# Manual of Petroleum Measurement Standards
# Chapter 4—Proving Systems

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

## Part 4—Determination of the Volume of Displacement and Tank Provers by the Gravimetric Method of Calibration

FIRST EDITION, OCTOBER 2010

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AMERICAN PETROLEUM INSTITUTE

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## 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. The parts consist of the following:

— 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 and Tank Provers by the Gravimetric Method of Calibration*.

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

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## Contents

## Introduction

This standard describes the gravimetric method of calibration (GM), which is used to determine the calibrated volume of both displacement and tank provers. All prover volumes shall be determined by calibration and not by calculation.

The GM differs from the waterdraw (volumetric) method found in API *MPMS* Ch. 4.9.2. The main difference between the methods is that a field standard test measure is replaced with a weighing system (weigh scale and container).

A majority of 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 are identical for the waterdraw and GMs. This standard will describe activities that are different from the waterdraw method. Therefore, it will be necessary for the user to reference API *MPMS* Ch. 4.9.1 and API *MPMS* Ch. 4.9.2 to perform all activities necessary for a calibration. Detailed volume calculation procedures for this method are included in Annex A.

# Chapter 4—Proving Systems
# Section 9—Methods of Calibration for Displacement and Volumetric Tank Provers
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## 1 Scope

### 1.1 General

This standard covers the specific procedures, equipment, and calculations required to determine the Base Prover Volume (BPV), of both tank and displacement provers by the gravimetric method of calibration (GM).

### 1.2 U.S. Customary (USC) and International System (SI) Units

This standard presents both International Systems (SI) and U.S. Customery (USC) units, and may be implemented in either system of units. The presentation of both units is for the convenience of the user, and is not necessarily the exact conversions. The system of units to be used is typically determined by contract, regulatory requirement, the manufacturer, or the user's calibration program.

### 1.3 National Metrology Institute

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

### 1.4 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 [e.g. the Occupational Safety and Health Administration (OSHA)] that govern the types of activities described in this standard, and to be familiar with all such safety and health regulations.

## 2 Normative References

The following referenced documents are indispensable for the application of this document. For date references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API *Manual of Petroleum Measurement Standards* (*MPMS*) Chapter 1, *Vocabulary*

API *MPMS* Chapter 4 (All Sections), *Proving Systems*

API *MPMS* Chapter 5 (All Sections), *Metering*

API *MPMS* Chapter 7 (All Sections), *Temperature Determination*

API *MPMS* Chapter 9 (All Sections), *Density Determination*

API *MPMS* Chapter 11 (All Sections), *Physical Properties Data*

API *MPMS* Chapter 12 (All Sections), *Calculation of Petroleum Quantities*

API *MPMS* Chapter 13 (All Sections), *Statistical Aspects of Measuring and Sampling*

API *MPMS* Chapter 14, Part 6—*Continuous Density Measurement*

API *MPMS* Chapter 15, *Guidelines for Use of the International System of Units (SI) in the Petroleum and Allied Industries*

ASTM E617-97: 2008 [1], *Standard Specification for Laboratory Weights And Precision Mass Standards*

EPA [2] *Secondary Drinking Water Regulations*

NIST Special Publication 250-72 [3], *Liquid Volume Calibration Service*

OIML International Recommendation R 111 [4], *Weights of classes* $E_1$, $E_2$, $F_1$, $F_2$, $M_1$, $M_{1-2}$, $M_2$, $M_{2-3}$ *and* $M_3$*—Part 1: Metrological and technical requirements*

## 3 Terms and Definitions

For the purposes of this document, the following definitions apply. The publications in Section 2 may be referenced for additional definitions relating to the calibration of displacement and tank provers.

**3.1**
**aggregate mass**
Each certified weight has a nominal value of mass along with an "as left mass" value from it's certificate. The nominal value of mass and the "as left mass" of the weight must be summed to determine the aggregate mass of the weight.

**3.2**
**as left mass**
The actual value of mass that a weight differs from the nominal value of mass of that weight. Example a 50 kg weight (nominal value) may have an as left mass of 0.001 kg. The aggregate mass of the weight would be 50.001 kg.

**3.3**
**calibration water**
The actual water used in the calibration process. The water used cannot be nontreated water defined in 3.8.

**3.4**
**container**
A collection tank that fits on a weigh scale (balance, load cell, weighing device, etc.) and contains either all or part of the fluid from the prover during calibration for weighing.

**3.5**
**direct traceability**
Documentation demonstrating that the standard in question (weight, pressure gauge, thermometer) was tested by a National Metrology Institute.

**3.6**
**expected mass**
The estimated mass to be weighed from the volume dispensed by the prover.

EXAMPLE For a prover with a nominal volume of 20 gal, the expected (estimated) mass of water would be 75.659 kg.

1 ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.
2 U.S. Environmental Protection Agency, Ariel Rios Building, 1200 Pennsylvania Avenue, Washington, DC 20460, www.epa.gov.
3 National Institute of Standards and Technology, 100 Bureau Drive, Stop 3460, Gaithersburg, Maryland 20899, www.nist.gov.
4 International Organization of Legal Metrology, 11 Rue Turgot, Paris, France F-75009, http://www.oiml.org/.

**3.7**
**indirect traceability**
Documentation demonstrating that the standard in question (weight, pressure gauge, thermometer) was tested by a laboratory with direct traceability to a National Metrology Institute and in compliance with that institute's quality assurance program.

**3.8**
**nontreated water**
Water that does not meet the potable or reference water definitions. Nontreated water is not used for gravimetric calibrations.

**3.9**
**potable water**
Water from an approved public municipal system that meets the EPA secondary contaminate levels for a maximum total dissolved solids of 500 mg/L (1000 μS).

**3.10**
**reference water**
Water from a distilled, deionized or reverse osmosis source with a maximum conductivity of 50 microsiemens (μS).

**3.11**
**tare**
A term meaning to perform the action to zero the weigh scale. An electronic weigh scale may indicate a mass reading with no mass applied. The weigh scale would then be tared (zeroed) before a weighing. A tare can normally be performed with a significant amount of mass on the weigh scale. The reason to tare with a mass applied would be to obtain a net change in mass.

**3.12**
**target mass (weight)**
The predetermined aggregate mass of test weight(s) needed for verification of the weigh scale. The target mass must be within ±20 % of the total mass.

**3.13**
**total mass**
The combined mass of the water to be weighed and the mass of the container. The mass of water to be weighed can be a partial, or the whole prover volume.

# 4 Prover Preparation

The guidelines or requirements for the preparation of provers for the GM are identical to those found in API *MPMS* Ch. 4.9.1 and API *MPMS* Ch. 4.9.2.

# 5 Preliminary and General Calibration Procedures

## 5.1 General

The preliminary and general calibration procedures for provers utilizing the GM are identical to those methods found in API *MPMS* Ch. 4.9.2 except for those procedures described in this section.

## 5.2 Preliminary Calibration Procedures

### 5.2.1 General

For displacement type provers, the water representing the prover volume is displaced into a container located on a weigh scale. For open tank provers, the GM may use either the drawing of water from the tank prover into the container or alternatively by filling of the tank prover from the container. The weight of the displaced water is then determined and corrected for the effect of air buoyancy to determine mass.

The mass obtained shall then be divided by the density of the water at the prover conditions of temperature and pressure to obtain the volume of water displaced. Corrections for temperature and pressure of the prover metal shall then be applied to this volume to determine the volume of the prover at reference conditions for any given calibration run. The prover base volume is the average of a set of runs that meet the repeatability criteria.

Because of environmental conditions in the field (wind, rain, snow, etc.) that may affect the weight measurement, the GM is more suitable for calibrations carried out in controlled environments.

### 5.2.2 Calibration Records

All the involved parties should review the calibration certificate from the previous prover calibration together with all the past maintenance records and calibration history of the prover that is available. Confirm that the identifying numbers on all the calibrated equipment (weights, thermometers, weigh scales, pressure gauges, etc.) to be used in the calibration correspond to their respective up-to-date traceability certificates.

### 5.2.3 Temperature and Pressure Device Verification

For procedures relating to temperature and pressure device verifications and applicable certificates of traceability refer to API *MPMS* Ch. 4.9.1.

### 5.2.4 Temperature and Pressure Readings

For procedures relating to temperature and pressure device readings refer to API *MPMS* Ch. 4.9.2. The temperature reading for the determination of the water density shall be obtained at the prover as in the waterdraw method. A temperature or pressure reading of the water in the container (or at the weight scale) is not required for a gravimetric calculation.

### 5.2.5 Gravimetric Calibration Unit (GM Unit)

The equipment used in the GM is the same as the waterdraw method found in API *MPMS* Ch. 4.9.2 except for the test measure is replaced with a weighing system.

A GM unit consists of a water reservoir, a low-pressure centrifugal pump, associated pipe work, hoses, and maybe a four-way valve. Included on the unit is a solenoid valve assembly, a control panel with detector switch indicator assembly, and a weighing system. The weighing system is normally positioned so that the water can be drained or pumped directly back into a reservoir. Single or multiple solenoid valves may be used, depending upon the piping configuration selected. Two-way or three-way type solenoid valves may be used as long as all valves can be verified for leakage. A centrifugal pump circulates water from the reservoir through the prover. The water is then returned either into the container and/or back into the reservoir.

### 5.2.6 Weighing System

#### 5.2.6.1 General

A weighing system consists of weigh scale(s), test weight(s), and a container(s) to hold the calibration water.

#### 5.2.6.2 Weigh Scale

A weigh scale shall be employed to determine the mass of the water displaced between volume detector sensors of the prover undergoing calibration. The weigh scale shall provide a minimum precision (repeatability) of ±0.0025 %, or ±1 part in 40,000, and shall be internally temperature compensated for an ambient temperature range of –10 °C, to +40 °C (14 °F to 104 °F). The above stated precision provides a four-to-one ratio of higher accuracy, to that of the prover undergoing calibration, of ±0.01 %, or ±1 part in 10,000.

The weigh scale shall be originally certified (calibrated) and supplied with indirect traceability to a national metrology institute. A documented performance verification (per manufacturer's recommendations) and recertification of the weigh scale(s) shall be conducted every three years. Recertifications must be performed by scale service company with national accreditation such as National Voluntary Laboratory Accreditation Program (NVLAP) or The American Association for Laboratory Accreditation (A2LA).

#### 5.2.6.3 Test Weights

Test laboratory weights and precision mass standards, in conformance with ASTM E617, or OIML International Recommendation R 111-1, shall be employed to verify/calibrate weigh scales used for gravimetric calibration of provers.

Test weights shall be certified initially and recertified every three years with direct or indirect traceability to a national metrology institute. A calibration certificate shall be issued by the calibration party, and maintained by user. The following minimum information shall be included on the calibration report:

— name and address of the calibrating party;

— identification and serial number of the calibrated weight;

— nominal mass value;

— as found, and as left mass of the weight;

— a statement of the estimated uncertainty of the weight;

— report number;

— national metrology institute certificate number;

— environmental conditions and procedures used;

— NVLAP or other type of national accreditation logo;

— information on the traceable standards used; and

— owner/client/contractor name and address.

Test weight(s) shall be ASTM E617 Class 0, Class 1, Class 2, Class 3, Class 4 or equivalent and shall not exceed a metric weight of 500 kg, or equivalent avoirdupois denominations [e.g. ASTM Class 4 "nominal" tolerances are one part in 50,000 (0.002 %)].

Multiple weights may be used in lieu of single weights. The plus or minus value "as left" mass for each weight shall be accumulated to establish an aggregate mass for each verification/calibration procedure. Test weight materials of construction shall be corrosion resistant, and practically nonmagnetic. An inspection of the weights shall be conducted to substantiate mass integrity of each weight (no loss or gain in mass). Any event resulting in possible change in the mass of a weight shall be reason for recertification prior to the three-year requirement.

#### 5.2.6.4 Container

The container is any vessel that meets these requirements:

— must center the contained mass of water to the weigh scale platform,

— material of construction and the condition of the container must not affect the conductivity or density of the water,

— container mass plus expected mass of fluid must not exceed the capacity of the weigh scale, and

— minimize evaporation of water in low humidity environments and/or higher atmospheric temperatures.

#### 5.2.6.5 Weigh Scale Verification/Calibration

Weigh scales used in the GM shall be verified or calibrated before each prover calibration procedure, or series thereof, conducted in a 24-hour period. Typically, a calibration is performed at one or two points over the scale's range, while verifications must be performed at each target mass. For each weigh scale verification and/or calibration procedure, the weigh scale(s) must adhere to the conditions below.

— Must be powered (turned on) for a sufficient amount of time to allow the electronics to stabilize (see manufacturers recommendations).

— Must be protected from wind drafts, rain, snow, etc., which could affect the weight measurement during the procedure.

— Must be equipped with a tare function, to tare out the weight of the container, prior to each calibration pass or container fill.

— Mounted on a level, stable, vibration free surface. If the weigh scale is not equipped with a level indicator, an appropriate level shall be used to verify that the weigh scale pan is horizontal.

— Must be level when empty, and when reading the total mass weight.

— Must be verified (calibrated) with test weight(s), as described in 5.2.6.3.

— Must be verified with a mass of test weights within ±20 % of the total mass. The total mass is the expected mass of the volume (partial or whole) dispensed from the prover plus the mass of the empty container.

— The mass indication (reading) of the weigh scale during verification, calibration, or weighing must be within the readability of the weigh scale and 0.005 % of the total mass.

— Linearity shall not be relied upon to provide the stated accuracy for multiple weigh points at various points within the capacity of the weigh scale. The weigh scale should be verified at each weigh point (total mass for each prover volume).

Reverification (or calibration) of the scale(s) is necessary due to:

— weigh scale relocation,

— weigh scale out of level during the procedure,

— change in volume (total mass) to be weighed by ±20 %,

— over-ranging the weigh scale,

— loss of power to weigh scale.

NOTE Refer to the weigh scale manufactures detailed instructions and recommendations for calibrations.

#### 5.2.6.6 Draining of the Container

A container may be drained in any manner that does not effect the level or position of the weigh scale. Pumping the water from the container is allowed, but the pump or discharge hose must be removed before taring or refilling. The container may retain residual water after draining, provided that the weigh scale is tared before the next fill sequence. Note that the amount of residual water should be minimal and must not be enough to make the next total mass outside of the target mass.

#### 5.2.6.7 Taring/Zeroing the Weigh Scale

A weigh scale may indicate a mass reading with no mass applied. The weigh scale would then be tared (zeroed) before a weighing of water. A tare can also be performed with a significant amount of mass on the weigh scale. The reason to tare with a mass applied would be to obtain a net change in mass.

The weigh scale should be tared/zeroed before:

— verification,

— calibration,

— placing the container on the weigh scale,

— each weighing sequence during the calibration.

### 5.2.7 Water Quality

#### 5.2.7.1 General

Ideally, for gravimetric calibrations, distilled or deionized water should be used. Water density is very important in gravimetric calibrations. Dirty water, heavily aerated water, hydrocarbon contaminated water, salt water, or any water of inferior quality, cannot be used (see Section 3 for water definitions). The density of the distilled or deionized water can be found in numerous tables. The algorithms developed by Patterson and Morris are currently used in petroleum industry standards.

For purposes of this standard, the density of water that has been defined as “reference water” can be obtained from the Patterson Morris algorithms in API *MPMS* Ch. 11.4.1. The “reference water” must be from a distilled, deionized or reverse osmosis source with a maximum conductivity of 50 µS.

Potable water from an approved public water (potable) supply may be used as calibration water in this procedure if “reference water” is unavailable (see definition in Section 3). If the density of the potable water exceeds 50 µS, the water density can be estimated for this procedure from its conductivity reading. The water conductivity should be determined at the completion of each run. Those conductivity readings used for each run must not differ by more than 200 µS and must not exceed 1000 µS during the prover calibration procedure. To determine the density of the potable water, see Equation (6) through Equation (11) in Annex A.

NOTE The use of potable water instead of “reference water” may increase the uncertainty of a gravimetric calibration.

#### 5.2.7.2 Water Conductivity Measurement

Water conducts electricity to some degree. Adding impurities that dissolve in the water such as salts increases its conductivity. Therefore, conductivity measurements can be used to correlate dissolved solids in solutions. Correlations improve as solids concentration and solids types are limited or similar.

Conductivity meters are common and typically simple instruments to operate. A meter for this standard:

— must be temperature compensated,

— indicate in the international unit of measure for conductivity, microsiemen (µS),

— indicate in increments of one for solutions below 75 µS, and

— indicate in increments of 10 or less for solutions above 75 µS.

Conductivity meter/measurement recommendations:

— use commercially-available standard and traceable solutions for calibration/verification,

— ensure no bubbles or particulate matter is in test solution,

— ensure meter (probe or cell) is properly immersed in test solution,

— ensure no salts or particulate matter is allowed to build up on probes or cells,

— rinse meter with deionized or distilled water before storage and any test sequence,

— follow manufactures recommendations for storage and calibration.

### 5.2.8 Air

Air must be vented from all high points in the system before beginning the calibration. The prover calibration depends upon a true hydraulic displacement, which is only possible in an air-free system. If air is found during a calibration pass, that pass is invalid and must not be used in the volume determinations. If air is found after the last calibration pass the complete calibration sequence is invalid and must be repeated.

### 5.2.9 Flow Rates During Calibration of Displacement Provers

Calibration flow rates should be chosen so that the displacer will have a steady continuous movement throughout the calibration pass. During all calibration passes it is desirable to keep the displacer moving smoothly at a constant flow rate. If the flow must be stopped at any time (e.g. waiting to empty container), the displacer should be stopped and restarted smoothly and quickly.

The minimum flow rate is experienced when the water flow is passing only through the solenoid valve. If the displacer shudders or moves erratically at this time, it may be a sign:

— that the displacer is not lubricated sufficiently,

— the displacer is sized incorrectly,

— that the solenoid valve opening is too small,

— that there is air in the system,

— that the water pressure is improperly changing.

The calibration shall be performed at flow rates such that the container can be filled without surging, overflowing, evaporation, or splashing water out of the top. Any splashing, overflowing or other loss of water from the container prior to the recording of the mass indication will render that calibration pass invalid.

For leak detection and reproducibility purposes, the flow rate for displacement provers shall be changed between successive calibration runs by 25 % or more.

The flow rate can be determined by one of two methods:

— a flow meter, or

— timing the entire calibration pass/run [(total volume/time) = flow rate].

Regardless of the method used, a change of 25 % or more to the flow rate applies to the entire calibration pass/run and not to just a portion of the pass/run.

#### 5.2.10 Number, Continuity and Sequence of Calibration Runs

A minimum of three consecutive calibration runs are required for a successful calibration of displacement provers.

Two consecutive calibration runs are required for a successful tank prover calibration. If the tank calibration scale is moved, then a third calibration run is required.

Any measured run is part of the consecutive chain. However, in the case of mishaps, such as the overflowing of a container, forgetting to close a drain valve, opening the wrong valve, missing a temperature, etc., the displacer may be returned to its previous starting position, and that particular pass or run started over.

If a displacement prover has multiple volumes, each volume shall be considered to be a stand-alone and independent prover volume. Each of these prover volumes shall be calibrated by a separate and independent calibration. Each calibration shall meet the same criteria as described above.

#### 5.2.11 Calculations and Repeatability

Detailed volume calculation procedures are included in Annex A of this standard. A majority of the calculations come from following editions of API *MPMS* Ch. 11.4.1, API *MPMS* Ch. 12.2.4, and API *MPMS* Ch. 14.6. Any equation referenced in Table A.1 will be superseded by calculations in any revised editions of these standards or new API *MPMS* Ch. 12 standards addressing gravimetric calibrations.

Repeatability between the results of successive prover volumes (passes and runs) at standard conditions must be calculated. For complete details on the determination of repeatability, refer to the API *MPMS* Ch. 12.2.4 or Equation (A.24) of this document.

#### 5.2.12 Calibration Certificate Package

All observed data shall be hand written in ink. All the observed data shall be proof read against the computer input-data before signing any documents. In case of discrepancies or errors discovered at a later date, the hand written observed data shall be used to correct the final volume. See Annex E for an example of gravimetric calibration datasheets.

A calibration certificate package for the GM shall include the applicable items listed in API *MPMS* Ch. 4.9.2 and these additional items:

— manufacturer, model, and serial number of weigh scale,

— weight certifications (see 5.2.6.3),

— documentation of weigh scale verification (see Annex F),

— certification for calibration water used to verify conductivity meter.

### 5.3 General Calibration Procedures

A majority of the activities necessary to conduct calibration runs, and record all the required data are identical for the "waterdraw" and "gravimetric" methods. The difference is that the field test measure is replaced with a weighing system. This section will briefly describe procedures for operation of the weighing system.

NOTE API *MPMS* Ch. 4.9.2 should be reviewed for detailed calibration information related to each type of prover and the issues of each type.

The weigh scale must be verified or calibrated before each procedure or series of procedures of provers of the same volume in a 24-hour period. Section 5.2.6.5 has additional details related to verification or calibration. The weigh scale must be verified prior to the prover calibration even if it has just been recently calibrated. Either procedure should not be performed until the weigh scale electronics have stabilized (reference manufacturers recommendations). Failure to allow the weigh scale to stabilize will result in incorrect readings or nonrepeatable indications.

The target mass for verification must be within ±20 % of the total mass as defined. The verification indication (reading) must be within 0.005 % of aggregate mass of the total number of weights used to reach the target weight. A complete verification is two consecutive indications (readings) within tolerance at the aggregate mass and at zero mass. An example for a 20-gal prover would be:

expected mass = 75.659 kg

container mass = 18 kg

total mass = 93.6591 kg

target mass = 75 kg to 112 kg

aggregate mass of four 22 kg weights is 90.724 kg

verification reading would be ±4.5 g of 90.724 kg

Once the verification procedure is complete, then the weigh scale should be tared. If only one container will be used per weigh scale, then the weigh scale should be tared with the container centered on the weigh scale platform. If multiple containers will be used per weigh scale, then an empty and total mass indication must be recorded per container to obtain the net mass of each container. Although it is not necessary to wet the container (fill with water) prior to a calibration sequence, the weigh scale must be level when the container is full of water.

A single weigh scale and container may have less uncertainty than multiple weight scales and containers. Typically, multiple weigh scales and containers are only used on provers smaller than 5 gal and/or larger than 50 gal. Multiple weigh scales may be necessary to achieve the weighing accuracy required by this standard.

The basic calibration sequence for a bidirectional prover using multiple weigh scales and containers is further described. After weigh scale verification and taring, start by positioning the displacer into its starting location under the first detector switch. The detector switches are named “A” and “B.”

1) The displacer is directed FORWARD to Detector A at normal flow rate, until it passes completely through this detector. Closing the circulation block valve then stops the flow.

2) The direction of the flow is changed to REVERSE using the four-way valve.

3) The circulation block valve is reopened and the displacer is now traveling in the REVERSE direction back through Detector A for a short distance until the audible or visual signal (if used) ceases. Closing the circulation block valve again stops the flow.

4) The direction of the flow is changed to FORWARD using the four-way valve.

5) The water flow is now directed through the solenoid valve, in the FORWARD direction. All the water is now passing only through the solenoid valve at a very slow flow rate.

6) At this time, the pressure of the system shall be read on the downstream side of the displacer. The pressure gauge is usually installed on the calibration unit manifold.

7) When Detector A is actuated, the solenoid valve operates and the water flow is directed into the first container.

NOTE This sequence describes the use of multiple containers and weigh scales.

The above procedure starts the filling of the first container. Continue filling until this container is near the expected mass for that container. At this time, slow the filling rate into the first container, and at the same time direct the water into the second container. The second container is now being filled and the first container, being full, is closed off from the water source. If necessary, the water level of the first container can be increased to a desired mass reading by the addition of water through the small filling valve. The mass indication of the first container is allowed to stabilize, the weight is recorded and the scale checked for level. The container is then drained and the weigh scale is tared prior to refilling.

When the second container is near its expected mass, its rate is slowed, and at the same time water is directed, either back to the first container, or to another container. Once the new container is being filled, the second container is closed off when its weight reaches its expected mass. Allow the mass indication to stabilize, record the weight and check for level. The container is then drained and the weigh scale is tared.

This procedure is continued until the last container is being filled. When the weigh scale reading approaches the expected mass, the main filling valve is closed off, and all the water being discharged is directed back through a solenoid valve, ready for an automatic shut-off at the end of the calibration pass. Once the displacer contacts Detector B, the solenoid valve will close and the water flow into the last container ceases. Open the water flow to drain, and allow the displacer to continue on through Detector B into the launching chamber.

It is recommended that the displacer be allowed to continue to the end of its travel (i.e. complete displacement) after the measured pass is completed before beginning the next pass. However, on large volume provers, in order to save time between passes it may be possible to hold the displacer downstream of Detector B between passes, if the temperature between passes is stable.

The displacer should then be repositioned back to Detector B, ready for the commencement of the “back” pass, which will be conducted in exactly the same manner as the “out” pass described above, but in the reverse direction.

The location for acquiring the prover temperature shall be as close as possible to and on the downstream side of each ending detector (for each pass). The prover temperature must be taken:

— after the main calibration flow has been established (usually maximum flow);

— after temperature has stabilized from change in flow to main (maximum) flow;

— within the first one-third of the calibration pass, volume, or mass.

Only one water temperature is required for each pass volume calculation, even if multiple containers are being filled for a given pass of the prover. Multiple temperatures should not be averaged for a pass.

The prover pressure is taken at the beginning of each pass, downstream of the displacer, while the displacer is slowly approaching the starting detector pass, and all the water is being discharged through the solenoid valve.

At the end of a successful calibration for a bidirectional prover there should be three consecutive round-trip runs, consisting of six consecutive passes, all meeting the repeatability requirements, for example, labeled as follows:

| | | |
|---|---|---|
| "Out" Pass 1: "Back" Pass 2: | = | Round-trip 1 |
| "Out" Pass 3: "Back" Pass 4: | = | Round-trip 2 |
| "Out" Pass 5: "Back" Pass 6: | = | Round-trip 3 |

NOTE The average value of three or more consecutive round-trip corrected volumes is considered to be the BPV. The corrected volumes of three or more consecutive round trip runs shall agree within a range of 0.020 %; the corrected volumes of three or more consecutive passes in the "out" direction, making up those round trips, shall agree within a range of 0.020 %; and the corrected volumes of three or more consecutive passes in the "back" direction, making up those round trips, shall also agree within a range of 0.020 %.

# 6 Calibration Procedures

## 6.1 General

The actual procedures for operation of various types of provers for calibration should be identical to those of API *MPMS* Ch. 4.9.2. The only difference in this method and the "waterdraw" method is that the field test measure is replaced by the weighing system.

NOTE This standard will only list the procedures for one type of prover, displacement type bidirectional provers with free displacers, to demonstrate the minor differences in prover calibration methods.

## 6.2 Calibration Preparation

Before beginning any calibration the following items shall be verified.

a) That the prover and its piping:

— have been inspected beforehand for good condition of internal coating,

— have been thoroughly cleaned and is free of hydrocarbons,

— have been cleaned of dirt and debris.

b) That any sphere type displacer being used has:

— been checked for condition including roundness and smoothness,

— been checked for water fullness and correct sizing.

c) That any piston type displacer being used has been checked for proper size and condition of seal.

d) That any thermowell being used for temperature measurements is:

— inserted into the middle third of the pipe diameter,

— inserted at a location as close as possible to and on the downstream side of each detector (for each pass),

— inserted in the flowing stream and not in a dead-leg,

— inserted in a small enough diameter pipe to allow accurate readings.

e) That the detector switches on displacement provers are in good condition, clean, and properly adjusted.

f) That the prover and all auxiliary “dead-space” piping have:

— been isolated with blinds or valves,

— been made water-clean and refilled with calibration water.

g) That the quality of the water to be used for the calibration meets the requirements in 5.2.7.

h) That all drain valves, relief valves, vent valves and manifold valves are sealing properly when closed.

i) That all hoses and connections from the calibration unit to the prover are in good condition, hydrocarbon and leak-free.

j) That all the piping and closed valves in the calibration unit have been verified to be leak-free.

k) That any four-way valves or sphere interchanges being used are operating and sealing properly.

l) That the water has been circulating through the displacement prover and the temperature has stabilized.

m) That all thermometers to be used in the calibration have been verified for condition and are in agreement with a certified or calibrated thermometer within a range of 0.1 °F (0.05 °C).

n) That any pressure gauge used in the calibration has been calibrated or certified to be accurate to 1 psig (1 kPag).

o) That the documentation on the thermometers and the pressure gauges has been inspected for traceability and current status.

p) That the documentation on the weigh scale(s), and test weights have been examined for traceability and current status.

q) That the documentation and equipment/calibration identification numbers have been checked to match.

r) That the weigh scale(s) and container(s) have all been:

— leveled, both at empty and at total mass,

— stabilized,

— protected from influences of the elements,

— verified at the proper target mass for that container or prover,

— container will hold the correct mass.

s) That the launching chambers and interchanges have been vented before the start of each pass of the displacer.

t) That all high points, where air could possibly be trapped, have been vented.

u) That the detector switches are connected to the calibration unit and operating correctly.

v) That the calibration unit is functioning correctly.

## 6.3 Displacement Type Bidirectional Provers with Free Displacers

### 6.3.1 General

During each calibration pass, determine the flow rate by one of the following methods:

— using a flow meter to monitor the flow rate while adjusting the filling valve(s),

— timing the entire calibration pass [(total volume/time) = flow rate].

During each calibration pass:

— record all prover pressure readings to the nearest 1 psig (1kPag),

— record the water conductivity to the nearest microsiemen,

— record all prover temperature readings to the nearest 0.1 °F within the first third of the prover pass volume.

NOTE The GM requires only the temperature and pressure readings for the prover be recorded.

The calibration can be conducted by starting from either launching chamber. For purposes of this discussion, it will be assumed that the four-way valve on the prover being calibrated is being used. Also, that the displacer (ball or piston) is sitting in the “home” position and that the four-way valve is in the “reverse” direction so that the water is circulating in the “back” direction.

### 6.3.2 Preliminary

Typical recommended steps for calibration of a bidirectional prover using two weigh scales and containers include, as follows:

1) determine that the weigh scales have been properly verified at the target mass;

2) identify the first and second detector switches (e.g. “A” and “B”) that will be used for each pass/run;

3) verify that the four-way valve is positioned so that the flow is in the “back” direction;

4) maintain continuous water circulation through the prover and calibration unit;

5) determine if the calibration water meets this standard’s requirements;

6) verify that all isolation valves downstream of the solenoid valve(s) are closed;

7) drain each container;

8) verify that weigh scales are clean, level and free from ambient disturbance;

9) tare each weigh scale.

#### 6.3.3 Out Pass

Typical recommended steps for calibration of a bidirectional prover using two weigh scales and containers include the following.

1) Determine and maintain the prescribed flow rate for this pass.

2) All high point vents in the prover system should be checked for air before starting a new pass.

3) Launch the displacer by positioning the four-way valve in the “out” direction.

4) Allow the displacer to go a short distance past the “A” detector switch in the “out” direction.

5) Use the four-way valve to reverse the flow to bring the displacer “back” across the “A” detector switch.

6) When the displacer has gone several seconds past the “A” detector switch, close the bypass valve.

7) Operate the four-way valve to redirect the flow to the “out” direction but with the flow stopped.

8) Check the four-way valve(s) for sealing integrity.

9) Set the controller so that the solenoid valve is open to the reservoir.

10) Open the solenoid isolation valve to allow water to flow directly into the reservoir.

11) As the displacer moves toward the “A” detector switch, observe and record the pressure.

12) Upon actuation of the “A” detector switch the solenoid valve will close to reservoir.

13) The flow to the reservoir is automatically stopped and all flow has ceased.

14) Close the solenoid isolation valve in-line with the now closed solenoid valve.

15) Note a two valve system may be used to automatically divert water to and from reservoir and containers.

16) Open the filling valve of the first container at the prescribed flow rate for this “out” pass. All the water is now being collected.

17) Read and record the prover temperature for this pass after main or full flow has been obtained, temperature has stabilized and within the first third of the total pass volume.

NOTE This temperature recording normally occurs during the first container fill, but not always.

18) When the first container is near being full or approaches its expected mass, begin to throttle the filling valve.

19) Simultaneously (as practical) begin opening the filling valve on the second container.

20) Open the second filling valve to attain the prescribed flow rate while closing the first filling valve.

21) Once the first container is full or has reached its expected mass, close the filling valve and let the contents stabilize.

22) Read the weigh scale indication and record mass indicated.

23) Verify that the first weigh scale/container is level and water conductivity is within specification of 5.2.7 before proceeding.

24) Drain the first container.

25) Once the container is empty, tare the weigh scale.

26) Fill, read each weigh scale, record mass indication, drain each container and tare each weigh scale in a continuous manner.

27) Rotate the filling and draining from one container to the next, until the final container is being filled.

28) When the last container is close to or has reached its total mass, open the solenoid isolation valve to this container.

29) Close the main filling valve for this container.

30) Upon actuation of the “B” detector switch the water flow into the last container is stopped.

31) Close the solenoid isolation valve to this container.

32) Open the main bypass valve and allow the displacer to go past the “B” detector switch.

33) It is recommended that the displacer be allowed to continue to near or into the launching chamber.

34) Take the final readings and drain this last container as with all the other containers to complete this “out” pass.

NOTE Ensure that the mass (weight) of the last container plus the mass values of all other containers, must be within the target mass.

35) Water circulation should go on continuously until the next launch to maintain temperature stability.

### 6.3.4 Back Pass

Typical recommended steps for calibration of a bidirectional prover using two weigh scales and containers include the following.

1) Determine and maintain the prescribed flow rate for this pass.

2) All high point vents in the prover system should be checked for air before starting a new pass.

3) To commence the next pass, launch the displacer by positioning the four-way valve in the “back” direction.

4) Allow the displacer to go a short distance past the “B” detector switch in the “back” direction.

5) Use the four-way valve to reverse the flow to bring the displacer “out” across the “B” detector switch.

6) When the displacer has gone several seconds past the “B” detector switch, close the bypass valve.

7) Operate the four-way valve to redirect the flow to the “back” direction but with the flow stopped.

8) Check the four-way valve(s) for sealing integrity.

9) Set the controller so that the solenoid valve is open to the reservoir.

10) Open the solenoid isolation valve to allow water to flow directly into the reservoir.

11) As the displacer moves toward the “B” detector switch, observe and record the pressure.

12) Upon actuation of the “B” detector switch the solenoid valve will close to the reservoir.

13) The flow to the reservoir is automatically stopped and all flow has ceased.

14) Close the solenoid isolation valve in-line with the now closed solenoid valve.

15) Open the filling valve to the first container at the prescribed flow rate for this “back” pass. All the water is now being collected.

16) Read and record the prover temperature for this pass after main or full flow has been obtained, temperature has stabilized and within the first third of the total pass volume.

NOTE This temperature recording normally occurs during the first container fill, but not always.

17) When the first container is near being full or approaches its expected mass, begin to throttle the filling valve.

18) Simultaneously (as practical) begin opening the filling valve of the second container.

19) Open the second filling valve to the prescribed flow rate while closing the first filling valve.

20) Once the first container is full or has reached the total mass, close its filling valve and let the contents stabilize.

21) Read the weigh scale indication and record mass indicated.

22) Verify that the first weigh scale/container is level and water conductivity is within specification of 5.2.7 before proceeding.

23) Drain the first container.

24) Once the container is empty, tare the weigh scale.

25) Fill, read each weigh scale, record the mass indication, drain each container and tare each weigh scale in a continuous manner.

26) Rotate from one container to the next, until the final container is being filled.

27) When the last container is close to or has reached its total mass, open the solenoid isolation valve to this container.

28) Close the main filling valve for this container.

29) Upon actuation of the “A” detector switch the water flow into the last container is stopped.

30) Close the solenoid isolation valve to this container.

31) Open the main bypass valve and allow the displacer to go past the “A” detector switch.

32) It is recommended that the displacer be allowed to continue to near or into the launching chamber.

33) Take the final mass readings and drain as with all the other containers to complete this “back” pass.

NOTE Ensure that the mass (weight) of the last container plus the mass values of all other containers, must be within the target mass.

34) This completes one round trip run composed of one “out” pass and one “back” pass.

35) Water circulation should go on continuously until the next launch to maintain temperature stability.

36) All the high points in the prover system should be vented before each pass.

37) Repeat Steps 8 through 80 until the criteria for a satisfactory calibration have been satisfied.

# 7 Troubleshooting Calibration Problems

## 7.1 General

Prover operation during a calibration should not vary between the different calibration methods. For troubleshooting prover calibrations, refer to API *MPMS* Ch. 4.9 (2005), Section 4.9.2.8 and Section 4.9.1.8. The difference between the “waterdraw” and the ”gravimetric” methods is that a weighing system replaces the field test measure.

NOTE This standard will only list the suggestions related specifically to the “gravimetric” calibration method.

## 7.2 Weighing System

Weighing system used in prover calibrations is the core equipment in the determination of the prover volume. The following issues can contribute to errors in the calibration results.

Weigh scale errors involve:

— incorrect test weight certification,

— unlevel weigh scale, empty or at total mass,

— insufficient stabilization time for weigh scale electronics,

— incorrect taring of weigh scale,

— incorrect calibration of weigh scale,

— verification outside the target mass,

— relocation of weigh scale without reverification,

— winds or air drafts causing weigh scale indications to fluctuate,

— weighing outside the target mass,

— ensure that the weigh scale is free standing and nothing impedes the movement of the weigh scale platform.

Weights errors involve:

— incorrect test weight certification,

— not using aggregate mass in calibrations or verifications,

— foreign material on weights,

— damage to weights that change its mass.

Container errors involve:

— container out of level,

— container not centered on weigh scale platform,

— overflowing a container,

— splashing water out of the container,

— evaporation of water in low humidity environment and/or higher atmospheric temperatures,

— leaking drain valve on the container(s).

## 7.3 Water Quality

Water quality is one of the most important factors in this method. Distilled or deionized water is preferred and recommended. The water quality must be as specified in 5.2.7. Any type of water contamination that may change the density of the water is unacceptable.

# Annex A
(normative)

# Calculation Procedures for the Determination of Base Prover Volume (BPV) of Displacement Provers by the Gravimetric Method (GM)

## A.1 Gravimetric Method—Summary

BPV calculations of a displacer prover, as determined by the volumetric method, are found in API *MPMS* Ch. 12.2.4. As of publication of this document, API *MPMS* Ch. 12.2.4 does not address the calculations for the GM. The equations for GM to determine a volume are widely known and commonly used. A majority of the equations in the annex are from current chapters of the *MPMS*. Table 1 of Annex A provides a reference for these equations. Discrimination levels for the equations should conform to those found in API *MPMS* Ch. 12 unless noted otherwise in this annex or until API *MPMS* Ch. 12 addresses these equations.

NOTE This annex is intended to be normative until a publication of API *MPMS* Ch. 12 addresses these calculations.

The procedure for calculating the BPV of a prover by the GM is somewhat parallel to the field verification of a pycnometer. In both methods you must know both the mass and the density of the calibration water used during the procedure, to accurately calculate the volume. The calculation procedure for determining the BPV of a prover by the gravimetric waterdraw method shall be in accordance with the following procedures and equations below.

## A.2 Air Density Determination

### A.2.1 Calculation of Air Density in SI Units

$$\rho_A = 0.001223068[1-(0.1049869h/1000)][519.67/(1.8T_f+491.67)] \tag{A.1}$$

### A.2.2 Calculation of Air Density in USC Units

$$\rho_A = 0.001223068[1-(0.032h/1000)][519.67/(T_f+459.67)] \tag{A.2}$$

where

$\rho_A$ is the density of dry air, in grams per cubic centimeter (SI and USC Units);

$h$ is the elevation above sea level, in meters (SI), in feet (USC);

$T_f$ is the test temperature, in degrees Celsius (SI), in degrees Fahrenheit (USC).

NOTE The density of air as calculated in Equation (A.1) and Equation (A.2) is a dry air density. Calculations have shown that the use of nonzero relative humidities has negligible effect on air buoyancy calculations. The density at 760 mmHg atmospheric pressure, 0 % relative humidity, 0 elevation and 15.5555555 °C (60 °F) is consistent with the latest International Committee of Weights and Measures (CIPM) 81/91 air density executable file available from NIST. The program is available at http://ts.nist.gov/ts/htdocs/230/235/labmetrologypage.htm.

## A.3 Calculation for the Correction for Air Buoyancy on Weighing (CBW)

$$CBW = \left[\frac{1-(0.0012/\rho_{TWr})}{1-(0.0012/\rho_{TWf})}\right]\left[\frac{1-(\rho_A/\rho_{TWf})}{1-(\rho_A/\rho_{Ftp})}\right] \tag{A.3}$$

where

$CBW$ is the correction for air buoyancy on weighing;

$\rho_{TWr}$ is the density of reference test weights, in grams per cubic centimeter;

$\rho_{TWf}$ is the density of field test weights, in grams per cubic centimeter as per certificate of traceability;

$\rho_{Ftp}$ is the density of fluid at test temperature and test pressure, in grams per cubic centimeter;

$\rho_A$ is the density of dry air, in grams per cubic centimeter.

NOTE The apparent mass of an object is equal to the mass of just enough reference material of a specified density ($\rho_{TWr}$) that will produce a balance reading equal to that produced by the object if the measurements are done in air. NIST specifies that the reference material density be taken at 20 °C in air with a density of 0.0012 g/cm$^3$ at 20 °C. The original basis for reporting apparent mass was apparent mass vs brass. The apparent mass versus a density of 8.0 g/cm$^3$ ($\rho_{TWr}$ = 8.0) is the more recent definition, and is used extensively throughout the world. The use of apparent mass versus 8.0 g/cm$^3$ is encouraged over apparent mass versus brass.

## A.4 Calculation for the Density of the Calibration Water (Distilled or Deionized)

The water density shall be determined as per the Patterson Morris Correlation for the density of distilled water.

NOTE This equation for the density of water is a fifth-order polynomial, and its useful range is 33.8 °F to 104 °F (1 °C to 40 °C), ITS-90.

**Caution—Actual calibrations should be avoided if possible at the minimum and maximum useful range of the above equation. Excessive evaporation may occur at the maximum temperature, whereas there is the potential of freezing if performing the calibration at the minimum temperature. A recommended range is 41 °F to 95 °F (5 °C to 35 °C).**

### A.4.1 Calculation of Distilled Water Density as a Function of Temperature in Degrees Celsius

$$\rho_{tC} = \rho_O[1-(A\Delta t + B\Delta t^2 + C\Delta t^3 + D\Delta t^4 + E\Delta t^5)] \quad (A.4)$$

where

$\rho_{tC}$ is density at temperature $t$ °C, in kilograms per cubic meter;

$\rho_o$ is density at temperature $t_o$, 999.97358 kg/m$^3$ (maximum density of distilled water);

$t$ is degrees Celsius;

$\Delta t$ is $t - t_o$;

$t_o$ is 3.9818E+00 (°C);

$A$ is 7.0134E–08 (°C)$^{-1}$;

$B$ is 7.926504E–06 (°C)$^{-2}$;

$C$ is –7.575677E–08 (°C)$^{-3}$;

$D$ is 7.314894E–10 (°C)$^{-4}$;

$E$ is –3.596458E–12 (°C)$^{-5}$.

### A.4.2 Calculation of Distilled Water Density as a Function of Temperature in Degrees Fahrenheit

$$\rho_{tF} = \rho_O[1 - (A\Delta t_F + B\Delta t_F^2 + C\Delta t_F^3 + D\Delta t_F^4 + E\Delta t_F^5)] \quad \text{(A.5)}$$

where

$\rho_{tF}$ is the density at temperature $t$ °F, in kilograms per cubic meter;

$\rho_o$ is the density at temperature $t_o$, 999.97358 kg/m$^3$ (maximum density of distilled water);

$t$ is degrees Fahrenheit;

$\Delta t_F$ is $\frac{(t-32)}{1.8} - t_o$

$t_o$ is 3.9818E+00 (°C);

$A$ is 7.0134E–08 (°C)$^{-1}$;

$B$ is 7.926504E–06 (°C)$^{-2}$;

$C$ is –7.575677E–08 (°C)$^{-3}$;

$D$ is 7.314894E–10 (°C)$^{-4}$;

$E$ is –3.596458E–12 (°C)$^{-5}$.

NOTE Calculated values from Equation (A.4) and Equation (A.5) are then divided by 1000 to convert density values from kilograms per cubic meter to density values of grams per cubic centimeter for further use. This value is then rounded to six decimal places. There is no correction required for the pressure effect on the water in the container, as it will be at atmospheric pressure.

## A.5 Calculation for the Density of Calibration Water That is Not Distilled or Deionized

Equation (A.4) and Equation (A.5) provide density correlations for the density of distilled water. If the water to be used in the GM does not meet the criteria of distilled or deionized water, water from an approved public water (potable) supply may be used in this procedure. The conductivity must not exceed 50 µs to meet the criteria for distilled or deionized water. If the conductivity exceeds 50 µs, and is less than 1000 µs, the density shall be determined as per the following calculation procedure.

NOTE Although the density of water that is neither distilled nor deionized must be determined using this procedure if the conductivity of the potable water exceeds 50 µs, it is recommended that this procedure be applied if the calibration water electrical conductivity exceeds 25 µs.

The conductivity of calibration water that is not distilled or deionized is measured and compared to the properties of seawater at the test temperature as a function of temperature at Salinity S35, and normal atmospheric pressure.

NOTE Salinity is defined as the saltiness of dissolved salt content of a body of water. A salinity of S35 means that for every 1 kg of seawater there is 35 grams of dissolved salts (mostly, but not entirely, the ions of sodium chloride).

### A.5.1 Procedure for Determining the Density of Calibration Water That is Not Distilled or Deionized

1) Calculate the density of distilled water at the test temperature of the calibration water:

   a) Equation (A.4) for SI units,

b) Equation (A.5) for USC units.

2) Calculate the density of Vienna Standard Mean Ocean Water (VSMOW) at the test temperature of the calibration water:

a) Equation (A.6) for SI units,

b) Equation (A.7) for USC units.

3) Calculate the electrical conductivity of VSMOW at the test temperature of the calibration water:

a) Equation (A.8) for SI units,

b) Equation (A.9) for USC units.

4) Measure the electrical conductivity of the calibration water at the test temperature in microsiemens per centimeter (µs/cm).

5) Calculate the density of the calibration water at the test temperature:

a) Equation (A.10) for SI units,

b) Equation (A.11) for USC units.

This calculated calibration water density is then applied to the corrected mass.

### A.5.2 Calculation for the Density of VSMOW as a Function of Temperature in Degrees Celsius

$$\rho_{VSMOW} = a + bt + ct^2 + dt^3 + et^4 + ft^5 + gt^6 + ht^7 \quad \text{(A.6)}$$

where

$\rho_{VSMOW}$ is the density of VSMOW, in grams per cubic centimeter at calibration temperature;

$t$ is the calibration reference temperature, in degrees Celsius;

$a$ is 1.028106E+00;

$b$ is –5.3511662E–05;

$c$ is –7.008371E–06;

$d$ is 1.10495E–07;

$e$ is –3.8015222E–09;

$f$ is 1.1307918E–10;

$g$ is –1.9496929E–12;

$h$ is 1.3968703E–14.

### A.5.3 Calculation for the Density of VSMOW as a Function of Temperature in Degrees Fahrenheit

$$\rho_{VSMOW} = a + bt + ct^2 + dt^3 + et^4 + ft^5 + gt^6 + ht^7 \quad \text{(A.7)}$$

where

$\rho_{\text{VSMOW}}$ is the density of VSMOW, in grams per cubic centimeter at calibration temperature;

$t$ is the calibration reference temperature, in degrees Fahrenheit;

$a$ is 1.0255154E+00;

$b$ is 2.6816412E–04;

$c$ is –9.80852701E–06;

$d$ is 1.9134207E–07;

$e$ is –2.8076392E–09;

$f$ is 2.5518686E–11;

$g$ is –1.2858870E–13;

$h$ is 2.7440442E–16.

### A.5.4 Calculation for the Electrical Conductivity of VSMOW as a Function of Temperature in Degrees Celsius

$$K_{\text{VSMOW Conductivity}} = a + bt + ct^2 + dt^3 + et^4 + ft^5 \quad \text{(A.8)}$$

where

$K_{\text{VSMOW Conductivity}}$ is the electricity conductivity of VSMOW, in siemens per centimeter at calibration temperature;

$t$ is the calibration reference temperature, in degrees Celsius;

$a$ is 2.9048022E–02;

$b$ is 8.6092727E–04;

$c$ is 4.7584848E–06;

$d$ is –3.0181818E–08;

$e$ is 3.6363637E–11;

$f$ is –1.2703431E–20.

### A.5.5 Calculation for the Electrical Conductivity of VSMOW as a Function of Temperature in Degrees Fahrenheit

$$_{\text{VSMOW Conductivity}} = a + bt + ct^2 + dt^3 + et^4 + f \quad \text{(A.9)}$$

where

$K_{\text{VSMOW Conductivity}}$ is the electricity conductivity of VSMOW, in siemens per centimeter at calibration temperature;

$t$ is the calibration reference temperature, in °F;

$a$ is 1.5429919E–02;

$b$ is 3.6725111E–04;

$c$ is 2.0043598E–06;

$d$ is –5.8221224E–09;

$e$ is 4.5139959E–12;

$f$ is –1.8059633E–15.

NOTE Calculated values from Equation (A.8) and Equation (A.9) are then multiplied by 1,000,000 to convert VSMOW conductivity values from siemens per centimeter to conductivity values of microsiemens per centimeter for further use. This value is then rounded to six decimal places.

### A.5.6 Calculation for the Determination of the Calibration Water Density in SI Units

$$\rho_{\text{Calibration Water}} = \rho_{\text{Distilled Water}}@T_{OBS} + \left[(\rho_{\text{VSMOW}}@T_{OBS} - \rho_{\text{Distilled Water}}@T_{OBS})\left(\frac{K_{\text{Calibration Water}}@T_{OBS}}{K_{\text{VSMOW}}@T_{OBS}}\right)\right] \quad \text{(A.10)}$$

where

| | |
|---|---|
| $\rho_{\text{Calibration Water}}$ | is the density of the calibration water at the test temperature, in grams per cubic centimeter; |
| $\rho_{\text{Distilled Water}}@\,T_{OBS}$ | is the density of distilled water at the test temperature, in degrees Celsius as per the Patterson Morris correlation for the density of water converted to grams per cubic centimeter; |
| $\rho_{\text{VSMOW}}@\,T_{OBS}$ | is the density of VSMOW water at the test temperature, in grams per cubic centimeter and degrees Celsius; |
| $K_{\text{Calibration Water}}@\,T_{OBS}$ | is the measured conductivity of the calibration water, in microsiemens per centimeter; |
| $K_{\text{VSMOW}}@\,T_{OBS}$ | is the electrical conductivity of VSMOW, in microsiemens per centimeter. |

### A.5.7 Calculation for the Determination of the Calibration Water Density in USC Units

$$\rho_{\text{Calibration Water}} = \rho_{\text{Distilled Water}}@T_{OBS} + \left[(\rho_{\text{VSMOW}}@T_{OBS} - \rho_{\text{Distilled Water}}@T_{OBS})\left(\frac{K_{\text{Calibration Water}}@T_{OBS}}{K_{\text{VSMOW}}@T_{OBS}}\right)\right] \quad \text{(A.11)}$$

where

| | |
|---|---|
| $\rho_{\text{Calibration Water}}$ | is the density of the calibration water at the test temperature, in grams per cubic centimeter; |
| $\rho_{\text{Distilled Water}}\,@\,T_{OBS}$ | is the density of distilled water at the test temperature, in degrees Fahrenheit as per the Patterson Morris correlation for the density of water converted to grams per cubic centimeter; |
| $\rho_{\text{VSMOW}}\,@\,T_{OBS}$ | is the density of VSMOW water at the test temperature, in grams per cubic centimeter and degrees Fahrenheit; |
| $K_{\text{Calibration Water}}\,@\,T_{OBS}$ | is the measured conductivity of the calibration water, in microsiemens per centimeter; |
| $K_{\text{VSMOW}}\,@\,T_{OBS}$ | is the electrical conductivity of VSMOW, in microsiemens per centimeter. |

NOTE Consult manufacturers' recommendation for the proper use of the conductivity meter. Some conductivity meters are temperature compensated as per datasheet provided with device.

## A.6 Calculation of the Corrected Mass of the Dispensed Water in the Container

The corrected mass of the water in the container shall be calculated as follows:

$$M_{fl} = AM_{fl} \times CBW \tag{A.12}$$

where

$M_{fl}$ is the corrected mass of water, in grams;

$AM_{fl}$ is the apparent mass of water (as per scale reading), in grams;

$CBW$ is the correction for air buoyancy on weighing.

## A.7 Determination of Dispensed Volume at Test Temperature and Atmospheric Pressure in the Container

The volume of water in the container at the test temperature and atmospheric pressure shall be calculated as follows:

$$DV_W = \frac{M_{fl}}{\rho Wt} \tag{A.13}$$

where

$DVw$ is the dispensed volume of water, in milliliters;

$M_{fl}$ is the mass of water, in grams;

$\rho W_t$ is the density of water at test temperature $t$ and atmospheric pressure, in grams per cubic centimeter [Equation (A.10)].

## A.8 Factors to Correct the Dispensed Volume to Reference Conditions

### A.8.1 Basic Correction for the Effect of Temperature on Steel

The correction for the effect of temperature on steel for displacement provers with internal detectors, assumes a single construction material, and shall be calculated as follows:

$$CTS = \{1 + [(T - Tb)\ Gc]\} \tag{A.14}$$

where

$CTS$ is the basic correction for the effects of temperature on steel;

$Gc$ is the mean coefficient of cubical expansion per degree temperature of the material of which the container is made between $Tb$ and $T$;

$Tb$ is the base temperature;

$T$ is the average liquid temperature in the container.

The correction for the effect of temperature on steel for displacement provers with external detectors, which are not mounted in the calibrated section of the pipe, shall be calculated as follows:

$$CTS = \{(1 + [(Tp - Tb)\ (Ga)])\ (1 + [(Td - Tb)\ (Gl)])\} \tag{A.15}$$

where

$CTS$ is the basic correction for the effects of temperature on steel;

$Ga$ is the area thermal coefficient of expansion for prover chamber;

$Gl$ is the linear thermal coefficient of expansion on displacer shaft;

$Tb$ is the base temperature;

$Td$ is the temperature of the detector mounting shaft or displacer shaft on prover with external detectors;

$Tp$ is the temperature of the prover chamber.

### A.8.2 Basic Correction for the Effect of Pressure on Steel

The correction for the effect of pressure on steel for displacement provers shall be calculated as follows:

$$CPS = 1 + \frac{(Pp \times ID)}{(E \times WT)} \tag{A.16}$$

and

$$ID = [OD - (2 \times WT)] \tag{A.17}$$

where

$CPS$ is the basic correction for pressure effects on steel;

$Pp$ is the internal operating pressure of prover, in gauge pressure units;

$ID$ is the internal diameter of prover;

$E$ is the modulus of elasticity of the metal in the calibrated section of the prover;

$OD$ is the outside diameter of the prover;

$WT$ is the wall thickness of the prover.

### A.8.3 Correction for Effect of Pressure on Water Density

The correction for the effect of pressure on the water density in the prover, shall be calculated using the following equation:

$$CPLp = \frac{1}{[1 - (P \times F)]} \tag{A.18}$$

where

$CPLp$ is the correction for the compressibility of a liquid in a prover;

$P$ is the operating prover pressure, taken at the beginning of the calibration pass when the water is flowing through the solenoid valve line to the receiving container, in gauge pressure units;

$F$ is the compressibility factor for water.

The compressibility factor ($F$) for water utilized in the calibration of provers is defined as:

a) for SI units, a constant ($F$) value 4.64E-07 per kilopascal,

b) for USC units, a constant ($F$) of value 3.20E-06 per pound per square inch.

### A.8.4 Correction Factor for Effect of Temperature on Prover Steel

When performing the gravimetric method, as there are no test measures required, there is no need to correct for the temperature difference between the test measure(s) and the prover. Therefore the equivalent of a combined correction factor ($CTS$), would only require a correction for the effect of temperature on the steel prover ($CTSp$). The total correction for the effect of temperature on the steel prover is as follows for the GM:

$$CTSp = \frac{1}{CTS} \tag{19}$$

where

$CTSp$ is the correction for the total effect of temperature on steel provers when performing the GM calibration;

$CTS$ is the correction for effect of temperature on steel [Equation (A.14) or Equation (A.15)].

## A.9 Waterdraw Base Volume Corrected for *CTSp*

The waterdraw base volume corrected for $CTSp$ shall be as follows:

$$WD = DV_W \times CTSp \tag{A.20}$$

where

$WD$ is the value for a single calibration pass corrected for $CTSp$;

$DV_W$ is the displaced volume of water in container at test temperature and atmospheric pressure [Equation (13)];

$CTSp$ is the correction for the total effect of temperature on steel provers when performing the GM calibration [Equation (A.19)].

## A.10 Waterdraw Value for a Single Calibration Pass Corrected for *CPSp* and *CPLp*

$$WDzb = \frac{WD}{(CPSp \times CPlp)} \tag{A.21}$$

where

$WDzb$ is the $WD$ value for a single calibration pass corrected for $CPSp$ and $CPLp$;

$WD$ is the value for a single calibration pass corrected for $CTSp$ [Equation (18)];

$CPSp$ is the correction for the effect of pressure on steel prover [Equation (14)];

$CPLp$ is the correction for compressibility of the water in prover [Equation (16)].

## A.11 Calibrated Prover Volume Run Sequence Termination

A minimum of three consecutive calibrated prover volumes (CPV)s must be performed to constitute a valid and acceptable calibration.

### A.11.1 Unidirectional Prover

If the prover is unidirectional, then the corrected volume as determined from a single calibration run (pass) of the prover is equal to the CPV. This calibration run is equivalent to an "out" pass only calculation, since the "back" pass calculation is not necessary in a unidirectional prover.

$$WDzb\ (\text{"out"}) = CPV \tag{A.22}$$

where

$WDzb$ is the $WD$ value for a single calibration pass corrected for $CPSp$ and $CPLp$ [Equation (A.21)];

$CPV$ is the calibrated prover volume for a single calibration pass.

### A.11.2 Bidirectional Prover

If the prover is bidirectional, then there is a requirement to make calibration passes in both forward and reverse directions. The reverse ("back") pass is an additional requirement for the purposes of making a complete round-trip. The sum of these two volumes will give the round trip volume for a bidirectional prover.

$$CPV = WDzb\ (\text{"out"}) + WDzb\ (\text{"back"}) \tag{A.23}$$

where

$CPV$ is the calibrated prover volume for a single calibration run;

$WDzb$ ("out") is the $WD$ ("out") value for a single calibration pass corrected for $CPSp$ and $CPLp$ [Equation (19)];

$WDzb$ ("back") is the $WD$ ("back") value for a single calibration pass corrected for $CPSp$ and $CPLp$ [Equation (19)].

## A.12 Calibrated Prover Repeatability Range Acceptability

For both a unidirectional and a bidirectional prover, a minimum of three consecutive CPVs, must all be within a range of 0.020 % to constitute a valid and acceptable calibration.

For a bidirectional prover three or more acceptable consecutive outward passes, $WDzb$ ("out"), must be within a range of 0.020 % and three or more acceptable consecutive backward passes, $WDzb$ ("back"), must be within a range of 0.020 %.

The repeatability range shall be calculated as follows:

$$\text{Repeatability (\%)} = \frac{(\text{highest } CPV - \text{lowest } CPV)}{(\text{lowest } CPV)} \times 100 \tag{A.24}$$

## A.13 BPV Calculation

The BPV for both a unidirectional and a bidirectional prover at reference conditions shall be calculated from the average of three or more consecutive CPVs as follows:

$$BPV = \frac{CPV(1) + CPV(2) + CPV(3)}{3} \tag{A.25}$$

or

$$BPV = \frac{\Sigma CPV(n)}{n} \tag{A.26}$$

where

$BPV$ is the base prover volume of the prover at reference conditions;

$CPV$ is the calibrated prover volume for a single calibration run;

$n$ is the number of acceptable consecutive runs.

Round the $BPV$ value in accordance with the requirement specified in API *MPMS* Ch. 12.2.4.

If any of the above criteria is not satisfied, then another calibration run sequence must be initiated until all the requirements for an acceptable prover calibration have been met.

Once all the above criteria have been satisfied, determine the BPV as the certified volume of the prover, and convert into the required volume units as described in API *MPMS* Ch. 12.2.4.

**Table A.1—Equation Reference Standards and Publications**

| Equation No. | *MPMS*/Working Group Reference | Section |
|---|---|---|
| Equation (A.1) | *MPMS* Ch. 14.6-2006 | 14.6.18.2.1 |
| Equation (A.2) | *MPMS* Ch. 14.6-2006 | 14.6.18.2.1 |
| Equation (A.3) | *MPMS* Ch. 14.6-2006 | 14.6.6.6.3 |
| Equation (A.4) | *MPMS* Ch. 11.4.1-2006 | 11.4.5.1 |
| Equation (A.5) | *MPMS* Ch. 11.4.1-2008 | 11.4.5.1 |
| Equation (A.6) | *MPMS* 4.9.4-2010 | A.5.2 |
| Equation (A.7) | *MPMS* .4.9.4-2010 | A.5.3 |
| Equation (A.8) | *MPMS* 4.9.4-2010 | A.5.4 |
| Equation (A.9) | *MPMS* 4.9.4-2010 | A.5.5 |
| Equation (A.10) | *MPMS* 4.9.4-2010 | A.5.6 |
| Equation (A.11) | *MPMS* 4.9.4-2010 | A.5.7 |
| Equation (A.12) | *MPMS* Ch. 14.6-2003 | 14.6.6.6.3 |
| Equation (A.13) | *MPMS* 4.9.4-2010 | A.7 |
| Equation (A.14) | *MPMS* Ch. 12.2.4-2009 | 10.2.1.1 |
| Equation (A.15) | *MPMS* Ch.12.2.4-2009 | 10.2.1.2 |
| Equation (A.16) | *MPMS* Ch. 12.2.4-2009 | 10.2.2.1 |
| Equation (A.17) | *MPMS* Ch. 12.2.4-2009 | 10.2.2.1 |
| Equation (A.18) | *MPMS* Ch.12.2.4-2009 | 10.1.2 |
| Equation (A.19) | Derived from *MPMS* Ch. 12.2.4-2009 | Derived from 10.3 |
| Equation (A.20) | Derived from *MPMS* Ch. 12.2.4-2009 | Derived from 12.2.3, Step 3 |
| Equation (A.21) | *MPMS* Ch. 12.2.4-2009 | Derived from 12.2.3, Step 6 |
| Equation (A.22) | *MPMS* Ch. 12.2.4-2009 | 12.1.4 |
| Equation (A.23) | *MPMS* Ch. 12.2.4-2009 | 12.1.4 |
| Equation (A.24) | *MPMS* Ch. 12.2.4-2009 | 12.1.4 |
| Equation (A.25) | *MPMS* Ch. 12.2.4-2009 | 12.1.4 |
| Equation (A.26) | *MPMS* Ch. 12.2.4-2009 | 12.1.4 |

# Annex B
(informative)

# Dynamic Prover Volume Calculation, Gravimetric Method (GM)—SI Units [5]

### Calibration of Positive Displacement Provers with External Detectors Example—Density Correction Factor for Calibration Water by Conductivity Measurement

[5] The examples above are merely for illustration purposes only (each company should develop its own approach). They are not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied, for reliance on or any omissions from the information contained in this document.

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Where applicable, authorities having jurisdiction should be consulted.

# Gravimetric Method - SI units

| | | | | | |
|---|---|---|---|---|---|
| Company: | API WG 4.9.4 | Prover Serial Number: | ST-0205161 | Date: | 2007-05-01 (YYYY-MM-DD) |
| Location: | ANYTOWN, CANADA | Prover Model Number: | S50C3C2E2 | | |

| | | | |
|---|---|---|---|
| Area thermal coefficient of expansion for prover chamber , Ga (°C) | 3.46E-05 | Prover Inside Diameter (mm) | 520.73 |
| Flow Tube Modulus of Elasticity (kPa) | 1.93E+08 | Prover Wall Thickness (mm) | 64.12 |
| Linear thermal coefficient of expansion on displacer shaft, Gl (°C) | 1.12E-05 | Standard Temperature (°C) | 15.00 |
| Compressibility factor of water in the prover, Fp (kPa) | 4.64E-07 | Standard Pressure (kPag) | 0.0 |
| Reference Weight Density SS ($g/cm^3$) | 7.84 | Standard Pressure (kPaa) | 101.325 |
| Field Weight Density CS ($g/cm^3$) | 7.20 | Elev. @ Anytown (meters) | 438.9 |

| Line # | Data | Calc Procedure | Acquired Data | Run 1 | Run 2 | Run 3 |
|---|---|---|---|---|---|---|
| 1 | I/P | | Apparent Mass of Water (g) | 150698 | 150694 | 150690 |
| 2 | I/P | | Air Temperature (°C) | 25.00 | 25.00 | 25.00 |
| 3 | I/P | | Switch Bar Temperature (°C) | 25.00 | 25.00 | 25.00 |
| 4 | I/P | | Prover Temperature (°C) | 20.00 | 20.00 | 20.00 |
| 5 | I/P | | Prover pressure (kPag) | 234.0 | 234.0 | 234.0 |
| 6 | I/P | For Dist Water enter 0 | Calibration Water Electrical Conductivity (µS) | 25.0 | 26.0 | 27.0 |
| 7 | I/P | | Run Time (sec) | 345 | 783 | 302 |
| | | | **Calculated Densities** | | | |
| 8 | eq 1 | | Density of Ambient Air ($g/cm^3$) | 0.001130 | 0.001130 | 0.001130 |
| 9 | eq 4 | | Density of Distilled Water @ Test Temp ($g/cm^3$) | 0.998206 | 0.998206 | 0.998206 |
| 10 | eq 6 | | Density of VSMOW Water @ Test Temp ($g/cm^3$) | 1.024763 | 1.024763 | 1.024763 |
| 11 | eq 8 | | K value of VSMOW Water @ Test Temp (µS/cm) | 47934 | 47934 | 47934 |
| 12 | eq 10 | L9 +((L10-L9) * (L6/L11)) | Density of Water in Container ($g/cm^3$) | 0.998220 | 0.998220 | 0.998221 |
| | | | **Volume Calculation** | | | |
| 13 | eq 3 | | CBW (Correction for Buoyancy of Weights) | 1.000990 | 1.000990 | 1.000990 |
| 14 | eq 12 | Line 1 * Line 13 | Corrected Mass of Water (g) | 150847.191 | 150843.187 | 150839.183 |
| 15 | eq 13 | Line 14 / Line 12 | Dispensed Water @ Test Temp & 0.0 kPag (ml) | 151116.200 | 151112.105 | 151108.010 |
| | | | **Factors for Correction to Standard Conditions** | | | |
| 16 | eq 15 | | Effect of Temp on Flow Tube Steel (CTS) | 1.000284 | 1.000284 | 1.000284 |
| 17 | eq 16 | | Effect of Pressure on Flow Tube (CPSp) | 1.000010 | 1.000010 | 1.000010 |
| 18 | eq 18 | | Effect of Pressure on Liquid in Flow Tube (CPLp) | 1.000109 | 1.000109 | 1.000109 |
| 19 | eq 19 | 1 / Line 16 | Correction for Temp Effect on the Prover (CTSp) | 0.999716 | 0.999716 | 0.999716 |
| 20 | eq 20 | Line 15 * Line 19 | WD = Disp Vol * CCTS | 151073.283 | 151069.189 | 151065.095 |
| 21 | eq 21 | L20 / (L17 * L18) | WDzb = WD / (CPSp * CPLp) | 151055.307 | 151051.214 | 151047.120 |
| 22 | eq 22 | | Calibrated Prover Volume per Run, (CPV) | 151055.307 | 151051.214 | 151047.120 |

| | | | | | |
|---|---|---|---|---|---|
| 23 | eq 25 | ΣLine 22 / nLine 22 | Base Prover Volume (BPV) @ 0.0 kPag & 15.00 °C | 151051.214 | ml |
| 24 | eq 24 | | Repeatability % | 0.0054 | |
| 25 | eq 25 | | CERTIFIED PROVER VOLUME @ 0.0 kPag & 15.00 °C | 151.051 | litres |
| | | | or | | |
| 26 | eq 25 | | CERTIFIED PROVER VOLUME @ 0.0 kPag & 15.00 °C | 0.151051 | $m^3$ |

| Previous Waterdraw: (YYYY-MM-DD) | Previous Volume ($m^3$) | Change in BPV (%) | Certified Thermometer | Weigh Scale Ser # |
|---|---|---|---|---|
| 2005-05-01 | 0.151044 | 0.0046 | 12345 | 6789 |

Comments: ______________________________

Performed By: ____________________ Date: 2007-05-01 (YYYY-MM-DD)

Witnessed By: ____________________ Date: 2007-05-01 (YYYY-MM-DD)

# Annex C
(informative)

# Dynamic Prover Volume Calculation, Gravimetric Method (GM)—USC Units [6]

## Calibration of Positive Displacement Prover with External Detectors Example—Density Correction Factor for Calibration Water by Conductivity Measurement

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# Gravimetric Method - USC units

**Company:** API WG 4.9.4 **Prover Serial Number:** ST-0205161 **Date:** 01-05-2007 (DD-MM-YYYY)

**Location:** ANYTOWN, USA **Prover Model Number:** S50C3C2E2

| | | | |
|---|---|---|---|
| Area thermal coefficient of expansion for prover chamber, Ga (°F) | 1.92E-05 | Prover Inside Diameter (in) | 20.501 |
| Flow Tube Modulus of Elasticity (Psi) | 2.80E+07 | Prover Wall Thickness (in) | 2.525 |
| Linear thermal coefficient of expansion on displacer shaft, Gl (°F) | 6.20E-06 | Standard Temperature (°F) | 60.0 |
| Compressibility factor of water in the prover, Fp (Psi) | 3.20E-06 | Standard Pressure (Psig) | 0.0 |
| Reference Weight Density SS (g/cm$^3$) | 7.84 | Standard Pressure (Psia) | 14.696 |
| Field Weight Density CS (g/cm$^3$) | 7.20 | Elev. @ Anytown (feet) | 1440.0 |

| Line # | Data | Calc Procedure | Acquired Data | Run 1 | Run 2 | Run 3 |
|---|---|---|---|---|---|---|
| 1 | I/P | | Apparent Mass of Water (g) | 150698 | 150694 | 150690 |
| 2 | I/P | | Air Temperature (°F) | 77.0 | 77.0 | 77.0 |
| 3 | I/P | | Switch Bar Temperature (°F) | 77.0 | 77.0 | 77.0 |
| 4 | I/P | | Prover Temperature (°F) | 68.0 | 68.0 | 68.0 |
| 5 | I/P | | Prover pressure (Psig) | 34.0 | 34.0 | 34.0 |
| 6 | I/P | For Dist Water enter 0 | Calibration Water Electrical Conductivity (µS) | 25.0 | 26.0 | 27.0 |
| 7 | I/P | | Run Time (sec) | 345 | 783 | 302 |
| | | | **Calculated Densities** | | | |
| 8 | eq 2 | | Density of Ambient Air (g/cm$^3$) | 0.001130 | 0.001130 | 0.001130 |
| 9 | eq 5 | | Density of Distilled Water @ Test Temp (g/cm$^3$) | 0.998206 | 0.998206 | 0.998206 |
| 10 | eq 7 | | Density of VSMOW Water @ Test Temp (g/cm$^3$) | 1.024763 | 1.024763 | 1.024763 |
| 11 | eq 9 | | K value of VSMOW Water @ Test Temp (µS/cm) | 47934 | 47934 | 47934 |
| 12 | e110 | L9 +((L10-L9) * (L6/L11)) | Density of Water in Container (g/cm$^3$) | 0.998220 | 0.998220 | 0.998221 |
| | | | **Volume Calculation** | | | |
| 13 | eq 3 | | CBW (Correction for Buoyancy of Weights) | 1.000990 | 1.000990 | 1.000990 |
| 14 | eq 12 | Line 1 * Line 13 | Corrected Mass of Water (g) | 150847.191 | 150843.187 | 150839.183 |
| 15 | e1 13 | Line 14 / Line 12 | Dispensed Water @ Test Temp & 0.0 Psig (ml) | 151116.200 | 151112.105 | 151108.010 |
| | | | **Factors for Correction to Standard Conditions** | | | |
| 16 | eq 15 | | Effect of Temp on Flow Tube Steel (CTS) | 1.000259 | 1.000259 | 1.000259 |
| 17 | eq 16 | | Effect of Pressure on Flow Tube (CPSp) | 1.000010 | 1.000010 | 1.000010 |
| 18 | eq 18 | | Effect of Pressure on Liquid in Flow Tube (CPLp) | 1.000109 | 1.000109 | 1.000109 |
| 19 | eq 19 | 1 / Line 16 | Correction for Temp Effect on the Prover (CTSp) | 0.999741 | 0.999741 | 0.999741 |
| 20 | eq 20 | Line 15 * Line 19 | WD = Disp Vol * CCTS | 151077.061 | 151072.967 | 151068.873 |
| 21 | eq 21 | L20 / (L17 * L18) | WDzb = WD / (CPSp * CPLp) | 151059.085 | 151054.991 | 151050.898 |
| 22 | eq 22 | | Calibrated Prover Volume per Run, (CPV) | 151059.085 | 151054.991 | 151050.898 |

| Line # | Data | Calc Procedure | | | |
|---|---|---|---|---|---|
| 23 | eq 25 | ΣLine 22 / nLine 22 | Base Prover Volume (BPV) @ 0.0 Psig & 60.0 °F | 151054.991 | ml |
| 24 | eq 24 | | Repeatability % | 0.0054 | |
| 25 | eq 25 | | CERTIFIED PROVER VOLUME @ 0.0 Psig & 60.0 °F | 0.950107 | Bbl |
| | | | or | | |
| 26 | eq 25 | | CERTIFIED PROVER VOLUME @ 0.0 Psig & 60.0 °F | 39.9045 | USgal |

| Previous Waterdraw: (DD-MM-YYYY) | Previous Volume (USgal) | Change in BPV (%) | Certified Thermometer | Weigh Scale Ser # |
|---|---|---|---|---|
| 01-05-2005 | 39.9029 | 0.0040 | 12345 | 6789 |

**Comments:** ______________________

**Performed By:** ______________________ **Date:** 01-05-2007 (DD-MM-YYYY)

**Witnessed By:** ______________________ **Date:** 01-05-2007 (DD-MM-YYYY)

# Annex D
(informative)

# Weigh Scale Verification Gravimetric Method (GM) (Example) [7]

| | | | |
|---|---|---|---|
| Job Number: | 13001 | Customer: | ABC Oil Company |
| Prover Serial Number: | ST9600935 | Model Number: | S-25 |
| Nominal Volume: | 20 gallons | Expected Mass: | 75.659 kg |
| Scale Serial Number: | 5682 S-02 | Scale Range: | 0-330 kg |
| Container Volume: | 40 gallons | Container Mass: | 18.000 kg |

Test Weight(s):

| Serial Number | Nominal Mass | As Left Mass | Aggregate Mass |
|---|---|---|---|
| 123 | 22.000 kg | 0.125 kg | 22.125 kg |
| 124 | 22.000 kg | 0.126 kg | 22.126 kg |
| 125 | 22.000 kg | 0.124 kg | 22.124 kg |
| 121 | 22.000 kg | 0.125 kg | 22.125 kg |

Total Aggregate Mass: 88.500 kg

Total Mass: 93.659 kg

Target Mass: 74.927 kg to 112.391 kg

Weight Scale Verification:

| Zero in kg | Aggregate Mass in kg | Indication Mass in kg | Diff in kg | Allowable Diff in kg | Diff from Allowable |
|---|---|---|---|---|---|
| 0.001 | 88.500 | 88.501 | 0.001 | 0.0044 | -0.0034 |
| 0.000 | 88.500 | 88.500 | 0.000 | 0.0044 | -0.0044 |

Comments:

Technician:____________________ Witness:____________________

Date:____________________ Witness:____________________

[7] The examples above are merely for illustration purposes only (each company should develop its own approach). They are not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied, for reliance on or any omissions from the information contained in this document.

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# Annex E
(informative)

# Run Datasheet Gravimetric Method (GM) (Example) [8]

## Calibration Data

| | | | |
|---|---|---|---|
| Serial Number: | ADC 123 | Customer: | ABC Oil |
| Job Number: | 0407CH | Model Number: | S-05 |

| | | | |
|---|---|---|---|
| Compressibility factor (water) | 3.2E-06 | Area Thermal Expansion Coefficient (Ga) | 1.920E-05 |
| Elevation | 25 | Detector Thermal Expansion Coefficient (Gl) | 6.200E-06 |
| Standard Temperature (°F) | 60.0 | Modulus of Elasticity (flow tube) (E) | 2.80E+07 |
| Standard Pressure (psig) | 0.0 | Flow Tube Inside Diameter (inches) (ID) | 10.0000 |
| Field Test Weight Density (gm/cc) | 7.2 | Flow Tube Wall Thickness (inches) (WT) | 1.3500 |
| | | Flow Tube Material | 304 SS |

| Acquired Data | Fill 1 | Fill 2 | Fill 3 | Fill 4 | Fill 5 |
|---|---|---|---|---|---|
| Run Time (sec) | 136.0 | 218.0 | 138.0 | 218.0 | 138.0 |
| Flow Rate (GPM) | 2.206 | 1.376 | 2.174 | 1.376 | 2.174 |
| Water Conductivity | 2 | 2 | 2 | 2 | 2 |
| Expected Mass of Water (Ww) (gm) | 18812.2 | 18812.2 | 18812.2 | 18811.8 | 18811.2 |
| Air Temperature (°F) | 75.7 | 76.4 | 77.0 | 77.5 | 78.1 |
| Detector Bar Temperature (Td) (°F) | 75.8 | 76.3 | 76.9 | 77.2 | 77.7 |
| Prover Temperature (Tp) (°F) | 77.6 | 77.8 | 78.0 | 78.2 | 78.5 |
| Prover pressure (Pp) (psig) | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 |

**Laboratory Conditions** 60 % (rh)
Barometric Pressure 29.93 inches Hg. 78.0 Ambient ( F)

| **Calibration Instruments** | Range | Serial Number | Calibration Date |
|---|---|---|---|
| Pressure | 0-100 psi | 716605 | 12/9/2003 |
| Temperature | 30-124F | 351035 | 12/22/2003 |
| Mass | 50 lb | S687,688,689,A | 10/15/2001 |
| Scale | 660 lb. | 81002728 | 3/5/2003 |

Witnessed: Date:

Performed By.

Comments: Installed new volume switch

[8] The examples above are merely for illustration purposes only (each company should develop its own approach). They are not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied, for reliance on or any omissions from the information contained in this document.

Users of this example should not rely exclusively on the information contained in this document. Sounds business, scientific, engineering, and safety judgement should be used in employing the information contained herein.

Where applicable, authorities having jurisdiction should be consulted.

# Annex F
(informative)

# Tank Prover Volume Calibration Gravimetric Method (GM)—USC Units (Distilled Water) (Example) [9]

| | | | |
|---|---|---|---|
| Manufacturer: | Seraphin | Customer: | ABC Oil |
| Serial Number: | ST 0299172 | Location: | Anywhere USA |
| Report Number: | 0704CH | Prover Owner: | XYZ Oil Co. |
| Elevation (feet): | 1.44E+03 | Standard Volume: | 40 gallons |
| Standard Temperature (?F): | 60 | Tank Material: | Carbon Steel |
| Standard Pressure (psig): | 0 | Cubical Coff. (Gc) | 1.86E-06 |
| Field Test Weight Density (g/cm$^3$) | 7.20 | $H_2O$ Conductivity: | 0 |
| Reference Weight Density (g/cm$^3$) | 7.84 | | |

| | Fill 1 | Fill 2 |
|---|---|---|
| Flow Rate (GPM) | 5.0 | 3.5 |
| **Acquired Data** | | |
| Expected mass of Water (Ww) (g) | 150698 | 150694 |
| Air Temperature (°F) | 77.0 | 77.0 |
| Water Temperature (°F) | 68.0 | 68.0 |
| **Calculated Densities** | | |
| Density of Air (DENa) (g/cm$^3$) | 0.001130 | 0.001130 |
| Water Density (RHOw) (g/cm$^3$) | 0.998206 | 0.998206 |
| Correction Buoyancy of Air | 1.000990 | 1.000990 |
| **Volume Calculation** | | |
| True Mass of Water (Mw) (g) | 150847.2 | 150847.2 |
| Volume of Water Dispensed (mL) | 151118.4 | 151118.4 |
| **Factors for Correction to Base Conditions** | | |
| Temperature Correction CTSp | 1.000015 | 1.000015 |
| CCTS | 0.999985 | 0.999985 |
| **Volume at Base Conditions (WD)** | 151116.13 | 151116.13 |
| % Run Deviation from Average | -0.000% | 0.000% |
| **% Run Repeatability** | **0.000%** | |

**Base Prover Volume (BVP)** **151116.3 mL**
9221.62 **cubic inches**
39.9204 **gallons**

Previous Volume 39.9228 gallons — Previous Calibration Date: 02/04/2000
Difference -0.006%

Performed By: ____________________ — Date: 02/05/2005
Witnessed: ____________________ — For: ABC Testing

[9] The examples above are merely for illustration purposes only (each company should develop its own approach). They are not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied, for reliance on or any omissions from the information contained in this document.

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# Annex G
(informative)

# Figures

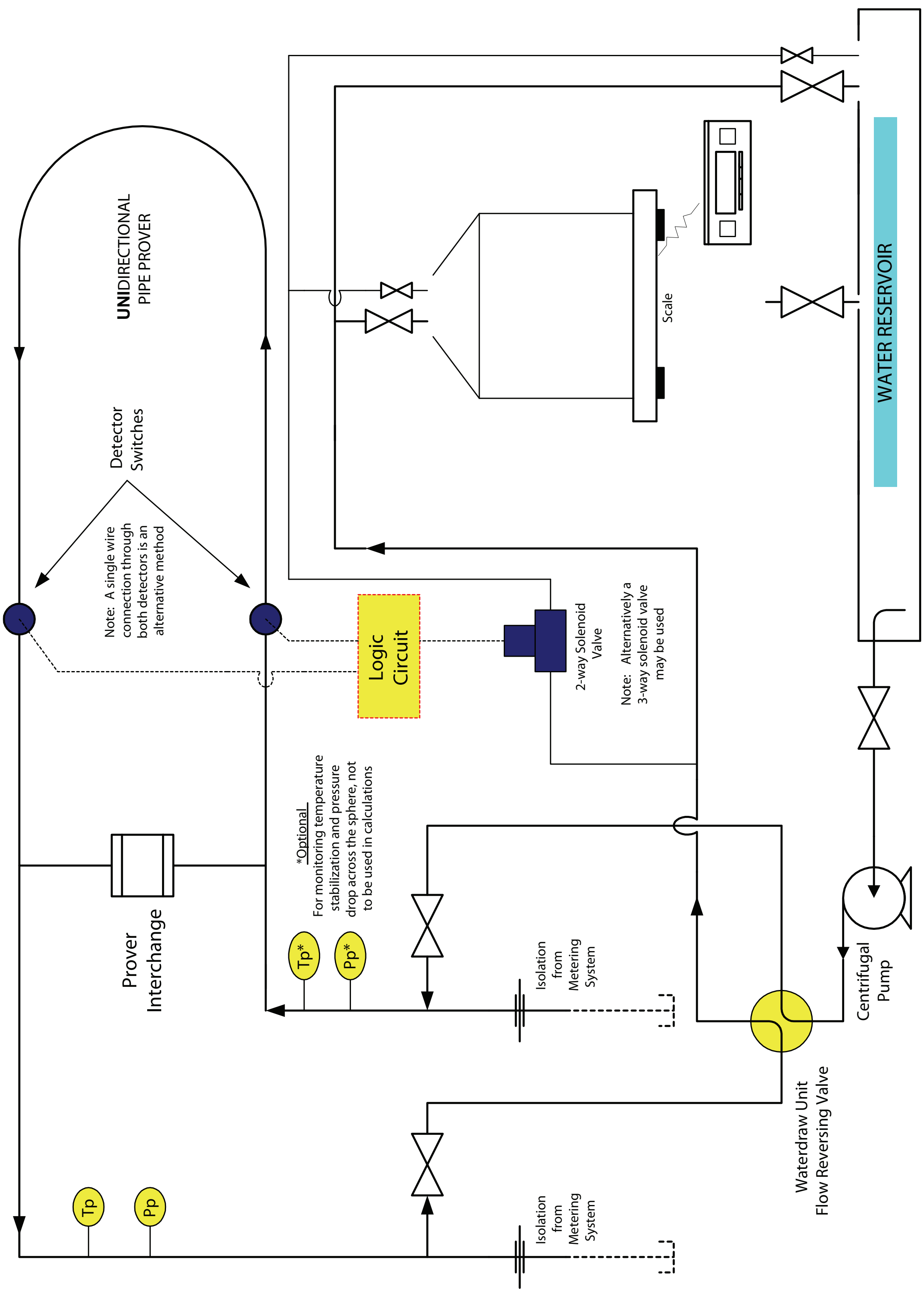


**Figure 1—Gravimetric Calibration of a Displacement Type Unidirectional Prover with a Free Displacer**

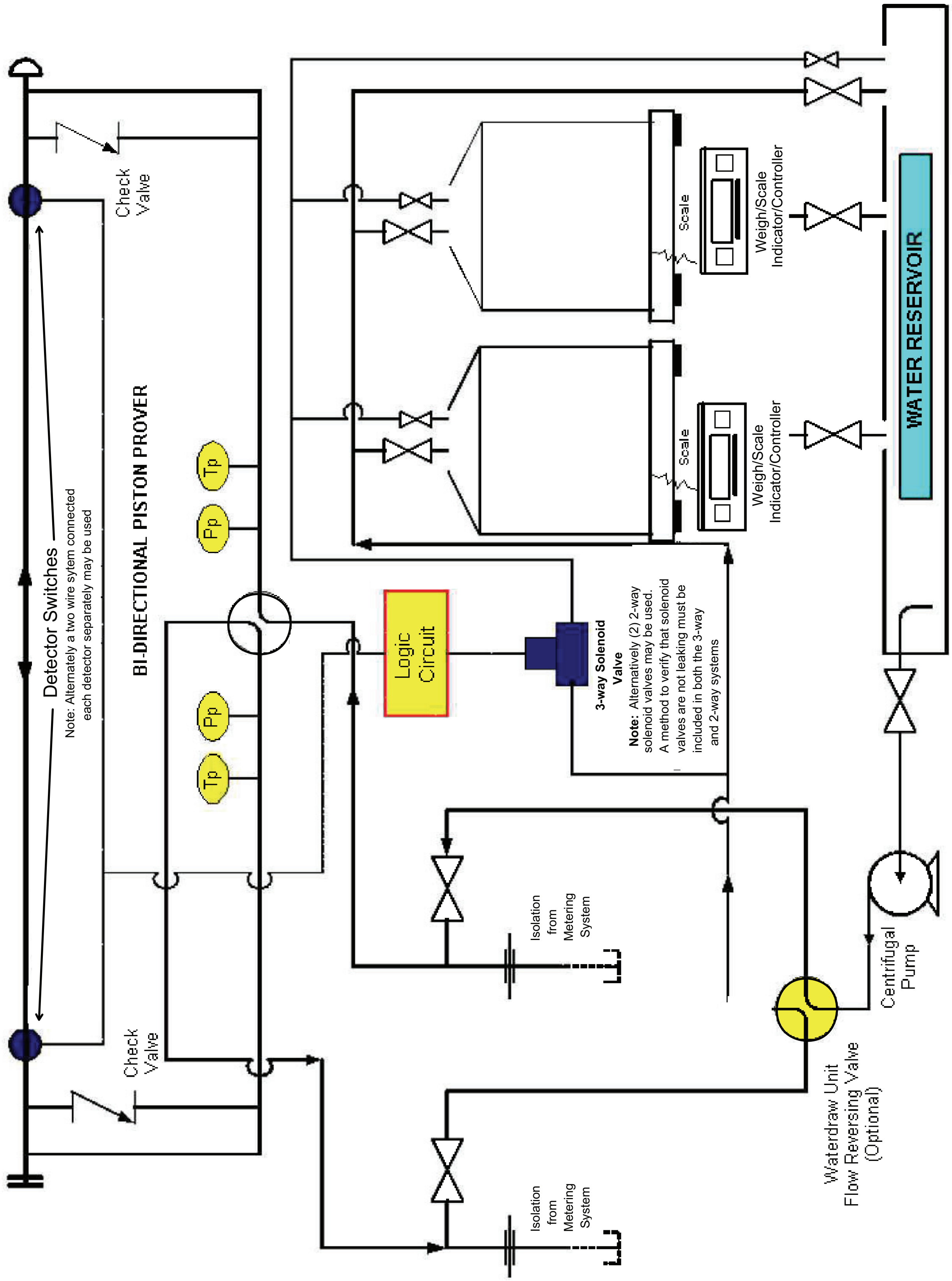


**Figure 2A—Gravimetric Calibration Displacement Type Bi-Directional Prover with a Free Piston Displacer and Check Valves in the Manifold**

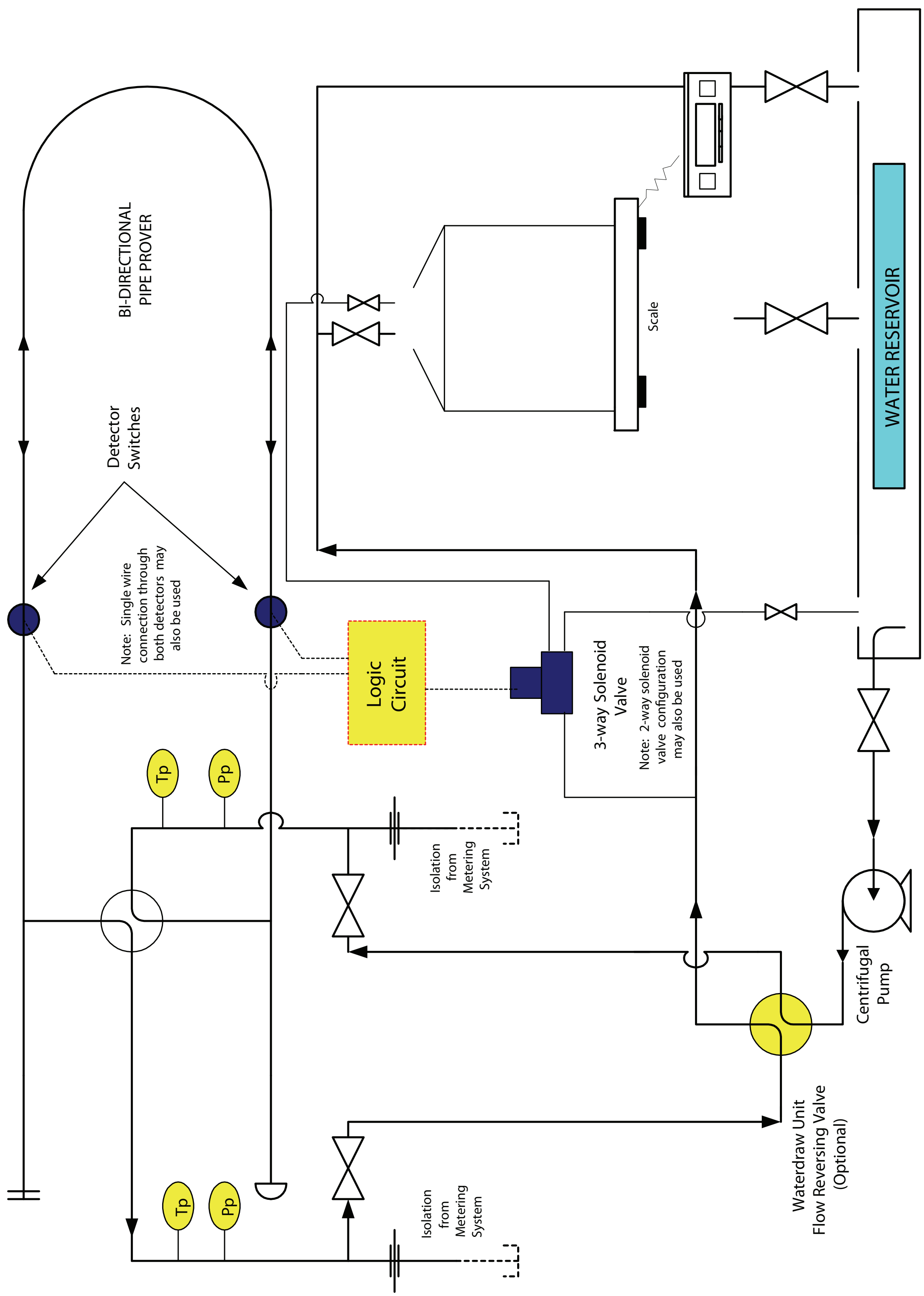


**Figure 2B—Gravimetric Calibration of a Displacement Type Bi-directional Prover with a Free Sphere Displacer**

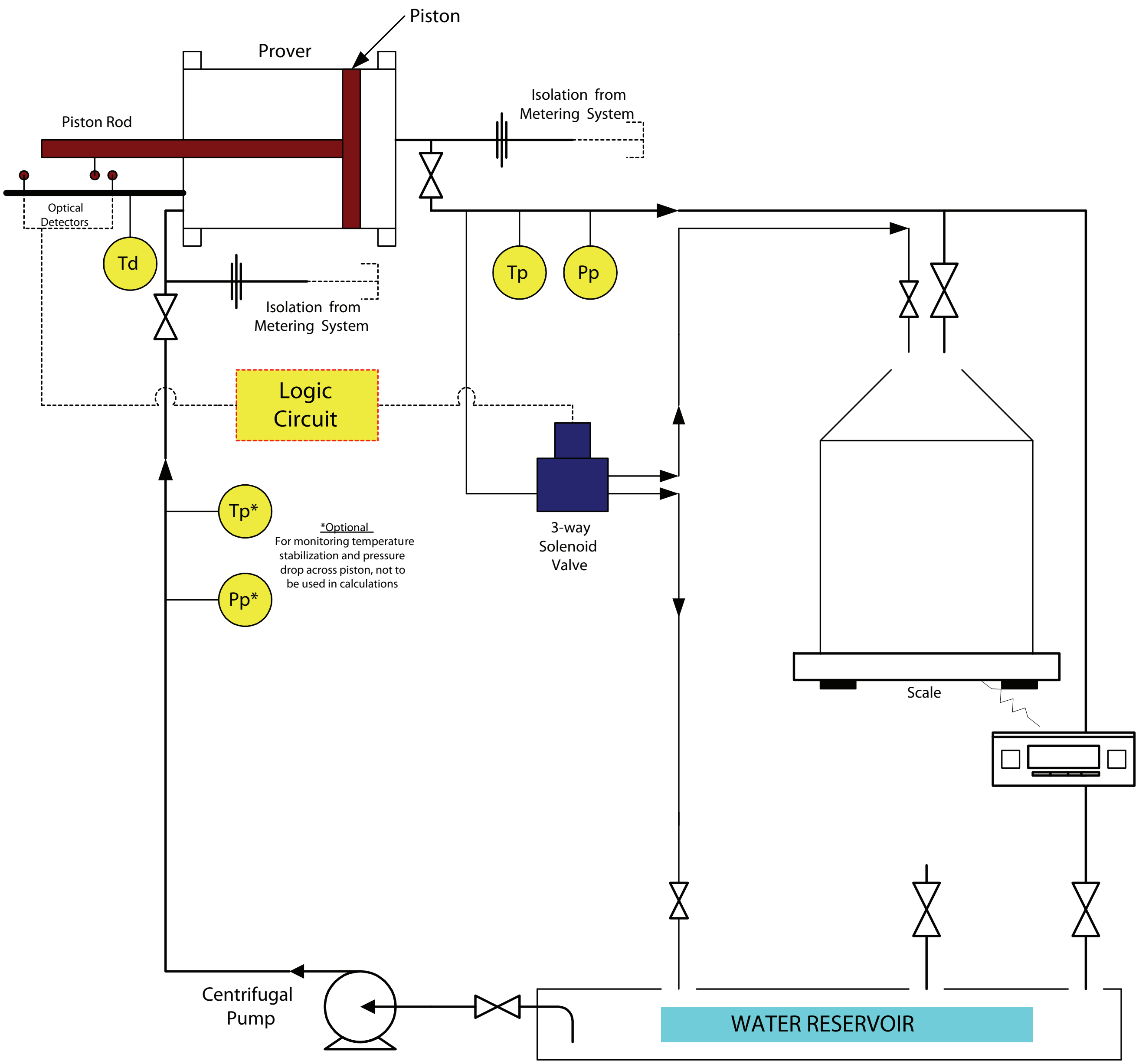


**Figure 3A—Gravimetric Calibration of the Downstream Volume of a Displacement Prover with a Captive Displacer and External Directors**

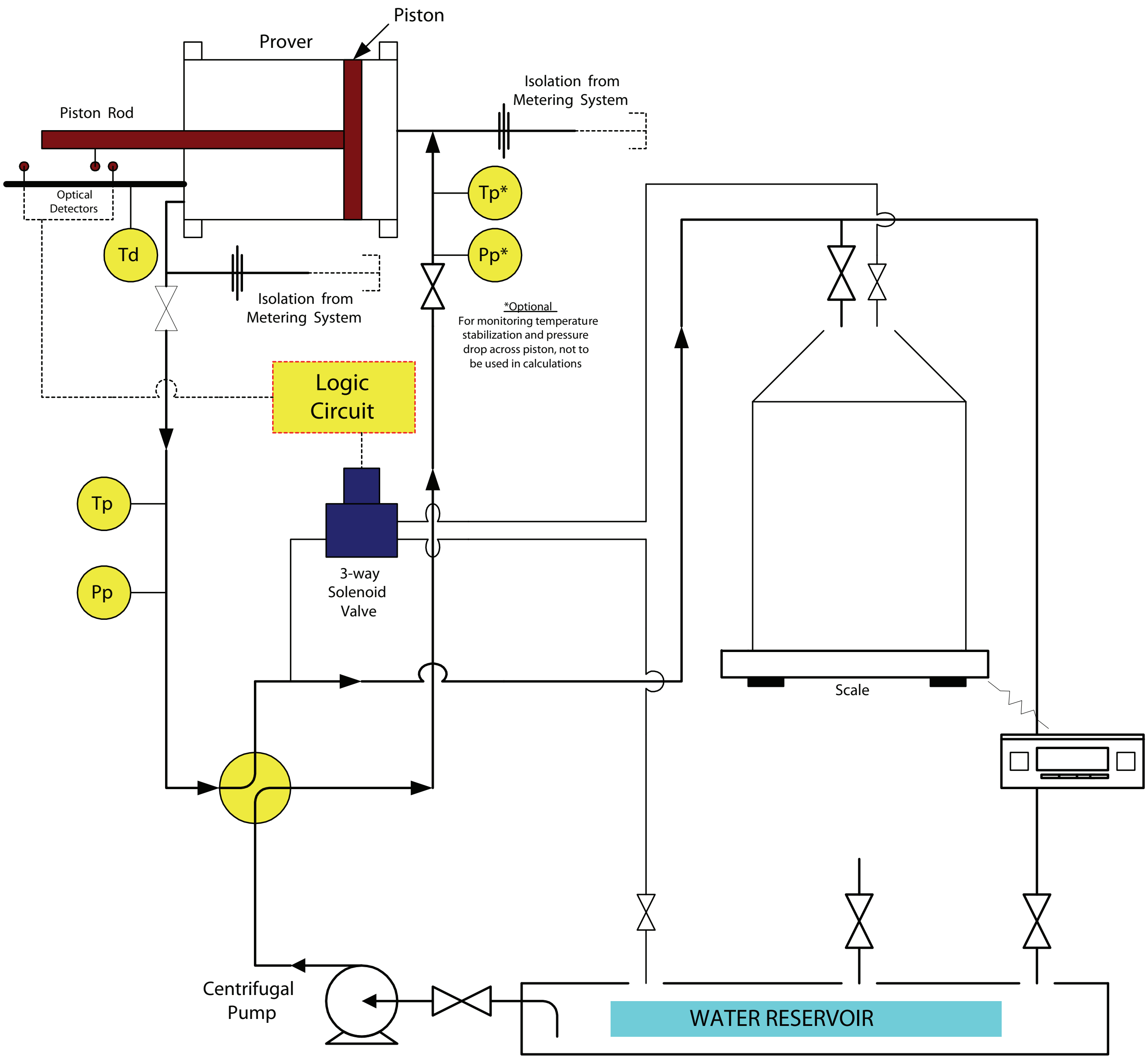


**Figure 3B—Gravimetric Calibration of the Upstream Volume of a Displacement Prover with a Captive Displacer and External Detectors**

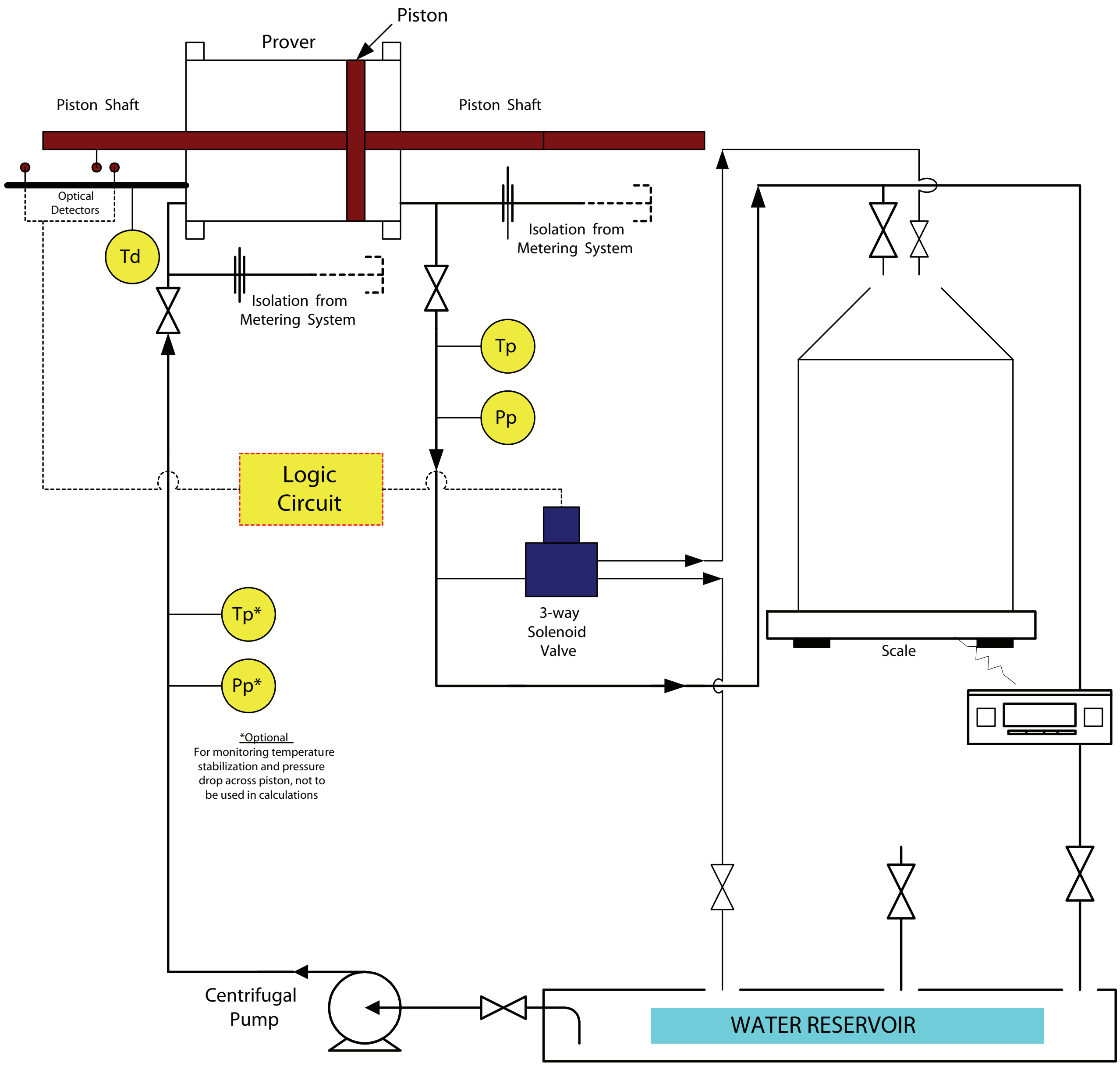


**Figure 3C—A Gravimetric Calibration of a Displacement Prover with Equal Size Diameter Shafts on Both Sides of a Captive Displacer, with External Detectors**

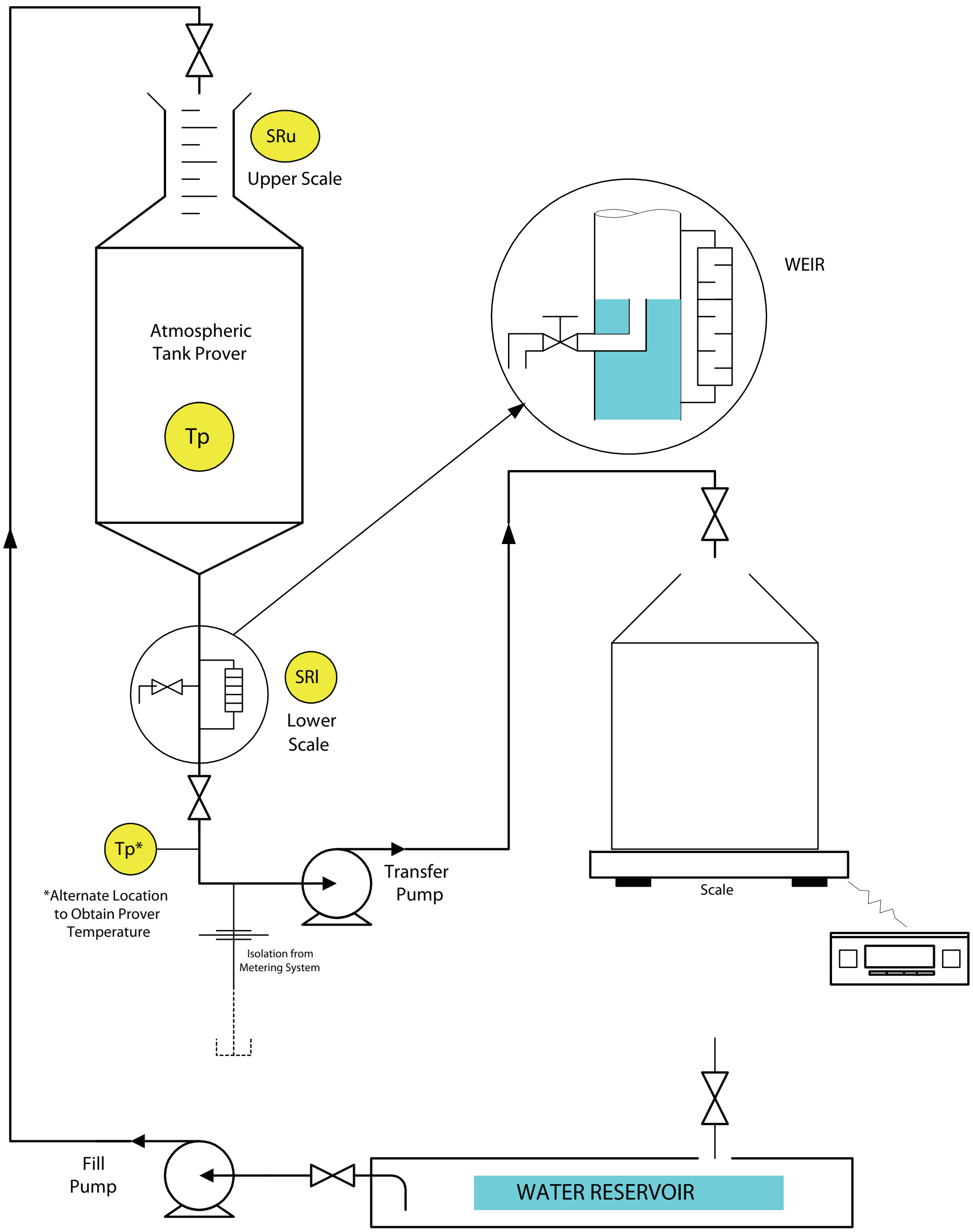


**Figure 4A—Waterdraw Calibration of a Volumetric Tank Prover with a Bottom-Weir**

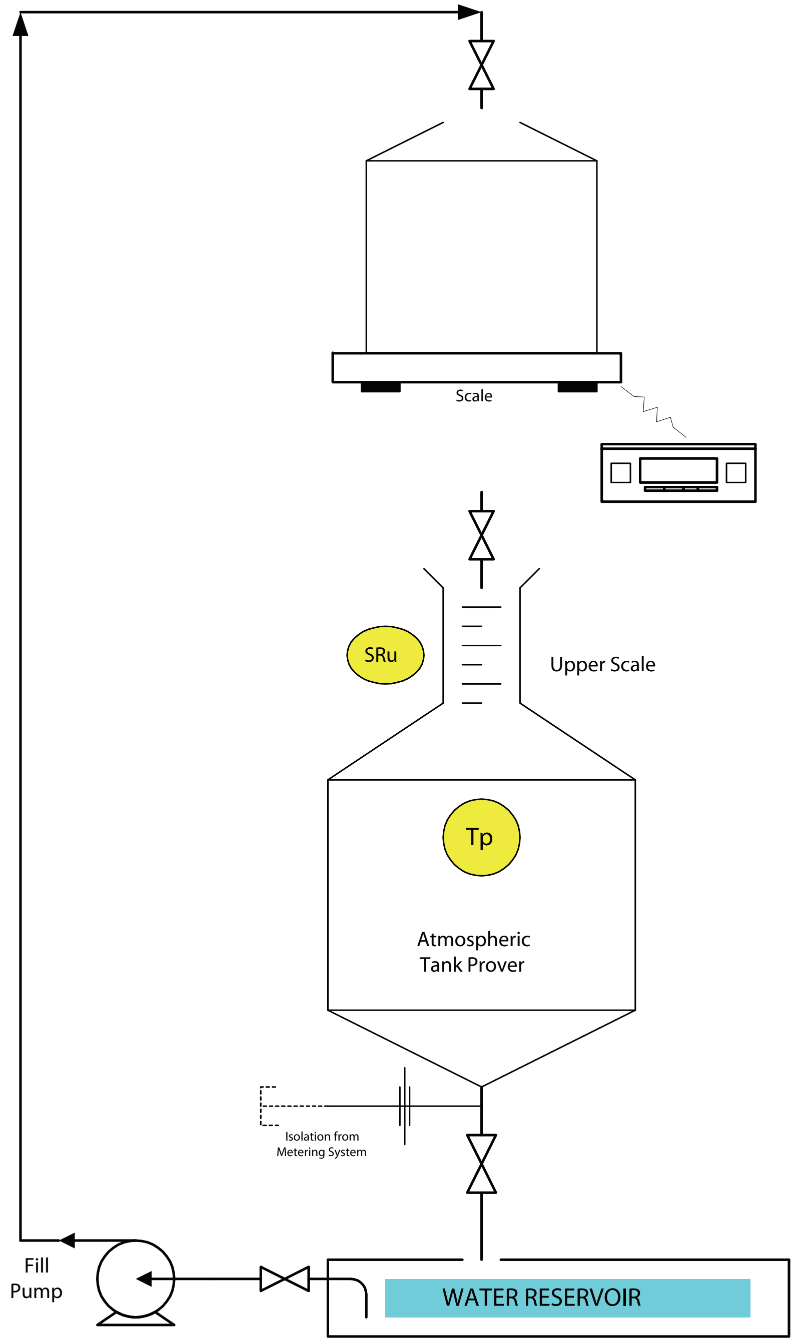


**Figure 4B—Gravimetric Calibration of a Volumetric Tank Prover with a Dry Bottom using the Water-fill Method**

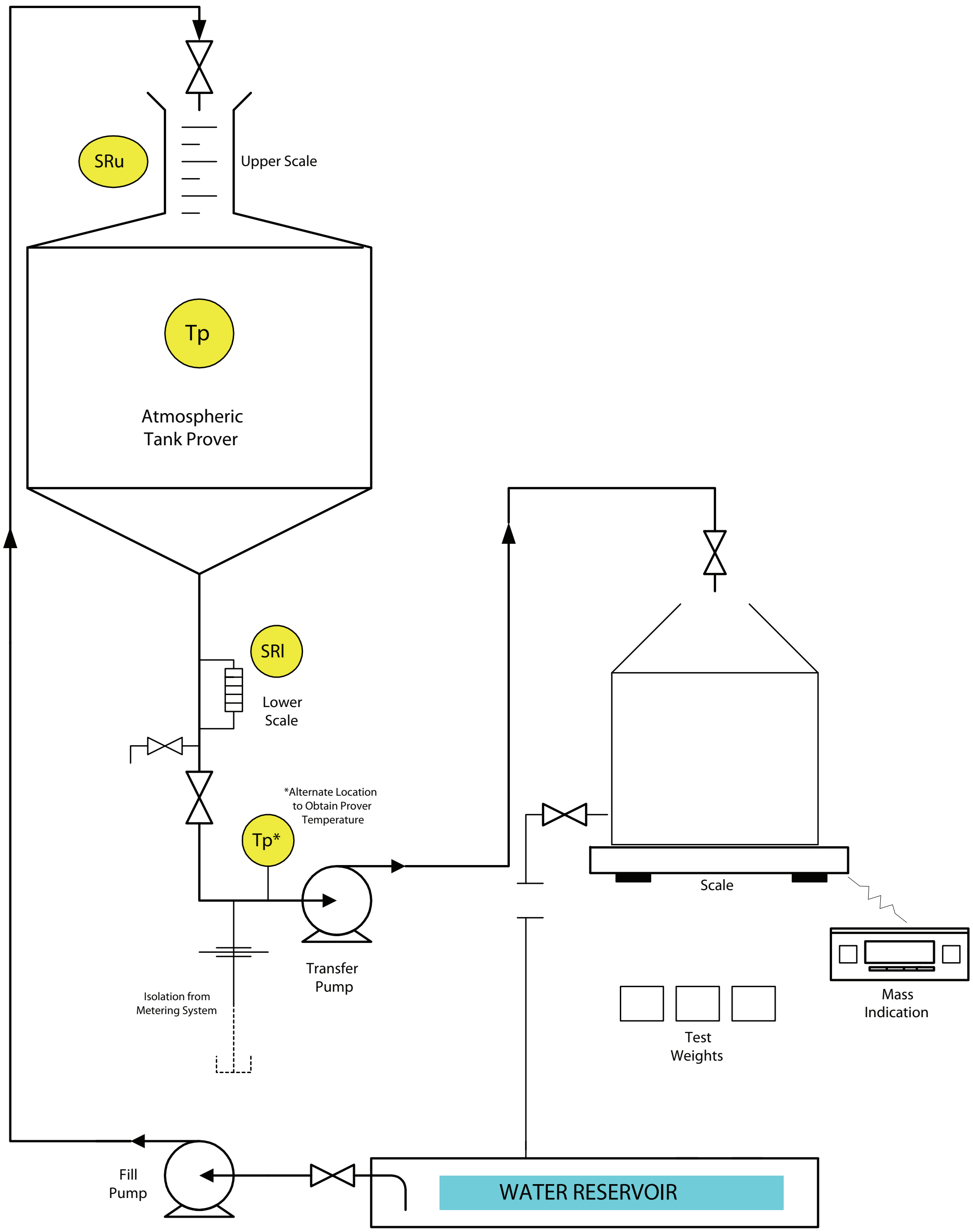


**Figure 4C—Gravimetric Calibration of a Volumetric Tank Prover with a Wet Bottom**

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