

Manual of Petroleum Measurement Standards Chapter 4—Proving Systems

Section 2—Displacement Provers

THIRD EDITION, SEPTEMBER 2003

REAFFIRMED, MARCH 2011

ADDENDUM, FEBRUARY 2015



AMERICAN PETROLEUM INSTITUTE

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Measurement Coordination

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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.

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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"

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Suggested revisions are invited and should be submitted to API, Standards department, 1220 L Street, NW, Washington, DC 20005.

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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 (*MFs*) 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.

1.4 REFERENCED PUBLICATIONS

API Manual of Petroleum Measurement Standards

- Chapter 1, "Vocabulary"
- Chapter 4, "Proving Systems,"
- Chapter 5, "Metering Systems"
- Chapter 6, "Metering Assemblies"
- Chapter 7, "Temperature Determination"
- Chapter 11, "Physical Properties Data"
- Chapter 12, "Calculations of Petroleum Quantities"
- Chapter 13, Statistical Concepts and Procedures in Measurement

DOT¹

49

Code of Federal Regulations Parts 171 – 177 (Subchapter C, "Hazardous Materials Regulations") and 390 – 397 (Subchapter B, "Federal Motor Carrier Safety Regulations")

NFPA²

70

National Electrical Code

2 General Performance Considerations

2.1 REPEATABILITY AND ACCURACY

Repeatability of a meter proving should not be considered the primary criterion for a prover's acceptability. Good repeatability does not necessarily indicate good accuracy because of the possibility of unknown systematic errors. Carrying out a series of repeated measurements under carefully controlled conditions and analyzing the results statistically can determine the repeatability of any prover/meter combination. The ultimate requirement for a prover is that it proves meters accurately.

The accuracy of the proving system depends on the accuracy of the instrumentation and the uncertainty of the prover's base volume. The repeatability and accuracy of the prover is established by calibration of the prover.

2.2 BASE PROVER VOLUME

The base volume of a unidirectional prover is the calibrated volume between detectors corrected to standard temperature and pressure conditions. The base volume of a bidirectional prover is expressed as the sum of the calibrated volumes between detectors in two consecutive one-way passes in opposite directions, each corrected to standard temperature and pressure conditions.

¹U.S. Department of Transportation. The *Code of Federal Regulations* is available from the U.S. Government Printing Office, Washington D.C., 20402.

²National Fire Protection Association, Batterymarch Park, Quincy, Massachusetts, 02269.

The base prover volume is determined with three or more consecutive calibration runs that repeat within a range of 0.02% by one of the three following methods—waterdraw, master meter or gravimetric (see API MPMS Ch. 4.9).

For the initial base volume determination of a new, modified, or refurbished prover, more than three calibration runs may be used to establish higher confidence in the calibration. When conditions exist that are likely to affect the accuracy of the calibrated volume of the prover, (e.g., corrosion, coating loss) the prover shall be repaired and recalibrated. For deposit buildup, which can be cleaned without affecting the surface of the calibrated volume, the prover need not be recalibrated.

Historical calibration data should be retained and evaluated to judge the suitability of prover calibration procedures and intervals.

2.3 VALVE SEATING

All valves used in displacement prover systems that can provide or contribute to a bypass of liquid around the prover or meter or to leakage between the prover and meter shall be of the double block-and-bleed type or an equivalent with a provision for seal verification.

The displacer-interchange valve in a unidirectional prover or the flow-diverter valve or valves in a bidirectional prover shall be fully seated and sealed before the displacer actuates the first detector. These and any other valves whose leakage can affect the accuracy of proving shall be provided with some means of demonstrating before, during, or after the proving run that they are leak-free.

2.4 FLOW STABILITY

The flow rate must be stable while the displacer is moving through the calibrated section of the prover (see API MPMS Ch. 4.8). Some factors affecting flow rate stability include adequate pre-run length, types of pumps in system, operating parameters, etc.

2.5 FREEDOM FROM HYDRAULIC SHOCK

A properly designed prover operating within its design flow range, the displacer will decelerate and come to rest safely at the end of its travel without excessive hydraulic shock to the displacer, displacement prover, and its associated piping.

2.6 TEMPERATURE STABILITY

Temperature stability is necessary to achieve acceptable proving results. This is normally accomplished by circulating liquid through the prover section until temperature stabilization is reached. When provers are installed aboveground, external insulation of the prover and associated piping may be necessary to improve temperature stability.

2.7 PRESSURE DROP ACROSS THE PROVER

In determining the size of the piping and openings to be used in the manifold and the prover, the pressure loss through the displacement prover system should be compatible with the acceptable pressure loss in the metering installation. Excessive pressure drop may prevent the meter from being proved at its normal flow rate(s) and/or minimum backpressure required for the meter.

2.8 METER PULSE TRAIN

The electrical pulse output from the meter can exhibit variations even though the flow rate through the meter is constant. These variations may be caused by mechanical and electrical imperfections of the meter, pulse generator, and in signal processing technique. Ideally, under stable flow conditions, the meter pulse train should be uniform. However, mechanical gears, bearing wear, blade imperfections, couplings, adjusting devices, counters, mechanical temperature correction devices, and other accessories reduce the uniformity of the meter pulses. For meters installed with a gear-stack, the further the pulse generator is from the meter, the more erratic the pulse train becomes.

Variations in the meter pulse output may result in unacceptable proving performance. Appendix E discusses the evaluation of pulse variations of meters.

2.9 DETECTORS

Detectors must indicate the position of the displacer within $\pm 0.005\%$ of the linear distance between switches (a range of 0.01%). The repeatability with which a prover's detector can signal the position of the displacer (which is one of the governing factors in determining the length of the calibrated prover section) must be ascertained as accurately as possible. Appendix A discusses this in more detail. For prover with external detectors, care must be taken to correct detector positions that are subject to temperature changes throughout the proving operation.

A detector switch is an externally mounted device on a prover, which has the ability to precisely detect, the displacer entering and exiting the prover calibrated section. The amount of fluid that is displaced between two detector switches is the calibrated volume of the prover. Provers typically have two detector switches. Additional switches may be used if more than one calibrated volume is required on the same prover, or they can also be used to signal the entrance of a displacer into the sphere receiving chamber.

3 General Equipment Considerations

3.1 MATERIALS AND FABRICATION

The materials selected for a prover shall conform to applicable codes, pressure and temperature ratings, corrosion resis-

tance, and area classifications. Pipe, fittings, and bends should be selected for roundness and smoothness to ensure consistent sealing of the displacer during a prover pass. Detailed inspection should be performed on pipe and fittings used in the calibrated section to insure the roundness of the pipe and the fittings are free of mandrel marks from shaping or forming.

3.2 INTERNAL AND EXTERNAL COATINGS

Internally coating the prover with a material that provides a hard, smooth, long-lasting finish will reduce corrosion, prolong the life of the displacer and the prover. This will improve the meter repeatability when proving at low flow rates. Experience has shown that internal coatings are particularly useful when the prover is used with liquids that have poor lubricating properties, such as gasoline or liquefied petroleum gas; however, in certain cases, satisfactory results and displacer longevity may be achieved when uncoated pipe is used. The materials selected for the internal coating application should be compatible with the liquid types expected. The coatings should be applied according to the manufacturer's recommendations. Extreme caution should be exercised in the surface preparation so that the coating is applied over a clean white-blasted metal with a minimum anchor pattern as specified by the manufacturer.

Externally coating the prover section and associated piping will reduce corrosion and will prolong the life of the prover, especially for installations where the prover is buried.

3.3 TEMPERATURE MEASUREMENT

Temperature sensors shall be of suitable range, resolution, and accuracy, and should indicate the temperature within the meter and the temperature within the calibrated section of the prover. A means shall be provided to measure temperature at the inlet and outlet of the prover (see API MPMS Ch. 7 for detail requirements). If it can be determined that the temperature of the flowing fluid at the meter and the prover does not vary by an amount that will result in a Ctl factor change of 0.0001 or less, one temperature probe may be used between the prover and the meter being proved. One temperature device is allowed on the outlet of a prover if the prover is upstream of the meter or on the inlet of the prover if the meter is upstream of the prover. Caution must be exercised to ensure that the temperature sensors are located where they will not be isolated from the liquid path.

3.4 PRESSURE MEASUREMENT

Pressure-measurement devices of suitable range and accuracy are to be used and installed at appropriate locations to indicate the pressure in the meter and the pressure in the prover. The pressure-measurement device should be installed near or on the meter and monitor the pressure in the meter. One pressure transmitter can be used if the pressure differ-

ence between the meter and the prover does not exceed the value for which the Cpl factor for the flowing fluid will change by more than 1 part in 10,000. The prover pressure should be monitored on the outlet of the prover if the meter is installed downstream of the prover or on the inlet of the prover if the meter is upstream of the prover. Caution must be exercised to ensure that the pressure sensors are located where they will not be isolated from the liquid path.

3.5 DISPLACING DEVICES

Prover displacers are devices, which travel through the prover calibrated section, operating the detector switches, and sweeping out the calibrated liquid volume. There are two types of displacers in common use, inflatable elastomer spheres and pistons. Other types of displacers are acceptable if they provide accuracy and repeatability that is equal to or better than the types described below.

3.5.1 Sphere Displacers

Materials used in the construction of elastomer spheres vary widely according to the applications for which they are to be used. Most commonly used are three basic materials, neoprene, nitrile and urethane. To obtain the best performance from any of these materials the operator should consider the chemical composition of the liquid that will be passing through the prover. Operating temperatures and pressures also affect the performance of these compounds in prover spheres. No one material or compound is ideal for all applications, therefore, proper material selection is extremely important.

Aromatic compounds, certain chemicals and oxygenates (MTBE, etc.) can attack all the above mentioned materials causing various degrees of softening, swelling and distortion of the shape of the sphere. Other materials such as Viton®, Teflon®, Buna®, etc., have also been used in sphere construction for applications that involve proving operations on specialized chemicals. Consultation with the manufacturer is recommended to determine the best material to be used in prover operations on a specific product.

The most common type of displacer is the inflatable elastomer sphere. It is usually made of neoprene, nitrile, or polyurethane. It has a hollow center with one or more valves used to inflate the sphere. The sphere is typically filled with glycol, or a 50/50-glycol and water mixture to prevent freezing. Care must be exercised to ensure that no air remains inside the sphere for compressibility purposes and to provide the sphere with negative buoyancy. Once the sphere has been filled, it is further inflated in order to increase its size over and above the inside diameter of the pipe. This over inflation is usually in the range of 2% – 3% for normal proving operations, depending upon the pipe diameter and condition of the pipe (see Appendix F). This arrangement allows the sphere to form a tight leak proof seal against the inside walls and to sweep the walls clean of any material (wax, etc.) that may accumulate.

Excessive over inflation of the sphere may result in sticking of the sphere, damage to the sphere, excessive wear, increased pressure drops, and damage to the prover. The effect is more pronounced in small diameter provers.

Under inflation can result in bypass around the sphere (leak) causing inaccuracies in the proving volume. This can be caused by the sphere contact length (the part touching the pipe wall) being less than the length of any opening in the pipe wall. It is possible that the prover can produce repeatable results by consistent bypass around the sphere that will be in error.

Measurement of the sphere can be accomplished either by means of a set of calipers, a sizing ring, or a flexible steel tape, by which the circumference is measured and the diameter calculated. Regardless of the method used, the measurement should be taken across several diameters. The smallest diameter measured is to be considered the real diameter of the sphere so that whatever inflation is chosen, the sphere will have a minimum diameter of that amount. Each measurement of a large sphere should be in a vertical plane. The purpose of sizing the sphere is to affect a seal across the displacer during its travel through the calibrated section of pipe. Any leakage across this sphere would result in an error in measurement.

The sphere size shall be verified periodically, and the sphere resized if necessary. Since wear is a function of lubricity, crude oil or lubricating oils give exceptionally long life, as opposed to prolonged service in a non-lubricating product such as LPG which gives no lubrication and enhances wear. Normally, many hundreds of runs can be made without resizing the sphere.

In order to perform maintenance and inspection of the sphere, provisions should be provided to easily and safely remove the sphere from the prover. These may include a quick opening closure to provide access to the launching chamber(s), a sphere removal tool to pick up the sphere, a hoist to lift the sphere, and access platforms around the launching chambers.

3.5.2 Piston Displacers

The design of a piston displacer varies according to different manufacturers and the requirements of the user. They should be made of materials compatible with the liquid or gas fluid service and are designed to weigh as little as possible.

The piston sealing rings or cups are made from either Teflon®, Viton®, polyurethane, nitrile, Buna® or neoprene, depending upon the liquid product and the operating temperatures and pressures to which the seals are exposed in the prover. Piston type displacers should have wear ring(s) to prevent the metal body of the piston from damaging the surface of the prover measuring chamber.

Pistons fitted with scraper cups made from various elastomer compounds do not require extenders to maintain the seal between the cup edges and the bore of the prover. If Teflon®

cups are used then the piston must be equipped with some type of expander device or material since Teflon® is not an elastomer and thus has no shape retention memory.

3.6 VALVES

Manifold valves that can contribute to a bypass of liquid around the prover or meter, or to leakage between the prover and the meter, shall be of the double block-and-bleed type, skilleted, or have provisions for verifying valve integrity. All valves whose leakage will affect the accuracy of proving shall be provided with some means of demonstrating that they are fully seated and completely sealed. This includes valves to adjoining meter runs, vents, and drains.

Pressure relief valves with discharge piping and leak-detection facilities are usually installed to control thermal expansion of the liquid in the prover while it is isolated from the mainstream. These devices should be positioned to avoid being located between the meter and the far most detector of the prover. For example, if the meter prover system is designed with the meter before the prover, the pressure relief should be located after the second detector. If the prover is located ahead of the meter, the pressure device should be installed before the first detector. Pressure relief valves should be avoided between the meter and the prover.

Bypass valves, flow reversal valves and displacer valves shall be fully seated and sealed so that the displacer is traveling at full velocity before it meets the first detector. Valves shall be selected and designed to prevent excessive pressure drop or hydraulic shock.

3.7 CONNECTIONS

Connections shall be provided on the prover or connecting piping to allow for calibration, venting, draining, and if necessary, pressure relief. The calibrated section of the prover between the detectors shall be designed to exclude any appurtenances such as vents or drains. If drains and vents are used between the meter and calibrated sections, a means should be provided to allow inspections for leakage or block-and-bleed valves should be provided on these connections.

3.7.1 Connections for Prover Calibration

Drains and vents for the prover, prover piping, and block-and-bleed valves should be connected to drain systems or other means should be provided to facilitate the handling of vented and drained fluids in a safe and environmentally suitable manner. Drains should be placed at locations to facilitate removal of water used for hydrostatic testing and calibrations. Figures 3, 4 and 5 show connections for water draw and/or master meter calibrations. Drains are not shown on the figures, but they should be placed at numerous low points on the piping. Vents should be installed at all high points on the piping.

3.7.2 Connections for Inspection

Flanges or other provisions should be provided for access to the inside surfaces of the calibrated and prerun sections. Internal access is an important consideration when internal coating of the prover is required. Care shall be exercised to ensure and maintain proper alignment and concentricity of pipe joints. All pipe, flanges, and fittings shall have the same internal diameter in the calibrated and pre-run sections.

3.7.3 Flange Connections in the Calibrated Section

Flanges in the calibrated volume shall be match bored and uniquely doweled or otherwise designed to maintain the match-bored position of the flanges. The calibrated section shall be designed to seal on a flange-face, metal-to-metal makeup, with the sealing being obtained from an O-ring type seal. All internal welds and metal surfaces shall be ground smooth to preclude damage to and leakage around the displacer.

3.8 DETECTORS

A detector switch is an externally mounted device on a prover, which has the ability to detect and repeat, within close tolerances, the displacer entrance into and its exit from the prover calibrated section. The amount of fluid that is displaced between two detector switches is the calibrated volume of the prover. The detector switches gate an electronic meter-proving counter that is connected to a meter pulse generator. Additional switches are used if more than one calibrated volume is required on the same prover, or they can also be used to signal the entrance of a displacer into the sphere resting chamber.

Displacer detectors must accurately and consistently indicate the position of the displacer within at least 1 part in 10,000 (0.01%) of the linear distance between switches. The accuracy with which the detector can determine the position of the displacer is one of the governing factors in determining the length of the prover's calibrated section. The detection devices must be rugged and reliable because replacement may require recalibration of the prover and temporary loss of meter proving capability.

When worn or damaged parts of a detector are replaced, care must be taken to ensure that neither the detector's actuating depth, the linear position, or its electrical switch components are altered to the extent that the prover volume is changed. This is especially true for unidirectional provers because changes in detector actuation are not compensated for round trip displacer travel as they are in bidirectional provers. If replacement of a detector changes the volume of the prover, recalibration is required.



Three types of detector switches (mechanical, proximity magnetic, and optical actuated) are presently in use for displacement provers.

3.8.1 Mechanically Actuated Detector Switches

The mechanical type of detector switch is used primarily with elastomer sphere displacers. Generally, it is actuated when the displacer makes contact with a stainless steel rod or ball which protrudes into the prover pipe. As the prover displacer moves with the flowing stream, the rod or ball is lifted in the detector. At some point in the upward travel of the rod or ball, an electronic switch is activated which indicates the displacer has been detected. Detector switches are normally hydraulically balanced. This prevents the switch from being activated from a pressure spike. In some cases, the switch part of the detector may be serviceable while the detector is in service and under pressure. Detectors on bidirectional provers should be installed under close tolerance so that the sensing characteristics in one direction are similar to those in the reverse direction. The electronic sensing elements in detectors should be designed so that the detector is not significantly affected by rotation of the mechanical plunger or by mechanical shock of the displacer. Openings through the pipe wall for detectors must be smaller than the longitudinal sealing area of the sphere or piston. On some piston designs multiple seals may be necessary.

3.8.2 Proximity Type Magnetically Actuated Detector Switches

Proximity-type magnetically actuated switches are used only with piston type displacers. This type of switch is mounted externally from the prover measuring section, with no parts inserted through the wall of the prover. It is actuated by either a magnetic material, such as a carbon steel or stainless steel exciter ring, or magnets on the piston displacer passing beneath the detector proximity switch. These switches have the ability to detect within close tolerances, the entrance and exit of the displacer into and out of the prover measuring section. These non-contact types of switches do not have to make physical contact with the displacer. However, non-contact sensors have a limited sensing distance that may also be displacer velocity dependent. To ensure consistent detection of the displacer, the distance between the detector and the displacer's detection elements should be no more than half the maximum sensing distance of the detector. It is important to ensure that these distances can be maintained. To accomplish this, the non-contact detectors should be installed on the side of the prover and the piston's seals should have sufficient stiffness to consistently support the weight of the piston. The sensing characteristics of the non-contact detector should be symmetrical and consistent between detectors so that they can be interchangeable.

3.8.3 Optically Actuated Detector Switches

The optical type detector switch is used primarily with piston provers utilizing externally mounted switches. Conventional design of the optical detector has a light source, together with a photoelectric detector cell, mounted opposite each other on a small metal base plate. This plate has the capability of keeping all the components in the same place, and can be mounted in the same exact location each time it is replaced. This makes for a very precise, repeatable location and mounting; which may permit a switch to be replaced without recalibration of the prover. In normal operations, the light source shines into the photoelectric cell until the light beam is interrupted by a lever or plate mounted to a moving rod connected to the displacer. Breaking of the light beam causes the detector switch to operate. These switches typically have a detection range within 0.0001 in. which permits pulse resolution to at least 1 part in 10,000 in a relatively short distance. Because these switches are externally mounted, a correction is required to compensate for any linear movement of these detectors based on thermal expansion/contraction. Normally two switches are used—one at the beginning and one at the ending of the movement of the displacer.

3.9 PERIPHERAL EQUIPMENT

A meter pulse generator shall be used to provide electrical pulses with satisfactory characteristics for the type of proving counter used.

An electronic pulse counter or flow computer is usually used in meter proving because of the ease and accuracy with which it can count high-frequency pulses and its ability to transmit this count to remote locations. The pulse-counting devices are equipped with an electronic start/stop switching circuit that is actuated by the prover's detectors.

A pulse interpolation system is required for those provers that cannot accumulate a minimum of 10,000 whole pulses between detectors on one pass of the displacer.

3.10 UNIDIRECTIONAL SPHERE PROVERS

3.10.1 General

Typical unidirectional prover piping is arranged so that the displacer is returned to a start position using a sphere handling interchange (see Figure 1). The interchange is the means by which the displacer is transferred from the downstream to the upstream end of the loop without being removed from the prover. The separator tee is the means by which the displacer's velocity is reduced to zero to allow it to enter into the interchange. The launching tee provides the means for allowing the displacer to enter the flowing stream.

These provers typically use electro-mechanical detector switches. The design of the prover usually allows the accumulation of 10,000 meter pulses for a proving pass. However, designs that accumulate less than 10,000 may be used for

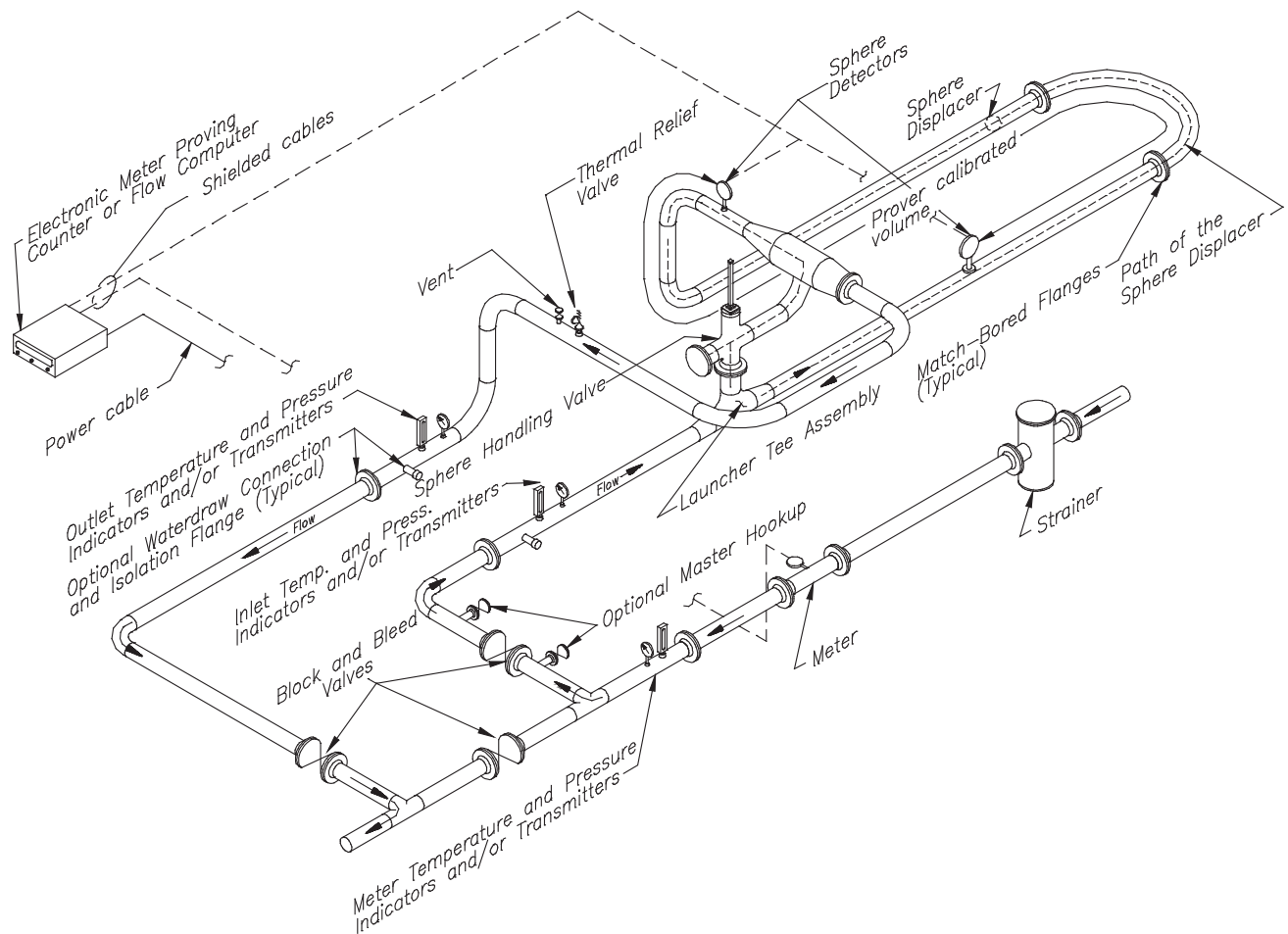


Figure 1—Typical Unidirectional Return-type Prover System

meter proving provided pulse interpolation is used and additional criteria defined in 4.3.2.2 are followed.

3.10.2 Sphere Interchange

The sphere interchange provides a means for transferring the sphere from the downstream end of the proving section to the upstream end. Sphere interchange may be accomplished with several different combinations of valves or other devices to minimize bypass flow or flow reversal through the interchange during the sphere transfer process. Some interchange designs use a launching tee to launch the displacer and a separator tee to receive the sphere and position it for the next proving run. Interchanges using this design typically have some type of valve or plunger to allow the displacer to travel between the separator tee and the launching tee and then seal between the two. In normal operation, a leak-tight seal between the two tees is essential before the sphere reaches the first detector switch of the proving section. To accomplish this, the interchange design must include either a hold ram to

retain the displacer until the seal between the two tees is made or a displacer prerun must be installed in the launching tee. The length of the displacer prerun is determined by the operational velocity of the sphere and the travel time of the displacer from the interchange valve to the launching tee.

3.10.3 Separator Tees

Separator tees should be at least two pipe sizes larger than the nominal size of the sphere or loop. Sizing is best determined by experience. The design of the separator tee shall ensure dependable separation of the sphere from the stream for all rates within the flow range of the prover. For practical purposes, the mean liquid velocity through the tee should be reduced to minimize the possibility of damage to the sphere or prover. The tee may sometimes need to be sized more than two pipe sizes larger to reduce the mean liquid velocity. Smooth-flow transition fittings on both ends of the tee are important. A means of directing the sphere into the interchange shall be provided at the downstream end.

3.10.4 Launching Tees

Launching tees should be at least two pipe sizes larger than the nominal size of the sphere or loop to allow the sphere to make the transition from the interchange to the calibrated section and to prevent damage to the sphere and prover.

The launching tee should provide a method ensuring the sphere launches successfully into the calibrated section of the prover during periods of low flow. If ramps are used, there needs to be enough clearance between the ramp and top of the pipe to allow the sphere to move down the ramp.

Launching tees shall have smooth transition fittings leading into the prover. Eccentric fittings are preferred.

3.10.5 Debris Removal

Some means for removal of debris and other contaminants should be considered in the design of new provers.

3.11 UNIDIRECTIONAL PISTON PROVERS

3.11.1 General Description

This section describes those provers historically referred to as “small volume provers.” These provers accumulate less than 10,000 whole, unaltered meter pulses between detectors during

one pass of the piston displacer, and therefore require pulse interpolation. Optical detector switches used with these provers are externally mounted from the flow media and are able to indicate the position of the displacer with a high degree of precision. As a result of this precision it is possible to have a very short distance between detector switches. The calibrated base volume of this prover is normally much smaller than sphere type unidirectional and bidirectional provers, typically having a maximum calibrated volume of 200 gallons. Since the small volume of these provers may not allow for the accumulation of 10,000 whole, unaltered pulses, the prover electronics must provide means for pulse interpolation. The only practice currently recognized by the API is double chronometry.

These provers allow flow in only one direction and provide a means of proving meters without reversing or disrupting the flow. This is done by an internal or external bypass valve design that allows fluid to pass through the device during non-proving or retraction mode (see Figure 2). The normal operation of these provers begins with the displacer at the starting position. When the bypass (poppet) valve is closed, the displacer is launched and passes through the calibrated section. Once the displacer has passed through the calibrated section, the bypass (poppet) valve opens and the displacer is retracted to the original starting position.

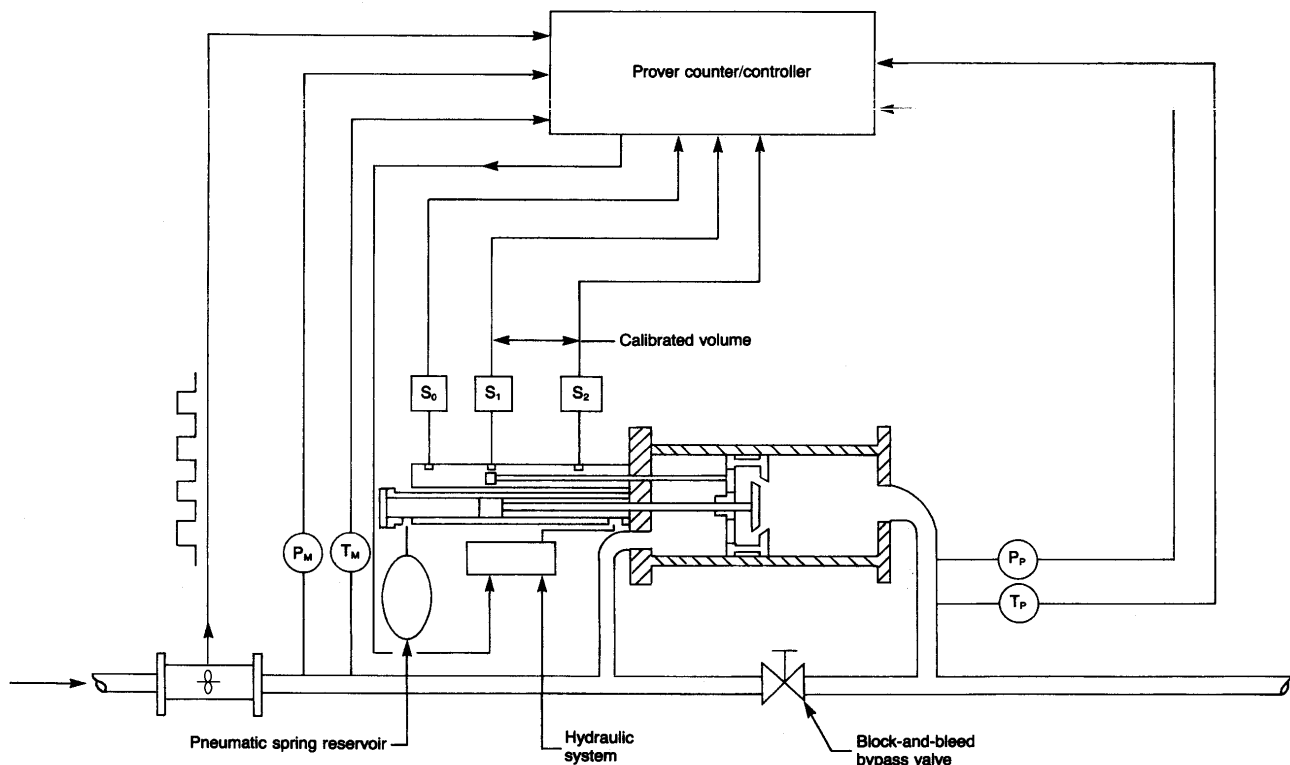


Figure 2—Piston Type Prover with Shaft and Optical Switches

3.11.2 Flow Tube

Unidirectional piston provers must utilize a precision flow tube normally honed and polished to provide a seamless and smooth finish. There shall be no obstructions or intrusions within the calibrated section of the tube. Coating materials such as hard chrome or nickel may be used to provide abrasion resistance. Flanges or other provisions should be included for access to the inside surfaces of the calibrated and pre-run sections. Care should be exercised to ensure and maintain proper alignment and concentricity of pipe joints.

3.11.3 Externally Mounted Detectors

Detectors are high precision, highly repeatable optical type switches mounted externally to the flow media. These switches are often mounted on material having an extremely low coefficient of thermal expansion characteristic. This minimizes the change in distance between the detector switches due to temperature variation. Any linear movement must be accounted for, as this will impact the calibrated volume of the prover. Detectors must indicate the position of the displacer within 0.01% of the linear distance between the detectors. The activation of the detector switches must correspond to the position of the piston displacer, which is normally achieved with a shaft connected directly to the piston displacer.

3.11.4 Piston Launch

Under proving conditions, the piston displacer must be set into motion from a stopped position and come to equilibrium velocity as the fluid traveling inside the flow tube prior to entering the calibrated section. The systems used to launch the piston can utilize the force of the fluid traveling through the prover, or an external system to apply a positive force such as compressed gas or springs. The prover design must allow sufficient length before the calibrated section to allow the piston to be launched and achieve equilibrium velocity prior to activating the first detector switch. Provers utilizing a bypass (poppet) design must ensure the poppet valve remain seated throughout the prover pass. This can be accomplished with the use of force from an external source (e.g., compressed gas or springs).

3.11.5 Piston Retraction

Inversely to the launching system, the prover must provide for retraction of the piston to its proving position. This can be accomplished with a hydraulic system or a mechanical drive. The retraction system must be designed such that it returns the piston to its original starting position. To accomplish this, fluid bypass (poppet) must be designed to allow retraction of the piston without blocking the flow stream. It must also be designed to minimize the pressure loss through the prover. Once in the original starting position, the prover is ready for another pass.

3.12 BIDIRECTIONAL SPHERE PROVERS

3.12.1 General

Typical bidirectional sphere provers (see Figure 3) have a length of pipe through which the displacer travels back and forth, actuating a detector at each end of the calibrated section. Suitable supplementary piping and a reversing valve or valve assembly that is either manually or automatically operated make possible the reversal of the flow through the prover. The main body of the prover is often a straight piece of pipe, but it may be contoured or folded to fit in a limited space or to make it more readily mobile.

These provers typically use mechanical detector switches.

3.12.2 Launching/Receiver Chambers

The launching/receiving chambers of bidirectional sphere provers are designed to pass liquids while restraining the displacer. The chambers should be at least two pipe sizes larger than the nominal size of the calibrated section. Inlets and outlets to the 4-way diverter valve shall have an area sufficient to avoid excessive pressure loss, and shall have a means to prevent entry of the displacer. The launching/receiving chambers must have an incline or ramp to facilitate launching of the sphere. The transition from the chamber to the pre-run needs to be a concentric reducer for a vertical chamber orientation and an eccentric reducer for all other orientations. All internal surfaces shall be de-burred to prevent damage to the sphere.

3.12.3 Flow Reversal

A single multi-port valve is commonly used for reversing the direction of the flow through the prover. Other means of flow reversal may also be used. All valves must be leak-free and allow continuous flow through the meter during proving. A method of checking for seal leakage during a proving pass shall be provided for all valves. The valve size and actuator shall be selected to limit hydraulic shock.

3.13 BIDIRECTIONAL PISTON PROVERS

3.13.1 General

Bidirectional piston provers (see Figure 4) have a straight length of pipe through which the displacer travels back and forth, actuating a detector at each end of the calibrated section. Suitable supplementary piping and a 4-way reversing valve or valve assembly that is either manually or automatically operated make possible the reversal of the flow through the prover.

3.13.2 Flow Reversal

A 4-way valve is typically used to reverse the flow in a piston prover. In many cases, check valves on the outlet piping are used to divert the flow in order to slow the piston down before it reaches the end of the prover. Other means of flow

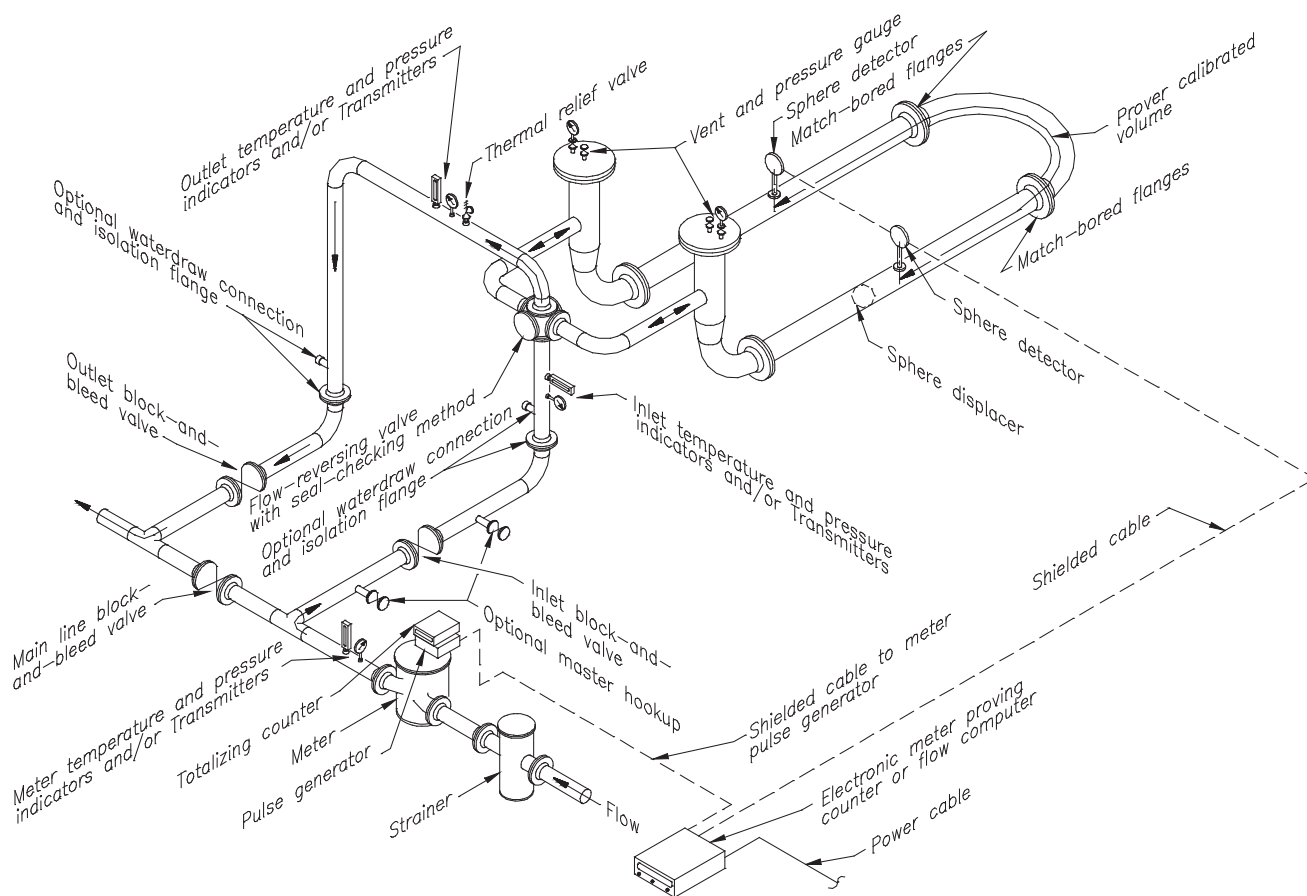


Figure 3—Typical Bidirectional U-type Sphere Prover System

reversal may also be used. However, all valves and flow reversal devices must be leak-free and allow continuous flow through the meter during proving. A method of checking for seal leakage during a proving pass shall be provided for all valves. The valve size and actuator shall be selected to limit hydraulic shock.

3.13.3 Inlets/Outlets

Each end of a bidirectional piston prover has separate inlet and outlet connections, typically of smaller diameter than the calibrated section piping. The inlets/outlets of bidirectional piston provers are designed to pass liquids while restraining the piston displacer in the prerun section of the prover. There are 2 sets of inlets and 2 sets of outlets in a bidirectional piston prover. Each end of the prover has an adjacent inlet and outlet, which connects to common piping of the flow-reversing valve.

The connections farthest from the calibrated section are referred to as the inlet connections, which allow flow to enter into the prover pipe, behind the displacer, at the beginning of a prover pass.

The connections nearest to the calibrated section are referred to as the outlet connections, which allows flow to exit the prover pipe during and after a prover pass. Since the inlet and outlet piping are connected to common piping of the reversing valve, a check valve must be installed on the outlet piping to block flow into the outlet and allow the displacer to move at the start of a prover pass.

The openings shall be designed to allow the piston to pass across the opening without damage to the seals. Openings shall be de-burred. Inlets and outlets to the 4-way reversing valve shall have an area sufficient to avoid excessive pressure loss, and shall have a means to prevent entry of the displacer.

3.13.4 Displacer Restrictions

The closure or end flange of a bidirectional piston prover must have a method of restricting the displacer in its resting position between the inlet and outlet connections. This restrictor insures the piston will completely de-accelerate before entering the edge of the inlet connection opening. Failure to de-accelerate the piston before it reaches the prover