Manual of Petroleum Measurement Standards Chapter 4—Proving Systems

Section 9—Methods of Calibration for Displacement and Volumetric Tank Provers

Part 2—Determination of the Volume of Displacement and Tank Provers by the Waterdraw Method of Calibration

FIRST EDITION, DECEMBER 2005

REAFFIRMED, SEPTEMBER 2025

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.

All rights reserved. No part of this work may be reproduced, 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, 200 Massachusetts Avenue, NW, Washington, DC 20001.

Copyright © 2005 American Petroleum Institute

FOREWORD

This multi-part publication consolidates and standardizes calibration procedures for displacement and volumetric tank provers used in the metering of petroleum liquids. It provides essential information on the operations involved in obtaining a valid, accurate and acceptable prover volume by different calibration methods. Units of measure in this publication are in the International System (SI) and United States Customary (USC) units consistent with North American industry practices. Part 1 is the introduction and contains those aspects that are generic to the various methods of calibration, including waterdraw (WD), master meter (MM) and gravimetric (GM). Each subsequent part is intended to be used in conjunction with Part 1 for the particular calibration procedure described. This section consists of the following four parts:

Part 1 – "Introduction to the Determination of the Volume of Displacement and Tank Provers"

Part 2 – "Determination of the Volume of Displacement and Tank Provers by the Waterdraw Method of Calibration"

Part 3 – "Determination of the Volume of Displacement Provers by the Master Meter Method of Calibration"

Part 4 – "Determination of the Volume of Displacement Provers by the Gravimetric Method of Calibration"

This standard was developed through the cooperative efforts of many individuals from the petroleum industry, under the sponsorship of the American Petroleum Institute.

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, 200 Massachusetts Avenue, NW, Washington, DC 20001. 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, 200 Massachusetts Avenue, NW, Washington, DC 20001.

Suggested revisions are invited and should be submitted to the Standards and Publications Department, API, 200 Massachusetts Avenue, NW, Washington, DC 20001, standards@api.org.

CONTENTS

Page

1.0 INTRODUCTION 1
1.1 U.S. Customary And Metric (Si) Units 1
1.2 National Weights and Measures Agencies 1
1.3 Safety Considerations 1

2.0 SCOPE 1

3.0 REFERENCE PUBLICATIONS 1

4.0 TERMS AND APPLICATIONS 2
4.1 TERMS 2
4.2 APPLICATIONS 2

5.0 PROVER CLEANING AND PREPARATION 3
5.1 Isolation of the Prover 3
5.2 Initial Prover Preparation 3
5.3 Purging and Cleaning of the Prover 4
5.4 Sphere Displacer Inspection, Sizing and Preparation 4
5.5 Water Filling, Venting and Circulation of Pipe Provers 7

6.0 PRELIMINARY AND GENERAL CALIBRATION PROCEDURES 7
6.1 General Calibration Discussion 7
6.2 Displacement Type Unidirectional Provers with Free Displacers 18
6.3 Displacement Type Bi-directional Provers with Free Displacers 19
6.4 Displacement Type Meter Provers with Captive Displacers 21
6.5 Atmospheric Tank Provers 22

7.0 CALIBRATION PROCEDURES BY TYPE OF PROVER 26
7.1 Calibration Preparation 26
7.2 Displacement Type Unidirectional Provers with Free Displacers 27
7.3 Displacement Type Bi-directional Provers with Free Displacers 28
7.4 Displacement Type Meter Provers with Captive Displacers 30
7.5 Atmospheric Tank Provers 32

8.0 TROUBLESHOOTING CALIBRATION PROBLEMS 35
8.1 Evaluation of Calibration Results 35
8.2 Leaks 36
8.3 Prover Detector Switches 36
8.4 Sphere Interchanges 36
8.5 Four-Way Valves 36
8.6 Displacers 37
8.7 Drains and Vents 38
8.8 Temperature and Pressure 38
8.9 Pumps, Hoses and Connections 39
8.10 Detector Switches, Solenoids and Logic Circuits 39
8.11 Field Standard Test Measures 39
8.12 Piping and Manifolds 39
8.13 Water Quality 40

CONTENTS

Page

8.14 Air and Entrained Gas 40
8.15 Prover Conditions and Coatings. 40

APPENDIX A (INFORMATIVE) UNCERTAINTIES IN METER PROVER CALIBRATIONS 41
APPENDIX B (NORMATIVE) EFFECTS OF TEMPERATURE CHANGES ON THE INTERFACE INVENTORY. 49
APPENDIX C (INFORMATIVE) EXAMPLES OF WATERDRAW DATA SHEETS . 53
APPENDIX D (INFORMATIVE) FIELD STANDARD TEST MEASURES 75

Figures

A.1 Uncertainty Analysis: Detector Switch Actuation Point with Respect to the Forward Movement of the Prover Sphere 42
1 Schematic Drawing of a Typical Layout for a Waterdraw Calibration of a Displacement Type Unidirectional Prover with a Free Displacer using Top-filling Test Measures 83
2A Schematic Drawing of a Typical Layout for a Waterdraw Calibration of a Displacement Type Bi-directional Prover with a Free Piston Displacer and Check Valves in the Manifold using Top-filling Test Measures. . . 84
2B Schematic Drawing of a Typical Layout for a Waterdraw Calibration of a Displacement Type Bi-directional Prover with a Free Sphere Displacer using Top-filling Test Measures. 85
3A Schematic Drawing of a Typical Layout for a Waterdraw Calibration of the Downstream Volume of a Displacement Prover with a Captive Displacer and External Detectors using Top-filling Test Measures. 86
3B Schematic Drawing of a Typical Layout for a Waterdraw Calibration of the Upstream Volume of a Displacement Prover with a Captive Displacer and External Detectors using Top-filling Test Measures. 87
3C Schematic Drawing of a Typical Layout for a Waterdraw Calibration of a Displacement Prover with Equal Size Diameter Shafts on Both Sides of a Captive Displacer and External Detectors using Top-filling Test Measures . 88
4A Schematic Drawing of a Typical Layout for a Waterdraw Calibration of a Volumetric Tank Prover with a Bottom Weir using Top-filling Test Measures . . 89
4B Schematic Drawing of a Typical Layout for a Waterdraw Calibration of a Volumetric Tank Prover with a Dry Bottom using the Water-fill Method and using Top-filling Test Measures. 90
4C Schematic Drawing of a Typical Layout for a Waterdraw Calibration of a Volumetric Tank Prover with a Wet Bottom using Top-filling Test Measures . . . 91
5 Alternate Method—Schematic Drawing of a Typical Layout for a Waterdraw Calibration of a Proving System using Bottom-filling Test Measures 92

CONTENTS

Page

Tables

1 Sphere Ovality Verification 5
2 Sphere Sealing Width Relationships. 7
A-1 Detector Switch, Sphere and Pipe Diameter Uncertainty 44
A-2 Uncertainty Due to Test Measure Combination 45
A-3 Estimated Uncertainty of Prover Calibration Runs (at the 95% confidence level) 46
A-4 Assumed Values from A.1, A.2 and A.3 for illustration purposes only 47
B-1 Temperature Difference in Interface Inventory 49
B-2 50
D-1 Test Measure Discharge Times Based on Volume and Drain Size 76
D-2 Normal and High Sensitivity Test Measures Interpolation of Volumes between the Lowest Scale Lines on Field Standard Test Measures 77
D-3 Example of Test Measures Available on Waterdraw Unit 78

Chapter 4—Proving Systems
Section 9—Methods of Calibration for Displacement And Volumetric Tank Provers
Part 2—Determination of the Volume of Displacement and Tank Provers by the Waterdraw Method of Calibration

1.0 Introduction

All prover volumes used to calibrate meters shall be determined by calibration and not by theoretical calculation. Volumetric provers have an exact reference volume, which has been determined by a recognized method of calibration. Techniques for the determination of this reference volume include the waterdraw, master meter and gravimetric methods of calibration. This standard describes only the waterdraw method of calibration, which is used to accurately determine the calibrated volume of both displacement and tank provers.

1.1 U.S. CUSTOMARY AND METRIC (SI) UNITS

This standard presents both International System (SI) and U.S. Customary (USC) units, and may be implemented in either system of units. The system of units to be used is typically determined by contract, regulatory requirement, the manufacturer, or the user's calibration program. Once a system of units is chosen for a given application, it is not the intent of this standard to allow the arbitrary changing of units within this standard.

1.2 NATIONAL WEIGHTS AND MEASURES AGENCIES

Throughout this document issues of traceability are addressed by references to NIST (National Institute of Standards and Technology). However, other appropriate national metrology institutes can be referenced.

1.3 SAFETY CONSIDERATIONS

There is no intent to cover safety aspects of conducting the work described in this standard, and it is the duty of the user to be familiar with all applicable safe work practices. It is also the duty of the user to comply with all existing federal, state or local regulations (for example, the Occupational Safety and Health Administration) that govern the types of activities described in this standard, and to be familiar with all such safety and health regulations.

2.0 Scope

This standard covers all the procedures required to determine the field data necessary to calculate a Base Prover Volume (BPV), of either Displacement Provers or Volumetric Tank Provers, by the Waterdraw Method of Calibration.

It will enable the user to perform all the activities necessary to prepare the prover, conduct calibration runs, and record all the required data necessary to calculate the base volumes of displacement and tank provers. Evaluation of the results and troubleshooting of many calibration problems are also discussed.

Detailed calculation procedures are not included in this standard. For complete details the of calculations applicable to this standard, refer to the latest edition of the API *Manual of Petroleum Measurement Standards*, Chapter 12, Section 2, Part 4, "Calculation of Prover Volumes by the Waterdraw Method."

3.0 Reference Publications

Publications that provided background information, and are a source of reference material on subjects related to waterdraw calibration include the following:

American Petroleum Institute
Manual of Petroleum Measurement Standards (MPMS)
- Chapter 1 "Vocabulary"
- Chapter 4 "Proving Systems"
- Chapter 5 "Metering"
- Chapter 7 "Temperature Determination"