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Examination of Vapor-Measuring Devices for Liquefied Petroleum Gas

A Manual for Weights and Measures Officials

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.

[2] Located at Boulder, Colorado 80302.

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Examination of Vapor-Measuring Devices for Liquefied Petroleum Gas

A Manual for Weights and Measures Officials

Stephen Hasko

Institute for Applied Technology
National Bureau of Standards
Washington, D.C. 20234

(Supersedes NBS Handbook 45)

U.S. DEPARTMENT OF COMMERCE, Rogers C. B. Morton, *Secretary*

James A. Baker, III, *Under Secretary*

Dr. Betsy Ancker-Johnson, *Assistant Secretary for Science and Technology*

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

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Preface

This publication is one of a number of Handbooks of the National Bureau of Standards (NBS) designed to present in compact form comprehensive technical guides for State and local weights and measures officials. This particular Handbook treats the examination of liquefied petroleum gas vapor-measuring devices. The Handbook is part of a series which will supersede NBS Handbook 45, *Testing of Measuring Equipment*. Each of the several types of measuring devices is being considered separately in acknowledgment of the increasing specialization in weights and measures supervision, the rapidly developing technological character of commercial measurement, and the everchanging equipment utilized in the measurement process.

Authority for such activity on the part of the Bureau is found in basic legislation (64 Stat. 371) wherein the Bureau is authorized to undertake, among others, the following functions: "cooperation with the States in securing uniformity in weights and measures laws and methods of inspection," and "The compilation and publication of general scientific and technical data resulting from the performance of the function specified herein or from other sources when such data are of importance to scientific or manufacturing interests or to the general public, and are not available elsewhere * * *."

The Handbook is published in loose-leaf form to permit updating as required, thus furthering its usefulness to the official in his field operations.

This publication is prepared primarily for testing with a bell prover since this is the predominant proving procedure in use at the present time. Other acceptable meter proving procedures are in existence and others probably will be developed in the future. This publication is not intended to limit the proving of the devices to bell proving equipment.

The Handbook has been prepared to be used with metric as well as customary units. Wherever applicable, tables have been provided in both units. In the procedure itself, only customary units are used when dealing with various units of measurement. The accepted practice is to use whole units, however, the industry has not made any decisions concerning such metric equivalents for a "hard conversion." To assist the reader, all metric and customary units are defined with respect to each other in the "Definitions" and sample report data tables have also been prepared using metric units.

Although this Handbook is prepared primarily for use by weights and measures officials of the States, counties, and cities, it is believed that the information presented will be useful to manufacturers, commercial, and industrial establishments interested in the measurement of liquefied petroleum gas.

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Examination of Vapor-Measuring Devices for Liquefied Petroleum Gas

Stephen Hasko

A manual for State and local weights and measures officials for the examination and test of liquefied petroleum gas vapor measuring devices. Definitions, test methods, and testing apparatus (including description and calibration procedures) are given. Inspection and test procedures are reviewed. A proposed test report form along with suggestions on reporting the results of a test are included. Provision is made for accommodating a changeover to metric units of registration in the definitions, correction tables, procedures, and in reporting a test.

Key words: bell prover; calibration; inspection; liquefied petroleum gas; pressure; report form; temperature; temperature compensator; test; vapor meter; volume.

1. Definitions [1, 2][1]

absolute pressure. Total pressure measured with respect to zero pressure [i.e. psia or kPa (absolute)].

atmospheric pressure (mean). The atmospheric pressure agreed to exist at the meter at various ranges of elevation, irrespective of variations in atmospheric pressure from time to time.

badge. A metal plate affixed to the meter by the manufacturer showing the manufacturer's name, serial number and model number of the meter, its rated capacity, and other basic meter information.

base pressure. The absolute pressure used in defining the gas measurement unit to be used, the gage pressure at the meter plus the mean atmospheric pressure. For most practical purposes the mean atmospheric pressure is the barometric pressure given in the altitude correction tables (table 1). For example: if the gage pressure at the meter is 11 in water column (WC) and the agreed atmospheric pressure is 14.4 psia, then the base pressure would be $14.4+11/27.7=14.4+0.4=14.8$ psia. There are 27.7 in WC in one psia.

bell prover. A calibrated cylindrical metal bell with a scale thereon which, in the downward travel in a surrounding annular tank containing a sealing medium, displaces air through the meter being proved or calibrated. The prover may be calibrated by "strapping" (a measurement and calculation technique) or by "bottling" (a volume comparison technique) with a standard cubic foot bottle or a Stillman portable cubic foot standard.

capacity rate. The rate of flow (in cubic feet or cubic meters per hour) of a liquefied petroleum gas vapor-measuring device as recommended by the manufacturer. This rate of flow should cause a pressure drop across the meter of ½-inch WC.

check rate. A rate of flow usually 20 to 35 percent of the capacity rate.

cubic-foot bottle. A specially constructed and calibrated metal bottle open at the lower end and so supported that it may be easily raised or lowered in a tank which contains a sealing medium. With the level of the sealing medium properly adjusted, the bottle, when lowered, will displace exactly 1 cubic foot of air upon coming to rest on the bottom of the tank. The marks on the bottle defining the cubic foot are the bottom of the lower neck and the gage mark which partially surrounds the gage glass in the upper neck. The calibration of the bottle must be traceable to the National Bureau of Standards.

cubic foot, metered. The quantity of gas that occupies 1 cubic foot when under pressure and temperature conditions existing in the meter.

cubic foot, standard. The quantity of gas defined in gas industry as that quantity which under a pressure of 14.73 psia and at a temperature of 60 °F occupies a volume of 1 cubic foot. (A quantity defined in the gas industry as that amount of gas that occupies 1 cubic foot under the conditions indicated.)

cubic meter, metered. The quantity of gas that occupies 1 cubic meter when under pressure and temperature conditions existing in the meter.

[1] Figures in brackets indicate the literature references on page 17.

cubic meter, standard. The quantity of gas which under a pressure of 101.56 kPa (14.73 psi) and at a temperature of 15.5 °C (60 °F) occupies a volume of 1 cubic meter (derived from cubic foot standard).

ft^3/h. Cubic feet per hour.

gage pressure. Pressure measured relative to atmospheric taken as zero (i.e. psi of kPa).

gage pressure, meter. The difference between the pressure at the meter and the atmospheric pressure.

liquefied petroleum gas. A liquefied hydro-carbon mixture composed predominantly of propane or butane which can be stored as a liquid and used as a gas at normal atmospheric pressures and temperatures.

low-flame test. A test simulating extremely low-flow rates such as pilot flow rates caused by pilot lights.

m^3/h. Cubic meters per hour.

meter register. An observation index for the cumulative reading of the gas flow through the meter. In addition there are one or two proving circles in which one revolution of the test hand represents ½, 1, 2, 5, or 10 cu ft, or 0.025, 0.05, 0.1, 0.2, or 0.25 cu m, depending on meter size. Where two proving circles are present, the circle representing the smallest volume per revolution is referred to as the "leak-test circle."

pilot flow rate. A minimum flow rate that a meter is required to register with a prescribed accuracy.

pressure drop. The loss in pressure between two points in a fluid flow system.

prover oil. A light oil of low vapor pressure used as a sealing medium in bell provers, cubic-foot bottles, and portable cubic-foot standards.

proving indicator. The test hand or pointer of the proving or leak-test circle on the meter register or index used for testing the meter and for indicating gas flow.

Stillman portable cubic-foot standard. A gasometer of the annular type, the bell being sealed with a light oil, the amount of its rise (and consequently of the volume of air or gas being measured) being under absolute control so that an exact cubic foot can be delivered.

strapping. A method of checking a bell prover by determining the relation between displaced volume and linear movement of a bell prover by means of measuring scale length, bell circumference and displacement of the sealing liquid.

vapor-measuring device (liquefied petroleum gas). A system including a metering mechanism or device of the meter type, equipped with a totalizing index, designed to measure and deliver liquefied petroleum gas in the vapor state by definite volumes, and generally installed in a permanent location. The meters are similar in construction and operation to the natural and manufactured gas meters. The majority of the meters are of the conventional diaphragm-type.

2. Testing Methods

The customary basic method of testing a LPG vapor meter for accuracy of registration is by passing a measured volume of air from a bell prover through the meter and comparing the registration of the meter with the volume indicated by the prover.

The use of reference meters for testing the accuracy of LPG vapor meters has certain limitations since a prover is still necessary to frequently verify the accuracy of the reference meter and an additional uncertainty due to the use of a prover is added to the test method, necessitating an increase in tolerances.

3. Testing Apparatus—Bell Prover

The testing apparatus (description, installation, calibration, and maintenance), prover room, and basic test procedures are well described by Beck [3]. Collett [4] also has discussed the calibration of bell provers. Both have given permission to draw freely from their publications.

3.1. Description

The tank and bell portion of a typical bell prover is shown schematically in figure 1 in both the raised and lowered positions. The bell prover consists of an annular metal tank (prover tank) open at the top and nearly filled with a sealing medium (usually an oil), in which a cylindrical tank called the bell, open at the bottom and having a dome-shaped top, can be raised or lowered. The liquid acting as a seal prevents air from entering or leaving the bell except through a pipe in a dry well which extends from the outside of the prover tank down underneath it and up on the inside to a point above the level of the liquid. The prover tank is made of two concentric tanks with a distance of about two inches between them. The inner tank has an airtight top through which the air supply pipe passes. This method of construction reduces the amount of oil required to seal the bell and when raised off the floor by the prover base permits more rapid temperature adjustment of the oil.

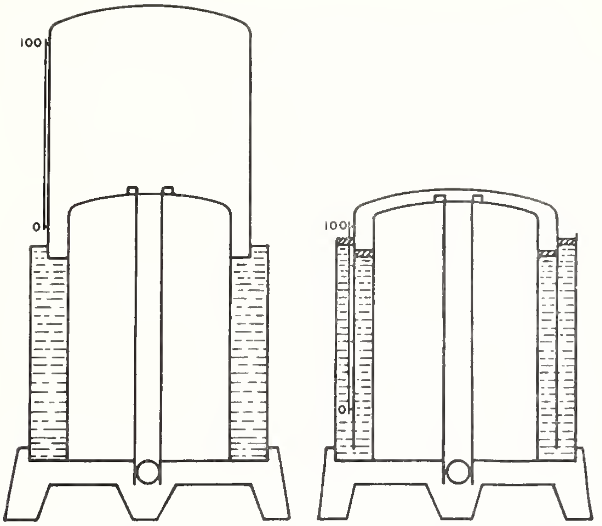

FIGURE 1. *Tank and bell portion of a typical bell prover (schematic).*

Figure 2 illustrates the exterior of a bell prover.

The bell is guided in its upward or downward movement by sets of rollers, at the top and at the bottom of the bell. These guide rollers revolve against the guide rods. The frame is supported by posts or columns which are fastened to the top rim of the prover tank. Two sets of antifriction rollers, which support the axle of the large counterbalance wheel and the cycloidal lever arm, rotate in brackets on the top of the cast iron frame. The weights which counterbalance the prover bell are attached to a chain which is carried over the counterbalance wheel and fastened to short chains or cables which are equally spaced and attached to the edge of the dome of the bell.

When air is removed from the prover and the bell descends into the liquid, the pressure would decrease, due to the increase of the volume of the submerged portion of the bell, if it were not for the shape of the cycloidal lever arm. This is designed so that as the prover bell descends into the liquid, the cord attached to the arm and supporting the secondary counterbalance weight moves in toward the axle decreasing the counterbalancing action of the smaller weight just enough to compensate for the loss in pressure due to the increased immersion of the bell.

At the top of the dry well or air pipe is a circular slide valve through which air is admitted to the prover, and at the side is a quick acting valve through which air is passed from the prover to the meter. A siphon-gage or U-gage is connected to the piping between the outlet valve and the meter for use in testing for leaks in the meter or connections to the meter.

Prover tanks are usually constructed of brass and bells of copper or stainless steel. They are usually made in capacities of 2, 5, 10, and 20 cubic feet. Special provers of 50, 100, and 200 cubic feet capacity and larger have been manufactured. Provers are regularly supplied with hose and fittings for connection to the meter, speed unions, and thermometers for air and liquid temperatures. It is desirable that the volume of the prover should be equal to or greater than the full reading of the proving circle of the index of the meter (see fig. 9).

Prover scales have generally been in whole and decimal units of the cubic foot. However, since meters for domestic use are already being made in whole and decimal units of the cubic meter, consideration should be given to the use of a combination prover scale in units of cubic feet and cubic meters. Prover builders have indicated that it would be no problem to supply such a combination scale.

Bell-type meter provers are normally used for pressure proving, that is, with the provers loaded to a pressure about 1.5 in of water above atmospheric pressure. To change the prover pressure, add or remove some of the main counterbalancing weight (additional weights placed upon the crown of the bell should be avoided). After the prover pressure is set, change the amount of sealing liquid until the

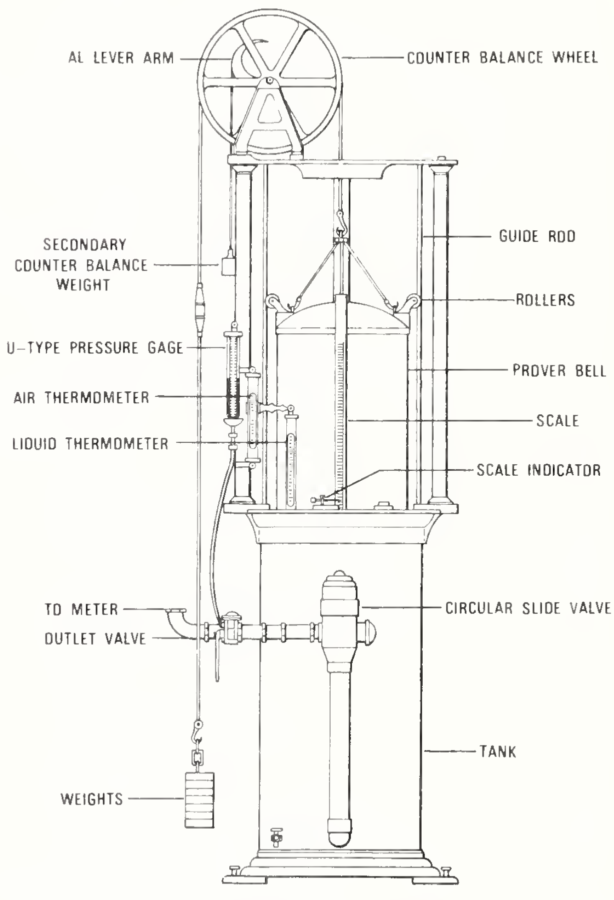

FIGURE 2. *Exterior view of a conventional bell prover.*

surface is at the elevation indicated in figure 3 when the bell is in the low position, and with the prover valves closed.

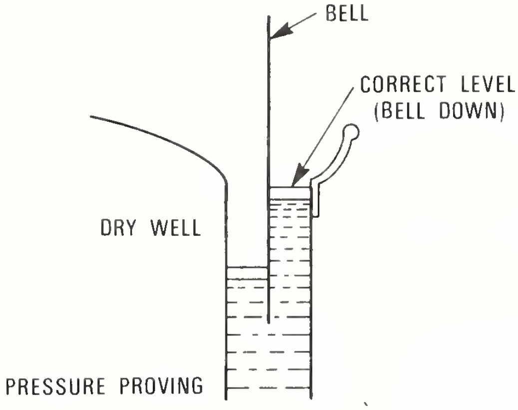

FIGURE 3. *Proper sealant level of prover.*

The prover should be checked daily for leaks. A leak test may be made after the temperatures of the room air and the liquid have equalized. Raise the prover bell and set the marker at zero on the scale or read out device. If there is any noticable change in indication in a 10-minute period, determine the cause and make the necessary corrections prior to resumption of testing. A more comprehensive leak test may be initiated in the same manner as the above procedure by permitting the bell to remain in this position for a period of 6 hours or longer (overnight). If the rate of change in reading is greater than 1 percent of the rated prover volume per 6 hours [5] determine the cause and make corrections before using the prover for testing meters. It is possible that the prover may not remain at zero, as expansion or contraction due to temperature changes and barometric pressure changes overnight may cause a rise or fall of as much as an inch or more on the scale. This expansion or contraction should, of course, be ignored. If on any particular day the change exceeds this amount, investigate for possible leaks.

The prover should be balanced in such a manner that the pressure of the air in the bell is constant regardless of the position of the bell. To verify this, the prover bell should not rise or fall at either the highest or lowest position of the bell when the prover valve is open and the prover pressure reduced to zero. If this is not the case, the counterweight of the cycloid should be adjusted. This is accomplished by adding or subtracting weight from the bell counterweight when the bell is in the lowest position and adding or subtracting weight from the counterweight of the cycloid when the bell is in the highest position. This is repeated until the bell will remain stationary at any point when the valve is open. The main counterweight may then be decreased until the desired prover pressure is obtained.

Originally water was used as a sealant in bell provers and cubic foot bottles. However, in view of the errors introduced into measurements of volumes of air in contact with water, it is highly advantageous to use a light oil of low vapor pressure instead of water. The advantages of this are:

1. Avoidance of errors due to change in volume by the introduction of a vapor into the air to be measured.
2. Elimination of errors due to a change of volume caused by the cooling effect of evaporation on the outside surfaces of the bottle and the proving bell.
3. The temperature of the prover will follow changes of room temperature more closely due to the low specific heat of the oil.
4. The testing apparatus is preserved in good condition by the sealing liquid.

Thus, the cubic-foot bottle and the meter prover may be compared with greater accuracy than when water is used, and with much less trouble. Also, the errors in actual meter testing are reduced since there is no undesirable change of volume of the air—assuming the temperature of the room is constant.

The use of oil has, on the other hand, some possible disadvantages, none of which appear serious. The oil slightly increases the risk of fire, and oil may adhere to the bell and form a temporary film, changing the proof of the bell. However, the proper selection of an oil will reduce these disadvantages to a point where they can be ignored.

Straw, transformer, or white oil have been found to be satisfactory. The oils should have approximately the following properties:

Pour-point	25 °F
Flash-point	310 °F
Fire-point	at least 310 °F
Viscosity at 100 °F	65–75 Seconds, Saybolt Viscosimeter
Specific gravity at 60 °F	0.850 to 0.870
Vapor pressure at 200 °F	Less than 0.60 mm mercury
Color	at least +30 Saybolt

The operator should keep the rollers and roller guides clean and well oiled. He should test the prover each week or month to see (a) that the bell will drop when loaded to a pressure of 0.05 in of water, or (b) that the variation in prover pressure does not exceed 0.05 in of water during the drop of the bell. The former test is made by raising the bell to the highest position, adjusting the prover pressure to 0.05 in of water by adding weights to the counterweight and then opening the prover valve and allowing the bell to drop under this pressure. If the bell does not drop, the obstruction should be located and removed. The latter test is made at a prover pressure of 1.5 in of water. When the bell is raised to the highest position, allow it to drain for 3 minutes. Then open the prover valve and drop the bell at a rate of 7.5 to 8.0 in per minute and observe the pressure variation on a gage capable of responding to dynamic pressure conditions and being read to 0.01 in of water pressure.

The valves of the prover should be kept free from dust and well greased at all times. Any grit in the valves will soon scratch the bearing surfaces and cause leaks. When not in use, the circular slide-valve should be covered to keep out dust.

3.2 Prover Calibration

There are two basic methods of calibrating a bell prover, "bottling" or "strapping" [3, 4]. "Bottling" a prover involves transferring a cubic foot of air between a cubic foot bottle or portable standard and the prover.

"Strapping" a prover is a method of calibration in which the physical dimensions of the bell, the tank, and the levels of the sealing liquid are measured and the capacity is then computed.

Dents in the portion of the bell that moves into and out of the sealing oil should not exceed 1 cu in per cubic foot of rated prover capacity. The maximum diameter of a given cross section of the bell should not be more than 1 percent greater than the average diameter of the cross-section [5].

The maximum temperature difference of all equipment including prover, cubic foot bottle, standard sealing fluid, and ambient air should not exceed 0.05 °F and should be held constant throughout the calibration period [5].

a. Cubic Foot Bottle

A cubic foot bottle such as would be used for bottling a prover is illustrated in figure 4. The nickel or chromium-plated copper bottle is open at the end of the lower neck and may be lowered into a tank of sealing liquid, similar to prover oil. As the liquid enters at the bottom and fills the interior up to a graduation mark on the gage glass in the upper neck, 1 cu ft of air is displaced and flows through a connecting tube to the prover bell, which rises.

The transfer of air can be from the descending bottle to the rising bell of the prover, or from the descending bell to the rising bottle. In either case the results should be approximately the same, except for slight differences in the behavior of the sealing liquid. A residual amount will remain on the walls of the instrument that has been standing in a raised position before it descends, while the rising surfaces of the other will carry adhering liquid upward. Because the total involved surface area of the bell will not be the same as that of the bottle, a perfect duplication of performance between the two cases cannot be expected.

Transfers can be made with the system under normal prover pressure, or with the counterweights adjusted to balance the bell at atmospheric pressure. The first method produces the slight difficulty of setting the liquid level in the gage glass of the bottle while it is slightly below the level of the surface in the tank; also it involves the necessity of raising the bottle at the end of the transfer until one or two small bubbles of air are seen to escape.

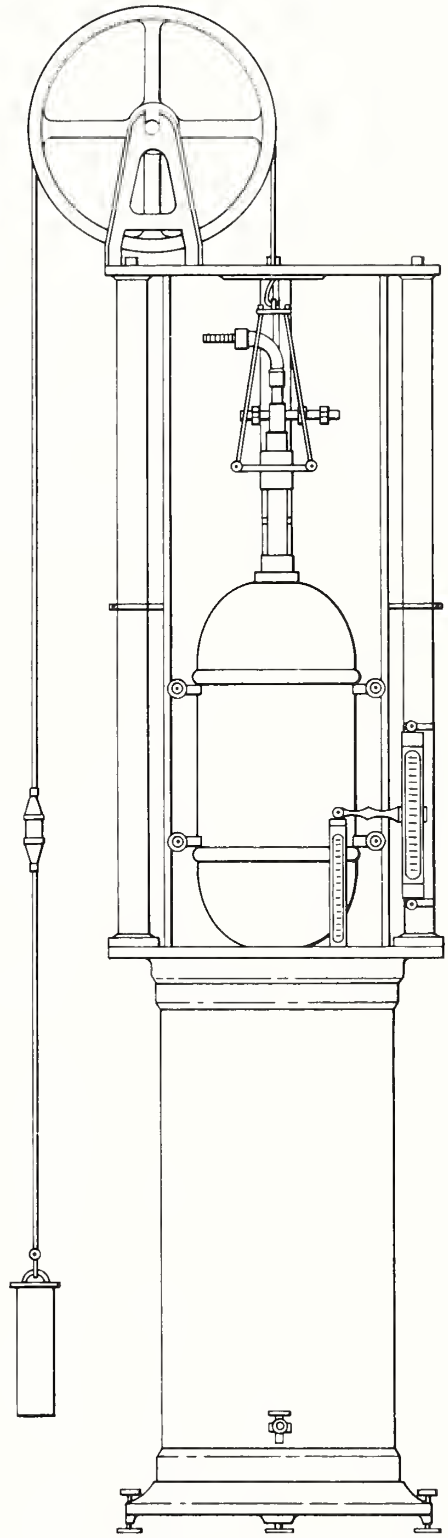

FIGURE 4. *Exterior view of a cubic foot bottle.*

For each cubic foot of air to be passed into or out of a prover, the bell is first placed in a position, by manipulating the rotary slide valve, so that the trial begins with a cubic-foot mark on the scale opposite the pointer. If the scale, the standard, and the procedure were all perfect, the next cubic-foot mark would be exactly opposite the pointer at the end of the test. The difference between 1 cu ft and the volume indicated by the scale is the error determined by the calibration. This procedure is repeated to measure successive cubic-foot increments until the entire range of the prover has been tested.

Frequently another device is used in place of the bottle called a "Stillman cubic-foot standard" (fig. 5) after its inventor, the late Mr. M. H. Stillman of the National Bureau of Standards [6]. A movable bell rises and descends in an annular tank very similar to that of a prover. The bell is guided by a central vertical column sliding in a close-fitting cylinder, and upward travel is limited by an adjustable stop. This standard is about as accurate as a cubic-foot bottle, is used in a similar procedure, and offers the additional advantage that it is easily portable. By draining the sealing oil from it, and placing it in its carrying case, a task which can be accomplished quite readily, the user can easily transport it from place to place, say by automobile. It is as easily set up and placed in service, except that a period of several hours is sometimes required for the temperature of the standard to stabilize and become equal to that of the prover to be tested. Because of its portability and its relatively small size compared to a bottle in an immersion tank, it has found wide-spread acceptance by State public utility commissions and weights and measures offices. Like the bottle, it can be sent to NBS for calibration.

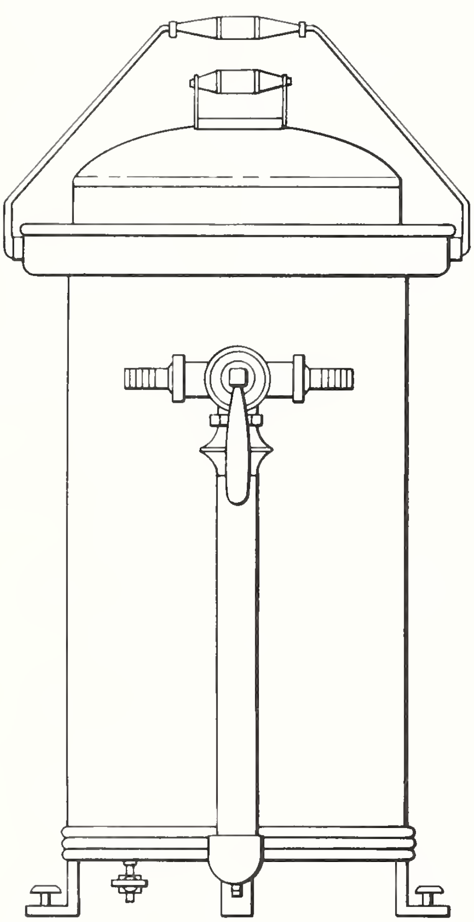

FIGURE 5. *Exterior view of a portable cubic foot standard.*

Temperature and barometric pressure are very critical in "bottling" procedures. A high degree of stability of these two factors is necessary.

This brief description of calibration by "bottling" is considered sufficient for the purposes of this handbook. Complete detailed instructions on this traditional and widely used procedure are given in publications [3] and [7] in this list of references.

b. Strapping

The procedure of "strapping" is illustrated by figures 6a and b, which show diagrammatically the cross section of a typical bell-type prover. The capacity of the bell, i.e., its internal volume, plus the volume of the metal in the bell, is designated as the "outside volume." Each term applies only to the volume above the liquid surface, or "seal."

The validity of the method is based on this relationship: When a prover bell is lowered from any position to any other position, the volume of gas discharged will be equal to the outside volume above the seal at the first position, minus the outside volume above the seal at the second position, plus the volume of the metal in the scale that becomes immersed, and minus the volume of the fluid that rises between the outside of the bell and the main tank. The truth of this statement is not immediately obvious, but will be made clear by a simple analysis.

First, the following must be defined:

Q = Volume of gas discharged by prover bell.
V = Change in exterior volume of the bell above the liquid surface.
B = Change in interior volume of the bell above the liquid surface.
W = Volume of liquid rise between inner tank and interior surface of the bell caused by liquid displaced by metal in bell and scale.
M = Volume of metal that becomes immersed in liquid.
S = Volume of metal scale buttons, guide rods, and thermometers that becomes immersed in liquid.
T = Volume of liquid rise between main tank and the outside of the bell caused by metal in bell and scale.

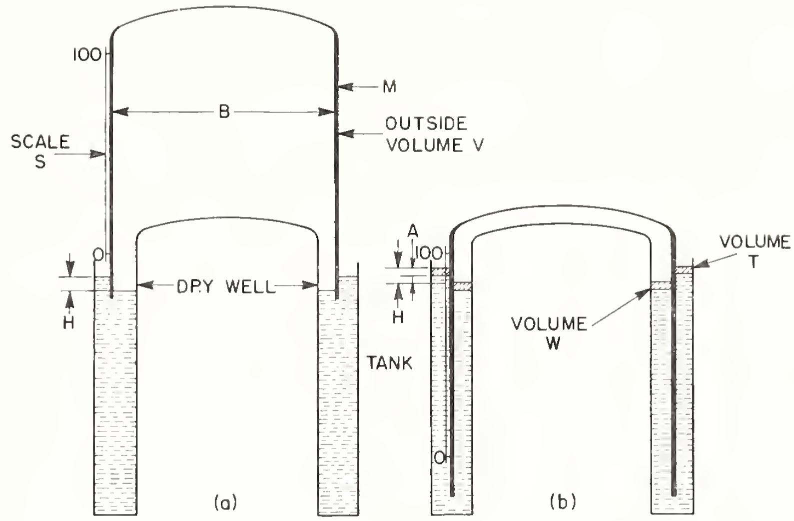

FIGURE 6. *"Strapping" data required as shown in cross section of bell-type prover.*

(a) In zero position. (b) In capacity cubic foot position.

Figure 6a illustrates the bell position at 0 on the scale, with an internal pressure represented by the difference in levels of the sealing liquid inside and outside of the bell, designated by H. As the bell descends to position 100, as shown in figure 6b, if there were no change in the level of the sealing liquid, the volume of gas, Q, discharged would be equal just to the change of interior volume of the bell, B, above the liquid surface. However, the level of the surface in the annular space between the main tank and the outside of the bell, and the level between the inside of the bell and the center tank, will rise because some liquid is displaced by the metal in the bell and the scale. The volume of liquid which rises between the inner tank and the interior surface of the bell, W, displaces gas and therefore adds to the volume of gas, Q, which is discharged. Thus,

(1) $$Q = B + W$$

The interior volume change, B, is equal to the outside volume change, V, minus the volume of the metal that becomes immersed, M, giving

(2) $$B = V - M$$

The volume of the immersed metal of the bell, M, plus the volume of the immersed metal of the scale, scale buttons, guide rods, and thermometers, S, is equal to the volume of the liquid which rises between the inside surface of the bell and inner tank, W, plus the volume of the liquid of which rises between the outside surface of the bell and the main tank, T. Thus,

(3) $$M + S = T + W$$

Substitution of equation (2) into (1) gives

(4) $$Q = V - M + W$$

Equation (3) may be rearranged as follows

(5) $$M = T + W - S$$

Substitution of equation (5) into equation (4) gives

(6) $$Q = V + S - T$$

Equation (6) is the principle upon which the method is based.

Adjust the prover oil level so that the surface of the oil remains within a constant-diameter section of the outer tank throughout the travel of the bell. Measure the outside diameter of the bell. Mark the bell at the oil level with the bell positioned so that the pointer is opposite the scale markings corresponding to 10, 30, 50, 70, and 90 percent of the full scale reading. Measure around the circumference of the bell with a steel tape, preferably calibrated for direct reading of outside diameter, at the plane of each of the marks on the bell. Use the average of these five readings as the outside diameter. (The diameter may also be determined by measuring the circumference with a steel tape capable of being read to the nearest 0.01 in. Calculate the diameter by dividing the average circumference by 3.1416 then subtracting the thickness of the tape.) The surface of the bell should be wiped off before any measurements are made.

Manufacturers state that prover bells up to 10 cu ft are usually quite cylindrical, with circumferences which do not deviate more than about plus or minus 0.03 in from the average circumference. If the deviation from the average circumference does not exceed ±0.0625 in, the calibration may be based on the average girth, and the scale would have equal division throughout its length. However, if the bell deviates more than ±0.0625 in from the average circumference, the strapping should be subdivided to volume increments of essentially constant girth. In laying out a plan for a calibration, the scale point at the middle of the increments being tested should be selected, and the corresponding plane of intersection of the liquid with the bell should be observed. The circumference of the bell should be measured in this plane.

The volume of liquid which rises in the tank is computed from the change in surface level and the bell and tank dimensions. Liquid-level reading should be carefully made by means of micrometer depth gage held firmly on a flat upper surface of the tank.

For the relationship $Q=V+S-T$ to be true, two requirements must be satisfied. First, the prover and counterweights must be adjusted to insure that the pressure within the bell is the same at any position as well as those seen in figures 6a and b. This may be checked by connecting a good draft gage or inclined manometer to indicate the internal pressure. Another procedure is to open the interior to atmosphere by means of the prover rotary valve, adjust the counterweights until the bell remains stationary at any position, and perform the calibration under these conditions. Second, the effect of oil drainage down the walls of the bell on the surface level of the liquid should be negligible. This generally does not affect the surface level of the liquid after the bell has been draining for several minutes.

A typical set of measured values and the calculations required are shown below [3]. The steel scales, verniers, and micrometers used in strapping should be of high quality; the bias or error inherent in the instruments should be relatively insignificant compared to the uncertainties associated with making the measurements. If reasonable care is used in calibrating, say, a 5 ft³ prover, the maximum variations between measurements by different observers and at different times should be not more than: 0.01 in for the length of the scale; 0.001 in for the average thickness and width of the scale; 0.001 in for the change in fluid surface level; and 0.003 in for the bell diameter and the distance from bell to tank [4].

Sample Strapping Calculation	
Average observed circumference of prover bell	66.047 in
Length of scale, 0 to 5 ft^3	25.03 in
Average thickness of prover scale	0.117 in
Average width of prover scale	1.125 in
Average distance between outer surface of bell and inner surface of outer prover tank	1.943 in
Oil rise in tank for bell travel 0 to 5 ft^3	0.345 in
Thickness of strapping scale	0.006 in
Corrected average circumference of prover bell, $66.047-(3.14\times 0.006)=$	66.028 in
Bell diameter, $D=66.028\div 3.1416$	21.017 in
Outside volume of bell, $V=\frac{3.1416\times(21.017)^2\times 25.031}{4}=$	8683.814 in^3
Volume of immersed portion of scale $S=25.03\times 1.125\times 0.117=$	3.295 in^3
Tank diameter at sealant level, $D=21.017+2\times(1.943)=$	24.903 in
Volume of oil rise, $T=\frac{3.1416\times(24.903^2-21.017^2)\times 0.345}{4}=$	48.352 in^3
Volume of air discharged, $\frac{V+S-T}{1728}=$	4.9993 ft^3
Scale too short by $\frac{5.000-4.9993}{5.000}\times 100=$	0.014%

4. Inspection of Commercial Devices

For a discussion of the purpose and scope of "inspection" as distinguished from "testing," see Section 4, National Bureau of Standards Handbook 44, *Specifications, Tolerances, and Other Technical Requirements for Commercial Weighing and Measuring Devices.*

Particular attention should be paid to code requirements pertaining to units of primary indicating elements and corrections for altitude. An altitude correction table for ranges of elevation (customary units) where the devices may be installed is provided in table 1. It would also be advisable to verify that, if the altitude correction factor is other than 1.00, it is used in computing the billing for commercial transactions made with the device. In addition, an altitude correction table (table 2) is provided for ranges of elevation in metric units.

TABLE 1. *Altitude corrections factors (customary)* [8, 9]

Elevation	Altitude correction factor	Barometric pressure	Product pressure (11 in WC)
feet		*psi*	*psi*
−150 to 400	1.02	14.64	15.04
above 400 to 950	1.00	14.35	14.74
above 950 to 1550	0.98	14.05	14.45
above 1550 to 2100	.96	13.76	14.15
above 2100 to 2700	.94	13.46	13.86
above 2700 to 3300	.92	13.17	13.56
above 3300 to 3950	.90	12.87	13.27
above 3950 to 4550	.88	12.58	12.97
above 4550 to 5200	.86	12.28	12.68
above 5200 to 5850	.84	11.99	12.38
above 5850 to 6500	.82	11.69	12.09
above 6500 to 7200	.80	11.40	11.79
above 7200 to 7900	.78	11.10	11.50
above 7900 to 8600	.76	10.81	11.20
above 8600 to 9350	.74	10.51	10.91
above 9350 to 10100	.72	10.22	10.61
above 10100 to 10850	.70	9.92	10.32
above 10850 to 11650	.68	9.63	10.03
above 11650 to 12450	.66	9.33	9.73
above 12450 to 13250	.64	9.04	9.44
above 13250 to 14100	.62	8.75	9.14
above 14100 to 14950	.60	8.45	8.85

5. Preparation and Testing of Commercial Devices

Properly conducted test procedures require a prover room where temperatures will remain constant, maintaining temperature control day and night (if necessary) to achieve the ideal conditions desired. In addition, the devices should be acclimated prior to testing and should be tested at rates anticipated during normal use.

TABLE 2. *Altitude Correction Factors (metric)* [8, 9]

Elevation	Altitude correction factor	Barometric pressure	Product pressure (28 cm WC)
meters		*kPa*	*kPa*
−46 to 122	1.02	100.9	103.7
above 122 to 290	1.00	98.9	101.6
above 290 to 472	0.98	96.9	99.6
above 472 to 640	.96	94.9	97.6
above 640 to 822	.94	92.8	95.6
above 822 to 1006	.92	90.8	93.5
above 1006 to 1204	.90	88.7	91.5
above 1204 to 1387	.88	86.7	89.4
above 1387 to 1585	.86	84.7	87.4
above 1585 to 1783	.84	82.7	85.4
above 1783 to 1981	.82	80.6	83.4
above 1981 to 2195	.80	78.6	81.3
above 2195 to 2408	.78	76.5	79.3
above 2408 to 2621	.76	74.5	77.2
above 2621 to 2850	.74	72.5	75.2
above 2850 to 3078	.72	70.5	73.2
above 3978 to 3307	.70	68.4	71.2
above 3307 to 3551	.68	66.4	69.2
above 3551 to 3795	.66	64.3	67.1
above 3795 to 4039	.64	62.3	65.1
above 4039 to 4298	.62	60.3	63.0
above 4298 to 4557	.60	58.3	61.0

5.1. Prover Room [3]

The selection of a proper location for a prover room requires careful study and attention to surrounding conditions. An interior well-lighted room (one without outside walls or windows) is preferred. Direct sunlight should never be allowed to fall on the prover or meters under test. Care should be exercised in heating or cooling the room. Temperature variations of 5 °F may be attained in inferior installations. In no case should the prover be located near radiators, steam pipes, or hot and cold air ducts. In addition, temperature changes greater than 5 °F should not occur during a period of 24 hours, since it is essential that the prover and the meters to be tested be as near the same temperature as possible. A difference of 5 °F between the temperature of the prover and the temperature of the meters under test may produce an error of 1 percent.

Air conditioning for a proving room should not be confused with ordinary space cooling as generally employed to achieve comfort for the room occupants. Ordinary "commercial" air conditioning can be worse than no cooling at all, since it can result in a fairly rapid cycling of temperatures and variations in temperature throughout the room. This could cause erratic results of greater magnitude than would be encountered if the temperature were allowed to drift throughout the day—but with lesser momentary temperature discrepancies at vital points.

Specifications for the air conditioning of proving rooms should result in a room of substantially constant temperature. This generally results in a modulated system where both warm and cool air are supplied simultaneously to the room—being governed by very sensitive controls. The duct work should be designed as to evenly distribute the conditioned air to all parts of the room—the location of both the supply ducts and return ducts should consequently be the result of a detailed study. Sometimes a false ceiling of perforated acoustic tile forms an inlet plenum chamber from which the whole room is bathed with the falling blanket of tempered air.

During conditions of satisfactory operation the air temperature within the prover bell should be within 0.5 °F of the ambient temperature. Temperatures at any one point in the room should not vary from a simultaneous temperature at any other point in the proving room proper by more than 1 °F. This usually requires multiple intake and multiple discharge grilles to prevent stratification and the existence of dead zones. The proving room should be under a slight positive pressure to prevent the inrush of untempered air when doors are opened. The circulation should correspond to substantially constant air velocities throughout the room and produce a complete air change every 10 minutes or less.

If an air supply is required for provers this would generally be obtained from a blower system or from a compressed air line. Care should be exercised that the temperature of the air supply to the prover is not different from proving room temperatures. The air should be thoroughly tempered, preferably, at a lower pressure to proving room temperature. Drawing air from the prover room does not insure that the air will be at prover room temperatures.

5.2. Test Preparation

To be assured that the meter will remain as nearly as possible in the same condition as it was when in service, meter screw caps should be put on as soon as the meter is removed from the customer's premises and they should not be removed until the meter is to be acclimated for test. The caps should be replaced immediately upon completion of the test.

Meters that have been in service are generally full of gas fumes and saturated with mercaptan odor. Provision should be made for exhausting from the room fumes and odors expelled during the test.

Meters received from service should be stored in the room in which they will be tested for a period of at least 16 hours with caps removed to acquire the temperature of the surrounding atmosphere. Meters before being tested should be kept off the floor and distributed so as to allow to provide good air circulation and temperature uniformity. They should not be subjected to any sudden changes in temperature, or to any influence tending to raise or lower their temperatures above or below that of the air in the immediate vicinity of the prover.

Meter testing may be performed with the same relative degree of accuracy, at any permissible working temperature between 60 °F and 90 °F, but it is essential that the meter, the air in the prover, and the sealing oil in the prover tank be maintained at the same temperature (within 2 °F) during the test [1].

Separate thermometers should be used for determining the temperatures of the air and of the sealing oil. These thermometers should be checked against each other routinely to determine that their readings do not differ more than one degree through a range from 60 °F to 100 °F.

Adjust the prover to supply air at 1.5 in WC [3] for all tests. The pressure drop across the meter during tests should not exceed an average of 0.5 in WC [1].

The inlet of the meter is attached to the prover hose by means of a suitable connection. Open the valve on the prover connection, place the palm of the hand over the meter outlet and then close the valve. Watch for a drop in pressure in the U-gage connected to the prover connection. If there is any drop, it is an indication of a leak in the connections or in the meter. The leak should be located and eliminated. Soap suds or a commercial liquid leak detector may be used to locate leaks. If the leak is found in the meter, it should be rejected with no further tests made on the device.

The prover valve, hose, and hose connections should be sufficiently large to permit the testing of large meters at the maximum rate at which the gas passes through the meters when in service. The loss of pressure between the bell of the prover and the meter should not exceed 0.5 in WC [3] (do not confuse this drop in pressure with the pressure drop across the meter).

A differential pressure gage connected across the inlet and outlet fittings of the meter under test may be used for measuring the pressure drop across the meter. Connections to the meter under test and the differential pressure gage should be made with adapter fittings as illustrated in figure 7. The adapter fittings [2, 10] should have an inside diameter (d) equal to that of the meter pipe connections within a tolerance of $\pm 1/32$ in. The length of the adapters should be at least eight times their inside diameter (d). The inside surface should be smooth and free from pits, scales, burrs, or other obstructions. The pressure taps should be located two diameters (d) from the meter inlet or outlet connections. The pressure tap holes should be $1/8$ to $1/4$ in inside diameter and bored perpendicular to the adapter wall. The intersection of the pressure tap hole and the inside wall of the adapter should be flush and free from burrs. No connection should be used

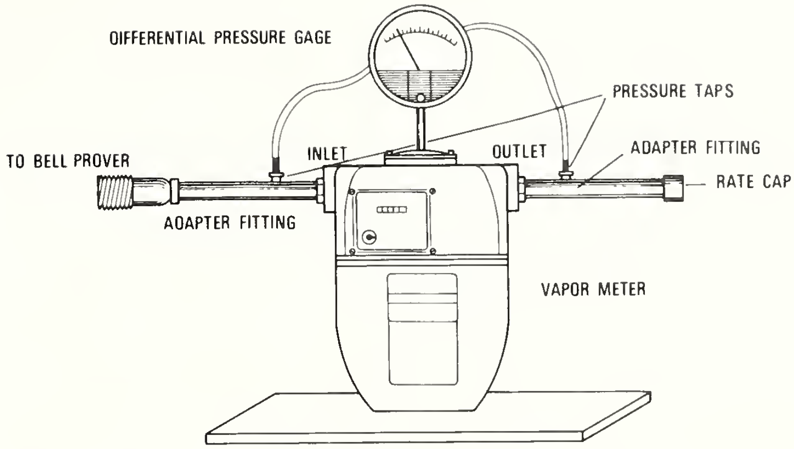

FIGURE 7. *View of meter under test with adapter fittings and differential pressure gage.*

which distorts the inside surface of the adapter fitting or projects into the flow passage.

Since the meters are tested with air as the test medium rather than the product they were designed to meter, the air capacity should be expressed in terms of gas capacity of the meter as follows:

$$\text{Air Capacity} = \text{Gas Capacity} \times \sqrt{\text{Specific Gravity of Gas}}$$

The flow rates used during the prover test should then be based upon the air capacity rate of the meter under test. The Specific Gravity of commercial propane is given as 1.53 and that of commercial butane as 2.00 [11].

The flow of prover air through the meter is controlled by a rate cap orifice plate on the discharge side of the meter. Thus, rate cap orifice plates should be available for all meters that are to be tested. Figure 8 is a cross-sectional view of a rate cap assembly [10]. The rate cap holder and orifice plates can be made from brass stock.

In testing meters removed on request or for high bill complaints, such meters should be tested in the condition "as received" from the customer's premises, and as soon after being removed as possible, giving due attention to securing temperature uniformity. When a number of consecutive tests are made upon a meter which has been in service for some time, in which air is used as the test medium, it is often noticed that the later tests indicate a lower proof than was indicated by the first tests. The difference between successive tests may be as much as several percent. The cause of this may be the evaporation of condensates that might be inside of the meter, or, in the case of leather diaphragms, it might be from a stiffening of the leather upon the release of condensates which previously saturated the material. As leather diaphragms lose these volatile oils they tend to become stiff, and the measuring chambers formed by them do not have the same capacity as before. For this reason the first test of such a meter with air probably gives results more closely duplicating the conditions of actual use.

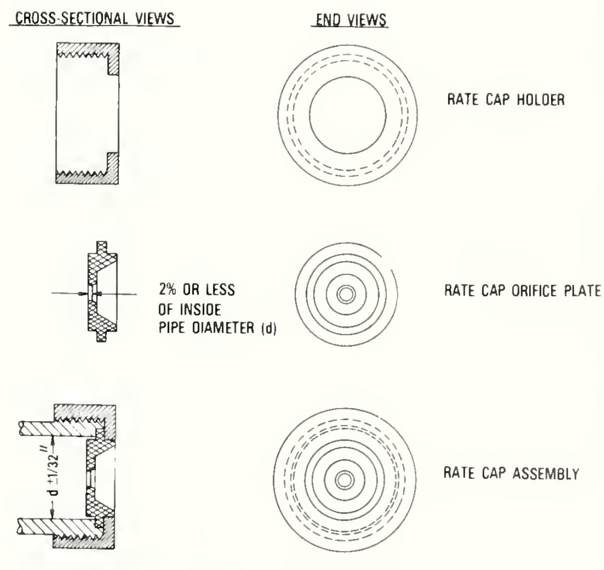

FIGURE 8. *Rate cap holder, orifice plate, and assembly.*

5.3. Temperature Compensator

If the meter is equipped with an automatic temperature compensator the volume of air metered by the device is automatically corrected to the volume at 60 °F (15.5 °C). However, the prover is measuring the volume of air at ambient prover temperature. Thus, the prover reading is corrected to 60 °F or 15.5 °C by multiplying it by the correction factor for the prover air temperature as given in table 3 for °F or table 4 (metric) for °C. This provides a common base temperature at 60 °F or 15.5 °C for comparing the meter and prover readings. Otherwise tests conducted on temperature compensated meters are similar to those conducted on nontemperature compensated meters.

Temperature compensated meters are labeled as such on the badge or immediately adjacent to the badge of the device and on the register.

TABLE 3. *Volume correction factors using a 60 °F base temperature*

Mean temperature, °F	Correction factor	Mean temperature, °F	Correction factor	Mean temperature, °F	Correction factor	Mean temperature, °F	Correction factor
−40	1.238	6	1.116	52	1.016	98	.9319
−39	1.235	7	1.113	53	1.014	99	.9302
−38	1.232	8	1.111	54	1.012	100	.9285
−37	1.230	9	1.109	55	1.010	101	.9269
−36	1.227	10	1.106	56	1.008	102	.9252
−35	1.224	11	1.104	57	1.006	103	.9236
−34	1.221	12	1.102	58	1.004	104	.9219
−33	1.218	13	1.099	59	1.002	105	.9203
−32	1.215	14	1.097	60	1.000	106	.9187
−31	1.212	15	1.095	61	0.9981	107	.9171
−30	1.209	16	1.092	62	.9962	108	.9154
−29	1.207	17	1.090	63	.9943	109	.9138
−28	1.204	18	1.088	64	.9924	110	.9122
−27	1.201	19	1.086	65	.9905	111	.9106
−26	1.198	20	1.083	66	.9886	112	.9090
−25	1.196	21	1.081	67	.9867	113	.9075
−24	1.193	22	1.079	68	.9848	114	.9059
−23	1-190	23	1.077	69	.9830	115	.9043
−22	1.187	24	1.074	70	.9811	116	.9027
−21	1.185	25	1.072	71	.9793	117	.9012
−20	1.182	26	1.070	72	.9774	118	.8996
−19	1.179	27	1.068	73	.9756	119	.8980
−18	1.177	28	1.066	74	.9738	120	.8965
−17	1.174	29	1.063	75	.9719	121	.8949
−16	1.171	30	1.061	76	.9701	122	.8934
−15	1.169	31	1.059	77	.9683	123	.8919
−14	1.166	32	1.057	78	.9665	124	.8903
−13	1.163	33	1.055	79	.9647	125	.8888
−12	1.161	34	1.053	80	.9629	126	.8873
−11	1.158	35	1.051	81	.9612	127	.8858
−10	1.156	36	1.048	82	.9594	128	.8843
−9	1.153	37	1.046	83	.9576	129	.8828
−8	1.151	38	1.044	84	.9559	130	.8813
−7	1.148	39	1.042	85	.9541	131	.8798
−6	1.146	40	1.040	86	.9524	132	.8783
−5	1.143	41	1.038	87	.9506	133	.8768
−4	1.140	42	1.036	88	.9489	134	.8754
−3	1.138	43	1.034	89	.9472	135	.8739
−2	1.136	44	1.032	90	.9454	136	.8724
−1	1.133	45	1.030	91	.9437	137	.8710
0	1.131	46	1.028	92	.9420	138	.8695
1	1.128	47	1.026	93	.9403	139	.8680
2	1.126	48	1.024	94	.9386	140	.8666
3	1.123	49	1.022	95	.9369		
4	1.121	50	1.020	96	0.9352		
5	1.118	51	1.018	97	.9335		

TABLE 4. *Volume correction factors (metric) using a 15.5 °C base temperature*

Mean temperature, °C	Correction factor	Mean temperature, °C	Correction factor
−40	1.238	11	1.016
−39	1.232	12	1.012
−38	1.228	13	1.009
−37	1.222	14	1.005
−36	1.217	15	1.002
−35	1.212	16	0.9985
−34	1.207	17	.9950
−33	1.202	18	.9916
−32	1.197	19	.9882
−31	1.192	20	.9848
−30	1.187	21	.9815
−29	1.182	22	.9782
−28	1.178	23	.9749
−27	1.173	24	.9716
−26	1.168	25	.9683
−25	1.163	26	.9651
−24	1.159	27	.9619
−23	1.154	28	.9587
−22	1.150	29	.9555
−21	1.145	30	.9524
−20	1.140	31	.9492
−19	1.136	32	.9461
−18	1.132	33	.9430
−17	1.127	34	.9399
−16	1.123	35	.9369
−15	1.118	36	0.9339
−14	1.114	37	.9309
−13	1.110	38	.9279
−12	1.106	39	.9249
−11	1.101	40	.9219
−10	1.097	41	.9190
−9	1.093	42	.9161
−8	1.089	43	.9132
−7	1.085	44	.9103
−6	1.081	45	.9075
−5	1.077	46	.9046
−4	1.073	47	.9017
−3	1.069	48	.8990
−2	1.065	49	.8962
−1	1.061	50	.8934
−0	1.057	51	.8907
1	1.053	52	.8879
2	1.049	53	.8852
3	1.045	54	.8825
4	1.042	55	.8798
5	1.038	56	.8771
6	1.034	57	.8745
7	1.031	58	.8718
8	1.027	59	.8692
9	1.023	60	.8667
10	1.020		

5.4. The Test

The test procedure is designed to be used with meters registering in cubic feet or cubic meters. Although temperatures are stated in °F this does not preclude the use of celsius thermometers or temperature units with the appropriate temperature correction or conversion factors.

Install capacity flow rate cap at meter outlet. Position meter proving hand on upswing by opening prover outlet valve. When meter proving hand reaches predetermined point, stop it by closing prover outlet valve. Position prover at desired starting point by using circular slide valve. Before making any tests, sufficient air from the prover should be passed through the meter to make at least one complete revolution of the test hand in the proving circle (Fig. 9). At the same time determine if a volume corresponding to that marked on the proving circle passes through the meter for one revolution of the test hand. If the readings do not correspond the index should be examined, as occasionally the wrong index is put in a meter. If the index or index gearing is not correct for the meter, the test should be stopped and the meter rejected. The purging should stop while the test hand is on the up movement, and at a division on the proving circle.

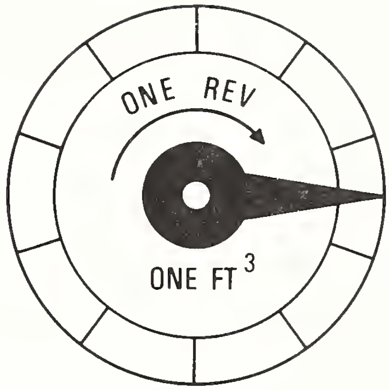

FIGURE 9. *Meter proving circle.*

Step 1. Verify that the capacity flow rate cap is on the meter outlet and that the prover pressure is 1.5 in of water.

Step 2. If the meter proving test hand is not at a predetermined test point on the upswing, position the test hand by opening prover outlet valve. Close valve when predetermined point has been reached. Mark the position on the index glass with a suitable pencil.

Step 3. Fill the prover bell and carefully adjust the zero scale reading by means of the prover slide-valve.

Step 4. Open the prover outlet valve and pass a sufficient volume from the prover through the meter to cause the proving hand to make at least one full revolution. The test draft should not be less than 2 cu ft or 0.05 cu m. Exercise care to insure that the proving hand is stopped exactly over the mark from which it started at the beginning of the test. Note and record the reading on the prover scale. During the test, note and record the pressure drop across the meter and the temperature of the prover air. The temperature of the air, bell prover oil, and the meters under test should be within 2 °F of one another [1]. Record cubic feet registered by meter proving circle.

Step. 5. If the meter is a temperature compensated meter, correct the prover volume to 60 °F, using the following formula:

$$\text{Prover Reading Corrected to 60 °F} = \text{Prover Reading} \times \begin{array}{c}\text{Volume Correction Factor for} \\ \text{Prover Air Temperature} \\ \text{(See table 3 or 4)}\end{array}$$

Step 6. The error, proof, or accuracy of the meter may be calculated by the following formulas:

Error in Delivery (%) =

$$\frac{\text{Corrected Prover Volume} - \text{Meter Indication}}{\text{Meter Indication}} \times 100$$

Error in Indication (%) =

$$\frac{\text{Meter Indication} - \text{Corrected Prover Volume}}{\text{Corrected Prover Volume}} \times 100$$

$$\text{Proof (\%)} = \frac{\text{Corrected Prover Volume}}{\text{Meter Indication}} \times 100$$

$$\text{Accuracy (\%)} = \frac{\text{Meter Indication}}{\text{Corrected Prover Volume}} \times 100$$

Since the tolerances as developed for Handbook 44 are based upon the test draft (meter indication), the test report results are presented as the error in delivery or percent proof. If the meter under test is a temperature compensated meter, the prover reading shall be corrected to 60 °F. Retain arithmetic sign.

Step 7. Repeat capacity rate test. (Steps 2 through 6.)

Step 8. Replace capacity rate cap with check rate cap [1].

Step 9. Repeat steps 2 through 6.

Step 10. Replace check rate cap with low flow test rate cap.

Step 11. Since the low flow test is time consuming (1 hour), a group of 4 to 10 meters may be manifolded to a common source of air (1.5 in WC pressure). The source of air may be the prover or a pressure regulated, filtered compressed-air supply. Record the volume of air (cu ft) registered by the device in 1 hour. The error of the meter may be calculated as follows:

Error in Delivery (%) =

$$\frac{\text{Vol. Low Flow Rate Cap} - \text{Meter Indication}}{\text{Meter Indication}} \times 100$$

If the meter under test is a temperature compensated meter, the prover reading shall be corrected to 60 °F. Retain arithmetic sign.

6. Test Report Form

A suggested Test Report Form is shown in figure 10. The form provides space in the upper portion for owner, customer (if any), and equipment identification. In the body of the form is space for recording the various test runs and for the calculations involved. At the bottom is space for indicating the official action taken as a result of the test, any remarks or instructions, the signature of the inspector, and the "acknowledgment" signature of equipment owner or operator. The upper portion of the report form should be filled in completely before testing of the device is initiated.

Since most of the meters in use at the present time are in cubic feet, the units were indicated in customary units. Where this situation does not prevail, the appropriate metric units should be employed.

7. Reporting a Test

The test data are entered in the appropriate space on the Report Form during and immediately following the test run.

In figure 11, the "Test Data" section of the sample Report Form has been filled out. The column entries are generally self explanatory. The direct prover reading is used in conjunction with the volume measured by the proving circle for calculating the error or proof of nontemperature compensated meters. Examples are as follows:

FOR NONTEMPERATURE COMPENSATED METERS

Error in Delivery (%) =

$$\frac{\text{Prover Volume} - \text{Meter Indication}}{\text{Meter Indication}} \times 100$$

Error is (+) if Prover Volume is larger than Meter Indication, (−) if the opposite is true.

$$\text{Proof (\%)} = \frac{\text{Prover Volume}}{\text{Meter Indication}} \times 100$$

Department Heading

Date ______________ Test No. ____________

LPG Vapor Meter Test Report

Owner ____

Address ____

Customer ____

Address ____

Meter: Make ______________ Model No. ______________ Ser. No. ____________

Capacity Rate ______________ Check Rate ______________
Altitude Correction Factor ____________ Index ______________
Temperature Compensator ______________________________
Last Tested ______________ Seal ______________
Type of Test: New Device ____________ Used (Complaint) ________
Rebuilt Device ____________ Used (Periodic) ________

TEST DATA

Prover: Pressure (in WC) ______________ Air Temperature (° F) __________

Run No.	Type of Test	Flow Rate	Pressure Drop Across Meter	Meter Proving Circle	Prover Reading Direct	Prover Reading Corrected to 60° F	Error in Delivery	Remarks
		CFH	in WC	cu ft	cu ft	cu ft	(%)	

Action taken· Approved ______________ Rejected ______________ Condemned __________

Remarks: ____

____

Inspector ______________________ Owner/Operator ______________________

FIGURE 10. *A suggested LPG Vapor Meter Test Report Form.*

TEST DATA

Prover: Pressure (in. water) 1.5 Air Temperature (°F) 74

Run No.	Type of Test	Flow Rate	Pressure Drop Across Meter	Meter Proving Circle	Prover Reading Direct	Prover Reading Corrected to 60° F	Error in Delivery	Remarks
		ft^3/H	in WC	ft^3	ft^3	ft^3	(%)	
1	Capacity	110	0.5	2	2.074	2.020	+1.0	
2	Capacity	110	0.5	2	2.076	2.022	+1.1	
3	Check	23	0.1	2	2.077	2.022	+1.1	
4	Low Flow Test	0.25	0.0	0.23	-	-	+9.1	

FIGURE 11. *Test data section of a sample report form (customary).*

For temperature compensated meters the error and proof are calculated as follows:

FOR TEMPERATURE COMPENSATED METERS

Error in Delivery (%) =

$$\frac{\text{Corrected Prover Volume} - \text{Meter Indication}}{\text{Meter Indication}} \times 100$$

Error is (+) if Prover Volume Corrected to 60 °F is larger than Meter Indication and (−) if the opposite is true.

Proof (%) =

$$\frac{\text{Corrected Prover Volume to 60 °F}}{\text{Meter Indication}} \times 100$$

Figure 12 is the completed "Test Data" section of the sample Report Form in metric units.

TEST DATA

Prover: Pressure (cm. water) 3.8 Air Temperature (°C) 23

Run No.	Type of Test	Flow Rate	Pressure Drop Across Meter	Meter Proving Circle	Prover Reading		Error in Delivery	Remarks
					Direct	Corrected to 15.5°C		
		m^3/H	cm WC	m^3	m^3	m^3	(%)	
1	Capacity	3.11	-	.05	.05180	.05050	+1.0	
2	Capacity	3.11	-	.05	.05185	.05055	+1.1	
3	Check	0.65	-	.05	.05186	.05056	+1.2	
4	Low Flow	.007	0.0	.0064	-	-	+9.3	

FIGURE 12. *Test data section of a sample report form (metric).*

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8. References

[1] NBS Handbook 44—4th Edition, Specifications, Tolerances, and other Technical Requirements for Commercial Weighing and Measuring Devices, 1971, Revised through 1974, Fundamental Considerations, General Code, and LPG Vapor Measuring Device Code.

[2] American National Standard for Gas Displacement Meters, ANSI B109.1–1973, pp. 1–3, 9–11.

[3] Beck, H. V., Displacement Gas Meters, American Meter Company, 1970, pp. 11–77, 85–89, 117–154.

[4] Collet, C. T., Calibration of Bell Provers by Dimensional Analysis and by Cubic Foot Standards. Paper presented by Appalachian Gas Measurement Short Course, Morgantown, West Virginia, 1965.

[5] Report of Technical Subcommittee on Prover Calibration Procedures, 1965.

[6] Stillman, M. H., A portable cubic-foot standard of gas, Nat. Bur. Stand. (U.S.), Technologic Paper T–114.

[7] Gas measuring instruments, Nat. Bur. Stand. (U.S.), Circ. 309, pp. 6–35 (1962).

[8] U.S. Standard Atmosphere, 1962, NASA, pp. 113–115.

[9] Brombacher, W. G., Johnson, D. P., and Cross, J. L., Mercury barometers and manometers, Nat. Bur. Stand. (U.S.), Monogr. 8, 59 pages (1964).

[10] Price, R. A., and Kemp, L. J., Standardization of Meter Differential Pressure Determination, Paper presented at the A.G.A. Operating Section Distribution and Underground Storage Conference, 1962, pp. 18–19.

[11] LP-Gas Vapor Metering, Rockwell Manufacturing Company, 1969.

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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.)*

A manual for State and local weights and measures officials for the examination and test of liquefied petroleum gas vapor measuring devices. Definitions, test methods, and testing apparatus (including description and calibration procedures) are given. Inspection and test procedures are reviewed. A proposed test report form along with suggestions on reporting the results of a test are included. Provision is made for accommodating a changeover to metric units of registration in the definitions, correction tables, procedures, and in reporting a test.

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)*

bell prover; calibration; inspection; liquefied petroleum gas; pressure; report form; temperature; temperature compensator; test; vapor meter; volume.

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