Manual of Petroleum Measurement Standards Chapter 4—Proving Systems

Section 2—Displacement Provers

THIRD EDITION, SEPTEMBER 2003

ADDENDUM, FEBRUARY 2015

REAFFIRMED, DECEMBER 2022

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.

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 under local, state, or federal laws.

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.

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.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. Sometimes a one-time extension of up to two years will be added to this review cycle. This publication will no longer be in effect five years after its publication date as an operative API standard or, where an extension has been granted, upon republication. Status of the publication can be ascertained from the API Standards department telephone (202) 682-8000. A catalog of API publications, programs and services is published annually and updated biannually by API, and available through Global Engineering Documents, 15 Inverness Way East, M/S C303B, Englewood, CO 80112-5776.

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 standard or comments and questions concerning the procedures under which this standard was developed should be directed in writing to the Director of the Standards department, American Petroleum Institute, 200 Massachusetts Avenue, NW, Washington, DC 20001. Requests for permission to reproduce or translate all or any part of the material published herein should be addressed to the Director, Business Services.

API standards are published to facilitate the broad availability of proven, sound engineering and operating practices. These standards are not intended to obviate the need for applying sound engineering judgment regarding when and where these standards should be utilized. The formulation and publication of API standards 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 4 of the *Manual of Petroleum Measurement Standards* was prepared as a guide for the design, installation, calibration, and operation of meter proving systems used by the majority of petroleum operators. The devices and practices covered in this chapter may not be applicable to all liquid hydrocarbons under all operating conditions. Other types of proving devices that are not covered in this chapter may be appropriate for use if agreed upon by the parties involved.

The information contained in this edition of Chapter 4 supersedes the information contained in the previous edition (First Edition, May 1978), which is no longer in print. It also supersedes the information on proving systems contained in API Standard 1101 *Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter* (First Edition, 1960); API Standard 2531 *Mechanical Displacement Meter Provers*; API Standard 2533 *Metering Viscous Hydrocarbons*; and API Standard 2534 *Measurement of Liquid Hydrocarbons by Turbine-meter Systems*, which are no longer in print.

This publication is primarily intended for use in the United States and is related to the standards, specifications, and procedures of the National Institute of Standards and Technology (NIST). When the information provided herein is used in other countries, the specifications and procedures of the appropriate national standards organizations may apply. Where appropriate, other test codes and procedures for checking pressure and electrical equipment may be used.

For the purposes of business transactions, limits on error or measurement tolerance are usually set by law, regulation, or mutual agreement between contracting parties. This publication is not intended to set tolerances for such purposes; it is intended only to describe methods by which acceptable approaches to any desired accuracy can be achieved.

Chapter 4 now contains the following sections:

Section 1, "Introduction"
Section 2, "Displacement Provers"
Section 4, "Tank Provers"
Section 5, "Master-meter Provers"
Section 6, "Pulse Interpolation"
Section 7, "Field-standard Test Measures"
Section 8, "Operation of Proving Systems"
Section 9, "Calibration of Provers"

Suggested revisions are invited and should be submitted to API, Standards department, 200 Massachusetts Avenue, NW, Washington, DC 20001.

CONTENTS

Page

Figures

Tables

Chapter 4—Proving Systems

Section 2—Displacement Provers

1 Introduction

This document, including figures, graphs and appendices addresses displacement provers. It includes provers that were commonly referred to as either "conventional" pipe provers or "small volume" provers. "Conventional" pipe provers were those with sufficient volume to accumulate a minimum of 10,000 whole meter pulses between detector switches for each pass of the displacer. "Small volume" provers were those with insufficient volume to accumulate a minimum of 10,000 whole meter pulses between detector switches for each pass of the displacer.

Displacement provers may be straight or folded in the form of a loop. Both mobile and stationary provers may be constructed in accordance with the principles described in this chapter. Displacement provers are also used for pipelines in which a calibrated portion of the pipeline (straight, U-shaped, or folded) serves as the reference volume. Some provers are arranged so that liquid can be displaced in either direction.

When using a displacement prover the flow of liquid is not interrupted during proving. This uninterrupted flow permits the meter to be proved under specific operating conditions and at a uniform rate of flow without having to start and stop.

The reference volume (the volume between detectors) required of a displacement prover depends on such factors as the discrimination of the proving counter, the repeatability of the detectors, and the repeatability required of the proving system as a whole. At least 10,000 whole meter pulses are required for Meter Factors (*MF*s) derived to a resolution of 0.0001. The relationship between the flow range of the meter and the reference volume must also be taken into account. For provers that do not accumulate a minimum of 10,000 whole meter pulses between detectors for each pass of the displacer, meter pulse discrimination using pulse interpolation techniques is required (see API *MPMS* Chapter 4.6).

1.1 SCOPE

This chapter outlines the essential elements of provers that do, and also do not, accumulate a minimum of 10,000 whole meter pulses between detector switches, and provides design and installation details for the types of displacement provers that are currently in use. The provers discussed in this chapter are designed for proving measurement devices under dynamic operating conditions with single-phase liquid hydrocarbons. These provers consist of a pipe section through which a displacer travels and activates detection devices before stopping at the end of the run as the stream is diverted or bypassed.

1.2 DISPLACEMENT PROVER SYSTEMS

All types of displacement prover systems operate on the principle of the repeatable displacement of a known volume of liquid from a calibrated section of pipe between two detectors. Displacement of the volume of liquid is achieved by an oversized sphere or a piston traveling through the pipe. A corresponding volume of liquid is simultaneously measured by a meter installed in series with the prover.

A meter that is being proved on a continuous-flow basis must be connected at the time of proof to a proving counter. The counter is started and stopped when the displacing device actuates the two detectors at the ends of the calibrated section.

The two types of continuous-flow displacement provers are unidirectional and bidirectional. The unidirectional prover allows the displacer to travel in only one direction through the proving section and has an arrangement for returning the displacer to its starting position. The bidirectional prover allows the displacer to travel first in one direction and then in the other by reversing the flow through the displacement prover.

Both unidirectional and bidirectional provers must be constructed so that the full flow of the stream through a meter being proved will pass through the prover. Displacement provers may be manually or automatically operated.

1.3 DEFINITION OF TERMS

Terms used in this chapter are defined below.

A **prover pass** is one movement of the displacer between the detectors in a prover.

A **prover round trip** refers to the forward and reverse passes in a bidirectional prover.

A **prover run** is equivalent to a prover pass in a unidirectional prover, a round trip in a bidirectional prover, or a group of multiple passes.

A **meter proof** refers to the multiple prover runs for purposes of determining a *MF*.

Interpulse deviations refer to random variations between meter pulses when the meter is operated at a constant flow rate.

Interpulse spacing refers to the meter pulse width or space when the meter is operated at a constant flow rate.

Pulse rate modulation refers to a consistent variation in meter pulse spacing when the meter is operated at a constant flow rate.

Pulse stability (P_S) refers to the variations of time between meter pulses.

A **proving counter** is a device that counts the pulses from the meter during a proving run.