NBS HANDBOOK 105-3

Revised 1979

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

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

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

NATIONAL BUREAU OF STANDARDS

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[1]Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington,D.C. 20234.
[2]Some divisions within the center are located at Boulder, Colorado, 80303.

The National Bureau of Standards was reorganized, effective April 9, 1978.

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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CONTENTS

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 in the field by State and local weights and measures officials and others in quantity determinations of liquid commodities.

Key words: Bottom loading; field standard provers; field standards; field standard test measures; provers; specifications; standards; test measures; tolerances; vapor recovery.

SCOPE AND FIELD OF APPLICATION

These specifications and tolerances are limited to non-pressure, graduated neck type, metal field standards, with or without vapor recovery capabilities.

The field standards covered by this publication are intended to be used by weights and measures officials.[1]* Manufacturers and distributors of liquid products, service maintenance personnel, research and testing laboratories, and others concerned with volume measurement of liquids may find these specifications and tolerances useful.

These specifications are not intended to make obsolete those field standards which were fabricated according to prior specifications.

Use of these standards at all appropriate levels of manufacture, distribution, and weights and measures inspection will help promote accuracy and uniformity in commerce.

The term "standard" as used in this publication refers to all sizes in general. Sizes up to and including 50 L, or 10 gal, are commonly referred to as test measures, and those of a larger size are referred to as provers. The provers referred to here are those whose volume is established between the shut-off valve and the nominal volume point on the graduated neck scale.

In some cases, larger or special purpose standards may be required which are not specifically covered in this publication; for example, test measures equipped with a 51-mm (2-in) diameter neck, or large provers mounted horizontally on a truck or trailer. Interested parties are urged to submit proposed designs to the Office of Weights and Measures, National Bureau of Standards, Washington, D.C. 20234 for evaluation before fabrication is begun.

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* The numbers in brackets refer to similarly numbered references at the end of this publication.

INTRODUCTION

The materials, designs, fabrication, and tolerances of the field standards herein specified are intended to permit their use in normal field testing operations as standards having nominal values. Proper use of these field standards will assist in providing measurement and standards traceability to the U.S. national standards of length and mass, through standards which have been supplied to the State weights and measures laboratories by the National Bureau of Standards, as authorized under Public Law 89-164. Field standards must be recalibrated periodically. The frequency of calibration required will depend upon usage and condition of the standards. Comparisons with other standards should be performed occasionally to detect those standards in need of recalibration.

Some of the specifications in this Handbook are the result of the American Petroleum Institute Research Associate Program at the National Bureau of Standards.[2]

It is recognized that during the transition period to the metric system there will be a need for sizes and dimensions to be expressed in the metric system, or the inch-pound system, or both. In this publication, both systems are used with the metric units given preference. The selected metric sizes of devices follow the practice of a 1, 2, 5 progression (except the 3000-liter size) and, in general, follow the current inch-pound size requirements. In some cases, such as pipe diameters and metal thicknesses where U.S. nominal metric dimensions have not been established, a soft conversion from existing inch-pound dimensions is shown. Soft conversion implies a change of nomenclature only; in this document, the alternative nomenclatures (metric and inch-pound) are shown by using parentheses and can be used interchangeably. Hard conversion is used to express metric capacities in (closely equivalent) round inch-pound units. Bracketed values are not to be used interchangeably with the comparable or corresponding metric values.

SPECIFICATIONS

1. Sizes

1.1 The recommended metric sizes of field standard test measures and the comparable sizes in inch-pound units (hard conversion) are: 5 L [1 gal], 20 L [5 gal], and 50 L [10 gal].

1.2. The recommended metric sizes of field standard provers, and the corresponding sizes in inch-pound units represented by the nominal volume lines located on scale plates are shown in Table 1. (See Section 5.5. and Figure 3.)

1.3. The 5000-liter [1321-gallon] prover, which is the largest of the provers described in this publication, is considered approximately the largest size which can be mounted vertically on a truck or trailer and meet height requirements and legal width regulations.

Table 1. Metric prover sizes and corresponding inch-pound sizes.

Metric	Inch-pound
100 L	26 gal
200	53
500	132
1000	264
2000	528
3000	793
5000	1321

2. Material

2.1. A field standard should be constructed of low carbon steel or 300 series stainless steel. Brackets, fittings, handles, and other associated hardware may be constructed of other materials provided they are durable and are suitable for their intended purpose.

2.2. These specifications are not intended to preclude the use of other suitable materials (i.e., plastic, reinforced plastic, aluminum, etc.) provided a standard made of such materials conforms to the applicable parts of these specifications. However, the material shall be thermally stable and not have an unduly high coefficient of thermal expansion which would render it unsuitable for field use. All applicable physical property data must be accurately documented for the material chosen. (See Section 7.1.)

3. Surface Finish

3.1. The interior surface of field standards made of low carbon steel shall be corrosion resistant. Resistance to corrosion shall be accomplished by terne plating, galvanizing, or coating with an epoxy resin, or other suitable material which will be impervious to the liquids for which the standard will be used.

3.2. The exterior surface of field standards made of low carbon steel shall be properly primed and coated with a glossy finish which is impervious to the liquids for which the standard will be used.

3.3. If a standard is to be used for measurements of food, such as milk, the appropriate governmental regulations regarding surface finish shall apply.

4. Design

4.1. Any cross section taken in a plane perpendicular to the vertical axis shall be circular, and the shape shall permit complete emptying and draining. Dimensional requirements are shown in Table 3.

4.2. Reinforcing bands and other means of support shall be used, where appropriate, to prevent distortion of a standard when it is full of liquid, or when it is being transported. (See Figure 1.) When a standard is level and full, its level condition should not change due to the weight of the liquid.

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

4.4. The bottom shall be designed to prevent distortion when filled and to provide protection against damage in use. (See Figure 1.)

4.5. A field standard shall be equipped with a liquid-level gage mounted on the side of the neck. (See Figures 1, 2, and 4.) The gage tube shall be borosilicate glass or plastic and be clear and free of any irregularities or defects which will distort the appearance of the liquid surface. If the tube is plastic it shall be rigid, durable, and remain clear for the life of the standard. It shall be impervious to liquids used and to cleaning agents. The tube shall be mounted in fittings which penetrate the cone near the neck and the neck near the top. The penetration of the neck is to allow passage of vapors from the tube for vapor recovery purposes. The fitting at the top of the tube shall have a removable plug to facilitate cleaning of the tube with a brush. Removal and replacement of the tube shall be accomplished without difficulty, and it shall be made leak proof by the use of compressable gaskets or "O" rings.

4.6. The volume of a standard shall be established without the use of fillers, adjusting plugs, or cavities of any kind.

4.7. A test measure shall stand solidly on a level surface with its vertical axis perpendicular to that surface.

4.8. A 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 trunions 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. (See Figure 1.)

4.9 The neck diameter of a test measure shall be sufficient to permit insertion of a hand and arm for manual cleaning and inspection.

4.10. 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 to 15 cm (4 to 6 in) of the bottom cone. More than one pipe may be installed if necessary. (See Figure 4.) 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.

4.11. A gravity discharge line, between the prover and the shut-off valve, shall have a downward slope of at least 7°. (See Fig. 2.) 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, a fast-acting valve (butterfly or equal), and a sight-flow indicator. A gravity line shall have a fitting to connect the drain or pump-off hose. The sight-flow indicator shall be downstream of the valve to detect leakage and shall have a moving element to allow verification of flow. The sight-flow indicator shall be optional on non-vehicle mounted provers and where flow can be otherwise observed. The hose fitting shall also be optional on non-vehicle mounted provers. Adequate support of all discharge lines shall be provided.

4.12. All removable piping, valves, and fittings which form a part of a prover volume shall be provided with a means of lead and wire sealing. Removal or movement of these parts shall not be possible without breaking the seal.

4.13. A prover not permanently installed shall have adequate provision for leveling. (See Figure 2.)

4.14. A truck or trailer on which a prover is mounted shall be equipped with a sufficient number of leveling jacks to maintain a level and stable condition when under load. (See Figure 4.)

5. Scales

5.1. The scale plate shall be rigid and corrosion resistant. It shall be mounted on a tangent to the front of, or slightly in front of, or directly behind the gage tube. In any case, it shall be not more than 6 mm (0.25 in) from the tube. (See Figure 3.)

5.2. Where the scale is mounted behind the gage tube, protection of the tube shall be provided by a gage shield. (See Figure 3.) The protective shield shall allow replacement of the gage tube without difficulty.

5.3. There shall be a sufficient number of scale brackets (minimum of two) to hold the plate(s) firmly. The brackets shall be mounted on two adjusting, or guide, rods. The scale plate(s) shall be securely attached to the brackets and be provided with a means for sealing. (See Figure 3.)

5.4. An adjusting rod shall be provided with a means for sealing which will prevent movement or play. (See Figure 3.) Removal or movement of the adjusting mechanism or scale plates shall not be possible without breaking the seal.

5.5. The basic scale on all standards shall be milliliters or cubic inches. To avoid confusion and possible reading errors, dual scales on any one scale plate are not permitted, e.g., milliliters and cubic inches. Dual scales are permitted only when two scale plates are used, such as shown in Figure 3. The basic scale shall be on the left side of the gage when viewed from the front. If one of the scales is graduated in units other than milliliters or cubic inches, it shall be placed on a plate to the right of the gage tube. If the two scales are in the same system, e.g., either metric or inch-pound the two zero lines shall lie in the same horizontal plane. Where the two scales are in different systems, e.g., metric and inch-pound, the placement of the nominal volume lines shall accurately reflect the relationship between the two systems. If the scales are not so aligned each scale shall be capable of being adjusted and sealed separately.

5.6. Where the design of the scale adjustment provides for movement of the scale by increments only, the maximum increment shall be 25 percent of the smallest scale division.

5.7. The minimum distance between any adjacent graduation lines shall be 1.5 mm (0.0625 in), and the lines shall be evenly spaced.

5.8. The scales shall be graduated both above and below the zero line by an amount not less than one and one-half times the maximum tolerance as determined by the prover size. These tolerances are currently listed in NBS Handbook 44.[1]

6. Scale Markings

6.1. The graduation lines, numbers, and other inscriptions on the scale plate shall be permanent and of a contrasting color to that of the plate.

6.2. Convenient major division lines, consistent with the measurement system used, shall be longer than subdivision lines and be numbered for volume indication. (See Figure 3.)

6.3. The length of the major (numbered) graduation lines on scale plates mounted tangent to the front of the gage tube 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 gage tube.

6.4. 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.

6.5. Scale plates mounted behind the gage glass shall have major graduations at least 20 mm (0.8 in) and subdivision lines at least 15 mm (0.6 in) in length. (See Figure 3.)

6.6. The zero line on all scale plates shall extend across the entire width of the plate and be clearly identified.

6.7. Scale plates shall be marked with the intended method of use, i.e., "CONTAINS" or "DELIVERS" or, "IN" or "EX".

7. Special Requirements

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

a. Name and address of manufacturer
b. Model number
c. Non-repetitive serial or identification number
d. Material identification
e. Material thickness
f. Cubic coefficient of thermal expansion of material per °C [°F]
g. Nominal volume at zero line on neck scale
h. Drain time after flow cessation

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

7.2. A prover shall be equipped with two adjustable spirit levels mounted, at right angles to each other, on the upper cone. Vehicle mounted provers may have the levels mounted on the sides near the bottom for convenience. Each level shall be mounted on a sturdy shelf and be equipped with a hinged protective cover. The adjusting screw shall be provided with a means for lead and wire sealing. (See Figure 2.)

7.3. All vehicle mounted provers, if not enclosed, shall be equipped with a cover. 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.

7.4. 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.

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

7.6. A prover system permanently equipped with a return pump shall be provided with a 3-way valve connected to the pump line and to the gravity line.

7.7. A return pump shall be of a centrifugal design, and self priming is preferred. The pump and piping shall be sized according to the prover volume. The flow rate shall be approximately 15% of the prover volume, with a minimum of 250 L/min (65 gpm).

7.8. The ends of all fill, drain, and vapor recovery pipes on the exterior of a truck or trailer mounted prover shall be capped.

7.9. An effective anti-swirl device shall be attached to the bottom cone of a prover to minimize liquid swirl during emptying. (See Figure 2.)

7.10. A grounding lug 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.

7.11. A ladder and expanded metal platform, when required to read the gage scale, shall be securely attached to the prover on the same side as the scale. The ladder shall be so constructed that there is no distortion of the prover when maximum anticipated load is applied.

7.12. One or two thermometer wells shall be installed in all closed-fill provers, and in all open-top provers larger than 1000 liters or 250 gallons. A well is to point inward and downward at an angle of approximately 15° from the horizontal. When a single well is installed, the end extending inside the prover should be at the approximate center of the cylindrical section height. If two wells are installed one end should be near the top and one near the bottom of the cylindrical section. (See Figure 4.)

8. Workmanship

8.1. All interior seams, whether welded or soldered, shall be filled and smooth to prevent the entrapment of air or liquid, and shall not leak.

8.2. 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.

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

8.4 Leveling jacks shall operate freely and be stable under load.

8.5. A field standard, together with its associated valves, piping, gage, 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.

8.6. All threaded connections, including plugs and caps, shall be thoroughly lubricated with a suitable nonhardening paste, or pipe joint tape, and shall not leak.

9. Bottom Loading

9.1. Meter installations equipped for bottom loading will 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 (barrel) of the prover, just above the bottom conical section. The vertical dimension, above grade, of the adapter should not exceed 122 centimeters (48 inches). Penetration of the prover should be accomplished with a weld elbow

as shown in Figure 4. The elbow shall direct the flow around the periphery of the prover and slightly downward. A small diameter bleed hole, about 3 millimeters (0.125 inch), shall be drilled in the top of the elbow (inside the prover) to eliminate trapping of air when the prover is being loaded by some means other than through the adapter. For the same reason, a small bleed valve shall be installed on top of the adapter fitting on the exterior of the prover wall. The bottom loading adapter shall comply with American Petroleum Institute RP 1004, "Bottom Loading and Vapor Recovery for MC-306 Tank Motor Vehicles," latest edition.

9.2. A throttling valve to achieve reduced flow rate for "special tests" may be required. This valve shall be installed between the flange of the bottom load adapter and the flange on the pipe entering the prover barrel. The valve shall be of the butterfly type with a 13-mm (0.5-inch) hole in the gate to prevent blocking total flow if closed. The valve handle shall be provided with a notched, indexing mechanism to mechanically hold the valve in the selected open position.

10. Tolerances

10.1. The tolerances in Table 2 are the maximum allowed if the standard is to be used without correction. They are based on 25 percent of the current acceptance tolerance (from NBS Handbook 44 tolerance tables) to be applied to the device being tested.[1] However, when a standard has been calibrated by a State weights and measures laboratory or other competent calibrating agency, it should be adjusted as close to nominal as possible.

10.2. If a higher degree of accuracy than that provided by a tolerance test is desired, the volume of the standard together with the uncertainty shall be documented.

Table 2. Capacity tolerances for nominal sizes of metal volumetric field standards.*

Size	Tolerance	Size	Tolerance
5 L	± 5 mL	1 gal	± 0.3 in^3
20	15	5	.8
50	25	10	1.5
100	60	26	3.5
200	100	53	6.0
500	150	132	11.0
1000	300	264	19.0
2000	600	528	35.0
3000	800	793	50.0
5000	1400	1321	85.0

* For intermediate or larger sizes the tolerances are to be determined as described in Section 10.1.

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

11. Vapor Recovery

11.1. Provers equipped with an external vapor recovery tube shall have the tube emerging from the neck just below the reinforced top and extending, tangent to the prover surface, to a point in the same approximate horizontal plane as the bottom load adapter. The tube shall terminate with a threaded tee to allow installation of the required vapor return fitting and valve to serve as a vacuum breaker during unloading. A combination vapor recovery and submerged fill pipe shall have a fitting for connecting with the filling adapter.

11.2. The size of the vapor recovery tube shall normally be 102 millimeters (4 inches). A smaller size may be required for some applications.

11.3. All provers with vapor recovery provisions shall be equipped with a pressure relief fitting of 20 to 35 kPa (3-5 psi) rating. (See figure 4.)

11.4. All provers with vapor recovery provisions shall be equipped with protection against excessive vacuum during unloading. This fitting shall have a vacuum rating of 20 kPa (3 psi).

Table 3. Dimensional Requirements

Size	Minimum Metal Thickness (low) carbon or Stainless steel)*	Neck Diameter (Inside)	Gage Tube Diameter (Inside)	Minimum Top Cone Pitch	Minimum Bottom Cone Pitch	Minimum Drain Size
5 L [1 gal]	0.8 mm** (0.0312 in)	98 mm (3 7/8 in)	13 mm (1/2 in)	35°	———	———
20 L [5 gal]	0.8 mm** (0.0312 in)	98 mm (3 7/8 in)	13 mm (1/2 in)	35°	———	———
50 L [10 gal]	0.8 mm** (0.0312 in)	98 mm (3 7/8 in)	13 mm (1/2 in)	35°	———	———
100 L [26 gal]	2.8 mm (0.109 in)	127 mm (5 in)	16 mm (5/8 in)	25°	20°	38 mm (1 1/2 in)
200 L [53 gal]	2.8 mm (0.109 in)	152 mm (6 in)	16 mm (5/8 in)	25°	20°	50 mm (2 in)
500 L [132 gal]	2.8 mm (0.109 in)	203 mm (8 in)	16 mm (5/8 in)	25°	20°	50 mm (2 in)
1000 L [264 gal]	2.8 mm (0.109 in)	254 mm (10 in)	16 mm (5/8 in)	25°	20°	50 mm (2 in)
2000 L [528 gal]	3.6 mm (0.141 in)	336 mm (13.25 in)	16 mm (5/8 in)	25°	20°	75 mm (3 in)
3000 L [793 gal]	4.4 mm (0.172 in)	336 mm (13.25 in)	16 mm (5/8 in)	25°	20°	100 mm (4 in)
5000 L [1321 gal]	4.4 mm (0.172 in)	387 mm (15.25 in)	16 mm (5/8 in)	25°	20°	100 mm (4 in)

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

** Minimum for the bottom shall be 1.3 mm (0.050 in).

DEFINITIONS

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

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

3. Borosilicate glass: Glass of a low coefficient of thermal expansion and known by such trade names* as Kimax (KG-33), or Pyrex.

4. Epoxy resin: Any of the various (usually heat-setting) resins that are made by polymerization of an epoxide (e.g., ethylene oxide or epichlorohdrin) with a diphenol.

5. Flow cessation: The moment when a full stream "breaks" and becomes a trickle or drip.

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

7. Vapor recovery: A system for entrapping and collecting vapors to prevent their being expelled into the atmosphere.

8. "IN": An indication that the standard is adjusted to contain its intended volume.

9. "EX": An indication that the standard is adjusted to deliver its intended volume.

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

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REFERENCES

[1] NBS Handbook 44, "Specifications, Tolerances and Other Technical Requirements for Commercial Weighing and Measuring Devices"

[2] Hine, D. J., "Evaluation of Metal Volumetric Standards Used in the Measurement of Liquid Hydrocarbons"

Table 4. Scale Graduations

Size	Minimum Volume Above and Below Zero	Value of Graduations
5 L [1 gal]	250 mL [15 in^3]	20 mL [1 in^3]
20 L [5 gal]	250 mL [15 in^3]	20 mL [1 in^3]
50 L [10 gal]	250 mL [15 in^3]	20 mL [1 in^3]
100 L [26 gal]	1650 mL [100 in^3]	50 mL [2 in^3]
200 L [53 gal]	2500 mL [150 in^3]	100 mL [5 in^3]
500 L [132 gal]	4650 mL [275 in^3]	200 mL [10 in^3]
1000 L [264 gal]	8300 mL [525 in^3]	200 mL [10 in^3]
2000 L [528 gal]	15600 mL [950 in^3]	500 mL [25 in^3]
3000 L [793 gal]	22800 mL [1400 in^3]	500 mL [25 in^3]
5000 L [1321 gal]	32400 mL [2000 in^3]	500 mL [25 in^3]

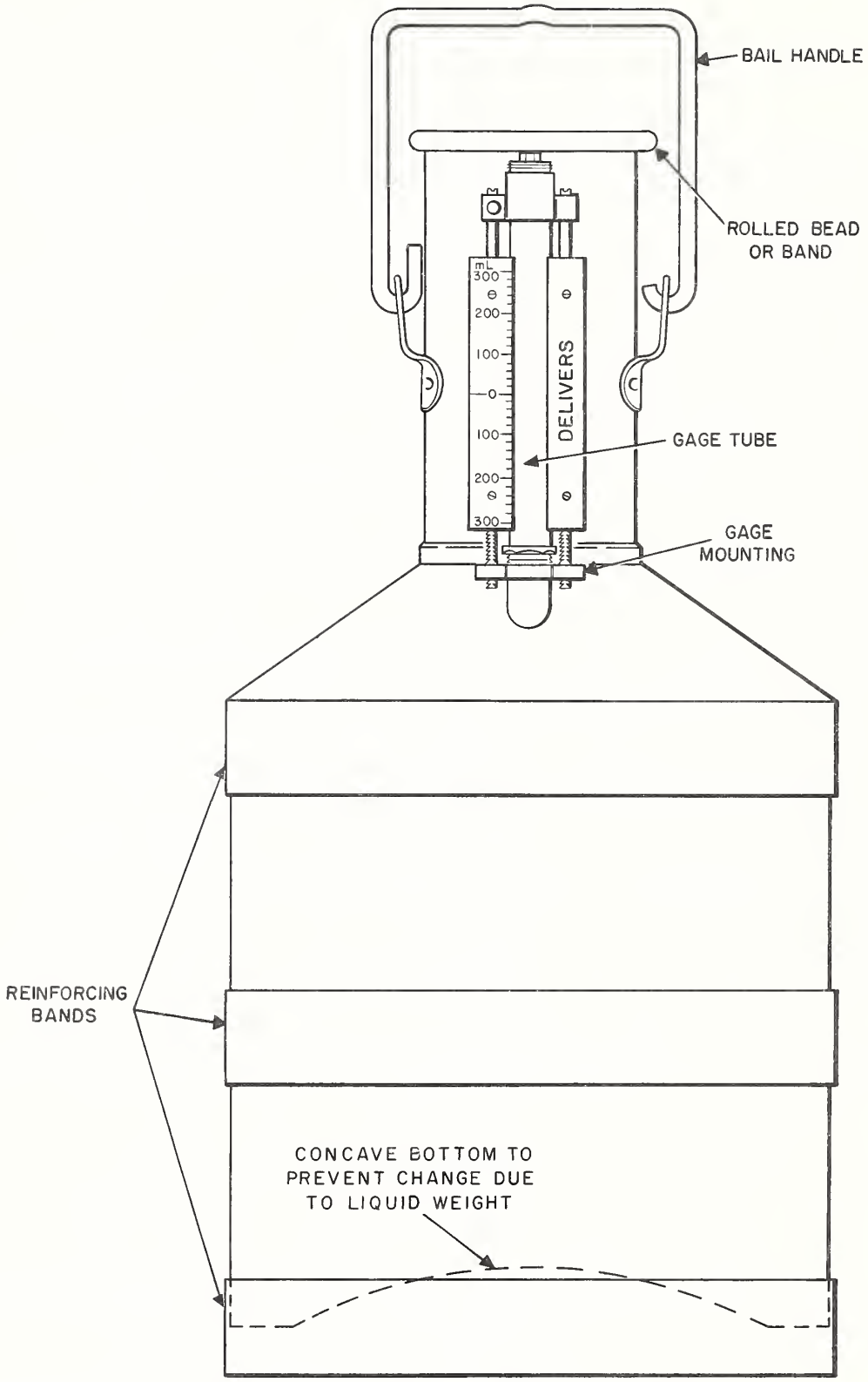

FIGURE 1. Field standard test measure.

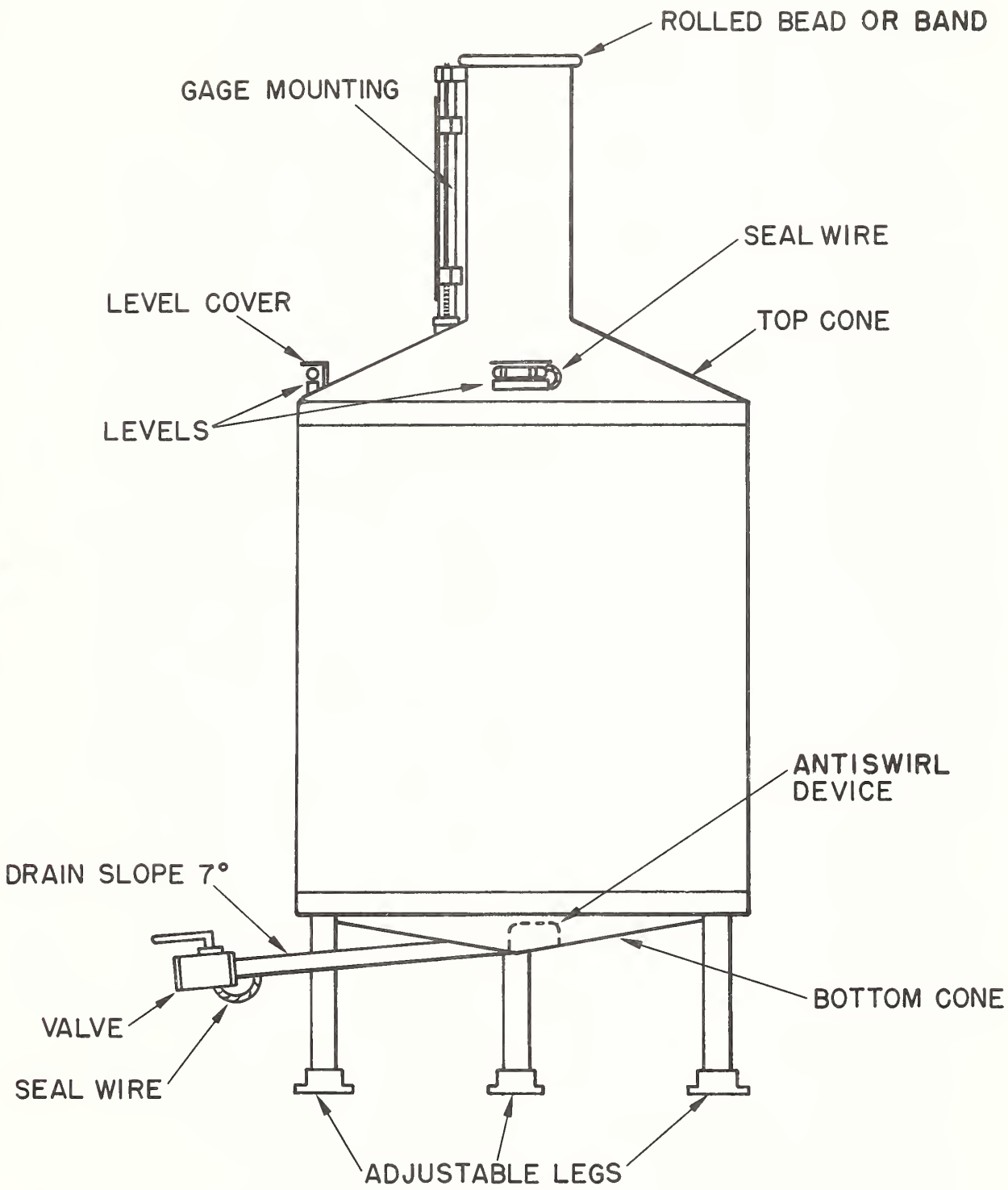

FIGURE 2. Field standard prover.

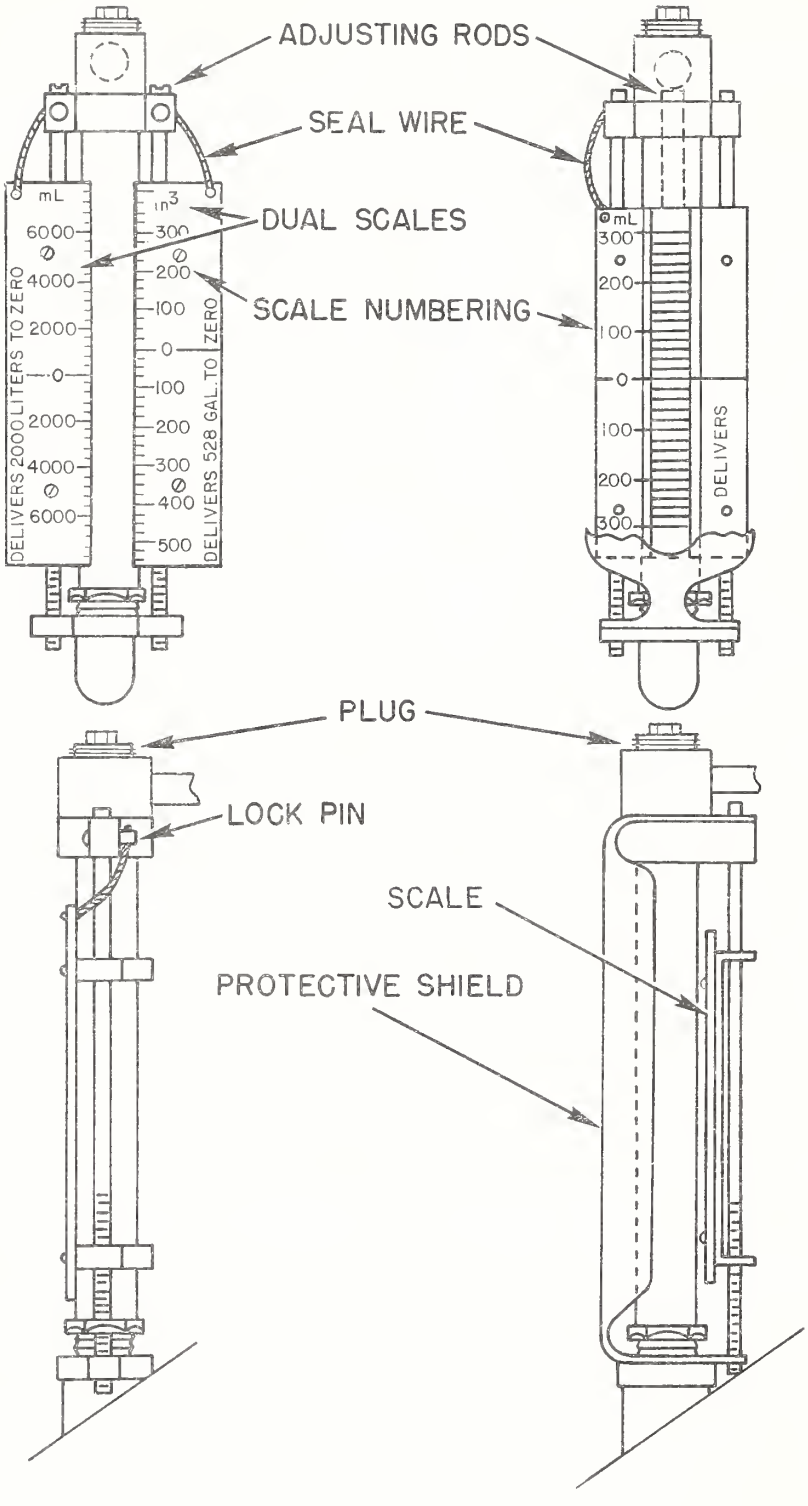

FIGURE 3. Gage assembly.

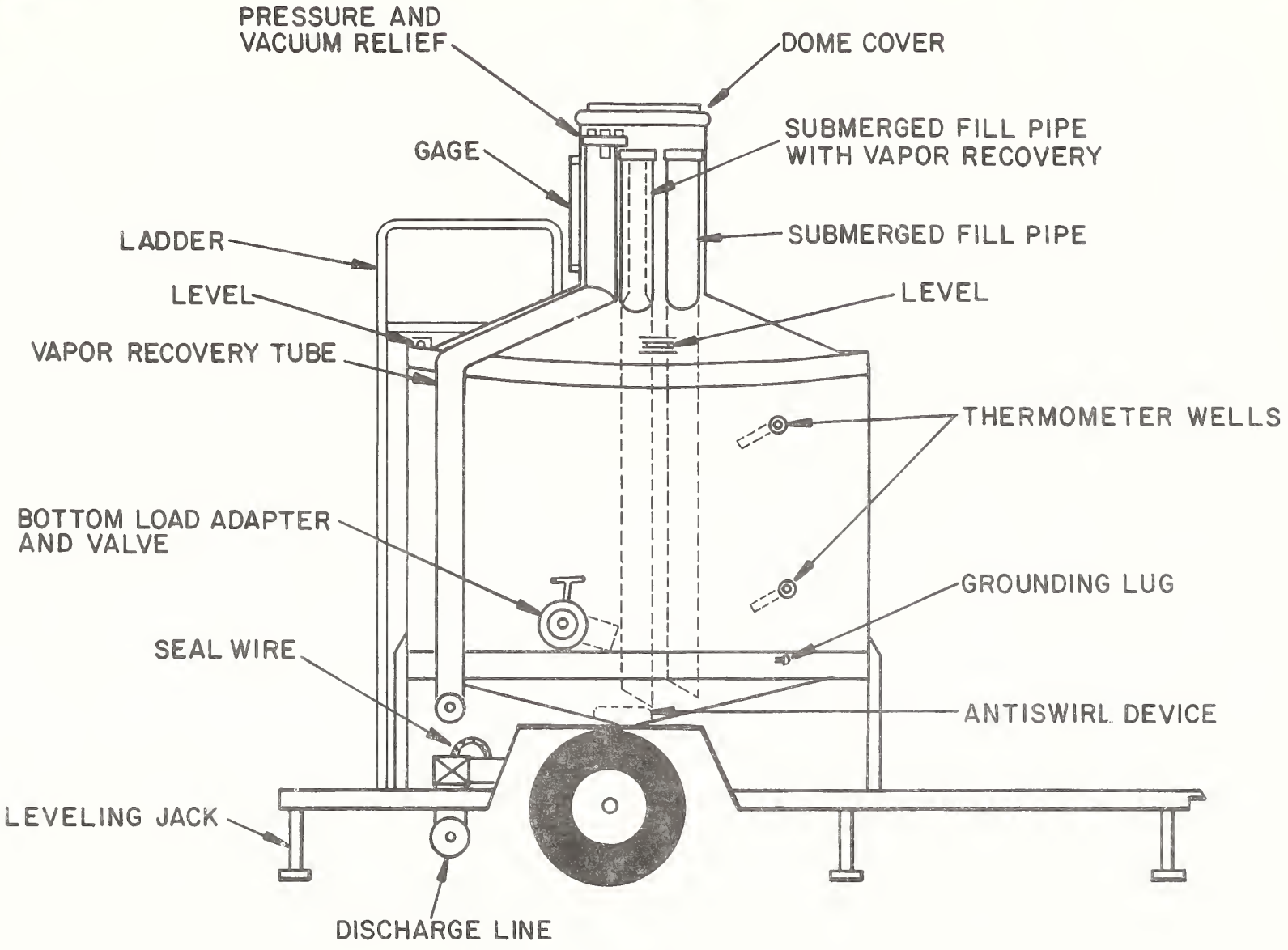

FIGURE 4. Portable prover.

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[ ] Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

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

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

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