Designation: D1475 – 13

Standard Test Method For Density of Liquid Coatings, Inks, and Related Products[1]

This standard is issued under the fixed designation D1475; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This test method covers the measurement of density of paints, inks, varnishes, lacquers, and components thereof, other than pigments, when in fluid form.

1.2 For higher precision when working with nonpigmented materials (drying oils, varnishes, resins and related materials), Test Method D1963 can be used to determine specific gravity and, thence, density.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3.1 *Exception*—The values for density are to be stated in inch-pound units.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific precaution statement is given in 8.1.1.1.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1193 Specification for Reagent Water

D1963 Test Method for Specific Gravity of Drying Oils, Varnishes, Resins, and Related Materials at 25/25°C (Withdrawn 2004)[3]

D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter

E180 Practice for Determining the Precision of ASTM Methods for Analysis and Testing of Industrial and Specialty Chemicals (Withdrawn 2009)[3]

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions:*

3.1.1 *density, n*—the mass of a unit volume of a material at a specified temperature. In this method, it is expressed as the weight in grams per millilitre, or as the weight in pounds avoirdupois of one U. S. gallon, of the liquid at the specified temperature; in the absence of other temperature specification, 25°C is assumed.

3.1.2 *specific gravity (relative density), n*—the ratio of the mass of a unit volume of a material at a stated temperature to the mass of the same volume of distilled water at the same temperature.

4. Summary of Test Method

4.1 The accurately known absolute density of distilled water at various temperatures (Table 1) is used to calibrate the volume of a container. The weight of the paint liquid contents of the same container at the standard temperature (25°C) or at an agreed-upon temperature is then determined and density of the contents calculated in terms of grams per millilitre, or pounds per gallon at the specified temperature.

5. Significance and Use

5.1 Density is weight per unit volume. It is a key property in the identification, characterization, and quality control of a wide range of materials. Density measurements in terms of weight per gallon are commonly used to check paint quality. If the density is not within specification, there is a good chance that there was a mischarge or other serious problem.

5.2 This test method is suitable for the determination of density of paint and related products and components when in liquid form. It is particularly applicable when the fluid has too high a viscosity or when a component is too volatile for a density balance determination.

5.3 This test method provides for the maximum accuracy required for hiding power determinations. It is equally suitable for work in which less accuracy is required, by ignoring the

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[1] This test method is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.24 on Physical Properties of Liquid Paints and Paint Materials.

Current edition approved Nov. 1, 2013. Published December 2013. Originally approved in 1957. Last previous edition approved in 2012 as D1475 – 98 (2012). DOI: 10.1520/D1475-13.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

TABLE 1 Absolute Density of Water, g/mL

°C	Density
15	0.999127
16	0.998971
17	0.998772
18	0.998623
19	0.998433
20	0.998231
21	0.998020
22	0.997798
23	0.997566
24	0.997324
25	0.997072
26	0.996811
27	0.996540
28	0.996260
29	0.995972
30	0.995684

directions for recalibration and consideration of temperature differentials, and using as the container a "weight-per-gallon" cup.

5.4 Automatic equipment for measuring density is available (see Test Method D4052) from several manufacturers. Such apparatus has been used for resins and latices as well as for oils and solvents. Before such equipment is used for a given product, results must be checked very carefully. Particularly with paints, inks, and resins, there are possibilities of gumming, fouling, and other interferences with operation.

6. Interferences

6.1 Highly viscous materials may entrap air and give erroneous low density values.

6.2 Paint or ink liquids may be trapped in the ground glass or metal joints of the pieces of apparatus and give erroneous, high density values.

7. Apparatus

7.1 *Cup or Pycnometer*—Any metal weight-per-gallon cup or glass pycnometer may be used, provided that it may be filled readily with a viscous liquid, adjusted to exact volume, covered to exclude loss of volatile matter, and readily cleaned.

NOTE 1—For materials that contain solvents that evaporate rapidly, a glass pycnometer of the weld type, with a narrow stopper and a cover should be used.

7.2 *Thermometers,* graduated in 0.1°C, such as are supplied with glass pycnometers.

7.3 *Constant-Temperature Bath,* held at 25 ± 0.1°C is desirable.

7.4 *Laboratory Analytical Balance.*

NOTE 2—The usual weight-per-gallon cup and similar specialized pycnometers may have filled weights that exceed the capacity of the usual laboratory analytical balance. In such cases, use of a hanging pan, triple-beam balance, with scales graduated to 0.01 g has been found to provide results the mean of which was consistent with the overall precision and accuracy of the method.

7.5 *Desiccator and Desiccated Balance,* or a room of reasonably constant temperature and humidity are desirable.

8. Calibration of Cup or Pycnometer

8.1 Determine the volume of the container at the specified temperature by employing the following steps:

8.1.1 Clean and dry the container and bring it to constant weight. Chromic acid (see 8.1.1.1) or other effective glass cleaner and nonresidual solvents may be used with glass containers and solvents with metal containers. For maximum accuracy, continue rinsing, drying, and weighing until the difference between two successive weighings does not exceed 0.001 % of the weight of the container. Fingerprints on the container will change the weight and must be avoided. Record the weight, *M*, in grams.

8.1.1.1 **Warning—**Chromic acid cleaning solution is corrosive to skin, eyes and mucous membranes and can cause severe burns. Avoid contact with eyes, skin or clothing. In making dilute solution, always add acid to water with care. Chromic acid cleaning solution is a strong oxidizer. Avoid contact with organic or reducing substances as a fire could results. See supplier's Material Safety Data Sheet for further information. Other cleaners are much safer and may be equally effective.

8.1.2 Fill the container with reagent water conforming to Type II of Specification D1193 at a temperature somewhat below that specified. Cap the container, leaving the overflow orifice open. Immediately remove excess overflowed water or water held in depressions by wiping dry with absorbent material. Avoid occluding air bubbles in the container.

8.1.3 Bring the container and contents to the specified temperature using the constant-temperature bath or room if necessary. This will cause further slight flow of water from the overflow orifice due to the expansion of the water with the rise of the temperature.

8.1.4 Remove the excess overflow by wiping carefully with absorbent material, avoiding wicking of water out of orifice, and immediately cap the overflow tube where such has been provided. Dry the outside of the container, if necessary, by wiping with absorbent material. Do not remove overflow that occurs subsequent to the first wiping after attainment of the desired temperature (Note 3). Immediately weigh the filled container to the nearest 0.001 % of its weight (Note 4). Record this weight, *N*, in grams.

NOTE 3—Handling the container with bare hands will increase the temperature and cause more overflow from the overflow orifice, and will also leave fingerprints; hence, handling only with tongs and with hands protected by clean, dry, absorbent material is recommended.

NOTE 4—Immediate and rapid weighing of the filled container is recommended here to minimize loss of weight due to evaporation of the water through orifices, and from overflow subsequent to the first wiping after attainment of temperature where this overflow is not retained by a cap.

8.1.5 Calculate the container volume as follows:

$$V = (N - M)/\rho \quad (1)$$

where:

V = volume of container, mL,
N = weight of container and water, g (8.1.4),
M = weight of dry container, g (8.1.1), and
ρ = absolute density of water at specified temperature, g/mL (see Table 1).

8.1.6 Obtain the mean of at least three determinations.

9. Procedure

9.1 Repeat the steps in Section 8, but do two determinations rather than three. Substitute the sample for the reagent water in Section 8 and a suitable nonresidual solvent for the acetone or alcohol (see Note 5). Record the weight of the filled container, *W*, and the weight of the empty container, *w*, in grams.

NOTE 5—Trapping of paint or ink liquids in ground glass or metal joints is likely to result in high values of density that appear to increase with the viscosity and density of the material; such errors should be minimized by firm seating of the joints.

NOTE 6—Trapping of air bubbles results in low values for density. The tendency to trap air increases with increasing viscosity. Specimens should not be tested if they contain bubbles or foam. Slow stirring, standing, or the application of a vacuum may remove bubbles. If these do not work, a dilution may be necessary (see Appendix X1).

9.2 Calculate the density in grams per millilitre as follows:

$$D_m = (W - w)/V \tag{2}$$

where:

D_m = density, g/mL.

9.3 Calculate the density in pounds per gallon as follows:

$$D = (W - w)K/V \tag{3}$$

where:

D = density, lb/gal,
K = 8.3454 (Note 7), and
V = volume of container, mL (see 8.1.6).

NOTE 7—The factor *K*, 8.3454, is calculated from volume-weight relationship as follows:

$$8.345404 = [(2.54)^{3A} \times (231.00)^{B}]/(453.59237)^{C}$$

[A] $(2.54)^3$ is the conversion factor for millilitres to cubic inches.
[B] 231.00 is the conversion factor for cubic inches to gallons.
[C] 453.59237 is the conversion factor for grams to pounds.

10. Report

10.1 In reporting the density, state the test temperature to the nearest 0.1°C, the units, and the value calculated to three places (for example, *D* = x.xxx lb/gal at 25°C); state the mean, the range, and the number of replicate determinations.

11. Precision and Bias

11.1 *Paints*—The precision estimates are based on an interlaboratory study in which one operator in each of six different laboratories analyzed in duplicate on two different days five samples of paint ranging in density from 8.5 to 12.5 lb/gal. The results were analyzed statistically in accordance with Practice E180. The within-laboratory coefficient of variation was found to be 0.20 % relative with 25 df and the between-laboratory coefficient of variation was 0.61 % relative with 20 df. Based on these coefficients, the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

11.1.1 *Repeatability*—Two results, each the mean of duplicate determinations, obtained by the same operator on different days should be considered suspect if they differ by more than 0.6 % relative.

11.1.2 *Reproducibility*—Two results, each the mean of duplicate determinations, obtained by operators in different laboratories should be considered suspect if they differ by more than 1.8 % relative.

11.2 *Inks*—A separate interlaboratory study of this test method was carried out for inks. In this study, one operator in each of seven laboratories made three determinations on four different paste ink samples. Paste inks were chosen because their viscosities are high and they would be expected to provide a difficult test for the method. The inks represented a density range of 8.4 to 8.9 lb/gal and exhibited viscosities ranging from a very soft news black to a relatively heavy sheet-fed offset ink. The results were analyzed statistically in accordance with Practice E691. The within-laboratory standard deviation was 0.030 lb/gal and the pooled laboratory standard deviation was 0.045 lb/gal. Based on these values, the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

11.2.1 *Repeatability*—Two results obtained by the same operator should be considered suspect if they differ by more than 0.084 lb/gal (1 %).

11.2.2 *Reproducibility*—Two results obtained by operators in different laboratories should be considered suspect if they differ by more than 0.125 lb/gal (1.5 %).

11.3 *Bias (Paint and Inks)*—Since there is no accepted reference material, bias cannot be determined.

12. Keywords

12.1 density; pycnometer; weight per gallon; weight per gallon cup

APPENDIXES

(Nonmandatory Information)

X1. DILUTING OF A MATERIAL TO IMPROVE AIR RELEASE

X1.1 To reduce viscosity and improve air release, a known weight of a material that traps air may be diluted with a known weight of a solvent or another diluent of known density. After careful blending to achieve homogeneity and release air, the density of the diluted material is measured by the technique described in this test method. The following equation may be used to calculate the density of the original material:

$$D_o = \frac{W_o}{\frac{W_o + W_d}{D_{d1}} - \frac{W_d}{D_{d2}}} \quad (X1.1)$$

where:

D_o = density of original material,
D_{d1} = density diluted measured in test,
D_{d2} = density diluent,
W_o = original weight, and
W_d = diluent weight.

X2. CENTRIFUGING OF MATERIAL TO REMOVE EXCESS AIR

X2.1 To reduce the variation in the density method, air is removed from the specimen by centrifuging the material, resulting in greater homogeneity between replicates. This greatly improves reproducibility and repeatability and results in slightly higher density readings.

X2.2 Apparatus

X2.2.1 *Centrifuge,* capable of a maximum of 4000 r/min[4],

X2.2.2 *Standard Density Cup,*

X2.2.3 *Thermometer.*

X2.3 Procedure

X2.3.1 Fill the centrifuge tube to the top (approximately 150 % of the density cup volume), adjust to the recommended temperature of 25°C ± 1. Place the tube in the centrifuge.

X2.3.2 Turn on the centrifuge and set the speed control to 2/3 power to attain a speed of 2700 to 3000 r/min.

X2.3.3 Continue to run for 15 to 20 s, stop the centrifuge, applying the brake as needed.

X2.3.4 Pour off the top foam layer.

X2.3.5 Transfer the specimen to a calibrated density cup and follow the procedure under Section 9.

X2.4 Precision and Bias

X2.4.1 An interlaboratory study in one company showed that the centrifuge procedure resulted in a 2-fold improvement in repeatability and reproducibility, as well as better accuracy.

X2.4.1.1 *Repeatability*—Two results obtained by the same operator should be considered suspect if they differ by more than 0.0054 g/mL (0.045 lb/gal).

X2.4.1.2 *Reproducibility*—Two results obtained by operators in different laboratories should be considered suspect if they differ by more than 0.0080 g/L (0.067 lb/gal).

[4] The centrifuge used in this study was a Dynac II.