CHAPTER 5 -- TEST EQUIPMENT

OBJECTIVES

After studying this chapter and reviewing its contents with your instructor, you will be able to:

1. Identify test equipment employed in field examinations of loading-rack metering systems.

2. Describe the design and operation of a field standard volumetric prover.

3. Describe the setup, operation, and general maintenance of test equipment.

4. Describe the steps in performing an official test draft.

5. Understand the use of report forms.

INTRODUCTION

Safe, accurate, and efficient examinations of loading-rack metering systems can only be performed if the inspector has the proper equipment and the knowledge, skills, and experience necessary to use this equipment correctly.

Because of the large volumes of flammable and toxic products transferred from the metering system to your equipment, "quick fix" substitutions for items of proper equipment are simply not acceptable. Furthermore, if you begin an examination only to discover part way through that you do not have all the right equipment and have to return to your office to obtain it, you will end up wasting your own time and causing some hardship to the operator of the device, who has made arrangements for the equipment and an assistant to be available to you. So you must be fully equipped to perform required procedures on the particular model or type of device that is scheduled for examination when you arrive at the site.

You also have the primary responsibility for maintaining your test equipment in a safe and accurate condition. Field standard provers like those described in this chapter are precision measuring instruments designed for the conditions of field testing. However, they can be rendered imprecise by accidental damage, improper operation, or neglect of regular care and maintenance.

This chapter presents an introduction to the basic equipment required for field examinations of loading-rack metering systems. We will cover setup, use, and maintenance procedures that you will review and practice in Field Training. Your instructor will describe any additional equipment or procedures that are employed in your jurisdiction.

BASIC EQUIPMENT

The following list includes the items of basic equipment required for an official field examination of a loading-rack metering system:

- One or more fire extinguishers, of the type described in Chapter 4.

- A first aid kit, supplied with the items recommended in Chapter 4.

- Protective gloves, goggles, and a hardhat as described in Chapter 4.

- A set of caution signs and markers, as described in Chapter 4.

- Provision for grounding the prover through the metering system.

- A calibrated field standard prover, of the correct capacity and design for the type of metering equipment being examined (see below), and equipped with overfill sensors and a return hose with standard fittings.

- A complete set of adaptors to facilitate connections to various types of systems.

- A supply of matched and accurate thermometers, capable of registering temperatures from 0 /F to 120 /F in increments of 0.5 °F, and accurate to within 0.2 / F. (Matched thermometers are thermometers that read the same temperature.) Thermometers may be of the partial immersion or digital type.

- A supply of ethylene glycol, to facilitate temperature transfer in thermometer wells. A bulb syringe should be used to fill the wells with this fluid.

- A suitable set of hand tools, such as pipe and crescent wrenches, screwdrivers, etc., in an equipment box.

- A stop watch, preferably one with a lap timer, is necessary for timing flow rates, prover discharge and drainage, etc.

- Temperature correction tables designed for the prover you are using (see below).

- API/ASTM Temperature Table 6B, used to calculate volume reduction to 60 °F for petroleum products. (Excerpts from this table are included in Appendix B of this manual.)

- NIST Handbook 44, along with copies of any other codes or regulations applicable in your jurisdiction, and a copy of an up-to-date Examination Procedure Outline (EPO) for loading-rack meters.

- A supply of official examination report forms used by your jurisdiction.

- A supply of lead-and-wire seals, tags, stickers, and any other marking devices used by your jurisdiction.

You may find it useful to make up an equipment checklist, especially if test equipment is shared by different inspectors in your jurisdiction.

FIELD STANDARD PROVERS

The largest and most expensive item of test equipment you take into the field with you is the field standard prover. It is a precision liquid-measuring device that provides a high degree of accuracy and reliability of measurement when operated and maintained correctly. Before we take a closer look at provers used for loading-rack metering systems, let us consider briefly the basic proving methods and equipment that are commonly used for these devices.

Methods of Proving Loading-Rack Metering Systems

There are two basic methods for conducting accuracy tests on liquid-measuring devices.

One of these is the gravimetric method. This type of measurement is based upon the fact that the volume of a known weight of a liquid at any given temperature and pressure can be calculated if its specific gravity is also known (the specific gravity of a liquid is the ratio of its density to that of water; see below). Therefore, if a container is filled with test liquid and weighed on an accurate scale, and the temperature and pressure of the liquid in the container are measured, it should be possible to determine from the observed weight (after subtracting the weight of the container), the volume that it contains. This could then be compared to the quantity registered by the metering device to determine the accuracy of the metering system.

The alternative method is volumetric proving. In this method, a standard volumetric measure, or prover (that is, a container of known capacity) is filled by the metering system. The quantity registered by the metering system is then compared with the volume actually delivered to the prover.

The above descriptions of these methods are somewhat simplified. In the case of the volumetric method, the quantity indicated by the prover must be corrected to reflect changes in temperature between the metered liquid and liquid in the prover. Corrections must also be made for the effects of temperature on the capacity of the prover itself.

The volumetric method is normally used in the field because it is less complicated and also approximates more closely the actual service conditions of a commercial delivery. For these reasons it is the recommended method, and the only one presented in this training manual.

Volumetric Proving Equipment

Most users of metering equipment take accuracy very seriously, and periodically test and adjust their systems. This is especially true in the wholesale petroleum industry: because of the vast volumes of product that pass through a metering system every day, even a small degree of inaccuracy can have an enormous economic impact. In addition, the heavy use of these devices in normal commercial service causes them to wear relatively quickly, necessitating regular adjustment.

A widely recognized guideline is that a meter should be tested and adjusted, if necessary, every 6 months or when total throughput equals 10,000 times the maximum discharge rate of the metering system. For example, a meter that delivers 1,000 gallons of product per minute (gpm) would be tested every 6 months or when it had metered 10 million gallons of product, whichever comes first. This will give you an idea of how much product a single meter can process: 10 million gallons over 6 months amounts to around 55,000 gallons per day!

Several different types of provers are commonly used for testing, adjusting, and calibrating loading-rack metering systems by the metering industry. Since you will hear these different types of provers discussed and arguments advanced, sometimes vehemently, for one technique over all others, we will describe four of the most common types briefly here.

Large-capacity volumetric provers are, perhaps, the most widely used type. This type is recommended by the NCWM for weights and measures jurisdictions and specified in NIST Handbook 44. Therefore, this manual presents procedures for large-capacity provers exclusively, and a detailed description of design features and guidelines for use will follow shortly in this chapter.

Basically, these are large metal volume measures, usually mounted on a truck or trailer, and thus generally similar to the receiving vessels (truck tanks, etc.) to which product is normally dispensed by the system. Furthermore, they are designed to connect to the metering system in the same manner as the receiving tanks to which the system normally delivers, and to be loaded at the discharge rate that is normally used in commercial deliveries.

In addition, because of their large capacity, testing with this type of prover approximates most closely the conditions of actual service. According to Handbook 44, the capacity of a prover employed in testing a wholesale metering device must equal the volume of product that passes through the meter in 1 minute at its maximum discharge rate, but in no case less than 50 gallons (most are much larger).

Another commonly used volumetric proving device is the in-line ballistic or loop prover. This type of prover may be permanently installed. Metered product propels a spheroid (ball) through a portion of a continuous circuit. The ball fits closely within the piping, so that product cannot pass around it. Sensors detect the passage of the ball past fixed points. The detectors are connected as inputs to a counter, which is also connected, through a pulser, or a similar sensing device, to the meter shaft.

Figure 5-1 illustrates the principle of operation of a typical loop prover. The combination of open and closed valves (depicted by the hourglass shapes in Figure 5-1, black indicating closed valves, white open valves) directs the flow of metered liquid.

In the upper drawing, the flow propels the spheroid first past Detector A. The detector senses the passage of the ball and emits a signal, which switches on the counter. At that moment, the counter begins to "count" the revolutions (and fractions of revolutions) of the meter shaft, functioning in the same way as a register. As the ball continues through the loop in the direction of flow, it eventually passes Detector B.

The signal emitted by Detector B as the ball passes halts the counter and simultaneously actuates the valves so that the flow momentarily bypasses the measurement loop and returns to storage, as shown in the middle drawing.

As soon as the liquid in the loop has come to a rest, valves are actuated to reverse the direction of flow, as shown in the lower drawing. When the ball passes Detector B, the counter is switched on again; when it passes Detector A, the counter is switched off and flow through the loop is again diverted, returning the system to the state shown in the middle drawing.

Each movement of the ball between the detectors is called a "pass." Since the quantity displaced during a pass is known, the performance of the meter can be determined by comparing the quantity indicated by the counter for the pass. Several passes are generally accumulated on the counter to increase the accuracy of the trial.

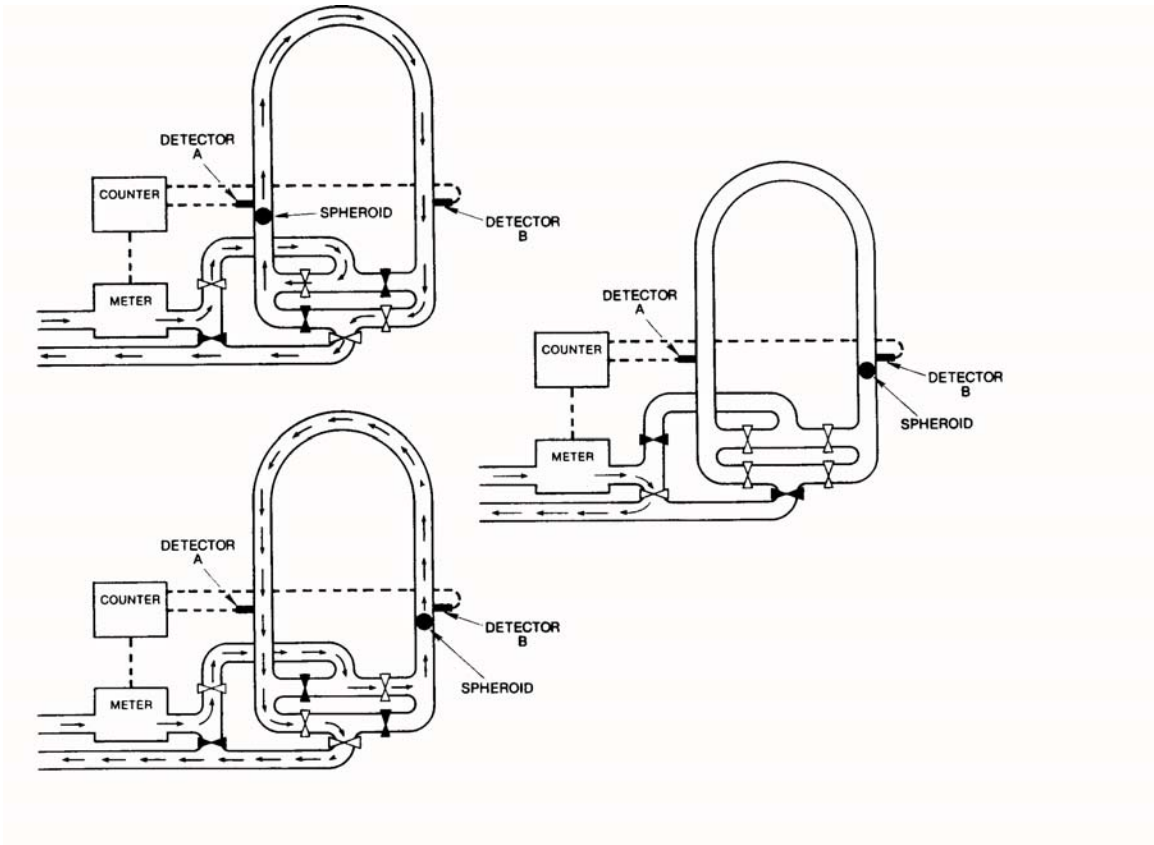


FIGURE 5-1. Operation of a loop prover.

The principle of operation of a small-volume prover is similar to that of a loop prover, although a piston often replaces the spheroid as a displacer. As the name implies, a much smaller quantity of test liquid is involved in the proving process. This is possible because small-volume provers employ high-precision detectors and techniques for determining fractions of pulse intervals.

Finally, many meter services and facilities use master meters to prove loading-rack metering systems. The master meter is simply a meter -- usually a turbine meter of the type described in Chapter 3 is used as a master meter -- whose accuracy is equal to or exceeds that of the meter being tested. Master meters must themselves be tested and recalibrated frequently.

Prover Design

The large-capacity prover, formally referred to as a "field standard prover" because it is employed as a test standard in field examinations, is itself a precision measuring device which must be tested and certified as correct periodically, like the devices it is used to test. In fact the performance requirements for provers, as for all field standards, are considerably more stringent than those that apply to the commercial devices that are

tested. As a rule, the standard must perform within tolerances that are no greater than 1/3 of the smallest tolerance to be applied when the standard is used.

To assure this degree of accuracy, provers must be certified by a State metrologist or by a licensed testing laboratory. Standard provers owned and maintained by weights and measures jurisdictions are used for almost all examinations. However, the official use of a prover owned by a device operator or meter calibration service may be permitted under special circumstances, provided that the prover has been certified by the appropriate State authority and is in good condition. Such a situation might arise if the jurisdiction desired to examine a particular metering system but could not provide an appropriate prover. Specific requirements for field standard provers are set forth in NIST Handbook 105-3, "Specifications and Tolerances for Graduated Neck Type Volumetric Field Standards."

Provers are constructed of metal (usually low carbon or stainless steel). The interior surfaces of low carbon steel provers are treated by galvanizing, plating, coating with epoxy resin, or some other means to resist corrosion from the test liquids they are used to measure. Provers are available in a variety of sizes, ranging from 20-gallon to 1,500-gallon or larger capacity. Those used for testing loading-rack meters generally fall within the range of 500 to 1,500 gallons. As mentioned earlier, the prover used to test a particular device must have a capacity that is equal to or greater than the quantity of product that is delivered by the system in 1 minute, operating at the maximum discharge rate recommended by the manufacturer. The reason for this requirement will be discussed presently.

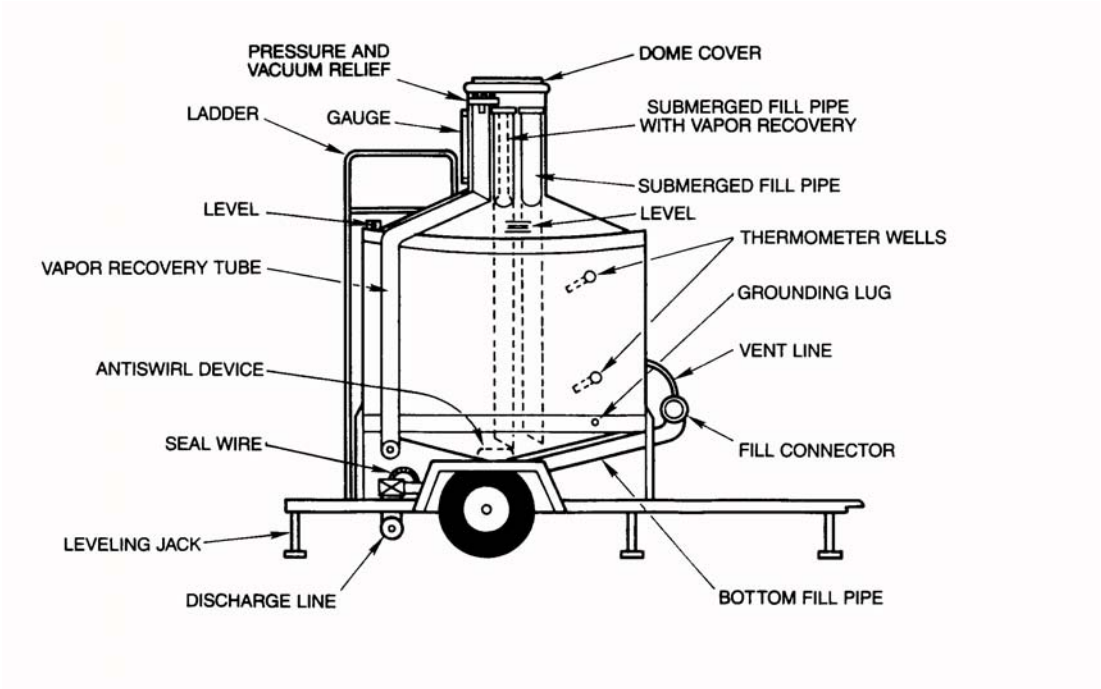
As you learned in Chapter 2, provers are designed either for top-loading or bottom/side loading. The prover used to test a metering system should be of the same type as the system. Figure 5-2 shows a prover that is capable of either top or bottom loading. (With the increasing use of bottom loading, many top-loading provers have been modified in recent years so that they can be used for both types of service.)

FIGURE 5-2. Large capacity, neck type prover.

The "dry-break" type coupler has been standardized for bottom loading. They are called dry-break couplers because shutter-like partitions near the outside rims of both connectors close instantly when they are disconnected, virtually eliminating any spill of product. To connect, the female coupling on the system loading arm is pushed onto the male coupling on the prover delivery inlet and a lever is pushed to lock the connection; connecting the couplings automatically opens the dry-break partitions. When the metering system pump is activated and the discharge valve is opened, delivery begins. Provers used for testing loading-rack systems are generally not equipped with throttling valves at the inlet, since the discharge rate is controlled automatically by the system control valve.

The purpose of the vent line near the inlet of the bottom-loading fill pipe is to ensure that air will not be trapped in the fill pipe as the liquid level rises in the prover. The volume of both the fill pipe and the discharge line (which is only partially visible in Figure 5-2) are included in the calibrated capacity of the prover, and both must be filled (and drained) completely to insure accurate measurement of test drafts.

The liquid inlet should incorporate features such as flow deflectors to minimize turbulence and splashing, especially at the beginning of the delivery. Recent studies have shown a large degree of variability in the amount of evaporation that occurs in bottom-loading provers of different designs under the same loading



conditions, especially for gasoline. In one series of tests, the quantity of gasoline vapor produced varied from one prover to another by as much as 20 percent of the capacity of the prover.

NIST Handbook 105-3 contains specifications for the design of neck type bottom-loading provers. The current tolerances for loading-rack metering systems include an allowance for uncertainty due to evaporation of product in the prover, the uncertainty of the calibration process when using different reference standards, variations in field procedures, and the repeatability of the meter and the test process itself.

Your jurisdiction should, if possible, have its provers tested to determine the amount of variability in evaporation and take appropriate steps to modify the design of the prover to minimize this factor if the variability exceeds the basic guideline of 6 percent of prover capacity. The manufacturer of the prover may be able to advise regarding specific modifications.

When this prover is top loaded, a spout (also referred to as a down tube or fill spout) attached to the end of the metering system discharge line is inserted into the fill pipe. This pipe, which is permanently attached to the prover, extends to the bottom of the tank to minimize splashing and is therefore referred to as submerged.

When the liquid level rises into the elongated neck of the prover (during either top or side/bottom loading), a portion of it enters a glass gauge tube, which penetrates the container through an opening in the top cone. When delivery is halted, the liquid/air interface in the gauge tube acts as an indicator with a scale plate that is mounted on the outside of the prover. We will look more closely at this scale shortly.

The prover is equipped with a vapor recovery tube, which is used when the prover is bottom loaded. Many bulk petroleum loading-rack systems are now equipped with vapor recovery, and it is likely that this design will eventually become universal as environmental legislation banning venting of gasoline vapors to the atmosphere is adopted in all States.

As the liquid level rises during delivery it acts like a slow-moving piston, displacing the mixture of air and vapor above it. If the metering system does not have vapor recovery equipment, the dome cover of the prover is left open, allowing the gases to be vented to the atmosphere (leaving the dome closed would result in pressurization of the prover, which would soon overcome the ability of the system pump to deliver product and create a very hazardous situation because the pressurized product could burst seals explosively, resulting in considerable spillage).

In a system with vapor recovery, the dome cover is kept closed, and a hose is attached, either to the submerged fill pipe with vapor recovery (top loading) or the vapor recovery tube (side/bottom loading), Displaced air and vapor then pass from the prover into this tube, which carries them to a container where vapor is separated from the air by condensing it. The air is then vented and the condensed product disposed of (usually by returning it to the storage tank).

The pressure relief valve permits venting from the closed vessel if, for one reason or another, the vapor recovery system can not draw off all the air/vapor that is expelled. Remember that liquid may be entering the prover at rates of up to 1,000 gallons per minute or more at full flow, displacing more than 2 cubic feet of gas per second, and several metering systems may be using the same vapor recovery unit simultaneously.

The vapor recovery line must be disconnected before the prover is drained, to prevent vapor from being drawn back into the prover by the partial vacuum created as the product level drops. During product return, the vacuum relief valve allows air to enter the prover with the dome cover closed.

Figure 5-2 does not show the location of the overfill level sensor, which would be located at a level near the top of the scale plate. The total capacity of the neck on a 1,000-gallon prover is not more than 20 or 25 gallons, and the space between the top of the scale plate and the dome cover will not accommodate more than 2 or 3 gallons. If the meter preset device should fail, or if the meter is drastically underregistering, product will very quickly reach this level, even if the control valve has slowed the discharge rate to a relatively slow 50 gpm for shutdown. Even an experienced and attentive operator, with quick reflexes and one hand on the emergency shutoff, would be unable to prevent some spillage.

If product overfills the prover, it will either spill from the top of the neck (if the dome cover is open) or force its way into the vapor recovery line, which may rupture under the strain. Neither event is desirable, and both are potentially hazardous.

The overfill sensor, which may be a float-actuated switch or other level-sensing device, responds almost instantaneously to the arrival of the liquid level, automatically sending a signal to the control valve to halt delivery immediately. If any spillage does occur (which is possible, since the time from liquid reaching the sensor level and overfill may be less than 1 second) it will be minimal.

At some facilities, product is drawn from the prover back to the system by a pump which is not part of the prover. However, this is not always the case, and the prover should be equipped with a return pump, of sufficient capacity to return product to the facility (not shown in Figure 5-2).

The pump should be of the centrifugal type, since this design tends not to pump air or vapor, and thus will not introduce gases into the product as it is being returned. For the same reason, the prover drain should have baffles, or some other anti-swirl device to prevent the formation of a vortex as the liquid is drained.

The prover pump propels product through the discharge line, which has a manual discharge valve upstream of the pump (not shown in Figure 5-2). The discharge line should also have a sight glass or some other flow-detecting device downstream of the discharge valve, since the drain procedure requires timing from the cessation of flow (see below).

When returning product, a flexible hose is usually connected between the prover discharge connector and the facility's product return system. Since this hose is emptied between drafts, it should have a bleed valve on the discharge end, so that air can be evacuated before product is returned.

Large-capacity provers may be either truck- or trailer-mounted. Note that the trailer-mounted prover shown in Figure 5-2 is equipped with levels and leveling jacks. It is essential that the prover be level back-to-front and side-to-side when it is full of test liquid, since the apparent level in the gauge tube will be affected by an out-of-level condition. (Think what happens when you tilt a tumbler full of water in any direction. Although the level of the water does not actually change -- unless you also raise or lower the glass -- it appears to rise relative to the side of the glass in the direction of the tilt; the neck and gauge glass of the prover correspond to the tumbler.)

The prover shown in Figure 5-2 also has a grounding lug. It is essential that the prover be well grounded to prevent the buildup of static charge, which would otherwise be considerable, especially when relatively viscous products like diesel or fuel oil are being measured. Many metering systems installed in recent years are equipped with a single coaxial connection, which can be mated with a compatible connector on the prover to carry power to the prover pump, connect the overfill sensor to the control valve or emergency shutoff, and ground the prover to the facility power supply ground, all through a single cable. In addition to being more convenient, this is generally more secure than having several separate electrical lines running between the system and the prover.

Finally, note that this prover has two thermometer wells (also called thermowells). Accurate immersion-type thermometers are inserted in these wells to monitor the temperature of product inside the prover at the time the gauge is read. The reliability of this temperature measurement is extremely important for accurate proving.

If the temperature of product in the prover is different from that of the product at the time when it passed through the meter, corrections must be made to insure comparability, since liquids generally expand in volume when heated and contract when cooled. In addition, the metal prover will also respond to temperature, increasing its capacity when it is warmer, and decreasing its capacity when it is cooler.

As you saw in our discussion of automatic temperature compensation in Chapter 3, a very small temperature difference can have impressive results. Another brief example may help bring home the importance of accurate temperature measurement as it relates to testing.

Let us suppose that gasoline is the test liquid, that an indicated draft of 1,000 gallons has been delivered to the prover, and that there is a difference of temperature of just 1 /F between the gasoline when it passed through the meter and when it is measured in the prover, with prover temperature being warmer.

The volume of a typical grade of gasoline expands or contracts by approximately 0.07 percent for every degree of temperature change. So, 1,000 gallons of product that passed through the meter will occupy a volume of 1,000.7 gallons in the prover. In this example, if the meter was exactly accurate, it would still appear to be underregistering, since the volume of product had increased.

Furthermore, if the prover is made of stainless steel, and is heated to the same temperature as the product it contains, it will expand slightly, increasing its capacity by about 0.0265 gallons for the 1-degree increase in temperature. This will offset the expansion of the gasoline, however, the net effect will be an increase in product volume as indicated on the prover gauge, of 0.67 gallons. This amount of product may not seem like very much, but it corresponds to almost 30 percent of the applicable acceptance tolerance for this device. Furthermore, keep in mind that one meter may have a throughput of 50-60,000 gallons per day or more.

If one facility had 20 such meters, and corrected them all on the basis of an erroneous temperature measurement of 1 /F, the result would be a total erroneous measurement of more than 600 gallons per day (and, since the correction would be to make the meters give less product, this would all be in favor of the device owner). Although this scenario is not likely because of the way meters are tested and serviced, it should give you a sense of the importance of accurate temperature measurement.

Some provers have only one thermowell. However, like the example in Figure 5-2, many have two, located at different heights on the prover body. This is because temperatures toward the top of the tank may be slightly higher than those at the bottom. Averaging the readings of a matched set of thermometers placed in upper and lower thermometer wells will give a reliable measurement.

A word should be said about one common variety of the prover design we have been looking at so far, called a <u>double-neck</u> or <u>wet-bottom</u> prover, an example of which is illustrated in Figure 5-3. This prover, as its name suggests, has a neck at the bottom that corresponds to its upper neck. Both are equipped with liquid level gauges, although the lower neck gauge has no graduations, but just a zero line.

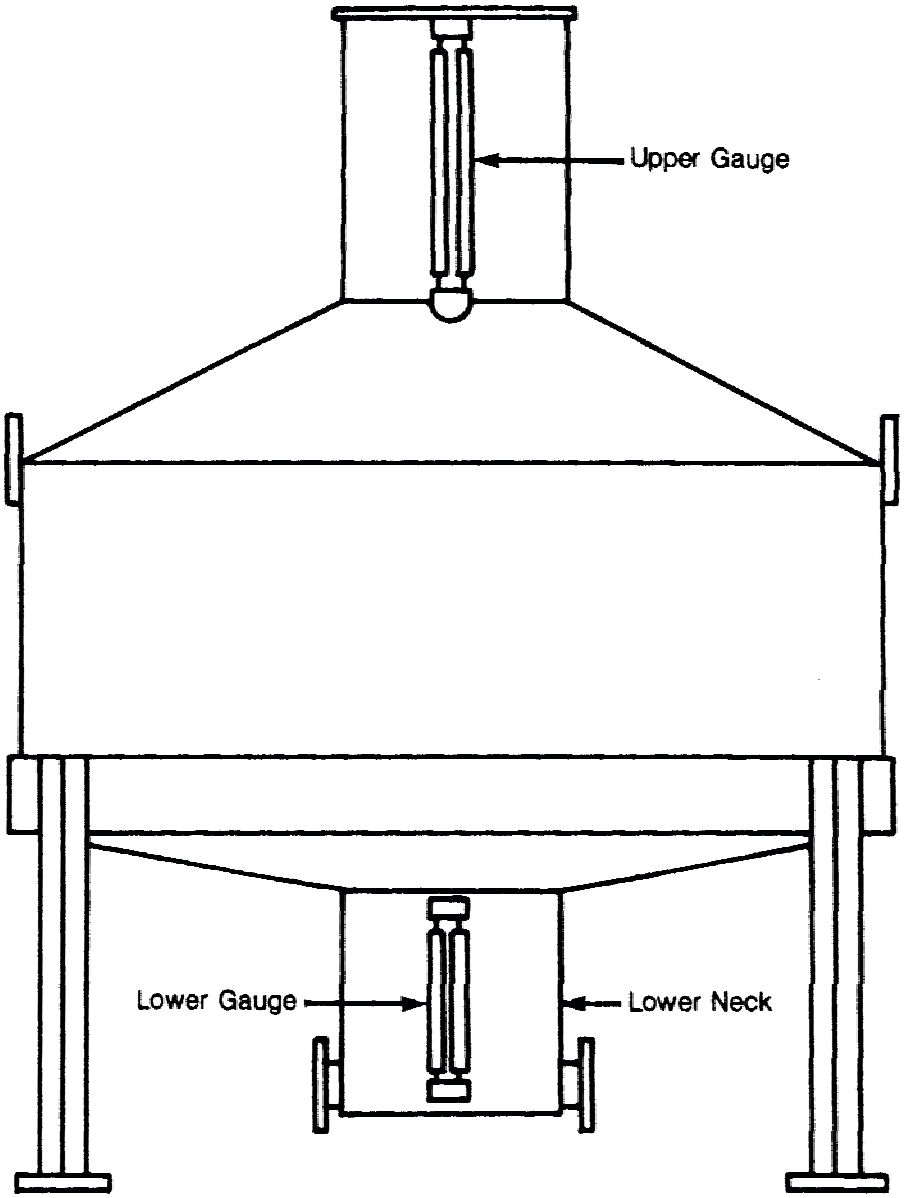


FIGURE 5-3. Wet-bottom prover.

The lower gauge is used to establish an accurate zero reading before each test draft. As the prover is being drained, the inspector watches the bottom gauge for the appearance of the top surface of the liquid. When he sees it at the top of the gauge, he closes the prover discharge valve, halting the emptying of the prover for a prescribed period of time (the reason for this will be described in the next section). Then the inspector opens the valve slightly, allowing enough liquid to drain to bring the level down to the zero line on the lower glass. At that point, he closes the discharge valve and the prover is ready to receive another draft.

Recalling the distinction between "wet" and "dry" hose systems which we discussed in Chapter 2, you can understand why this is referred to as a "wet-bottom" prover. In contrast to dry-bottom provers, like the one in Figure 5-2, in which the discharge line is drained before each test draft, a wet-bottom prover retains some product in its lower neck between deliveries.

It might seem at first that wet-bottom provers are more accurate than dry-bottom provers, because the user controls the drainage while monitoring a liquid level gauge. In fact, this is not the case: the accuracy of both types depends primarily upon the proper and consistent observation of the drain time (see below). The second gauge on a wet-bottom prover is simply used to establish a zero fill point.

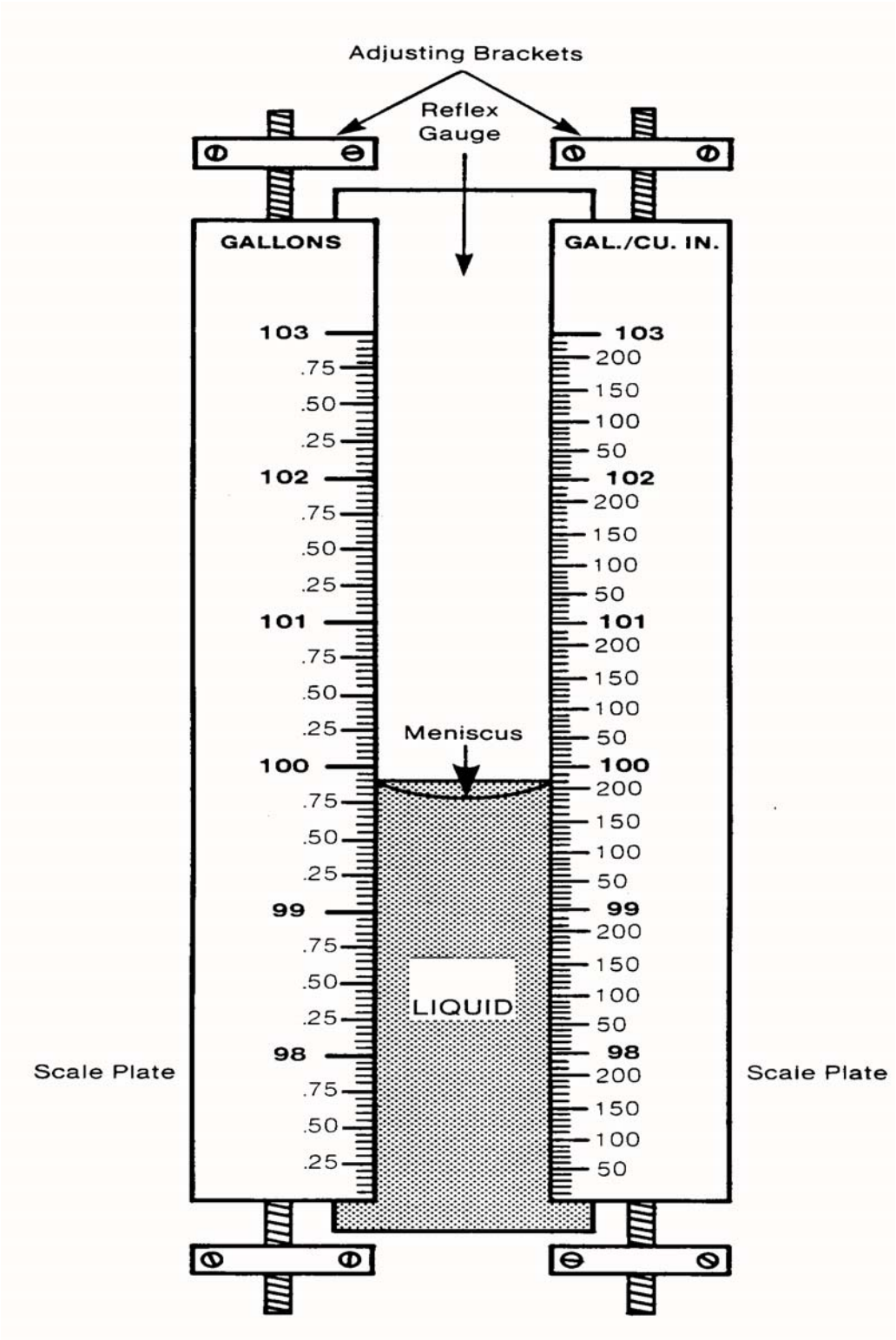
Wet-bottom provers do have two advantages. The first is that the liquid retained in the lower neck prevents air from being returned to the metering system. The other advantage of a wet-bottom prover is that vaporization is minimized, since product is delivered through the bottom of the lower neck. After the initial wet down of the prover (see below), the lower neck contains liquid, so there is less splashing.

On the other hand, the drain procedure for wet-bottom provers involves more steps than does the relatively simple procedure for a dry-bottom prover (described below).

Before turning to the setup and operation of the prover, we should have a closer look at the liquid-level gauge assembly located on the upper neck of the prover, since this is where the prover is actually read. Figure 5-4 is a closeup of the gauge assembly.

On either side of the liquid-level gauge are scale plates, which are mounted on brackets that permit their height to be adjusted for calibration independently. The scale plates are normally sealed to the bracket assembly with lead-and-wire seals to assure that their height has not changed.

The zero line on the scale plate represents the nominal capacity of the prover; graduations above and below the zero line indicate amounts over or under the nominal capacity. The scales are required to be graduated both above and below the zero line by an amount not less than 1.5 times the maximum tolerance, as determined by the size of the prover and the types of meters that are tested.


Adjusting Brackets
Reflex Gauge
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103
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Meniscus
LIQUID
Scale Plate
Scale Plate

FIGURE 5-4. Gauge and scale assembly.

According to Handbook 44, the largest applicable tolerances for a 1,000-gallon test draft used for testing loading-rack meters is 5 gallons (determination of tolerances will be described in Chapter 6); therefore, the graduations both above and below the zero line must represent an amount not less than 5 x 1.5 = 7.5 gallons (1,732 cubic inches).

One scale may be graduated in cubic inches or in units of the metric system (liters), the other in decimal gallons. Until 1987, performance tolerances for wholesale meters were expressed in cubic inches. However, since computations for volume corrections use decimal gallons, both units were useful. Many provers still have twin scales, in cubic inches and gallons, and some may have cubic inches and liters. Fortunately, conversion from cubic inches to decimal gallons is easy (dividing the quantity in cubic inches by 231 gives the quantity in decimal gallons). The National Institute of Standards and Technology recommends that the smallest graduated intervals for these scales have values no greater than what is specified in NIST Handbook 105-3 Table 2a and b.

The inspector should be at eye level with the liquid level in the gauge tube when reading the gauge. The top surface of the liquid will be slightly concave, creating a shallow dish-like surface, which is called the meniscus.

Figure 5-5 illustrates what the meniscus of a transparent, or semi-transparent, liquid might look like when viewed at eye level. The upper, flat line is the highest level on the gauge tube to which the liquid clings: this is not the meniscus. The curve at the liquid surface is the meniscus itself.

This curvature will vary with the optical properties of the tube and the liquid being measured, the width of the gauge tube, and other factors; in some cases, the curvature of the meniscus may not be as distinct as in Figure 5-5. In fact, the meniscus may be relatively flat, giving the appearance when viewed at eye level of a slightly thickened disk.

The lower curve may also appear to have some thickness, and may appear as a darkened, lens-shaped disk, as in Figure 5-5, especially when a dark surface, such as a piece of paper, is placed behind and low on the tube.

In the case of transparent, or semi-transparent liquids, the reading should always be made using the bottom of the meniscus as an index.

In the case of opaque liquids, the only surface that is visible when viewed from eye level is the flat line at the top in Figure 5-5, indicating the highest level of liquid clinging to the side of the tube. This line must be used as an index for reading the gauge when the liquid is opaque, because it is the only surface you can see; you cannot see the meniscus of an opaque liquid.

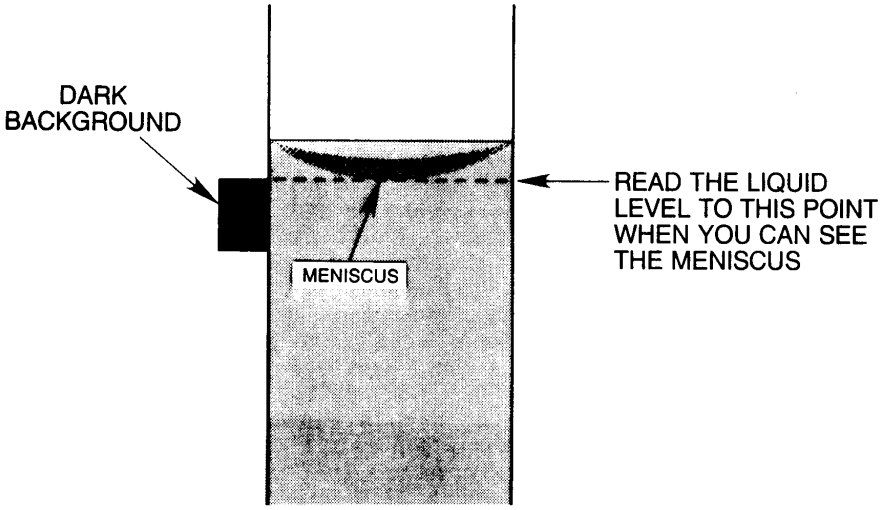

FIGURE 5-5. The meniscus.

When reading the gauge, you should always record the value of the graduation that is nearest the level you are using as an index (e.g., the bottom of the meniscus for a transparent liquid). If the index appears to be exactly between two graduations, record the even value. For example, if the index coincides with a line midway between graduations representing +1.5 gal and +1.6 gal, you would record +1.6 gal, the even value; if the index was exactly between graduations representing +1.6 gal and +1.7 gal, you would still record +1.6 gal, again, the even value.

Consider the example shown in Figure 5-6. The liquid is transparent, so we read the value of the graduations on the two scales provided (gallons on the left and cubic inches on the right) that are nearest to a line coinciding with the bottom of the meniscus. In this case, the values would be +1.8 gal and +425 cu in. If this liquid were opaque, the meniscus would not be visible, and we would record the values of the graduations nearest the line indicating the level of liquid clinging to the tube, in this case, +1.9 gal or +450 cu in.

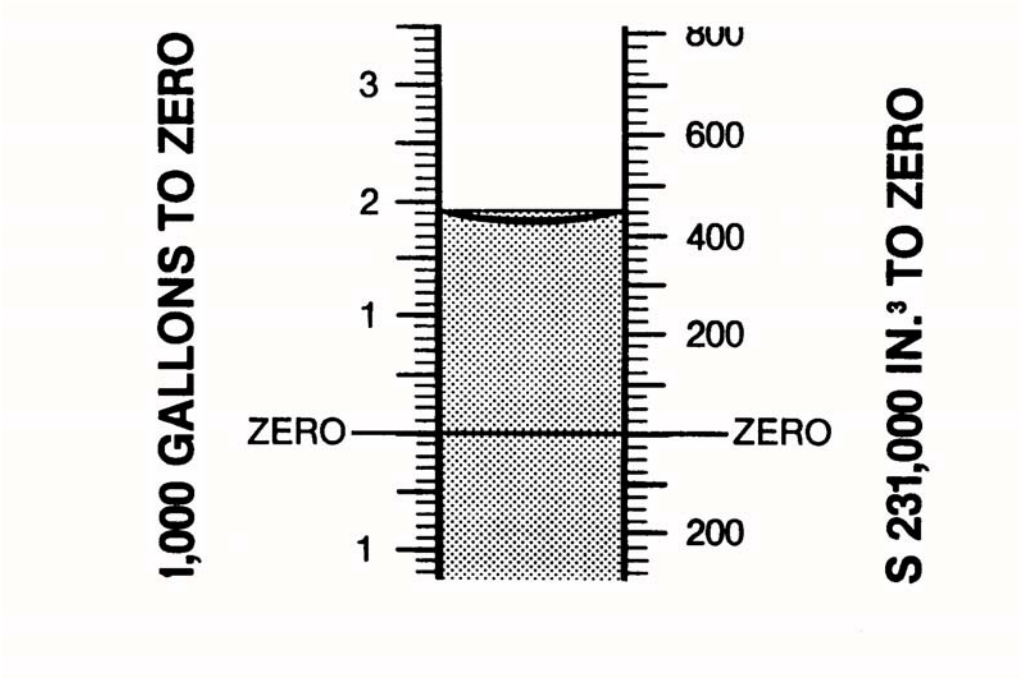

FIGURE 5-6. Reading the prover gauge.

PREPARATIONS FOR TESTING

Setting Up the Prover

Now that you understand the basic design and operation of the prover, let us look at procedures for setting it up and preparing it to accept a test draft.

Note that several of these steps should be performed by the operator of the metering system, not the inspector. Specifically, the inspector should require that the operator, who is familiar with the metering equipment, stand by to make the connections between the prover and the system. This person should also be responsible for operating the system during the test. If the inspector makes the connections or operates the system incorrectly and damage to the metering system results, the inspector will be responsible for that damage.

You will practice and review these procedures thoroughly in the course of your Field Training. Test procedures are covered in detail in Chapter 7 of this manual. As always, the cardinal rule is: SAFETY FIRST.

- Position the prover on a level surface adjacent to the loading rack, making sure that loading arms will reach the prover inlet. The location of the prover should be such that you can see the meter and register from the position from which you operate the prover valves.

- Position caution signs to prevent vehicles or pedestrians from moving through the area adjacent to the prover and meter.

- Position fire extinguishers and other safety equipment where they will be within easy reach if needed.

- Ground the prover to a suitable ground; also connect overfill sensor and power supply line to the system.

- Level the prover from back to front and side to side, using the levels mounted on the prover. If the prover is mounted on a truck bed or trailer, jacks should be manipulated to raise the bed so that it is not resting on the vehicle wheels before leveling.

- Check fittings for adaptors required for connecting the prover to the system.

- Note and record totalizer reading on the metering system register (the reason for this step will be explained in Chapter 7).

- Install thermometers in meter and prover thermometer wells, inspecting the wells first for dirt and other obstructions, clearing them as necessary, and filling them with ethylene glycol.

- Check prover valves to make sure that they are closed tight. Also check all bleed valves.

- HAVE THE OPERATOR connect the system delivery hose to the prover inlet line. Make sure that the connection is tight.

- Connect the vapor return line to the prover.

- If product return can be effected without moving the prover, HAVE THE OPERATOR connect the prover liquid return line to the system inlet.

- Check all connections to assure yourself that they are tight and that prover valves and bleeders are fully closed.

At this point the prover is connected to the metering system and ready to accept delivery of product. However, the setup procedure is not yet complete: the prover must be level and it must be "wet", and these conditions can only be established when it is full of liquid. Before describing these procedures, let us consider briefly what is involved in "wetting" the prover, and why it is necessary.

Wetting the Prover

Volumetric provers are calibrated to "deliver" their rated capacity when filled to the zero line on the upper neck gauge. In fact, they contain slightly more than their rated capacity when full. The reason for this is that test liquids have a tendency to cling to surfaces with which they come in contact: after the prover has been drained, a film of liquid is present on the inner surfaces of the container. The capacity of the prover with respect to a subsequent delivery of product is now reduced by the amount of clingage.

Because it is impracticable to remove the clingage between test drafts, the prover is calibrated when it is wet, that is, with clingage already present. Accordingly, the prover should be wet before it is used to measure an official test draft. In the following procedure, the prover is filled, then emptied and allowed to drain for 30 seconds (the drain period that was used when the prover was calibrated).

The prover is then "wet". After the prover has been wet, the same drain procedure must be followed for all subsequent test drafts to assure that the calibrated volume and the actual volume are the same.

This "wet-down" not only wets the inside of the prover, but also serves the important function of bringing the prover to the temperature of the product in the metering system. Wetting the prover is part of the setup procedure described below. However, this step may need to be repeated if considerable time passes between successive test drafts, since some clingage will evaporate.

Even though the procedure described below is similar to that used for official test drafts, the "wet-down" is not an official test draft, and results obtained should not be used in determining the accuracy of the metering system. However, temperature readings should be taken, both at the meter and at the prover, and recorded for comparison with readings from subsequent drafts.

The wet-down also presents a good opportunity to test the automatic preset and to become familiar with the system's operation. In addition, you can time the discharge rate during the wet-down, to insure that it is within the rated limits for the system (requirements regarding the system discharge rate will be described in Chapter 6).

After checking all connections, continue the prover wetting procedure as follows:

- Set the quantity preset for the nominal capacity of the prover.

- Activate the system pump.

- Open the system discharge valve.

- Check for leaks, especially at the prover inlet and discharge line, and from the meter to the discharge outlet. If leaks are discovered on the discharge side of the meter, halt the test, drain the prover, and do not proceed until they have been repaired.

- Observe and record temperature at the meter at least twice during the delivery, at regular intervals. For example, observe and record the meter temperature once when approximately 1/3 of the total quantity has been delivered and once when about 2/3 has been delivered. Read temperature to the nearest 0.5 /F.

- As the end of the delivery approaches, monitor the gauge glass carefully and have the assistant call out the quantity remaining to be delivered. Be prepared to use the emergency shutoff immediately if the preset fails to halt the delivery at the quantity set or if the liquid level rises above the top of the sight glass and the overfill sensor does not automatically halt delivery.

- When delivery has halted, deactivate the system pump and disconnect the bottom loading coupling or remove the fill spout from the top loading inlet. Make sure that the fill spout drains completely.

- Read and record prover temperature to the nearest 0.5 /F. If two thermometers are used, the average of the two readings should be recorded.

- Record totalizer reading.

- Disconnect the vapor recovery line. This must be done before the prover is drained.

- With the prover full of liquid, check that the prover is level from back to front and side to side, and make necessary adjustments. This is important, since the load of product may have shifted the balance of the prover and thereby thrown it out of level.

- Open prover return line valve, slowly. Open air bleed valve on return line to drive air from the discharge line downstream of the prover discharge valve.

- Start the prover return pump.

- Perform drain procedure.

  For dry-bottom prover:

  - Monitor flow indicator on discharge line.

  - When flow breaks to a trickle, start stopwatch and shut off prover pump.

  - At end of 30-second drain period, close prover discharge valve.

  For wet-bottom prover:

  - Monitor lower neck gauge.

  - As the liquid level appears in the top of the lower neck gauge close the return line discharge valve.

  - Start stopwatch as soon as valve is closed.

  - Turn off the prover return pump.

  - At the end of the 30-second drain period (as indicated by the stopwatch) zero the liquid level in the lower neck gauge of the prover, cracking the discharge valve to lower liquid level to the zero line.

The prover is now wet and level, and ready to receive an official test draft.

Test Drafts

As you will learn in Chapter 7, an official field examination of a loading-rack metering system requires a minimum of two test drafts, and sometimes several more. The basic procedure is similar to that described above for wetting the prover, but there are a few important differences and several additional steps.

Before beginning delivery:

- Check all connections. Reconnect vapor recovery line.

- HAVE THE OPERATOR start the system pump to pack the delivery hose.

- Reset the system register so that it indicates zero exactly. If system is equipped with a printer, insert ticket.

During delivery:

- Use your stopwatch to monitor the flow rate. Start timing when the system control valve has increased flow to full. Reasons and the procedure for this step are explained in Chapter 7.

After delivery has been halted:

- Record meter and prover readings. If bubbles or foam appear in the prover gauge, wait until they have subsided before taking a reading. If the system has a mechanical register and preset has not halted delivery exactly on a graduation, record the indication to the nearest 1/10th of a minimum graduation (generally 0.1 gallon). To do this you must visually subdivide the graduated interval, a skill which requires considerable practice before it can be done confidently.

MAINTENANCE OF THE PROVER

The following are general maintenance procedures for a large-capacity volumetric prover. Be especially careful to note any damage that has occurred to the prover, any performance that seems abnormal to you, and especially any leaks, and report these observations to your supervisor immediately. If repairs are required they must be made by qualified service personnel and the prover recalibrated if necessary before it is returned to service. Your jurisdiction should have a regular program of reinspection and recertification for provers.

- After the last delivery at a particular site or the last delivery of the day, drain the prover thoroughly.

- Store hoses and cables carefully to avoid damage and crimping.

- Clean dirt from fittings and connections at the end of an examination and at the end of each day. Make sure that inlet and outlet connections are capped securely and that adaptors and other fittings are stored in a manner that will minimize the possibility of damage during transportation.

- Cover thermometer wells when they are not in use and check regularly to make sure they are clean. Never leave a thermometer in the well while the prover is being transported. Clean dirt from thermometers and store them carefully.

- If the return line is equipped with a strainer, check it regularly and clean or replace as necessary.

- Follow manufacturer's instructions for lubricating the return pump and servicing valves.

- Use an inspector's extension mirror and explosion proof flashlight to inspect the inside of the prover periodically. If dents, corrosion, or foreign material are discovered, have the prover cleaned or repaired immediately.

REPORT FORMS

Every official action you take as an inspector must be recorded. Reports of your activity are used not only for your own recordkeeping, but also by your jurisdiction for a variety of administrative, research, and planning purposes. For examinations of loading-rack metering systems you will have to keep records of:

- the device(s) examined,

- the findings of your examination,

- the official disposition regarding approval or rejection of each device, and

- actions taken as a result of that disposition.

This list represents a minimum set of required information. It is quite probable that your jurisdiction will require additional items.

A good report form should:

- Be complete enough and in a suitable form so that it may be the primary record; that is, it should not be necessary for someone to copy the report information onto other records.

- Contain space for recording all the test data you collect and use when you follow the Examination Procedure Outline.

- Give the owner or operator of the metering equipment a clear and specific understanding of the compliance or noncompliance of his or her equipment, and the official action taken as a result of examination findings.

- Serve as a guide to repairpersons in providing service for a rejected device.

- Provide an historical record of individual devices and commercial operators, with necessary data from which statistics can be derived.

- Be of a clear and straightforward design, easy to use and understand.

At the present time, every jurisdiction uses its own report forms and reporting procedures. Your instructor will explain the forms and procedures used in your jurisdiction.

The Office of Weights and Measures at the National Institute of Standards and Technology has designed a sample report form for recording official test data and other relevant information for loading-rack metering systems. This form has the features described above, and will be used for illustrating the recording of test data and computations that are covered in Chapter 7 of this manual.

SUMMARY

The correct test equipment and its proper operation, care, and maintenance, are essential to safe, accurate, and efficient examinations of loading-rack metering systems. Two basic methods have been employed in testing liquid-measuring devices: the gravimetric method and the volumetric method. The latter is considered more accurate and efficient for testing in the field, and approximates more closely the actual operating conditions of a commercial delivery.

The large-capacity field standard prover is a precision test instrument. Before it can be used to perform volumetric tests it must be set up correctly. Procedures for prover setup include making connections to the metering system and leveling, and wetting the prover. Procedures for drawing test drafts are similar to those used in wetting the prover, but include several important differences and additional steps.

Regular and proper maintenance of the prover is necessary if it is to perform accurately and reliably in the field. Report forms, which are used to record all official activities of the weights and measures official, are an essential item of standard equipment for field examinations. Their design and use must be clearly understood.