Manual of Petroleum Measurement Standards Chapter 5—Metering

Section 2—Measurement of Liquid Hydrocarbons by Displacement Meters

THIRD EDITION, SEPTEMBER 2005

REAFFIRMED, SEPTEMBER 2010

energy API®

AMERICAN PETROLEUM INSTITUTE

Manual of Petroleum Measurement Standards Chapter 5—Metering

Section 2—Measurement of Liquid Hydrocarbons by Displacement Meters

Measurement Coordination

THIRD EDITION, SEPTEMBER 2005

REAFFIRMED, SEPTEMBER 2010

energy API®

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 assure 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.

FOREWORD

Chapter 5 of the API Manual of Petroleum Measurement Standards (API *MPMS*) provides recommendations, based on best industry practice, for the custody transfer metering of liquid hydrocarbons. The various sections of this Chapter are intended to be used in conjunction with API *MPMS* Chapter 6 to provide design criteria for custody transfer metering encountered in most aircraft, marine, pipeline, and terminal applications. The information contained in this chapter may also be applied to non-custody transfer metering.

The chapter deals with the principal types of meters currently in use: displacement meters, turbine meters and Coriolis meters. If other types of meters gain wide acceptance for the measurement of liquid hydrocarbon custody transfers, they will be included in subsequent sections of this chapter.

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.

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, N.W., Washington, D.C. 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 and updated quarterly by API, 1220 L Street, N.W., Washington, D.C. 20005.

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

CONTENTS

Manual of Petroleum Measurement Standards

Chapter 5—Metering

Section 2—Measurement of Liquid Hydrocarbons by Displacement Meters

5.2.1 Introduction

API *MPMS* Chapter 5.2, together with the general considerations for measurement by meters found in API *MPMS* Chapter 5.1, describes methods for obtaining accurate quantity measurement with displacement meters in liquid hydrocarbon service.

A displacement meter is a volume measuring device which separates a flowing liquid stream into discrete volumes and counts the separated volumes. The meter carries through its measuring element a theoretical swept volume of liquid, plus the slippage for each stroke, revolution, or cycle of the moving parts. The indicated volume of the displacement meter must be compared with a known volume that has been determined by proving, as discussed in *MPMS* Chapter 4.

It is recognized that meters other than the types described in this chapter are used to meter liquid hydrocarbons. This publication does not endorse or advocate the preferential use of displacement meters, nor does it intend to restrict the development of other types of meters.

5.2.2 Scope

This section of API *MPMS* Chapter 5 covers the unique performance characteristics of displacement meters in liquid hydrocarbon service

5.2.3 Field of Application

The field of application of this section is all segments of the petroleum industry in which dynamic measurement of liquid hydrocarbons is required. This section does not apply to the measurement of two-phase fluids.

5.2.4 Referenced Publications

The current editions of the following API *MPMS* Standards contain information applicable to this chapter:

API *Manual of Petroleum Measurement Standards*

Chapter 4	"Proving Systems"
Chapter 4.2	"Pipe Provers"
Chapter 5.1	"General Considerations for Measurement by Meters"
Chapter 5.4	"Accessory Equipment for Liquid Meters"
Chapter 7	"Temperature"
Chapter 8	"Sampling"
Chapter 11.1	"Volume Correction Factors" (ASTM1 D 1250, ISO2 91.1)
Chapter 12	"Calculation of Petroleum Quantities"
Chapter 13	"Statistical Aspects of Measuring and Sampling"

5.2.5 Meter Performance

Meter performance is defined by how well a metering system produces, or can be made to produce, accurate measurements. See 5.1 for additional details.

5.2.5.1 METER READOUT ADJUSTMENT METHODS

Either of two methods of meter readout adjustment may be used, depending on the meter's intended application and anticipated operating conditions.

5.2.5.1.1 Direct Volume Readout Method

With the first method the readout is adjusted until the change in meter reading during a proving equals or nearly equals the volume measured in the prover. It is then sealed to provide security against unauthorized adjustment. Adjusted meters are most frequently used on retail delivery trucks and on truck and rail-car loading racks, where it is desirable to have a direct quantity readout without having to apply mathematical corrections. An adjusted or direct-reading meter is correct only for the liquid and flow conditions at which it was proved.

5.2.5.1.2 Meter Factor Method

With the second method of meter readout adjustment, the meter readout is not adjusted, and a meter factor is calculated. The meter factor is a number obtained by dividing the actual volume of liquid passed through the meter during proving by the volume indicated by the meter. For subsequent metering operations, the actual throughput or measured volume is determined by multiplying the volume indicated by the meter by the meter factor (see Chapter 4 and Chapter 12.2).

When direct quantity readout is not required, the use of a meter factor is preferred for several reasons:

a. It is difficult or impossible to adjust a meter calibrator mechanism to register with the same resolution that is achieved when a meter factor is determined.

b. Adjustment generally requires one or more reprovings to confirm the accuracy of the adjustment.

c. In applications where the meter is to be used with several different liquids or under several different sets of operating conditions, a different meter factor can be determined for each liquid and for each set of operating conditions.

For most pipelines, terminals, and marine loading and unloading facilities, meters are initially adjusted to be correct at average conditions, and the mechanisms are sealed at that setting. Meter factors are then determined for each petroleum liquid and for each set of operating conditions at which the meters are used. This method provides flexibility and maintains maximum accuracy.

5.2.5.2 CAUSES OF VARIATIONS IN METER FACTOR

There are many factors which can change the performance of a displacement meter. Some factors, such as the entrance of foreign matter into the meter, can be remedied only by eliminating the cause of the problem. Other factors depend on the properties of the liquid being measured; these must be overcome by properly designing and operating the metering system.

The variables which have the greatest effect on the meter factor are flow rate, viscosity, temperature, and foreign matter (for example, paraffin in the liquid). If a meter is proved and operated on liquids with inherently identical properties, under the same conditions as in service, the highest level of accuracy may be expected. If there are changes in one or more of the liquid properties or in the operating conditions between the proving and the operating cycles, then a change in meter factor may result, and a new meter factor must be determined.

5.2.5.2.1 Flow Rate Changes

Meter factor varies with flow rate. At the lower end of the range of flow rates, the meter-factor curve may become less reliable and less consistent than it is at the middle and higher rates. If a plot of meter factor versus flow rate has been developed for a given set of operating conditions, it is possible to select a meter factor from the curve; however, if a proving system is permanently installed, it is preferable to reprove the meter and apply the value determined by the reproving. If a change in total flow rate occurs in a bank of two, three, or more displacement meters installed in parallel, the usual procedure is to avoid overranging or underranging an individual meter by varying the number of meters in use, thereby distributing the total flow among a suitable number of parallel displacement meters.

5.2.5.2.2 Viscosity Changes

The meter factor of a displacement meter is affected by changes in viscosity which results in variable “slippage”. Slippage is a term used to describe the small flow rate through the meter clearances which bypasses the measuring chamber. The meter factor accounts for the rate of slippage only if the slippage rate is constant. Viscosity may vary as a result of changes in the liquids to be measured or as a result of changes in temperature that occur without any change in the liquid. It is therefore important to take into account the parameters that have changed before a meter factor is selected from a plot of meter factor versus viscosity. It is preferable to reprove the meter if the liquid changes or if a significant viscosity change occurs.

5.2.5.2.3 Temperature Changes

In addition to affecting the viscosity of the liquid, changes in the temperature of the liquid have other important effects on meter performance, as reflected in the meter factor. For example, the volume displaced by a cycle of movements of the measuring chambers is affected by temperature. The mechanical clearances of the displacement meter may also be affected by temperature. Higher temperatures may partially vaporize the liquid, causing two-phase flow, which will severely impair measurement performance.

Either an automatic temperature compensator, or a calculated temperature correction based on the volume weighted average temperature of the delivery, may be used to correct indicated volume to a volume at a base or reference temperature.

5.2.5.2.4 Pressure Changes

If the pressure of a liquid when it is metered varies from the pressure that existed during proving, the relative volume of the liquid will change as a result of its compressibility. The potential for error increases in proportion to the magnitude of the difference between the proving and operating conditions. For greatest accuracy, the meter should be proved at the operating conditions (see Chapter 4 and Chapter 12).

The physical dimensions of the meter measuring chamber will also vary as a result of changes in the expansion of its housing with varying pressures. The use of double-case meters prevents this from occurring.

Volumetric corrections for pressure effects on liquids that have vapor pressures above atmospheric pressure are referenced to the equilibrium vapor pressure of the liquid at a standard temperature, 60°F, 15°C, or 20°C, rather than to atmospheric pressure, which is the typical reference for liquids with measurement-temperature vapor pressures below atmospheric pressure. Both the volume of the liquid in the prover and the indicated metered volume are corrected from the measurement pressure to the equivalent volumes at the equilibrium vapor pressure at 60°F, 15°C, or 20°C. This is a two-step calculation which involves correcting both measurement volumes to the equivalent volumes at equilibrium vapor pressure at the measurement temperature. The volumes are then corrected to the equivalent volumes at the equilibrium vapor pressure at 60°F, 15°C, or 20°C. A detailed discussion of this calculation is included in Chapter 12.2.

5.2.5.2.5 Cleanliness and Lubricating Qualities of the Liquid

The bearing surfaces in displacement meters are normally lubricated by the flowing liquid. When the flowing liquid is heavily laden with abrasive material (e.g., sandy crude oil), and/or has poor lubricating properties (e.g., natural gas liquids), conventional displacement meters will wear rapidly, often resulting in frequent meter factor changes and frequent meter repair.

5.2.5.2.6 Deposits/Coatings

Coatings deposited on the internal surfaces of a displacement meter from paraffin, etc., in the hydrocarbon, can change the meter factor in two ways. First, a deposited coating can reduce the meter clearances, thereby reducing “slippage” through the clearances. Second, a coating on the surfaces forming the measuring chamber will reduce its volume, which reduces the meter’s “volume per revolution”. On most displacement meters the thickness of this coating is limited, as all of the surfaces of the measuring chamber are wiped during operation. Both of these effects reduce the meter factor of the displacement meter.

5.2.5.2.7 Torque Load Changes

When the torque load required to rotate the meter and its meter mounted accessories changes significantly the meter factor may be affected. Increasing torque load increases the pressure differential across the meter and its meter clearances, which may increase “slippage” through the clearances. This would increase the meter factor.

5.2.5.2.8 Meter Back Pressure

There is a possible need for back pressure control to prevent liquid flashing before or at the meter. For example, this can occur on meter runs where the only back pressure is tank head. When the tank level is very low, there may be insufficient back pressure at the meter to prevent liquid flashing.

API®

American Petroleum Institute

2005 Publications Order Form

Effective January 1, 2005.
API Members receive a 30% discount where applicable.
The member discount does not apply to purchases made for the purpose of resale or for incorporation into commercial products, training courses, workshops, or other commercial enterprises.

Available through Global Engineering Documents:
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**
Online Orders: **www.global.ihs.com**

Date: ____________________

❑ **API Member** (Check if Yes)

Invoice To (❑ Check here if same as "Ship To")

Name:
Title:
Company:
Department:
Address:

City: State/Province:
Zip/Postal Code: Country:
Telephone:
Fax:
E-Mail:

Ship To (UPS will not deliver to a P.O. Box)

Name:
Title:
Company:
Department:
Address:

City: State/Province:
Zip/Postal Code: Country:
Telephone:
Fax:
E-Mail:

Quantity	Product Number	Title	SO★	Unit Price	Total
	H05014	MPMS 5.1, General Considerations for Measurement by Meters		$75.00	
	H05035	MPMS 5.3, Measurement of Liquid Hydrocarbons by Turbine Meters		$85.00	
	H05044	MPMS 5.4, Accessory Equipment for Liquid Meters		$75.00	

❑ **Payment Enclosed** ❑ **P.O. No.** (Enclose Copy) ____________

❑ **Charge My Global Account No.** ____________

❑ **VISA** ❑ **MasterCard** ❑ **American Express** ❑ **Diners Club** ❑ **Discover**

Credit Card No.:
Print Name (As It Appears on Card):
Expiration Date:
Signature:

Subtotal	
Applicable Sales Tax *(see below)*	
Rush Shipping Fee *(see below)*	
Shipping and Handling *(see below)*	
Total *(in U.S. Dollars)*	

★ ***To be placed on Standing Order for future editions of this publication, place a check mark in the SO column and sign here:***

Pricing and availability subject to change without notice.

Mail Orders – Payment by check or money order in U.S. dollars is required except for established accounts. State and local taxes, $10 processing fee*, and 5% shipping must be added. Send mail orders to: **API Publications, Global Engineering Documents, 15 Inverness Way East, M/S C303B, Englewood, CO 80112-5776, USA.**
Purchase Orders – Purchase orders are accepted from established accounts. Invoice will include actual freight cost, a $10 processing fee*, plus state and local taxes.
Telephone Orders – If ordering by telephone, a $10 processing fee* and actual freight costs will be added to the order.
Sales Tax – All U.S. purchases must include applicable state and local sales tax. Customers claiming tax-exempt status must provide Global with a copy of their exemption certificate.
Shipping (U.S. Orders) – Orders shipped within the U.S. are sent via traceable means. Most orders are shipped the same day. Subscription updates are sent by First-Class Mail. Other options, including next-day service, air service, and fax transmission are available at additional cost. Call 1-800-854-7179 for more information.
Shipping (International Orders) – Standard international shipping is by air express courier service. Subscription updates are sent by World Mail. Normal delivery is 3-4 days from shipping date.
Rush Shipping Fee – Next Day Delivery orders charge is $20 in addition to the carrier charges. Next Day Delivery orders must be placed by 2:00 p.m. MST to ensure overnight delivery.
Returns – All returns must be pre-approved by calling Global's Customer Service Department at 1-800-624-3974 for information and assistance. There may be a 15% restocking fee. Special order items, electronic documents, and age-dated materials are non-returnable.
***Minimum Order –** There is a $50 minimum for all orders containing hardcopy documents. The $50 minimum applies to the order subtotal including the $10 processing fee, excluding any applicable taxes and freight charges. If the total cost of the documents on the order plus the $10 processing fee is less than $50, the processing fee will be increased to bring the order amount up to the $50 minimum. This processing fee will be applied before any applicable deposit account, quantity or member discounts have been applied. There is no minimum for orders containing only electronically delivered documents.

Additional copies are available through Global Engineering Documents at (800) 854-7179 or (303) 397-7956

Information about API Publications, Programs and Services is available on the World Wide Web at: http://www.api.org

API
American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005-4070
202-682-8000

Product No. H05023