~~Designation:D1555–04a~~ Designation: D 1555 – 09

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

This standard is issued under the fixed designation D 1555; 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 Department of Defense.

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, 300 to 350°F and 350 to 400°F aromatic hydrocarbons, and cyclohexane. A method is given for calculating the volume at 60°F from an observed volume at *t*°F. Table 1 lists the density in pounds per gallon at 60°F 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~~

1.3 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

1.3.1 A complete SI unit companion standard has been developed in Test Method D 1555M.

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.*

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 1555M Test Method for Calculation of Volume and Weight of Industrial Aromatic Hydrocarbons and Cyclohexane [Metric]

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:*

American Petroleum Society Research Project 44[3]

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

~~TRC Thermodynamic Tables—Hydrocarbons,~~ NSRDS-NIST 75-121~~NSRDS-NIST 75-121,~~ TRC Thermodynamic Tables—Hydrocarbons, Supplement No. 121, April 30, 2001[4]

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 pure materials at 60°F 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).

---

[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.

Current edition approved ~~Dec.~~June 1, ~~2004.~~2009. Published ~~January 2005.~~July 2009. Originally approved in 1957. Last previous edition approved in 2004 as D 1555 – 04a.

[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] "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.

[4] 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 °F	Boiling Point °F	60°F Density *in Vacuo* g/cc[A,B]	Density *in Vacuo* at 60°F lb/gal[C]	Density *in Air* at 60°F lb/gal[D]
Benzene	42.0	176.2	0.88373	7.3751	7.3662
Cumene	-140.9	306.3	0.86538	7.2219	7.2130
Cyclohexane	43.8	177.3	0.78265	6.5315	6.5225
Ethylbenzene	-139.0	277.1	0.87077	7.2669	7.2580
Styrene	-23.1	293.4	0.90979	7.5926	7.5837
Toluene	-139.0	231.1	0.87096	7.2685	7.2596
m-Xylene	-54.2	282.4	0.86784	7.2425	7.2336
o-Xylene	-13.3	291.9	0.88340	7.3723	7.3634
p-Xylene	55.9	281.0	0.86456	7.2151	7.2062

[A] Based on regression of 2001 TRC Thermodynamic Tables, Hydrocarbons, NSRDS-NIST 75-121 (April 30, 2001). The data is presented in Appendix X1.
[B] Specific Gravity has been deleted from this table as unnecessary to this standard. If needed, divide 60°F density in g/cc divided by 0.999016 g/cc. See Appendix X2.
[C] Produced by multiplying the density in g/cc by 8.34540438 and rounding to 4 decimal places.
[D] Produced using lb/gal = (Density · 1.00014992597 – 0.00119940779543) · 8.34540438, rounding to 4 decimal places. See Appendix X3.

NOTE 1—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.

4.2 The VCF (Volume Correction Factor) equations provided below were derived from the Volume Correction Tables presented in the previous edition of this standard, Method D 1555-95. Although reported as based on the American Petroleum Institute Research Project 44, the actual documentation that could be found is incomplete. As regression of the NIST data (Appendix X1) provided VCFs that differ from the historical VCFs by only 0 to ± 0.12 % (depending on the compound), the decision was made to use the previous method's VCF tables.

4.3 The VCF tables were regressed with a commercially available data regression program (TableCurve 2D V4). However, any modern regression program should produce the same results.

4.4 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 60°F. Alternatively, if the composition has been quantified one can use the VCFs of each component (if available) to calculate a weighted average density at different temperatures and then process the data as mentioned above.

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%
300-350°F Aromatic Hydrocarbons	All proportions
350-400°F Aromatic Hydrocarbons	All proportions

5. Volume Correction Factor Implementation Procedure

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

$$VCF = a + bt + ct^2 + dt^3 + et^4 \quad (1)$$

where:

t = temperature in °F

and constants a through e are specific to each compound (presented in Table 3).

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

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 140°F (150°F 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 1°F increments for the user's convenience (Table 4).

6. Use of the Implementation Procedure

6.1 *Volume Reduction to 60°F*—Enter the appropriate equation with the temperature to the nearest 0.1 degree Fahrenheit 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 60°F of a tank car of *p*-xylene whose volume was measured to be 9280 gal at a mean temperature of 88.7°F?

6.1.1.1 Enter Eq 1 with 88.7 and the appropriate constants from Table 3 to calculate a VCF of 0.98414. The volume at 60°F is:

$$9280 \cdot 0.98414 = 9132.8 \text{ gal}$$

6.2 *Converting Volume to Weight for Chemicals Listed in Table 1*—Multiply the volume in gallons at 60°F (5 digits) by the appropriate density in pounds per gallon at 60°F (see Table 1 and Table 1 Note).

6.2.1 *Example 2*—What is the weight of *p*-xylene whose net volume is 9132.8 gal?

6.2.1.1 The weight is:

$$9132.8 \cdot 7.2151 = 65{,}894 \text{ lb } \textit{in vacuo}$$

or

$$9132.8 \cdot 7.2062 = 65{,}813 \text{ lb } \textit{in air}$$

6.3 *Converting Volume to Weight for Mixtures*—Correct the measured bulk volume to 60°F as described in 6.1. Determine the density (all weights *in vacuo*) at 60°F in grams per millilitre (or grams per cubic centimetre, they are equivalent) as described in Section 7. To obtain the density in pounds per gallon *in vacuo*, multiply by the factor described in footnote C of Table 1. To obtain the density in pounds per gallon *in air* at 60°F, use the equation described in footnote D of Table 1 (or refer to Appendix X3).

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 measured and determined to be 0.8651 g/mL (*in vacuo*) at 60°F, the density in lb/gal is:

$$(0.8651 \cdot 8.34540438) = 7.2196 \text{ lb/gal } \textit{in vacuo}$$

or

$$(0.8651 \cdot 1.00014992597 - 0.00119940779543) \cdot 8.34540438 = 7.2107 \text{ lb/gal } \textit{in air}$$

TABLE 3 VCF Constants

Product	a	b	c	d	e
Benzene	1.038382492	-6.2307×10^{-4}	-2.8505×10^{-7}	1.2692×10^{-10}	0
Cumene	1.032401114	-5.3445×10^{-4}	-9.5067×10^{-8}	3.6272×10^{-11}	0
Cyclohexane	1.039337296	-6.4728×10^{-4}	-1.4582×10^{-7}	1.03538×10^{-10}	0
Ethylbenzene	1.033346632	-5.5243×10^{-4}	8.37035×10^{-10}	-1.2692×10^{-9}	5.55061×10^{-12}
Styrene	1.032227515	-5.3444×10^{-4}	-4.4323×10^{-8}	0	0
Toluene	1.035323647	-5.8887×10^{-4}	2.46508×10^{-9}	-7.2802×10^{-12}	0
m-Xylene[A]	1.031887514	-5.2326×10^{-4}	-1.3253×10^{-7}	-7.35960×10^{-11}	0
o-Xylene	1.031436449	-5.2302×10^{-4}	-2.5217×10^{-9}	-2.13840×10^{-10}	0
p-Xylene	1.032307000	-5.2815×10^{-4}	-1.8416×10^{-7}	1.89256×10^{-10}	0
300-350°F	1.031118000	-5.1827×10^{-4}	-3.5109×10^{-9}	-1.98360×10^{-11}	0
350-400°F	1.029099000	-4.8287×10^{-4}	-3.7692×10^{-8}	3.78575×10^{-11}	0

[A] and Mixed Xylenes.

The weight of the net volume is thus:

$$9132.8 \cdot 7.2196 - 65{,}935 \text{ lb } \textit{in vacuo}$$

or

$$9132.8 \cdot 7.2107 = 65{,}854 \text{ lb } \textit{in air}$$

6.3.2 *Example 4*—What is the weight of the contents of a tank car of mixed xylenes having a measured 60°F density of 0.87638 g/mL (*in vacuo*), whose volume was determined to be 9280 gal at a mean temperature of 88.7°F?

6.3.2.1 Enter Eq 1 with 88.7 and the appropriate constants from Table 3 to calculate a VCF of 0.98438. The volume at 60°F is then 9280 · 0.98438 = 9135.0 gal.

6.3.2.2 The density in lb/gal at 60°F is:

$$(0.87638 \cdot 8.34540438) = 7.3137 \text{ lb/gal } \textit{in vacuo}$$

or

$$(0.87638 \cdot 1.00014992597 - 0.00119940779543) \cdot 8.34540438 = 7.3048 \text{ lb/gal } \textit{in air}$$

6.3.2.3 The weight of the net volume is thus:

$$9135 \cdot 7.3137 = 66{,}811 \text{ lb } \textit{in vacuo}$$

or

$$9135 \cdot 7.3048 = 66{,}729 \text{ lb } \textit{in air}$$

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 4052are suitable and are written to give density *in vacuo*. They should be used with caution, however, as they may be using the 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; 300 to 350°F aromatic hydrocarbons; 350 to 400°F aromatic hydrocarbons; toluene; volume; weight

TABLE 4 Volume Correction Factors

Volume Correction to 60°F											
Temperature °F	Benzene	Cumene	Cyclohexane	Ethylbenzene	Styrene	Toluene	*m*-Xylene and Mixed Xylenes	*o*-Xylene	*p*-Xylene	300 to 350° Aromatic Hydrocarbons	350 to 400° Aromatic Hydrocarbons
-5.0	...	...	...	...	...	1.03827	...	...	...	...	...
-4.0	...	...	...	...	...	1.03768	...	...	...	...	...
-3.0	...	...	...	...	...	1.03709	...	...	...	...	...
-2.0	...	...	...	...	...	1.03650	...	...	...	...	...
-1.0	...	...	...	...	...	1.03591	...	...	...	...	...
0.0	...	...	...	...	...	1.03532	...	...	...	...	...
1.0	...	...	...	...	...	1.03473	...	...	...	...	...
2.0	...	...	...	...	...	1.03415	...	...	...	...	...
3.0	...	...	...	...	...	1.03356	...	...	...	...	...
4.0	...	...	...	...	...	1.03297	...	...	...	...	...
5.0	...	1.02973	...	1.03058	...	1.03238	1.02927	1.02882	...	1.02853	1.02668
6.0	...	1.02919	...	1.03003	...	1.03179	1.02874	1.02830	...	1.02801	1.02620
7.0	...	1.02866	...	1.02948	...	1.03120	1.02822	1.02778	...	1.02749	1.02572
8.0	...	1.02812	...	1.02893	...	1.03061	1.02769	1.02725	...	1.02697	1.02523
9.0	...	1.02758	...	1.02837	...	1.03002	1.02717	1.02673	...	1.02645	1.02475
10.0	...	1.02705	...	1.02782	...	1.02944	1.02664	1.02621	...	1.02593	1.02427
11.0	...	1.02651	...	1.02727	...	1.02885	1.02612	1.02568	...	1.02542	1.02378
12.0	...	1.02597	...	1.02672	...	1.02826	1.02559	1.02516	...	1.02490	1.02330
13.0	...	1.02544	...	1.02616	...	1.02767	1.02506	1.02464	...	1.02438	1.02282
14.0	...	1.02490	...	1.02561	...	1.02708	1.02454	1.02411	...	1.02386	1.02233
15.0	...	1.02436	...	1.02506	1.02420	1.02649	1.02401	1.02359	...	1.02334	1.02185
16.0	...	1.02383	...	1.02450	1.02367	1.02590	1.02348	1.02307	...	1.02282	1.02136
17.0	...	1.02329	...	1.02395	1.02313	1.02531	1.02295	1.02254	...	1.02231	1.02088
18.0	...	1.02275	...	1.02340	1.02259	1.02472	1.02243	1.02202	...	1.02179	1.02040
19.0	...	1.02221	...	1.02284	1.02206	1.02414	1.02190	1.02150	...	1.02127	1.01991
20.0	...	1.02167	...	1.02229	1.02152	1.02355	1.02137	1.02097	...	1.02075	1.01943
21.0	...	1.02114	...	1.02174	1.02098	1.02296	1.02084	1.02045	...	1.02023	1.01894
22.0	...	1.02060	...	1.02118	1.02045	1.02237	1.02031	1.01993	...	1.01971	1.01846
23.0	...	1.02006	...	1.02063	1.01991	1.02178	1.01978	1.01940	...	1.01920	1.01797
24.0	...	1.01952	...	1.02007	1.01938	1.02119	1.01925	1.01888	...	1.01868	1.01749
25.0	...	1.01898	...	1.01952	1.01884	1.02060	1.01872	1.01836	...	1.01816	1.01700
26.0	...	1.01844	...	1.01896	1.01830	1.02001	1.01819	1.01783	...	1.01764	1.01652
27.0	...	1.01790	...	1.01841	1.01777	1.01943	1.01766	1.01731	...	1.01712	1.01603
28.0	...	1.01736	...	1.01785	1.01723	1.01884	1.01713	1.01679	...	1.01660	1.01555
29.0	...	1.01682	...	1.01730	1.01669	1.01825	1.01660	1.01626	...	1.01608	1.01506
30.0	...	1.01628	...	1.01674	1.01615	1.01766	1.01607	1.01574	...	1.01557	1.01458
31.0	...	1.01574	...	1.01619	1.01562	1.01707	1.01554	1.01521	...	1.01505	1.01409
32.0	...	1.01520	...	1.01563	1.01508	1.01648	1.01501	1.01469	...	1.01453	1.01361
33.0	...	1.01466	...	1.01508	1.01454	1.01589	1.01447	1.01417	...	1.01401	1.01312
34.0	...	1.01412	...	1.01452	1.01401	1.01530	1.01394	1.01364	...	1.01349	1.01264
35.0	...	1.01358	...	1.01397	1.01347	1.01472	1.01341	1.01312	...	1.01297	1.01215
36.0	...	1.01304	...	1.01341	1.01293	1.01413	1.01287	1.01259	...	1.01245	1.01167
37.0	...	1.01250	...	1.01285	1.01239	1.01354	1.01234	1.01207	...	1.01194	1.01118
38.0	...	1.01196	...	1.01230	1.01185	1.01295	1.01181	1.01155	...	1.01142	1.01070
39.0	...	1.01142	...	1.01174	1.01132	1.01236	1.01127	1.01102	...	1.01090	1.01021
40.0	...	1.01087	...	1.01118	1.01078	1.01177	1.01074	1.01050	...	1.01038	1.00973
41.0	...	1.01033	...	1.01063	1.01024	1.01118	1.01021	1.00997	...	1.00986	1.00924
42.0	...	1.00979	...	1.01007	1.00970	1.01059	1.00967	1.00945	...	1.00934	1.00875
43.0	1.01107	1.00925		1.00951	1.00916	1.01001	1.00914	1.00892	...	1.00882	1.00827
44.0	1.01043	1.00870	1.01058	1.00895	1.00863	1.00942	1.00860	1.00840	...	1.00831	1.00778
45.0	1.00978	1.00816	1.00992	1.00840	1.00809	1.00883	1.00807	1.00788	...	1.00779	1.00730
46.0	1.00913	1.00762	1.00926	1.00784	1.00755	1.00824	1.00753	1.00735	...	1.00727	1.00681
47.0	1.00848	1.00708	1.00860	1.00728	1.00701	1.00765	1.00699	1.00683	...	1.00675	1.00632
48.0	1.00783	1.00653	1.00794	1.00672	1.00647	1.00706	1.00646	1.00630	...	1.00623	1.00584
49.0	1.00718	1.00599	1.00728	1.00616	1.00593	1.00647	1.00592	1.00578	...	1.00571	1.00535
50.0	1.00653	1.00545	1.00662	1.00560	1.00539	1.00589	1.00538	1.00525	...	1.00519	1.00487
51.0	1.00588	1.00490	1.00596	1.00504	1.00486	1.00530	1.00485	1.00473	...	1.00467	1.00438
52.0	1.00523	1.00436	1.00530	1.00448	1.00432	1.00471	1.00431	1.00420	...	1.00416	1.00389
53.0	1.00458	1.00381	1.00464	1.00393	1.00378	1.00412	1.00377	1.00368	...	1.00364	1.00341
54.0	1.00393	1.00327	1.00398	1.00337	1.00324	1.00353	1.00323	1.00315	...	1.00312	1.00292
55.0	1.00327	1.00272	1.00331	1.00281	1.00270	1.00294	1.00270	1.00263	...	1.00260	1.00243
56.0	1.00262	1.00218	1.00265	1.00224	1.00216	1.00235	1.00216	1.00210	1.00219	1.00208	1.00195
57.0	1.00196	1.00164	1.00199	1.00168	1.00162	1.00176	1.00162	1.00158	1.00164	1.00156	1.00146
58.0	1.00131	1.00109	1.00132	1.00112	1.00108	1.00118	1.00108	1.00105	1.00109	1.00104	1.00097
59.0	1.00066	1.00055	1.00066	1.00056	1.00054	1.00059	1.00054	1.00053	1.00054	1.00052	1.00049
60.0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
61.0	0.99934	0.99945	0.99933	0.99944	0.99946	0.99941	0.99946	0.99947	0.99945	0.99949	0.99951
62.0	0.99869	0.99891	0.99867	0.99888	0.99892	0.99882	0.99892	0.99895	0.99890	0.99897	0.99903
63.0	0.99803	0.99836	0.99801	0.99832	0.99838	0.99823	0.99838	0.99842	0.99835	0.99845	0.99854