# CHAPTER 7 -- EXAMINATION PROCEDURES, PART II: THE TEST

## OBJECTIVES

After you have studied this chapter, and reviewed its contents with your instructor, you will be able to:

1. Describe, in general terms, the theory of tolerances as it applies to tests of loading-rack metering systems.

2. Describe procedures for conducting performance tests of loading-rack metering systems, as prescribed in the EPO.

3. Record, analyze, and interpret Test results.

## INTRODUCTION

A liquid-measuring device that conforms with all of the specifications and requirements set forth in Handbook 44 relating to its design, installation, maintenance, and use may still not be capable of the high degree of accuracy and consistency of measurement demanded for commercial service. The reason for this is that the meter -- being a mechanical device that has moving parts -- is subject to wear in normal service, and this wear will eventually have an effect on accuracy. As a result, the condition of the meter (and associated elements like the register) is an important factor that must be determined.

Thorough inspection may give you some indication of the condition of the system you are examining, but this impression will be based upon evidence that is limited to observations made while the system is not in operation, and so may even be misleading. For example, a metering system that is clean and, to all outward appearances, well maintained, may be badly worn and in need of adjustment or reconditioning. The only way to determine the condition of the equipment -- and thereby to determine how accurate it is likely to be when used for commercial service -- is to test its performance under conditions that approximate as closely as possible actual service conditions. This is the purpose of the Test portion of an official field examination.

In fact, the Test is actually comprised of several separate tests, each of which has a specific testing objective. Some of these tests are designed to determine the accuracy of the system over the range of operating conditions for which it was designed (and, presumably, is used). Others are intended to test specific elements of the system. You should understand not only how to perform these tests, but also the reasons for performing them.

In addition, you will learn that the results of these performance tests can often provide information that is useful to the operator and to repairpersons in making needed repairs, even on equipment that is technically in compliance with weights and measures requirements at the time of the examination. Thus, you should understand how to interpret the results you obtain and inform the operator of their significance.

This chapter is intended as an introduction to the procedures that you will review and practice in the course of your field training. As was the case for the Inspection, we will follow the NIST Examination Procedure Outlines (EPO) for loading-rack meters, reviewing relevant requirements and specifications from Handbook 44. Your instructor will describe policies and procedures employed by your jurisdiction that differ from those outlined in the EPO.

Throughout this chapter, we will refer to the sample report form reproduced in Figures 7-1 and 7-4, which illustrate the recording of test data and calculations. (You may wish to remove these pages from your book so that you can refer to them as we proceed without having to flip back and forth.)

## PREPARATION FOR TESTING

Prior to beginning the Test you will have set up your test equipment and performed a safety check, as described in Chapters 4 and 5. You will also have completed the Pretest Determinations and Inspection described in the last chapter. You should also have prepared your report form by recording certain basic information about the device you are going to be testing. This basic information includes:

- the date and time of the test
- the name and complete address of the operator of the device
- the make and model, size, and serial number of the meter (from the meter identification plate)
- the maximum and minimum discharge rates that are marked on the meter
- the accessory devices that are part of the system (ticket printer, thermometer well, automatic temperature compensator, etc.)
- the values currently registered on each of the system's totalizers
- the identity of the product being metered, and its API gravity or specific gravity.

This information is important for recordkeeping purposes, and some of it -- the maximum and minimum discharge rates, the API gravity, and the existence of a temperature compensator -- are necessary for determining specific test factors, as you will see below.

You need to record totalizer readings before the Test begins, and again at its conclusion, in order to determine the total quantity of product metered during the Test. The operator must be furnished with this data so that he or she can reconcile inventory figures, since product dispensed during the Test will have been recorded on the totalizer as delivered, even though it has all been returned to the operator's tank. Recording the beginning and ending totalizer readings simplifies the calculation of the total amount dispensed, since it saves adding indicated quantities for several test drafts. If the register is of the computing type and has a money-value totalizer, you should record this value as well.

It is good practice to record this information before you begin other Test activities, so that it will be available and will not be overlooked while you are concentrating on other tasks. Note how these data are recorded in the top portion of the sample report form shown in Figure 7-1.

## TOLERANCES

As part of the Pretest Determinations, you have determined the applicable tolerances for the tests that you will conduct. Remember from our discussion in Chapter 6 that the LMD Code specifies three tolerances for loading-rack meter errors, two for Normal Tests and one for Special Tests. It is time to say something more about these designations, and about the theory that underlies tolerances in general.

It is recognized that the measuring device being tested is not capable of errorless performance under all operating conditions that may occur in the field. For this reason, tolerances are established to fix the acceptable range of inaccuracy for weighing and measuring devices in commercial service.

Tolerances are developed on the basis of scientific testing of devices and procedures. All factors that can influence performance but are not controllable by the device operator or tester are identified. These include the basic repeatability of the device, the expected accuracy of test equipment, test factors (such as environmental conditions), and test procedures (such as differences in reading indications, operating controls, etc.). Tolerances incorporate allowances for these uncontrollable factors.

At the same time, tolerances are designed to permit only measurement errors small enough not to cause serious economic injury to either buyer or seller. The tolerances that apply to a particular device must not be so stringent as to make the costs of manufacturing and maintaining commercial equipment unreasonably high, since these costs are ultimately passed on to the consumer. The tolerances established by code or regulation and enforced by weights and measures officials are generally considered as minimum standards by manufacturers of metering equipment; industry can, and often does, establish its own performance standards that are more stringent.

The tolerances for loading-rack meters prescribed in Handbook 44 are expressed in terms of a percentage of the indicated quantity. The actual tolerance values are determined by four factors:

- the length of time the device has been in service,
- the type of test that is being performed,
- the size of the test draft, and
- the units indicated on the meter

For loading-rack metering equipment -- as for all mechanical devices whose performance can be affected as a result of extended use -- Handbook 44 establishes two sets of tolerances (see General Code, Sections G-T.1. and G.T.2.):

- <u>acceptance tolerances</u> apply to:

  (a) any equipment to be put into commercial use for the first time;

  (b) equipment that has been placed in commercial service within 30 days and is being officially tested for the first time;

  (c) equipment that has been returned to commercial service following official rejection for failure to conform to performance requirements and is being officially tested for the first time within 30 days after corrective service;

  (d) equipment that is being officially tested for the first time within 30 days after major reconditioning or overhaul; and

  (e) equipment undergoing type evaluation.

- <u>maintenance tolerances</u> generally apply to equipment that has been in service for more than 30 days.

As you learned in Chapter 6, on Normal Tests the acceptance tolerance for loading-rack meters is 0.2 percent of the volume indicated by the meter at the conclusion of the test draft. The maintenance tolerance is 0.3 percent, that is, half again as large as the acceptance tolerance. The maintenance tolerance, therefore, constitutes a somewhat less stringent compliance standard, and thus allows a limited degree of deterioration in performance and generally assures a reasonable period of use before the system must be adjusted.

Handbook 44 also establishes two different classes or types of tests, "normal" tests and "special" tests. They are described in paragraphs N.4.1 and N.4.2 of the LMD Code. We will look more closely at these two types of tests later in this chapter when we discuss specific procedures.

For now, you should simply consider that a Normal Test is intended to test performance under conditions that approximate as closely as possible those that are most usual for the system, that is, conditions that are "normal."

Special Tests, on the other hand, are used to assess the performance of the system under operating conditions that are not normal in this sense, but that are within the range of conditions for which the device was designed and that may occur in commercial service.

You will recall from Chapter 6 that the tolerance for Special Tests of loading-rack meters is 0.5 percent, regardless of whether the test is for acceptance or maintenance.

You should record the applicable percentages on your report form, so that you can determine the actual tolerance value, in units of volume. This is accomplished simply by multiplying the percentage by the volume indicated on the meter register.

For example, if the meter reads 1,000 gallons at the conclusion of a Special Test, the tolerance value would be 0.005 x 1,000 = 5 gallons. If the difference between the actual volume delivered, as indicated by the (corrected) prover reading, and the quantity indicated on the meter (1,000 gal) is greater than 5 gallons, the device does not meet this performance requirement.

Note that tolerances apply both to <u>underregistration</u> (when the actual volume delivered is greater than the volume indicated on the meter, that is, a negative meter error) and <u>overregistration</u> (when the actual volume delivered is less than the volume indicated on the meter, a positive meter error). Thus, adding and subtracting the tolerance value from the indicated quantity gives us the range of acceptable indications.

In the example above, if the <u>actual</u> volume delivered is more than 995 gallons (1,000 gal - 5 gal) but not more than 1,005 gallons (1,000 gal + 5 gal), the metering system is within tolerances for that test.

## THE TEST

The Test portion of an official field examination, as set forth in the EPO for loading-rack meters, can be summarized as follows:

- At least two test drafts are drawn and recorded. One of these tests is a Normal Test, conducted at the system's maximum discharge rate; the other is a Special Test, conducted at a rate of flow that is at or near the minimum discharge rate recommended by the manufacturer of the meter. If the system is equipped with an automatic temperature compensator, the ATCS is left activated (as found) for both of these tests.

- If the system is equipped with an automatic temperature compensator and indicates compensated volume only, a second Normal Test is conducted, with the ATCS deactivated. This provides the basis for assessment of the accuracy of the ATCS. If the system indicates both net and gross volume, a second Normal Test is not required.

- Delivery errors are recorded for each draft, based upon prover readings that have been corrected for expansion of the prover due to thermal expansion or contraction, and for the temperature difference between product at the meter and at the prover. On a temperature compensated run, the prover reading is corrected to reflect the volume of the liquid at its reference temperature. These errors are compared to the applicable tolerances to determine conformance with performance

requirements. Additional test drafts may be drawn to confirm results if they are close to tolerances.

- All primary indicating and recording elements are checked for comparability of indications and computing type devices are tested for agreement between indicated and mathematically computed money values.

- The performance of temperature sensors and the quantity preset is assessed.

- Additional tests may be conducted to test electronic systems for susceptibility to RFI/EMI.

Before looking at the Test procedures in detail, let us turn our attention briefly to several steps that are repeated for each test draft. These are listed together at the beginning of the Test section of the EPO, where they are designated Test Notes.

## TEST NOTES

### Items 1-3

The first three items under Test Notes relate to setting up the prover: leveling the prover; connecting safety interlock, ground cable, and vapor-recovery hose; verifying that prover valves are closed and pump is functional. These preparatory activities were described in Chapter 5.

4. Note the totalizer reading. Totalizer should be checked before and after each draft to determine its proper operation.

   In addition to noting the totalizer reading at the beginning and end of the Test, as described earlier in this chapter, readings should be observed and checked for each test draft. Even though totalizers are generally not primary indicating elements, they do display quantity and should therefore be accurate. Subtract the reading at the end of each draft from the beginning reading. The result should equal the indicated quantity for that draft. Be sure that you check comparable readings: gross volume totalizer readings should be compared with gross volume indication, net volume totalizer reading with net volume indication.

5. Care should be exercised to insure that the temperature difference between the product in the meter and product in the prover is small.

   The procedures for both compensated and non-compensated tests specify that the indicated prover volume should be corrected to reflect its volume at a temperature of 60 /F.

   However, an increase in temperature between the meter and prover can increase the rate of evaporation of product inside the prover, which will diminish the accuracy of test results, especially if the product is relatively volatile, like gasoline.

   As mentioned in Chapter 5, one important function of wetting the prover is to equalize temperatures, because the liquid product tends to either warm or cool the prover to a temperature that is close to that of product in the meter. It is therefore important to minimize the length of time between test drafts, especially In extreme conditions, when the ambient temperature is either very hot or very cold, or when there is high wind.

If the temperature differential does not diminish steadily with subsequent drafts, or if the difference is more than a couple of degrees, some action should be taken. First, check thermometer wells for dirt or grease that could be distorting readings. If more than a few minutes have transpired between drafts, it may be necessary to re-wet the prover (this will also restore evaporated clingage).

6. For top loading provers, take precautions to minimize splashing and to maintain the fill spout in a consistent position.

   Top-loading provers are, in general, most likely to produce significant evaporation from splashing. The fill spout should be positioned in such a way that splashing is minimized. Holding the fill spout in a consistent position from one draft to the next will lessen the variability in the amount of vapor produced.

7. Examine printed tickets and invoices.

   The LMD Code includes a number of requirements relating to comparability of indications and recorded representations, money-value computations on computing type devices, and notices regarding temperature compensation, if employed. These requirements are cited in the EPO.

   If the system is equipped with a ticket printer, print a ticket for each test draft. You should also, if possible, obtain samples of actual used tickets, to verify that required information and format is adhered to.

   Keep in mind that these requirements apply to any recording element or recorded representation that is involved in the transaction, whether located at the rack or at some remote location. For example, invoices produced at a printer located in the terminal office should also be inspected.

   In summary, you should check the printed ticket to determine:

   - whether values are printed digitally. Printed representations of a dial face or some similar analog representation are not acceptable (G-S.5.6.).

   - whether all electronic digital values of like value in a system agree with one another; for example, whether the quantity shown on an electronic register agrees exactly with the amount printed electronically on the invoice or bill of lading.

     In systems where a mechanical analog device interfaces with an electronic device, like values must agree to the nearest minimum graduation. For example, the quantity shown on a mechanical register must agree to the nearest minimum graduation with the quantity amount printed by an electronic ticket printer (for a system where the minimum graduation is 0.1 gal, if the mechanical register indicates between 1000.1 and 1000.2 gallons and the indication is closer to 1000.2, the electronic digital printer must print 1000.2). Because the electronic printer cannot display values between minimum graduated intervals, any analog value that falls between values must be rounded up or down; therefore, Handbook 44 recognizes that you may not have exact agreement between analog and digital devices.

   - if the device is of the computing type, whether it displays the total computed price, the total volume of the delivery, and the price per gallon or liter (UR.3.4.). These items may be printed or in clear hand script.

   - if the system is equipped with a temperature compensating system (automatic or nonautomatic), whether the ticket states that the volume has been adjusted to the reference temperature of the

product (60 /F for petroleum products). If the ATCS is electronic (automatic), the ticket must also indicate the API gravity, specific gravity, or coefficient of expansion; product temperature; and gross volume (UR.3.6.1.2.). If the correction is made manually (nonautomatically), the product temperature used in making the adjustment (only) is required to be shown (UR.3.6.2.2.).

- whether all recorded representations are readable (see G-S.5.1., discussed in the last chapter).

All tickets printed for test purposes should be returned to the operator at the conclusion of the examination so that he or she can record control numbers on the tickets and reconcile ticket inventory. You should retain a carbon copy of this information, if possible, for your records.

Money values indicated or recorded on any digital computing type device must agree with the mathematically computed price to within 1 cent (S.1.7.2.).

8. Prover readings are to be determined by reading the bottom of the meniscus for transparent liquids, and the top of the meniscus for opaque liquids.

Again, the most important thing is to be consistent. Depending on the test liquid and the design of the sight gauge, the difference can be considerable.

9. When monitoring drainage of the prover, one of the following methods should be followed depending on prover design. Precautions should be taken to insure that the drainage procedure is followed in a consistent manner for each test.

a. If the prover has a lower neck equipped with a drain sight glass, close the drain valve prior to the liquid level reaching the zero mark indicator. After 30 seconds drain time, open the small drain-off valve and lower the liquid level to the zero mark. Do not readjust the liquid level again, even if continued drainage brings the liquid level above the zero line.

b. If the prover is not equipped with a lower sight glass, leave the drain valve open until continuous flow ceases and dripping commences. Begin timing when dripping starts and close drain valve after 30 seconds.

These methods and their importance were explained in Chapter 5.

10. Temperature readings are to be taken to the nearest 0.5 /F. Take the temperature of the test liquid in the prover immediately following each accuracy test. For provers equipped with more than one thermometer, the temperature of the test liquid is the mathematical average of the individual readings.

A thermometer placed in the thermowell adjacent to the meter is to be used to determine meter temperature. Meter temperature is to be taken at least twice (e.g., at 1/3 and 2/3 prover capacity) during each delivery and averaged.

As was explained in Chapter 5, a very small error in temperature sensing or reading can have a significant effect on test results, especially when the product being tested has a high coefficient of expansion. Remember that a 0.5 /F difference in the temperature of gasoline will result in approximately a 0.035 percent difference in volume, which is equivalent to 17.5 percent of the acceptance tolerance for a Normal Test of a loading-rack meter.

Note that temperature readings at the meter are taken only when the system is not equipped with an ATCS, or for tests during which the temperature compensating device has been deactivated (see below). For test purposes, the volume indicated by the system when an ATCS is operative is assumed to be adjusted to the reference temperature.

The temperature of product coming directly from the storage tank will be quite consistent. However, product that has been sitting in the supply line, meter, and discharge line of the system is likely to be affected by ambient temperature, wind, and radiant heating. Product temperature is, therefore, likely to change considerably over the course of a test draft. For this reason, at least two temperature readings are taken at the meter and averaged, equidistant from the middle of the draft.*

Some provers are equipped with thermometer wells at different heights on the prover vessel. The reason for this is that convection may carry heat to the top of the vessel, while cooler product sinks to the bottom. Again, readings should be averaged. To prevent subsequent change, prover temperature reading(s) should be taken as close as possible in time to the prover volume reading.

11. Automatic-stop mechanism must stop flow within one-half the minimum interval indicated.

Handbook 44 sets forth no tolerance or maximum variation for the quantity preset. According to this guideline in the EPO, if a mechanical meter system is preset for a 1,000-gallon draft, and the minimum interval is 1 gallon, the preset should stop it at an indicated quantity of less than 1,000.5 gal and more than 999.5 gal. In the case of an electronic meter with a minimum interval of 1 gallon, under the conditions noted above, the preset should stop the meter when exactly 1000 gallons are indicated.

Although failure to meet the guideline stated in this Test Note should not affect the accuracy of the volume indication, the purchaser may not verify the quantity after it has been entered in the preset, and could therefore receive less (or more) product than he believes he has received.

In addition, because of the small diameter and minimal head space in most neck-type provers, the reliability of the quantity preset is essential to safe testing.

The EPO cites paragraph G-UR.4.1. as the authority for this guideline. This is the general requirement for maintenance of equipment, discussed in Chapter 6. This guideline interprets the portion of the requirement that states "All equipment . . . shall be continuously maintained in proper operating condition. . . ."

## TEST PROCEDURE

The EPO for loading-rack meters includes a detailed, step-by-step procedure for the various performance tests prescribed. You will learn and practice these procedures in the course of your field training. Many of the steps correspond to those described in Chapter 5 for drawing test drafts. Rather than review these steps in detail, let us look at each of the tests set forth, concentrating on the data to be recorded, its meaning, and interpretation.

We will use the sample test report forms in Figures 7-1 and 7-4 to illustrate how data are recorded and computations are made for a typical test. Note that the Worksheets that accompany the EPO perform some of the basic computations that will be described here. However, they are intended primarily for the use of service personnel, and do not provide for the complete documentation required for an official examination procedure.

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*For an electronic loading-rack metering system, it may be necessary to observe and record the temperature at the meter more frequently. Your instructor will explain your jurisdiction's policy in this regard.

Normal Tests

The first test of the system is a Normal Test, and should approximate as closely as possible the conditions of service that occur in most deliveries: the draft is drawn at the system's full flow rate, and if the system is equipped with an automatic temperature compensator, this device is left activated during the first test draft.

> N.4.1. NORMAL TESTS. - The "normal" test of a device shall be made at the maximum discharge flow rate developed under the conditions of installation. Any additional tests conducted at flow rates down to and including one-half of the sum of the maximum discharge flow rate and the rated minimum discharge flow rate shall be considered normal tests.
> (Amended 1991)
>
> N.4.1.1. WHOLESALE DEVICES EQUIPPED WITH AUTOMATIC TEMPERATURE COMPENSATING SYSTEMS. - On wholesale devices equipped with automatic temperature compensating systems, normal tests shall be conducted;
>
> (a) by comparing the compensated volume indicated or recorded to the actual delivered volume corrected to 15 °C (60 °F); and
>
> (b) with the temperature compensating system deactivated, comparing the uncompensated volume indicated or recorded to the actual delivered volume.
>
> The first test shall be performed with the automatic temperature-compensating system operating in the "as found" condition.
>
> On devices that indicate or record both the compensated and uncompensated volume for each delivery, the tests in (a) and (b) may be performed as a single test.
> (Amended 1987)

LMD Code, § N.4.1.

On the sample report form, test data for the first test are recorded in the column of blanks, marked "1st Run." The first entries in this column indicate that it is a Normal Test and that the ATCS is activated (see Figure 7-1).

## Loading-Rack Meter Test Report

Date 9/27/90 Time 10:15 (am)/pm Test No. 78901
Name of Business UNICORN OIL CO.
Address 456 RIVER ROAD, CITY, STATE 12345

Make of Meter EXACTI-FLOW Serial No. C-6543 Size 6 (in)
Model No. WZ-20 Totalizer Readings: 1. Start 726784 Finish
Meter Location #12 Product UNLEADED GASOLINE API GR. @ 60 °F 60.0
Marked Discharge Rate: Max. 1000 gal/min Min. 2.00 gal/min
Accessories: Indicator ✓ Ticket Printer ✓ Temp Comp Sys ✓ Thermometer Well ✓ Other
Tolerance Applied: Maintenance ✓ Acceptance

| Test Data | 1st Run | 2nd Run | 3rd Run | 4th Run |
|---|---|---|---|---|
| 1. Type test | | | | |
| a. Normal (N) or Special (S): | N✓ S_ | N_ S_ | N_ S_ | N_ S_ |
| b. Compensated (C) or Uncompensated (U): | C✓ U_ | C_ U_ | C_ U_ | C_ U_ |
| 2. Actual discharge rate (gal/min) | 923 | | | |
| 3a. Totalizer Reading - Start | 728105 | | | |
| 3b. Totalizer Reading - Finish | 729407 | | | |
| **Prover Data** | | | | |
| 4. Ave temp of product in prover to nearest 0.5 °F | 81 | | | |
| 5. Prover reading | 1319.2 | | | |
| 6. Corr for expans/contrac of prover: Cts = 1 + (T - 60).0000265 (stainless steel) Cts = 1 + (T - 60).0000186 (mild steel) (or Table A-1, A-2 value) | 1.0006 | | | |
| 7. Vol corr for prover reading (Ctl) (based on #4 and Table 6B) | .9856 | | | |
| 8. Prover reading corrected to 60 °F (Item 5 x Item 6 x Item 7) (gal) | 1300.98 | | | |
| **Meter Data** | | | | |
| 9. Meter reading: | | | | |
| 9a. Gross (uncompensated) (gal) | — | | | |
| 9b. Net (compensated) (gal) | 1302 | | | |
| Use for uncompensated run or for systems that give both gross and net readings | | | | |
| 9a1. Ave temp of prod at meter to the nearest 0.5 °F | | | | |
| 9a2. Vol corr for meter reading (Ctl) (based on #9a1 and Table 6B) | | | | |
| 9a3. Meter reading corrected to 60 °F (Item 9a x Item 9a2) (gal) | | | | |
| 10. Net delivery error (gal) (Item 8 - Item 9b) | -1.02 gal | | | |
| 11. Corrected gross delivery error (gal) (Item 8 - Item 9a3) | — | | | |
| 12a. Gross Tol (applic %* x Item 9a) | — | | | |
| 12b. Net Tol (applic %* x Item 9b) | 3.91 gal | | | |

*Normal Test Tolerances: Accept 0.2%, Maint 0.3% - Special Test Tolerances: Accept & Maint 0.5%
13. Auto Temp Comp Sys only - Diff between net (comp) delivery error (Item 10) and corrected gross (uncomp) delivery error (Item 11) _____ (Shall not exceed 0.2 percent x nominal size of prover)

Action Taken: Approved ___ Rejected ___ Condemned ___

Remarks:

Inspector: Owner/Operator

FIGURE 7-1. Sample Report Form,
First Test Draft Complete.

You should time the first test draft to determine the actual maximum discharge rate of the system. The easiest way to do this is to time the delivery of 100 gallons of product and divide 6000 by the observed time in seconds. The result will be the discharge rate in gallons per minute.

For example, if you determine that it took 6.5 seconds for the delivery of 100 gallons of product, then the discharge rate is 6000/6.5 = 923 gpm. This rate should not exceed the maximum discharge rate marked on the meter identification plate. You should mark this amount on your report for future reference (see Figure 7-1, Item 2).

Remember that most systems are designed for a slow startup rate, to minimize evaporation and static buildup. Wait until the automatic flow control valve opens to allow full flow before beginning the timing. You should be able to hear the increase in flow. If not, wait until the approximate mid-point of the delivery to begin timing.

The system in our example does have an ATCS, which will be operative during this first test draft. Since the registered volume will be assumed to have been corrected to 60 °F, the actual temperature at the meter is irrelevant, and need not be recorded.

However, the prover temperature must be observed and recorded to the nearest 0.5 /F. Remember that this should be done as soon as possible after the delivery is completed and that the prover gauge should be read immediately thereafter. If more than one thermowell is used, the temperatures should be averaged. Note how the average prover temperature and prover volume (to the nearest minimum graduation) are recorded in Items 3 and 4 on the sample report form.

In the case of an analog system, the EPO specifies that the register must be read to the nearest 0.1 gallon. To do this, you will have to visually subdivide the graduated interval.

In the case of a digital device, you will simply record the indicated digital value, which may reflect rounding. However, many electronic registers can be set to display in a "test mode," or "proving mode," in which tenths of a gallon (or liter) are displayed. If available, the operator should set the register for this mode.

In a system equipped with a quantity preset, the delivery should stop automatically on an even gallon, since you will have set the preset for the nominal capacity of the prover. However, sometimes the preset does not operate precisely, and the register may consequently read slightly more or less than the preset volume. Of course, the preset may also fail or perform unsatisfactorily, although this is not common.

To review, by the end of the first test of a temperature compensated system, you should have recorded the following items of data:

- the actual discharge rate (Item 2 on the same report form)
- the temperature of product in the prover immediately following product delivery (Item 4)
- the prover reading (Item 5)
- the register reading (Item 9b; and 9a, if the system indicates both net and gross quantities).

Before proceeding further, review the recorded test data and look for apparent anomalies. When satisfied that the test data are valid, proceed to make the appropriate corrections to the prover reading for temperature. Since our example is a temperature compensated draft, there are two corrections:

- for thermal expansion or contraction of the prover;

- to adjust the prover reading to the reference temperature of the product (60 /F in the case of a petroleum product, as in our example), so that it will be comparable to the reading provided by the ATCS.

These corrections can be computed in a single step on the report form (Item 8). However, first the appropriate correction factor for each must be determined. Most jurisdictions use the petroleum measurement tables published by API to obtain these factors. Samples of these API tables have been reproduced in Appendix B.

One set of tables (Tables A-1 and A-2) provides correction factors for expansion or contraction of the prover. This factor is often referred to as "Cts" (for Correction for Temperature of the Standard). Because coefficients of cubical expansion vary for different metals, one table is provided for provers made of mild steel, the other for stainless steel provers. Figure 7-2 shows Table A-2, used for stainless steel provers (see Appendix B for Table A-1). Since the prover in our example is made of stainless steel, we will use Table A-2 (see Figure 7-2) to obtain the Cts.

**Table A-2—Temperature Correction Factors for Stainless Steel**

$C_{ts}$ for stainless steel having a cubical coefficient of expansion of $2.65 \times 10^{-5}$ per °F

| Observed Temperature, °F | $C_{ts}$ Value | Observed Temperature, °F | $C_{ts}$ Value |
|---|---|---|---|
| −9.8– −6.1 | 0.9982 | 73.3– 76.9 | 1.0004 |
| −6.0– −2.3 | 0.9983 | 77.0– 80.7 | 1.0005 |
| −2.3– 1.5 | 0.9984 | 80.8– 84.5 | 1.0006 |
| 1.6– 5.2 | 0.9985 | 84.6– 88.3 | 1.0007 |
| 5.3– 9.0 | 0.9986 | 88.4– 92.0 | 1.0008 |
| 9.1– 12.8 | 0.9987 | 92.1– 95.8 | 1.0009 |
| 12.9– 16.6 | 0.9988 | 95.9– 99.6 | 1.0010 |
| 16.7– 20.3 | 0.9989 | 99.7–103.3 | 1.0011 |
| 20.4– 24.1 | 0.9990 | 103.4–107.1 | 1.0012 |
| 24.2– 27.9 | 0.9991 | 107.2–110.9 | 1.0013 |
| 28.0– 31.6 | 0.9992 | 111.0–114.7 | 1.0014 |
| 31.7– 35.4 | 0.9993 | 114.8–118.4 | 1.0015 |
| 35.5– 39.2 | 0.9994 | 118.5–122.2 | 1.0016 |
| 9.3– 43.0 | 0.9995 | 122.3–126.0 | 1.0017 |
| 43.1– 46.7 | 0.9996 | 126.1–129.8 | 1.0018 |
| 46.8– 50.5 | 0.9997 | 129.9–133.5 | 1.0019 |
| 50.6– 54.3 | 0.9998 | 133.6–137.3 | 1.0020 |
| 54.4– 58.1 | 0.9999 | 137.4–141.1 | 1.0021 |
| 58.2– 61.8 | 1.0000 | 141.2–144.9 | 1.0022 |
| 61.9– 65.6 | 1.0001 | 145.0–148.6 | 1.0023 |
| 65.7– 69.4 | 1.0002 | 148.7–152.4 | 1.0024 |
| 69.5– 73.2 | 1.0003 | 152.5–156.2 | 1.0025 |

NOTE: This table is suitable for application in meter proving: in prover calibration use the formulas. For the formula used to derive the tabulated values and to calculate values, see F12.2.5.1.

FIGURE 7-2. Table A-2 (Courtesy American Petroleum Institute)

We locate the prover temperature (which may be an average of readings from two thermometers) among the ranges of temperatures in the columns headed "Observed Temperature, /F" on Table A-2. Our prover temperature is 81 /F, which is located in the range of temperatures "80.8 - 84.5". The corresponding number in the adjacent column is the correction factor, in this case, 1.0006. This value has been recorded as Item 6 on the sample test report in Figure 7-1.

Note that the report form provides formulas at Item 6, which may be used to compute the prover correction factor in place of the API tables. Since 'T' in the formulas stands for the temperature recorded at Item 4, if we insert the value from our example in the formula for stainless steel we can compute the Cts directly: Cts = 1 + (81 - 60).0000265 = 1.0005565. Note that this value rounds to the same factor as that given in Table A-2, 1.0006.

After recording the Cts in Item 6, the next step is to determine the factor to correct the product in the prover to its reference temperature. Multiplying this factor, referred to as "Ctl" (for Correction for Temperature of the Liquid), by the prover reading should replicate approximately the correction made by the ATCS.

Another set of tables (Table 6B) is used to determine the Ctl for liquids, such as petroleum products, that have a reference temperature of 60 /F. (If you were testing a system that dispenses product with a different reference temperature, Table 6B could not be used.) As you will see presently, these tables are also used to correct meter gross volumes after uncompensated test runs (that is, when an ATCS is not present or is deactivated). The appropriate page from Table 6B for our example is reproduced in Figure 7-3).

The correction factor is determined by finding the prover temperature in the left-hand column and reading the value in that row under the API gravity of the product being metered. In our example, we are given an API gravity of 60.0, as recorded in the top section of the report form. As you have learned, the API gravity of the product can usually be ascertained by asking the operator, if it is not marked on the meter.

We find the prover temperature (81.0 °F) in the left-hand column of the page from Table 6B and read the corresponding value in the column headed by 60.0 (for the API gravity). The resulting value, 0.9856, is recorded on Item 7 of the test report, as the Ctl.

To make the correction itself, we multiply the two factors (Cts and Ctl) by the volume indicated on the prover (Item 5). The resulting value, recorded as Item 8, is the volume the prover would register if product and prover were both at 60 /F. In our example, the corrected (net) prover volume is 1,300.98 gallons.

As indicated on the report form, Items 9a1-9a3 are used only for uncompensated runs, or for systems that indicate both net and gross quantities, so we will pass over them for the moment.

TABLE 6B, GENERALIZED PRODUCTS
VOLUME CORRECTION TO 60 F

| TEMP. F | API GRAVITY AT 60 F 60.0 | 60.5 | 61.0 | 61.5 | 62.0 | 62.5 | 63.0 | 63.5 | 64.0 | 64.5 | 65.0 | TEMP. F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FACTOR FOR CORRECTING VOLUME TO 60 F | | | | | | | | | | | |
| 75.0 | 0.9897 | 0.9897 | 0.9896 | 0.9896 | 0.9896 | 0.9895 | 0.9895 | 0.9894 | 0.9894 | 0.9893 | 0.9893 | 75.0 |
| 75.5 | 0.9894 | 0.9893 | 0.9893 | 0.9892 | 0.9892 | 0.9892 | 0.9891 | 0.9891 | 0.9890 | 0.9890 | 0.9889 | 75.5 |
| 76.0 | 0.9890 | 0.9890 | 0.9889 | 0.9889 | 0.9889 | 0.9888 | 0.9888 | 0.9887 | 0.9887 | 0.9886 | 0.9886 | 76.0 |
| 76.5 | 0.9887 | 0.9886 | 0.9886 | 0.9886 | 0.9885 | 0.9885 | 0.9884 | 0.9884 | 0.9883 | 0.9883 | 0.9882 | 76.5 |
| 77.0 | 0.9883 | 0.9883 | 0.9882 | 0.9882 | 0.9882 | 0.9881 | 0.9881 | 0.9880 | 0.9880 | 0.9879 | 0.9879 | 77.0 |
| 77.5 | 0.9880 | 0.9879 | 0.9879 | 0.9879 | 0.9878 | 0.9878 | 0.9877 | 0.9877 | 0.9876 | 0.9876 | 0.9875 | 77.5 |
| 78.0 | 0.9877 | 0.9876 | 0.9876 | 0.9875 | 0.9875 | 0.9874 | 0.9874 | 0.9873 | 0.9873 | 0.9872 | 0.9872 | 78.0 |
| 78.5 | 0.9873 | 0.9873 | 0.9872 | 0.9872 | 0.9871 | 0.9871 | 0.9870 | 0.9870 | 0.9869 | 0.9869 | 0.9868 | 78.5 |
| 79.0 | 0.9870 | 0.9869 | 0.9869 | 0.9868 | 0.9868 | 0.9867 | 0.9867 | 0.9866 | 0.9865 | 0.9865 | 0.9864 | 79.0 |
| 79.5 | 0.9866 | 0.9866 | 0.9865 | 0.9865 | 0.9864 | 0.9864 | 0.9863 | 0.9862 | 0.9862 | 0.9861 | 0.9861 | 79.5 |
| 80.0 | 0.9863 | 0.9862 | 0.9862 | 0.9861 | 0.9861 | 0.9860 | 0.9859 | 0.9859 | 0.9858 | 0.9858 | 0.9857 | 80.0 |
| 80.5 | 0.9859 | 0.9859 | 0.9858 | 0.9858 | 0.9857 | 0.9857 | 0.9856 | 0.9855 | 0.9855 | 0.9854 | 0.9854 | 80.5 |
| 81.0 | 0.9856 | 0.9855 | 0.9855 | 0.9854 | 0.9854 | 0.9853 | 0.9852 | 0.9852 | 0.9851 | 0.9851 | 0.9850 | 81.0 |
| 81.5 | 0.9852 | 0.9852 | 0.9851 | 0.9851 | 0.9850 | 0.9849 | 0.9849 | 0.9848 | 0.9848 | 0.9847 | 0.9846 | 81.5 |
| 82.0 | 0.9849 | 0.9848 | 0.9848 | 0.9847 | 0.9847 | 0.9846 | 0.9845 | 0.9845 | 0.9844 | 0.9844 | 0.9843 | 82.0 |
| 82.5 | 0.9846 | 0.9845 | 0.9844 | 0.9844 | 0.9843 | 0.9842 | 0.9842 | 0.9841 | 0.9841 | 0.9840 | 0.9839 | 82.5 |
| 83.0 | 0.9842 | 0.9841 | 0.9841 | 0.9840 | 0.9840 | 0.9839 | 0.9838 | 0.9838 | 0.9837 | 0.9836 | 0.9836 | 83.0 |
| 83.5 | 0.9839 | 0.9838 | 0.9837 | 0.9837 | 0.9836 | 0.9835 | 0.9835 | 0.9834 | 0.9833 | 0.9833 | 0.9832 | 83.5 |
| 84.0 | 0.9835 | 0.9835 | 0.9834 | 0.9833 | 0.9833 | 0.9832 | 0.9831 | 0.9831 | 0.9830 | 0.9829 | 0.9829 | 84.0 |
| 84.5 | 0.9832 | 0.9831 | 0.9830 | 0.9830 | 0.9829 | 0.9828 | 0.9828 | 0.9827 | 0.9826 | 0.9826 | 0.9825 | 84.5 |
| 85.0 | 0.9828 | 0.9828 | 0.9827 | 0.9826 | 0.9826 | 0.9825 | 0.9824 | 0.9823 | 0.9823 | 0.9822 | 0.9821 | 85.0 |
| 85.5 | 0.9825 | 0.9824 | 0.9823 | 0.9823 | 0.9822 | 0.9821 | 0.9821 | 0.9820 | 0.9819 | 0.9819 | 0.9818 | 85.5 |
| 86.0 | 0.9821 | 0.9821 | 0.9820 | 0.9819 | 0.9819 | 0.9818 | 0.9817 | 0.9816 | 0.9816 | 0.9815 | 0.9814 | 86.0 |
| 86.5 | 0.9818 | 0.9817 | 0.9816 | 0.9816 | 0.9815 | 0.9814 | 0.9814 | 0.9813 | 0.9812 | 0.9811 | 0.9811 | 86.5 |
| 87.0 | 0.9814 | 0.9814 | 0.9813 | 0.9812 | 0.9812 | 0.9811 | 0.9810 | 0.9809 | 0.9809 | 0.9808 | 0.9807 | 87.0 |
| 87.5 | 0.9811 | 0.9810 | 0.9810 | 0.9809 | 0.9808 | 0.9807 | 0.9806 | 0.9806 | 0.9805 | 0.9804 | 0.9803 | 87.5 |
| 88.0 | 0.9808 | 0.9807 | 0.9806 | 0.9805 | 0.9805 | 0.9804 | 0.9803 | 0.9802 | 0.9801 | 0.9801 | 0.9800 | 88.0 |
| 88.5 | 0.9804 | 0.9803 | 0.9803 | 0.9802 | 0.9801 | 0.9800 | 0.9799 | 0.9799 | 0.9798 | 0.9797 | 0.9796 | 88.5 |
| 89.0 | 0.9801 | 0.9800 | 0.9799 | 0.9798 | 0.9797 | 0.9797 | 0.9796 | 0.9795 | 0.9794 | 0.9793 | 0.9793 | 89.0 |
| 89.5 | 0.9797 | 0.9796 | 0.9796 | 0.9795 | 0.9794 | 0.9793 | 0.9792 | 0.9792 | 0.9791 | 0.9790 | 0.9789 | 89.5 |
| 90.0 | 0.9794 | 0.9793 | 0.9792 | 0.9791 | 0.9790 | 0.9790 | 0.9789 | 0.9788 | 0.9787 | 0.9786 | 0.9785 | 90.0 |

* DENOTES EXTRAPOLATED VALUE

API GRAVITY = 60.0 TO 65.0

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FIGURE 7-3. PAGE 228, TABLE 6B (Courtesy American Petroleum Institute)

The next step is to calculate and record the delivery error for this draft, determined by subtracting the net meter reading (Item 9b) from the corrected prover reading (Item 8). The resulting value, with the appropriate sign, is recorded on the report form as Item 10. For our example, the delivery error is 1300.98 gallons - 1302 gallons = -1.02 gallons.

Note that meter error is determined here in terms of delivery, a practice that is common in the metering industry. In contrast, Handbook 44 speaks of registration (General Code, G-T.3.; LMD Code, T.1.; Definitions, see **overregistration and underregistration**). Errors in registration are determined by subtracting the corrected prover reading from the meter reading. Both methods of expressing meter error produce the same value: only the signs are different. Since tolerances for loading-rack meters apply to both plus and minus errors, the sign is irrelevant from the point of view of determining compliance.

In our example, we computed a delivery error of -1.02 gallons, and could say that the system is underdelivering, that is, delivering less than it registers. Using the same test data, but expressing meter errors in terms of registration, we would compute an error of 1302 gallons - 1300.98 gallons = +1.02 gallons, and could say that the system is overregistering, that is registering more than it actually delivers.

To determine whether the system complies with the performance requirement for this test, we compare the meter error with the applicable tolerance. The applicable tolerance for the test is the appropriate percentage (since this is a Normal Test, either 0.2 percent for acceptance, or 0.3 percent for maintenance) times the indicated quantity (Item 9b). Note that the report form lists all three tolerance percentages below Item 12b. For a compensated (only) test run, like our example, the result is recorded as Item 12b. (Items 11 and 12a are used, again, either for uncompensated tests or for systems that indicate both net and gross quantities. We will return to them shortly.)

In our example, the tolerance is for maintenance, so the applicable tolerance is 0.003 x 1302 gal = 3.91 gal.

The meter error is compared with the applicable tolerance. Since the tolerance applies to both overregistration and underregistration, we disregard the sign of the error (plus or minus) for this comparison. If the error is close to the tolerance (a good practical guideline is 10 percent of the tolerance) or outside it, the EPO directs us to repeat the test. In other words, a meter must test outside the tolerance on two consecutive drafts in order to fail a test; if the first trial is not very close to the tolerance, the test need not be repeated.

In the example we have been following, the meter error for this draft (-1.02 gal) is well within the applicable tolerance (3.91 gal), so we can proceed to the next test.

Uncompensated Normal Test

If the metering system indicates gross gallons only (that is, it is not equipped with an automatic temperature compensator), the Normal Test is conducted in the same way, except that the temperature of product at or near the meter must be recorded during the test and an additional temperature correction may be required: if the temperature of product in the prover and at the meter are not the same, both the prover and meter volumes will have to be corrected to 60 /F in order to make them comparable. Note, however, that if the observed temperatures are the same at the meter and prover, the indicated volumes will be comparable without correction.

If the system is equipped with an ATCS, and indicates net gallons only (like the system in our example), the ATCS is deactivated after the compensated Normal Test (as above), and a second Normal Test is conducted. Since the indicated volume is uncompensated on this second test, the procedure will be the same as for a system that is not equipped with an ATCS.

If the system indicates both net and gross volume, a second Normal Test is not required: net and gross volume indications are recorded at the conclusion of the first run, and net and gross meter errors are calculated as if on separate runs.

Since our example was for a system equipped with an ATCS, let us continue to look at the uncompensated Normal Test for that device. The data and computations are recorded in the second column on the sample report form in Figure 7-4, labeled "2nd Run."

Discharge rate, totalizer readings, prover temperature, prover volume, and meter reading are all read and recorded as described for the compensated test run (Items 2-5, 9a), and the prover volume is corrected in the same manner (Items 6-8). Review these steps on the form to make sure that you understand them.

The major difference in the procedure for uncompensated drafts reflects the fact that both the meter and prover volumes may require correction to the reference temperature to make them comparable. The EPO therefore prescribes observing and recording temperature at the meter during the test.

## Loading-Rack Meter Test Report

Date 9/27/90 Time 10:15 (am)/pm Test No. 78901
Name of Business UNICORN OIL CO.
Address 456 RIVER RD., CITY, STATE 12345

Make of Meter EXACTI-FLOW Serial No. C-6543 Size 6 (in)
Model No. W2-20 Totalizer Readings: 1. Start 726784 Finish 732047
Meter Location #12 Product UNLEADED GASOLINE API GR. @ 60 °F 60.0
Marked Discharge Rate: Max. 1000 gal/min Min. 2000 gal/min
Accessories: Indicator ✓ Ticket Printer ✓ Temp Comp Sys ✓ Thermometer Well ✓ Other ____
Tolerance Applied: Maintenance ✓ Acceptance ____

| Test Data | 1st Run | 2nd Run | 3rd Run | 4th Run |
|---|---|---|---|---|
| 1. Type test | | | | |
| a. Normal (N) or Special (S): | N✓ S__ | N✓ S__ | N__ S✓ | N__ S__ |
| b. Compensated (C) or Uncompensated (U): | C✓ U__ | C__ U✓ | C__ U✓ | C__ U__ |
| 2. Actual discharge rate (gal/min) | 923 | 923 | | |
| 3a. Totalizer Reading - Start | 728105 | 729407 | 730727 | |
| 3b. Totalizer Reading - Finish | 729407 | 730727 | 732047 | |
| **Prover Data** | | | | |
| 4. Ave temp of product in prover to nearest 0.5 °F | 81 | 83 | 84 | |
| 5. Prover reading | 1319.2 | 1318.6 | 1329.2 | |
| 6. Corr for expans/contrac of prover: Cts = 1 + (T - 60).0000265 (stainless steel) Cts = 1 + (T - 60).0000186 (mild steel) (or Table A-1, A-2 value) | 1.0006 | 1.0006 | 1.0006 | |
| 7. Vol corr for prover reading (Ctl) (based on #4 and Table 6B) | .9856 | .9842 | .9835 | |
| 8. Prover reading corrected to 60 °F (Item 5 x Item 6 x Item 7) (gal) | 1300.98 | 1298.54 | 1306.08 | |
| **Meter Data** | | | | |
| 9. Meter reading: | | | | |
| 9a. Gross (uncompensated) (gal) | — | 1320 | 1320 | |
| 9b. Net (compensated) (gal) | 1302 | — | | |
| **Use for uncompensated run or for systems that give both gross and net readings** | | | | |
| 9a1. Ave temp of prod at meter to the nearest 0.5 °F | | 80 | 80 | |
| 9a2. Vol corr for meter reading (Ctl) (based on #9a1 and Table 6B) | | .9863 | .9863 | |
| 9a3. Meter reading corrected to 60 °F (Item 9a x Item 9a2) (gal) | | 1301.92 | 1301.92 | |
| 10. Net delivery error (gal) (Item 8 - Item 9b) | -1.02 gal | — | — | |
| 11. Corrected gross delivery error (gal) (Item 8 - Item 9a3) | — | -3.38 | +4.16 | |
| 12a. Gross Tol (applic %* x Item 9a) | — | | | |
| 12b. Net Tol (applic %* x Item 9b) | 3.91 gal | 3.96 gal | 6.60 gal | |

*Normal Test Tolerances: Accept 0.2%, Maint 0.3% - Special Test Tolerances: Accept & Maint 0.5%

13. Auto Temp Comp Sys only - Diff between net (comp) delivery error (Item 10) and corrected gross (uncomp) delivery error (Item 11) 2.36 gal (Shall not exceed 0.2 percent x nominal size of prover)

Action Taken: Approved ✓ Rejected ____ Condemned ____

Remarks: METER IS WITHIN TOLERANCES BUT BADLY WORN. RECONDITIONING OR REPLACEMENT NECESSARY

Inspector: ____ Owner/Operator ____

FIGURE 7-4. Sample Report Form, Completed.

As specified under Test Notes, you will observe and record the temperature of product at the meter at least twice during the delivery, at regular intervals: for example, when the register indicates approximately one-third and two-thirds of the nominal capacity of the prover. Thus, for our 1,320-gallon draft, meter temperature could be recorded at approximately 435 gallons delivered and again at about 870 gallons. Read and record the temperature each time to the nearest 0.5 /F. These temperatures are averaged to approximate the temperature of the delivery (Item 9a1).

If the average meter temperature is not the same as the prover temperature (Item 4), the meter volume must be corrected to the reference temperature. A Ctl is determined using Table 6B again (Item 9a2) and the correction computed (Item 9a3) in the same manner as described above for the prover volume correction. No correction is made for thermal expansion or contraction of the meter itself. Gross delivery error and applicable tolerance (Items 11 and 12a) are calculated as above.

Review these additional steps and computations (Items 9a1-9a3) on the sample report form. In this case, the observed error (-3.38 gal), although within the applicable tolerance for a maintenance test (3.96 gal), is very close to the tolerance. Although it is not quite within 10 percent (actually, it is just within 15 percent), it might be wise to repeat this test, depending upon your interpretation of the result.

If the system normally operates with an automatic temperature compensator, like the one in our example, this uncompensated test is also a test of the effectiveness of the ATCS. The LMD Code specifies a maximum allowable variation for meter errors observed with the ATCS activated and deactivated.

> T.2.3.5. AUTOMATIC TEMPERATURE COMPENSATING SYSTEMS. - The difference between the meter error (expressed as a percentage) for results determined with and without the automatic temperature compensating system activated shall not exceed:
>
> (a) 0.2 percent for mechanical automatic temperature compensating systems; and
>
> (b) 0.1 percent for electronic automatic temperature compensating systems.
>
> The delivered quantities for each test shall be approximately the same size. The results of each test *shall be within the applicable acceptance or maintenance tolerance.*
> *[Nonretroactive as of January 1, 1988.]*
> (Added 1987) (Amended 1992 and 1996)

LMD Code § T.2.3.5.

The actual variation between the errors is recorded as Item 13 on the report form. In our example, the difference between the meter errors for the two Normal Tests conducted is -2.36 gallons (-3.38 gallons minus -1.02 gallons). This is within 0.2 percent of the test draft (1,320 gal x .002 = 2.64 gal)* but, again, very close. Although the error for the first (compensated) draft was well within the applicable tolerance, at least some of the difference is likely to be due to faulty operation of the ATCS; it may even be that the meter has been adjusted to overregister in order to compensate for the ATCS. In a situation like this, in which test results are critically close to two separate tolerances, it is probably wise to conduct another uncompensated test.

Note also that the temperature difference has increased from 1 degree to 3 degrees since the first test of this system. This points either to a source of excessive heating of the prover, too much time between test drafts, or too much time between drawing the draft and taking temperature and volume readings, or perhaps a

*For this calculation, use the nominal size of the prover as the size of the test draft.

combination of these factors. Since increased evaporation would tend to increase apparent overregistration, and because the direction of the errors is toward increased overregistration, every effort should be made to control this factor.

The interpretation of this test might differ somewhat, depending if the test results obtained on the uncompensated test run we just looked at were for a metering system that is not equipped with an ATCS.

If this was an uncompensated meter, this would be the first and only Normal Test. If the results of the Special Test (see below) did not indicate that the meter was badly worn, and generally confirmed that the meter just needed adjustment, you might wish to inform the owner or operator of the test results and recommend that the meter should be adjusted, even though the meter is technically in conformance. You might point out to him or her that periodic adjustment of metering devices is considered proper maintenance, which is required by Handbook 44 (Gen. Code § G-UR.4.1.), and that adjustments should be used to bring the device as close as possible to zero error (G-UR.4.3.).

After recording the final results of the Normal Test(s) on our report form, we can turn to the Special Test of the system.

Special Test

The final volumetric performance test prescribed by the EPO for a loading-rack meter system is a Special Test. It is customarily referred to as a "slow-flow" test because the test draft is drawn at a flow rate that is at or near the minimum discharge rate recommended by the manufacturer (see below). The tolerance set forth in the LMD Code for Special Tests is 0.5% of the indicated volume. If the system is equipped with an ATCS and only displays net gallons, the device is left deactivated for the Special Test. Temperature corrections are the same as those for an uncompensated Normal Test.

> N.4.2. SPECIAL TESTS. - "Special" tests, to develop the operating characteristics of a liquid-measuring device and any special elements and accessories attached to or associated with the device, shall be made as circumstances require. Any test except as set forth in N.4.1. shall be considered a special test.
>
> * * *
>
> N.4.2.4. WHOLESALE DEVICES. - "Special" tests shall be made to develop the operating characteristics of a measuring system and any special associated or attached elements and accessories. "Special" tests shall include a test at the slower of the following rates:
>
> (a) 20 percent of the marked maximum discharge rate; or
>
> (b) the minimum discharge rate marked on the device.

LMD Code, § N.4.2, in part

In fact, the only difference in procedure between the Special Test and the Normal Test involves maintaining a low discharge rate during the delivery. According to the LMD Code (§ N.4.2.4.), the discharge rate for this test should be either the minimum rate recommended by the manufacturer, as marked on the meter, or 20 percent of the recommended maximum rate, whichever is the slower rate.

The delivery of the test draft will have to be monitored with a watch that displays seconds or, preferably, with a stopwatch. You should ask to have the automatic control valve programmed to deliver at the desired slow-flow rate, if possible. If it is necessary to use the prover inlet valve as a throttle to achieve the specified slow-flow discharge rate, avoid operating the valve abruptly, especially over wide ranges, since this may affect meter performance in a way that does not occur under normal slow-flow operation. In addition, excessive throttling at the prover inlet may encourage evaporation.

You should determine and record the actual discharge rate for the draft using the same method as for the Normal Test: time 100 gallons of delivery after the meter has come up to steady state and divide 6000 by the elapsed time in seconds.

You can review the recorded data, temperature corrections, and computation of meter error for our sample in the column of Figure 7-4 labeled "3rd Run." Since the procedure is identical to the uncompensated test with regard to recording of data and computations, we will not consider these in detail, but turn our attention to the interpretation of the results of the Special Test (slow flow) of a loading-rack meter.

The primary purpose of a slow-flow test is to determine the condition of the meter. Figure 7-5 illustrates the type of results you may obtain and their significance.

The curves describe the performance of a typical positive-displacement metering system in various conditions of wear over the range of discharge rates at which it operates. The curve marked "a" represents the expected performance of a meter that is new or that has recently been reconditioned and readjusted. You can see that the performance at full rated flow and at 20 percent of full rated flow is virtually identical. At these rates the system "gives" very slightly: that is, it delivers slightly more product than it registers.

You will see why we use the term "gives" rather than "underregisters" if you compare the curve marked "b", which depicts the performances that may be expected of a meter that has been in service for some time since its last adjustment. As you can see, it is out of tolerance at both ends of its rated discharge range, and <u>underregisters</u> at all delivery rates. However, its performance at full flow and at 20 percent of full rated flow are still virtually identical, and the shape of the curve is nearly the same as that of "a". As was the case for the newly adjusted meter described by curve "a", this meter "gives" slightly more at both ends of its range than at intermediate rates, but gives about the same amount of product at slow flow as at maximum flow.

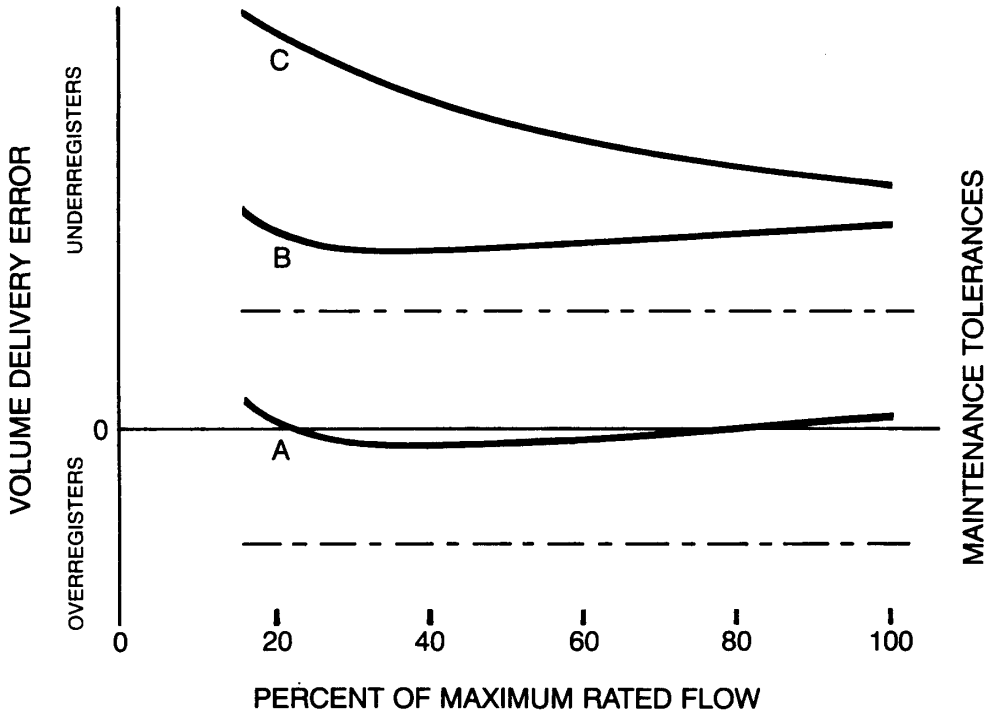


FIGURE 7-5. Meter Accuracy Curves

This kind of performance indicates that the system's registration simply needs to be readjusted to bring it as close as possible to zero error. This can usually be accomplished through the meter adjuster, whether that device is mechanical or electronic, and does not require dismantling and reconditioning the meter. The effect of the adjustment will be to "lower" the performance curve so that it is situated approximately where "a" is with respect to the zero-error line.

Curve "c", depicts the performance of a meter that is badly worn. Not only does it underregister rather severely at all flow rates, but it "gives" substantially more at slow rates of flow than it does at its maximum rate. It is this characteristic of the performance curve that indicates that the meter is badly worn, not merely the fact that it underregisters.

As a positive displacement meter wears, the clearances between the segmenting elements and the walls of the meter chamber tend to widen (see Chapter 3 to review the operation of the meter). This results in more product slippage, and hence underregistration at all discharge rates. However, at relatively low flow rates, the rate of slippage is markedly higher because of the low flow rate.

Simply readjusting a meter that is this badly worn (see Figure 7-6) will not remedy the situation, even if it brings registration temporarily within tolerance, since the condition will continue to deteriorate rapidly and the system will very quickly be out of tolerance again. The only adequate remedy is to recondition or overhaul the meter, replacing badly worn components and adjusting others.

You can see how the results of the Special Test, conducted at a slow flow rate, when compared with the results of the Normal Test, can indicate the condition of the meter: they represent the critical points on a performance curve like those we have been looking at -- their relative positions on the curve indicate the extent of wear. In

general, the greater the difference between meter errors observed for the Normal and Special Tests, the stronger the indication that the meter chamber is worn and in need of reconditioning.

The performance curves shown in Figure 7-5 are somewhat idealized. In practice it is normal for a meter to give slightly more product at its specified slow-flow rate, even if it is in good condition. However, if the meter error recorded for a slow-flow test indicates less "give" than was observed for delivery at the system's maximum discharge rate, you have reason to be suspicious of the results.

Throttling at the prover inlet valve to obtain the specified low flow rate may result in production of vapor in the prover, which will have the effect of offsetting the increased slippage of product, even to the point of indicating relative overregistration. This might happen, for example, if the system is not equipped with an external pump bypass circuit, or if the bypass circuit has been shut or throttled because of a worn pump. If this occurs, you should repeat the Special Test at a discharge rate somewhat higher than that specified, or at a lower pumping speed, and compare the results to those for the earlier test. The operator should be informed that the system is not capable of registering accurately at the lower rate, and that steps should be taken to correct this condition. A notation to that effect should also be made on your test report.

After some experience with different makes and models of metering equipment, you will develop the ability to judge whether the degree of difference observed in results between a given set of Normal and Special Tests suggests wear that is sufficient to require that the meter be reconditioned. Because such repair is costly to the operator, you should check borderline results with the manufacturer or a qualified repairperson.

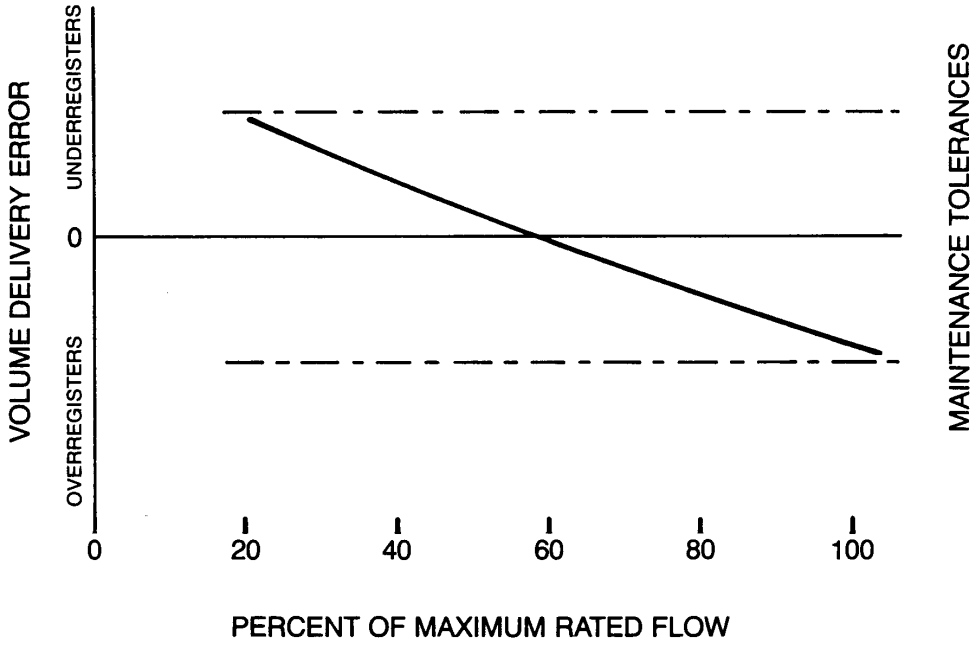


FIGURE 7-6. Adjustment of a Badly Worn Meter.

It is most likely that a meter that is badly worn will be out of tolerance on the Special Test and possibly on the Normal Test as well. However, note that the tolerances apply individually to results of the separate tests. It is therefore possible that a badly worn meter could be technically in conformance with performance requirements. For example, if the operator of a device like the one whose performance is depicted by curve "c" were to attempt to remedy the out-of-tolerance condition by readjusting, the effect might be to lower the curve as shown in Figure 7-6. Although this has the desired effect of bringing the meter technically within tolerances, it is not an adequate remedy.

Because replacement or reconditioning is considerably more expensive than readjusting the meter, and usually means taking the system out of service for a period of time, the operator may prefer to attempt a remedy such as this. In the long run, he or she will probably simply be incurring further expense to have the system repaired correctly, but may argue that the meter is technically in compliance with weights and measures regulations.

In such a situation, you may determine that the system does not conform with the requirement of the General Code that the equipment be "maintained in a proper operating condition" (§ G-UR.4.1.) and that adjustments may not be used to compensate for "defective or abnormal installation or accessories or for badly worn or otherwise defective parts of the assembly" (§ G-UR.4.3.). To save yourself and the device owner considerable time and expense, you should inform him or her of this requirement when results of the Special Test strongly suggest that the meter is badly worn even though it is within tolerances.

In general, if the range of errors observed in the Normal and Special Tests approaches or exceeds the sum of the applicable tolerances for underregistration and overregistration, the meter is badly worn and replacement or reconditioning is in order. In some cases, a recommendation that the meter be reconditioned may be appropriate even if the range of errors is somewhat smaller. This is especially true if the metering system is outside of one or more tolerances and will be rejected anyway on those grounds.

One situation is illustrated in the example we have been using. As the completed results for the Special Test show (Figure 7-4), the system is underregistering to a considerable degree (delivery error of +4.16 gal), although it does not exceed the applicable tolerance. The range of meter errors between the second and third test drafts is 7.54 gallons, and indicates a considerable degree of meter wear. Even though the meter is technically within tolerances, the operator should be informed that the meter is clearly in need of reconditioning.

While the specific type of interpretation described above relates primarily to positive-displacement meters, slow-flow tests are also important in determining the performance characteristics of turbine meters. The lower the discharge rate, the slower the rotors of a turbine meter turn, and this could affect the accuracy of the meter.

## Additional Tests

In addition to the performance tests described above, the EPO for loading-rack meters specifies an examination of the discharge line to determine whether it meets requirements regarding retention of product between deliveries.

You will recall from an earlier discussion that bottom-loading systems are "wet-hose." In a wet-hose system, the discharge line must be kept full of liquid ("packed") between deliveries. The LMD Code (Section S.3.7.) therefore requires that wet-hose systems incorporate an anti-drain valve to prevent drainage of the discharge hose.

In contrast, most top-loading systems are considered to be "dry-hose," at least insofar as the fill spout that drops vertically into the receiving tank inlet during loading is concerned. All product must be drained from the spout (and any portion of the discharge line downstream of the discharge valve) into the receiving tank at the

conclusion of each delivery, and the line must remain empty (dry) between deliveries. The design of dry-hose systems is required by Handbook 44 to facilitate and ensure complete drainage (Section S.3.4.).

The inspector should visually check between deliveries to determine whether there is significant leakage of product from the discharge end of a wet hose, or whether a significant amount of product remains in the fill tube of a top-loading system after it has been removed from the receiving tank inlet. In either case, a very small amount of liquid product may normally be present, and should be discounted.

The tests prescribed in the EPO are designed for a routine field examination. If you are examining the device in response to complaints, or have reason to believe that the prescribed procedures do not adequately test the system, you may wish to perform additional tests. However, keep in mind not only the cost to the owner or operator of devices that are taken out of service, even temporarily, but also the cost to the jurisdiction of additional testing.

One additional test that is sometimes necessary for electronic systems is a test for radio frequency and/or electromagnetic interference (RFI/EMI). Electromagnetic radiation generated by motors, power lines, lights, and radio or TV transmissions can interfere with the electronic signals generated by the pulser, or with the computer circuitry of the register or temperature compensator. Although metering devices are designed to be shielded from such environmental effects, this shielding may be inadequate, or the source of interference may be unusually strong. Symptoms of RFI/EMI are usually erratic registration or temporary blanking out or distortion of indicators. However, in the absence of clear evidence of RFI/EMI, other explanations should also be considered: diagnosing RFI/EMI by testing alone can be very difficult.

Your instructor will describe your jurisdiction's policies and procedures for conducting RFI/EMI tests and other additional tests not prescribed in the EPO.

### Concluding the Test

When you are satisfied with the results for all performance tests specified in the EPO, you should make sure that all product has been returned to the operator's tank and that you have taken a final totalizer reading. If an ATCS has been deactivated, the operator should reactivate it and a new security seal should be installed (see Chapter 8). Then disconnect the prover from the system. Only after the metering system and prover are secure should you proceed to the post-test tasks that are described in the next chapter.

## SUMMARY

The purpose of the Test component of an official field examination is to determine whether the system being examined can perform within legal limits of inaccuracy (tolerances) under conditions that approximate, as nearly as possible, actual service conditions. The Test is comprised of several distinct procedures: some are designed to develop the operating characteristics of the system, others test for performance of specific elements or under specific conditions that may affect accuracy in commercial service. Appropriate corrections are made for the effect of temperature differences between the meter and prover on the volume of product in the prover and prover capacity, and for comparability with automatically compensated (net) indications.

The first official test draft is always made at the system's maximum discharge rate (Normal Test); if the system is equipped with an ATCS, it is left activated for this draft.

A second Normal Test is conducted for systems that indicate compensated volume only; the ATCS is deactivated and the Normal Test procedure repeated. Results of this draft should confirm those of the first test draft; if not, they may point to faulty operation of the ATCS.

The final volumetric test is a Special Test, conducted at a rate of flow at or near the recommended minimum for the device. It is intended to indicate the capability of the meter to perform accurately over the range of operating conditions for which it was designed. In the case of a positive-displacement meter, interpretation of test results may also indicate the condition of the meter.

Comparison and interpretation of results obtained from various Test procedures can provide operators, repairpersons, and the weights and measures jurisdiction with important information regarding the current condition of the loading-rack metering systems examined.