Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures

3. Specifications and Tolerances for Graduated Neck Type Volumetric Field Standards

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The 1997 revision of Handbook 105-3 includes the following changes since it was last published in 1979:

1. References to the National Bureau of Standards (NBS) have been replaced by the National Institute of Standards and Technology (NIST).

2. Reference to and incorporation of international standards (such as those of the International Organization for Legal Metrology, OIML) and national industry standards (such as those of the American Society for Testing and Materials, ASTM) have been made where possible.

3. The addition of references to direct the user to publications that will assist with effective use of field standards as described herein.

Additionally, the process for updating the publication has changed to include the following:

1. Conversion of the previous handbook to electronic media to allow future changes to be incorporated in a more timely manner.

2. Organized peer review to ensure incorporation of the latest technology and viewpoints of technical experts.

Note regarding units of measure:
The SI unit of volume is the cubic decimeter (dm^3) or the cubic centimeter (cm^3). The Twelfth General (International) Conference on Weights and Measures redefined the litre [herein spelled liter] as a "special name for the cubic decimeter," but agreed to permit the continuance of the terms liter (L) and milliliter (mL), except in association with measurements of the highest precision. The commercial measurement system in the United States continues to use gallons and cubic inches for practical applications. Since commercial applications in the United States use units other than SI or other accepted metric units, this document references other common units in current use.

Acknowledgment:
The previous edition of this Handbook was written by Blayne C. Keysar of NBS in 1979. Special thanks regarding this updated edition is given to Karl Herken, metrologist with the State of Kansas, for his assistance with review of reference materials, evaluation of comments submitted during peer review, and for typing and editing the document in WordPerfect format. Special acknowledgment is given to Emil Hazarian, metrologist with Los Angeles County Weights and Measures, for preparing drawings and schematic diagrams. Thanks are also given to numerous metrologists (of both State and industry laboratories) for their technical review of several drafts.

*Trade names used in this paper do not imply recommendation or endorsement by the National Institute of Standards and Technology.

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SPECIFICATIONS AND TOLERANCES
FOR REFERENCE STANDARDS AND FIELD STANDARD
WEIGHTS AND MEASURES

3. Specifications and Tolerances for
Graduated Neck Type Volumetric Field Standards

These specifications and tolerances are recommended as minimum requirements for standards used by State and local weights and measures officials and others in the verification of meters used in quantity determination of liquid commodities.

Key words: bottom loading; field standard provers; field standard test measures; provers; specifications; standards; test measures; tolerances; vapor recovery; volumetric standards; volumetric specifications and tolerances; weights and measures.

INTRODUCTION

Graduated neck type test measures and provers are used primarily to test commercial liquid measuring devices for compliance with commercial requirements. Use of these standards at all appropriate levels of manufacture, distribution, and weights and measures inspection will help promote accuracy and uniformity in commerce. Field standards covered by this handbook include standard and "high-resolution" test measures (such as 20-liter/5-gallon measures) and graduated neck type provers. Hand-held test measures, free-standing or mounted test measures and provers are addressed in this handbook. The breadth of topics in this handbook is intended to provide information for manufacturers, calibration staff, weights and measures officials, and other end users. References are provided when additional information may be useful to the reader.

1 Scope

1.1 "Field Standard" Classification

These specifications are limited to non-pressurized, graduated neck type metal field standards, with or without vapor recovery capabilities where the volume is established between a shut-off valve or bottom-neck zero graduation and an upper-neck nominal graduation. The term "standard" as used in this publication refers to all sizes in general. Sizes up to and including 40 L (10 gal) are commonly referred to as test measures when hand-held. Mounted standards and those of a larger size are commonly referred to as provers.

1.1.1 Test Measures

Test measures are small (< 40 L/10 gal) hand-held volumetric measures, with or without a graduated bottom-neck (also called bottom-zero or wet-bottom).

1.1.2 Provers
Provers are large (> 40 L/10 gal) bottom-drain volumetric measures or small mounted provers that are bottom-drain, with or without a graduated bottom-neck (also called bottom-zero or wet-bottom). Provers may be free standing or permanently mounted on a truck, platform, or trailer.

1.1.3 High-resolution type
High-resolution test measures and provers are designed with a small diameter neck and are used to achieve greater neck volume resolution. High-resolution equipment is typically used in a laboratory setting, but may also be used in field settings. This type of measure may also be characterized by the terms “high-accuracy” or “high-sensitivity.”

1.2 Laboratory Standards
Test measures and provers may be used in a laboratory setting as primary or secondary standards. Additional specifications and tolerances may be applicable in those situations. Slicker plate type laboratory standards are not addressed in this handbook.

1.3 Retroactivity
These specifications are not intended to make obsolete those field standards fabricated to meet prior specifications. All new test measures and provers must meet these requirements prior to certification for legal use. This handbook may be used as a guide to evaluate adequacy and retrofit existing provers to limit the amount of petroleum product vapor generated during the test of a metering device (see Section 4.4.8).

1.4 Safety Considerations
This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Specific safety information is documented in the API references.

Commercial liquid measuring devices, tested with these standards, are typically used to measure quantities of petroleum products. Petroleum products are known hazardous materials and hazardous wastes. The user is encouraged to obtain Material Safety Data Sheets (MSDS) from the manufacturer of any product encountered. Federal, state and local safety and disposal regulations concerning hazardous materials encountered should be reviewed by the user.

2 Reference Documents
2.1 OIML[1]
2.1.1 Fourth Preliminary Draft, International Document on Measurement of Volume of Liquids, Hierarchy Schemes, December 1987.

2.2 NIST[2]
2.2.1 Handbook 44, Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices, see current edition, published annually.

2.2.2 Handbook 145, Handbook for the Quality Assurance of Metrological Measurements, 1986 or later edition.

2.3 API[3]

2.3.1 Manual of Petroleum Measurement Standards, Chapter 4, Proving Systems:
2.3.1.1 Section 4, Tank Provers.
2.3.1.2 Section 7, Field-Standard Test Measures.
2.3.1.3 Chapter 12, Calculation of Petroleum Quantities.
2.3.1.4 RP 1004, Bottom Loading and Vapor Recovery for MC-306 Tank Motor Vehicle.

2.4 ASTM[4]

2.4.1 D 1250, Standard Guide for Petroleum Measurement Tables.
2.4.2 Table 24, Volume Reduction to 60 °F.
2.4.3 Table 24B, Generalized Products, Correction of Volume to 60 °F Against Relative Density 60/60 °F.
2.4.4 Table 34, Reduction of Volume to 60 °F Against S.G. 60/60 °F for Light Petroleum Gases.

3 Terminology

Bleed valve. Valve to bleed entrapped air from a pipe, valve, or fitting.

Bottom loading. Method of filling a volumetric vessel. Intake is made with a bottom load adapter.

Capacity, nominal. The nominal capacity of a field standard test measure or prover is the volume used to designate the test measure or prover (e.g., 5 gallon test measure). The volume is determined by the nominal mark on a graduated upper neck gauge on a test measure and between the nominal mark on the graduated upper neck gauge and the lower shut off valve or zero mark on a lower neck gauge on a prover.

Cubical coefficient of thermal expansion. Three dimensional expansion or contraction of a material due to temperature change, expressed $^{\circ}C^{-1}$ or $^{\circ}F^{-1}$.

Epoxy resin. Any of the various (usually heat-setting) resins that are made by polymerization of an epoxide (e.g., ethylene oxide or epichlorohydrin) with a diphenol. Commonly used as an adhesive or sealant.

Field standard test measure. A measure that can be hand held and is usually less than 40 L (10 gal).

"High Resolution" standard. A standard with a small diameter neck for improved resolution in reading the meniscus. Generally used in the laboratory as a standard or check standard for measurement control of a primary standard.

Main flow cessation. The moment when a full discharge stream "breaks" and becomes a trickle or a drip.

Prover. Bottom drain is implied. Filled from the top or bottom loading, depending on intended use. May be free standing or mounted permanently or on truck or trailer and not hand held.

Reference temperature. The temperature at which the measure is intended **to contain** or **to deliver** its nominal capacity.

Sight-flow-indicator. A fitting with windows to visually observe the flow through a pipe.

Submerged fill pipe. Pipe used in top filling to minimize foaming of liquids, such as fuel oil and milk, by discharging the product into the bottom of a prover.

To contain. An indication that the standard is adjusted to contain its intended volume when filled from its empty condition at a reference temperature. For the purpose of this handbook, the empty condition is “dry” and test measures or provers are generally not used in this condition.

To deliver. An indication that the standard is adjusted to deliver its intended volume at a reference temperature. Provers used in a “wet” condition are marked To Deliver.

Tolerance. Maximum permissible error. A value fixing the limit of allowable error or departure from the true performance or value.

Vapor recovery. A system for entrapping and collecting vapors for return to the tank to prevent expulsion into the atmosphere.

4 Specifications

4.1 Physical Size

4.1.1 Size Declaration

The recommended sizes of metric and U.S. Customary (inch-pound) test measures and provers are shown in Tables 1a, 1b, 2a, and 2b. Nominal volumes in each system are ideally selected in multiples of 1, 2, and 5 (liters or gallons).

4.1.2 Special Applications

Test measures and provers are generally selected to minimize the number of deliveries required for volume transfer calibration. Selection may be for use as general laboratory standards for calibration of other test measures or provers, for calibration of LPG provers, or for calibration of dynamic small volume provers

Fifteen is the maximum recommended number of deliveries from a standard to a prover under test to minimize calibration uncertainties. Selection of provers as laboratory standards should take into consideration the largest size of unknown prover likely to be tested.

Provers for use in testing LPG provers are commonly of the 20 gal, 25 gal, or 100 gal size.

Dynamic small volume provers have a variety of measuring sections available as follows: 20 L (5 gal), 40 L (10 gal), 57 L (15 gal), 60 L (15 gal), 120 L (30 gal), 159 L (42 gal), 250 L (65 gal), 318 L (84 gal), 650 L (170 gal). A 60 L (15 gal) standard is recommended as the most common for small volume prover calibrations.

4.1.3 Size Limitations

The 5000 L (1500 gal) prover, which is the largest of the provers described in this publication, is nearly the largest size which can be mounted vertically on a truck or trailer and meet highway height and width requirements.

4.2 Reference Temperature

The temperature at which test measures and provers are referenced during calibration and during use for testing petroleum products is generally 15.56 °C (60 °F). International standards reference petroleum products to 15 °C. Provers may be used for applications other than petroleum products; in such cases the appropriate reference temperature should be used.

4.3 Material

4.3.1 Steel Construction

Test measures and provers shall be constructed of low carbon steel or 300-series stainless steel. All parts of a test measure or prover (i.e., neck and integral hardware) shall be made of identical material. Non-integral hardware may be of other materials provided the hardware is durable and suitable for its intended purpose.

4.3.2 Intended Use Considerations

Material must be chosen based on intended use and shall be thermally stable. The use of oxygenated fuels, chemicals (e.g., fertilizers, pesticides), or food products may dictate the type of metal that may be used. Laboratory standards should be made of 300-series stainless steel.

4.3.3 Non Steel Construction Materials

Proposals for the exemption of material requirements and for use of other suitable materials should be submitted to the Office of Weights and Measures, National Institute of Standards and Technology (NIST). All applicable physical property data shall be accurately documented for any material chosen. The proposed material will be evaluated to determine the suitability for the intended use, and the requestor will be informed in writing of the decision.

EVALUATION NOTE: An unduly high coefficient of thermal expansion (e.g., such as for plastic or aluminum) is inappropriate for field use in meter verification because uncorrected thermal expansion introduces an error or uncertainty which is a large percentage of the applicable tolerance.

4.4 Physical and Mechanical Properties

4.4.1 Body

Any cross section taken in a plane perpendicular to the vertical axis shall be circular. The volume of a standard shall be established without the use of fillers, adjusting plugs, or cavities of any kind and so that the nominal capacity is approximately mid scale on the scale plate.

4.4.2 Shape

The shape of the test measure or prover shall ensure complete emptying, draining, and the prevention of air entrapment.

4.4.3 Top and Bottom Cone

4.4.3.1 Cone pitch

Recommended top and bottom cone pitches, are provided in Tables 1a and 1b. Cone pitches are intended to facilitate complete emptying and draining.

NOTE: Deviation from recommended cone pitch requires a laboratory evaluation of repeatability and assurance of no air entrapment.

4.4.3.2 Bottom cone anti-vortex design

An effective anti-vortex device shall be attached to the bottom cone of a prover to minimize liquid swirl during emptying. A prover or test measure must be designed to prevent the trapping of air, whether top or bottom filled.

NOTE 1: Fins or plates are often used to limit circular product motion that creates a vortex.

Note 2: Calibration of provers generally requires top filling regardless of top or bottom fill applications to allow for delivery by gravity drain from the laboratory standard.

4.4.3.3 Cone trough

Where a support band extends above the joint between the body of the prover and the top cone, the trough shall have a suitable drain.

4.4.4 Neck

The neck (upper or lower) of a test measure or prover shall be specially inspected and selected for uniformity in its circular cross section. The neck shall be perpendicular to a level horizontal plane. The top of the neck of a field standard shall be finished in such a manner that by placing a precision machinist spirit level across it, the level position of the standard can be determined. This also provides for the proper adjustment of replacement levels on provers.

4.4.4.1 Neck reinforcement

The opening at the top of the neck shall be reinforced by a rolled bead, or band welded to the neck. (See Figures 1, 2, and 3).

4.4.4.2 Neck diameter
Maximum neck diameters are specified in Tables 1a and 1b. The neck diameter of a test measure shall be sufficient to permit cleaning and inspection. Neck diameters may vary; the critical factors affecting neck diameter are the volume above and below zero, the graduation sizes, and the minimum space between graduations.

4.4.4.3 Neck attachment to cone
The upper neck and lower neck (when present, i.e., bottom zero) shall be attached flush with the cone seam and in such a way that the neck does not project into either cone thus preventing air or water entrapment at the joint.

4.4.4.4 Neck drains
Laboratory standards may have a neck drain on the upper neck to be used for adjusting the delivery from the standard to a nominal volume. The upper neck drain must be installed on the lower portion of the neck, below the sight gauge assembly.

A lower drain on the gravity discharge line is permitted to adjust the level of a bottom-zero when present. This drain should be installed above the shut off valve and shall not interfere with use of the prover for meter verification. Operator control of this valve must allow simultaneous visibility of the bottom sight gauge.

4.4.5 Support
The test measure or prover and associated support structure shall be designed to prevent prover distortion and to provide protection against damage when routinely transported on a trailer or truck or when fully loaded.

4.4.5.1 Design
Reinforcing bands, adequate material thickness, or other means of support to the test measure or prover body shall be used to prevent distortion of a standard when it is full of liquid or when it is being transported. The bottom of hand-held test measures shall be concave and of adequate thickness to prevent distortion when filled.

4.4.5.2 Structure
The supporting structure of the volumetric standard consisting of legs, framework, or mounting structure shall not be attached directly to the body of the prover. Legs or other mounting structure must be attached either to an exposed portion of a reinforcing band that extends beyond the body of the prover or to the outside of a reinforcement band or plate that is attached to the body.

4.4.6 Thermometer Wells
A thermometer well shall be installed on the main vessel of all laboratory standards and field standard provers. A well shall extend at least 8 inches into, and protrude 2 inches out of the prover at a downward angle of approximately 15° from the horizontal plane and which will contain a temperature conducting liquid. If electronic temperature sensors are used (inserted in top of prover)

or dial face thermometers are installed to meet depth, location, and accuracy requirements, a well is not required. No thermometer well is required for field test measures.

4.4.6.1 Single well
For provers up to and including 1000 L (200 gal), a single well is acceptable. When a single well is installed, it should be located so that its lower (closed) end is at the approximate center of the vertical cross section of the prover.

4.4.6.2 Multiple wells
For provers larger than 1000 L (200 gal), multiple wells are required. If two wells are installed, one end should be near the top and one near the bottom of the cylindrical section. If three wells are installed, they should be evenly spaced in the upper, middle, and lower portions of the prover

4.4.6.3 Temperature sensing devices
Temperature measurement devices must be explosion proof, removable and replaceable. Temperature measurements shall be accurate and traceable to national standards.

When electronic sensors are used inside the prover, temperature measurements shall be made at evenly spaced locations at the top, middle, and lower portions of the prover

4.4.7 Drains

A gravity discharge line, between the prover and the shut-off valve, shall have a downward slope of at least 5° from the horizontal plane. All gravity and pump discharge lines downstream from the shut-off valve shall be positioned so as to ensure complete emptying of the prover. A discharge line shall consist of a length of pipe, and a fast-acting valve (e.g., butterfly). A gravity line shall have a fitting to connect the drain or pump-off hose.   A gravity line fitting is optional on non-vehicle mounted provers. All discharge lines shall be supported.

4.4.7.1 Sight flow indicator
For provers larger than 1000 L (200 gal) provision shall be made for observing fluid flow downstream of the shut off valve. A sight-flow indicator is optional where flow can be visually observed and on non-vehicle mounted provers.

NOTE: Means for visually observing fluid flow and the empty condition and drain time on a prover is critical for accurate volumetric determination. Listening for a change in the pump sound to indicate a drained condition is not adequate. It is reliant on the operator’s hearing and experience and does not encourage proper drain times. Moving element indicators may restrict flow and may not adequately indicate low fluid flows.

4.4.8 Minimization of Product Vaporization or Foaming

Prover systems (including prover body, hoses, valves, loading mechanisms) shall be designed in such a way as to minimize product vaporization to less than 5% of the prover volume or to minimize foaming during loading (regardless of means for loading).

NOTE: Physical means for minimizing foaming or vaporization have included a variety of designs including bottom loading for petroleum products with lower molecular weight and submerged fill pipes for diesel products; most methods involve means for allowing a quick fill of inlet and even diversion of product (e.g., baffles, diffuser plates) to prevent splashing, circular motion, and turbulence.

4.4.9 Fill Pipe

A submerged fill pipe, when used on a prover, shall be permanently installed adjacent to the neck and be provided with a cap. The pipe shall pass through the cone and extend to within 10 cm to 15 cm (4 in to 6 in) of the bottom cone. More than one pipe may be installed if necessary. The top portion of the fill pipe shall be connected to the top portion of the neck by a bleed line. This will allow the pipe to fill with liquid when the prover is being filled by other means, i.e., through the neck or through a bottom load adapter.

4.4.10 Bottom Loading

Meter installations equipped for bottom loading require that a prover be fitted with an adapter to mate with the loading arm. The adapter shall be attached to the lower portion of the vertical section. The vertical dimension, above grade, of the adapter should not exceed 122 cm (48 in). The bottom loading adapter shall comply with American Petroleum Institute RP 1004, "Bottom Loading and Vapor Recovery for MC-306 Tank Motor Vehicle," latest edition.

4.4.11 Electronic Overflow Systems

For safety reasons, most meter systems will not operate without a proper connection to an electronic overflow system for safety reasons. Electronic overflow systems on provers may use float, thermistor, or optical sensors in the neck.

4.4.12 Vapor Recovery

4.4.12.1 Tube Placement

Provers equipped with an external vapor recovery tube shall originate at the top of the neck below the reinforcement band and end at a convenient point to interface with the vapor recovery hose of the system under test.

The tube shall have appropriate fittings for connecting with the vapor return fitting and valve.

4.4.12.2 Recovery tube size

The size of the vapor recovery tube shall be sized appropriately for the systems being tested with appropriate fittings.

4.4.12.3 Pressure relief valve

Provers with vapor recovery provisions shall be equipped with a pressure relief fitting for 20 kPa to 35 kPa (3 psi to 5 psi) rating.

4.4.12.4 Vacuum relief

Provers with vapor recovery provisions shall be equipped with protection against excessive vacuum during unloading. This fitting shall have vacuum relief rated at 20 kPa (3 psi).

4.4.12.5 Emergency venting

Provers used for flammable or combustible products shall be equipped with emergency venting to relieve excess pressure caused by exposure of the prover to fire.

4.4.13 Hardware

4.4.13.1 Handles

A hand-held test measure shall be equipped with a bail handle and shall hang with its axis vertical when filled with liquid. The bail handle shall be attached by strong trunnions to the neck rather than to the cone to minimize any possibility of distortion of the measure when it is suspended while full of liquid.

4.4.13.2 Plumbing

Any plumbing needed for filling or discharge of the prover shall not interfere with calibration. Prover drain systems shall disconnect for gravity drain during calibration and for observation of the cessation of flow, except where a prover system with permanent plumbing is equipped with means for observing sight flow and has a return pump with a 3-way valve or a system of valves connected to the pump line and to the gravity line. In the case of a system of valves, the main valve that determines the nominal capacity must be placed closest to the lower neck in the discharge line.

4.4.14 Prover Leveling

4.4.14.1 Test measures

Field standard test measures shall be level within applicable tolerances whether suspended by the bail handle, leveled at the neck or placed on a level surface, as determined by a machinist spirit level.

4.4.14.2 Provers

All provers, including those permanently mounted, shall have adequate provision for leveling. (See section 4.6.1 for level specifications and mounting).

A truck or trailer on which a prover is mounted shall be equipped with at least three leveling jacks to maintain a level and stable condition when under full liquid load.

4.4.15 Gauge Assembly

4.4.15.1 Tube

Field standard test measures and provers shall be equipped with a (liquid-level) gauge tube mounted on the side of the neck. The gauge tube shall be made of borosilicate glass and be clear and free of any markings, irregularities or defects which will distort the appearance of the liquid surface. The tube shall be mounted in fittings which penetrate the cone near the neck (as flush as possible to minimize air entrapment) and which penetrate the neck near the top of the tube (to allow passage of vapors from the tube for vapor recovery purposes). The fitting at the top of the tube may have a removable plug so the tube can be cleaned. The plug shall not interfere with proper vapor equalization (i.e., no pressure build-up that affects the liquid level in the gauge). Removal and replacement of the tube shall be made possible and leak proof by the use of compressible gaskets or "O" rings.

4.4.15.2 Shield
On provers where protection of the tube is provided by a shield or cover, the design of the cover shall allow replacement of the gauge tube without difficulty.

4.4.16 Scale Plate and Graduations

4.4.16.1 Material
The scale plate shall be rigid, and resistant to corrosion and discoloration (anodized aluminum or stainless steel.

4.4.16.2 Location
The scale plate shall be mounted on a secant to the front of, or slightly in front of the gauge tube. In any case, it shall be not more than 6 mm (0.25 in) from the tube.

4.4.16.3 Mounting
There shall be a sufficient number of scale brackets (minimum of two) to hold the scale plate(s) firmly. The brackets shall be mounted on two adjusting, guide rods using corrosion resistant hardware. The scale plate(s) shall be securely attached to the brackets and be provided with a means for sealing.

4.4.16.4 Scale units
The basic scale on all standards shall be milliliters or liters on metric test measures and provers, cubic inches or decimal gallons on U.S. customary test measures or provers. Scales with identical units on each side of the scale plate may be of one piece construction and adjustable and sealable as a unit.

4.4.16.5 Mixed scale units
If a secondary unit scale is used, two scale plates are required that shall be capable of being adjusted and sealed independently. The secondary units shall be placed on the right side of the sight tube.

4.4.16.6 Sealing and adjustment
All adjustments shall be provided with a means for sealing which will prevent movement or play. Removal or movement of the adjusting mechanism or scale plates shall not be possible without breaking the seal.

4.4.16.7 Incremental adjustment
Where the design of the scale adjustment provides for the movement of the scale by increments, the maximum increment shall be less than 25 percent of the smallest scale division. Any gauge movement or play in the adjustment mechanism or scale plates shall be less than 1/4 of the smallest scale division.

4.4.16.8 Graduation spacing
The minimum distance between any adjacent graduations lines shall be 2 mm (0.0625 in), and the lines shall be evenly spaced.

4.4.16.9 Span of graduations
The sight gauge scale shall be graduated both above and below the nominal capacity graduation by an amount not less than 1.5 times the maintenance tolerance (or 1.5 percent of the prover volume) for the volume determined by the prover nominal capacity.

4.4.16.10 Scale lines
The graduation lines, numbers, and other inscriptions on the scale plate shall be engraved or etched, permanent, and of a contrasting color to that of the plate.

4.4.16.11 Line spacing and width
Major division lines, consistent with the measurement system used, shall be longer than subdivision lines and be numbered. The length of the major (numbered) graduation lines on scale plate shall be no less than 6 mm (0.25 in), and the intermediate lines shall be no less than 3 mm (0.125 in) in length. All lines shall extend to the edge of the scale plate nearest the gauge tube. Graduation lines shall be of uniform width and not more than 0.6 mm (0.025 in) or less than 0.4 mm (0.015 in) wide.

4.4.16.12 Nominal and zero marking
The nominal volume and zero lines on all scale plates shall extend across the entire width of the scale plate and shall be clearly identified. Provers with a bottom zero shall have only one line.

4.4.16.13 Additional markings
Scale plates shall be clearly marked with the nominal volume of the prover and the intended method of use such as “To Contain” or “To Deliver.” A standard with two scale plates, graduated in different units, shall have each nominal capacity mark clearly identified. Letters and numbers shall be legible and of adequate size, in no event smaller in height than 5 mm (0.2 in).

4.5 Workmanship, Finish, and Appearance

4.5.1 Air Entrapment

Fabrication shall insure that no pockets, dents, or crevices will be present which may entrap air or liquid, or impair the proper filling or draining of the standard. All drainage piping must be routed at a level lower than the bottom wet zero if present, or at a level lower than the shut off valve to prevent liquid from returning to the prover once the valve is opened, and to prevent an air pocket from forming when the prover is tested in the certifying laboratory.

4.5.2 Finished Quality

A field standard, together with its associated valves, piping, gauge, etc., shall be free of slag, scale, weld or solder splatter, grit, dirt, dents, interior rust, water or product residue, or any other foreign matter before shipment from the factory or before submission for calibration.

4.5.3 Required Assembly

5.3.1.1 Gauge Assembly

All parts of the gauge assembly, and all piping and valves which affect the volume of a field standard, shall be fully assembled by the manufacturer or supplier.

4.5.4 Thread Connector Lubricant

All threaded connections, including plugs and caps, shall be thoroughly lubricated with a suitable nonhardening paste, or pipe joint tape, and shall not leak. Connections and lubricants must be impervious to product used in the prover.

4.5.5 Valve Operation

All valves shall operate freely and positively and shall not leak under normal operating pressures.

MAINTENANCE NOTE: It has been recommended that butterfly valve "O-rings" be changed just prior to calibration; however, an “as found” calibration value will not be available.

4.5.6 Leveling Jack Operation

All leveling jacks shall operate freely and be stable under load. Load rating should be determined on the basis of 125 percent of the anticipated maximum load including the heaviest product to be tested.

4.5.7 Metal Joints

All seams, whether welded or soldered, shall be filled and smooth to provide a continuous surface to prevent the entrapment of air or liquid, and shall not leak.

NOTE: The calibration process should evaluate joints of field standards for leaks, particularly at neck and cone interfaces.

4.5.8 Internal Coatings

The interior surface of standards made of low carbon steel shall be corrosion resistant or coated with a suitable material which will be impervious to the liquids for which the standard will be used.

4.5.9 Exterior Coatings

The exterior surface of field standards made of low carbon steel shall be properly primed and coated with a glossy finish (white) or a color which is reflective and prevents any unnecessary heating of the product within the prover and that is impervious to the liquids for which the standard will be used.

4.5.9.1 Coating for edible commodities

If a standard is to be used for measurements of edible products, such as water or milk, governmental regulations regarding surface finish shall apply.

4.5.10 Identification

4.5.10.1 Content

Each standard shall bear, in a conspicuous place, the following information:

1. nominal capacity;
2. reference temperature for calibration;
3. name and address of manufacturer;
4. model number and year of manufacture;
5. nonrepetitive serial or identification number;
6. material identification and thickness;
7. cubical coefficient of thermal expansion of material per $^\circ$C ($^\circ$F);
8. “10 second drain after delivery” for hand-held test measures or “30 second drain after main flow cessation” for bottom-drain test measures or provers; and
9. delivery time if hand-held.

4.5.10.2 Placement

Identification information shall be engraved or embossed on the standard or permanently placed on a metal plate which is permanently attached to the standard by the manufacturer without the use of adhesives.

4.6 Other Requirements

4.6.1 Levels

All bottom-drain test measures and provers shall be equipped with two, non spring loaded, adjustable spirit levels mounted at right angles to each other, on the upper cone or where best visible from a standing position. Each level shall be mounted on a sturdy shelf and be equipped with a protective cover. The adjusting screws shall have provisions for sealing.

NOTE: A "bull's-eye" level is permitted in lieu of two spirit levels, if the level, in combination with prover design, has sufficient sensitivity to ensure proper reading of the liquid level in the standard. Vehicle or trailer mounted provers may have auxiliary levels mounted at a lower plane for operator convenience in adjusting leveling jacks. Primary levels on the prover should be used to adjust auxiliary levels and as a reference; auxiliary levels are only to be used for coarse leveling.

4.6.2 Return Pump

The pump and piping shall be sized according to the prover volume and should be designed for use in petroleum service if applicable. A return pump of a self-priming, centrifugal design is recommended.

NOTE: Pumping rates must be balanced between convenience and deviation from total drain time differences between meter verification and gravity drain calibration.

4.6.3 Neck Cover

The neck of all vehicle mounted provers shall be equipped with a cover to prevent contamination or damage during transportation. The cover may be a vapor-tight hinged type, or if on large size provers, a pressure activated fill (PAF) manhole cover as used on tank trucks.

4.6.4 Pipe Caps

The ends of all fill, drain, product return, and vapor recovery pipes on a truck or trailer mounted prover shall be supplied with removable caps or mounted male fittings of like size to secure and caps hoses when not in use.

4.6.5 Electrical Requirements

4.6.5.1 Grounding

A grounding lug or other mechanism is required on provers used for volatile liquids to protect against accidental discharge of static electricity. The lug shall be securely attached to the skirt of the prover and on the same side from which the prover is loaded.

4.6.5.2 Wiring

All electrical connections must be explosion proof. All wiring, including low voltage wiring shall meet the requirements of Article 300, 500, Group D, Class 1, Division 1, and 250.45 and/or other applicable articles of the latest edition of the National Electrical Code.

4.6.6 Ladders and Platforms

A ladder and expanded metal platform (with appropriate safety hand rails), when required, shall be secure and designed to support the operator while reading or servicing the neck-gauge assembly. The ladder shall be so constructed that there is no distortion of the prover when the ladder is in use. Ladder rungs should be constructed of a nonslip material.

5 Tolerances (Maximum Permissible Errors)

5.1 Capacity Tolerances

The tolerances in Tables 1a and 1b are the maximum allowed if the standard is to be used without correction in meter testing applications. Provers should be adjusted during calibration to nominal values if at all possible. Capacity tolerances are based on an evaluation of the expanded uncertainty of the calibration as compared with one third of the current acceptance tolerance (from NIST Handbook 44 tolerance tables applied to the device being tested). The tolerance of the field standards must be less than 0.02 percent of the total volume (rounded to the nearest convenient unit) due to the combined standard uncertainty of all other factors such as the laboratory standard, the calibration process, and the standard uncertainty associated with the neck calibration.

5.2 Neck Calibration Tolerances

The maximum capacity tolerance between the nominal volume line and any other line on the scale shall be less than 0.5 percent of the total graduated neck volume.

6 Verification Requirements

6.1 Legal Requirements

The specifications and tolerances herein specified are intended to permit the use of the equipment in normal field testing operations as standards having nominal values. Weights and measures requirements, including but not limited to, inspection, testing, and sealing, by a NIST recognized laboratory shall be followed.

NOTE: Some States have requirements not documented here. Check with the local jurisdiction for specific requirements.

6.2 Traceability

Field standards used for legal metrology shall be traceable to national standards by calibration in a laboratory recognized by NIST in that parameter, range, and scope.

6.3 Calibration Reports

Acceptable accuracy and traceability to national or international standards shall be documented in a calibration report using accepted test methods. A calibration report must be prepared that states the calibration method used, the calibration medium (should be water), the nominal volume of the prover, the reference temperature, the calibration error on the graduated neck, the expanded uncertainty (k=2), the prover serial number and date.

6.4 Initial and Periodic Verification

Field standards must be verified prior to use and rechecked as often as regulations or circumstances require, especially when damage is known or suspected, seals are broken or valves in the measuring section are replaced. Test measure and prover calibration may be established at 1 year intervals and extended or reduced based on historical evidence up to the limit determined by State or local regulations, but should not exceed 3 years due to possible leaking valves or seals which are often difficult to observe under field conditions.

7 Test Methods and References

Volume certification of test measures or provers shall be by a documented NIST procedure or other national or international recognized procedure. Hand held test measures require a 30 s (± 5 s) pour followed by a 10 s drain, with the measure held at a 10° to 15° angle from vertical, during calibration and use. Provers are emptied, followed by a 30 s drain following the cessation of flow.

Reference methods are as follows:

7.1 NIST Handbook 145, SOP 18
Recommended Standard Operations Procedure for Calibration of Graduated Neck-Type Metal Volumetric Field Standards: Volumetric Transfer Method.

7.2 NIST Handbook 145, SOP 19
Recommended Standard Operations Procedure for Calibration of Large Neck-Type Metal Provers: Volumetric Method.

7.3 API, Manual of Petroleum Measurement Standards
Chapter 4, Proving Systems, Waterdraw Calibration.

NOTE: Field Calibrations
A "field" calibration is considered one in which a calibration is conducted outdoors in uncontrolled environments. NIST recognizes laboratories for specific measurement parameters, ranges, and scopes (expanded uncertainties). Calibration conducted under field and laboratory conditions are not considered equivalent and NIST does not recognize jurisdictions for field testing of standards. Expanded uncertainties associated with laboratory conditions are often greater than one third of the NIST Handbook 44 tolerance applied to the metering device under test and for this reason NIST discourages the field testing of standards where environmental conditions increase standard uncertainties.

The responsibility for ensuring accuracy and traceability, with sufficiently small expanded uncertainties to meet requirements in NIST Handbook 44 is the responsibility of the local jurisdiction. The care required for field calibrations includes proper safety, clean and air-free water supply, measurement control programs, and a stable temperature-controlled environment shaded from direct sunshine to allow the prover, field standard, and test liquid (water) to reach an equilibrium temperature, with minimal evaporation. Environmental conditions should be controlled (or selected) to be as close to laboratory conditions as possible. All data and appropriate environmental conditions must be documented regardless of test location.

8 Uncertainties
8.1 Legal Applications
Uncertainties of the calibration must be evaluated according to the ISO Guide to the Expression of Uncertainty in Measurement,[5]
1993 to ensure that the three to one accuracy ratio contained in NIST Handbook 44 is maintained. In 1996, the smallest acceptance tolerance for liquid measuring devices is 0.2 percent (0.16 percent for vehicle tank meters) of the measured volume. Therefore, the expanded uncertainty for the calibration of a test measure or prover must be less than 0.07 percent of the measured volume.

8.2 Sources of Variation

8.2.1 Accuracy

Accurate measurement demands the use of calibration equipment and standards with accuracy traceable to national or international standards and the use of standard procedures. Accurate and traceable measurements require the analysis of measurement uncertainty and an evaluation of that uncertainty to determine the adequacy for its intended use. In the case of field standards used in weights and measures applications, the expanded uncertainty for calibration must be less than 0.07 percent of the measured volume.

To achieve the required expanded uncertainty, the following estimates demonstrate the required standard uncertainties associated with major contributors in the calibration:
laboratory standard(s): 0.01 percent of the volume of the prover under test;
measurement process: 0.02 percent of the volume of the prover under test;
neck calibration: 0.5 percent of the neck volume (the neck volume is at least 3 percent of total volume) of the prover under test; and
applicable tolerance: 0.02 percent of the nominal volume for the prover under test.
When these factors are combined in a root-sum-square method and multiplied by a k-factor of two (95 percent confidence interval), it provides an uncertainty of less than 0.07 percent of the measured volume. If any one of the factors listed is greater than what is noted in the above list, the other factors must be reduced to compensate when one desires to maintain the required values for the expanded uncertainty.

E.g., for the previous example, the values are combined as follows:

$$U = 2 * \sqrt{0.01^2 + 0.02^2 + (0.5 * .03)^2 + 0.02^2}$$

To achieve the necessary accuracy, the corrected volume depends on:
use of proper temperature corrections;
the uncertainty associated with the cubical coefficient of thermal expansion;
the accuracy of temperature measurements.

Through proper use of documented laboratory and field procedures, additional uncertainty factors may be minimized to a level that does not contribute significantly to the previously described factors. Additional standard uncertainties in the calibration of field standards and their use in meter verification may include:
how the prover level is established;
how delivery and drain times are determined;
the use of a proper “wet down” prior to calibration or use;
whether gravity drain is used during calibration or whether the volume of water is eliminated by pumping;
differences in drain between calibration and use;
the cleanliness of the prover and calibration medium;

prover retention characteristics related to inside surface, contamination or corrosion, and total drain times;
possible air entrapment in the water; and
the ability to properly read the meniscus.

Proper reading of the meniscus should be followed to prevent additional error in the calibration and use (see NIST Handbook 145, Good Measurement Practice 3).

8.2.2 Repeatability

Fifteen is the maximum recommended number of deliveries from a laboratory standard to a prover under test to minimize calibration uncertainties to the levels identified previously. Volumetric values obtained during repeated runs of a single calibration must agree to within 0.02 percent of the test volume.

Repeatability problems may be due to a leak in the valves or seals of the prover, contamination or lack of cleanliness, or poor field conditions such as when calibration is conducted in unstable environments. Repeatability problems must be corrected before calibration can be completed.

Notes

1. OIML, L'Organisation Internationale Métrologie Légale, Bureau International De Metrologie Legale, 11, Rue Turgot, 75009, Paris, France.

2. NIST, National Institute of Standards and Technology, Gaithersburg, MD 20899.

3. API, American Petroleum Institute 1220 L St. NW, Washington, DC 20005.

4. ASTM, American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA, 19428-2959.

5. ISO, International Organization for Standardization, Geneva, Switzerland.

Table 1a. Dimensional requirements for metric provers

Size (L)	Minimum Metal Thickness* (in)	Maximum Upper Neck ID*** (in)	Gauge Tube ID (in)	Top Cone Pitch	Bottom Cone Pitch	Minimum Drain Size (in)
5	0.0312 **	3.875	0.5	35°	---	---
20	0.0312 **	3.875	0.5	35°	20°	1.5
50	0.0312 **	3.875	0.5	35°	20°	1.5
100	0.109	5	0.625	25°	20°	1.5
200	0.109	6	0.625	25°	20°	2
500	0.109	8	0.625	25°	20°	2
1 000	0.109	10	0.625	25°	20°	2
2 000	0.141	13.25	0.625	25°	20°	3
3 000	0.172	13.25	0.625	25°	20°	4
5 000	0.172	15.25	0.625	25°	20°	4

ID = inside diameter.

* Thicknesses are intended to be nominal. Materials used in the United States are available in "gauge" and inches. Actual thickness of sheet metal stock will vary slightly.

** Values given are for the top and sides; minimum thickness for the bottom shall be 0.050 in.

***Neck diameter may vary; the critical factors to be considered which affect neck diameter are the volume above and below zero, the graduation sizes, the minimum space between graduations and the use of fill pipes and vapor recovery systems.

For a capacity intermediate between two capacities listed above, the sizes prescribed for the lower capacity shall be applied.

Table 1b. Dimensional requirement for U.S. customary provers

Size (gal)	Minimum Metal Thickness * (in)	Maximum Neck ID*** (in)	Gauge Tube ID (in)	Top Cone Pitch	Bottom Cone Pitch	Minimum Drain Size (in)
1	0.0312**	3.875	0.5	35°	--	--
5	0.0312**	3.875	0.5	35°	20	1.5
10	0.0312**	3.875	0.5	35°	20	1.5
25	0.109	5	0.675	25°	20	1.5
50	0.109	5	0.675	25°	20	1.5
100	0.109	7	0.675	25°	20	2
200	0.109	10	0.675	25°	20	2
500	0.141	17	0.675	25°	20	3
1000	0.172	17	0.675	25°	20	4
1500	0.172	20	0.675	25°	20	4

ID = inside diameter.

* Thicknesses are intended to be nominal. Actual thickness of sheet metal stock will vary slightly.

** Values given are for the top and sides; minimum thickness for the bottom shall be 0.050 in.

***Neck diameter may vary; the critical factors to be considered which affect neck diameter are the volume above and below zero, the graduation sizes, the minimum space between graduations and the use of fill pipes and vapor recovery systems.

For a capacity intermediate between two capacities listed above, the sizes prescribed for the lower capacity shall be applied.

Table 2a. Scale plate tolerances for metric field standards and provers

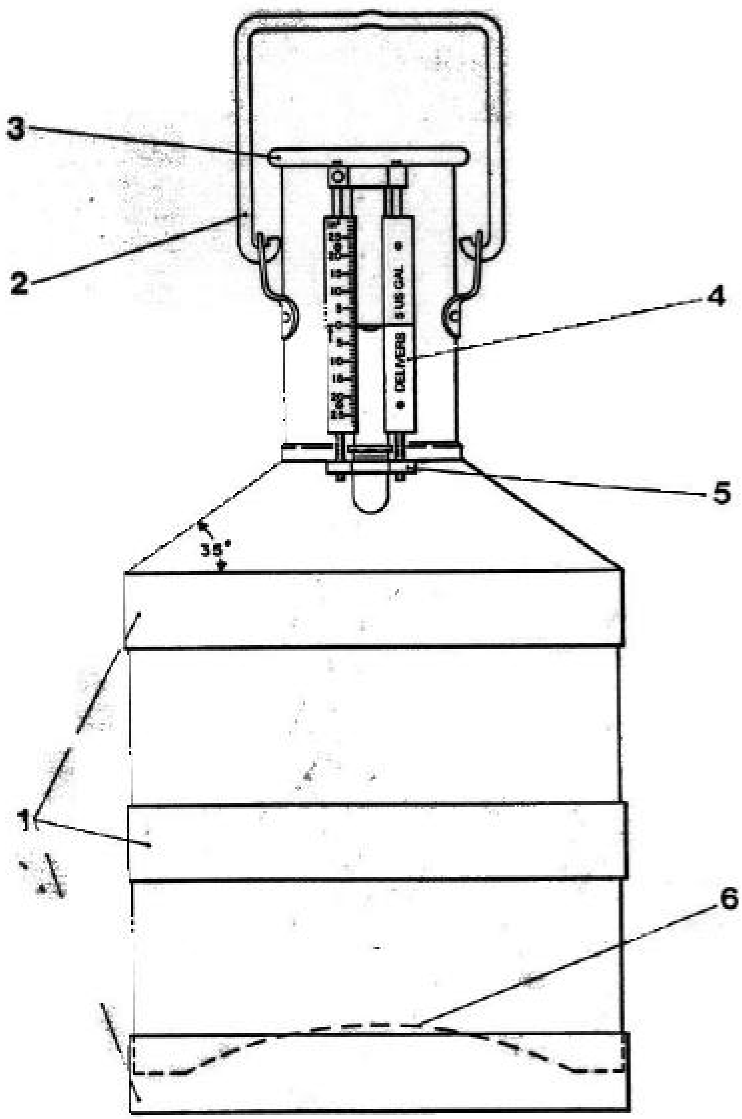
Capacity (in^3)	Tolerance (0.02 percent)	Scale Plate		
(L)	(mL)	Neck Volume on Scale (1.5 percent)*	Maximum Value of Division (mL)	Subdivisions (mL)
5	1	75 mL	2	--
10	2	150 mL	5	--
20	4	300 mL	10	--
50	10	750 mL	20	--
100	20	1.5 L	50	25
200	40	3.0 L	100	50
500	100	7.5 L	200	100
1 000	200	15 L	500	250
2 000	400	30 L	1000	500
3 000	600	45 L	1000	500
5 000	1000	75 L	1000	500

*The neck volume is to contain a minimum of 1.5 times the maintenance tolerance in both under registration and over registration for the listed nominal capacities for a total neck volume of 3 percent. If increased readability of range or increased sensitivity is desired, the length of the reading scale may be adjusted with proportional adjustment of neck diameter, provided height constraints are not exceeded.

Table 2b. Scale plate tolerances for customary field standards and provers

Capacity	Tolerance (0.02 percent)	Scale Plate		
(gal)	(in^3)	Neck Volume on Scale (1.5 percent)*	Maximum Value of Division (in^3)	Subdivisions (in^3)
1	0.05	4 in^3	0.1	--
5	0.2	18 in^3	1	--
10	0.2	36 in^3	1	--
25	1	90 in^3	2	--
50	2	180 in^3	5	1
100	5	1.5 gal	5	1
200	9	3 gal	20	10
500	20	7.6 gal	100	20
1 000	40	15.2 gal	100	20
1 500	60	22.5 gal	100	20

*The neck volume is to contain a minimum of 1.5 times the maintenance tolerance in both under registration and over registration for the listed nominal capacities for a total neck volume of 3 percent. If increased readability of range or increased sensitivity is desired, the length of the reading scale may be adjusted with proportional adjustment of neck diameter, provided height constraints are not exceeded.



1 Reinforcing Bands

2 Handle (raised)

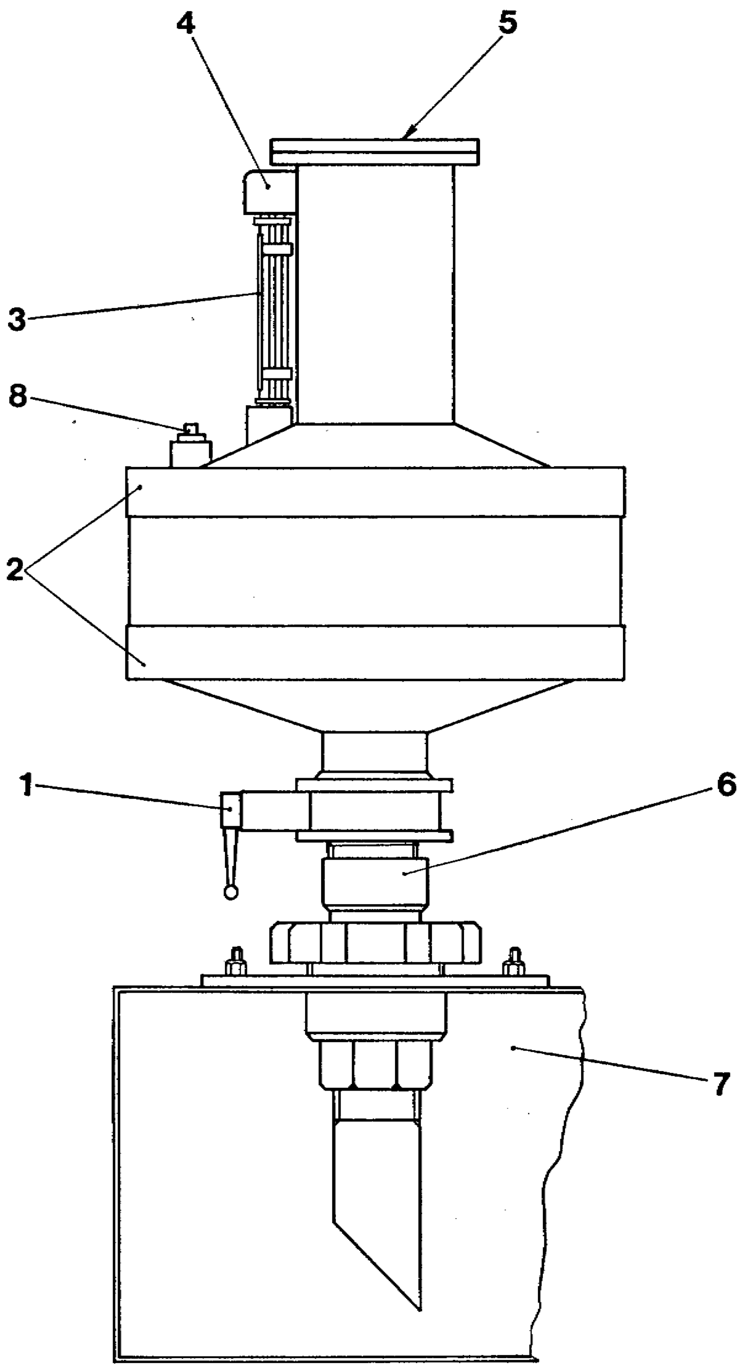
3 Rolled Bead (level surface)

4 Gauge Assembly

5 Gauge Mounting

6 Concave Bottom

Figure 1. 5 gallon hand-held test measure.



1 Drain Valve

2 Reinforcing Bands

3 Gauge Assembly

4 Gauge Mounting

5 Neck Reinforcement

6 Ball Joint

7 Truck Storage/Transfer Tank

8 Level

Figure 2. 5 gallon truck mounted prover.

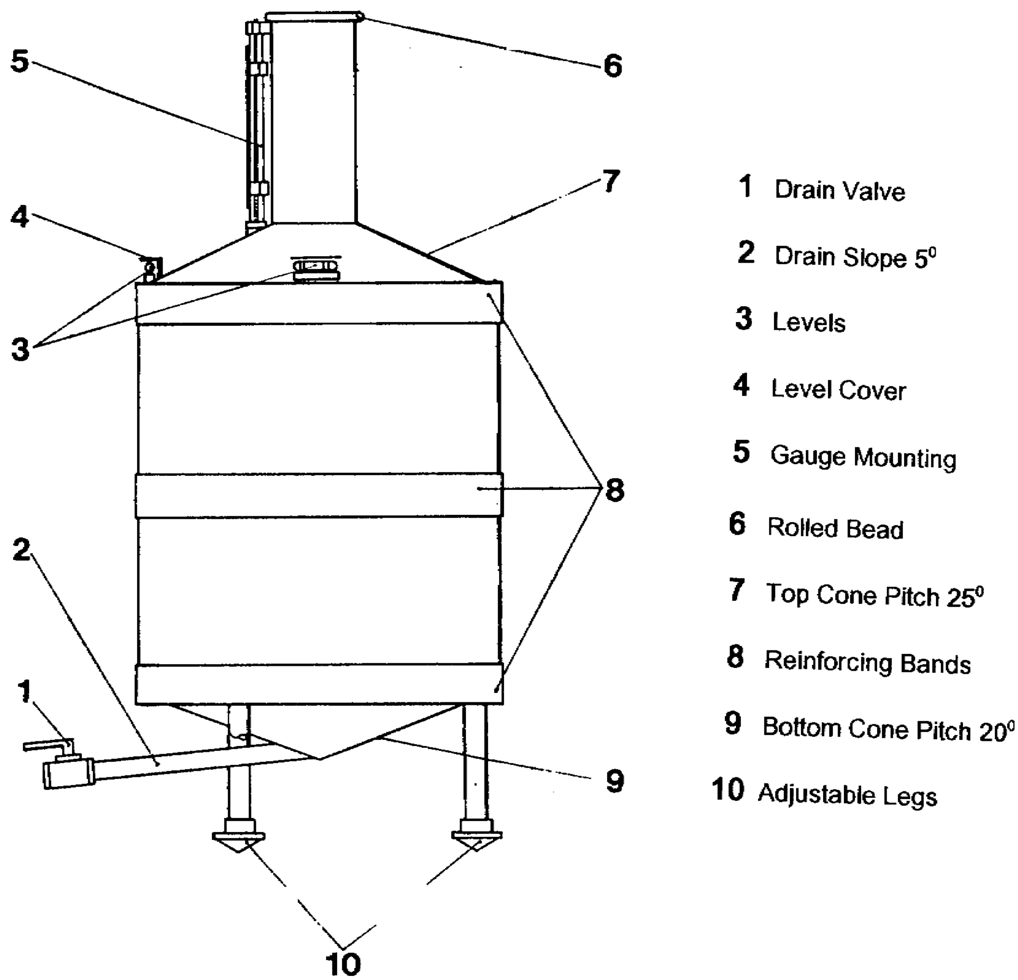


Figure 3. Field standard prover.

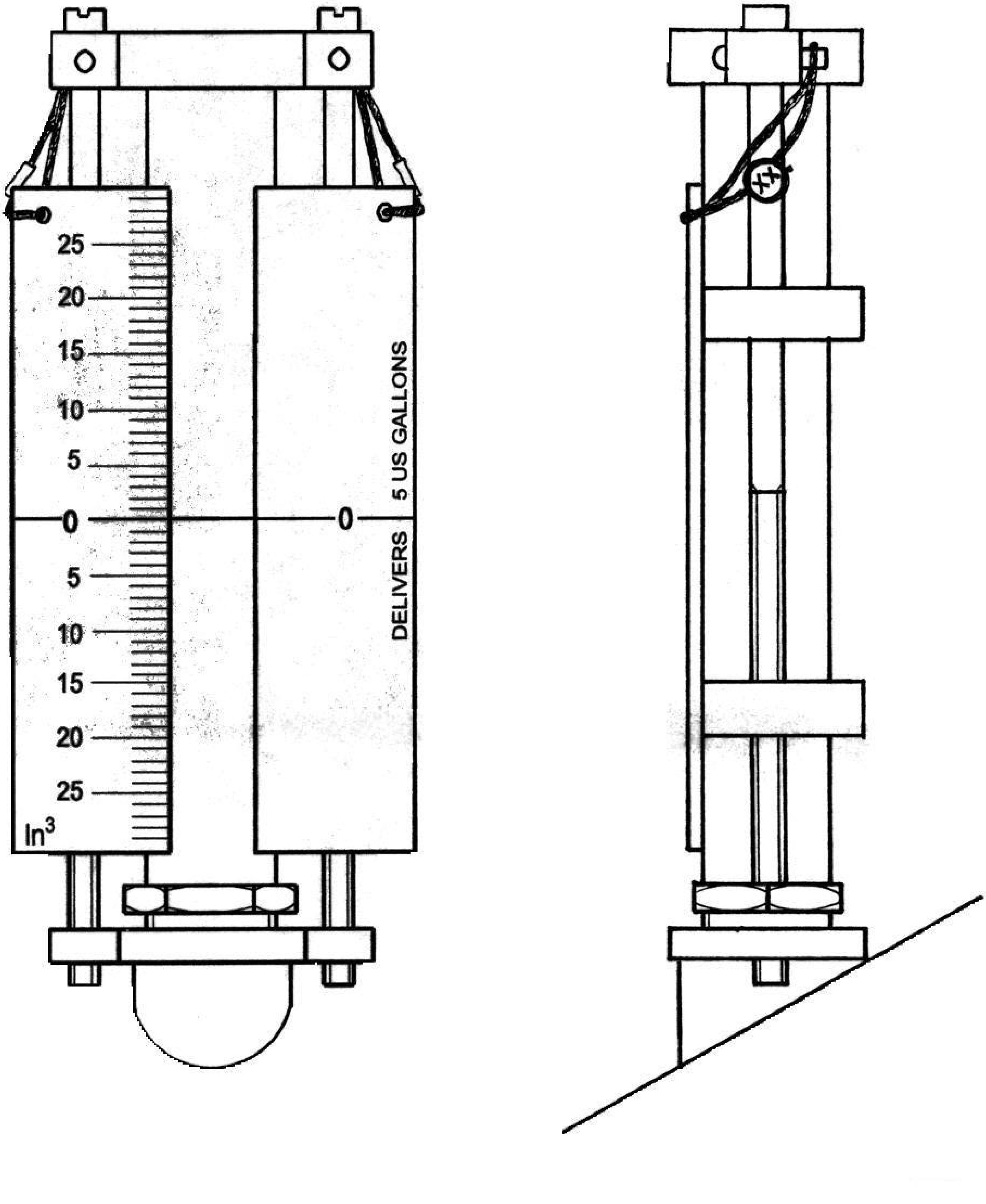


Figure 4. **Gauge assembly.**

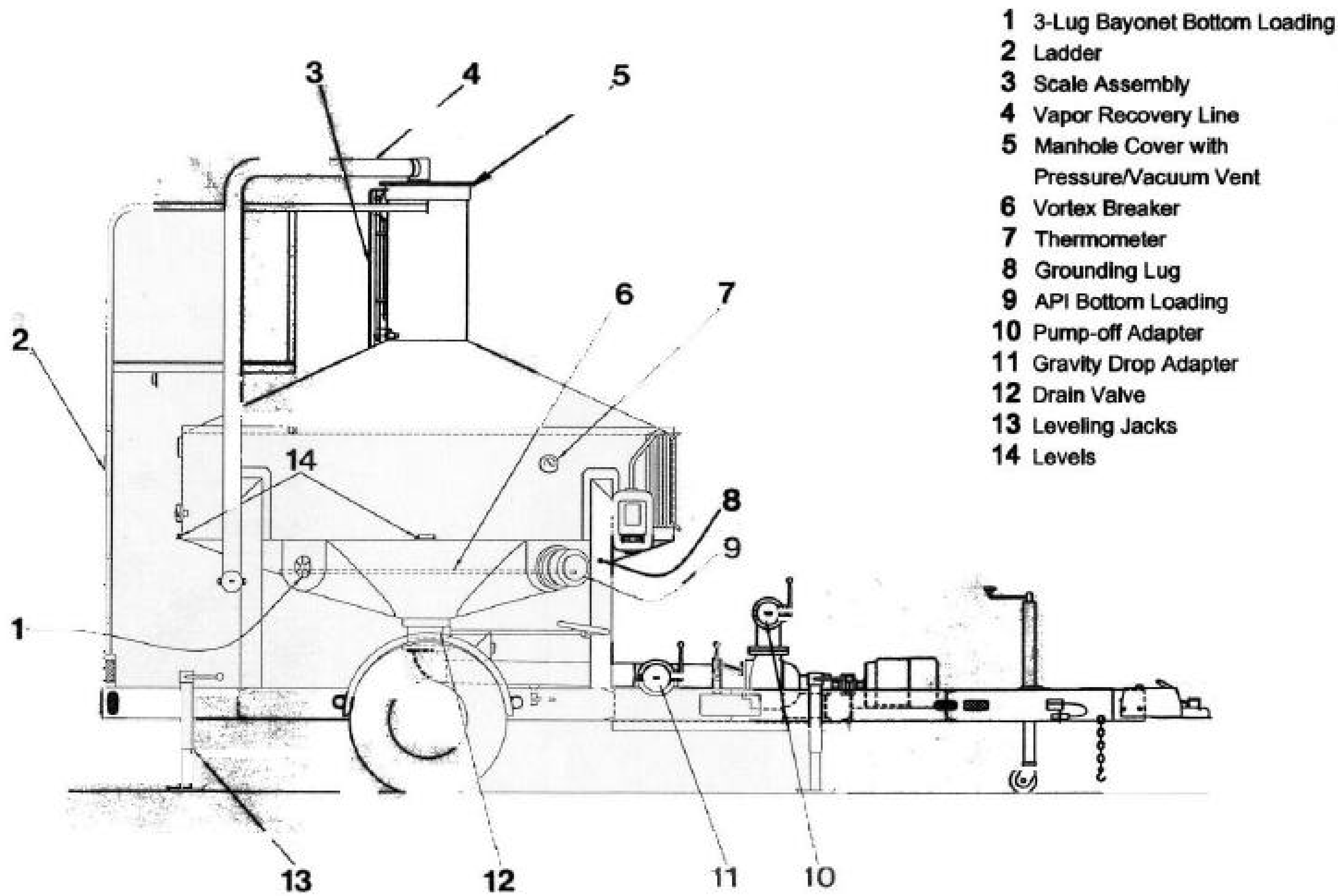


Figure 5. Portable prover.

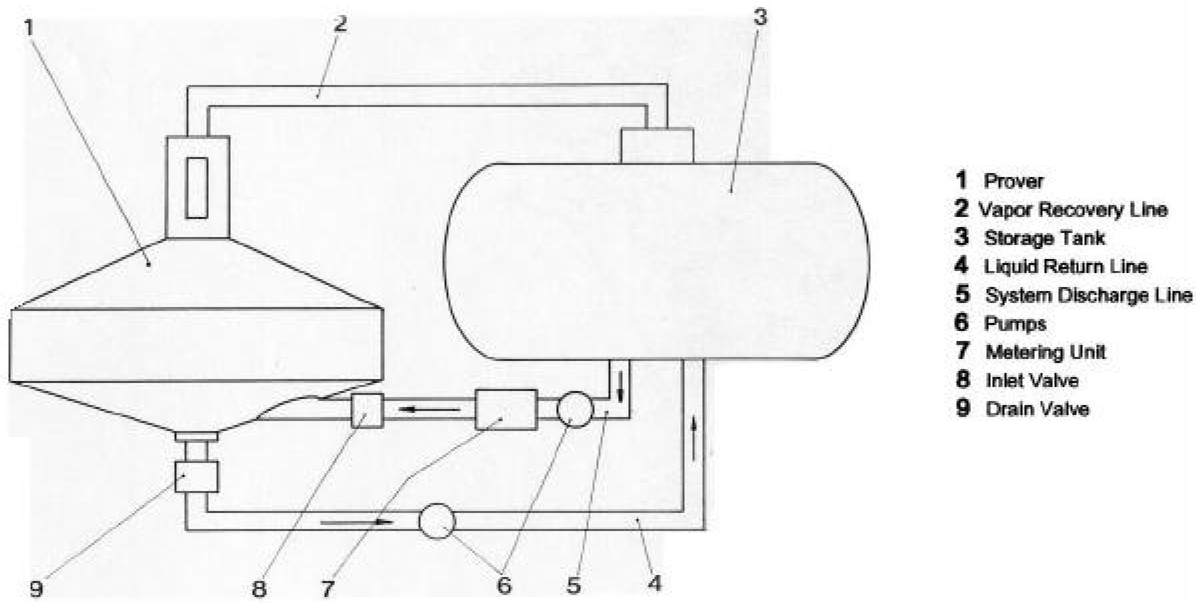


Figure 6. Schematic for use of prover in meter verification.