Designation: D5201 – 05a (Reapproved 2014)

Standard Practice for Calculating Formulation Physical Constants of Paints and Coatings[1]

This standard is issued under the fixed designation D5201; 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 practice covers procedures commonly used in the paint industry to formulate paints and coating materials. It describes procedures for calculating formulation values for weight solids, volume solids, solvent content, volatile organic compound (VOC) content, hazardous air pollutant (HAP) content, and density of liquid paints and coatings. These values are calculated from basic formulation data. These calculations may be related to either as-supplied (unreduced) or as-applied (reduced) coating materials, including multicomponent types.

1.2 These calculated, formulation-based values may or may not be acceptable for VOC regulatory purposes, depending on the specific wording of the applicable regulation. Some regulations require analysis of the coating. Some rules allow the use of formulation data, however, some adjustments may be needed to the values calculated in this practice before they are used for regulatory purposes (see 4.3).

1.3 For purposes of this practice, it is assumed that volatile components evaporate and the materials that remain are identified as coating solids. For example, solvents are normally used to adjust viscosity for application and appearance of the coating. Other liquid materials, such as plasticizers, reactive diluents, etc., that are expected to be retained in the dried film to affect the final physical properties should be classified as part of the coating solids. Standards such as Test Methods D2369, D4758, D5403 and Guide D2832 may be used to determine volatile or nonvolatile content of specific components. For purposes of this practice it is assumed that the blended formulation behaves as an *ideal* solution with no volume change on mixing (see 6.2).

1.4 Volatile by-products of cross-linking reactions (cure volatiles) are not considered in these calculations since the object of this practice is to define paint physical constants based on formulation information. Variations in raw materials, variations in the production processes, test methods, and test method accuracy are not taken into account in these calculations.

1.5 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard. However, they may be readily converted into SI units, if required by the user (for example, see Note 4).

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D153 Test Methods for Specific Gravity of Pigments

D1475 Test Method For Density of Liquid Coatings, Inks, and Related Products

D2369 Test Method for Volatile Content of Coatings

D2832 Guide for Determining Volatile and Nonvolatile Content of Paint and Related Coatings

D3960 Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings

D4758 Test Method for Nonvolatile Content of Latexes (Withdrawn 2007)[3]

D5403 Test Methods for Volatile Content of Radiation Curable Materials

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *U. S. Environmental Protection Agency Documents:*

Code of Federal Regulations Title 40 Part 51.100 (s) Definition of VOC *Clean Air Act, Section 112*[4,5]

Code of Federal Regulations Title 40 Part 63, Subpart

[1] This practice 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.

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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.

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

[4] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. They are also available at the EPA website: http://www.epa.gov/ttn/atw/coat/coatingscalc.html.

[5] A list of hazardous air pollutants (HAPs) may be found at the following website: http://www.epa.gov/ttn/atw/188polls.html. Modifications to this original list may be found at the following website: http://www.epa.gov/ttnatw01/atwsmod.html or at the Code of Federal Regulations, Title 40, Part 63, Subpart C.

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

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NNNN, Table 3 (Default Organic HAP Mass Fraction for Solvents and Solvent Blends) and Subpart RRRR Table 4 (Default Organic HAP Mass Fraction for Petroleum Solvent Groups)[4]

EPA Federal Reference Method 24 – Determination of Volatile Matter Content, Water Content, Density Volume Solids, and Weight Solids, of Surface Coatings[4]

EPA Federal Reference Method 311 – Analysis of Hazardous Air Pollutant Compound in Paints and Coatings by Direct Injection into a Gas Chromatograph[4]

EPA 450/3-88-018 U.S. Environmental Protection Agency Protocol for Determining the Daily Volatile Organic Compound Emission Rate of Automobile and Light Duty Truck Topcoat Operations[6]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *formula density, n*—(see Test Method D1475), the calculated mass of a unit volume of material at the specified temperature.

3.1.1.1 *Discussion*—In this practice, density is expressed in pounds per U.S. gallon (lb/gal) since this is commonly used in the coatings industry. Where dry materials are concerned, actual density (not bulk density) should be determined analytically or obtained from supplier information. Use Test Methods D153 where applicable.

3.1.2 *formula HAP content, n*—calculated amount based on formula content (such as pounds of HAP per gallon of coating solids).

3.1.2.1 *Discussion*—This is a theoretical value that may be an approximation of the HAP content that would be obtained by an analytical determination, for example, EPA Reference Method 311.

3.1.3 *formula percent volume solids content, n*—the calculated volume of nonvolatile material in a formula divided by the total volume of the paint material, times 100 %.

3.1.4 *formula percent weight solids content, n*—the calculated weight of nonvolatile material in a formula divided by the total weight of the coating material, times 100 %.

3.1.5 *formula solvent content, n*—the calculated weight of the solvents in a specific volume of paint (such as pounds of solvent per gallon of paint), which is determined by totaling all solvents present.

3.1.5.1 *Discussion*—Volatile by-products of cross-linking reactions (cure volatiles) are *not* included in the formula solvent content.

3.1.6 *formula volatile density, n*—the calculated density of the combined volatile composition (includes VOC, exempt solvents, water, ammonia, etc.).

3.1.7 *formula VOC content, n*—calculated amount based upon total formula solvent content, (such as pounds of solvent per gallon of paint) exclusive of water or solvents that are not VOC. This is a theoretical value that may be an approximation of the VOC content that would be obtained by an analytical determination, for example, EPA Reference Method 24.

3.1.7.1 *Discussion*—Solvent and VOC are not equivalent terms. See 40 CFR 51·100 (Par·S) for the current EPA definition of volatile organic compound (VOC) and description of compounds that are exempt. Ammonia and water are not VOC, as they are not organic compounds.

4. Significance and Use

4.1 Physical constants of paints and coatings are required in all aspects of their formulation, manufacture and use. This practice demonstrates standard methods agreed upon for calculating formulation values for some of these physical constants. The calculations are the same for either metric or inch/pound units.

4.2 These formula values may not be used to replace measured values required by government regulations unless specifically stated in the governing documents.

4.3 Some regulations allow compliance determination using formulation data instead of analytical data. This formulation data may not yield the same results as the required analytical method, which could be performed on a sample from any production batch of the coating. In these cases, the user may wish to compare formulation data to analytical data and develop a factor that adjusts for variability of raw materials, variability of production batches, cure volatiles, and variability of the analytical methods.

5. Calculations

5.1 Calculated values should be rounded to the appropriate number of significant digits in accordance with Practice E29, Guidelines for Retaining Significant Figures in Calculation and Reporting of Test Results.

5.2 *Formula Density (weight per unit volume):*

5.2.1 The formula density (D_f) can be calculated from the total weight (W_f) and total volume (V_f) of the formulation. The formulation volume can be calculated from the weight and density of each ingredient as given by the following equation:

$$D_f = W_f/V_f = [W_1 + W_2 + \ldots W_n]/[W_1/D_1 + W_2/D_2 + \ldots W_n/D_{fn}] = [sum]\, W_i/[sum]\, W_i/D_i \quad (1)$$

where:

n = number of items in the formulation,
D_f = formula density, lb/gal (g/L),
W_f = total weight of formula, lb (g),
V_f = total volume of formula, gal (L),
W_i = weight of ingredient, lb (g), and
D_i = density of ingredient.

5.2.1.1 An example would be as follows where the weight (W) and density (D) of each ingredient are known:

Ingredient	Weight W, (lb)	Density D, (lb/gal)	Volume V, (gal)
1	81.50	7.74	10.530
2	6.10	7.90	0.772
3	0.40	8.72	0.046
4	12.00	7.65	1.569
Formula	100.00	D_f	12.917

[6] 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. Refer to EPA 450/3-88-018 dated December 1988. This protocol makes reference to the paint formulation physical constants for VOC and volume solids content.

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