



Designation: D1555M – 16

# Standard Test Method for Calculation of Volume and Weight of Industrial Aromatic Hydrocarbons and Cyclohexane [Metric]<sup>1</sup>

This standard is issued under the fixed designation D1555M; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This standard is for use in calculating the weight and volume of benzene, toluene, mixed xylenes, styrene, ortho-xylene, meta-xylene, para-xylene, cumene, ethylbenzene, 148.9 to 176.7°C and 176.7 to 204.4°C aromatic hydrocarbons, and cyclohexane. A method is given for calculating the volume at 15°C and 20°C from an observed volume at  $t^\circ\text{C}$ . Table 1 lists the density *in vacuo* at 60°F for chemicals used to develop the relationship. Densities (or weights) “*in vacuo*” represent the true density (or weight) if measured in a vacuum without the buoyancy effect of air acting on the liquid. It is representative of the actual amount of product present. Densities (or weights) “*in air*” represent what would actually be measured on a scale. The difference is on the order of 0.13 %. Modern densitometers measure density *in vacuo* and the ASTM recommends the use of *in vacuo* densities (or weights).

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

1.2.1 A complete inch-pound unit companion standard has been developed in Test Method D1555.

1.3 *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.*

1.4 *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.*

<sup>1</sup> 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 D16.01 on Benzene, Toluene, Xylenes, Cyclohexane and Their Derivatives.

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## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

D1217 Test Method for Density and Relative Density (Specific Gravity) of Liquids by Bingham Pycnometer

D1555 Test Method for Calculation of Volume and Weight of Industrial Aromatic Hydrocarbons and Cyclohexane

D3505 Test Method for Density or Relative Density of Pure Liquid Chemicals

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

### 2.2 Other Documents:

American Petroleum Society Research Project 44<sup>3</sup>

Patterson, J. B., and Morris, E. C., *Metrologia*, 31, 1994, pp. 277-288

TRC Thermodynamic Tables—Hydrocarbons, NSRDS-NIST 75-121, Supplement No. 121, April 30, 2001<sup>4</sup>

## 3. Significance and Use

3.1 This test method is suitable for use in calculating weights and volumes of the products outlined in Section 1. The information presented in this method can be used for determining quantities of the above-stated aromatic hydrocarbons in tanks, shipping containers, etc.

## 4. Basic Data

4.1 Densities of materials should be determined by measurement (see Section 7). Densities of pure materials at 60°F may be estimated from densities furnished by NSRDS-NIST 75-121 (National Standard Reference Data Series—National Institute of Standards and Technology).

4.2 The VCF (Volume Correction Factor) equations provided below are derived from the Volume Correction implementation procedures presented in Method D1555.

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

<sup>3</sup> “Selected Values of Properties of Hydrocarbons and Related Compounds,” prepared by American Petroleum Institute Research Project 44 at the Chemical Thermodynamics Center, Department of Chemistry, Texas A&M, College Station, TX.

<sup>4</sup> Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, <http://www.nist.gov>.

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

**TABLE 1 Physical Properties**

Product	Freezing Point °C	Boiling Point °C	Density <i>in Vacuo</i> at 15°C g/cc <sup>A,B,C</sup>	Density <i>in Air</i> at 15°C g/cc <sup>D</sup>	Density <i>in Vacuo</i> at 20°C g/cc <sup>C,E,F</sup>	Density <i>in Air</i> at 20°C g/cc <sup>D</sup>
Benzene	5.6	80.1	0.88431	0.88324	0.87908	0.87801
Cumene	-96.1	152.4	0.86586	0.86479	0.86160	0.86053
Cyclohexane	6.6	80.7	0.78317	0.78209	0.77849	0.77741
Ethylbenzene	-95.0	136.2	0.87126	0.87019	0.86685	0.86578
Styrene	-30.6	145.2	0.91028	0.90922	0.90586	0.90480
Toluene	-95.0	110.6	0.87147	0.87040	0.86686	0.86579
<i>m</i> -Xylene	-47.9	139.1	0.86831	0.86724	0.86408	0.86301
<i>o</i> -Xylene	-25.2	144.4	0.88387	0.88280	0.87968	0.87861
<i>p</i> -Xylene	13.3	138.3	0.86503	0.86396	0.86076	0.85969

<sup>A</sup> Obtained from Method D1555 – 04a by multiplying the chemical's 60°F density by the volume correction factor for 59°F.

<sup>B</sup> Specific Gravity at 15°C is not presented in this table as it is unnecessary to this standard. If needed, divide 15°C density in g/cc by 0.999102 g/cc. See Appendix X1.

<sup>C</sup> g/cc can be converted to kg/1000L or kg/m<sup>3</sup> by multiplying by 1000.

<sup>D</sup> Produced using the equation: Density g/mL<sub>in air</sub> = (1.000149926 × Density g/mL<sub>in vacuo</sub> – 0.001199407795) and rounding to 5 decimal places. See Appendix X2.

<sup>E</sup> Obtained from Method D1555 - 04a by multiplying the chemical's 60°F density by the volume correction factor for 68°F.

<sup>F</sup> Specific Gravity at 20°C is not presented in this table as it is unnecessary to this standard. If needed, divide 20°C density in g/cc by 0.998206 g/cc. See Appendix X1.

4.3 The former VCF tables were based on data for compounds used in American Petroleum Institute Research Project 44 for which the purity is not clearly defined, but were reported to be usable for materials in the ranges indicated in Table 2. The data supporting this conclusion appears to be unavailable at the present time; however there is no reason to change this recommendation. If, depending on the composition of the impurities, there is reason to suspect that the VCF implementation procedures presented below do not apply to a particular impure product, a separate implementation procedure should be independently determined. This may be done by measuring the density of a representative sample at different temperatures throughout the expected working temperature range, regressing the data to obtain a temperature/density equation that best reproduces the observed data, and then dividing the constants of the temperature/density equation by the calculated density at 15°C and 20°C.

## 5. Volume Correction Factor Implementation Procedure

5.1 The following general equation is used to generate the Volume Correction Factors:

$$VCF = \frac{a + b(1.8t + 32) + c(1.8t + 32)^2 + d(1.8t + 32)^3 + e(1.8t + 32)^4}{VCF^{xx}} \quad (1)$$

**TABLE 2 Application Range of Implementation Procedure**

Impure Products	Range
Benzene	95 to 100%
Cumene	95 to 100%
Cyclohexane	90 to 100%
Ethylbenzene	95 to 100%
Styrene	95 to 100%
Toluene	95 to 100%
Mixed Xylenes	All proportions
<i>m</i> -Xylene	95 to 100%
<i>o</i> -Xylene	95 to 100%
<i>p</i> -Xylene	94 to 100%
148.9-176.7°C Aromatic Hydrocarbons	All proportions
176.7-204.4°C Aromatic Hydrocarbons	All proportions

where:

$$t = \text{temperature in } ^\circ\text{C},$$

$$VCF^{xx} = VCF^{59^\circ\text{F}} \text{ or } VCF^{68^\circ\text{F}}$$

constants a through e and VCF<sup>xx</sup> are specific to each compound (obtained from Method D1555 and presented in Table 3).

5.1.1 Temperature may be entered in tenths of a degree Celsius.

5.1.2 The calculated result is rounded to the appropriate significant figures if it is to be reported and not rounded if to be used in another calculation. No intermediate rounding or truncation should be done.

5.1.3 The equations are valid for liquid product up to 60°C (65.5°C for *p*-xylene).

5.1.4 This implementation procedure replaces the printed tables of previous editions of this Method for determining VCFs. **The implementation procedure is the Standard, not the printed tables.** However, the printed tables are provided in 0.5°C increments for the user's convenience (Tables 4 and 5).

## 6. Use of the Implementation Procedure

6.1 *Convert Volume to 15°C or 20°C*—Enter the appropriate equation with the temperature to the nearest 0.1 degree Celsius at which the bulk volume was measured (temperature *t*). Multiply the bulk volume measurement at temperature *t* by the VCF.

6.1.1 *Example 1*—What is the volume at 15°C and at 20°C of a tank car of *p*-xylene whose volume was measured to be 35,129 liters at a mean temperature of 31.7°C?

For 15°C, enter Eq 1 with 31.7°C and the appropriate constants from Table 3 to calculate a VCF of 0.983411909349613. Multiply the volume at 31.7°C by the volume correction factor 0.983411909349613 to obtain the volume at 15°C.

$$35129 \cdot 0.983411909349613 = 34,546.2769635425 \text{ or } 34546 \text{ liters}$$

If this value is to be reported, it may be rounded appropriately. The unrounded intermediate value should be used for additional calculations.

**TABLE 3 VCF Constants**

Product	a	b	c	d	e	VCF <sup>59F</sup>	VCF <sup>68F</sup>
Benzene	1.038382492	-6.2307 × 10 <sup>-4</sup>	-2.8505 × 10 <sup>-7</sup>	1.2692 × 10 <sup>-10</sup>	0	1.00066	0.99474
Cumene	1.032401114	-5.3445 × 10 <sup>-4</sup>	-9.5067 × 10 <sup>-8</sup>	3.6272 × 10 <sup>-11</sup>	0	1.00055	0.99563
Cyclohexane	1.039337296	-6.4728 × 10 <sup>-4</sup>	-1.4582 × 10 <sup>-7</sup>	1.03538 × 10 <sup>-10</sup>	0	1.00066	0.99468
Ethylbenzene	1.033346632	-5.5243 × 10 <sup>-4</sup>	8.37035 × 10 <sup>-10</sup>	-1.2692 × 10 <sup>-9</sup>	5.55061 × 10 <sup>-12</sup>	1.00056	0.99550
Styrene	1.032227515	-5.3444 × 10 <sup>-4</sup>	-4.4323 × 10 <sup>-8</sup>	0	0	1.00054	0.99568
Toluene	1.035323647	-5.8887 × 10 <sup>-4</sup>	2.46508 × 10 <sup>-9</sup>	-7.2802 × 10 <sup>-12</sup>	0	1.00059	0.99529
<i>m</i> -Xylene <sup>A</sup>	1.031887514	-5.2326 × 10 <sup>-4</sup>	-1.3253 × 10 <sup>-7</sup>	-7.35960 × 10 <sup>-11</sup>	0	1.00054	0.99567
<i>o</i> -Xylene	1.031436449	-5.2302 × 10 <sup>-4</sup>	-2.5217 × 10 <sup>-9</sup>	-2.13840 × 10 <sup>-10</sup>	0	1.00053	0.99579
<i>p</i> -Xylene	1.032307000	-5.2815 × 10 <sup>-4</sup>	-1.8416 × 10 <sup>-7</sup>	1.89256 × 10 <sup>-10</sup>	0	1.00054	0.99560
148.9-176.7°C	1.031118000	-5.1827 × 10 <sup>-4</sup>	-3.5109 × 10 <sup>-9</sup>	-1.98360 × 10 <sup>-11</sup>	0	1.00052	0.99585
176.7-204.4°C	1.029099000	-4.8287 × 10 <sup>-4</sup>	-3.7692 × 10 <sup>-8</sup>	3.78575 × 10 <sup>-11</sup>	0	1.00049	0.99610

<sup>A</sup> and Mixed Xylenes.

For 20°C, enter **Eq 1** with 31.7°C and the appropriate constants for **Table 3** to calculate a VCF of 0.98829143409066. Multiply the volume at 31.7°C by the volume correction factor 0.98829143409066 to obtain the volume at 15°C.

$$34,546.2769635425 \text{ liters} * 0.86352964240057$$

$$= 29831.7341925989 \text{ kg in air}$$

$$35129 \cdot 0.98829143409066 = 34,717.6897881708 \text{ or } 34,718 \text{ liters}$$

**6.2 Converting Volume to Weight for Chemicals Listed in Table 1**—Convert the measured bulk to liters at 15°C or 20°C as described in **6.1**. Determine the density (all weights *in vacuo*) at 15°C or 20°C in grams per milliliter (equivalent to grams per cubic centimeter and kilograms per liter) as described in Section **7**. To obtain the density *in air* at 15°C or 20°C, use the equation described in footnote D of **Table 1** or refer to **Appendix X2**:

$$D_{\text{g/mL}_{in\ air}} = [1.00014926 \cdot D_{\text{g/mL}_{in\ vacuo}} - 0.00119940779543]$$

To obtain the weight multiply the density by the volume to obtain the weight *in vacuo* or *in air*.

**6.2.1 Example 2**—The density of the *p*-xylene in Example 1 has been determined to be 0.8646 g/mL (*in vacuo*) at 15°C, the density *in air* is:

$$D_{in\ air} = [1.00014926 \cdot 0.8646 - 0.00119940779543] \\ = 0.86352964240057 \text{ g/mL}$$

The weight of the net volume is thus:

$$34,546.2769635425 \text{ liters} * 0.8646 \\ = 298687110.626788 \text{ kg in vacuo}$$

If this value is to be reported, the value can be rounded as needed by the user. The unrounded intermediate value should be used for additional calculations.

A similar procedure would be followed for a reference density of 20°C.

## 7. Density Determination

**7.1** Density determinations may be carried out by any procedure known to be reliable to at least 4 digits. Test Methods **D1217**, **D3505**, and **D4052** are suitable and are written to give density *in vacuo*. They should be used with caution, however, as they may be using older data than that upon which this standard is based upon.

## 8. Precision and Bias

**8.1** Since this is a calculation method, no precision and bias statement is required.

## 9. Keywords

9.1 aromatic; benzene; calculation; conversion; cumene; density; ethylbenzene; *in air*; *in vacuo*; *m*-xylene; mixed xylene; *o*-xylene; *p*-xylene; specific gravity; styrene; 148.9 to 176.7°C aromatic hydrocarbons; 176.7 to 204.4°C aromatic hydrocarbons; toluene; volume; weight

**TABLE 4 Volume Correction Factors**

Volume Correction to 15°C

Temperature °C	Benzene	Cumene	Cyclohexane	Ethyl Benzene	Styrene	Toluene	<i>m</i> -Xylene and Mixed Xylenes	<i>o</i> -Xylene	<i>p</i> -Xylene	148.9 to 176.7°C Aromatic Hydrocarbons	176.7 to 204.4°C Aromatic Hydrocarbons
-20.5	...	...	...	...	...	...	...	...	...	...	...
-20.0	...	...	...	...	...	1.03707	...	...	...	...	...
-19.5	...	...	...	...	...	1.03654	...	...	...	...	...
-19.0	...	...	...	...	...	1.03601	...	...	...	...	...
-18.5	...	...	...	...	...	1.03548	...	...	...	...	...
-18.0	...	...	...	...	...	1.03495	...	...	...	...	...
-17.5	...	...	...	...	...	1.03442	...	...	...	...	...
-17.0	...	...	...	...	...	1.03389	...	...	...	...	...
-16.5	...	...	...	...	...	1.03336	...	...	...	...	...
-16.0	...	...	...	...	...	1.03283	...	...	...	...	...
-15.5	...	...	...	...	...	1.03230	...	...	...	...	...
-15.0	...	1.02916	...	1.03001	...	1.03177	1.02871	1.02828	...	1.02799	1.02618
-14.5	...	1.02868	...	1.02951	...	1.03124	1.02824	1.02781	...	1.02753	1.02575
-14.0	...	1.02820	...	1.02901	...	1.03071	1.02777	1.02734	...	1.02706	1.02531
-13.5	...	1.02771	...	1.02852	...	1.03018	1.02682	1.02639	...	1.02659	1.02488
-13.0	...	1.02723	...	1.02802	...	1.02965	1.02682	1.02639	...	1.02613	1.02444
-12.5	...	1.02675	...	1.02752	...	1.02912	1.02635	1.02592	...	1.02566	1.02401
-12.0	...	1.02627	...	1.02702	...	1.02859	1.02588	1.02545	...	1.02519	1.02357
-11.5	...	1.02579	...	1.02653	...	1.02806	1.02540	1.02498	...	1.02473	1.02314
-11.0	...	1.02530	...	1.02603	...	1.02753	1.02493	1.02451	...	1.02426	1.02270
-10.5	...	1.02482	...	1.02553	...	1.02700	1.02446	1.02404	...	1.02380	1.02227
-10.0	...	1.02434	...	1.02504	...	1.02647	1.02398	1.02357	...	1.02333	1.02183
-9.5	...	1.02385	...	1.02454	...	1.02594	1.02351	1.02310	...	1.02286	1.02140
-9.0	...	1.02337	...	1.02404	1.02322	1.02542	1.02303	1.02263	...	1.02240	1.02096
-8.5	...	1.02289	...	1.02354	1.02274	1.02489	1.02256	1.02216	...	1.02193	1.02052
-8.0	...	1.02240	...	1.02304	1.02226	1.02436	1.02208	1.02169	...	1.02146	1.02009
-7.5	...	1.02192	...	1.02255	1.02177	1.02383	1.02161	1.02122	...	1.02100	1.01965
-7.0	...	1.02144	...	1.02205	1.02129	1.02330	1.02113	1.02075	...	1.02053	1.01922
-6.5	...	1.02095	...	1.02155	1.02081	1.02277	1.02066	1.02028	...	1.02007	1.01878
-6.0	...	1.02047	...	1.02105	1.02033	1.02224	1.02018	1.01980	...	1.01960	1.01835
-5.5	...	1.01998	...	1.02055	1.01984	1.02171	1.01971	1.01933	...	1.01913	1.01791
-5.0	...	1.01950	...	1.02006	1.01936	1.02118	1.01923	1.01886	...	1.01867	1.01747
-4.5	...	1.01901	...	1.01956	1.01888	1.02065	1.01875	1.01839	...	1.01820	1.01704
-4.0	...	1.01853	...	1.01906	1.01840	1.02012	1.01828	1.01792	...	1.01773	1.01660
-3.5	...	1.01804	...	1.01856	1.01791	1.01959	1.01780	1.01745	...	1.01727	1.01617
-3.0	...	1.01756	...	1.01806	1.01743	1.01906	1.01732	1.01696	...	1.01680	1.01573
-2.5	...	1.01707	...	1.01756	1.01695	1.01853	1.01685	1.01651	...	1.01633	1.01529
-2.0	...	1.01659	...	1.01706	1.01646	1.01800	1.01637	1.01604	...	1.01587	1.01486
-1.5	...	1.01610	...	1.01656	1.01598	1.01747	1.01589	1.01557	...	1.01540	1.01442
-1.0	...	1.01562	...	1.01606	1.01550	1.01694	1.01541	1.01510	...	1.01493	1.01399
-0.5	...	1.01513	...	1.01557	1.01502	1.01641	1.01494	1.01462	...	1.01447	1.01355
0.0	...	1.01464	...	1.01507	1.01453	1.01588	1.01446	1.01415	...	1.01400	1.01311
0.5	...	1.01416	...	1.01457	1.01405	1.01535	1.01398	1.01368	...	1.01354	1.01268
1.0	...	1.01367	...	1.01407	1.01357	1.01482	1.01350	1.01321	...	1.01307	1.01224
1.5	...	1.01319	...	1.01357	1.01308	1.01429	1.01302	1.01274	...	1.01260	1.01180
2.0	...	1.01270	...	1.01307	1.01260	1.01376	1.01254	1.01227	...	1.01214	1.01137
2.5	...	1.01221	...	1.01257	1.01211	1.01324	1.01206	1.01180	...	1.01167	1.01093
3.0	...	1.01173	...	1.01206	1.01163	1.01271	1.01158	1.01132	...	1.01120	1.01049
3.5	...	1.01124	...	1.01156	1.01115	1.01218	1.01110	1.01085	...	1.01074	1.01006
4.0	...	1.01075	...	1.01106	1.01066	1.01165	1.01062	1.01038	...	1.01027	1.00962
4.5	...	1.01026	...	1.01056	1.01018	1.01112	1.01014	1.00991	...	1.00980	1.00918
5.0	...	1.00978	...	1.01006	1.00970	1.01059	1.00966	1.00944	...	1.00934	1.00875
5.5	...	1.00929	...	1.00956	1.00921	1.01006	1.00918	1.00897	...	1.00887	1.00831
6.0	1.01054	1.00880	...	1.00906	1.00873	1.00953	1.00870	1.00850	...	1.00840	1.00787
6.5	1.00995	1.00831	...	1.00856	1.00824	1.00900	1.00822	1.00802	...	1.00794	1.00744
7.0	1.00937	1.00782	1.00952	1.00805	1.00776	1.00847	1.00774	1.00755	...	1.00747	1.00700
7.5	1.00879	1.00734	1.00893	1.00755	1.00727	1.00794	1.00725	1.00708	...	1.00700	1.00656
8.0	1.00821	1.00685	1.00833	1.00705	1.00679	1.00741	1.00677	1.00661	...	1.00654	1.00612
8.5	1.00762	1.00636	1.00774	1.00655	1.00631	1.00688	1.00629	1.00614	...	1.00607	1.00569
9.0	1.00704	1.00587	1.00715	1.00605	1.00582	1.00635	1.00581	1.00566	...	1.00560	1.00525
9.5	1.00645	1.00538	1.00655	1.00554	1.00534	1.00582	1.00532	1.00519	...	1.00514	1.00481
10.0	1.00587	1.00489	1.00596	1.00504	1.00485	1.00529	1.00484	1.00472	...	1.00467	1.00437
10.5	1.00528	1.00440	1.00536	1.00454	1.00437	1.00476	1.00436	1.00425	...	1.00420	1.00394
11.0	1.00470	1.00391	1.00477	1.00403	1.00388	1.00423	1.00387	1.00378	...	1.00374	1.00350
11.5	1.00411	1.00342	1.00417	1.00353	1.00340	1.00370	1.00339	1.00330	...	1.00327	1.00306
12.0	1.00352	1.00294	1.00358	1.00303	1.00291	1.00317	1.00291	1.00283	...	1.00280	1.00262
12.5	1.00294	1.00245	1.00298	1.00252	1.00243	1.00264	1.00242	1.00236	...	1.00234	1.00219
13.0	1.00235	1.00196	1.00239	1.00202	1.00194	1.00212	1.00194	1.00189	...	1.00187	1.00175
13.5	1.00176	1.00147	1.00179	1.00152	1.00146	1.00159	1.00145	1.00141	1.00148	1.00140	1.00131
14.0	1.00117	1.00098	1.00119	1.00101	1.00097	1.00106	1.00097	1.00094	1.00099	1.00094	1.00087



**TABLE 4** *Continued*

Volume Correction to 15°C

Temperature °C	Benzene	Cumene	Cyclohexane	Ethyl Benzene	Styrene	Toluene	<i>m</i> -Xylene and Mixed Xylenes	<i>o</i> -Xylene	<i>p</i> -Xylene	148.9 to 176.7°C Aromatic Hydrocarbons	176.7 to 204.4°C Aromatic Hydrocarbons
49.5	0.95834	0.96582	0.95836	0.96486	0.96634	0.96347	0.96592	0.96717	0.96546	0.96777	0.96966
50.0	0.95772	0.96532	0.95775	0.96435	0.96584	0.96294	0.96542	0.96669	0.96495	0.96730	0.96922
50.5	0.95711	0.96482	0.95714	0.96384	0.96535	0.96241	0.96492	0.96621	0.96445	0.96683	0.96878
51.0	0.95649	0.96432	0.96653	0.96332	0.96486	0.96188	0.96442	0.96573	0.96394	0.96636	0.96834
51.5	0.95587	0.96382	0.95592	0.96281	0.96437	0.96135	0.96391	0.96525	0.96343	0.96589	0.96790
52.0	0.95525	0.96332	0.95531	0.96230	0.96388	0.96082	0.96341	0.96477	0.96292	0.96543	0.96746
52.5	0.95463	0.96282	0.95470	0.96179	0.96339	0.96029	0.96291	0.96429	0.96241	0.96496	0.96702
53.0	0.95401	0.96231	0.95409	0.96128	0.96290	0.95976	0.96240	0.96381	0.96190	0.96449	0.96657
53.5	0.95339	0.96181	0.95348	0.96077	0.96241	0.95923	0.96190	0.96333	0.96139	0.96402	0.96613
54.0	0.95277	0.96131	0.95287	0.96026	0.96192	0.95870	0.96139	0.96285	0.96089	0.96356	0.96569
54.5	0.95215	0.96081	0.95226	0.95975	0.96143	0.95817	0.96089	0.96237	0.96038	0.96309	0.96525
55.0	0.95153	0.96031	0.95165	0.95924	0.96094	0.95764	0.96038	0.96189	0.95987	0.96262	0.96481
55.5	0.95090	0.95981	0.95103	0.95873	0.96045	0.95711	0.95988	0.96141	0.95936	0.96215	0.96437
56.0	0.95028	0.95931	0.95042	0.95822	0.95995	0.95658	0.95937	0.96092	0.95885	0.96168	0.96393
56.5	0.94966	0.95881	0.94981	0.95771	0.95946	0.95605	0.95886	0.96044	0.95834	0.96122	0.96348
57.0	0.94904	0.95830	0.94920	0.95720	0.95897	0.95552	0.95836	0.95996	0.95783	0.96075	0.96304
57.5	0.94841	0.95780	0.94859	0.95669	0.95848	0.95500	0.95785	0.95948	0.95732	0.96028	0.96260
58.0	0.94779	0.95730	0.94797	0.05618	0.95799	0.95447	0.95735	0.95900	0.95680	0.95981	0.96216
58.5	0.94716	0.95680	0.94736	0.95567	0.95750	0.95394	0.95684	0.95852	0.95629	0.95934	0.96172
59.0	0.94654	0.95629	0.94675	0.95516	0.95700	0.95341	0.95633	0.95803	0.95578	0.95888	0.96128
59.5	0.94592	0.95579	0.94613	0.95465	0.95651	0.95288	0.95582	0.95755	0.95527	0.95841	0.96083
60.0	0.94529	0.95529	0.94552	0.95414	0.95602	0.95235	0.95532	0.95757	0.95476	0.95794	0.96039
60.5	...	...	...	...	...	...	...	...	0.95425	...	...
61.0	...	...	...	...	...	...	...	...	0.95374	...	...
61.5	...	...	...	...	...	...	...	...	0.95323	...	...
62.0	...	...	...	...	...	...	...	...	0.95271	...	...
62.5	...	...	...	...	...	...	...	...	0.95220	...	...
63.0	...	...	...	...	...	...	...	...	0.95169	...	...
63.5	...	...	...	...	...	...	...	...	0.95118	...	...
64.0	...	...	...	...	...	...	...	...	0.95066	...	...
64.5	...	...	...	...	...	...	...	...	0.95015	...	...
65.0	...	...	...	...	...	...	...	...	0.94964	...	...
65.5	...	...	...	...	...	...	...	...	0.94912	...	...

**TABLE 5 Volume Correction Factors**

Volume Correction to 20°C

Temperature °C							<i>m</i> -Xylene and Mixed			148.9 to 176.7°C	176.7 to 204.4°C
	Benzene	Cumene	Cyclohexane	Ethyl Benzene	Styrene	Toluene	Xylenes	<i>o</i> -Xylene	<i>p</i> -Xylene	Aromatic Hydrocarbons	Aromatic Hydrocarbons
-20.5	...	...	...	...	...	...	...	...	...	...	...
-20.0	...	...	...	...	...	1.04259	...	...	...	...	...
-19.5	...	...	...	...	...	1.04206	...	...	...	...	...
-19.0	...	...	...	...	...	1.04152	...	...	...	...	...
-18.5	...	...	...	...	...	1.04099	...	...	...	...	...
-18.0	...	...	...	...	...	1.04046	...	...	...	...	...
-17.5	...	...	...	...	...	1.03993	...	...	...	...	...
-17.0	...	...	...	...	...	1.03939	...	...	...	...	...
-16.5	...	...	...	...	...	1.03886	...	...	...	...	...
-16.0	...	...	...	...	...	1.03833	...	...	...	...	...
-15.5	...	...	...	...	...	1.03780	...	...	...	...	...
-15.0	...	1.03425	...	1.03524	...	1.03726	1.03374	1.03317	...	1.03281	1.03070
-14.5	...	1.03376	...	1.03474	...	1.03673	1.03327	1.03270	...	1.03234	1.03027
-14.0	...	1.03328	...	1.03424	...	1.03620	1.03280	1.03223	...	1.03188	1.02983
-13.5	...	1.03279	...	1.03374	...	1.03567	1.03232	1.03175	...	1.03141	1.02939
-13.0	...	1.03231	...	1.03324	...	1.03514	1.03185	1.03128	...	1.03094	1.02896
-12.5	...	1.03182	...	1.03274	...	0.03460	1.03137	1.03081	...	1.03047	1.02852
-12.0	...	1.03134	...	1.03225	...	1.03407	1.03089	1.03033	...	1.03000	1.02808
-11.5	...	1.03085	...	1.03175	...	1.03354	1.03042	1.02986	...	1.02953	1.02765
-11.0	...	1.03037	...	1.03125	...	1.03301	1.02994	1.02939	...	1.02907	1.02721
-10.5	...	1.02988	...	1.03075	...	1.03247	1.02947	1.02892	...	1.02860	1.02677
-10.0	...	1.02940	...	1.03025	...	1.03194	1.02899	1.02844	...	1.02813	1.02633
-9.5	...	1.02891	...	1.02975	...	1.03141	1.02851	1.02797	...	1.02766	1.02590
-9.0	...	1.02843	...	1.02925	1.02821	1.03088	1.02804	1.02750	...	1.02719	1.02546
-8.5	...	1.02794	...	1.02875	1.02773	1.03034	1.02756	1.02702	...	1.02672	1.02502
-8.0	...	1.02746	...	1.02824	1.02725	1.02981	1.02708	1.02655	...	1.02625	1.02458
-7.5	...	1.02697	...	1.02774	1.02676	0.02928	1.02661	1.02608	...	1.02579	1.02415
-7.0	...	1.02648	...	1.02724	1.02628	1.02875	1.02613	1.02561	...	1.02532	1.02371
-6.5	...	1.02600	...	1.02674	1.02579	1.02821	1.02565	1.02513	...	1.02485	1.02327
-6.0	...	1.02551	...	1.02624	1.02531	1.02768	1.02517	1.02466	...	1.02438	1.02283
-5.5	...	1.02502	...	1.02574	1.02482	1.02715	1.02469	1.02419	...	1.02391	1.02240
-5.0	...	1.02454	...	1.02524	1.02434	1.02662	1.02422	1.02371	...	1.02344	1.02196
-4.5	...	1.02405	...	1.02474	1.02385	1.02608	1.02374	1.02324	...	1.02297	1.02152
-4.0	...	1.02356	...	1.02424	1.02337	1.02555	1.02326	1.02277	...	1.02251	1.02108
-3.5	...	1.02307	...	1.02374	1.02288	1.02502	1.02278	1.02229	...	1.02204	1.02065
-3.0	...	1.02259	...	1.02324	1.02240	1.02449	1.02230	1.02182	...	1.02157	1.02021
-2.5	...	1.02210	...	1.02273	1.02191	1.02395	1.02182	1.02135	...	1.02110	1.01977
-2.0	...	1.02161	...	1.02223	1.02143	1.02342	1.02134	1.02087	...	1.02063	1.01933
-1.5	...	1.02112	...	1.02173	1.02094	1.02289	1.02086	1.02040	...	1.02016	1.01889
-1.0	...	1.02064	...	1.02123	1.02046	1.02236	1.02038	1.01993	...	1.01969	1.01845
-0.5	...	1.02015	...	1.02073	1.01997	1.02182	1.01990	1.01945	...	1.01923	1.01802
0.0	...	1.01966	...	1.02022	1.01948	1.02129	1.01942	1.01898	...	1.01876	1.01758
0.5	...	1.01917	...	1.01972	1.01900	1.02076	1.01894	1.01851	...	1.01829	1.01714
1.0	...	1.01868	...	1.01922	1.01851	1.02023	1.01846	1.01803	...	1.01782	1.01670
1.5	...	1.01819	...	1.01872	1.01803	1.01970	1.01798	1.01756	...	1.01735	1.01626
2.0	...	1.01770	...	1.01821	1.01754	1.01916	1.01749	1.01709	...	1.01688	1.01582
2.5	...	1.01721	...	1.01771	1.01706	1.01863	1.01701	1.01661	...	1.01641	1.01539
3.0	...	1.01672	...	0.01721	1.01657	1.01810	1.01653	1.01614	...	1.01594	1.01495
3.5	...	1.01624	...	1.01671	1.01608	1.01757	1.01605	1.01567	...	1.01548	1.01451
4.0	...	1.01575	...	1.01620	1.01560	1.01703	1.01557	1.01519	...	1.01501	1.01407
4.5	...	1.01526	...	1.01570	1.01511	1.01650	1.01508	1.01472	...	1.01454	1.01363
5.0	...	1.01477	...	1.01519	1.01462	1.01597	1.01460	1.01424	...	1.01407	1.01319
5.5	...	1.01428	...	1.01469	1.01414	1.01544	1.01412	1.01377	...	1.01360	1.01275
6.0	1.01655	1.01379	...	1.01419	1.01365	1.01490	1.01363	1.01330	...	1.01313	1.01231
6.5	1.01596	1.01330	...	1.01368	1.01316	1.01437	1.01315	1.01282	...	1.01266	1.01188
7.0	1.01538	1.01280	1.01559	1.01318	1.01268	1.01384	1.01266	1.01235	...	1.01220	1.01144
7.5	1.01479	1.01231	1.01499	1.01267	1.01219	1.01331	1.01218	1.01187	...	1.01173	1.01100
8.0	1.01421	1.01182	1.01440	1.01217	1.01170	1.01277	1.01170	1.01140	...	1.01126	1.01056
8.5	1.01362	1.01133	1.01380	1.01166	1.01122	1.01224	1.01121	1.01093	...	1.01079	1.01012
9.0	1.01303	1.01084	1.01320	1.01116	1.01073	1.01171	1.01073	1.01045	...	1.01032	1.00968
9.5	1.01244	1.01035	1.01260	1.01065	1.01024	1.01118	1.01024	1.00998	...	1.00985	1.00924
10.0	1.01185	1.00986	1.01201	1.01015	1.00976	1.01065	1.00976	1.00950	...	1.00938	1.00880
10.5	1.01127	1.00937	1.01141	1.00964	1.00927	1.01011	1.00927	1.00903	...	1.00981	1.00836
11.0	1.01068	1.00888	1.01081	1.00914	1.00878	1.00958	1.00878	1.00855	...	1.00844	1.00792
11.5	1.01009	1.00838	1.01021	1.00863	1.00830	1.00905	1.00830	1.00808	...	1.00798	1.00748
12.0	1.00950	1.00789	1.00961	1.00813	1.00781	1.00852	1.00781	1.00760	...	1.00751	1.00704
12.5	1.00891	1.00740	1.00901	1.00762	1.00732	1.00798	1.00733	1.00713	...	1.00704	1.00660
13.0	1.00831	1.00691	1.00841	1.00711	1.00683	1.00745	1.00684	1.00666	...	1.00657	1.00616
13.5	1.00772	1.00641	1.00781	1.00661	1.00635	1.00692	1.00635	1.00618	1.00645	1.00610	1.00572
14.0	1.00713	1.00592	1.00721	1.00610	1.00586	1.00639	1.00587	1.00571	1.00596	1.00563	1.00528





**TABLE 5** *Continued*

Volume Correction to 20°C

Temperature °C							<i>m</i> -Xylene and Mixed Xylenes	<i>o</i> -Xylene	<i>p</i> -Xylene	148.9 to 176.7°C Aromatic Hydrocarbons	176.7 to 204.4°C Aromatic Hydrocarbons
	Benzene	Cumene	Cyclohexane	Ethyl Benzene	Styrene	Toluene					
49.5	0.96404	0.97059	0.96413	0.96976	0.97105	0.96860	0.97065	0.97177	0.97025	0.97230	0.97394
50.0	0.96342	0.97009	0.96351	0.96925	0.97056	0.96805	0.97014	0.97129	0.96974	0.97183	0.97349
50.5	0.96280	0.96959	0.96290	0.96874	0.97007	0.96753	0.96964	0.97081	0.96923	0.97136	0.97305
51.0	0.96218	0.96908	0.96228	0.96822	0.96957	0.96700	0.96913	0.97033	0.96872	0.97089	0.97261
51.5	0.96156	0.96858	0.96167	0.96771	0.96908	0.96647	0.96863	0.96985	0.96821	0.97042	0.97216
52.0	0.96093	0.96808	0.96106	0.96719	0.96859	0.96594	0.96812	0.96936	0.96770	0.96995	0.97172
52.5	0.96031	0.96757	0.96044	0.96668	0.96809	0.96540	0.96762	0.96888	0.96719	0.96948	0.97128
53.0	0.95969	0.96707	0.95983	0.96617	0.96760	0.96487	0.96711	0.96840	0.96668	0.96901	0.97083
53.5	0.95906	0.96657	0.95921	0.96565	0.96711	0.96434	0.96660	0.96791	0.96616	0.96854	0.97039
54.0	0.95844	0.96606	0.95860	0.96514	0.96661	0.96381	0.96609	0.96743	0.96565	0.96807	0.96995
54.5	0.95781	0.96556	0.95798	0.96463	0.96612	0.96327	0.96559	0.96695	0.96514	0.96760	0.96950
55.0	0.95719	0.96506	0.95737	0.96411	0.96563	0.96274	0.96508	0.96647	0.96463	0.96713	0.96906
55.5	0.95656	0.96455	0.95675	0.96360	0.96513	0.96221	0.96457	0.96598	0.96412	0.96666	0.96862
56.0	0.95594	0.96405	0.95614	0.96309	0.96464	0.96168	0.96406	0.96550	0.96360	0.96619	0.96817
56.5	0.95531	0.96354	0.95552	0.96257	0.96415	0.96115	0.96355	0.96502	0.96309	0.96572	0.96773
57.0	0.95468	0.96304	0.95490	0.96206	0.96365	0.96061	0.96305	0.96453	0.96258	0.96525	0.96729
57.5	0.95406	0.96253	0.95429	0.96155	0.96316	0.96008	0.96254	0.96405	0.96207	0.96478	0.96684
58.0	0.95343	0.96203	0.95367	0.96104	0.96266	0.95955	0.96203	0.96356	0.96155	0.96431	0.96640
58.5	0.95280	0.96152	0.95306	0.96052	0.96217	0.95902	0.96152	0.96308	0.96104	0.96384	0.96596
59.0	0.95217	0.96102	0.95244	0.96001	0.96168	0.95848	0.96101	0.96260	0.96053	0.96337	0.96551
59.5	0.95154	0.96051	0.95182	0.95950	0.96118	0.95795	0.96050	0.96211	0.96001	0.96290	0.96507
60.0	0.95092	0.96001	0.95120	0.95899	0.96069	0.95742	0.95999	0.96163	0.95950	0.96243	0.96462
60.5	...	...	...	...	...	...	...	...	0.95898	...	...
61.0	...	...	...	...	...	...	...	...	0.95847	...	...
61.5	...	...	...	...	...	...	...	...	0.95795	...	...
62.0	...	...	...	...	...	...	...	...	0.95744	...	...
62.5	...	...	...	...	...	...	...	...	0.95693	...	...
63.0	...	...	...	...	...	...	...	...	0.95641	...	...
63.5	...	...	...	...	...	...	...	...	0.95590	...	...
64.0	...	...	...	...	...	...	...	...	0.95538	...	...
64.5	...	...	...	...	...	...	...	...	0.95486	...	...
65.0	...	...	...	...	...	...	...	...	0.95435	...	...
65.5	...	...	...	...	...	...	...	...	0.95383	...	...

## APPENDICES

### (Nonmandatory Information)

#### X1. PHYSICAL CONSTANTS

##### INTRODUCTION

This Appendix is included for documentation purposes only and is not necessary for implementation of this standard.

##### X1.1 *Density of Weights*

X1.1.1 NIST Handbook 44, Appendix B and Handbook 105–1 state that brass is no longer used for balance weights due to its softness. A generic reference weight of 8.0g/cm<sup>3</sup> density at 20°C is used by international agreement. Since a specific material is no longer specified, no calculation of density at reference temperature can be made.

$$B^{20} = 8.0 \text{ g/cm}^3$$

##### X1.2 *Density of Standard Air*

X1.2.1 NIST Handbook 44, Appendix B and Handbook 105–1 specify a temperature of 20°C for air buoyancy calcu-

lations. The latest International Committee of Weights and Measures (CIPM) 81/91 Air Density Executable File yields a density of 0.001199228 g/cm<sup>3</sup> (760 mm, 50 % humidity, 20°C). The program is available (as of this writing) at <http://ts.nist.gov/ts/htdocs/230/235/labmetrologypage.htm>.

##### X1.3 *Density of Water*

X1.3.1 The equation of J. B. Patterson and E. C. Morris yields a density of water at 15°C of 0.999102 g/cc and 0.998206 g/cc at 20°C.

## X2. DENSITY AT 15°C (OR 20°C) IN AIR EQUIVALENT TO ABSOLUTE DENSITY AT 15°C (OR 20°C)

This Appendix is included for documentation purposes only and is not necessary for implementation of this standard.

X2.1 The following is a derivation of the equation for converting density *in vacuo* to density *in air*.

Consider mass  $d$  to be measured balanced on a scale *in vacuo* (no air) by an equal reference mass  $b$ . When balanced, all forces acting on the system cancel each other. Thus, force  $F_d = m_d \cdot a$  ( $a$  = acceleration of gravity) acting on the mass  $m_d$  is balanced by an equal force  $F_b = m_b \cdot a$  on the reference mass  $m_b$ .

$$F_d = F_b$$

$$m_d \cdot a = m_b \cdot a$$

When balanced *in air*, each mass is counteracted by a force equal to the weight of the air it displaces (Archimedes's principle). Therefore,  $F_{ad} = m_{ad} \cdot a$  and  $F_{ab} = m_{ab} \cdot a$ , where  $m_{ad}$  is the mass of air displacing  $m_d$  and  $m_{ab}$  is the mass of air displacing  $m_b$ .

$$F_d - F_{ad} = F_b - F_{ab}$$

$$m_d \cdot a - m_{ad} \cdot a = m_b \cdot a - m_{ab} \cdot a$$

$$m_d - m_{ad} = m_b - m_{ab}$$

Multiplying the right side of the equation by one in the form of  $m_b/m_b$  gives:

$$m_d - m_{ad} = \frac{m_b - m_{ab}}{m_b} \cdot m_b$$

Similarly, multiplying each side of the equation by the volumes involved ( $V_d$  for mass  $m_d$ ,  $V_b$  for mass  $m_b$ ):

$$(m_d - m_{ad}) \cdot \frac{V_d}{V_d} = \frac{1/V_b(m_b - m_{ab})}{1/V_b} \cdot m_b$$

$$\left( \frac{m_d - m_{ad}}{V_d - V_d} \right) = \frac{m_b/V_b - m_{ab}/V_b}{m_b/V_b} \cdot [m_b/V_d]$$

For volumes at 15°C (or 20°C), these ratios are densities at 15°C (or 20°C). However, the air and reference weight

densities to be used for air buoyancy corrections are 20°C (68°F) by international agreement (X1.1 and X1.2); the difference between the ratio of the densities at 20°C (68°F) and that at 60°F is considered negligible. Thus:

$$D^{XX} - A^{20} = \frac{B^{15} - A^{20}}{B^{20}} \cdot [m_b/V_d]^{XX}$$

$$[m_b/V_d]^{XX} = \frac{D^{XX} - A^{20}}{B^{20} - A^{20}} = \frac{D^{XX} - A^{20}}{1 - (A^{20}/B^{20})}$$

where:

- $D^{XX}$  = density of liquid at either 15°C or 20°C *in vacuo*,  $m_d / V_d$ ,
- $A^{20}$  = density of standard air at 20°C *in vacuo*,  $m_{ad} / V_d$  or  $m_{ab} / V_b$ ,
- $B^{20}$  = density of reference weights at 20°C *in vacuo*,  $m_b / V_b$ , and
- $[m_b/V_d]^{XX}$  = density of liquid at either 15°C or 20°C *in air* (when balanced, the mass of the reference weight equals the mass of the liquid).

Selection of the proper conversion factor  $f$  is used to change units from one unit system to another, say, g/mL to lb/gal (or any other expression of density).

$$[m_b/V_d]^{XX} = \frac{D^{XX} - A^{20}}{1 - (A^{20}/B^{20})} \cdot f$$

Substituting with the values from Appendix X1, this equation becomes:

$$[m_b/V_d]^{XX} = [1.000149926 \cdot D^{XX} - 0.001199407795] \cdot f$$

To convert g/cc (*in vacuo*) to g/cc (*in air*):  $f = 1$ .

## SUMMARY OF CHANGES

Committee D16 has identified the location of selected changes to this standard since the last issue (D1555M-08<sup>e1</sup>) that may impact the use of this standard. (Approved November 1, 2016.)

- (1) Some editorial remarks have been removed from the method.
- (2) The method of arithmetically averaging the pure densities for a mixture was eliminated.

- (3) The use of Table 1 for determining base density was eliminated.
- (4) The rounding of the results is not explicitly defined.

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