## August 2005

# Series 2 -
# Gravimetric Testing of Oil Meters:
# Converting Net Weight to Corrected Volume

*By Dick Suiter*

This is the second and final article on the gravimetric testing of oil meters. The first article described the process of weighing metered oil in an appropriate container (test vessel) to determine the net weight of the volume delivered through the meter. Once the net weight of the volume of oil delivered is determined, the next step is to convert the net weight of the oil delivered to a measurement of volume and make corrections necessary to determine if the meter is accurate within prescribed tolerances. (**Note:** The first article in the series, which appeared in the June 2005 edition of the *Weights & Measures Quarterly*, is available for review on the NIST Weights and Measures Division website at www.nist.gov/owm where you will find a link entitled Weights & Measures Newsletter Quarterly Archive under "Publications" in the center column of the home page.)

Several terms used in this article are defined as follows for your reference:

*Density:* weight per unit of volume (i.e., pounds/gallon or kilograms/liter).
*Specific gravity:* the ratio of the density of a substance to the density of some substance (as pure water) taken as a standard when both densities are obtained by weighing in air.
*API Gravity:* a value obtained using an hydrometer designed to directly read the relative density of a petroleum product, e.g., oil.

API correction tables are used to convert net weight to corrected volume. In 1921 the American Petroleum Institute (API), the United States Bureau of Mines, and NIST selected the API scale (density) as the standard for petroleum products in the United States and developed the formula for converting specific gravity to API gravity. In the 1940s the API Tables for Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils were first published. In 1980 the tables, which are currently used by many weights and measures jurisdictions for testing loading-rack, vehicle-tank, or LPG meters, were updated. To obtain a temperature and pressure volume correction factors CD for generalized crude oils, refined products and lubricating oils, contact either API or ASTM at http://api-ec.api.org or http://astm.org, respectively.

Once the net weight of the metered oil has been determined, it must be converted to a volume by using the correction tables and the calculations. It is then compared to the volume indicated on the meter so the accuracy error of the meter can be determined. To convert the net weight of the product to a corrected volume, the density of the product at the temperature in the test vessel at the time of the weight determination must be

established. Several methods for determining the density of the oil in the test vessel are available.

(1) **Product Data Sheets:** Some jurisdictions use API gravity information from data sheets provided by the manufacturer or distributor of the oil. The data sheets will normally provide the API Gravity at 60 °F and may provide the specific gravity and density in pounds per gallon of the oil tested. This method assumes that the API gravity supplied is correct and that all production "lots" of a particular product or grade will have the same API gravity. It also assumes that successive deliveries into the storage tank at the meter site are of the same API gravity. The following steps can be used with this method to determine the density of the oil in the test vessel:

Step 1. - Deliver a test draft that approximates a normal delivery into the test vessel on the scale. When using this method, the temperature of the product in the test vessel should be determined immediately after each test run.

Step 2. - Determine and record the net weight of the oil (e.g., 407 lb). Also record the temperature of the product from Step 1.

Step 3. - If the temperature of the product is other than 60 °F, the actual density of the product in terms of API Gravity can be determined using the API Table 5B - Generalized Products Correction of Observed API Gravity to API Gravity at 60 °F. The observed API gravity can then be converted to specific gravity and the specific gravity can be converted to "lb per gallon" using the value of 8.337193 lb per gallon at 60 °F, as referenced in J. B. Patterson and E. C. Morris's book, *Measurement of Absolute Water Density, 1 ºC to 40 ºC*. As a formula both conversions are expressed as follows:

$$specific\ gravity = \frac{141.5}{API\ Gravity + 131.5}$$

$$density\ in\ lb/gal = Specific\ Gravity \times 8.337193$$

The conversions are expressed as a single formula as follows:

$$density\ in\ lb/gal = \left(\frac{141.5}{API\ Gravity + 131.5}\right) x\ 8.337193$$

**Example:**

Using the combined formula for a 15W-40 grade oil with an API gravity of 28.3 at 60 °F,

$$density\ in\ lb/gal = \left(\frac{141.5}{28.3 + 131.5}\right) x\ 8.337193 = 7.38\ lb/gal$$

Step 4. - The net weight of the product in the test vessel is divided by the density (lb/gallon) from the formula to determine the actual volume in gallons delivered. Using the above example, if the net weight was 407 lb, the gallons delivered would be as follows:

$$407 \text{ lb} \div 7.38 \text{ lb/gal} = 55.149 \text{ gal}$$

Step 5. - The actual volume delivered is then compared with the indicated volume on the meter to determine the meter error. If the meter indication was 55.0 gal, the error in the meter would be as follows:

$$55.0 - 55.149 = - 0.149 \text{ gal}$$
(underregistration)

Meter Indication - Actual Volume = Meter Error

(2) **Hydrometer Method:** Another method of verifying the density of the product being tested at the time of the test uses a Combined Form Hydrometer (Thermohydrometers). Designed to measure the API density of petroleum products, Combined Form Hydrometers incorporate a thermometer inside the body or stem to measure the temperature of the sample. This type of hydrometer is readily available from most scientific equipment suppliers. Specific instructions for using the hydrometer are supplied by the hydrometer manufacturer. The basic concept behind any model is that a separate sample of the product being tested is collected and placed in an appropriate glass cylinder and the hydrometer is placed in the sample. Once the hydrometer is placed in the product, the temperature of the hydrometer should be allowed to stabilize with the product temperature. After the temperatures have stabilized, the API gravity is read directly from the hydrometer. The reading of the hydrometer is corrected for the effect of temperature on the sample if different than 60 °F. The same formula and steps as shown in method 1 above are then used to determine the meter error. Some hydrometer manufacturers also provide conversion tables that provide a weight per gallon for a range of API gravities. Though the tables are easy to use, they don't provide a weight for every API gravity the inspector may encounter. Trying to interpolate values in the table may be more difficult than using the formula provided above.

(3) **Electronic Spreadsheet:** Those jurisdictions that provide laptop computers to their field staff can use an electronic spreadsheet that incorporates all of the readings collected and formulas to perform the necessary conversions. Jim Hedman of the Minnesota Weights and Measures Petroleum Laboratory has developed such a spreadsheet using Microsoft Excel. Minnesota Weights and Measures has offered to share that spread sheet with other jurisdictions. If you are interested in getting an electronic copy of the spreadsheet, please contact Carol Hockert, MN Director of Weights and Measures, by at carol.hockert@state.mn.us or at (651) 215- 5823.

For further information on gravimetric testing of oil meters, please contact Dick Suiter by at rsuiter@nist.gov or at (301) 975-4406.