

Manual of Petroleum Measurement Standards Chapter 18.2

Custody Transfer of Crude Oil from Lease Tanks Using Alternative Measurement Methods

FIRST EDITION, JULY 2016

Committee Use Only



AMERICAN PETROLEUM INSTITUTE

Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to ensure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

Classified areas may vary depending on the location, conditions, equipment, and substances involved in any given situation. Users of this standard should consult with the appropriate authorities having jurisdiction.

Users of this standard should not rely exclusively on the information contained in this document. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein.

API is not undertaking to meet the duties of employers, manufacturers, or suppliers to warn and properly train and equip their employees, and others exposed, concerning health and safety risks and precautions, nor undertaking their obligations to comply with authorities having jurisdiction.

Information concerning safety and health risks and proper precautions with respect to particular materials and conditions should be obtained from the employer, the manufacturer or supplier of that material, or the material safety data sheet.

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

Users of instructions should not rely exclusively on the information contained in this document. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein.

Where applicable, authorities having jurisdiction should be consulted.

Work sites and equipment operations may differ. Users are solely responsible for assessing their specific equipment and premises in determining the appropriateness of applying the instructions. At all times users should employ sound business, scientific, engineering, and judgment safety when using this standard.

All rights reserved. No part of this work may be reproduced, translated, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the publisher, API Publishing Services, 1220 L Street, NW, Washington, DC 20005.

Foreword

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

Shall: As used in a standard, “shall” denotes a minimum requirement in order to conform to the specification.

Should: As used in a standard, “should” denotes a recommendation or that which is advised but not required in order to conform to the specification.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 1220 L Street, NW, Washington, DC 20005.

Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

Committee Use Only

Contents

1	Scope	1
2	Normative References	1
3	Terms and Definitions	2
4	Safety	2
5	Selection of Methods for Quantity and Quality Determinations Using Available Equipment in Zones ..	3
6	General Responsibilities for Production Operators and Crude Oil Truck Drivers	4
6.1	General	4
6.2	Production Operators	4
6.3	Crude Oil Truck Drivers	5
7	Maintenance and Calibration of Equipment	5
8	Assessing Oil Merchantability	5
9	Measurement Equipment for the Trailer Zone	5
10	Measurement Equipment for the Transition Zone	6
10.1	General	6
10.2	Quality Determination	7
11	Measurement Equipment for the Tank Zone	10
11.1	General	10
11.2	Static Measurement	10
11.3	Tank Calibration	10
11.4	Automatic Tank Gauging Systems	10
11.5	Hydrostatic Tank Gauging	12
11.6	Measurement System Installation, Initial Verification, and Calibration	13
11.7	Measurement System Commissioning	13
12	Record Keeping	13
13	Capability and Uncertainty	13
13.1	General	13
13.2	Procedures	14
14	Run Tickets and Tank Turndowns	24
14.1	Run Tickets or Measurement Tickets	24
14.2	Tank Turndowns	24
	Annex A (informative) Zone Matrices	25
	Annex B (normative) Uncertainty Determination Development	26
	Bibliography	29
	Figure	
1	Zones	4
	Table	
1	Applicable Standard for Meter	7

Introduction

The API *Manual of Petroleum Measurement Standards (MPMS)* covers individual standards for sampling, temperature determination, gauging, and quality testing. This publication integrates these standards, by reference, into a framework that may be applied during custody transfer of crude oil from lease tanks to a tank truck without requiring direct access to the tank thief gauge hatch. Many of the individual standards have guidelines defining the frequency and tolerances for installation, verification, and calibration of the specified equipment under controlled or ideal conditions allowing for uncertainty within custody transfer requirements. However, with the conditions encountered in many of today's applications, the installation, verification, and calibration of measurement devices may have higher uncertainties due to the operational characteristics and limited access available at the lease site. In the interest of safety and environmental concerns, these higher uncertainties may still provide acceptable measurement for custody transfer of crude oil from tanks using the defined alternate methods. The alternate measurement methods discussed in this standard are intended to minimize uncertainty and bias while encouraging consistent measurement and testing practices using existing technologies within API standards that are available at the time of the development of this standard. They are not intended to interfere with business contracts, existing API standards, or the development of new technologies or to comprise the only acceptable alternate methods of custody transfer of crude oil by trucks.

Committee Use Only

Custody Transfer of Crude Oil from Lease Tanks Using Alternative Measurement Methods

1 Scope

This standard defines the minimum equipment and methods used to determine the quantity and quality of crude oil being loaded from a lease tank to a truck trailer without requiring direct access to a lease tank gauge hatch. Methods and equipment described are grouped by tank zone, trailer zone, and the transition zone between the two (see Section 5). The equipment used for measurement is dependent on the existing design of the lease equipment, the equipment used to transport the product, or a combination of the two. Some sites may require measurements from multiple zones in order to arrive at an accurate load quantity and quality.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API MPMS Chapter 2, *Tank Calibration – All relevant sections*

API MPMS Chapter 3.1A, *Standard Practice for the Manual Gauging of Petroleum and Petroleum Products*

API MPMS Chapter 3.1B, *Standard Practice for Level Measurement of Liquid Hydrocarbons in Stationary Tanks by Automatic Tank Gauging*

API MPMS Chapter 3.6, *Measurement of Liquid Hydrocarbons by Hybrid Tank Measurement Systems*

API MPMS Chapter 4, *Proving Systems – All relevant sections*

API MPMS Chapter 5.2, *Measurement of Liquid Hydrocarbons by Displacement Meters*

API MPMS Chapter 5.3, *Measurement of Liquid Hydrocarbons by Turbine Meters*

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

API MPMS Chapter 5.8, *Measurement of Liquid Hydrocarbons by Ultrasonic Flow Meters*

API MPMS Chapter 6.1, *Lease Automatic Custody Transfer (LACT) Systems*

API MPMS Chapter 7, *Temperature Determination – All relevant sections*

API MPMS Chapter 7.3, *Temperature Determination—Fixed Automatic Tank Temperature Systems*

API MPMS Chapter 8.2, *Standard Practice for Automatic Sampling of Liquid Petroleum and Petroleum Products*

API MPMS Chapter 9, *Density Determination – All relevant sections*

API MPMS Chapter 10, *Sediment and Water – All relevant sections*

API MPMS Chapter 12, *Calculation of Petroleum Quantities – All relevant sections*

API MPMS Chapter 14.3, *Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids—Concentric, Square-edged Orifice Meters – All relevant parts*

API MPMS Chapter 16.2, *Mass Measurement of Liquid Hydrocarbons in Vertical Cylindrical Storage Tanks by Hydrostatic Tank Gauging*

API MPMS Chapter 21.2, *Electronic Liquid Volume Measurement Using Positive Displacement and Turbine Meters*

API MPMS Chapter 22.2, *Testing Protocols—Differential Pressure Flow Measurement Devices*

3 Terms and Definitions

For the purposes of this document, the following definitions apply.

NOTE See API MPMS Chapter 1, online Terms and Definitions Database, for additional terms and definitions applicable to this document.

3.1

crude oil lease tank

A tank that is calibrated per API MPMS Chapter 2 standards that stores crude oil from producing leases waiting to be transported by a carrier.

3.2

crude oil truck driver

COTD

Assumes that the driver is also the gauger; however, it should be recognized that these duties may be divided between different individuals: a person who only drives the tank truck and a gauger or applicable representative who is responsible for measurement and testing.

3.3

linearized tank table

LTT

The linearized tank table value corresponding to the opening gauge measurement, closing gauge measurement, and free water gauge measurement.

3.4

merchantability

A term applied to liquid hydrocarbons judged to be acceptable for custody transfer to a carrier. The oil is settled and contains no more than a set amount of suspended sediment and water (S&W) and other impurities. The amount of S&W or other impurities shall be agreed upon by both parties to have a mutual understanding of what is merchantable product.

4 Safety

Safety is an essential part of crude oil trucking operations both on roadways and during custody transfer. API MPMS Chapter 18.1 was developed for applications where access to lease tanks to perform the associated measurement and quality tasks was not restricted and where the settling and weathering of crude oil prior to custody transfer was possible. There are many applications today where these conditions cannot be met. Opening thief hatches of storage tanks can lead to the rapid release of high concentrations of hydrocarbon gases and vapors. Be aware that those may result in very low oxygen levels and toxic and flammable conditions around and over the hatch. This standard was developed to encourage uniform, technically defensible measurement and testing practices for crude oil gathered from lease tanks when access to the tank's thief hatch may be restricted.

Safety is an essential part of crude oil trucking operations both on roadways and during custody transfer, so the crude oil truck driver (COTD) shall be thoroughly familiar with all government and company safety regulations as well as API Recommended Practice 2003, which outlines safety procedures that are important for truck transports.

Refer to appropriate government regulations and publications, including the following:

- OSHA 29 CFR 1910.106, *Flammable and Combustible Liquids*;
- OSHA 29 CFR 1910.132, *Personal Protective Equipment*;
- OSHA 29 CFR 1910.134, *Respiratory Protection*;

- OSHA 29 CFR 1910.147, *The Control of Hazardous Energy (Lockout/Tagout)*;
- OSHA 29 CFR 1910.307, *Hazardous (Classified) Locations*;
- OSHA 29 CFR 1910.1000, *Air Contaminants*;
- OSHA 29 CFR 1910.1200, *Hazard Communication*;
- OSHA Publication 3843, NIOSH-OSHA Hazard Alert, *Health and Safety Risks for Workers Involved in Manual Tank Gauging and Sampling at Oil and Gas Extraction Sites*.

These references are provided for informational purposes only and do not provide legal advice on compliance with regulations. Where applicable, authorities having jurisdiction should be consulted.

5 Selection of Methods for Quantity and Quality Determinations Using Available Equipment in Zones

As stated in the Scope of the document, this standard defines some of the equipment and methods used to determine the quantity and quality of oil being loaded from a lease tank to a truck trailer without requiring direct access to a lease tank gauge hatch. The methods and equipment that will be used are based on:

- a) establishing a list/matrix of all the existing and/or available equipment in the tank, trailer, and transition zones and understanding all the potential uncertainty and bias of the equipment;
- b) understanding and documenting the potential conditions that will exist during the loading of the product that may affect the equipment and process used to determine the quantity and quality of the product;
- c) assessing all the data to determine the capability of developing a measurement method or process that will provide the lowest uncertainty and minimize any bias to an acceptable level utilizing the available equipment in any combination of the three zones.

Quantity and quality determinations made under many of the conditions experienced in today's production are challenging due to safety and environmental concerns but necessary. Unstabilized liquid hydrocarbons may contain varying amounts of dissolved natural gas and some entrained water. These conditions reduce the ability of any equipment to achieve its intended accuracy, so it is important to account for them in assessing the potential impact to the alternate measurement process developed. The lowest uncertainty will generally be associated with the most stabilized product.

This standard does not address other methods for determination of quantity and quality at locations off-site because they are covered by existing industry standards. Other methods, such as mass measurement by weigh scale or custody transfer at the loading or unloading point by measurement system, have the potential for much lower uncertainty and may have to be considered if the zone methods do not meet an acceptable level of uncertainty to all the parties involved in the transaction.

The following determinations shall be made in one, two, or all of the zones for comparison purposes:

- a) merchantability (see Section 8),
- b) indicated/observed volume,
- c) product temperature,
- d) API gravity and observed temperature,
- e) suspended S&W,
- f) calculated volume (gross standard volume [GSV] and net standard volume [NSV]) (refer to API *MPMS* Chapter 12).

Methods and equipment described are grouped by tank zone, trailer zone, and the transition zone between the two (see Figure 1).

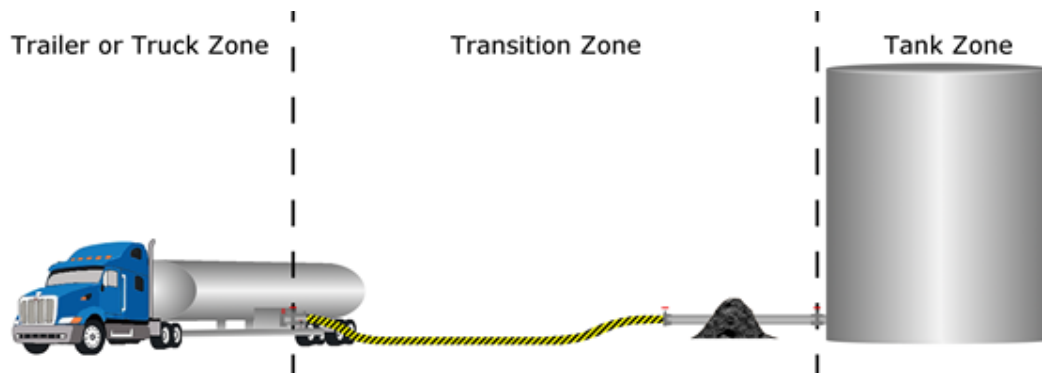


Figure 1—Zones

Tank Zone

A term used to describe the interior of the tank and any equipment attached to the tank, such as a tank gauge. The tank zone includes an outlet valve but not a hose. Once the product has left the outlet valve, it is no longer in the tank zone.

Transition Zone

A term used to describe the area between tank and truck during custody transfer. The transition zone begins once the product has left the outlet valve of the tank, such as through a hose, and ends at the start of its destination, i.e. an inlet valve of a trailer.

Trailer Zone

A term used to describe the interior of a trailer after a product has left the transition zone. The trailer zone begins with the inlet valve of a trailer and includes the interior of the trailer.

See Annex A for the zone matrices to assist in determining available equipment for each measured determination.

The user, after determining the available measurement equipment for both quality and quantity, shall then assess the potential uncertainty and bias that exists (see Section 13).

6 General Responsibilities for Production Operators and Crude Oil Truck Drivers

6.1 General

Because the ownership of the crude oil being gathered can change and the custody is always passed from the lease tank to the transporting truck as the crude oil passes the tank's last fixed outlet flange, accurate custody transfer is extremely important to both the shipper and the carrier. Therefore, all measurements shall be taken carefully and completed to the full satisfaction of all parties or their authorized representatives.

6.2 Production Operators

Production operators should be responsible for ensuring that the oil in the tank is ready for custody transfer. This involves making sure that the tank is isolated from production, settled, and weathered. Any free water on the bottom of the tank should be drained to ensure that there are at least 4 in. of clearance below the sales outlet of the tank. The suspended S&W should also be checked to ensure that it is below the acceptable limits. However, achieving these conditions may not always be possible due to excessive production and limited storage tanks. When conditions do not allow for tank isolation, proper settling, weathering of the crude oil, and verification of suspended S&W in the crude oil, then alternate methods may be used for custody transfer. Whatever conditions

exist, the production operator shall ensure that the free water has been drained to an acceptable level below the sales outlet of the tank before the truck is dispatched to the lease to pick up the load.

6.3 Crude Oil Truck Drivers

The COTD should be responsible for obtaining measurement and testing the oil prior to, during, or after the loading process and documenting the information on the run ticket. Detecting and reporting defective or inadequate control conditions, such as dents, settling, or leaks, should be completed by the COTD. The API *MPMS* covers individual procedures for sampling, temperature determination, gauging, and quality testing. This standard allows for the integration of these procedures into a sequence that can be applied during custody transfer of crude oil from lease tanks to a tank truck using alternate measurement methods.

7 Maintenance and Calibration of Equipment

This standard assumes that the equipment available for use is installed, calibrated, and maintained to an acceptable level based on manufacturer's recommendations and industry best practices. The following sections present installation, calibration, and maintenance considerations when the equipment is introduced in the measurement zones. Consult the applicable API *MPMS* standards for additional information regarding requirements for specific devices.

8 Assessing Oil Merchantability

The determination of merchantable oil by the application of this standard may carry conditions that require special care and consideration. For instance, during start-up of new production leases, the flows may exceed available tank storage capacities to the effect of presenting operational constraint limits that do not allow the oil to meet properly settled conditions. Additionally, high H₂S levels may present conditions that restrict or prevent producers from physically gauging and sampling their respective lease tanks, per manual gauging methods. For these conditions, additional measurements methods and practices shall be considered for determining oil merchantability prior to loading.

Understanding water levels in tanks is a key component in lease tank load operations. The clearance between the bottom of the tank outlet pipe and the top of the free water and sediment level should be ≥ 4 in. prior to and during the loading process.

If state or other regulations specify a clearance level >4 in., the applicable minimum clearance level shall apply.

The crude oil transferred may have further specifications or requirements pending applicable contracts between the parties and receiving pipeline tariffs. In the event pipeline transportation (destinations) is involved, all crude oil transferred should be reviewed for meeting the quality requirements of the applicable transporting pipeline as set out in the applicable tariff/rules and regulations.

9 Measurement Equipment for the Trailer Zone

Trailers have the ability to provide quantity information if properly configured. Horizontal tanks can be strapped or water drawn in accordance with industry standards and therefore can provide incremental volumes using manual and/or automatic tank gauges (ATGs). Trailers may also have temperature sensors mounted internal to the trailer to provide accurate wetted temperatures of the liquids.

The calibration/verification of the automatic equipment used in the trailer zone might require the use of the manual method of gauging the volume of product in the trailer and comparing it to the trailer ATG reading. The manual gauging of a strapped horizontal trailer (e.g. API *MPMS* Chapter 2.2E and Chapter 2.2F) is not addressed in this standard. Calibration/verification of onboard trailer ATGs might also be accomplished using a liquid fill calibration procedure or a master meter method (e.g. API *MPMS* Chapter 4.5 and Chapter 4.9.2 and API Standard 2555).

The user should consult the applicable standard for process and frequency for whatever procedure is used to calibrate/verify trailer-mounted measurement equipment.

In order for volume measurements from the trailer to be used, it shall have a capacity table created using appropriate API standards. The ATG system shall use the capacity table or increments for that specific trailer when calculating volume. Tolerances shall meet the API standard used for calibration of the trailer tank and should properly address deadwood, slope or tilt, position of the ATG device, and other physical properties such as density, temperature, and pressure. It should be noted that, if the ATG system is installed in the tank center longitudinally, any correction for tilt may be unnecessary if the trailer tank is on level ground. Temperature sensors incorporated into the ATG shall meet accuracy requirements in accordance with API MPMS Chapter 7.3.

Although trailer zone measurements may present higher levels of uncertainty, they may provide acceptable measurements in extreme or harsh conditions such as high H₂S or live production scenarios.

10 Measurement Equipment for the Transition Zone

10.1 General

The transition zone is the area between tank and truck during custody transfer of crude. It starts downstream of the outlet valve of the tank and ends upstream of an inlet valve of a trailer. Equipment used in the transition zone associated with the measurement should be maintained in accordance with applicable codes, regulations, and API standards.

10.1.1 Dynamic Volume Determination

It may be possible to determine the volume of oil loaded from a tank to a trailer using an in-line meter. The choice of the in-line meter is up to the user; however, there are many factors that can have a significant effect on the accuracy of an in-line meter when measuring a load volume. These factors are discussed in detail in the appropriate metering sections of API MPMS Chapter 5. These effects need to be taken into account when determining the accuracy of an in-line meter to determine the volume of oil loaded onto a trailer.

In-line metering is recommended to be performed downstream of a pump. This is to ensure that the meter remains full at all times during flow (i.e. no cavitation at the meter). If the metering is performed upstream of a pump, the user shall provide data detailing the accuracy of the equipment under possible cavitation conditions.

If applicable, the flow computer, temperature transmitter, and any other electronic equipment associated with the measurement shall be maintained in accordance with API MPMS Chapter 21.2.

Trailer-mounted meters are subject to adverse conditions and hazards associated with travelling on oil field roads. Proper maintenance of these devices is essential to ensure that the accuracy of the device does not change over time.

Metering of liquid hydrocarbons can be performed in accordance with the applicable standard, referenced in Table 1. Whatever meter type is chosen, it shall meet the requirements of the applicable standard listed in Table 1.

Table 1—Applicable Standard for Meter

Meter Type	Applicable Standard
Positive displacement meter	API MPMS 5.2
Turbine meter	API MPMS 5.3
Coriolis meter	API MPMS 5.6
Ultrasonic meter	API MPMS 5.8
Differential pressure meter	API MPMS 22.2
LACT systems	API MPMS 6.1
Orifice meter	API MPMS 14.3

Proving of in-line metering shall be performed according to the applicable standard for that meter and per API MPMS Chapter 4. Proving requirements may need to be adjusted for regulatory compliance.

10.1.2 Static Volume Determination

Equipment may be incorporated with the system or be an external hydrostatic tank gauge (HTG) comprised of one or multiple pressure sensors (see API MPMS Chapter 3.6 and Chapter 16.2).

10.2 Quality Determination

10.2.1 General

In order for the samples to be representative, the following criteria shall be met.

- The fluid should be mixed by either a static mixer, a pump, or piping configuration.
- The fluid should be flowing at a velocity that ensures that the fluid is well mixed.

The sample probe should be located and oriented as described in API MPMS Chapter 8.2. If a mixer/sampler or gear pump setup has been tested to show that it can properly mix and sample the product, then the following procedure should be used to determine the quality of the product being loaded onto the trailer.

- 1) Regardless of whether the first step is determining the merchantability of the product utilizing an acceptable device that is capable of indicating the tank water/oil interface level, the merchantability shall still be checked with the in-line mixer/sampler or gear pump as mixer.

Merchantability sample should be collected at a time to ensure that the sample being taken represents the oil at the sales tank outlet. This will be dependent on the load line volume between the tank outlet and the sampling point.

- 2) Once merchantability sample(s) has been collected, shut down pump and close inlet valve to trailer.
- 3) Analyze the merchantability sample(s) per API MPMS Chapter 10.
- 4) If product is merchantable, continue pumping. If product is nonmerchantable, proceed per agreement between the parties.

- 5) Collect the first S&W sample at approximately $\frac{1}{4}$ of the way into the load. This sample may be set aside and analyzed with the second S&W sample.
- 6) Collect the API gravity sample at approximately half way through the load.
- 7) Analyze API gravity per API *MPMS* Chapter 9.
- 8) Collect the second S&W sample at approximately $\frac{3}{4}$ of the way into the load.
- 9) Analyze S&W samples per API *MPMS* Chapter 10.
 - a) At a minimum, the samples collected in steps 5 and 8 should be analyzed for the load S&W.
 - b) In order to get a more accurate average S&W, it might be beneficial to collect and analyze additional samples.
- 10) Record S&W, API gravity, observed temperature, and tank bottoms, if available, on a run ticket.

10.2.2 In-line Mixer and Sampler

If static or dynamic mixing is being considered, the manufacturer should be consulted as to its design and application. The manufacturer of the sampling system should be consulted to ensure that the sampling system is designed properly. A system verification should be performed on sampling systems after it is installed to determine the uncertainty associated with the sampling system. See API *MPMS* Chapter 8.2 for crude characteristics that can affect mixing.

Due to normal pumping arrangements using a truck trailer pump, a vacuum is likely at the sample point, not allowing a sample to flow from sample point. It is necessary to have a minimal positive pressure to drive a sample from the sample port. The following procedure ensures that both the backpressure is high enough to obtain a sample and the velocity is high enough to mix the sample.

- 1) Place a spill container under the sample valve.
- 2) While pumping, open the sample valve.
- 3) If product flows from sample valve, proceed to step 5.
- 4) If product does not flow, increase backpressure by partially closing inlet valve on trailer pump until product flows from sample valve.
- 5) Allow enough product to flow through sample valve to bleed the sample line, then close sample valve.
- 6) Acquire a sample in a container that is appropriate for the analysis to be performed.
- 7) Fill sample collection container to desired level.
- 8) Close sample valve.
- 9) Fully open inlet valve on trailer.

10.2.3 Using Gear Pump as Mixer

The use of a gear pump as a method of mixing the stream should be considered when determining a sample point. Samples taken directly downstream of a gear pump can be representative if the location of the sample tap is installed and tested per API *MPMS* Chapter 8.2.

Verification of the sample system shall be performed to ensure that the probe's location and mixing is adequate for the oil being sampled. The use of a manual valve to extract the required sample will be necessary.

When manually pulling a sample downstream of a gear pump, use the following procedure.

- 1) Place a spill container under the sample valve.
- 2) While pumping, open the sample valve.
- 3) If product flows from sample valve, allow enough product to flow through sample valve to bleed the sample line, then close sample valve.
- 4) Acquire a sample in a container that is appropriate for the analysis to be performed.
- 5) Fill sample collection container to desired level.
- 6) Close sample valve.

If a gear pump setup has been tested to show that it can properly mix and sample the product, then the following procedure should be used to determine the quality of product being loaded onto the trailer.

If the merchantability of the product is determined using the ATGs that indicate the water/oil interface level, the merchantability shall be checked with the gear pump mixer/sampler. The merchantability sample should be collected at a time to ensure that the sample being taken represents the oil at the sales tank outlet. This will be dependent on the load line volume between the tank outlet and the sampling point.

- 1) Once merchantability sample(s) has been collected, shut down pump and close inlet valve to trailer.
- 2) Analyze the merchantability sample(s) per API *MPMS* Chapter 10.
- 3) If product is merchantable, continue pumping.
- 4) Collect the first S&W sample at approximately $\frac{1}{4}$ of the way into the load. This sample may be set aside and analyzed with the second S&W sample.
- 5) Collect the gravity sample at approximately half way through the load.
- 6) Analyze product gravity per API *MPMS* Chapter 9.
- 7) Collect the second S&W sample at approximately $\frac{3}{4}$ of the way into the load.
- 8) Analyze S&W samples per API *MPMS* Chapter 10.
 - a) The parties may agree to more than two samples, but at a minimum, the samples collected in steps 4 and 7 should be analyzed for the load S&W.
 - b) In order to get a more accurate average S&W, it might be beneficial to collect and analyze additional samples.
- 9) Record S&W, API gravity, observed temperature, and tank bottoms, if available, on a run ticket.

10.2.4 Temperature Determination

An in-line temperature may be recorded to determine the temperature of the fluid loaded onto the truck in accordance with API *MPMS* Chapter 7. Two methods may be used to determine the average temperature throughout the load.

- 1) Use an electronic averaging thermometer throughout the entire load.
- 2) Average three flowing temperatures taken at approximately $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$ of the way into the load. The observed temperature taken in step 7 from Section 10.2.1 shall not be used in this average.

Record the fluid temperature determined above on a run ticket.

11 Measurement Equipment for the Tank Zone

11.1 General

Within the tank zone there are many ways to obtain the proper measurements needed for custody transfer. This section addresses some of these methods but is not exclusive of other methods that can be used. ATG systems are an option for measurement in the tank zone. ATG systems are capable of measuring the level, interface, and temperature of the product in the tank. Another method of measurement of liquid hydrocarbons in vertical cylindrical storage tanks is by HTG systems. With HTG systems, the volume is derived from the liquid mass or levels, calculated using the measured pressures and densities and the tank capacity tables.

In order for volume measurements from the tank to be used, the tank shall have a capacity table created using appropriate API standards. The tank measurement system shall use the proper certified tank capacity table. Tolerances shall meet API *MPMS* Chapter 2.2 for calibration of storage tanks and should properly address deadwood and position of the measurement system and other physical properties such as density, temperature, and pressure. Temperature sensors incorporated into the measurement system shall meet accuracy and placement requirements in accordance with API *MPMS* Chapter 7.

11.2 Static Measurement

Static measurement of liquids is accomplished using automated level (gauging) determination. The volume or mass delivered is a function of the liquid's physical properties, temperature, pressure, or the measured or calculated density corrected for nonmerchantable components as well as the tank strapping table.

11.3 Tank Calibration

For static measurement, the tank geometry shall be reliably known. For instance, precise tank circumference and height are critical in determining liquid volumes and the development of capacity tables for custody transfer transactions and inventory control. API *MPMS* Chapter 2 provides measurement and computational procedures for the development of capacity tables. All such measurements should be witnessed by all parties involved to ensure compliance with the procedure outlined in the standard and overall measurement integrity.

11.4 Automatic Tank Gauging Systems

11.4.1 General

This section covers, in general, level measurement of liquid hydrocarbons in stationary, aboveground, atmospheric lease tanks using ATGs. It also discusses automatic tank gauging in general and accuracy, installation, commissioning, calibration, and verification of ATGs that measure either innage or ullage. Before choosing to install and use an ATG system, reference should be made to API *MPMS* Chapter 3.1B for details.

11.4.2 Safety

All ATGs shall be capable of withstanding the pressure, temperature, and other environmental conditions likely to be encountered in service.

All ATGs shall be sealed to withstand the vapor pressure of liquid in the tank.

Manual tank gauging can be associated with exposure to immediately dangerous vapors. Workers should be familiar with all government and company safety procedures for tank gauging as well as API Recommended Practice 2003.

When an ATG is verified or calibrated by manual gauging, the manual gauging should be done in accordance with API *MPMS* Chapter 3.1A.

11.4.3 Response Time

ATGs shall afford sufficient dynamic response time in order to reliably track liquid levels even during maximum rates of tank filling or emptying. Even so, disturbances to liquid surfaces caused by eddies and currents shall be considered as they can adversely affect readings. For optimum results, static readings are recommended.

11.4.4 General Precautions

The following general measurement precautions affect the accuracy and performance of all types of ATGs. They should be observed where they are applicable.

- a) Tank temperature should be measured at the same time the tank level is measured. The tank temperature should be representative of the tank contents in accordance with API *MPMS* Chapter 7.
- b) Level measurements should be recorded as soon as they are taken, unless the remote readout equipment of the ATG system automatically records the levels periodically.
- c) The same procedures should be used to measure a tank level before the product transfer (opening gauge) and after the product transfer (closing gauge).
- d) All parts of the ATG in contact with the product or its vapor should be compatible with the product to avoid both product contamination and ATG corrosion. The ATG should be designed to meet the operating conditions.
- e) Refer to API *MPMS* Chapter 3.1A for guidance on settling time before tank levels are measured.
- f) ATGs should provide security to prevent unauthorized adjustment or tampering. ATGs used in custody transfer applications should provide facilities to allow sealing for calibration adjustment.

11.4.5 Data Acquisition

There are multiple devices available to capture the level indications from a measurement system and provide a visual or printed value in a safe location for inclusion on a custody transfer report. The following clauses provide recommendations for the specification of the communication between level transmitter(s) and receiver(s) and vice versa. The measurement data provided by an ATG may include other information. The ATG system should be designed and installed such that the data transmission and receiving unit should:

- a) not compromise the reliability of the measurements taken; the difference between the level readings displayed by the remote receiving unit and the level readings displayed (or measured) by the ATG at the tank should comply with API *MPMS* Chapter 3.1B;
- b) not compromise the resolution of the measurement output signal;
- c) provide proper security and protection of the measured data to ensure their integrity;
- d) provide adequate speed to meet the update time required for the receiving unit;
- e) be electromagnetically immune.

11.5 Hydrostatic Tank Gauging

11.5.1 General

This section provides general guidance for the measurement of liquid hydrocarbons in vertical cylindrical lease tanks by HTG systems for use in the custody transfer of hydrocarbon fluids. This type of system uses high-precision, thermally stable, and calibrated pressure transducers suitable for the measurement application. When using this practice for custody transfer, a referral should be made to API MPMS Chapter 16.2 for specific requirements. Volume is derived from the liquid mass or levels, calculated using the measured pressures and densities and the tank capacity table. Individual components used in deriving the volume, such as density, can be calculated using the established industry standards for inventory calculations.

In addition, a free water/clearance level technology can be installed in the same configuration as HTGs.

11.5.2 Safety

Safety and material compatibility precautions should be taken when using HTG equipment. Manufacturer's recommendations on the use and installation of the equipment should be followed. Users should comply with all applicable codes and regulations, API standards, and the National Electric Code.

11.5.3 Temperature Measurement

Temperature measurements are very important in an HTG system to account for varying environmental conditions. Temperature can have an effect on the following:

- calculation of the volumetric expansion of the tank shell;
- calculation of the reference density from observed density (used in HTG systems that calculate level and density as well as volume); if the reference density is known and a middle pressure sensor is not used, the temperature sensor might still be required for the observed density calculations.

Ambient temperature can have an effect on the following:

- calculation of ambient air density,
- calculation of the volumetric expansion of the tank shell,
- correction for thermal expansion of the positioning of pressure sensors.

11.5.4 Hydrostatic Tank Gauging System Processor

A processor receives data from the various output signals and transducers, then applies those data in the calculation of liquid level using tank tables. It also uses the data together with the tank and liquid parameters to compute the volume of inventory in the storage tank. The stored parameters fall into four groups: tank data, sensor data, liquid data, and ambient data. The parameters that are required by the application should be programmed into the HTG system processor. If a middle pressure sensor is installed, density can no longer be measured by the HTG system when the product level drops below the level of a middle pressure sensor. Below the middle pressure sensor, the last measured value of product density is used. The processor may be dedicated to a single tank, shared among several tanks, or be a portable device carried between tanks. The processor may also perform linearization and/or temperature compensation corrections for the pressure sensors. The tank gauging processor may be incorporated with the system or be an external one. Refer to API MPMS Chapter 16.2 for additional information on processors.

11.6 Measurement System Installation, Initial Verification, and Calibration

Installation of the measurement system should be consistent with all applicable codes, safety practices, manufacturers' recommendations, and applicable state and federal regulatory requirements. Site-specific standard best practices should be developed to ensure consistency with regard to mounting, accessibility during accuracy verification, maintenance, and any inherent atmospheric conditions that could affect the performance and accuracy.

Prior to initial setting or initial verification of a new or repaired measurement system, the tank should be allowed to stand at a constant level long enough for air or vapor to be released from the liquid and for the tank bottom to reach a stable position as recommended in API *MPMS* Chapter 2. New tanks should be filled and allowed to stand to minimize the errors caused by initial bottom settlement.

A verification program should be established for all measurement systems used for custody transfer. Use of statistical quality control methods to monitor the performance of measurement systems is recommended, especially for measurement systems in custody transfer applications. Measurement systems used for custody transfer should be verified at multiple points within the applicable operating range on a regular basis, conforming to all applicable standards.

This standard provides an alternative method to API *MPMS* Chapter 18.1 using automatic methods. The accuracy requirements in API *MPMS* Chapter 18.1 should be used as a guideline. For installation, verification, and calibration procedures, refer to API *MPMS* Chapter 3.1B for ATG type systems and API *MPMS* Chapter 16.2 for HTG and particular manufacturer's instructions.

11.7 Measurement System Commissioning

Commissioning is performed following any measurement system installation. Some or all parts of the commissioning procedure may also be repeated if some or all of the measurement system is replaced after a hardware failure or a measurement system update. Records should be kept of all data for future use during maintenance. If any measurement parameters have changed, their new values should be entered into the measurement system processor. It is recommended that the tank capacity table be verified as conforming to all applicable standards. Capacity tables are normally derived from calibration reports that give break points in the volume/level table. Refer to API *MPMS* Chapter 2.2A or Chapter 2.2B for development of the tank calibration report. These data should be checked against the tank capacity table.

The values measured and calculated by the measurement system should be compared with those provided by manual measurements. If the readings agree with the uncertainties of the measurement system and the manual measurement, the measurement system can be assumed to be operating properly. If the values do not agree, further investigation is required.

12 Record Keeping

Records should be kept of the initial setting, initial verification, and subsequent verifications. Records of maintenance work should be kept. See all applicable API *MPMS* standards referenced in this document.

13 Capability and Uncertainty

13.1 General

The overall uncertainty by any tank volume determination depends on many variables including the equipment and methods used, equipment installation methods, and changes in operating conditions over time. In all cases, custody transfer measurements require mutual acceptability among the involved parties and can in some cases fall under federal, state, and local regulations.

The liquid level and/or other parameters necessary for liquid volume and mass calculation measurement uncertainty are a function of the equipment and methods used as well as by the methods themselves.

Prior to field installation or use, all measurement devices used (in the tank zone) for custody transfer shall be verified or calibrated against one or more certified measurement devices over the device's entire range of use. The certified measurement instrument shall be traceable to a standard or standard suitable to the involved parties.

The combined uncertainty of the installed measurement instrument includes both the intrinsic accuracy of the measurement device, as verified by the initial setup and calibration, and those effects caused by installation and operating conditions and by any field calibrations performed.

Measurement systems and measurements derived therefrom are affected by the same inherent uncertainty limitations as manual tank gauging. It is imperative that the user understand these limitations, which are addressed in API MPMS Chapter 3.1A and generally summarized below for convenience (other limitations are also listed in API MPMS Chapter 3.1B):

- tank capacity table, including the effect of tank tilt and hydrostatic pressure;
- bottom movement;
- encrustation;
- movement of the manual gauging reference point or the reference point during tank transfers or because of thermal expansion (both affect ullage gauging);
- measurements using innage-based devices are affected by vertical movement of the datum plate used to calibrate or vertical movement of the reference point during tank transfers;
- random and system errors in level, density, and temperature measurements;
- expansion of the tank diameter due to temperature;
- operational procedures used in fluid transfer;
- errors caused by improper installation;
- errors in transmitting the tank level and temperature information to a remote readout;
- errors in tank capacity table, physical property, and other data input into the tank gauging system computer.

13.2 Procedures

The purpose of this section is to outline the procedures for determining the overall uncertainty in the custody transfer volumes of oil transferred from the lease tank to the truck. The overall uncertainty can contain elements of uncertainty from each of the three zones as discussed previously. This procedure is used to answer the following questions:

- Given the allowable uncertainty for custody transfer volume, what selection of measurement devices can be made in each zone to meet the overall uncertainty criterion in the NSV?
- Given the selection (or existing) measurement devices and the individual uncertainty associated with those devices, what is the overall uncertainty in the NSV?

The uncertainty development for static and dynamic measurement systems is given in Annex B. With those equations, the NSV uncertainty basis measurements in all zones can be calculated. The uncertainties for the variables (e.g. T , P , MF) in the uncertainty equations are obtained either from manufacturer's specification sheets

and information, from calibration tracking, or from device discrimination. Examples are a temperature measurement device that is certified to 0.2 °F, a meter factor that has an uncertainty of 0.0011 from meter factor tracking history, or a hydrometer that is certified and read to 0.5° API.

EXAMPLE 1 A truck was loaded from a lease tank containing 380 bbl of oil. The truck was capable of holding 180 bbl, and the tank was isolated for delivery. An ATG device (API *MPMS* Chapter 3.1B) was used to measure the oil level in the tank (zone) both before and after delivery. No free water was detected. A small automatic flow proportional sampler (API *MPMS* Chapter 8.2) was used with temperature and temperature averaging devices in the transition zone. The opening gauge was 19' 0+0/4", and the closing gauge was 10' 1+1/4". The average temperature was 48 °F, and the average pressure was 5.5 psig. The S&W was determined using the centrifuge field method (API *MPMS* Chapter 10.4) to be 0.20 %, and the gravity was determined to be 42.5° API corrected to 60 °F using a hydrometer (API *MPMS* Chapter 9.1). The CTL and CPL from API *MPMS* Chapter 11.1^[3] were 1.00619 and 1.00003, respectively. As calculated:

$$GOV = 177.92 \text{ bbl,}$$

$$GSV = 179.02 \text{ bbl,}$$

$$NSV = 178.66 \text{ bbl.}$$

The uncertainties in each of the measured and calculated variables are summarized below. The uncertainties for the devices used in this specific example are obtained from the manufacturer's data sheets and certifications; F_p and α_{60} uncertainties are calculated from the equations developed in Annex B and are given below.

Variable	Description	Units	As Measured	Uncertainty (+/-)
l_{open}	Opening gauge	Feet, inches, quarter-inches	19' 0+0/4"	1/8"
		Feet	19.00000'	0.010417'
l_{close}	Closing gauge	Feet, inches, quarter-inches	10' 1+1/4"	1/8"
		Feet	10.010147'	0.010417'
$LTT_{l_{open}}$	Linearized tank table at Open	bbl/feet	20.00000	0.010417
$LTT_{l_{close}}$	Linearized tank table at Close	bbl/feet	20.00000	0.010417
T	Observed temperature	°F	48.0 °F	0.5 °F
P	Observed pressure	psig	5.5 psig	0.2 psig
API_{60}	API gravity at 60 °F	API °	42.5°	0.1°
$S\&W$	Measured S&W	% Volume	0.20 %	0.02 %
F_p	Liquid compressibility	psi ⁻¹	5.40×10^{-6}	0.35×10^{-6}
α_{60}	Liquid coefficient of thermal expansion	°F ⁻¹	517×10^{-6}	17×10^{-6}
NSV	Net standard volume	bbl	178.66 bbl	0.43 bbl

$$\begin{aligned}\rho_{60} &= \frac{141.5}{131.5 + API_{60}} \rho_{60,W} \\ &= \frac{141.5}{131.5 + 42.5} \times 999.012 \text{ kg/m}^3 \\ &= 812.41 \text{ kg/m}^3\end{aligned}$$

and

$$\begin{aligned}\delta\rho_{60} &= \frac{\delta API_{60}}{131.5 + API_{60}} \rho_{60} \\ &= \frac{0.1}{131.5 + 42.5} \times 812.41 \text{ kg/m}^3 \\ &= 0.47 \text{ kg/m}^3\end{aligned}$$

and

$$\begin{aligned}F_p &= \exp\left(A + BT + \frac{C + DT}{\rho_{60}^2}\right) \\ &= \exp\left(-1.9947 + 1.3427 \times 10^{-4} \times 48.0 + \frac{793,920 + 2326 \times 48.0}{(812.41)^2}\right) \times 10^{-5} \\ &= 5.40\text{E-}6 \text{ 1/psi}\end{aligned}$$

and

$$\begin{aligned}\delta F_p &= \pm \left[(0.065)^2 + \left(B + \frac{D}{\rho_{60}^2}\right)^2 \delta T^2 + 4 \left(\frac{C + DT}{\rho_{60}^2}\right)^2 \left(\frac{\delta API_{60}}{131.5 + API_{60}}\right)^2 \right]^{\frac{1}{2}} F_p \\ &= \pm \left[(0.065)^2 + \left(1.3427 \times 10^{-4} + \frac{2326}{(812.41)^2}\right)^2 \times (0.5)^2 \right]^{\frac{1}{2}} \\ &\quad + 4 \times \left(\frac{973,920 + 2326 \times 48.0}{(812.41)^2}\right)^2 (0.47)^2 \right]^{\frac{1}{2}} \times 5.40\text{E-}6 \text{ 1/psi} \\ &= \pm 351.2\text{E-}9 \text{ 1/psi}\end{aligned}$$

and

$$\begin{aligned}\alpha_{60} &= \frac{K_0}{\rho_{60}^2} \\ &= \frac{341}{(812.41)^2} \\ &= 516.7\text{E-}6 \text{ 1/}^\circ\text{F}\end{aligned}$$

and

$$\begin{aligned}\delta_{\alpha_{60}} &= \pm \left[(0.033)^2 + 4 \left(\frac{\delta_{API_{60}}}{131.5 + API_{60}} \right)^2 \right]^{\frac{1}{2}} \alpha_{60} \\ &= \pm \left[(0.033)^2 + 4 \left(\frac{0.1}{131.5 + 42.5} \right)^2 \right]^{\frac{1}{2}} \times 516.7E-6 \text{ 1/}^\circ\text{F} \\ &= 17.1E-6 \text{ 1/}^\circ\text{F}\end{aligned}$$

and

$$\begin{aligned}C_{TL} &= \exp\{-\alpha_{60} (T - 60)[1 + 0.8 \alpha_{60} (T - 60)]\} \\ &= \exp\{-516.7E-6 \times (48.0 - 60) \times [1 + 0.8 \times 516.7E-6 \times (48.0 - 60)]\} \\ &= 1.00619\end{aligned}$$

and

$$\begin{aligned}\delta_{C_{TL}} &= \pm \left\{ [\alpha_{60} (1 + 1.6 \alpha_{60} (T - T_{60}))]^2 \left[(T - T_{60})^2 \left(\frac{\delta_{\alpha_{60}}}{\alpha_{60}} \right)^2 + \delta_T^2 \right] \right\}^{\frac{1}{2}} C_{TL} \\ &= \pm \left\{ [516.7E-6 \times (1 + 1.6 \times 516.7E-6 \times (48.0 - 60))]^2 \left[(48.0 - 60)^2 \left(\frac{17.1E-6}{516.7E-6} \right)^2 + (0.5)^2 \right] \right\}^{\frac{1}{2}} 1.00619 \\ &= \pm 0.00033\end{aligned}$$

and

$$\begin{aligned}C_{PL} &= \frac{1}{1 - F_p P} \\ &= \frac{1}{1 - 5.40E-6 \times 5.5} \\ &= 1.00003\end{aligned}$$

and

$$\begin{aligned}\delta_{C_{PL}} &= \pm \left\{ (C_{PL} F_p)^2 \left[P^2 \left(\frac{\delta_{F_p}}{F_p} \right)^2 + \delta_P^2 \right] \right\}^{\frac{1}{2}} C_{PL} \\ &= \pm \left\{ (1.00003 \times 5.40E-6)^2 \times \left[(5.5)^2 \times \left(\frac{351.2E-9}{5.40E-6} \right)^2 + (0.2)^2 \right] \right\}^{\frac{1}{2}} \times 1.00003 \\ &= \pm 0.00000\end{aligned}$$

and

$$\begin{aligned} C_{sw} &= \left(1 - \frac{SW \%}{100 \%}\right) \\ &= \left(1 - \frac{0.20 \%}{100 \%}\right) \\ &= 0.99800 \end{aligned}$$

and

$$\begin{aligned} \delta_{C_{sw}} &= \pm \frac{\delta_{sw}}{100 \%} \\ &= \pm \frac{0.02 \%}{100 \%} \\ &= \pm 0.00020 \end{aligned}$$

The GOV , GSV , and NSV calculations and associated uncertainty, δ_{GOV} , δ_{GSV} , and δ_{NSV} , are given by:

$$\begin{aligned} GOV &= abs(l_{close}LTT_{l_{close}} - l_{open}LTT_{l_{open}}) - l_{FW}LTT_{l_{FW}} \\ &= abs(10.010147 \times 20.00000 - 19.00000 \times 20.00000) - 0 \times 20.00000 \\ &= 177.92 \text{ bbl} \end{aligned}$$

and

$$\begin{aligned} GSV &= GOV C_{TL} C_{PL} \\ &= 177.42 \times 1.00619 \times 1.00003 \\ &= 179.02 \text{ bbl} \end{aligned}$$

and

$$\begin{aligned} NSV &= GSV C_{sw} \\ &= 179.02 \times 0.99800 \\ &= 178.66 \text{ bbl} \end{aligned}$$

The uncertainty is calculated as follows:

$$\begin{aligned} \delta_{GOV} &= \pm \left[l_{close}^2 \delta_{LTT_{l_{close}}}^2 + \delta_{l_{close}}^2 LTT_{l_{close}}^2 + l_{open}^2 \delta_{LTT_{l_{open}}}^2 + \delta_{l_{open}}^2 LTT_{l_{open}}^2 + l_{fw}^2 \delta_{LTT_{l_{fw}}}^2 \right]^{\frac{1}{2}} GOV \\ &= \pm [(10.010147 \times 0.010417)^2 + (0.010417 \times 20.00000)^2 + (19.00000 \times 0.010417)^2 + (0.010417 \times 20.00000)^2]^{\frac{1}{2}} \times 177.92 \\ &= \pm 0.42 \text{ bbl} \end{aligned}$$

and

$$\begin{aligned}\delta_{GSV} &= \pm \left[\left(\frac{\delta_{GOV}}{GOV} \right)^2 + \left(\frac{\delta_{CTL}}{CTL} \right)^2 + \left(\frac{\delta_{CPL}}{CPL} \right)^2 \right]^{1/2} GSV \\ &= \pm \left[\left(\frac{0.42}{177.92} \right)^2 + \left(\frac{0.00033}{1.00619} \right)^2 + \left(\frac{0.00000}{1.00003} \right)^2 \right]^{1/2} \times 179.02 \\ &= \pm 0.43 \text{ bbl}\end{aligned}$$

and

$$\begin{aligned}\delta_{NSV} &= \pm \left[\left(\frac{\delta_{CSW}}{CSW} \right)^2 + \left(\frac{\delta_{GOV}}{GOV} \right)^2 + \left(\frac{\delta_{CTL}}{CTL} \right)^2 + \left(\frac{\delta_{CPL}}{CPL} \right)^2 \right]^{1/2} NSV \\ &= \pm \left[\left(\frac{0.00020}{0.99800} \right)^2 + \left(\frac{0.42}{177.92} \right)^2 + \left(\frac{0.00033}{1.00619} \right)^2 + \left(\frac{0.00000}{1.00003} \right)^2 \right]^{1/2} \times 178.66 \\ &= \pm 0.43 \text{ bbl}\end{aligned}$$

Note that:

$$\begin{aligned}NSV \text{ uncertainty } \% &= \frac{\delta_{NSV}}{NSV} \times 100 \% \\ &= \frac{\pm 0.43}{178.66} \times 100 \% \\ &= \pm 0.24 \%\end{aligned}$$

The tank in this example was a 20.0 foot to reference 400 bbl tank with a strapping table in quarter-inches. The linearized value for the tank table used in the example is 1.66 bbl/in.

EXAMPLE 2—Dynamic Measurement A truck was loaded from a lease tank containing 320 bbl of oil. The truck was capable of holding 180 bbl, and the tank was isolated for delivery. The truck was equipped with a Coriolis meter for volumetric measurements (API *MPMS* Chapter 5.6 and Chapter 12). No free water was detected. A small automatic flow proportional sampler (API *MPMS* Chapter 8.2) was mounted on the truck with temperature and temperature averaging devices in the truck zone. The opening meter indicated that volume was 106,474.26 bbl, and the closing meter indicated that volume was 106,650.92 bbl. The average temperature was 82.5 °F, and the average pressure was 44.2 psig. The S&W was determined using the centrifuge field method (API *MPMS* Chapter 10.4) to be 0.20 %, and the gravity was determined to be 48.5° API corrected to 60 °F using a hydrometer (API *MPMS* Chapter 9.1). The CTL and CPL from API *MPMS* Chapter 11.1^[3] were 0.98751 and 1.00030, respectively. The last meter factor from proving was 1.0013, and the meter factor tracking chart shows the meter factor uncertainty to be 0.0015.

$$GV = 176.89 \text{ bbl,}$$

$$GSV = 174.73 \text{ bbl,}$$

$$NSV = 178.38 \text{ bbl.}$$

The uncertainties in each of the measured and calculated variables can be summarized as follows:

Variable	Description	Units	As Measured	Uncertainty (+/-)
IV_{open}	Opening meter volume	bbl	106,474.26	0.01
IV_{close}	Closing meter volume	bbl	106,650.92	0.01
MF	Meter factor	—	1.0013	0.0015
T	Measured temperature	°F	82.5 °F	0.5 °F
P	Measured pressure	psig	44.2 psig	0.2 psig
API_{60}	API gravity at 60 °F	API °	48.5°	0.1°
$S\&W$	Measured S&W	% Volume	0.20 %	0.02 %
F_p	Liquid compressibility	psi ⁻¹	6.80×10^{-6}	442×10^{-9}
α_{60}	Liquid coefficient of thermal expansion	°F ⁻¹	553×10^{-6}	18×10^{-6}
NSV	Net standard volume	bbl	174.38 bbl	0.28 bbl

$$\begin{aligned}\rho_{60} &= \frac{141.5}{131.5 + API_{60}} \rho_{60,W} \\ &= \frac{141.5}{131.5 + 48.5} \times 999.012 \text{ kg/m}^3 \\ &= 785.33 \text{ kg/m}^3\end{aligned}$$

and

$$\begin{aligned}\delta\rho_{60} &= \frac{\delta API_{60}}{131.5 + API_{60}} \rho_{60} \\ &= \frac{0.1}{131.5 + 48.5} \times 785.33 \text{ kg/m}^3 \\ &= 0.44 \text{ kg/m}^3\end{aligned}$$

and

$$\begin{aligned}F_p &= \exp\left(A + BT + \frac{C+DT}{\rho_{60}^2}\right) \\ &= \exp\left(-1.9947 + 1.3427 \times 10^{-5} \times 82.5 + \frac{793,920 + 2326 \times 82.5}{(785.33)^2}\right) \times 10^{-5} \\ &= 6.80\text{E-}6 \text{ 1/psi}\end{aligned}$$

and

$$\begin{aligned}\delta_{F_p} &= \pm \left[(0.065)^2 + \left(B + \frac{D}{\rho_{60}^2} \right)^2 \delta_T^2 + 4 \left(\frac{C + DT}{\rho_{60}^2} \right)^2 \left(\frac{\delta_{API_{60}}}{131.5 + API_{60}} \right)^2 \right]^{\frac{1}{2}} F_p \\ &= \pm \left[(0.065)^2 + \left(1.3427E-4 + \frac{2326}{(785.33)^2} \right)^2 \times (0.5)^2 \right]^{\frac{1}{2}} \\ &\quad + 4 \times \left(\frac{793,920 + 2326 \times 82.5}{(785.33)^2} \right)^2 \times \left(\frac{0.1}{131.5 + 48.5} \right)^2 \right]^{\frac{1}{2}} \times 6.80E-6 \text{ 1/psi} \\ &= \pm 442.4E-9 \text{ 1/psi}\end{aligned}$$

and

$$\begin{aligned}\alpha_{60} &= \frac{K_0}{\rho_{60}^2} \\ &= \frac{341}{(785.33)^2} \\ &= 552.9E-6 \text{ 1/}^\circ\text{F}\end{aligned}$$

and

$$\begin{aligned}\delta_{\alpha_{60}} &= \pm \left[(0.033)^2 + 4 \left(\frac{\delta_{API_{60}}}{131.5 + API_{60}} \right)^2 \right]^{\frac{1}{2}} \alpha_{60} \\ &= \pm \left[(0.033)^2 + 4 \times \left(\frac{0.1}{131.5 + 48.5} \right)^2 \right]^{\frac{1}{2}} \times 552.9E-6 \text{ 1/}^\circ\text{F} \\ &= \pm 18.3E-6 \text{ 1/}^\circ\text{F}\end{aligned}$$

and

$$\begin{aligned}C_{TL} &= \exp\{-\alpha_{60} (T - 60)[1 + 0.8 \alpha_{60} (T - 60)]\} \\ &= \exp\{-552.9E-6 \times (82.5 - 60)[1 + 0.8 \times 552.9E-6 \times (82.5 - 60)]\} \\ &= 0.98751\end{aligned}$$

and

$$\begin{aligned}\delta_{C_{TL}} &= \pm \left\{ \left[\alpha_{60} (1 + 1.6 \alpha_{60} (T - T_{60})) \right]^2 \left[(T - T_{60})^2 \left(\frac{\delta_{\alpha_{60}}}{\alpha_{60}} \right)^2 + \delta_T^2 \right] \right\}^{\frac{1}{2}} C_{TL} \\ &= \pm \left\{ \left[552.9E-6 \times (1 + 1.6 \times 552.9E-6 \times (82.5 - 60)) \right]^2 \times \left[(82.5 - 60)^2 \times \left(\frac{18.3E-6}{552.9E-6} \right)^2 + (0.5)^2 \right] \right\}^{\frac{1}{2}} 0.98751 \\ &= \pm 0.00050\end{aligned}$$

and

$$\begin{aligned} C_{PL} &= \frac{1}{1-F_p P} \\ &= \frac{1}{1-6.80\text{E-}6 \times 44.2} \\ &= 1.00030 \end{aligned}$$

and

$$\begin{aligned} \delta_{C_{PL}} &= \pm \left\{ (C_{PL} F_p)^2 \left[P^2 \left(\frac{\delta_{F_p}}{F_p} \right)^2 + \delta_P^2 \right] \right\}^{\frac{1}{2}} C_{PL} \\ &= \pm \left\{ (1.00030 \times 6.80\text{E-}6)^2 \left[(44.2)^2 \left(\frac{442.4\text{E-}9}{6.80\text{E-}6} \right)^2 + (0.2)^2 \right] \right\}^{\frac{1}{2}} \times 1.00030 \\ &= \pm 0.00002 \end{aligned}$$

and

$$\begin{aligned} C_{sw} &= \left(1 - \frac{SW \%}{100 \%} \right) \\ &= \left(1 - \frac{0.20 \%}{100 \%} \right) \\ &= 0.99800 \end{aligned}$$

and

$$\begin{aligned} \delta_{C_{sw}} &= \pm \frac{\delta_{sw}}{100 \%} \\ &= \pm \frac{0.02 \%}{100 \%} \\ &= \pm 0.00020 \end{aligned}$$

The GV , G_{SV} , and NSV calculations and associated uncertainty, δ_{GV} , $\delta_{G_{SV}}$, and δ_{NSV} , are given by:

$$\begin{aligned} GV &= (IV_{close} - IV_{open}) MF \\ &= (106,650.92 - 106,474.26) \times 1.0013 \\ &= 176.89 \text{ bbl} \end{aligned}$$

and

$$\begin{aligned} GSV &= GV C_{TL} C_{PL} \\ &= 176.89 \times 0.98751 \times 1.00030 \\ &= 174.73 \text{ bbl} \end{aligned}$$

and

$$\begin{aligned} NSV &= GSV C_{SW} \\ &= 174.73 \times 0.99800 \\ &= 178.38 \text{ bbl} \end{aligned}$$

The uncertainty is calculated as follows:

$$\begin{aligned} \delta_{GV} &= \pm \left(MF^2 \delta_{IV_{close}}^2 + MF^2 \delta_{IV_{open}}^2 + (IV_{close} - IV_{open})^2 \delta_{MF}^2 \right)^{\frac{1}{2}} GV \\ &= \pm \left((1.0013 \times 0.01)^2 + (1.0013 \times 0.01)^2 + (106,650.92 - 106,474.26)^2 (0.0015)^2 \right)^{\frac{1}{2}} \times 176.89 \\ &= \pm 0.27 \text{ bbl} \end{aligned}$$

and

$$\begin{aligned} \delta_{GSV} &= \pm \left[\left(\frac{\delta_{GV}}{GV} \right)^2 + \left(\frac{\delta_{CTL}}{CTL} \right)^2 + \left(\frac{\delta_{CPL}}{CPL} \right)^2 \right]^{\frac{1}{2}} GSV \\ &= \pm \left[\left(\frac{0.27}{176.89} \right)^2 + \left(\frac{0.00050}{0.98751} \right)^2 + \left(\frac{0.00002}{1.00030} \right)^2 \right]^{\frac{1}{2}} 174.73 \\ &= \pm 0.28 \text{ bbl} \end{aligned}$$

and

$$\begin{aligned} \delta_{NSV} &= \pm \left[\left(\frac{\delta_{C_{SW}}}{C_{SW}} \right)^2 + \left(\frac{\delta_{GV}}{GV} \right)^2 + \left(\frac{\delta_{CTL}}{CTL} \right)^2 + \left(\frac{\delta_{CPL}}{CPL} \right)^2 \right]^{\frac{1}{2}} NSV \\ &= \pm \left[\left(\frac{0.00020}{0.99800} \right)^2 + \left(\frac{0.27}{176.89} \right)^2 + \left(\frac{0.00050}{0.98751} \right)^2 + \left(\frac{0.00002}{1.00030} \right)^2 \right]^{\frac{1}{2}} 174.38 \\ &= \pm 0.28 \text{ bbl} \end{aligned}$$

Note that:

$$\begin{aligned} \text{NSV uncertainty \%} &= \frac{\delta_{\text{NSV}}}{\text{NSV}} \times 100 \% \\ &= \frac{\pm 0.28}{174.38} \times 100 \% \\ &= \pm 0.16 \% \end{aligned}$$

14 Run Tickets and Tank Turndowns

14.1 Run Tickets or Measurement Tickets

A measurement ticket, often referred to as a “run ticket,” is a written, printed, or electronic document that is an acknowledgment of the receipt or transfer of petroleum or petroleum products. If a change in ownership or custody occurs during the transfer, the run ticket serves as documentation between the parties involved as to the measured quantities and tested qualities of the liquids transferred. The measurement ticket shall contain all of the observed field data required to calculate the NSV of liquid transferred. The run ticket shall also contain other information pertaining to the buyer, seller, and required regulatory information.

Although a detailed explanation of preparing run tickets is not included in this standard, the importance of accuracy shall be underscored. COTDs should record their gauge readings, tank temperatures, and quality test results on memo pads, and at the end of the measurement and testing activities, they should carefully transcribe the recorded data to the run tickets or electronic data entry device and double-check the data for completeness. Since manually written run tickets are multiple-copy forms, write with sufficient pressure to ensure that all copies are legible. See Section 12 for record keeping.

Manifests and run tickets should be prepared in accordance with all federal, state, local, and corporate rules, regulations, and policies.

14.2 Tank Turndowns

A turndown refers to the rejection of a tank’s contents on the basis of the COTD’s or gauger’s evaluation and analysis. When a tank is turned down for any reason, it is a common practice for the COTD to provide the reason for rejection, in writing, to the producer of the oil lease. This notification is usually done on a copy of a run ticket or a local form. It is also common practice for the producer to correct the situation and then to advise the COTD’s company that the turned-down oil is ready for pickup.

Tank turndowns have the potential to financially impact both the producer and the trucking company. A turndown may cause the producer to have to shut in a well due to a lack of tank storage space and can cause a financial burden on the trucking company to dispatch trucks to a lease without being able to load the oil. This impact can be reduced by proper monitoring and removal of free water from the oil storage tanks by the production operator.

Annex A
(informative)

Zone Matrices

Tank Zone Matrix			
Measured Determination	Available Equipment	Available Equipment	Available Equipment
Free water/clearance level/ merchantability			
Observed volume/calculated volume			
Product temperature			
Observed gravity and temperature			
Suspended S&W			

Transition Zone Matrix			
Measured Determination	Available Equipment	Available Equipment	Available Equipment
Free water/clearance level/ merchantability			
Indicated volume/calculated volume			
Product temperature			
Observed gravity and temperature			
Suspended S&W			

Trailer Zone Matrix			
Measured Determination	Available Equipment	Available Equipment	Available Equipment
Observed volume/calculated volume/ level measurement(s)			
Product temperature			

Annex B (normative)

Uncertainty Determination Development

This development assumes that the reference temperatures are 60 °F and 0 psig and that the correction from ITS-90 to ITS-68 used in API *MPMS* Chapter 11.1^[3] may be neglected. The uncertainty of the custody transfer volume or *NSV* is derived from the measurements made that comprise the volume calculation. From API *MPMS* Chapter 12, the measurements needed to calculate the *NSV* in sequence are as follows:

$$NSV = GOV C_{sw} C_{TPL}$$

$$C_{sw} = \left(1 - \frac{SW \%}{100 \%}\right)$$

where (from API *MPMS* Chapter 11.1^[3])

$$\begin{aligned} C_{TPL} &= f(T, P, API_{60}, \alpha, F_p) \\ &= C_{TL}(T, P, API_{60}, \alpha) \times C_{PL}(T, P, API_{60}, F_p) \end{aligned}$$

where

$$C_{TL} = \exp\{-\alpha (T - T_{60}) x [1 + 0.8 \alpha (T - T_{60} + \beta_{ref})]\}$$

$$C_{PL} = \frac{1}{1 - F_p P}$$

$$\begin{aligned} \alpha &= f(\text{commodity type}, \rho_{60}) \\ &= \frac{K_0}{\rho_{60}^2} \text{ for crudes} \quad K_0 = 341 \end{aligned}$$

$$F_p = \exp\left(A + BT + \frac{C + DT}{\rho_{60}^2}\right)$$

$$\rho_{60} = \frac{141.5}{131.5 + API_{60}} \times \rho_{60,W}$$

From the root-mean-squared “differential” representation for combined uncertainty, for a general complex function with n variables (API *MPMS* Chapter 13):

$$y = f(x_1, x_2, x_3, \dots, x_n)$$

With associated uncertainties, δ_i , for each variable:

$$\delta_y = f(\delta_{x_1}, \delta_{x_2}, \delta_{x_3}, \dots, \delta_{x_n})$$

the uncertainty in y can be written as follows:

$$\delta_y = \pm \sqrt{\left(\frac{\partial y}{\partial x_1} \delta_{x_1}\right)^2 + \left(\frac{\partial y}{\partial x_2} \delta_{x_2}\right)^2 + \left(\frac{\partial y}{\partial x_3} \delta_{x_3}\right)^2 + \dots + \left(\frac{\partial y}{\partial x_n} \delta_{x_n}\right)^2}$$

Following this procedure, the uncertainty of the G_{SV} and N_{SV} can be written as follows:

$$\frac{\delta_{G_{SV}}}{G_{SV}} = \pm \left[\left(\frac{\delta_{GOV}}{GOV}\right)^2 + \left(\frac{\delta_{CTL}}{CTL}\right)^2 + \left(\frac{\delta_{C_{PL}}}{C_{PL}}\right)^2 \right]^{\frac{1}{2}}$$

$$\frac{\delta_{N_{SV}}}{N_{SV}} = \pm \left[\left(\frac{\delta_{C_{sw}}}{C_{sw}}\right)^2 + \left(\frac{\delta_{GOV}}{GOV}\right)^2 + \left(\frac{\delta_{CTL}}{CTL}\right)^2 + \left(\frac{\delta_{C_{PL}}}{C_{PL}}\right)^2 \right]^{1/2}$$

The expression of $\delta_{C_{sw}}$ is determined from the uncertainty of the S&W measurement, δ_{sw} , and is given by the expression:

$$\delta_{C_{sw}} = \frac{\delta_{sw}}{100 \%}$$

The uncertainty of C_{TL} and C_{PL} depends on the uncertainty of API_{60} , T , and P , as well as the uncertainty associated with the correlations for α and F_p .

The correlation uncertainty for C_{TL} reported in API *MPMS* Chapter 11.1^[3] is equivalent to an α correlation uncertainty of 3.3 %. When combined with the uncertainty of the API_{60} , the combined uncertainty for a crude oil α is given by:

$$\left(\frac{\delta_{\alpha}}{\alpha}\right)^2 = (0.033)^2 + 4 \left(\frac{\delta_{API_{60}}}{131.5 + API_{60}}\right)^2$$

which when combined with the T uncertainty can be used to calculate the C_{TL} uncertainty as follows:

$$\left(\frac{\delta_{C_{TL}}}{C_{TL}}\right)^2 = [\alpha(1 + 1.6\alpha(T - T_{60}))]^2 \left[(T - T_{60})^2 \left(\frac{\delta_{\alpha}}{\alpha}\right)^2 + \delta_T^2 \right]$$

For most practical considerations, the α uncertainty is dominated by the correlational uncertainty, so the effects of the API_{60} uncertainty may be ignored when estimating the α uncertainty.

The correlation uncertainty for F_p reported in API *MPMS* Chapter 11.2.1^[4] is 6.5 %; when combined with the reported uncertainty of the API_{60} and T , results in the following expression for the uncertainty of F_p :

$$\left(\frac{\delta_{F_p}}{F_p}\right)^2 = (0.065)^2 + \left(B + \frac{D}{\rho_{60}^2}\right)^2 \delta_T^2 + 4 \left(\frac{C+DT}{\rho_{60}^2}\right)^2 \left(\frac{\delta_{API_{60}}}{131.5+API_{60}}\right)^2$$

For most practical considerations, the F_p uncertainty is dominated by the correlational uncertainty. Therefore, the effects of the uncertainty in API_{60} and T may be ignored when estimating the F_p uncertainty.

Applying this expression to the calculation of the uncertainty of the C_{PL} results in an uncertainty expression of:

$$\left(\frac{\delta_{C_{PL}}}{C_{PL}}\right)^2 = (C_{PL} F_p)^2 \left[P_{obs}^2 \left(\frac{\delta_{F_p}}{F_p}\right)^2 + \delta_{P_{obs}}^2 \right]$$

Static calculation—Typically, tank shell corrections and floating roof corrections do not apply to lease tanks or trucks. Therefore:

$$GOV = TOV - FW$$

where

$$TOV = \text{abs} \left(l_{\text{close}} LTT_{l_{\text{close}}} - l_{\text{open}} LTT_{l_{\text{open}}} \right)$$

and

$$FW = l_{FW} LTT_{l_{FW}}$$

for tank or truck zone measured volumes, where TOV is calculated from opening and closing gauge measurements l_i , with the application of a strapping table linearized in the region of the measurements $LTT_{l_{\text{open}}}$ and $LTT_{l_{\text{close}}}$. FW is only calculated from the gauge measurement l_{FW} with application of a strapping table linearized to the region of the measurement $LTT_{l_{FW}}$ in volume per lineal distance.

The overall uncertainty in the GOV for this case is given by:

$$\delta_{GOV}^2 = l_{\text{close}}^2 \delta_{LTT_{l_{\text{close}}}}^2 + \delta_{l_{\text{close}}}^2 LTT_{l_{\text{close}}} + l_{\text{open}}^2 \delta_{LTT_{l_{\text{open}}}}^2 + \delta_{l_{\text{open}}}^2 LTT_{l_{\text{open}}} + l_{FW}^2 \delta_{LTT_{l_{FW}}}^2$$

or

$$\delta_{GOV} = \pm \left[l_{\text{close}}^2 \delta_{LTT_{l_{\text{close}}}}^2 + \delta_{l_{\text{close}}}^2 LTT_{l_{\text{close}}} + l_{\text{open}}^2 \delta_{LTT_{l_{\text{open}}}}^2 + \delta_{l_{\text{open}}}^2 LTT_{l_{\text{open}}} + l_{FW}^2 \delta_{LTT_{l_{FW}}}^2 \right]^{\frac{1}{2}}$$

Dynamic calculation—For metered volumes:

$$\begin{aligned} GV &= IV \times MF \\ &= (IV_{\text{close}} - IV_{\text{open}}) MF \end{aligned}$$

where

IV_{open} and IV_{close} are the indicated meter readings at the opening and closing of the measured volume.

The overall uncertainty in the GV for this case is given by:

$$\delta_{GV}^2 = MF^2 \delta_{IV_{\text{close}}}^2 + MF^2 \delta_{IV_{\text{open}}}^2 + (IV_{\text{close}} - IV_{\text{open}})^2 \delta_{MF}^2$$

or

$$\delta_{GV} = \pm \left(MF^2 \delta_{IV_{\text{close}}}^2 + MF^2 \delta_{IV_{\text{open}}}^2 + (IV_{\text{close}} - IV_{\text{open}})^2 \delta_{MF}^2 \right)^{\frac{1}{2}}$$

Since gross volume, or GV nomenclature for dynamic systems, is used, substitute GV for GOV in the uncertainty development above to find δ_{GSV} and δ_{NSV} .

Bibliography

- [1] API MPMS Chapter 4.5, *Master Meter Provers*
- [2] API MPMS Chapter 4.9.2, *Determination of the Volume of Displacement and Tank Provers by the Waterdraw Method of Calibration*
- [3] API MPMS Chapter 11.1–2004, *Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils*, including Addendum 1, 2007
- [4] API MPMS Chapter 11.2.1–1984, *Compressibility Factors for Hydrocarbons: 0–90° API Gravity Range*
- [5] API MPMS Chapter 13, *Statistical Aspects of Measuring and Sampling*
- [6] API Standard 2555, *Method for Liquid Calibration of Tanks*

Committee Use Only

ce Only



AMERICAN PETROLEUM INSTITUTE

1220 L Street, NW
Washington, DC 20005-4070
USA

202-682-8000

Additional copies are available online at www.api.org/pubs

Phone Orders: 1-800-854-7179 (Toll-free in the U.S. and Canada)
303-397-7956 (Local and International)
Fax Orders: 303-397-2740

Information about API publications, programs and services is available on the web at www.api.org.

Product No. H180201