Designation: D3505 – 18

Standard Test Method for Density or Relative Density of Pure Liquid Chemicals[1]

This standard is issued under the fixed designation D3505; 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 describes a simplified procedure for the measurement of density or relative density of pure liquid chemicals for which accurate temperature expansion functions are known. It is restricted to liquids having vapor pressures not exceeding 79 993 Pascal (0.800 bar, 600 mm Hg (0.789 atm) at the equilibration temperature, and having viscosities not exceeding 15 cSt at 20°C.

1.2 Means are provided for reporting results in the following units:

Density g/cm^3 at 20°C
Density g/mL at 20°C
Relative density 20°C/4°C
Relative density 15.56°C/15.56°C

NOTE 1—This test method is based on the old definition of 1 L = 1.000028 dm^3 (1 mL = 1.000028 cm^3). In 1964 the General Conference on Weights and Measures withdrew this definition of the litre and declared that the word "litre" was a special name for the cubic decimetre, thus making 1 mL = 1 cm^3 exactly.

NOTE 2—An alternative method for determining relative density of pure liquid chemicals is Test Method D4052.

1.3 In determining the conformance of the test results using this method to applicable specifications, results shall be rounded off in accordance with the rounding-off method of Practice E29.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* Specific hazard statements are given in Section 8, Hazards.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1193 Specification for Reagent Water
D1555 Test Method for Calculation of Volume and Weight of Industrial Aromatic Hydrocarbons and Cyclohexane
D3437 Practice for Sampling and Handling Liquid Cyclic Products
D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
D6809 Guide for Quality Control and Quality Assurance Procedures for Aromatic Hydrocarbons and Related Materials
E1 Specification for ASTM Liquid-in-Glass Thermometers
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *Other Document:*

OSHA Regulations, 29 CFR paragraphs 1910.1000 and 1910.1200[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *density, n*—the mass of material per unit volume at a given temperature called the "reference temperature." Weight corrected to a standard acceleration of gravity and corrected for the buoyant effect of air is used to measure mass. This method specifies the use of a beam balance to determine weight so that no correction for variation in acceleration of gravity is necessary. When a torsion or spring balance is used, such correction must be applied.

[1] This test method is under the jurisdiction of ASTM Committee D16 on Aromatic, Industrial, Specialty and Related Chemicals and is the direct responsibility of Subcommittee D16.04 on Instrumental Analysis.

Current edition approved Feb. 15, 2018. Published May 2018. Originally approved in 1976. Last previous edition approved in 2012 as D3505 – 12$^{\varepsilon 1}$. DOI: 10.1520/D3505-18.

[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] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.

***A Summary of Changes section appears at the end of this standard**

3.1.2 *relative density, n*—the ratio of the density of the material at reference temperature "*t*" to the density of pure water, in consistent units, at reference temperature t_2. It is common practice to use reference temperature t_1 equal to t_2.

3.1.2.1 Since the mass of water at 4°C is very close to 1 g/mL or 1 g/cm^3, it is common practice to set the reference temperature t_2 for water at 4°C. When this is done and the density of the material is given in grams per millilitre, or grams per cubic centimetre, the value of density is very nearly identical to the value for relative density. Thus, density at 20°C in g/cm^3 or g/mL, is nearly identical with relative density 20°C/4°C.

4. Summary of Test Method

NOTE 3—See Appendix X1 for details on the method and derivation of formulas.

4.1 For materials listed in Table 1 the sample is drawn into a weighed and calibrated bicapillary pycnometer. The filler pycnometer is allowed to come to equilibrium at any convenient temperature between 10 and 30°C. The equilibrium temperature is measured to the nearest 0.02°C. The weight is determined using a beam balance. The density, relative density, or commercial density at the desired reference temperature is then calculated from the sample weight, a calibration factor proportional to an equal volume of water, and a multiplier which corrects for the buoyancy of air and the change in volume of the pycnometer and the sample due to deviation from the chosen reference temperature.

4.2 For liquids not listed in Table 1, the sample is equilibrated at the desired reference temperature, usually 20°C or 15.56°C, the density, relative density, or commercial density is then calculated from the sample weight, a calibration factor proportional to an equal volume of water and a term which corrects for the buoyancy of air. In the case of volatile liquids such as pentane, the time between reading of volume at the equilibrium temperature and weighing must not be prolonged, otherwise weight loss through evaporation may result in errors.[4]

5. Significance and Use

5.1 This test method is suitable for setting specification, for use as an internal quality control tool, and for use in development or research work on industrial aromatic hydrocarbons and related materials. In addition to the pure liquid chemicals for which expansion functions are known, it may also be used for liquids for which temperature expansion data are not available, or for impure liquid chemicals if certain limitations are observed. Information derived from this test can be used to describe the relationship between weight and volume.

6. Apparatus

6.1 *Pycnometer,* 9 to 10-mL capacity, conforming to the dimensions given in Fig. 1, constructed of borosilicate glass, and having a total weight not exceeding 30 g.

6.2 *Bath,* having a depth of at least 300 mm, capable of being maintained constant to ±0.02°C at any convenient temperature between 10°C and 30°C. Provide a support for the pycnometer (see Fig. 2) constructed of any suitable noncorrosive metal.

NOTE 4—If the laboratory air temperature does not vary more than 0.02°C during temperature equilibration a special bath is not needed.

6.3 *Bath Thermometer,* an ASTM Precision Thermometer, having a range from −8 to +32°C and conforming to the requirements for Thermometer 63C as prescribed in Specification E1.

7. Reagents and Materials

7.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[5] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Type I of Specification D1193.

8. Hazards

8.1 Consult current OSHA regulations, supplier's Safety Data Sheets, and local regulations, for all materials used in this test method. Especially be careful when using hot chromic acid solution.

9. Sampling and Handling

9.1 Sample the material in accordance with Practice D3437.

10. Preparation of Apparatus

10.1 *Acid Cleaning,* for use when the pycnometer is to be calibrated or when liquid fails to drain cleanly from the walls of the pycnometer or its capillary. Thoroughly clean with hot chromic acid solution and rinse well with reagent water conforming to Type I of Specification D1193. Other safer, nontoxic, and suitable cleaning procedures may be used. Dry at 105 to 110°C for at least 1 h, preferably with a slow current of filtered air passing through the pycnometer.

10.2 *Solvent Cleaning,* for use between determinations. Rinse with toluene and then with anhydrous acetone, drying with a filtered stream of dry air.

11. Calibration of Apparatus

11.1 Using the procedure described in Section 12, determine the weight of freshly boiled reagent water conforming to Type I of Specification D1193 held by the pycnometer with the water

[4] For a more complete discussion on the use of this design pycnometer, see Lipken, Davidson, Harvey and Kurtz, *Industrial Engineering Chemistry, Analytical Edition*; Vol 16, 1944, p. 55.

[5] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For Suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

TABLE 1 PART I 20°C Reference Temperature Multiplier, F20, for use in Computing Density, 13.1

CHOOSE A MULTIPLIER FOR THE MATERIAL BEING MEASURED CORRESPONDING TO THE BATH TEMPERATURE AT WHICH THE PYCNOMETER EQUILIBRATED.

TEMP DEGC	BENZENE	TOLUENE	MIXED XYLENES	O-XYLENE	M-XYLENE	P-XYLENE	STYRENE	CYCLO-HEXANE
10.0	0.98822	0.98941	0.99028	0.99052	0.99028	0.99011	0.99029	0.98912
10.2	0.98845	0.98962	0.99047	0.99070	0.99047	0.99030	0.99048	0.98933
10.4	0.98868	0.98983	0.99066	0.99089	0.99066	0.99049	0.99066	0.98953
10.6	0.98891	0.99003	0.99085	0.99107	0.99085	0.99069	0.99085	0.98973
10.8	0.98914	0.99024	0.99104	0.99126	0.99104	0.99088	0.99104	0.98993
11.0	0.98937	0.99045	0.99123	0.99144	0.99123	0.99107	0.99123	0.99013
11.2	0.98960	0.99066	0.99142	0.99163	0.99142	0.99126	0.99142	0.99034
11.4	0.98982	0.99086	0.99161	0.99181	0.99161	0.99146	0.99161	0.99054
11.6	0.99005	0.99107	0.99179	0.99200	0.99179	0.99165	0.99180	0.99075
11.8	0.99028	0.99128	0.99198	0.99218	0.99198	0.99184	0.99199	0.99095
12.0	0.99051	0.99148	0.99217	0.99237	0.99217	0.99204	0.99218	0.99116
12.2	0.99074	0.99169	0.99236	0.99255	0.99236	0.99223	0.99237	0.99136
12.4	0.99097	0.99190	0.99255	0.99274	0.99255	0.99242	0.99256	0.99157
12.6	0.99120	0.99211	0.99274	0.99292	0.99274	0.99262	0.99275	0.99178
12.8	0.99144	0.99231	0.99293	0.99311	0.99293	0.99281	0.99294	0.99199
13.0	0.99167	0.99252	0.99312	0.99329	0.99312	0.99300	0.99313	0.99220
13.2	0.99190	0.99273	0.99331	0.99348	0.99331	0.99320	0.99332	0.99240
13.4	0.99213	0.99294	0.99350	0.99367	0.99350	0.99339	0.99351	0.99261
13.6	0.99236	0.99315	0.99369	0.99385	0.99369	0.99358	0.99370	0.99282
13.8	0.99259	0.99335	0.99389	0.99404	0.99389	0.99378	0.99390	0.99303
14.0	0.99282	0.99356	0.99408	0.99422	0.99408	0.99397	0.99409	0.99325
14.2	0.99305	0.99377	0.99427	0.99441	0.99427	0.99417	0.99428	0.99346
14.4	0.99329	0.99398	0.99446	0.99460	0.99446	0.99436	0.99447	0.99367
14.6	0.99352	0.99419	0.99465	0.99478	0.99465	0.99456	0.99466	0.99388
14.8	0.99375	0.99440	0.99484	0.99497	0.99484	0.99475	0.99485	0.99410
15.0	0.99398	0.99461	0.99503	0.99516	0.99503	0.99495	0.99504	0.99431
15.2	0.99421	0.99481	0.99522	0.99534	0.99522	0.99514	0.99523	0.99452
15.4	0.99445	0.99502	0.99541	0.99553	0.99541	0.99534	0.99542	0.99474
15.6	0.99468	0.99523	0.99561	0.99572	0.99561	0.99553	0.99562	0.99496
15.8	0.99491	0.99544	0.99580	0.99590	0.99580	0.99573	0.99581	0.99517
16.0	0.99515	0.99565	0.99599	0.99609	0.99599	0.99592	0.99600	0.99539
16.2	0.99538	0.99586	0.99618	0.99628	0.99618	0.99612	0.99619	0.99561
16.4	0.99561	0.99607	0.99637	0.99646	0.99637	0.99631	0.99638	0.99582
16.6	0.99585	0.99628	0.99657	0.99665	0.99657	0.99651	0.99658	0.99604
16.8	0.99608	0.99649	0.99676	0.99684	0.99676	0.99670	0.99677	0.99626
17.0	0.99632	0.99670	0.99695	0.99703	0.99695	0.99690	0.99696	0.99648
17.2	0.99655	0.99691	0.99714	0.99721	0.99714	0.99710	0.99715	0.99670
17.4	0.99679	0.99712	0.99734	0.99740	0.99734	0.99729	0.99734	0.99692
17.6	0.99702	0.99733	0.99753	0.99759	0.99753	0.99749	0.99754	0.99715
17.8	0.99726	0.99754	0.99772	0.99778	0.99772	0.99768	0.99773	0.99737
18.0	0.99749	0.99775	0.99791	0.99797	0.99791	0.99788	0.99792	0.99759
18.2	0.99773	0.99796	0.99811	0.99815	0.99811	0.99808	0.99811	0.99781
18.4	0.99796	0.99817	0.99830	0.99834	0.99830	0.99827	0.99831	0.99804
18.6	0.99820	0.99838	0.99849	0.99853	0.99849	0.99847	0.99850	0.99826
18.8	0.99843	0.99859	0.99869	0.99872	0.99869	0.99867	0.99869	0.99849
19.0	0.99867	0.99880	0.99888	0.99891	0.99888	0.99886	0.99888	0.99871
19.2	0.99890	0.99901	0.99907	0.99910	0.99907	0.99906	0.99908	0.99894
19.4	0.99914	0.99922	0.99927	0.99928	0.99927	0.99926	0.99927	0.99917
19.6	0.99938	0.99943	0.99946	0.99947	0.99946	0.99946	0.99946	0.99939
19.8	0.99961	0.99964	0.99966	0.99966	0.99966	0.99965	0.99966	0.99962
20.0	0.99985	0.99985	0.99985	0.99985	0.99985	0.99985	0.99985	0.99985