Designation: D 1555M – 04a

METRIC

Standard Test Method for Calculation of Volume and Weight of Industrial Aromatic Hydrocarbons and Cyclohexane [Metric][1]

This standard is issued under the fixed designation D 1555M; 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.

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 from an observed volume at *t*°C. Table 1 lists the density in grams per cubic centimetre at 15°C for high purity chemicals.

1.2 Calculated results shall be rounded off in accordance with the rounding-off method of Practice E 29.

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.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 1217 Test Method for Density and Relative Density (Specific Gravity) of Liquids by Bingham Pycnometer

D 1555 Method for Calculation of Volume and Weight of Industrial Aromatic Hydrocarbons and Cyclohexane

D 3505 Test Method for Density or Relative Density of Pure Liquid Chemicals

D 4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *Other Documents:*

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

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 can be used for determining quantities of the above-stated aromatic hydrocarbons in tanks, shipping containers, etc.

4. Basic Data

4.1 Densities of pure materials at 15°C are derived from densities furnished by NSRDS-NIST 75-121 (National Standard Reference Data Series—National Institute of Standards and Technology). Densities of impure materials should be determined by actual measurement (see Section 7).

4.2 The VCF (Volume Correction Factor) equations provided below are derived from the Volume Correction implementation procedures presented in Method D 1555 - 04.

4.3 The former VCF tables were based on data for compounds of the highest purity, 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. Alternatively, if the composition has been quantified one can use the VCFs of each component (if available) to calculate a

[1] This test method is under the jurisdiction of ASTM Committee D16 on Aromatic Hydrocarbons 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] 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.

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

TABLE 1 Physical Properties

Product	Freezing Point °C	Boiling Point °C	Density *in Vacuo* at 15°C g/cc[A,B,C]	Density *in Air* at 15°C g/cc[D]
Benzene	5.6	80.1	0.88431	0.88324
Cumene	-96.1	152.4	0.86586	0.86479
Cyclohexane	6.6	80.7	0.78317	0.78209
Ethylbenzene	-95.0	136.2	0.87126	0.87019
Styrene	-30.6	145.2	0.91028	0.90922
Toluene	-95.0	110.6	0.87147	0.87040
m-Xylene	-47.9	139.1	0.86831	0.86724
o-Xylene	-25.2	144.4	0.88387	0.88280
p-Xylene	13.3	138.3	0.86501	0.86394

[A] Obtained from Method D 1555 – 04 by multiplying the chemical's 60°F density by the volume correction factor for 59°F.
[B] 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.
[C] g/cc can be converted to kg/1000L or kg/m^3 by multiplying by 1000.
[D] Produced using g/cc = (Density · 1.00014992597 – 0.00119940779543) and rounding to 5 decimal places. See Appendix X2.

NOTE—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 and API recommend the use of *in vacuo* densities (or weights); however, the purchaser and seller should agree on which to use in their transactions.

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
m-Xylene	95 to 100%
o-Xylene	95 to 100%
p-Xylene	94 to 100%
148.9-176.7°C Aromatic Hydrocarbons	All proportions
176.7-204.4°C Aromatic Hydrocarbons	All proportions

weighted average density at different temperatures and then process the data as mentioned above.

5. Volume Correction Factor Implementation Procedure

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

$$\text{VCF} = (a + b\,(1.8t+32) + c\,(1.8t+32)^2 + d\,(1.8t+32)^3 + e\,(1.8t+32)^4)/VCF^{59F} \quad (1)$$

where:

t = temperature in °C

and the constants a through e and VCF^{59F} are specific to each compound (obtained from Method D 1555 – 04 and presented in Table 3).

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

5.1.2 The final result is rounded to 5 places past the decimal. 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 the previous edition of this Method for determining VCFs. **The implementation procedure is the Standard, not the printed tables**. However, a printout of the implementation procedure is provided in 0.5°C increments for the user's convenience (Table 4).

TABLE 3 VCF Constants

Product	a	b	c	d	e	VCF^{59F}
Benzene	1.038382492	-6.2307×10^{-4}	-2.8505×10^{-7}	1.2692×10^{-10}	0	1.00066
Cumene	1.032401114	-5.3445×10^{-4}	-9.5067×10^{-8}	3.6272×10^{-11}	0	1.00055
Cyclohexane	1.039337296	-6.4728×10^{-4}	-1.4582×10^{-7}	1.03538×10^{-10}	0	1.00066
Ethylbenzene	1.033346632	-5.5243×10^{-4}	8.37035×10^{-10}	-1.2692×10^{-9}	5.55061×10^{-12}	1.00056
Styrene	1.032227515	-5.3444×10^{-4}	-4.4323×10^{-8}	0	0	1.00054
Toluene	1.035323647	-5.8887×10^{-4}	2.46508×10^{-9}	-7.2802×10^{-12}	0	1.00059
m-Xylene[A]	1.031887514	-5.2326×10^{-4}	-1.3253×10^{-7}	-7.35960×10^{-11}	0	1.00054
o-Xylene	1.031436449	-5.2302×10^{-4}	-2.5217×10^{-9}	-2.13840×10^{-10}	0	1.00053
p-Xylene	1.032307000	-5.2815×10^{-4}	-1.8416×10^{-7}	1.89256×10^{-10}	0	1.00054
148.9-176.7°C	1.031118000	-5.1827×10^{-4}	-3.5109×10^{-9}	-1.98360×10^{-11}	0	1.00052
176.7-204.4°C	1.029099000	-4.8287×10^{-4}	-3.7692×10^{-8}	3.78575×10^{-11}	0	1.00049

[A] and Mixed Xylenes.

6. Use of the Implementation Procedure

6.1 *Volume Reduction to 15°C*—Enter the appropriate equation with the temperature to the nearest 0.1 degree Centigrade at which the bulk volume was measured (temperature *t*). After performing the mathematical operations, round the resulting VCF to 5 places past the decimal. Multiply the bulk volume measurement at temperature *t* by the VCF.

NOTE 1—The purchaser and seller should agree on a reasonable policy in regard to rounding of final numbers in all computations. Rounding the final weight or volume to five significant figures is, in most cases, also acceptable.

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

6.1.1.1 Enter Eq 1 with 31.7 and the appropriate constants from Table 3 to calculate a VCF of 0.98341. The volume at 15°C is:

$$35{,}129 \cdot 0.98341 = 34{,}546 \text{ litres}$$

6.2 *Converting Volume to Weight for Chemicals Listed in Table 1*—Multiply the volume in litres at 15°C by the appropriate density in kg/L at 15°C (see Table 1 and Table 1 Note).

6.2.1 *Example 2*—What is the weight of *p*-xylene whose volume is 34,546 litres?

6.2.1.1 The weight is:

$$34{,}546 \cdot 0.86501 = 29{,}883 \text{ kg } \textit{in vacuo}$$

or

$$34{,}546 \cdot 0.86394 = 29{,}846 \text{ kg } \textit{in air}$$

6.3 *Converting Volume to Weight for Mixtures*—Correct the measured bulk volume to 15°C as described in 6.1. Determine the density *in vacuo* at 15°C in grams per millilitre (equivalent to grams per cubic centimetre and kilograms per litre) as described in Section 7. To obtain the density *in air* at 15°C, use the equation described in footnote D of Table 1 (or refer to Appendix X2).

6.3.1 *Example 3*—If the *p*-xylene in Example 2 is less than 100 % pure, its density should be determined by actual measurement. For instance, if the *p*-xylene is 95 % pure and its density has been determined to be 0.86555 g/mL (*in vacuo*) at 15°C, the density *in air* is:

$$(0.86555 \cdot 1.00014992597 - 0.00119940779543) = 0.86448 \text{ g/cc } \textit{in air}$$

6.3.1.1 The weight of the net volume is thus:

$$34{,}546 \cdot 0.86555 = 29{,}901 \text{ kg } \textit{in vacuo}$$

or

$$34\,546 \cdot 0.86448 = 29{,}864 \text{ kg } \textit{in air}$$

6.3.2 *Example 4*—What is the weight of the contents of a tank car of mixed xylenes having a measured 15°C density of 0.87685 g/mL (*in vacuo*), whose volume was determined to be 35,129 litres at a mean temperature of 31.7°C?

6.3.2.1 Enter Eq 1 with 31.7 and the appropriate constants from Table 3 to calculate a VCF of 0.98365. The volume at 15°C is:

$$35{,}129 \cdot 0.98365 = 34{,}555 \text{ litres}$$

6.3.2.2 The density *in air* at 15°C is:

$$(0.87685 \cdot 1.00014992597 - 0.00119940779543) = 0.87578 \text{ g/cc } \textit{in air}$$

6.3.2.3 The weight of the net volume is thus:

$$34{,}555 \cdot 0.87685 = 30{,}300 \text{ kg } \textit{in vacuo}$$

or

$$34\,555 \cdot 0.87578 = 30{,}263 \text{ kg } \textit{in air}$$

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 D 1217, D 3505, and D 4052 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	Ethylbenzene	Styrene	Toluene	*m*-Xylene and Mixed Xylenes	*o*-Xylene	*p*-Xylene	300 to 350°C Aromatic Hydrocarbons	350 to 400°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	1.02730	1.02686	...	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	1.01698	...	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