February 2004

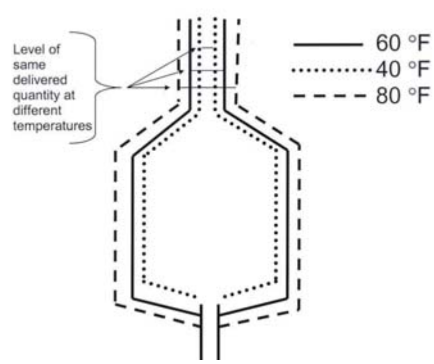
Temperature is a Big Factor in Vehicle-Tank Meter Test

By Dick Suiter

Nearly all weights and measures officials are aware that a gallon of heating oil or gasoline is defined as having a volume of 231 in^3 at a reference temperature of 60 ºF. If you measure a gallon of product at 60 ºF and then vary the temperature, the volume of the product will expand as you increase the temperature above 60 ºF and will contract as you reduce the temperature below 60 ºF. However, if you change the temperature of the product before it is measured, you will still deliver a volume of 231 in^3 for each indicated gallon, assuming there is no meter error.

Now let's consider the effect of temperature on a test measure or prover. Graduated neck-type volumetric field standards intended to be used for testing petroleum products are calibrated to deliver their nominal capacity at the same reference temperature of 60 ºF. If you vary the temperature of the product being introduced into the test vessel, the metal of the vessel will expand or contract as the temperature goes up or down. Thus, the actual volume of the vessel will increase as the temperature of the product increases above 60 ºF or decrease if the product temperature is less than 60 ºF. The amount of the change in volume is directly related to the cubical coefficient of thermal expansion for the type of metal used to construct the test vessel and is proportional to the nominal volume of the test vessel.

Effect of Temperature Change on Prover



The common metals used for construction of volumetric field standards are mild steel and stainless steel. The accepted cubical coefficient of thermal expansion for the metals used to construct volumetric field standards is 0.0000186/ºF for mild steel and 0.0000265/ºF for stainless steel.

For example, if you have a stainless steel volumetric field standard, the volume of the standard in gallons will change by an amount equal to 0.0000265 times the nominal volume of the standard times the difference in the temperature of the product, in the standard, from 60 ºF. If you want the result to be in cubic inches you merely add the additional step of multiplying the change in volume in gallons by 231. If you are testing a vehicle-tank meter using a 100-gallon stainless steel prover and the temperature of the product passing through the meter and coming from the nozzle of the delivery hose is 80 ºF, the change of volume of the prover is significant. The change is calculated as follows:

$$0.0000265 \times (80^{\circ} - 60^{\circ}) \times 100 \text{ gal} \times 231 \text{ or } 12 \text{ in}^3$$

If the nominal capacity of the prover doubles to 200 gallons the change in volume at 80 ºF also doubles to 24 in^3.

In the example above with a product temperature of 80 ºF, if the reading in the sight glass of a 100-gallon prover is +65 in^3 without consideration for temperature of the prover, that reading is within the maintenance tolerance of 0.3 gallons or 69.3 in^3. At a prover temperature of 80 ºF the metal of the prover has expanded by approximately 0.6 in^3 for every degree of temperature change. Thus, the volume of the prover has in fact increased by 12 in^3, meaning that the level of the product in the sight glass has effectively been lowered by that amount. If the prover reading is corrected for the temperature difference, the true reading is now +77 in^3, meaning the meter error is greater than the applicable maintenance tolerance of 0.3 gallon or 69.3 in^3.

As another example, consider a test of a vehicle-tank meter using a 200-gallon stainless steel prover where the product temperature is 35 ºF. If the reading in the sight glass is plus 150 in^3 without consideration for temperature, that reading is well beyond the allowable maintenance tolerance 0.6 gallon or 138.6 in^3. At a prover temperature of 35 ºF the change in volume of the prover is as follows:

$$0.0000265 \times (35^{\circ} - 60^{\circ}) \times 200 \text{ gal} \times 231 \text{ or } -30.6 \text{ in}^3$$

The volume of the prover has in fact decreased by 30.6 in^3, meaning that the level of the product in the sight glass has effectively been raised by that amount. If the prover reading is corrected for the temperature difference, the true reading is now +119.4 in^3, meaning the meter error is well within the applicable tolerance of 0.6 gallon or 138.6 in^3.

The impact of temperature correction becomes more significant when acceptance tolerances are applicable to the meter being tested. Regardless of whether maintenance or acceptance tolerances are applicable, it becomes readily apparent that neglecting to take the effect of temperature on the prover volume into account when using larger volumetric field standards to test meters, such as vehicle-tank meters or retail motor-fuel dispensers with a flow rate greater than 30 gpm, greatly increases the probability of inappropriately rejecting or approving meters. While it is not difficult to calculate the appropriate correction for a volumetric field standard at any product temperature, there are tables that have been developed for some of the more common size provers. It also is not difficult to develop a correction table for any size prover.

If you have questions about availability of an existing correction table or developing a table for your prover size or anything else related to this article please contact Dick Suiter by e-mail at rsuiter@nist.gov or by phone at (301) 975-4406.