Manual of Petroleum Measurement Standards
Chapter 5—Metering

Section 2—Measurement of Liquid Hydrocarbons by Displacement Meters

THIRD EDITION, SEPTEMBER 2005

REAFFIRMED, SEPTEMBER 2010

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AMERICAN PETROLEUM INSTITUTE

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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.

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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.

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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.

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