NET-22.2 3.X. Volumetric Test Procedure for Viscous and Non-Viscous Liquids by Portable Digital Density Meter.

Source:
Mr. Ronald Hayes (retired)

Purpose:
Allow the use of digital density meters for package checking testing of viscous and non-viscous liquids.

Item Under Consideration:
Amend Handbook 133, Checking the Net Contents of Packaged Goods, as follows:

3.1.1. Test Methods

Notes:

(2) When checking liquid products using a volumetric or gravimetric procedure, the temperature of the samples must be maintained at the reference temperature ± 2 °C (± 5 °F), **except when 3.X. Gravimetric Test Procedure for Viscous and Non-Viscous Liquids by Portable Digital Density Meter is used.**

3.X. Gravimetric Test Procedure for Viscous and Non-Viscous Liquids by Portable Digital Density Meter

This test procedure can be used to determine the net contents of most package goods labeled in fluid volume. Manufacturer's instructions must be reviewed prior to use, to determine if the meter is suitable for testing the intended product.

This procedure is also useful for ensuring product quality for commodities (e.g., DEF, Antifreeze) that have a density requirement in their respective specifications.

This test procedure is suitable for measuring the density of homogenous liquids including dairy products such as milk and half & half; petroleum products such as fuel, motor oil, transmission fluid, paint thinner, brake fluid, diesel exhaust fluid, automotive coolant; pulp-free juices, wine, distilled spirits, water, mouth wash, alcohol, syrups, cooking oils, solvents, cleaning supplies, chemicals, as well as other viscous and non-viscous liquids. All products tested shall be free of suspended gas, air, sediment, suspended matter.

This test procedure may be used as a substitute for testing non-viscous liquids gravimetrically using a flask (refer to 3.2. Gravimetric Test Procedure for Non-Viscous Liquids), the volumetric flask test procedure (refer to 3.3. Volumetric Test Procedure for Non-Viscous Liquids) or testing viscous fluids by the volumetric headspace procedure (refer to 3.4. Volumetric Test Procedures for Viscous Fluids – Headspace).

NOTE: This shall not be used for liquids with suspended solids such as orange juice with pulp, buttermilk, liquids requiring "shake before use", paint, or carbonated products (soda, beer, etc.) or substances not approved by the digital density meter manufacturer.

Prior to using for compliance testing, the official's metrological laboratory should perform a comparison between the densities obtained between Sections 3.2. Gravimetric Test Procedure for Non-Viscous Liquids or 3.3. Volumetric Test Procedure for Non-Viscous Liquids, and the digital density meter.

This test procedure can also be a time saver for screening products for proper fill and for quality control purposes.

3.X.1. Test Equipment

- **A scale that meets the requirements in Chapter 2, Section 2.2. "Measurement Standards and Test Equipment."**

  Note: To verify that the scale has adequate resolution for use, it is first necessary to determine the density of the liquid. Using the density, convert the labeled volume to weight. Based on the labeled volume, determine the MAV using Table 2-6 "Maximum Allowable Variations for Packages Labeled by Liquid and Dry Volume" found in Appendix A. Using the density, convert the MAV from volume to weight. Next verify that the scale division is no larger than MAV/6 for the package size under test. The smallest graduation on the scale must not exceed the weight value for MAV/6.

Example:

Assume the inspector is using a scale with 1 g (0.002 lb) increments to test packages labeled 1 L (33.8 fl oz) that have an MAV of 29 mL (1 fl oz). Also, assume the inspector finds that the weight of 1 L of the liquid is 943 g (2.078 lb).

Density: 1 L = 943 g (2.078 lb)

MAV: 29 mL (1 fl oz)

Convert Density into mL and fl oz:

943 g ÷ 1000 mL= 0.943 g/mL (2.07 8 lb ÷ 33.8 fl oz = 0.061 4 lb/fl oz)

Convert MAV from Volume (mL/fl oz) to Weight:

29 mL × 0.943 g/mL = 27.347 g (1 fl oz × 0.061 4 lb/fl oz = 0.064 lb)

MAV in Weight/6

27.347 g ÷ 6 = 4.557 g 0.064 ÷ 6 = 0.010 lb

In this example, the 1 g (0.002 lb) scale division is smaller than the MAV/6 value of 4.557 g (0.010 lb) so the scale is suitable for making a density determination.

- **Low pressure air pump– (e.g., an aquarium air pump)**

- **Syringe (glass or plastic with Luer fitting 5mL or larger)**

  Note: Plastic syringe should be free of any lubricating substances

- **Distilled or deionized water**

- **Cleaning agents (See Table 3.X4. Cleaning Agents)**

- **Waste container**

- **Barometer for obtaining the prevailing barometric pressure, with an accuracy of ±3.0 mmHg**

- **Thermometer for measuring air temperature with a tolerance of ±1°C (2°F)**

- **Portable digital density meter meeting a minimum requirement of:**

Measuring Range	
Density	**0 – 3 g/cm^3**
Temperature	**0 – 40 °C (32 – 104 °F)[a]**
Viscosity	**0 – 1000 mPa·s**
Accuracy[b]	
Density	**0.001 g/cm^3**
Temperature	**0.2 °C (0.4 °F)**
Repeatability s.d.	
Density	**0.0005 g/cm^3**
Temperature	**0.1 °C (0.1 °F)**
Sample Volume	**2 mL**
Sample Temperature	**max. 100 °C (212 °F)**
footnotes **[a] Filling at higher temperatures possible.** **[b] Viscosity < 100 mPa·s, density < g/cm^3**	

3.X.2. Test Procedure

1. **Follow Section 2.3.1. "Define the Inspection Lot." Use a "Category A" sampling plan in the inspection. Select a random sample.**

2. **Bring the sample packages and their contents to a temperature between the reference temperature and ambient temperature.**

3. **Packages may be gently rolled to mix contents. Avoid shaking liquids. Shaking some products such as flavored milk will entrap air that will affect density measurements.**

4. **The digital density meter must at ambient temperature. Avoid causing condensation within the unit. Condensation could cause instrument malfunction and harm.**

5. **Using distilled or deionized water, validate the digital density meter per the manufacturer's calibration instructions. The digital density meter shall calibrate within allowable density range (±0.0005). The digital density meter shall be validated once each day prior to usage.**

6. **Ensure the digital density meter is clean prior to testing. Any residual liquid should be drained, and the unit should be flushed with a small amount of the sample to be tested. Flush and discard the sample two times before taking a measurement.**

7. **Follow the manufacturer's instructions to select the correct method, when using a meter with built in correction factors, and measure the density of the sample using the built-in pump or syringe. Fill the sample slowly and gently. If gas or air bubbles are present drain sample and refill.**

   Note: Use of a syringe may be desirable to allow sample specimen to achieve ambient temperature prior to introduction of specimen into testing cell and for viscous specimens.

8. **Once the digital density meter has stabilized (maintained reading ± 0.2 °C (± 0.5 °F) for 10 seconds) record density and temperature as indicated on instrument.**

9. **Apply density coefficient of expansion (Alpha) also known as the density correction factor (DCF), to correct to the reference temperature. See Table X.1. Reference Temperatures of Liquids. If the Alpha correction is not known, then factor can be calculated using the below formula.**

   Note: Some digital density meters may be programmed to automatically apply this correction.

   Calculating the Temperature Coefficient Alpha
   Temperature coefficient Alpha = $\left|\frac{\rho^1-\rho_2}{T^1-T_2}\right|$
   ρ_1 **…. *density at temperature*** T_1
   ρ_2 **…. *density at temperature*** T_2
   T_1 **…. *temperature at initial measurement***
   T_2 **…. *temperature at second measurement***

   Note: If the density correction factor is not known but the volume correction factor (VCF) is known, the DCF can be calculated from the VCF using the following formula.

   Density Temperature Factor Alpha = Absolute Value of Beta × Density.

10. **Apply viscosity correction if viscosity > 85 centipoise at 21 °C (70 °F) by adding the value in Table X.. Density Measurement to your density measurement. After this correction, this value is the density of the substance in in the vacuum at the prescribed reference temperature.**

    Note: Some digital density meters may be pre-programmed to automatically apply. See Table X. Viscosity Corrections of Common Materials

11. **Apply the apparent density correction by applying one of the following steps:**

    (1) **multiplying the density by 0.999; or**

    (2) **multiplying the density by the Apparent Mass Factor from Table X.3. ; or**

    (3) **calculate apparent density by using the following.**

    Converting True Density into Apparent Density

    The apparent density $Paap$ is defined as:

$$Paap = \frac{Ptrue{,}sample - Pair}{1 - \frac{Pair}{8.0\ g/\text{cm3}}}$$

    Where:

    P_{aap} = ***apparent density of the sample***

    $P_{steel} = 8.0\ g/cm^3$

    P_{air} = ***true density of air***

    $P_{true,sample}$ = ***true density of the sample***

The apparent density is smaller than the true density and can be calculated from the true density considering the buoyancy of the sample in air and the weight and density of a reference weight in steel.

*** Pair = true density of air as calculated from equation in Table X.0.**

After application of this factor or calculation, the new value is density of the substance in air.

12. **Drain the instrument and repeat Steps 6–10 on a second specimen of the same package for verification of first measurement.**

13. **Compare the two readings, they must agree within 0.0003 g/cc. Calculate the average density of the two specimens from the sample. If the difference of two readings is greater than 0.0003 g/cc, discard results and repeat testing of sample. Air or undissolved gas will cause erroneous measurement errors. The user of the test procedure shall always visually inspect for undissolved gas in the measurement tube for a valid test.**

14. **Repeat testing for the second (or subsequent) package(s) of the lot.**

15. **Calculate the Average Product Density of sample 1 and sample 2. The two results must agree within 0.0005 g/cc. If the difference between the densities of the two packages exceeds 0.0005 g/cc, use the volumetric procedure in Section 3.3. "Volumetric Test Procedure for Non-Viscous Liquids."**

16. **Determine the Average Used Dry Tare Weight of the sample according to provisions of Section 2.3.5. "Procedures for Determining Tare."**

17. **Calculate the "nominal gross weight" using the following formula:**

Nominal Gross Weight = (Average Product Density [in weight units]) × (Labeled Volume) +

(Average Used Dry Tare Weight)

18. **Weigh the remaining packages in the sample.**

19. **Subtract the nominal gross weight from the gross weight of each package to obtain package errors in terms of weight. All sample packages are compared to the nominal gross weight.**

20. **To convert the average error or package error from weight to volume, use the following formula:**

Package Error in Volume = Package Error in Weight ÷ Average Product Density Per

Volume Unit of Measure

21. **The digital density meter must be stored clean. After final use of the day or extended period of time, the instrument shall be drained and cleaned following the manufacturer's recommended cleaning procedures and using two cleaning agents. The first cleaning agent removes sample residue, and the second cleaning agent removes the first cleaning agent. See Table X.4. Cleaning Agents for examples of cleaning agents recommended by a digital density meter manufacturer.**

NOTE: If the unit will be immediately used to measure another sample of similar composition, the unit may be drained and flushed with new sample three times before the next analysis.

22. **Connect digital density meter to a low-pressure air source, such as an aquarium air pump, to dry the unit's measurement cell.**

3.X.3. Evaluation of Results

Follow the procedures in Chapter 2, Section 2.3.7. "Evaluate for Compliance" to determine lot conformance.

Table X.0. Density Measurement

Calculate the density of air at the temperature of test using the following equation:

ρ_{air}, g/mL = 0.001293[273.15/T][P/760]

where:

T = temperature, K, and

P = barometric pressure, torr.

°C	mmHg	d_{air}, g/mL
15.56	760	0.001223314

Table X.1. Density Coefficient Factor (Alpha)			
Notice: This Table is currently under review. Do not use without validation.			
Product	**alpha/°C**	**Typical Density at 20°C, g/cm³**	**Reference Temperature, °C**
Petroleum Products			
Benzene	0.00125	0.989	15.56
n-Heptane	0.00124	0.684	15.56
Gasoline	0.00095	0.74	15.56
Kerosene, jet fuel	0.00099	0.81	15.56
Oil (unused engine oil)	0.0007	-	15.56
Paint Thinner	-	-	15.56
Paraffin oil	0.000764	-	15.56
n-Pentane	0.00158	-	15.56
Toluene	0.00108	-	15.56
-	-	-	-

Generalized Petroleum Products (ASTM D1250 Table 54B)	-	-	-
-	-	-	-
Distilled Spirits	-	-	**15.56**
-	-	-	-
Other Liquids and Wine			
Acetic acid	**0.0011**	-	**20**
Acetone	**0.00143**	**0.799**	**20**
Alcohol, ethyl (ethanol)	**0.00109**	**0.789**	**20**
Alcohol, methyl	**0.00149**	**0.792**	**20**
Ammonia	**0.00245**	-	**20**
Aniline	**0.00085**	**1.022**	**20**
Ether	**0.0016**	-	**20**
Ethyl acetate	**0.00138**	-	**20**
Ethylene glycol	**0.00057**	**1.115**	**20**
Isobutyl alcohol	**0.00094**	-	**20**
Glycerin (glycerol)	**0.0005**	**1.261**	**20**
Olive oil	**0.0007**	-	**20**
Sulfuric acid, concentrated	**0.00055**	-	**20**
Turpentine	**0.001**	-	**20**
Water	**0.00018**	**0.9982**	**20**
-	-	-	-
Diesel Exhaust Fluid	**0.00022**	**1.08805**	**20**
-	-	-	-
Dairy Products	**alpha/°C**	**Typical Density at 4°C, kg/L**	**Reference Temperature, °C**
Homogenized milk	**0.00025**	**1.033**	**4**
Skim milk, pkg	**0.00019**	**1.036**	**4**
Fortified skim	**0.00019**	**1.041**	**4**
Half and half	**0.00044**	**1.027**	**4**
Half and half, fort.	**0.00044**	**1.031**	**4**
Light cream	**0.00056**	**1.021**	**4**

Heavy cream	**0.00088**	**1.008**	**4**

Table X.2. Viscosity Corrections of Common Materials

Material	**Viscosity in Centipoise**	**Correction**
Water	**1 cps**	
Milk	**3 cps**	
SAE 10 Motor Oil	**85–140 cps**	**0.0003**
SAE 20 Motor Oil	**140–420 cps**	**0.0006**
SAE 30 Motor Oil	**420–650 cps**	**0.0007**
SAE 40 Motor Oil	**650–900 cps**	**0.0007**
Castrol Oil	**1,000 cps**	**0.0008**
Karo Syrup	**5,000 cps**	**0.0008**
Honey	**10,000 cps**	**0.00085**

Table X.3. Apparent Mass Factor

Elevation, ft	**sea level**	**1500**	**3000**	**4500**	**6000**
Barometer, mmHg	**760**	**720**	**680**	**640**	**600**
density, g/cc	**Apparent Mass Factor**				
0.500	**0.9977**	**0.9979**	**0.9980**	**0.9981**	**0.9982**
0.600	**0.9981**	**0.9982**	**0.9983**	**0.9984**	**0.9985**
0.700	**0.9984**	**0.9985**	**0.9986**	**0.9987**	**0.9988**
0.800	**0.9986**	**0.9987**	**0.9988**	**0.9989**	**0.9989**
0.900	**0.9988**	**0.9989**	**0.9989**	**0.9990**	**0.9991**
1.000	**0.9989**	**0.9990**	**0.9991**	**0.9991**	**0.9992**
1.100	**0.9991**	**0.9991**	**0.9992**	**0.9992**	**0.9993**
1.200	**0.9991**	**0.9992**	**0.9992**	**0.9993**	**0.9993**
1.300	**0.9992**	**0.9993**	**0.9993**	**0.9993**	**0.9994**
1.400	**0.9993**	**0.9993**	**0.9994**	**0.9994**	**0.9994**
1.500	**0.9993**	**0.9994**	**0.9994**	**0.9994**	**0.9995**
Elevation or prevailing barometric pressure at the location of measurement.					

Table X.4. Cleaning Agents

Commodity	**Cleaning Liquid 1**	**Cleaning Liquid 2**
Petroleum products	**Toluene, petroleum naptha, petroleum ether, n-nonane, cyclohexane**	**Ethanol**
Battery acid	**Tap water**	**Ultra-pure (bi-distilled or deionized) water**
Liquid soap and detergent, shampoo	**Tap water**	**Ultra-pure (bi-distilled or deionized) water**
Salad dressing, mayonnaise	**Petroleum naptha, dish washing agent in water**	**Ethanol**
Suntan lotion	**Tap water**	**Ethanol**
Spirits	**Tap water**	**Ultra-pure (bi-distilled or deionized) water**
Grape juice, syrup	**Warm tap water**	**Ultra-pure (bi-distilled or deionized) water**
Milk*	**Tap water, enzymatic lab cleaner**	**Ultra-pure (bi-distilled or deionized) water**

***NOTE: Do not introduce ethanol or other alcohols into instrument without first flushing all milk products from instruments.**