June 2005

Series 1 - Gravimetric Testing of Oil Meters: Equipment Needs and Scale Requirements

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The use of positive displacement meters to deliver motor oils directly to construction sites, farms, and distributor sites using a truck-mounted meter is becoming more commonplace. Some of the delivery units are older tank trucks using a vehicle tank meter. Others have a small meter mounted inside a box truck making deliveries from 55-gallon drums. Meters are also frequently used to fill larger containers of oil in package form, such as 5-gallon pails to 55-gallon drums. Testing these meters for accuracy presents a challenge for weights and measures officials. Traditional methods, such as using open neck provers, don’t work for testing oil products. Not only is it difficult and time consuming, the effect of product viscosity on drain time can invalidate the prover calibration and, in some cases, can make it very difficult to clean the prover. Burnouts of pump-off motors have been reported. Gravimetric test procedures, while also somewhat difficult and time consuming, are preferable particularly for larger test drafts.

This is the first in a series of two articles that will address equipment needs, scale requirements, the weighing process, and the conversion of the net weight of measured product to a corrected volume for determining meter error. This article will explore the process of weighing metered product (oil) in an appropriate container (test vessel) to determine the net weight of the volume delivered through the meter. The second article in the series will examine the conversion of the net weight of the oil delivered to a measurement of volume and the corrections necessary to determine if the meter is accurate. The second article will also examine several methods for determining those corrections.

Volumetric standards, such as open top provers or test measures, are typically calibrated to a capacity starting with a "wet down" condition that is referred to as the "to deliver" capacity using water as the calibration fluid. The calibration process includes a specified drain time based on the size and design of the prover. The "to deliver" calibration takes into account the amount of water that clings to the prover walls each time it is properly drained. In field use, each time a "to deliver" prover is used, the proper starting point for testing is established through a "wetting" process. The prover is normally filled with product from the meter under test to its nominal capacity and drained following prescribed pour and drain times. For some liquids, such as gasoline and diesel fuel, the difference in product clingage is considered similar enough to water that the effect on calibration can be ignored. When using a prover to test an oil meter, the amount of oil that will cling to the prover walls upon draining is obviously much greater than when that same prover is filled and drained using water or motor fuel. This fact makes it impossible to make multiple test drafts without completely cleaning the prover and reestablishing a correct "wet" starting point between drafts--a procedure that is not practical to accomplish in the field.

Gravimetric testing of oil meters has its own set of drawbacks and difficulties, but in most cases gravimetric testing is less difficult and perhaps more accurate than using a volumetric standard, provided appropriate equipment is used and appropriate corrections for product composition are made. Necessary testing equipment include:

- appropriate test vessel(s)
- suitable scale(s)
- certified thermometer
- appropriate means to determine the density of the product being tested
- temperature correction information

An appropriate test vessel can be made of any suitable material provided it is large enough to hold appropriate size drafts for the meter under test. It is preferable if the user of the meter under test provides the test vessel(s). In some cases the test draft can be made into a vessel that the user then conveys to a customer such as a 55-gallon drum or a customer's portable tank.

A scale used in gravimetric testing is referred to as a "reference scale." A reference scale needs to meet certain criteria to be appropriate for gravimetric testing. The scale must have the capacity to accommodate the weight of the test vessel(s) plus at least one appropriate test draft per vessel. If the scale has sufficient capacity, it may be possible to make multiple test runs into the same test vessel. The scale division size must also be appropriate. In many cases the resolution of the scale used for conducting the meter test can be increased by using error weights (see NCWM Publication 14, Weighing Devices, Digital Electronic Scales, Section 73) or, if available, an expanded resolution mode feature on the indicator. Several resources are available to help you determine if a scale is suitable for use as a reference scale.

(1) For devices used to fill containers in package form, NIST Handbook 133 states that a scale used for gravimetric testing of packaged fluid products must have at least 100 scale divisions and a scale division size no greater than 1/6 of the maximum allowable variation (MAV) for the package size being weighed. An MAV is a deviation from the labeled weight, measure, or count of an individual package beyond which the deficiency is considered unreasonable. The MAV/6 criteria should be applied to the smallest container size that is filled using the meter under test.

(2) NCWM Publication 14 also includes reference scale criteria for testing a meter using gravimetric test procedures. Publication 14 criteria requires that any test draft shall be equal to or greater than ten times the division size of the available reference scale divided by the applicable draft tolerance in percent for the device under test. There are two approaches for determining whether or not a scale can be used for testing at a particular site. One can either determine the size of the average delivery at the test site and then select a scale that is appropriate for that draft size or if only a particular scale division size is available, the size of the test draft can be increased such that the scale division becomes suitable, provided the scale has sufficient capacity to accommodate the weight of the empty vessel plus the test draft.

(3) Juana Williams (WMD) provided additional information on this process in her March 2005 Weights and Measures Quarterly article titled "Using Reference Scales". This article can be viewed and downloaded from the WMD home page at www.nist.gov/owm under the publications link "Weights and Measures Quarterly Newsletter Archive"– weighing articles.

Note: In all cases the smallest test draft must equal at least one-minute's flow at the maximum flow rate marked on the meter under test.

The scale should be tested for accuracy in the range anticipated for use immediately prior to the gravimetric test of the meter. For larger scales the maximum time between the scale test and the gravimetric meter testing must not exceed 24 hours. The scale should be tested using error weights to determine actual errors in the scale, particularly at the points where tare (the weight of the vessel prior to a test draft) and gross weight (the weight of the vessel and product after a test draft) readings will be made. It is desirable to eliminate as much scale error as practicable, but if that is not possible, the scale errors at the critical reading points should be factored into any calculations. It is also appropriate to conduct an abbreviated test following the gravimetic meter testing to verify that the scale accuracy has not changed.

The process of making test runs through the meter under test and weighing the test vessel for tare, gross, and net weight are fairly straightforward. If only a single draft is to be delivered into the test vessel, the empty vessel should be weighed using error weights or an expanded resolution of the scale indication. After the test draft is delivered into the test vessel, it is again weighed using error weights or expanded resolution to determine the gross weight. The empty weight of the test vessel is then subtracted from the gross weight to provide the net weight of the oil. If multiple drafts are made into the same test vessel, the gross weight of each draft becomes the tare value for the subsequent draft.

Example:

Draft 1		
Tare Weight	=	The weight of empty test vessel 1
Gross Weight	=	The weight of the empty test vessel plus the weight of test draft 1
Net Weight	=	The Gross Weight minus the Tare Weigh
Gross Volume	=	The Net Weight converted to Volume
Corrected Volume	=	The Gross Volume with appropriate corrections applied
Draft 2		
Tare Weight	=	The weight of empty test vessel 2 or the gross weight of test vessel 1 following draft 1
Gross Weight	=	The weight of the test vessel 1 or 2 plus the weight of test draft 2
Net Weight	=	The Gross Weight minus the Tare Weigh
Gross Volume	=	The Net Weight converted to Volume
Corrected Volume	=	The Gross Volume with appropriate corrections applied

Article two in this series will explore the conversion of the net weight of the oil to a *corrected* volume for verifying the accuracy of the meter under test and various methods for determining that corrected volume.