basis of the requirements stated in this standard.

#### 4.3 PART 3—PROVING REPORTS

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

Recording of field data and rules for rounding, calculation sequences, 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 standard.

#### 4.4 PART 4—CALCULATION OF BASE PROVER VOLUMES BY WATERDRAW METHOD

The waterdraw method uses the displacement (or drawing) of water from the prover into certified volumetric field 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 test measures must be traceable to the appropriate national weights and measures organization.

Recording of field data, rules for rounding, calculation sequences, 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 standard.

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

The master meter method uses a transfer meter (or transfer standard). The transfer meter is proved under actual operating

conditions by a prover that has been previously calibrated by the waterdraw method, and is designated the master meter. This master meter is then used to determine the base volume of a field operating prover.

Recording of field data, rules for rounding, calculation sequences, 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 standard.

### 5 References

Several documents served as references for the revisions of this standard. In particular, past editions of API *MPMS* Chapter 12.2 (ANSI/API 12.2) provided a wealth of information. The following are other publications that served as a resource of information for this revision:

#### 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 Analysis”

#### ASTM<sup>1</sup>

D1250	<i>Petroleum Measurement Tables</i> , current edition
D1250	<i>Petroleum Measurement Tables</i> (historical edition-1952)
D1550	<i>ASTM Butadiene Measurement Tables</i>
D1555	<i>Calculation of Volume and Weight of Industrial Aromatic Hydrocarbons</i>

#### NIST<sup>2</sup>

Handbook 105-3	<i>Specifications and Tolerances for Reference Standards and Field Standards</i>
Handbook 105-7	<i>Small Volume Provers</i>
Monograph 62	<i>Testing of Metal Volumetric Standards</i>

<sup>1</sup>American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshocken, Pennsylvania 19428, USA.

<sup>2</sup>U.S. Department of Commerce, National Institute of Standards and Technology, Washington, D.C. 20234 (formerly National Bureau of Standards).

## 6 Field of Application

### 6.1 APPLICABLE LIQUIDS

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.

The application of this standard is limited to liquids that 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 standards, or, alternatively, by 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 measurement, the method for determining the density of the liquid shall be mutually agreed upon by all concerned.

### 6.2 BASE CONDITIONS

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

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 as follows:

United States Customary (USC) Units:

Pressure: 14.696 psia (101.325 kPa<sub>a</sub>)

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)

For liquids, 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.

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

## 7 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.

### 7.1 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 the 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.

For example using USC units, if the temperature is measured to  $-0.14^{\circ}\text{F}$ , then the value should be rounded to  $-0.1^{\circ}\text{F}$ . If the temperature is measured to  $54.66^{\circ}\text{F}$ , then the value should be rounded to  $54.7^{\circ}\text{F}$ .

For example using SI units, if the temperature is measured to  $-14.561^{\circ}\text{C}$ , then the value should be rounded to  $-14.55^{\circ}\text{C}$ . If the temperature is measured to  $12.576^{\circ}\text{C}$ , then the value should be rounded to  $12.60^{\circ}\text{C}$ .

### 7.2 DISCRIMINATION LEVELS

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

For example, if the parties agree to use a thermometer graduated in whole  $^{\circ}\text{F}$  or  $1/2^{\circ}\text{C}$  increments, then the device is normally read to levels of  $0.5^{\circ}\text{F}$ , or  $0.25^{\circ}\text{C}$  resolution. Likewise, if the parties agree to use a “smart” temperature transmitter, which can indicate to  $0.01^{\circ}\text{F}$  or  $0.005^{\circ}\text{C}$ , then the reading shall be rounded to the nearest  $0.1^{\circ}\text{F}$  or  $0.05^{\circ}\text{C}$  value prior to recording for calculation purposes.

The volume discrimination levels specified are in many circumstances beyond the uncertainty of the measurements. The discrimination levels specified are not technically based, but comply with the historical accounting practices for the petroleum industry.

## 8 Definitions, Symbols, and Abbreviations

The definitions, symbols and abbreviations described below are acceptable and in common use for the application of Part 2, "Measurement Tickets."

### 8.1 DEFINITIONS

**8.1.1 barrel (bbl):** a unit volume equal to 9,702.0 cubic inches, or 42.0 U.S. gallons.

**8.1.2 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.

**8.1.3 calibration certificate:** a document stating the base prover volume (BPV) and other physical data required for the calibration of flow meters (i.e., E, Gc, Ga, and Gl).

**8.1.4 composite K-factor (CKF):** a K-factor adjusted from normal operating pressure (CPL) to standard pressure and used to correct the indicated volume where the gravity, temperature, and pressure are considered constant throughout the delivery.

**8.1.5 composite meter factor (CMF):** a meter factor corrected from normal operating pressure (CPL) to base pressure. This term is used for meter applications where the gravity, temperature, and pressure are considered constant during the ticket period.

**8.1.6 cubic meter (m<sup>3</sup>):** a unit of volume equal to 1,000,000.0 milliliters (ml), or 1,000.0 liters.

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

**8.1.8 indicated standard volume (ISV):** the indicated meter volume (ISVm) corrected to base conditions. It does not contain any correction for the meter's performance (MF, MMF, or CMF).

**8.1.9 indicated volume (IV):** the change in the meter register head volume that occurs during a proving run ( $MR_o - MR_c$ ). The word registration, though not preferred, often has the same meaning. Alternatively, 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).

**8.1.10 K-factor (KF):** 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 to gross volume. If a new K-factor is not used, then a nominal K-factor may be utilized to generate a new meter factor, which will then correct the indicated volume of the meter to gross volume.

**8.1.11 liter (l):** a unit of volume equal to 1,000.0 milliliters (ml) or 0.001 cubic meters. One liter equals 0.264172 US gallons.

**8.1.12 master meter:** a transfer device (meter) that is proved using a certified prover (called the master prover) and is then used to calibrate other meter provers or to prove other flow meters.

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

**8.1.14 master prover:** a 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 is then used to calibrate a master meter.

**8.1.15 measurement ticket:** the generalized term used in this publication to embrace and supersede expressions of long standing expressions such as "run ticket," "meter ticket," and "receipt and delivery ticket."

**8.1.16 meter accuracy (MA):** defined as the reciprocal of the meter factor. It is a term specifically utilized for loading rack meters where the meter is mechanically or electronically adjusted at the time of proving to ensure that the meter factor is approximately unity.

**8.1.17 meter factor (MF):** used to correct the indicated volume of a meter (IVm) to its actual metered volume. It is a dimensionless term obtained by dividing the gross standard volume of the liquid passed through the prover (GSVp) when compared to the indicated standard volume (ISVm) as registered by the meter being proved.

**8.1.18 meter reading (MR<sub>o</sub>, MR<sub>c</sub>):** the instantaneous display of the register on a meter head. When the difference between a closing and an opening reading is being discussed, such a difference should be called an indicated volume.

**8.1.19 net standard volume (NSV):** the gross standard volume corrected for nonmerchantable quantities such as sediment and water (CSW).

**8.1.20 nominal K-factor (NKF):** the number of pulses per indicated unit volume which is 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 use a nominal K-factor throughout the operating life of the meter to provide an audit trail for the meter proving.

**8.1.21 pass:** a single movement of the displacer between detectors which define the calibrated volume of a prover.

**8.1.22 pressure weighted average (PWA):** the average liquid pressure at the meter for the ticket period.

For volumetric methods, the pressure weighted average is the average of the pressure values sampled at uniform flow intervals and is representative of the entire measurement ticket period.

$$\text{PWA} = [\text{SUM}_1^n (P_i)] / n$$

where

n = the number of uniform intervals

For time-based methods, the pressure weighted average is the sum of the pressure values sampled during the time interval, multiplied by the volume or mass determined during the same time interval, and divided by the entire volume measured.

$$\text{PWA} = [\text{SUM} (P_i \times V_i)] / V_t$$

**8.1.23 proving report:** a document showing all the meter and prover data, together with all the other parameters used to calculate the reported meter factor.

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

**8.1.25 run, meter proving:** one pass of a unidirectional prover, one round-trip of a bidirectional prover, or one filling/emptying of a tank prover, the results of which are deemed sufficient to provide a single value of the meter factor (MF, CMF, MMF) or K-factor (KF, CKF) when using the average meter factor method of calculation.

**8.1.26 temperature weighted (TWA):** the average liquid temperature at the meter for the ticket period.

For volumetric based methods, the temperature weighted average is the average of the temperature values sampled at uniform flow intervals and representative of the entire measurement ticket period.

$$\text{TWA} = [\text{SUM}_1^n (T_i)] / n$$

where

n = the number of uniform intervals

For time-based methods, the temperature weighted average is the sum of the temperature values sampled during the time interval, multiplied by the volume or mass determined during the same time interval, and divided by the entire volume measured.

$$\text{TWA} = [\text{SUM} (T_i \times V_i)] / V_t$$

**8.1.27 U.S. gallon (gal):** a unit volume equal to 231.0 cubic inches.

## 8.2 SYMBOLS AND ABBREVIATIONS

A combination of upper case, lower case, and subscripted notation is used in this publication, the uppercase notation may be used as deemed appropriate.

Additional letters may be added to the symbolic notations below for clarity and specificity.

### Units

SI	International system of units (pascal, cubic meter, kilogram, metric system).
USC	U.S. customary units (inch, pound, cubic inch, traditional system).

### Liquid Density

API	Density of liquid in degrees API gravity units.
API <sub>b</sub>	Base density in degrees API gravity units.
API <sub>obs</sub>	Observed density at base pressure in degrees API gravity units.
DEN	Density in kilogram per cubic meter (kg/m <sup>3</sup> ) units.
DEN <sub>b</sub>	Base density in kilogram per cubic meter (kg/m <sup>3</sup> ) units.
DEN <sub>obs</sub>	Observed density at base pressure in kilogram per cubic meter (kg/m <sup>3</sup> ) units.
RD	Density of liquid in relative density.
RD <sub>b</sub>	Base liquid density in relative density.
RD <sub>obs</sub>	Observed liquid density at base pressure in relative density.
RHO	Density of liquid in mass per unit volume.
RHO <sub>b</sub>	Base density.
RHO <sub>obs</sub>	Observed liquid density at base pressure.

### Temperature

°C	Celsius temperature scale.
°F	Fahrenheit temperature scale.
T	Temperature.
T <sub>b</sub>	Base temperature in °F or °C.
T <sub>obs</sub>	Observed temperature to determine RHO <sub>b</sub> (i.e., hydrometer temperature) in °F or °C.
TWA	Weighted average temperature of liquid for measurement ticket calculations in °F or °C.

## Pressure

kPa	Kilopascals (SI) pressure units.
kPa <sub>a</sub>	Kilopascals in absolute pressure units.
kPa <sub>g</sub>	Kilopascals in gauge pressure units.
psi	Pounds per square inch (USC) pressure units.
psia	Pounds per square inch in absolute pressure units.
psig	Pounds per square inch in gauge pressure units.
P	Pressure
Pb	Base pressure in psi or kpa pressure units.
Pb <sub>a</sub>	Base pressure in absolute pressure units.
Pb <sub>g</sub>	Base pressure in gauge pressure units.
Pe	Equilibrium vapor pressure of liquid at normal operating conditions in absolute pressure units.
PWA	Weighted average pressure of liquid for measurement ticket calculations in gauge pressure units.

## Correction Factors

CCF	Combined correction factor (for ticket calculations).
CPL	Correction for compressibility of liquid at normal operating conditions (for CMF and ticket calculations).
CSW	Fiscal correction for sediment and water.
CTL	Correction for the effect of temperature on liquid at normal operating conditions (for ticket calculations).
F	Compressibility factor of liquid in meter at normal operating conditions (for CMF and ticket calculations).
MA	Meter accuracy factor.
MF	Meter factor.
CMF	Composite meter factor.

## Volumes

GV	Gross volume.
GSV	Gross standard volume (for ticket calculations).
IV	Indicated volume (for ticket calculations).
ISV	Indicated standard volume.
NSV	Net standard volume (for ticket calculations).
SWV	Sediment and water volume (for ticket calculations).

## 9 Correction Factors

Calculations in this publication are based on correcting the measured volume of the merchantable liquid to its volume at base conditions. Correction factors are provided to adjust the metered volume to base conditions, to adjust for inaccuracies associated with the meter's performance, to combine factors for ease of calculations, and to adjust for nonmerchantable quantities.

### 9.1 LIQUID DENSITY CORRECTION FACTORS

The liquid's density shall be determined by appropriate technical standards or, if necessary, proper correlations or equations of state. If multiple parties are involved in the measurement, the method selected for determining the liquid's densities shall be mutually agreed upon.

API *MPMS* Chapter 12.2, Part 1, Appendix B—Liquid Density Correlation, contains a list of recommended liquid versus API correlations in accordance with API's position paper dated 1981. Where an API correlation does not currently exist, the appropriate ASTM standard has been provided to assist the user community.

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 as follows:

CTL	corrects for the effect of temperature on the liquid density.
CPL	corrects for the effect of compressibility on the liquid density.

#### 9.1.1 Correction for Effect of Temperature on Liquid (CTL)

If a quantity 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 temperature.

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 ( $\rho_b$ ) and weighted average temperature (TWA).

#### 9.1.2 Correction for Compressibility on Liquid (CPL)

If a petroleum liquid is subjected to a change in pressure, the liquid density will increase as the pressure increases and decrease as the pressure decreases. The correction factor for the effect of compressibility on liquid density is called CPL.

The CPL factor is a function of the liquid's compressibility factor (F), weighted average pressure (PWA), equilibrium vapor pressure of the liquid (Pe), and base pressure (Pb).

The compressibility factor ( $F$ ) is a function of the liquid's base density ( $RHO_b$ ) and weighted average temperature (TWA).

## 9.2 METER FACTORS AND COMPOSITE METER FACTORS (MFs, CMFs)

Meter factors (MFs) and composite meter factors (CMFs) are terms to adjust for inaccuracies associated with the meter's performance as determined at the time of proving. Unless the meter is equipped with an adjustment that alters its registration to account for the MF, an MF must be applied to the indicated volume of the meter.

MFs are used to adjust the indicated volume ( $MR_c - MR_o$ ) of a meter for inaccuracies associated with the meter's performance as determined at the time of proving.

CMFs are meter factors that have been corrected from normal operating pressure to base pressure using the CPL that would otherwise belong on the measurement ticket. CMFs may be used in applications where the relative density, temperature, and pressure are considered to be constant throughout the measurement ticket period.

## 9.3 COMBINED CORRECTION FACTOR (CCF)

When multiplying a large number (for example, an IV) by a small number (for example, a correction factor) over and over again, a lowering of the precision may occur in the calculations. In addition, errors can occur in mathematical calculations due to sequencing and rounding between different machines or programs. To minimize these errors, the industry selected a method that combines correction factors in a specified sequence and maximum discrimination levels. The method for combining two or more correction factors is to first obtain a CCF by serial multiplication of the individual correction factors and rounding the CCF to a required number of decimal places.

## 9.4 CORRECTION FOR SEDIMENT AND WATER (CSW)

Sediment and water are not considered merchantable components of certain hydrocarbon liquids, such as crude oil and certain refined products. As a result, a correction for sediment and water (CSW) is required to adjust the GSV of the liquid for these nonmerchantable quantities.

## 10 Recording of Field Data

Recording of field data shall be in accordance with the discrimination levels specified in the following section.

Discrimination levels for field data less than those specified are permitted if mutually agreeable between the parties involved in the transaction (see Table 1).

Discrimination levels for field data greater than those specified in the various tables are not in agreement with the intent of this standard.

## 11 Rules for Rounding, Computational Sequence and Discrimination Levels

The Measurement Ticket Flow Chart (Figure 1) and the following subsections rigorously specify the rounding, calculational sequence, and discrimination levels required for measurement ticket calculations.

The rounding, calculational sequence, and discrimination levels for  $RHO_b$ ,  $F$ , and CTL terms are, for the most part, contained in the references listed in API *MPMS* Chapter 12.2, Part 1, Appendix B—Liquid Density Correlation. If a reference does not contain an implementation procedure, refer to Appendix B, which contains a suggested method for solving this problem.

### Determine $RHO_b$

Using the observed density ( $RHO_{obs}$ ) and observed temperature ( $T_{obs}$ ), calculate the base density ( $RHO_b$ ) by appropriate technical standards or, if necessary, proper correlations or equations of state. Round the  $RHO_b$  value in accordance with Table 2 specifications.

For some liquids (such as solvents), the base density is constant as a result of stringent specifications. This  $RHO_b$  value shall be stated in accordance with the requirements specified in Table 2.

Note: For some metering facilities, an online density meter is installed to assist in determining  $RHO_b$ . The user should refer to API *MPMS* Chapter 12.2, Part 1, Appendix B—Liquid Density Correlation, for special calculational requirements.

### Determine CTL

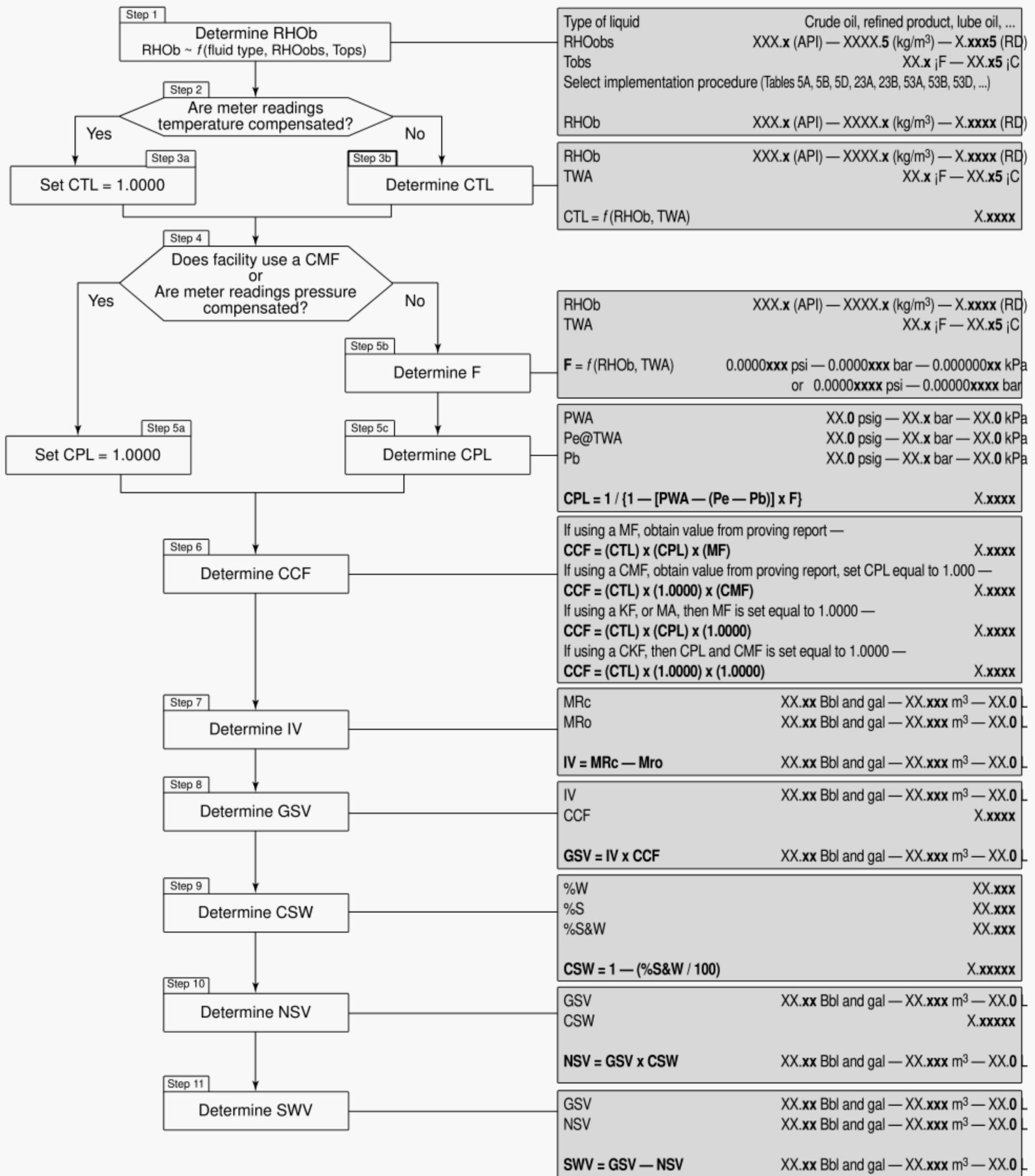
Using the  $RHO_b$  and TWA, calculate the CTL value using the appropriate standard. Round this value to the requirements specified in Table 6.

Note: When using temperature compensated meter readings ( $MR_o$ ,  $MR_c$ ), the CTL value shall be set at 1.0000 for measurement ticket calculations.

### Determine $F$

Using  $RHO_b$  and TWA, calculate the  $F$  value using the appropriate standard. Round this value to the requirements specified in Table 5.

Note: When using a CMF, or if the meter readings are pressure compensated, the CPL value shall be set at 1.0000 for CCF measurement ticket calculations.



Notes:

1. In order to comply with API MPMS Chapter 11.1 Volume X implementation requirements, RHO<sub>b</sub> shall be rounded to the nearest 0.1 API and the TWA must be rounded to the nearest 0.1°F, to properly determine the Correction for Effect of Temperature on Liquid, CTL.
2. In order to comply with API MPMS Chapter 11.2.1 implementation requirements, RHO<sub>b</sub> shall be rounded to the nearest 0.5 API and the TWA must be rounded to the nearest 0.5°F, to properly determine the Compressibility Factor, F.

Figure 1—Measurement Ticket Flow Chart

Table 1—Specified Discrimination Levels for Field Data

Field Data	Table
<b>Liquid Data</b>	
RHO <sub>obs</sub>	2
RHO <sub>b</sub>	2
T <sub>obs</sub>	3
Pe	4
S&W (%)	6
<b>Meter Data</b>	
TWA	3
PWA	4
MF	6
CMF	6
MR <sub>o</sub>	7
MR <sub>c</sub>	7

Table 2—Liquid Density Discrimination Levels

	API	DEN (kg/m <sup>3</sup> )	RD
Observed Density (RHO <sub>obs</sub> )	XXX.X	XXXX.5	X.XXX5
Base Density (RHO <sub>b</sub> )	XXX.X	XXXX.X	X.XXXX

Table 3—Temperature Discrimination Levels

	USC Units (°F)	SI Units (°C)
Observed Temperature (T <sub>obs</sub> )	XX.X	XX.X5
Base Temperature (T <sub>b</sub> )	60.0	15.00
Weighted Avg. Temperature (TWA)	XX.X	XX.X5

Table 4—Pressure Discrimination Levels

	USC Units		SI Units	
	(psi)	(bar)	(kPa)	(kPa)
Base Pressure (Pb)	XX.0	XX.X	XX.0	XX.0
Weighted Avg. Pressure (PWA)	XX.0	XX.X	XX.0	XX.0
Eq Vapor Pressure (Pe)	XX.0	XX.X	XX.0	XX.0

Table 5—Compressibility Factor Discrimination Levels

	USC Units		SI Units	
	(psi)	(bar)	(kPa)	(kPa)
Compressibility Factor (F)	0.00000XXX	0.0000XXX	0.000000XX	0.000000XX
or				
	0.000XXXX	0.00000XXXX		

**Determine CPL**

Using F, PWA, Pe, and Pb, calculate the CPL value using the following expression. Round this value to the requirements specified in Table 6.

$$CPL = 1 / (1 - [PWA - (Pe - Pb)] \times [F])$$

Note: In the CPL equation listed above, the value used for Pe shall be not less than Pb.

Note: When using a CMF, or if the meter readings are pressure compensated, the CPL value shall be set at 1.0000 for CCF measurement ticket calculations.

**Determine CCF**

Calculate the CCF by the appropriate equation shown below. Round this value to the requirements specified in Table 6.

For facilities that utilize MFs,

$$CCF = CTL \times CPL \times MF$$

For facilities that utilize CMFs,

$$CCF = CTL \times CPL \times CMF$$

Note: When using a CMF, the CPL value shall be set at 1.0000 for CCF measurement ticket calculations.

Note: When using temperature compensated meter readings (MR<sub>o</sub>, MR<sub>c</sub>, IV<sub>m</sub>), the CTL value shall be set at 1.0000 for CCF measurement ticket calculations.

**Determine IV**

Calculate the IV by subtracting the Opening Meter Reading (MR<sub>o</sub>) from the Closing Meter Reading (MR<sub>c</sub>).

$$IV = MR_c - MR_o$$

Round the IV value to the requirements specified in Table 7.

**Determine GSV**

The GSV is correlated by the following equation. Round the GSV value to the requirements specified in Table 7.

$$GSV = IV \times CCF$$

**Determine CSW**

Calculate the CSW by subtracting the total combined percentage of sediment and water. Round the CSW value to the requirements specified in Table 6.

$$CSW = 1 - (\%S\&W / 100)$$

**Determine NSV**

The NSV is the equivalent volume of a liquid at its base conditions, which does not include nonmerchantable items such as sediment and water.

The following is the formula for calculating NSV:

$$\text{NSV} = \text{GSV} \times \text{CSW}$$

Round the NSV value to the requirements specified in Table 7.

**Determine SWV**

The S&W Volume (SWV) is a calculated quantity based upon the percent sediment and water (%S&W) determined by a representative sample of the quantity of liquid being measured. It represents the nonhydrocarbon portion of the liquid and is calculated as follows:

$$\text{SWV} = \text{GSV} - [\text{GSV} \times (1 - [\% \text{S\&W} / 100])]$$

which simplifies the following equation:

$$\text{SWV} = \text{GSV} - \text{NSV}$$

Round the SWV value to the GSV and NSV requirements

Table 6—Correction Factor Discrimination Levels

%S&W	XX.XXX
CSW	X.XXXXX
CTL	X.XXXX
CPL	X.XXXX
MF	X.XXXX
CMF	X.XXXX
CCF	X.XXXX

Note: The %S&W and CSW results are as specified in API MPMS Chapter 10—Sediment and Water.

Table 7—Volume Discrimination Levels

	USC Units		SI Units	
	(Bbl)	(gal)	(m <sup>3</sup> )	(L)
Op Meter Reading (MR <sub>o</sub> )	XX.XX	XX.XX	XX.XXX	XX.0
Cl Meter Reading (MR <sub>c</sub> )	XX.XX	XX.XX	XX.XXX	XX.0
Indicated Volume (IV)	XX.XX	XX.XX	XX.XXX	XX.0
Gross Std Volume (GSV)	XX.XX	XX.XX	XX.XXX	XX.0
Net Std Volume (NSV)	XX.XX	XX.XX	XX.XXX	XX.0
S&W Volume (SWV)	XX.XX	XX.XX	XX.XXX	XX.0

## 12 Measurement Ticket Examples

### 12.1 LOW VAPOR PRESSURE LIQUIDS

The following are examples of low vapor pressure liquids.

#### Example 1

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#### Low Vapor Pressure Liquid Utilizing a Nontemperature Compensated Meter With a Meter Factor

---

##### Liquid Data

Liquid:	Crude Oil
Observed Density ( $RHO_{obs}$ ):	40.7 API
Observed Temperature ( $T_{obs}$ ):	75.1°F
Pe @ TWA:	0 psig
% S&W:	0.149

##### Meter Data

Closing Meter Reading ( $MR_c$ ):	3,867,455.15 Bbls
Opening Meter Reading ( $MR_o$ ):	3,814,326.76 Bbls
Meter Factor (MF):	1.0016
Weighted Average Temperature, (TWA) °F:	76.0
Weighted Average Pressure, (PWA) psig:	80

##### Calculations

1.	Base Density ( $RHO_b$ ):	39.4 API @ 60
2.	CTL Factor:	0.9920
3.	F-Factor:	0.00000568
4.	CPL Factor:	1.0005
5.	CCF = (CTL x CPL x MF):	0.9941
6.	Indicated Volume IV = ( $MR_c - MR_o$ ):	53,128.39 Bbls
7.	Gross Standard Volume GSV = (IV x CCF):	52,814.93 Bbls
8.	CSW = $1 - (\% \text{ S\&W} / 100)$ :	0.99851
9.	Net Standard Volume NSV = (GSV x CSW):	52,736.24 Bbls
10.	S&W Volume SWV = GSV - NSV:	78.69 Bbls

- $RHO_b$  determined in accordance with implementation procedures contained in API *MPMS* Chapter 11.1, Volume X.
- CTL and F-factor determined in accordance with implementation procedures contained in API *MPMS* Chapter 11.1, Volume X and API *MPMS* Chapter 11.2.1.

## Example 2

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### Low Vapor Pressure Liquid Utilizing a Nontemperature Compensated Meter With a Composite Meter Factor

---

#### Liquid Data

Liquid:	Unleaded Gasoline
Observed Density ( $RHO_{obs}$ ):	48.2 API
Observed Temperature ( $T_{obs}$ ):	54.6°F
Pe @ TWA:	0 psig
% S&W:	0.000

#### Meter Data

Closing Meter Reading ( $MR_c$ ):	4,521,378.68 Bbls
Opening Meter Reading ( $MR_o$ ):	4,234,153.35 Bbls
Meter Factor (MF):	0.9983
Weighted Average Temperature, (TWA) °F:	71.3
Weighted Average Pressure, (PWA) psig:	NA

#### Calculations

1.	Base Density ( $RHO_b$ ):	48.7 API @ 60
2.	CTL Factor:	0.9938
3.	F-Factor:	NA
4.	CPL Factor:	1.0000
5.	CCF = (CTL x CPL x CMF):	0.9921
6.	Indicated Volume IV = ( $MR_c - MR_o$ ):	287,225.33 Bbls
7.	Gross Standard Volume GSV = (IV x CCF):	284,956.25 Bbls
8.	CSW = $1 - (\% \text{ S\&W} / 100)$ :	1.00000
9.	Net Standard Volume NSV = (GSV x CSW):	284,956.25 Bbls
10.	S&W Volume SWV = GSV - NSV:	0.00 Bbls

- a.  $RHO_b$  determined in accordance with implementation procedures contained in API *MPMS* Chapter 11.1, Volume X.
- b. CTL and F-factor determined in accordance with implementation procedures contained in API *MPMS* Chapter 11.1, Volume X and API *MPMS* Chapter 11.2.1.

### Example 3

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#### Low Vapor Pressure Liquid Utilizing a Temperature Compensated Meter With a Meter Factor

---

#### Liquid Data

Liquid:	Crude Oil
Observed Density ( $RHO_{obs}$ ):	37.2 API
Observed Temperature ( $T_{obs}$ ):	86.7°F
Pe @ TWA:	0 psig
% S&W:	0.100

#### Meter Data

Closing Meter Reading ( $MR_c$ ):	1,725,352.39 Bbls
Opening Meter Reading ( $MR_o$ ):	1,678,269.54 Bbls
Meter Factor (MF):	1.0253
Weighted Average Temperature, (TWA) °F:	86.1
Weighted Average Pressure, (PWA) psig:	111

#### Calculations

- |     |   |                |
|-----|---|----------------|
| 1.  | Base Density ( $RHO_b$ ):                   | 35.1 API @ 60  |
| 2.  | CTL Factor:                                 | 1.0000         |
| 3.  | F-Factor:                                   | 0.00000549     |
| 4.  | CPL Factor:                                 | 1.0006         |
| 5.  | CCF = (CTL x CPL x CMF):                    | 1.0259         |
| 6.  | Indicated Volume<br>IV = ( $MR_c - MR_o$ ): | 47,082.85 Bbls |
| 7.  | Gross Standard Volume<br>GSV = (IV x CCF):  | 48,302.30 Bbls |
| 8.  | CSW = $1 - (\% \text{ S\&W} / 100)$ :       | 0.99900        |
| 9.  | Net Standard Volume<br>NSV = (GSV x CSW):   | 48,254.00 Bbls |
| 10. | S&W Volume<br>SWV = GSV - NSV:              | 48.30 Bbls     |
- $RHO_b$  determined in accordance with implementation procedures contained in API *MPMS* Chapter 11.1, Volume X.
  - CTL and F-factor determined in accordance with implementation procedures contained in API *MPMS* Chapter 11.1, Volume X and API *MPMS* Chapter 11.2.1.



**12.2 HIGH VAPOR PRESSURE LIQUIDS**

The following are examples of high vapor pressure liquids.

**Example 5**


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 High Vapor Pressure Liquid Utilizing a Nontemperature Compensated Meter With a Meter Factor
 

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**Liquid Data**

Liquid:	Propane
Observed Density ( $RHO_{obs}$ ):	0.5050 RD
Observed Temperature ( $T_{obs}$ ):	60.0°F
Pe @ TWA:	159.5 psig
% S&W:	0.000

**Meter Data**

Closing Meter Reading ( $MR_c$ ):	4,325,452.32 Bbls
Opening Meter Reading ( $MR_o$ ):	3,958,415.36 Bbls
Meter Factor (MF):	1.0000
Weighted Average Temperature, (TWA) °F:	88.1°F
Weighted Average Pressure, (PWA) psig:	425 psig

**Calculations**

1.	Base Density ( $RHO_b$ ):	0.5050 RD @ 60
2.	CTL Factor:	0.9515
3.	F-Factor:	0.000049285
4.	CPL Factor:	1.0133
5.	CCF = (CTL x CPL x MF):	0.9642
6.	Indicated Volume IV = ( $MR_c - MR_o$ ):	367,036.96 Bbls
7.	Gross Standard Volume GSV = (IV x CCF):	353,897.04 Bbls
8.	CSW = $1 - (\% \text{ S\&W} / 100)$ :	1.00000
9.	Net Standard Volume NSV = (GSV x CSW):	353,897.04 Bbls
10.	S&W Volume SWV = GSV - NSV:	0.00 Bbls

- $RHO_b$  determined in accordance with GPA TP-25.
- CTL and F-factor determined in accordance with implementation procedures contained in API MPMS Chapter 11.2.2, and API MPMS Chapter 11.2.2 Addendum.

## Example 6

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### High Vapor Pressure Liquid Utilizing a Nontemperature Compensated Meter With a Composite Meter Factor

---

#### Liquid Data

Liquid:	Propane
Observed Density ( $RHO_{obs}$ ):	0.5050 RD
Observed Temperature ( $T_{obs}$ ):	60.0°F
Pe @ TWA:	NA
% S&W:	0.000

#### Meter Data

Closing Meter Reading ( $MR_c$ ):	4,325,452.32 Bbls
Opening Meter Reading ( $MR_o$ ):	3,958,415.36 Bbls
Composite Meter Factor (CMF):	1.0009
Weighted Average Temperature, (TWA) °F:	88.1°F
Weighted Average Pressure, (PWA) psig:	NA

#### Calculations

1.	Base Density ( $RHO_b$ ):	0.5050 RD @ 60
2.	CTL Factor:	0.9515
3.	F-Factor:	NA
4.	CPL Factor:	1.0000
5.	CCF = (CTL x CPL x CMF):	0.9524
6.	Indicated Volume IV = ( $MR_c - MR_o$ ):	367,036.96 Bbls
7.	Gross Standard Volume GSV = (IV x CCF):	349,566.00 Bbls
8.	CSW = $1 - (\% \text{ S\&W} / 100)$ :	1.00000
9.	Net Standard Volume NSV = (GSV x CSW):	349,566.00 Bbls
10.	S&W Volume SWV = GSV - NSV:	0.00 Bbls

- a.  $RHO_b$  determined in accordance with GPA TP-25.
- b. CTL and F-factor determined in accordance with implementation procedures contained in API MPMS Chapter 11.2.2, and API MPMS Chapter 11.2.2 Addendum.

## Example 7

---

### High Vapor Pressure Liquid Utilizing a Temperature Compensated Meter With a Meter Factor

---

#### Liquid Data

Liquid:	Propane
Observed Density ( $RHO_{obs}$ ):	0.5050 RD
Observed Temperature ( $T_{obs}$ ):	60.0°F
Pe @ TWA:	159.5 psig
% S&W:	0.000

#### Meter Data

Closing Meter Reading ( $MR_c$ ):	4,325,452.32 Bbls
Opening Meter Reading ( $MR_o$ ):	3,958,415.36 Bbls
Meter Factor (MF):	1.0000
Weighted Average Temperature, (TWA) °F:	88.1°F
Weighted Average Pressure, (PWA) psig:	425 psig

#### Calculations

1.	Base Density ( $RHO_b$ ):	0.5050 RD @ 60
2.	CTL Factor:	1.0000
3.	F-Factor:	0.000049259
4.	CPL Factor:	1.0133
5.	CCF = (CTL x CPL x MF):	1.0133
6.	Indicated Volume IV = ( $MR_c - MR_o$ ):	367,036.96 Bbls
7.	Gross Standard Volume GSV = (IV x CCF):	371,918.55 Bbls
8.	CSW = $1 - (\% \text{ S\&W} / 100)$ :	1.00000
9.	Net Standard Volume NSV = (GSV x CSW):	371,918.55 Bbls
10.	S&W Volume SWV = GSV - NSV:	0.00 Bbls

- a.  $RHO_b$  determined in accordance with GPA TP-25.
- b. CTL and F-factor determined in accordance with implementation procedures contained in API MPMS Chapter 11.2.2, and API MPMS Chapter 11.2.2 Addendum.

## Example 8

---

### High Vapor Pressure Liquid Utilizing a Temperature Compensated Meter With a Composite Meter Factor

---

#### Liquid Data

Liquid:	Propane
Observed Density ( $RHO_{obs}$ ):	0.5050 RD
Observed Temperature ( $T_{obs}$ ):	60.0°F
Pe @ TWA:	NA
% S&W:	0.000

#### Meter Data

Closing Meter Reading ( $MR_c$ ):	4,325,452.32 Bbls
Opening Meter Reading ( $MR_o$ ):	3,958,415.36 Bbls
Composite Meter Factor (CMF):	1.0009
Weighted Average Temperature, (TWA) °F:	NA
Weighted Average Pressure, (PWA) psig:	NA

#### Calculations

1.	Base Density ( $RHO_b$ ):	0.5050 RD @ 60
2.	CTL Factor:	1.0000
3.	F-Factor:	NA
4.	CPL Factor:	1.0000
5.	CCF = (CTL x CPL x CMF):	1.0009
6.	Indicated Volume IV = ( $MR_c - MR_o$ ):	367,036.96 Bbls
7.	Gross Standard Volume GSV = (IV x CCF):	367,367.29 Bbls
8.	CSW = $1 - (\% \text{ S\&W} / 100)$ :	1.00000
9.	Net Standard Volume NSV = (GSV x CSW):	367,367.29 Bbls
10.	S&W Volume SWV = GSV - NSV:	0.00 Bbls

- a.  $RHO_b$  determined in accordance with GPA TP-25.
- b. CTL and F-factor determined in accordance with implementation procedures contained in API MPMS Chapter 11.2.2, and API MPMS Chapter 11.2.2 Addendum.

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