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Meter Testing and Corrections – Corrections During Liquid Meter Testing

By Tina Butcher

When conducting tests of liquid-measuring devices such as loading-rack meters, LPG meters, and vehicle-tank meters, several corrections are used to account for the effects of influences such as pressure (in a closed vessel such as an LPG prover) and temperature. It is necessary for the weights and measures official to understand why these corrections must be made.

Why Make Corrections?

To ensure a fair test of any weighing or measuring device, it is important that no aspect of the test procedure used by the inspector or service agent unfairly (or unreasonably) affects the results of the test. Test standards must be accurate and appropriate. The Fundamental Considerations of NIST Handbook 44 specify that, when a standard is used without correction, its combined error and uncertainty must be less than one-third of the applicable device tolerance. Likewise, the procedures used by the inspector or service agent should not introduce significant errors into the test process. For example, it is important that an inspector set up equipment correctly, read a prover accurately, adhere to established drain times, and follow recognized test procedures.

What Corrections Need to Be Made?

Influences in effect at the time of the test must be also be accounted for. Temperature and pressure can affect measurement results, and corrections need to be made during some types of meter testing to account for the effects of these influences. Three corrections that should be considered, particularly during the testing of larger meters and LPG, are illustrated in the following diagram and explained in the text that follows. These corrections are particularly important for products such as LPG that have a high coefficient of expansion.

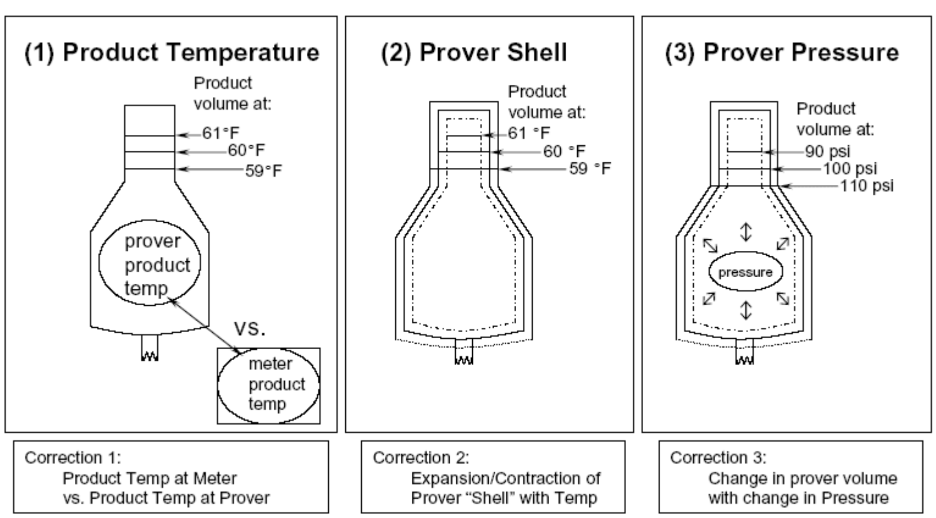

Fig. 1 – Three Corrections

(1) Correction for Product Temperature
This correction accounts for a change in product volume resulting from a difference between the temperature of the product at the meter and the temperature of the product at the prover.

Product expands as temperature increases and contracts as temperature decreases. For example, a given volume of product measured at 61 ºF occupies more space than that same product measured at 59 ºF or 60 ºF as illustrated in Figure 2.

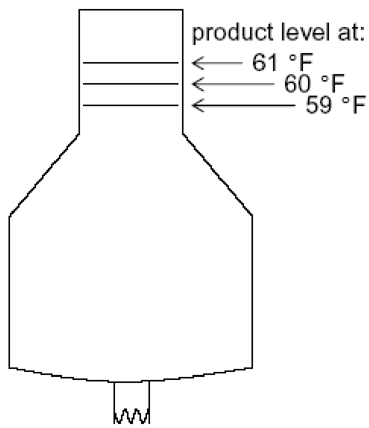

Fig. 2 – Effect of Temperature on Product Volume

The rate at which a product expands and contracts in response to temperature is referred to as its "coefficient of expansion." For reference, the widely accepted coefficient of expansion for gasoline is 0.00069/°F and for diesel is 0.00050/°F.

Consider an example where the meter measures the volume at a product temperature of 59 °F. What happens if the temperature of the product rises to 61 °F as it travels between the meter and the prover? As the temperature rises, the product will expand, raising the product level to a higher volume in the prover than it would have been had the temperature remained the same as it was at the meter. To compare the volume indicated on the prover with the volume indicated on the meter without making any adjustments or corrections would not be a fair test since you would essentially be comparing a 59 °F volume with a 61 °F volume. Consequently, for most meter tests, a correction must be made to ensure that the prover readings and the meter readings are both based upon volumes at the same temperature.

For a non-temperature compensated meter, there are two methods for accomplishing this correction. One is to adjust the product volume at the meter to its volume at 60 °F, adjust the volume at the prover to 60°F, and then compare the two adjusted volumes. The second method is to adjust the volume at the prover to the volume it would be if it were at the same temperature as the meter temperature and then compare the corrected value to the meter reading. Most NIST training courses on meters use the first method, which is illustrated in the example below. The American Petroleum Institute (API) publishes tables (including Table 6B, "Generalized products: Correction of Volume to 60 °F") that list factors used to correct volumes to 60 °F, making this method reasonably quick and easy. To obtain a temperature and pressure volume correction factors CD for generalized crude oils, refined products, and lubricating oils, contact either API or ASTM International (originally known as American Society for Testing and Materials) at http://api-ec.api.org or http://astm.org, respectively.

To adjust a volume to 60 °F using the API tables, first find the factor corresponding to the temperature of the product. Multiply the factor by the volume; the result is the "volume corrected to 60 °F." That is, what the volume would be if its temperature were actually adjusted to 60 °F.

Product Type:
Gasoline with an API gravity of 60.0:

Meter Indicated Volume:	200.0 gallons
Product Temperature at Meter:	59 °F
API Correction Factor for 59 EF:	1.0007
Meter Volume Corrected to 60EF:	200.0 x 1.0007 = 200.14 gallons
Prover Indicated Volume:	201.00 gallons
Product Temperature at Prover:	61 °F
API Correction Factor for 61 EF:	0.9993
Prover Volume Corrected to 60EF:	201.0 x 0.9993 = 200.9 gallons

The results of 200.14 gallons at the meter and 200.9 gallons at the prover can now be compared since both have been adjusted to the corresponding volumes at 60 °F.

Note that it is important to use "matched" thermometers (thermometers that read the same temperature within a certain allowance) during this process to ensure there are no significant differences between the thermometer used at the meter and the thermometer used at the prover.

(2) Correction for Prover Temperature
This correction accounts for the change in prover volume due to the expansion or contraction of the ***prover*** *with changes in temperature.*

Just like the product being metered expands or contracts with changes in temperature, the metal from which a prover is made will also expand or contract with temperature changes. Graduated neck-type volumetric field standards which are used to test meters measuring refined petroleum products are calibrated to deliver their nominal capacities at a reference temperature of 60 °F. If the temperature of the prover drops below 60 °F, the metal will contract, thus reducing the volume of the prover. If the temperature of the prover rises above 60 °F, the metal will expand, thereby increasing the volume of the prover.

The rate at which the prover metal expands and contracts in response to temperature is referred to as its "cubical coefficient of expansion." Provers are commonly constructed

from stainless steel or mild steel. The coefficient of expansion for stainless steel is 2.65 x 10-5 (or 0.0000265) and for mild steel is 1.86 x 10-5 (or 0.0000186).
To correct for the effect of temperature on the prover metal, the following equation is used:

Coefficient of Expansion x (Temperature of Prover – 60 °F) x Prover Nominal Capacity

In the example above, for a 200-gallon prover at 61 °F, the correction would be calculated as follows if the prover were constructed of stainless steel:

0.0000265 x (61-60) x 200 = 0.0053 gallons x 231 = 1.22 cubic inches

This means that the volume of the prover has increased by 1.22 cubic inches at 61 ºF. Thus, the reading in the prover would be 1.22 cubic inches less than it would be if the temperature were at the prover reference temperature of 60 °F. To apply the correction, 1.22 cubic inches would be added to the prover reading of 201.00 gallons.

Consider what would happen if the temperature were 81 °F. The effect is much more significant:

0.0000265 x (81-60) x 200 = 0.1113 gallons x 231 in3/gal = 25.7 cubic inches

In this case, the prover would have increased its capacity by 25.7 cubic inches and this amount would need to be added to the prover reading in order to account for the effect of temperature on the prover metal.

For a more detailed description of this correction for vehicle-tank meter testing, see Dick Suiter's February 2004 *W&M Quarterly* article, "Temperature is a Big Factor in Vehicle-Tank Meter Test." To access the article, go to the WMD website at www.nist.gov/owm; select "Weights and Measures Quarterly Newsletter Archive" under the "Publications" section and look for Series B-007 under the "Measuring" category.

(3) Correction for Prover Pressure
This correction accounts for the change in prover volume due to the expansion or contraction of the prover with changes in pressure.

In a closed system such as that during LPG meter testing, pressure can affect measurement results. It is not necessary to make this correction to tests of "open" systems where pressure is not a factor, such as tests of vehicle-tank meters or loading rack meters delivering refined petroleum products which are liquids at atmospheric temperatures and pressures.

Volumetric field standards which are used to test meters measuring liquefied petroleum gas and anhydrous ammonia are calibrated at a reference pressure of 100 pounds per square inch (psi). If the pressure of the prover rises above 100 psi, the prover will expand, thus increasing its volume from its calibrated volume. Likewise, if the pressure drops below 100 psi, the prover will contract, thus decreasing the volume from its calibrated volume.

The rate at which this change occurs is not a linear function; the response of a particular prover to pressurization may be unique to that individual prover and is not predictable from its material or design. When a prover is calibrated, a pressure correction table is prepared, showing the appropriate corrections at various pressures. The correction for pressure is obtained from this chart and is added or subtracted from the prover reading according to the chart.

Note that a large difference between the product pressure at the meter and the product pressure in the prover may indicate a restriction in the system. A difference greater than about 5 psi should prompt you to investigate and correct any system problems prior to continuing with the test.

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