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A Guideline for Surface Coating Calculations

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A Guide For Surface Coating Calculations

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ABSTRACT

The calculation of volatile organic compound emissions from surface coating operations to determine compliance is often a complicated task, sometimes creating confusion with compliance authorities and sources alike. In an attempt to minimize this confusion, EPA (OAQPS) has periodically issued guidance in this area, generally in the form of memoranda to the EPA Regional Offices. EPA guidance for submitting data on surface coatings and performing basic calculations is contained in the document entitled "Procedures for Certifying Quantity of Volatile Organic Compounds Emitted by Paint, Ink and Other Coatings," EPA 450/3-84-019, published in December 1984.

"A Guideline for Surface Coating Calculations" takes the above guidance process one step further. Example calculations are included for basic emission problems, compliance determinations, equivalency determinations, application of transfer efficiency, and calculations involving complex multiproduct plants. Graphs and tables useful in approximating and double-checking these calculations are also included.

SECTION 1

INTRODUCTION

1.1 BACKGROUND

Surface coating entails the deposition of a solid film on a surface through the application of a coating material such as paint, lacquer, or varnish. Surface coating operations are significant volatile organic compound (VOC) emission sources. Most coatings contain VOCs which evaporate during the coating application and curing processes, rather than becoming part of the dry film.

The U.S. Environmental Protection Agency (EPA) has issued Control Techniques Guidelines (CTGs) for many surface coating operations, including cans, metal coils, paper, fabric, automobiles, light-duty trucks, metal furniture, large appliances, magnet wire, miscellaneous metal parts and products, graphic arts, and flatwood paneling. The emission limits recommended in these guidelines have been adopted by many state and local agencies. The EPA has also issued new source performance standards (NSPS) for many surface coating operations, including automobile, light-duty trucks, beverage cans, metal coils, large appliances, metal furniture, pressure sensitive tapes and labels, vinyl printing and topcoating, and publication rotogravure printing.

To comply with these regulations, a surface coating operator might elect to change to low VOC content coatings, to use add-on controls such as incineration or carbon adsorption, or to improve transfer efficiency. In cases where compliance is achieved by a change in coating alone, VOC emissions can be calculated from the VOC content of the coating as applied to the substrate. When add-on controls or transfer efficiency improvements are used, more complex calculations can be performed to determine the effectiveness of the control strategy. It is more convenient (and frequently more reliable) to establish VOC compliance or non-compliance through these calculations than it is to measure total VOC emissions directly.

The emission limits for existing sources recommended in the CTGs and adopted by many state and local agencies are expressed in terms of pounds of VOC per gallon of coating less water. These units are directly useful only for cases where compliance is achieved with low VOC content coatings alone. When add-on controls or transfer efficiency improvements are used, compliance calculations must be done on an equivalent solids basis. The reasons for this are explained graphically in Glossary of Air Pollution Control of Industrial Coating Operations, EPA-450/3-83-013R, December 1983. Pages 26-29 of this document are located in Appendix A. The emission limits in most surface coating NSPSs are expressed in terms of pounds of VOC per gallon of coating solids applied. The reader should review this concept in Appendix A before continuing in this guideline manual. This calculation guide assumes that the solids used or applied in a specific process remain constant for a given example (solids equivalency).

1.2 DESCRIPTION OF VOC CALCULATIONS

This document presents sample calculations typical of those used to determine compliance or to evaluate control strategies. These step-by-step calculations are accompanied by explanations that are useful to persons unfamiliar with surface coating operations. Basic calculations are included along with calculations to determine compliance and equivalency (necessary for evaluating bubbles, offsets, netting, etc.). Transfer efficiency problems requiring a series of calculations are included.

The basis for most of the sample calculations is the information and procedures discussed in Procedure for Certifying Quantity of Volatile Organic Compounds Emitted by Paint, Ink, and Other Coatings, EPA-450/3-84-019, December 1984, which is reprinted as Appendix B of this report and referred to as the "VOC Data Sheets". The first VOC Data Sheet provides information on the VOCs present in a coating when it is sold by the manufacturer to the coater. This is referred to as the VOC content of the coating "as supplied by the coating manufacturer to the user." The second VOC Data Sheet provides information on the VOCs present in the coating as it is used by the coater and includes the effect of dilution solvent added before application. This is referred to as the VOC content "as applied to the substrate by the user." For dip or flow coating operations, this should include any make-up solvent which is added to a coating to replace evaporated solvent and therefore maintain a specific viscosity of the coating being applied. The calculations in this document assume that the inspector has obtained the coating data from the VOC Data Sheets. However, it is up to the inspector to verify this data. EPA Reference Method 24 or individual ASTM methods are the final judge in determining compliance. Appendix C contains a copy of Reference Method 24.

Some confusion may exist regarding the meanings and proper uses of terms. As defined in Appendix B, the term "as applied" means the condition of a coating after dilution by the user just prior to application to the substrate. However, the term "solids applied" means the amount coating solids that actually adheres to the object being coated, not the amount of solids leaving the applicator. In contrast, the term "solids used" refers to the total amount of solids used in an application, not the amount of solids that actually adheres to substrate. Care should be taken when using these terms to avoid confusion.

1.3 NEGLIGIBLY PHOTOCHEMICALLY REACTIVE MATERIALS

A volatile organic compound is defined in 40 CFR Subpart A, General Provisions, §60.2, as any organic compound which participates in atmospheric photochemical reactions; or which is measured by a reference method, an equivalent method, or an alternative method; or which is determined by procedures specified under any subpart. The EPA considers the following organic solvents to have negligible photochemical reactivity, and therefore does not consider them to be VOCs:

Methane[1]
Ethane[1]
1,1,1-trichloroethane (methyl chloroform)[1]
Methylene chloride[2]
Trichlorofluoromethane (CFC-11)[3]
Dichlorodifluoromethane (CFC-12)[3]
Chlorodifluoromethane (CFC-22)[3]
Trifluoromethane (CFC-23)[3]
Trichlorotrifluoroethane (CFC-113)[1]

Dichlorotetrafluoroethane (CFC-114)[3]
Chloropentafluoroethane (CFC-115)[3]

Many states also do not consider some or all of these materials to be VOCs.

Two of these compounds, 1,1,1-trichloroethane and methylene chloride, are used as solvents in some coatings. These materials should not be counted as VOCs if they are "exempt" from the applicable regulation. The method for discounting these materials is described in some of the examples and in Appendix B. Generally, these materials, when "exempt" from the applicable regulation, are treated in the same manner as water in emission calculations.

Only the compounds listed above and any compounds given the status of "negligibly photochemically reactive" by the U.S. EPA in a future Federal Register may be considered as exempt from Federal enforcement of applicable State SIP VOC regulations. Also, Rule 66 should not be referenced for exempting compounds as per 42 FR 35314, July 8, 1977.

[1] 42 FR 35314, July 8, 1977

[2] 45 FR 32042, June 4, 1979

[3] 45 FR 48941, July 22, 1980

SECTION 2

BASIC CALCULATIONS

This section presents examples of basic types of calculations. The examples closely follow the VOC Data Sheets (Appendix B).

2.1 DETERMINING THE MASS OF VOC EMITTED PER VOLUME OF SOLIDS

Example 1 -

Determine the mass of VOC emitted per volume of solids for a solvent-borne coating. The following data are given:

A.	Coating Density	= 10.0 lb/gal
B.	Total Volatiles	= 60 percent by weight
C.	Water Content	= 0
D.	Organic* Volatiles Content	= 60 percent by weight
E.	Nonvolatiles Content (Solids)	= 35 percent by volume

Mass of VOC emitted per volume of solids is:

$$\frac{10.0 \text{ lb coating}}{\text{gal coating}} \times \frac{0.60 \text{ lb VOC}}{\text{lb coating}} \times \frac{1 \text{ gal coating}}{0.35 \text{ gal solids}} = \frac{17.1 \text{ lb VOC}}{\text{gal solids}}$$

- -

Example 2 -

Determine the mass of VOC emitted per volume of solids for a waterborne coating. The following data are given:

A.	Coating Density	= 9.0 lb/gal
B.	Total Volatiles	= 70 percent by weight
C.	Water Content	= 30 percent by weight
D.	Organic* Volatiles Content	= 70-30=40 percent by weight
E.	Nonvolatiles Content (Solids)	= 19.6 percent by volume

*Photochemically reactive materials only.

Mass of VOC emitted per volume of solids is:

$$\frac{9.0 \text{ lb coating}}{\text{gal coating}} \times \frac{0.40 \text{ lb VOC}}{\text{lb coating}} \times \frac{1 \text{ gal coating}}{0.196 \text{ gal solids}} = \frac{18.4 \text{ lb VOC}}{\text{gal solids}}$$

- -

Example 3 -

Determine the mass of VOC emitted per volume of solids for a coating that contains some negligibly photochemically reactive (NPR) solvents. The following data are given:

A.	Coating Density	= 11.0 lb/gal
B.	Total Volatiles	= 80 percent by weight
C.	NPR Solvent Content	= 40 percent by weight
D.	Organic* Volatiles Content	= 40 percent by weight
E.	Nonvolatiles Content (Solids)	= 15 percent by volume

Mass of VOC emitted per volume of solids is:

$$\frac{11.0 \text{ lb coating}}{\text{gal coating}} \times \frac{0.40 \text{ lb VOC}}{\text{lb coating}} \times \frac{1 \text{ gal coating}}{0.15 \text{ gal solids}} = \frac{29.3 \text{ lb VOC}}{\text{gal solids}}$$

- -

2.2 DETERMINING THE MASS OF VOC EMITTED PER VOLUME OF COATING LESS WATER

Example 4 -

Determine the mass of VOC emitted per volume of coating less water for a solvent-borne coating. The following data are given:

A.	Coating Density	= 10 lb/gal
B.	Total Volatiles	= 60 percent weight
C.	Water Content	= 0
D.	Organic* Volatiles Content	= 60 percent weight

Mass of VOC per volume of coating less water is:

$$\frac{10 \text{ lb coating}}{\text{gal coating}} \times \frac{0.60 \text{ lb VOC}}{\text{lb coating}} \times \frac{1 \text{ gal coating}}{(1-0) \text{ gal coating less water}}$$

$$= \frac{6 \text{ lb VOC}}{\text{gal coating less water}}$$

*Photochemically reactive materials only.

- -

Example 5 -

Determine the mass of VOC emitted per volume of coating less water for a water-borne coating. The following data are given:

A. Coating Density	= 9.0 lb/gal
B. Total Volatiles	= 70 percent by weight
C. Water Content	= 30 percent by weight
D. Organic* Volatiles Content	= 70-30=40 percent by weight

The mass of water in the coating is:

$$\frac{9.0 \text{ lb coating}}{\text{gal coating}} \times \frac{0.3 \text{ lb water}}{\text{lb coating}} = \frac{2.7 \text{ lb water}}{\text{gal coating}}$$

The volume of water in the coating is:

$$\frac{2.7 \text{ lb water}}{\text{gal coating}} \times \frac{1}{\frac{8.33 \text{ lb water}}{\text{gal water}}} = \frac{0.32 \text{ gal water}}{\text{gal coating}}$$

The mass of VOC in the coating is:

$$\frac{9.0 \text{ lb coating}}{\text{gal coating}} \times \frac{0.4 \text{ lb VOC}}{\text{lb coating}} = \frac{3.6 \text{ lb VOC}}{\text{gal coating}}$$

The mass of VOC emitted per volume of coating less water is:

$$\frac{\frac{3.6 \text{ lb VOC}}{\text{gal coating}}}{\frac{1 \text{ gal coating} - 0.32 \text{ gal water}}{\text{gal coating}}} = \frac{5.3 \text{ lb VOC}}{\text{gal coating less water}}$$

- -

Example 6 -

Determine the mass of VOC emitted per gallon of coating less negligibly photochemically reactive material for a coating that contains some negligibly photochemically reactive material.

The following data are given:

A. Coating Density	= 10.5 lb/gallon
B. Total Volatiles	= 80 percent by weight
C. NPR Solvent Content	= 40 percent by weight
D. Organic* Volatiles Content	= 40 percent by weight
E. NPR Solvent Density	= 11.0 lb/gal

*Photochemically reactive materials only.

The mass of VOC per volume of coating is:

$$\frac{10.5 \text{ lb coating}}{\text{gal coating}} \times \frac{0.4 \text{ lb VOC}}{\text{lb coating}} = \frac{4.2 \text{ lb VOC}}{\text{gal coating}}$$

The mass of NPR solvent in the coating is:

$$\frac{10.5 \text{ lb coating}}{\text{gal coating}} \times \frac{0.4 \text{ lb NPR solvent}}{\text{lb coating}} = \frac{4.2 \text{ lb NPR solvent}}{\text{gal coating}}$$

The volume of NPR solvent in the coating is:

$$\frac{4.2 \text{ lb NPR solvent}}{\text{gal coating}} \times \frac{1}{\frac{11.0 \text{ lb NPR solvent}}{\text{gal NPR solvent}}} = \frac{0.38 \text{ gal NPR solvent}}{\text{gal coating}}$$

The mass of VOC per gallon of coating less NPR solvent is:

$$\frac{\frac{4.2 \text{ lb VOC}}{\text{gal coating}}}{\frac{1 \text{ gal coating} - 0.38 \text{ gal NPR solvent}}{1 \text{ gal coating}}} = \frac{6.8 \text{ lb VOC}}{\text{gal coating less NPR solvent}}$$

SECTION 3
TRANSFER EFFICIENCY

When spray guns are used to apply coatings, much of the coating material either bounces off the surface being coated or misses it altogether. Transfer efficiency (TE) is the ratio of the amount of coating solids deposited on the coated part to the amount of coating solids used. Regardless of the TE, all of the VOCs in the dispensed coating are emitted whether or not the coating actually reaches and adheres to the surface. Consequently, improved TE can reduce VOC emissions because less coating is used. EPA has defined baseline transfer efficiencies of 60 percent for RACT in metal furniture and appliance coating and 30 percent for RACT waterborne equivalence in the automobile industry (for both primer-surfacer and topcoat applications). If a base TE has not been documented by EPA, then the company must satisfactorily document their base TE prior to equivalency calculations/demonstrations. To obtain TE credits, a company must prove its baseline TE with documentation, and document the new TE.

3.1 DETERMINING THE MASS OF VOC EMITTED PER VOLUME OF SOLIDS APPLIED

Example 1 -

Determine the mass of VOC emitted per volume of solids applied given the following data:

A. VOC content of coating $= \frac{4.0 \text{ lb VOC}}{\text{gal solids}}$

B. Transfer efficiency = 40 percent

Mass of VOC emitted per volume of solids applied is:

$$\frac{4.0 \text{ lb VOC}}{\text{gal solids}} \times \frac{1 \text{ gal solids used}}{0.4 \text{ gal solids applied}} = \frac{10.0 \text{ lb VOC}}{\text{gal solids applied}}$$

- -

Example 2 -

Determine the mass of VOC emitted per volume of solids applied given the following data:

A. VOC content of coating = 3.0 lb VOC/gal coating less water
B. Nonvolatiles content = 55 percent by volume
C. Transfer efficiency = 60 percent
D. Water Content = None

$$\frac{3.0 \text{ lb VOC}}{\text{gal coating less water}} \times \frac{1 \text{ gal coating less water}}{0.55 \text{ gal solids}} \times \frac{1 \text{ gal solids used}}{0.60 \text{ gal solids applied}}$$

$$= \frac{9.1 \text{ lb VOC}}{1 \text{ gallon solids applied}}$$

Note: For a waterborne coating, be careful of using pounds of VOC per gallon of coating less water and volume nonvolatiles content as a fraction of the total coating including water. These two items cannot simply be combined to get pounds of VOC per gallon of solids. The best method is to follow Example 2 in Section 2 and then factor in transfer efficiency. Alternatively, the volume nonvolatiles content could be determined for the coating less water if the volume fraction water is known or calculated as follows:

$$\text{Volume fraction nonvolatiles in coating less water} = \frac{\text{volume fraction nonvolatiles in coating including water}}{1 - \text{volume fraction water}}$$

- -

3.2 CALCULATING AVERAGE TRANSFER EFFICIENCY

Example 3 -

A plant operates two coating lines. Each line uses both manual electrostatic spray guns (TE = 60 percent) and rotating-head electrostatic spray guns (TE = 80 percent). Table 1 contains the applicable data. What is the average transfer efficiency?

$$\text{Average TE} = \frac{\text{total liters of solids deposited}}{\text{total liters of solids used}} = \frac{38.4 + 36.8}{64 + 46} \times 100$$

$$= \frac{75.2}{110} \times 100 = 68 \text{ percent}$$

TABLE 1. EXAMPLE CALCULATION OF AVERAGE TE WHEN SEVERAL DIFFERENT COATING APPLICATION METHODS ARE USED

Coating line	Total liters of coating used	Volume percent solids	Total liters of solids used	Application Method: Manual electrostatic spray (TE = 60%)*			Application Method: Rotating-head electrostatic spray (TE = 80%)*		
				Liters of coating used	Liters of solids used	Liters of solids deposited	Liters of coating used	Liters of solids used	Liters of solids deposited
A	100	50	50	80	40	24	20	10	8
B	100	60	60	40	24	14.4	60	36	28.8
TOTAL					64	38.4		46	36.8

*These TE values are illustrative values only. Actual TE must be determined to calculate actual emissions.

SECTION 4
COMPLIANCE DETERMINATIONS

4.1 CALCULATING COATING COMPLIANCE WITH A STANDARD

Example 1 -

A coater is required to meet an emission limit of 3.5 pounds of VOC per gallon of coating less water. Does a coating with a density of 12 pounds per gallon that contains 25 weight percent VOC comply? The coating contains no water or negligibly photochemically reactive solvents.

$$\frac{12 \text{ lb coating}}{\text{gal coating}} \times \frac{0.25 \text{ lb VOC}}{\text{lb coating}} \times \frac{1 \text{ gal coating}}{(1-0) \text{ gal coating less water}}$$

$$= \frac{3 \text{ lb VOC}}{\text{gal coating less water}}$$

So, the coating complies with the regulation.

- -

Example 2 -

A coater is required to meet an emission limit of 4.0 pounds VOC per gallon of solids. Does a coating with a density of 10 pounds per gallon that contains 60 weight percent volatiles, 45 weight percent water, and 30 volume percent solids comply?

The weight percent organic volatiles is 60-45=15.

The VOC content of the coating is:

$$\frac{10 \text{ lb coating}}{\text{gal coating}} \times \frac{0.15 \text{ lb VOC}}{\text{lb coating}} \times \frac{1 \text{ gal coating}}{0.30 \text{ gal solids}} = \frac{5 \text{ lb VOC}}{\text{gal solids}}$$

So, the coating does not comply with the regulation.

- -

Example 3 -

A coater is required to meet an emission limit of 10 pounds VOC per gallon of solids applied. Does the coating in Example 2 comply if it is applied at a transfer efficiency of 80 percent?

$$\frac{5 \text{ lb VOC}}{\text{gal solids}} \times \frac{1 \text{ gal solids used}}{0.80 \text{ gallon solids applied}} = \frac{6.3 \text{ lb VOC}}{\text{gal solids applied}}$$

So, the coating meets the regulation.

- -

Example 4 -

A metal furniture coater uses a coating containing 0.40 kg VOC/liter of coating (less water and exempt solvents). The coating contains 55 volume percent solids. The transfer efficiency is 87 percent. Is the plant in compliance if the maximum allowable emissions are 1.0 kg VOC/liter solids applied?

The solution is found by using the following basic equation:

$$\frac{\text{mass of VOC used}}{\text{volume of coating solids used}} \times \frac{1}{\text{TE}} = \frac{\text{mass of VOC used}}{\text{volume of coating solids applied}}$$

Emissions are:

$$\frac{0.40 \text{ kg VOC}}{\text{1 liter of coating less water and exempt solvents}} \times \frac{\text{1 liter of coating less water and exempt solvents}}{0.55 \text{ liter solids}} \times$$

$$\frac{1 \text{ liter solids}}{0.87 \text{ liter solids applied}} = \frac{0.84 \text{ kg VOC}}{1 \text{ liter solids applied}}$$

Since 0.84 is less than 1.0, the coating operation is in compliance.

Note: This example is similar to Example 2 in Section 3.1. Therefore, the note mentioned after Example 2 applies to this example too.

- -

4.2 CALCULATING COMPLIANCE WHEN ADD-ON CONTROLS ARE USED

Example 5 -

A coater is required to meet an emission limit of 6 pounds of VOC per gallon of solids. What percent emission reduction is needed if the coater uses a coating with 22 pounds of VOC per gallon of solids?

$$\frac{22-6}{22} \times 100 = \frac{16}{22} \times 100 = 73 \text{ percent emission reduction}$$

Example 6 -

A coater is required to meet an emission limit of 3.7 pounds of VOC per gallon of coating less water. What percent emission reduction is needed if the coater uses a solvent-borne coating with 5.0 pounds of VOC per gallon of coating less water and a volume solids content of 25 percent?

This calculation must be done on a solids basis. First, the emission limit must be converted to pounds of VOC per gallon of solids. To do this, an assumed VOC density of 7.36 pounds per gallon is used to calculate the volume solids content of the "presumptive" RACT coating.

$$\frac{3.7 \text{ lb VOC}}{\text{gal coating less water}} \times \frac{1 \text{ gal VOC}}{7.36 \text{ lb VOC}} \times 100 = 50 \text{ volume percent VOC}$$

$$100-50 = 50 \text{ volume percent solids}$$

$$\frac{3.7 \text{ lb VOC}}{\text{gal coating}} \times \frac{1 \text{ gal coating}}{0.50 \text{ gal solids}} = \frac{7.4 \text{ lb VOC}}{\text{gal solids}}$$

Next, the VOC content of the coating used must also be calculated on a solids basis.

$$\frac{5.0 \text{ lb VOC}}{\text{gal coating}} \times \frac{1 \text{ gal coating}}{0.25 \text{ gal solids}} = \frac{20 \text{ lb VOC}}{\text{gal solids}}$$

Now the required percent reduction can be calculated.

$$\frac{20-7.4}{20} \times 100 = 63 \text{ percent emission reduction}$$

Notes:

1. An erroneous result is obtained if this calculation is not done on a solids basis. Using pounds of VOC per gallon of coating less water the result would be:

$$\frac{5.0-3.7}{5.0} \times 100 = 26 \text{ percent emission reduction}$$

This would not give equivalent emissions as it does not take into account that the "presumptive" RACT coating not only has lower VOC content, but higher solids content as well.

2. An assumed VOC density of 7.36 pounds per gallon is used to calculate the volume solids content of the "presumptive" RACT coating because this same value was used to determine the "presumptive" recommended RACT emission limits from volume solids data.

3. The volume solids content of actual coatings should be determined directly from coating formulation data as described in the VOC Data Sheets. Ocassionally, it may be useful to back calculate volume solids from VOC content and actual solvent or VOC density, but this must be done with extreme caution. When an inspector gathers data on the actual coatings used at a facility, the volume solids content should be obtained from coating formulation data from the facility or the coating manufacturer. The volume solids content should not be back calculated.

SECTION 5

EQUIVALENCY DETERMINATIONS

Equivalency calculations are required when compliance decisions must be made for replacement coatings, bubbles, offsets, netting, etc. This type of calculation relates primarily to the CTG source categories. This section presents example equivalency calculations.

VOC equivalency calculations must be made on a solids basis. The amount of solids needed to coat a surface to a particular film thickness is the same regardless of the coating composition used. Reducing the solids content of an organic solvent-borne coating increases the quantity of coating required and increases VOC emissions because more coating is used and the coating has a higher VOC content.

5.1 CALCULATING ALLOWABLE HOURLY EMISSIONS FOR A SOLVENT-BORNE COATING*

Example 1 -

A surface coater uses 10 gallons per hour of a coating that contains 5.5 lb VOC per gallon of coating and 25 volume percent solids. New regulations indicate that the coating formulation must meet an emission limit of 3.0 lb of VOC per gallon of coating (with a solvent density of 7.36 lb per gallon) or the coater must control VOC emissions to an equivalent level. Assuming that the production rate (solids usage rate), transfer efficiency, and film thickness stay constant, what are the coater's "allowable" hourly VOC emissions?

For the existing coating, the actual VOC emissions are:

$$\frac{10 \text{ gal coating}}{\text{h}} \times \frac{5.5 \text{ lb VOC}}{\text{gal coating}} = \frac{55 \text{ lb VOC}}{\text{h}}$$

*This example presents a method for determining hourly VOC mass emissions for offset calculations; however, RACT limitations should normally be based on either applicable coating formulations or control efficiency requirements. An hourly cap would normally only be used in addition to these RACT limitations.

The solids usage rate is:

$$\frac{10 \text{ gal coating}}{\text{h}} \times \frac{0.25 \text{ gal solids}}{\text{gal coating}} = \frac{2.5 \text{ gal solids}}{\text{h}}$$

For the complying coating, the VOC (solvent) volume fraction is:

$$\frac{3.0 \text{ lb VOC}}{\text{gal coating}} \times \frac{1 \text{ gal VOC}}{7.36 \text{ lb VOC}} = \frac{0.41 \text{ gal VOC}}{\text{gal coating}}$$

The complying coating solids volume fraction is:

$$1.0 - 0.41 = \frac{0.59 \text{ gal solids}}{\text{gal coating}}$$

Using the solids usage rate calculated above, the gallons of complying coating required are:

$$\frac{2.5 \text{ gal solids}}{\text{h}} \times \frac{\text{gal coating}}{0.59 \text{ gal solids}} = \frac{4.24 \text{ gal complying coating}}{\text{h}}$$

The emissions rate at the existing solids applied rate is:

$$\frac{3.0 \text{ lb VOC}}{\text{gal coating}} \times \frac{4.24 \text{ gal coating}}{\text{h}} = \frac{12.72 \text{ lb VOC}}{\text{h}}$$

- -

5.2 EQUIVALENCY CALCULATIONS FOR A CAN COATING OPERATION

Example 2 -

The RACT equivalence requirements for can coating operations are tabulated in 45 FR 80825, dated December 8, 1980. An analysis of two coatings used in an actual plant is:

		Coating No. 1	Coating No. 2
(1)	Actual pounds of VOC per gallon of coating less water and exempt solvents as applied	5.42	1.09
(2)	Gallons of each coating applied	110	240
(3)	Control efficiency, percent	0.81	--
(4)	Volume percent water and exempt solvents in coatings	--	41.3

(continued)

		Coating No. 1	Coating No. 2
(5)	Volume percent solids	26.4	50.0
(6)	Allowable emission limit, lb VOC/gal coating less water and exempt solvents	2.8	2.8

Calculate the following:

(1) Gallons of solids applied.

(2) Pounds of VOC per gallon of solids.

(3) Pounds of VOC emitted.

(4) Allowable VOC emissions.

Answers:

(1) The gallons of solids applied can be calculated as follows:

Gallons of solids applied = (gallons of coating used) x (volume percent solids) ÷ 100%

(Since the quantity of solids used in the equation appears as a percentage it is necessary to divide by 100%.)

Coating No. 1:

$$110 \text{ gal coating applied} \times \frac{26.4 \text{ gal solids}}{100 \text{ gal coating}} = 29 \text{ gal solids applied}$$

Coating No. 2:

$$240 \text{ gal coating applied} \times \frac{50 \text{ gal solids}}{100 \text{ gal coating}} = 120 \text{ gal solids applied}$$

(2) As noted on Page 10, the pounds of VOC per gallon of solids can be calculated as follows:

$$\frac{\text{lb VOC}}{\text{gal of solids}} = \frac{\text{lb VOC/gal coating less water}}{\frac{\text{volume percent solids}}{100\text{-volume percent water}}}$$

Coating No. 1:

$$\frac{5.42 \text{ lb VOC}}{\text{gal coating less water}} \times \frac{100 \text{ gal coating}}{26.4 \text{ gal solids}} \times \frac{100 - 0 \text{ gal coating less water}}{100 \text{ gal coating}}$$

$$= \frac{20.53 \text{ lb VOC}}{\text{gal solids}}$$

Coating No. 2:

$$\frac{1.09 \text{ lb VOC}}{\text{gal coating less water}} \times \frac{100 \text{ gal coating}}{50.0 \text{ gal solids}} \times \frac{100 - 41.3 \text{ gal coating less water}}{100 \text{ gal coating}}$$

$$= \frac{1.28 \text{ lb VOC}}{\text{gal solids}}$$

(3) The pounds of VOC emitted can be calculated as follows:

$$\frac{\text{lb of VOC}}{\text{gal of solids}} \times \text{gal of solids} \times (1 - \text{overall control efficiency*})$$

Coating No. 1:

$$\frac{20.53 \text{ lb VOC}}{\text{gal solids}} \times 29.0 \text{ gal solids} \times (1 - 0.81) = 113.1 \text{ lb VOC}$$

Coating No. 2:

$$\frac{1.28 \text{ lb VOC}}{\text{gal solids}} \times 120 \text{ gal solids} \times (1 - 0) = 153.6 \text{ lb VOC}$$

(4) The allowable VOC emissions can be calculated as follows:

As calculated in Item (2), the gallons of solids applied for coatings No. 1 and No. 2 were 29 and 120, respectively. Assume that the coater will apply the same volume of solids with a RACT complying coating.

Given: (1) Emission limit: 2.8 lb VOC/gal coating

(2) VOC density: 7.36 lb VOC/gal

*The overall control efficiency is equal to the fraction of total VOC used that is destroyed or recovered by the control system. Overall control efficiency = capture device efficiency x control device efficiency.

Allowable pounds of VOC = gallons of complying coating applied x allowable emission limit,

$$= \frac{\text{gal solids applied (per unit of time)}}{\text{volume fraction solids in complying coating}} \times \frac{\text{2.8 lb VOC}}{\text{gal coating less water and exempt solvents}}$$

Volume fraction VOC:

$$\frac{\text{2.8 lb VOC}}{\text{gal coating}} \times \frac{\text{1 gal VOC}}{\text{7.36 lb VOC}} = \frac{\text{0.38 gal VOC}}{\text{gal coating}}$$

Volume fraction solids:

$$1 - 0.38 \text{ gal coating} = \frac{\text{0.62 gal solids}}{\text{gal coating}}$$

Allowable pounds of VOC for Coating No. 1:

$$29 \text{ gal solids} \times \frac{\text{1 gal coating}}{\text{0.62 gal solids}} \times \frac{\text{2.8 lb VOC}}{\text{gal coating}}$$

$$= 131 \text{ lb VOC}$$

Allowable pounds of VOC for Coating No. 2:

$$120 \text{ gal solids} \times \frac{\text{gal coating}}{\text{0.62 gal solids}} \times \frac{\text{2.8 lb VOC}}{\text{gal coating}}$$

$$= 542 \text{ lb VOC}$$

Table 2 shows the calculation sequence.

TABLE 2. SUGGESTED FORMAT FOR DETERMINING COMPLIANCE FOR CAN COATING OPERATIONS.

	Lb VOC/ gal coating less water (a)*	Volume % solids (b)*	Volume % solvent (c)	Volume % water (d)*	Lb VOC/ gal solids[1] (e)	Application rate (gal/ units produced (f)*	Units pro- duced (g)*	Gal coating applied (f x g) (h)	Gal solids applied (b x h ÷ 100) (i)	Over- all Add- on Con- trol effi- ciency[2] (j)*	Lb of VOC [e x i] (1 - j) (k)
					Actual Emissions[3]						
Sheet coating	5.42	26.4	-	0	20.52	22	5	110	29.0	0.81	113.0
Sheet coating	1.09	50.0	-	41.3	1.28	10	24	240	120.0	-	153.0
Sheet coating	5.06	31.2	-	0	16.23	10	24	240	74.9	0.81	231.0
Side seam	6.34	13.9	-	0	45.59	1.5	18	27	3.8	-	173.8
Inside spray	3.91	16.0	-	65.9	8.33	8	24	192	30.7	-	255.7
End compound	4.20	42.9	-	0	9.80	1.5	24	36	15.4	-	150.0
ACTUAL TOTAL EMISSIONS											1,077.5
					Allowable Emissions Using Complying Coating[4]						
Sheet coating	2.8	62.0	38.0	-	4.52	9.4	5	47	29.0	-	131.0
Sheet coating	2.8	62.0	38.0	-	4.52	8.1	24	194	120.0	-	542.0
Sheet coating	2.8	62.0	38.0	-	4.52	5.0	24	121	74.9	-	338.0
Side seam	5.5	25.3	74.7	-	21.76	0.8	18	15	3.8	-	82.7
Inside spray	4.2	42.9	57.1	-	9.78	3.0	24	72	30.7	-	300.2
End compound	3.7	49.7	50.3	-	7.44	1.3	24	31	15.4	-	114.6
ACTUAL TOTAL EMISSIONS											1,509.5

*Note: Data in columns a, b, d, f, g, and j (under actual emissions) were obtained from plant records including thinning solvent. Data in columns a, b, and d were determined using procedures in the VOC Data Sheets.

[1]For actual coatings, $e = \dfrac{a}{\left(\dfrac{b}{100 - d}\right)}$

For complying coatings, $e = \dfrac{a}{1 - \dfrac{a}{D}}$

TABLE 2. (continued)

D = Presumed density of VOC for complying coating (7.36 lb/gal).

[2]Control efficiency varies with emission control devices used. The percent capture and control efficiency must be established by using approved test methods. The source must always maintain process and control system parameters as close as possible to those used in the original capture and control efficiency demonstration. If there are any significant changes in these parameters, the source must make a new capture and/or control efficiency demonstration as deemed appropriate by the compliance authority.

[3]Concept based on the following principal for comparing actual and allowable emissions: lb VOC emitted = lb VOC/gal of solids x gal of solids applied per unit. (Same gal of solids applied for actual and allowable emissions.)

[4]Complies with State VOC emission limitations.

SECTION 6

COMPLEX CALCULATIONS

This section presents example calculations demonstrating situations that may require a series of calculations.

6.1 COMPLIANCE DETERMINATION FOR AUTO PLANT PRIMER-SURFACER (GUIDE COAT) OPERATION

Example 1 -

An auto primer-surfacer operation uses a coating that contains 3.58 lb VOC/gal of coating with a transfer efficiency of 50 percent. The RACT emission limit is 2.8 lb VOC/gal of coating less water at 30 percent transfer efficiency (waterborne equivalence). Is the operation in compliance?

Given: (1) The manufacturer's data show that the undiluted coating has 50.0 volume percent solids.

(2) The plant adds 0.05 gal of thinner blend per gallon of undiluted coating:

(a) 0.02 gallon of thinner No. 1/gallon undiluted coating (thinner density 7.36 lb/gal).

(b) 0.02 gallon of thinner No. 2/gallon undiluted coating (thinner density 5.43 lb/gal).

(c) 0.01 gallon of thinner No. 3/gallon undiluted coating (thinner density 9.52 lb/gal).

(3) The density of the undiluted coating is 10.25 lb/gal.

(4) Weight fraction of VOC in undiluted coating =

$$\frac{0.333 \text{ lb VOC solvent}}{\text{lb undiluted coating}}$$

First, verify the VOC content of the coating. In order to do this, the VOC content of the undiluted coating and the thinners must be calculated. The mass of VOC in the undiluted coating is:

$$\frac{0.333 \text{ lb VOC}}{\text{lb undiluted coating}} \times \frac{10.25 \text{ lb undiluted coating}}{\text{gal undiluted coating}} = \frac{3.41 \text{ lb VOC}}{\text{gal undiluted coating}}$$

The mass of thinner added per gallon of undiluted coating is:

$$\frac{0.02 \text{ gal thinner No. 1}}{\text{gal undiluted coating}} \times \frac{7.36 \text{ lb thinner No. 1}}{\text{gal thinner No. 1}} + \frac{0.02 \text{ gal thinner No. 2}}{\text{gal undiluted coating}}$$

$$\times \frac{5.43 \text{ lb thinner No. 2}}{\text{gal thinner No. 2}} + \frac{0.01 \text{ gal thinner No. 3}}{\text{gal undiluted coating}} \times \frac{9.52 \text{ lb thinner No. 3}}{\text{gal thinner No. 3}}$$

$$= 0.147 + 0.109 + 0.095 = \frac{0.351 \text{ lb thinner}}{\text{gal undiluted coating}}$$

The mass VOC per volume coating at application is:

$$\frac{3.41 \text{ lb VOC/gal undiluted coating} + 0.351 \text{ lb thinner/gal undiluted coating}}{1.05 \text{ gal coating/gal undiluted coating}}$$

$$= 3.58 \text{ lb VOC/gal coating}$$

The undiluted coating has 50.0 volume percent solids. After the coating is diluted with 0.05 gallon of thinner per gallon of coating, the volume percent solids is:

$$\frac{0.50}{1 + 0.05} = \frac{0.48 \text{ gal solids}}{\text{volume coating}}$$

The equivalency calculations must be made on a solids basis. The formula for determining the maximum allowable emissions on a solids basis is:

$$\text{Allowable emissions} = \frac{\text{allowable mass of VOC per volume coating}}{\text{(baseline TE) (baseline volume solids)}}$$

As noted in earlier examples, an assumed VOC density of 7.36 gal is used to calculate the volume solids content of the "presumptive" RACT coating.

The volume of VOC in the "presumptive" RACT coating is:

$$\frac{2.8 \text{ lb VOC}}{\text{gal coating}} \times \frac{1 \text{ gal VOC}}{7.36 \text{ lb VOC}} = \frac{0.38 \text{ gal VOC}}{\text{gal coating}}$$

Therefore, the baseline volume of solids is:

$$1 - 0.38 = \frac{0.62 \text{ gal solids}}{\text{gal coating}}$$

Allowable emissions are:

$$\frac{2.8 \text{ lb VOC}}{\text{gal coating}} \times \frac{1 \text{ gal coating}}{0.62 \text{ gal solids}} \times \frac{1 \text{ gal solids}}{0.30 \text{ gal solids applied}} = \frac{15.1 \text{ lb VOC}}{\text{gal solids applied}}$$

The formula for actual emissions is:

$$\text{Actual emissions} = \frac{\text{actual mass VOC per volume coating}}{(\text{actual \% TE})\left(\frac{\text{actual volume solids}}{\text{gal coating}}\right)}$$

The actual mass of VOC per volume coating is 3.58 lb VOC/gallon coating. The actual transfer efficiency is 50 percent. The actual volume of solids in the sprayed coating is 48 percent.

Actual emissions are:

$$\frac{3.58 \text{ lb VOC}}{\text{gal coating}} \times \frac{1 \text{ gal coating}}{0.48 \text{ gal solids}} \times \frac{1 \text{ gal solids}}{0.50 \text{ gal solids applied}} = \frac{14.9 \text{ lb VOC}}{\text{gal solids applied}}$$

Actual emissions (14.9 lb VOC per gallon of solids applied) are less than the maximum allowable emissions (15.1 lb VOC per gallon of solids applied); therefore, the operation is in compliance.

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6.2 DETERMINING COMPLIANCE FOR A LARGE APPLIANCE COATING LINE USING SEVERAL TYPES OF SPRAY EQUIPMENT

Example 2 -

A large appliance manufacturer has a coating operation that employs electrostatic spray coating equipment and manual spray coating equipment. The following data are available regarding the operation. Determine the compliance status. If the large appliance manufacturer is out of compliance, what percent reduction is required to achieve compliance?

	(A) Electrostatic coating	(B) Manual coating
Transfer efficiency, percent	90	40
Average volume percent of solids in coating	39	39
VOC content, lb VOC/gal coating less water	4.5	4.5
Gallons of coating used per day	30.4	47.1
Emission limit, lb/gallon less water	2.8	2.8
Baseline transfer efficiency for large appliances, percent	60	60

The baseline transfer efficiency is 60 percent for a large appliance coater. Table 3 is a tabulation of the available data and calculation results. The actual calculations follow.

TABLE 3. LARGE APPLIANCE MULTITRANSFER EFFICIENCY CALCULATION.

Spray type	Gallons of coating/day	Solids, vol. %	Lb VOC/gallon coating	Lb VOC/gallon solids	% TE	Lb VOC/gallon solids applied	Gallons of solids applied/day	Pounds of VOC/day
Actual emissions								
A	30.4	39	4.5	11.5	90	12.8	10.7	136.8
B	47.1	39	4.5	11.5	40	28.8	7.3	212.0
Total								348.8
Allowed emissions								
A	28.8	62	2.8	4.5	60	7.5	10.7	80.6
B	19.6	62	2.8	4.5	60	7.5	7.3	54.9
Total								135.5

Under the actual emissions category, the following calculations can be made.

For A and B, the mass of VOC per volume of solids is:

$$\frac{4.5 \text{ lb VOC}}{\text{gal coating}} \times \frac{1 \text{ gal coating}}{0.39 \text{ gal solids}} = \frac{11.5 \text{ lb VOC}}{\text{gal solids}}$$

For A, the mass of VOC per volume of solids applied is:

$$\frac{4.5 \text{ lb VOC}}{\text{gal coating}} \times \frac{1 \text{ gal coating}}{0.39 \text{ gal solids}} \times \frac{1 \text{ gal solids}}{0.90 \text{ gal solids applied}} = \frac{12.82 \text{ lb VOC}}{\text{gal solids applied}}$$

For B, the mass of VOC per volume of solids applied is:

$$\frac{4.5 \text{ lb VOC}}{\text{gal coating}} \times \frac{1 \text{ gal coating}}{0.39 \text{ gal solids}} \times \frac{1 \text{ gal solids}}{0.40 \text{ gal solids applied}} = \frac{28.85 \text{ lb VOC}}{\text{gal solids applied}}$$

For A, the volume of solids applied per day is:

$$\frac{30.4 \text{ gal coating}}{\text{day}} \times \frac{0.39 \text{ gal solids}}{\text{gal coating}} \times \frac{0.90 \text{ gal solids applied}}{\text{gal solids used}} = \frac{10.7 \text{ gal solids applied}}{\text{day}}$$

For B, the volume of solids applied per day is:

$$\frac{47.1 \text{ gal coating}}{\text{day}} \times \frac{0.39 \text{ gal solids}}{\text{gal coating}} \times \frac{0.40 \text{ gal solids applied}}{\text{gal solids used}} = \frac{7.3 \text{ gal solids applied}}{\text{day}}$$

For A, the mass of VOC emissions per day is:

$$\frac{4.5 \text{ lb VOC}}{\text{gal coating}} \times \frac{30.4 \text{ gal coating}}{\text{day}} = \frac{136.8 \text{ lb VOC}}{\text{day}}$$

For B, the mass of VOC emissions per day is:

$$\frac{4.5 \text{ lb VOC}}{\text{gal coating}} \times \frac{47.1 \text{ gal coating}}{\text{day}} = \frac{212.0 \text{ lb VOC}}{\text{day}}$$

Under the allowed emissions category, the following calculations can be made.

For A and B, the volume fraction of VOC in the baseline coating is:

$$\frac{2.8 \text{ lb VOC}}{\text{gal coating}} \times \frac{1 \text{ gal VOC}}{7.36 \text{ lb VOC}} = \frac{0.38 \text{ gal VOC}}{\text{gal coating}}$$

The volume fraction solids in the coating is:

$$1 - \frac{0.38 \text{ gal VOC}}{\text{gal coating}} = \frac{0.62 \text{ gal solids}}{\text{gal coating}}$$

The baseline mass of VOC per volume solids is:

$$\frac{2.8 \text{ lb VOC}}{\text{gal coating}} \times \frac{1 \text{ gal coating}}{0.62 \text{ gal solids}} = \frac{4.5 \text{ lb VOC}}{\text{gal solids}}$$

For A and B, the maximum allowable emissions are:

$$\frac{2.8 \text{ lb VOC}}{\text{gal coating}} \times \frac{1 \text{ gal coating}}{0.62 \text{ gal solids}} \times \frac{1 \text{ gal solids used}}{0.60 \text{ gal solids applied}} = \frac{7.5 \text{ lb VOC}}{\text{gal solids applied}}$$

The volume of solids applied remains the same. Therefore, for A, the gallons of complying coating used per day would be:

$$\frac{10.7 \text{ gal solids applied}}{\text{day}} \times \frac{1 \text{ gal coating}}{0.62 \text{ gal solids}} \times \frac{1 \text{ gal solids used}}{0.6 \text{ gal solids applied}}$$

$$= \frac{28.8 \text{ gal coating}}{\text{day}}$$

For B, the gallons of complying coating used per day would be:

$$\frac{7.3 \text{ gal solids}}{\text{day}} \times \frac{1 \text{ gal coating}}{0.62 \text{ gal solids}} \times \frac{1 \text{ gal solids used}}{0.6 \text{ gal solids applied}} = \frac{19.6 \text{ gal coating}}{\text{day}}$$

For A, the mass of VOC emissions allowed per day is:

$$\frac{2.8 \text{ lb VOC}}{\text{gal coating}} \times \frac{28.8 \text{ gal coating}}{\text{day}} = \frac{80.6 \text{ lb VOC}}{\text{day}}.$$

For B, the mass of VOC emissions allowed per day is:

$$\frac{2.8 \text{ lb VOC}}{\text{gal coating}} \times \frac{19.6 \text{ gal coating}}{\text{day}} = \frac{54.9 \text{ lb VOC}}{\text{day}}$$

The total actual VOC emissions from A and B are 348.8 lb VOC per day. The total allowable VOC emissions are 135.5 lb VOC per day. Therefore, the operation is out of compliance. To achieve compliance, the required reduction in emissions is:

$$\frac{348.8 - 135.5}{348.8} \times 100 = 61 \text{ percent}$$

SECTION 7

GRAPHS AND TABLES USEFUL IN APPROXIMATING AND DOUBLE-CHECKING SURFACE COATING CALCULATIONS

Figure 1 can be used to evaluate compliance alternatives for waterborne and organic-borne coatings. This can be done by drawing a horizontal line from the required VOC content of coating (less water and exempt solvents) to the appropriate curve (depending on ratio of water to organic solvent in coating). A vertical line is then drawn from the point of intersection to the x-axis which yields the volume percent solids. All of the coatings represented by the horizontal line have the same pounds of VOC solvent per gallon of coating (less water and exempt solvents). A vertical line in Figure 1 from the volume percent solids to the organic-borne line represents all of the coatings with the same volume percent solids. Horizontal lines drawn from the appropriate waterborne curves yield the VOC contents of the coatings less water and exempt solvents. Note that these values are considerably different for coatings with the same solids contents.

Figures 2 and 3 are the same graph, only Figure 2 is drawn to a larger scale. If the pounds of VOC solvent per gallon of coating (less water and exempt solvents) is known, these figures can be used to approximate the pounds of VOC solvent per gallon of coating solids, assuming a solvent density of 7.36 pounds per gallon.

Table 4 presents volume percent solids equivalency data for different coating operations. Table 5 presents CTG Equivalency Data. A VOC density of 7.36 pounds per gallon is assumed in these tables. Table 6 provides equivalent solids deposited limits. Table 7 presents some useful conversion factors.

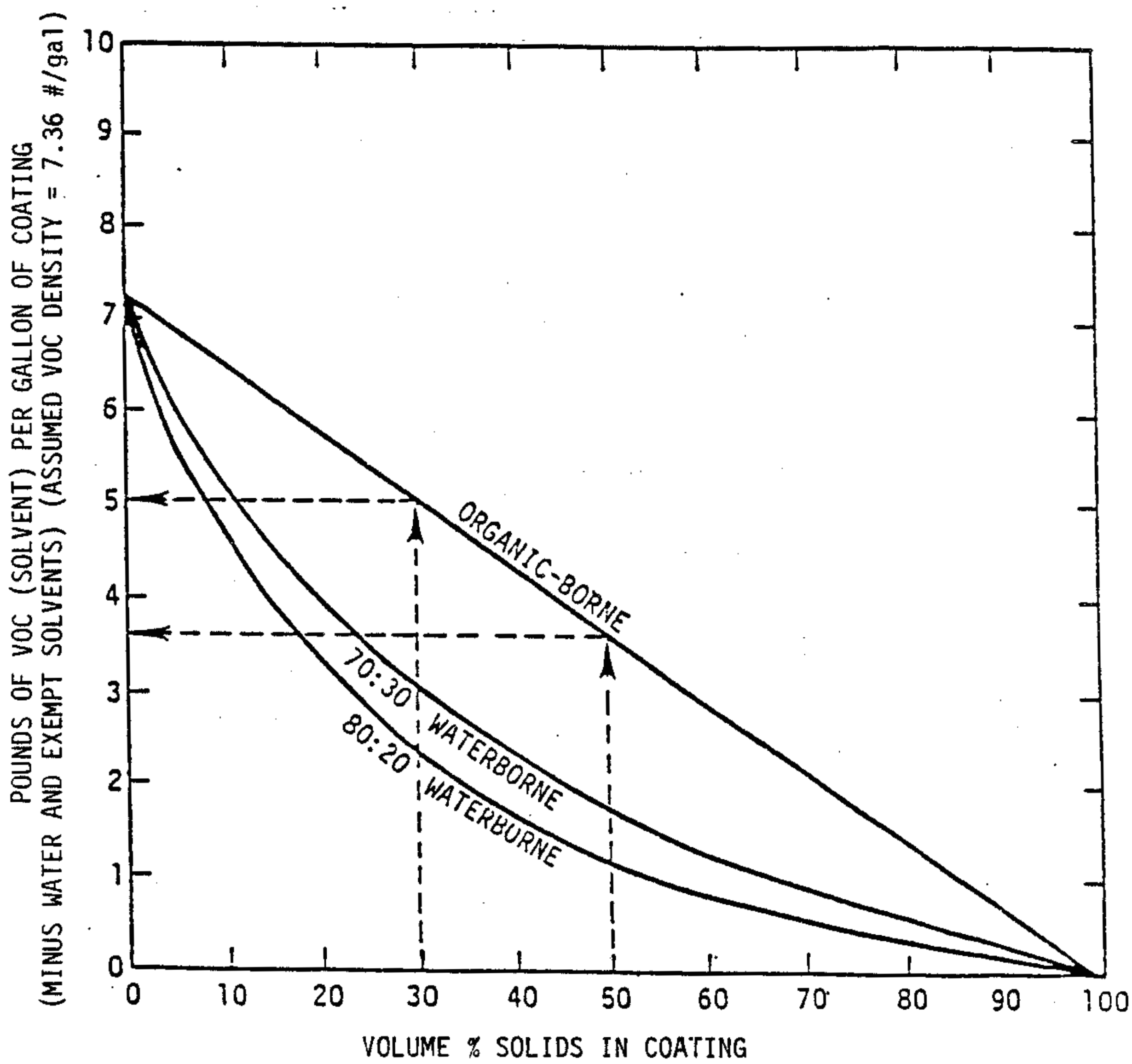


Figure 1. Graph for determining equivalent solids/VOC (solvent) contents of waterborne and organic-borne coatings.

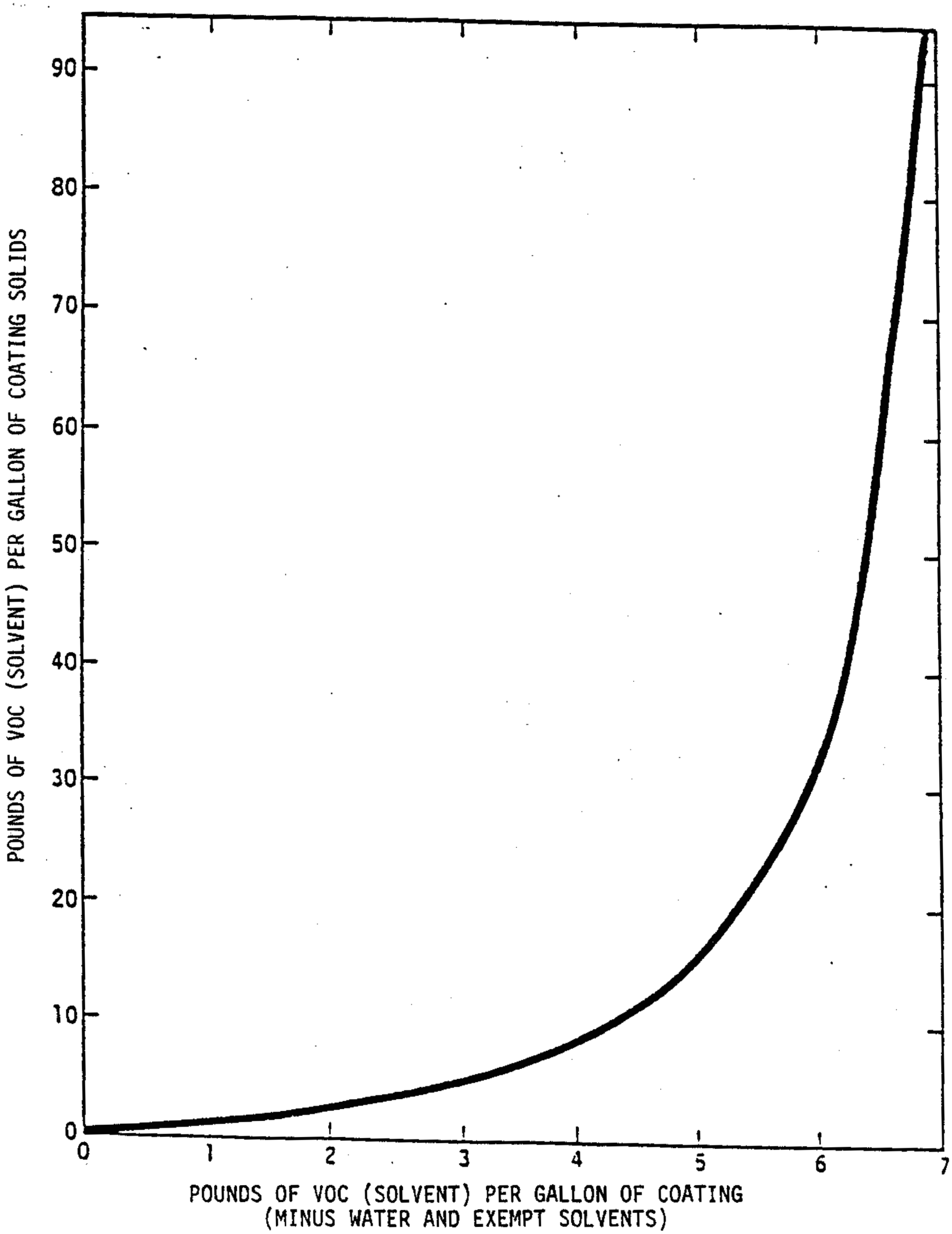


Figure 2. Graph for determining pounds of VOC (solvent) per gallon of coating solids.

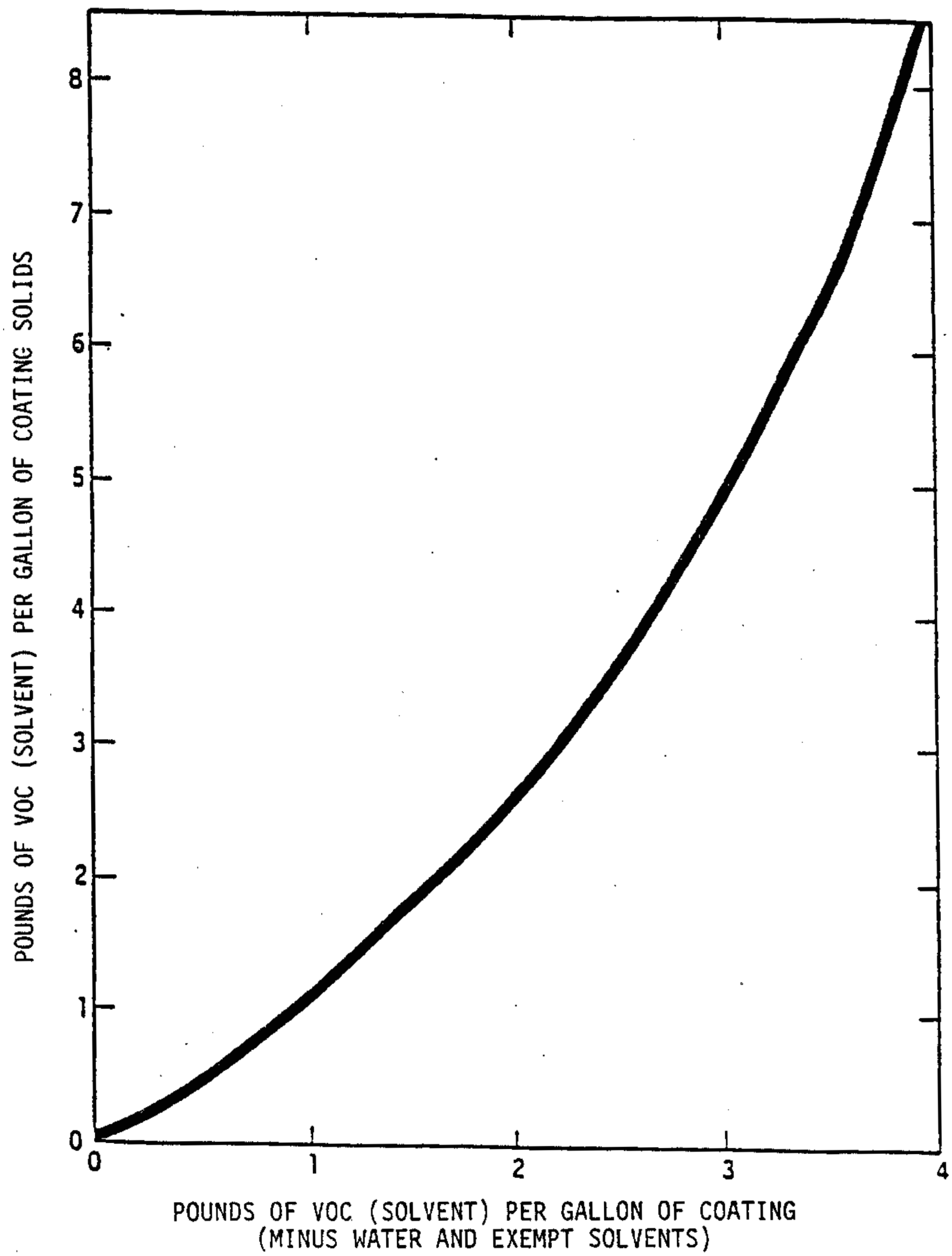


Figure 3. Smaller-scale graph for determining pounds of VOC (solvent) per gallon of coating solids.

TABLE 4. CTG VOLUME PERCENT SOLIDS EQUIVALENCY DATA

Industrial finishing categories	Kg VOC per liter of coating less water	Lb VOC per gallon of coating less water	Solvent-borne coating equivalent volume % solids
CAN INDUSTRY			
Sheet basecoat (exterior and interior) and over-varnish; two-piece can exterior (basecoat and over-varnish)	0.34	2.8	62.0
Two- and three-piece can interior body spray, two-piece can exterior end (spray or roll coat)	0.51	4.2	42.9
Three-piece can side-seam spray	0.66	5.5	25.3
End sealing compound	0.44	3.7	49.7
COIL COATING			
Prime and topcoat or single coat operation	0.31	2.6	64.7
FABRIC COATING			
Fabric coating line	0.35	2.9	60.6
Vinyl coating line	0.45	3.8	48.4
PAPER COATING			
Coating line	0.35	2.9	60.6
AUTOMOTIVE AND LIGHT-DUTY TRUCK ASSEMBLY PLANT			
Primer (electrodeposited) application, flashoff area and oven	0.14	1.2	83.7
Surfacer (guide-coat) application, flashoff area and oven	0.34	2.8	62.0
Topcoat application, flashoff area and oven	0.34	2.8	62.0

(continued)

TABLE 4. (continued)

Industrial finishing categories	Kg VOC per liter of coating less water	Lb VOC per gallon of coating less water	Solvent-borne coating equivalent volume % solids
AUTOMOTIVE AND LIGHT-DUTY TRUCK ASSEMBLY PLANT (continued)			
Final repair application, flashoff area and oven	0.58	4.8	34.8
METAL FURNITURE			
Coating line	0.36	3.0	59.2
MAGNET WIRE INSULATION			
Wire coating oven	0.20	1.7	76.9
LARGE APPLIANCES			
Prime, single, or topcoat application area, flashoff area and oven	0.34	2.8	62.0
MISCELLANEOUS METAL PARTS			
Air-dried items	0.42	3.5	52.4
Clear-coated items	0.52	4.3	41.6
Frequent-color-change items	0.36	3.0	59.2
Powder-coated items	0.05	0.4	94.6
Extreme performance coatings	0.42	3.5	52.4

TABLE 5. CTG EQUIVALENCY DATA (VOC DENSITY = 7.36 LB/GAL)

Industrial finishing categories	Solvent-borne coating equivalent volume % solids	Lb VOC per gallon of coating less water	Kg VOC per liter of coating less water	Lb VOC per gallon of solids	Kg VOC per liter of solids
<u>Can Industry</u>					
Sheet basecoat (exterior and interior) and over-varnish; two-piece can exterior (base-coat and over-varnish)	62.0	2.8	0.34	4.5	0.55
Two- and three-piece can interior body spray, two-piece can exterior end spray or roll coat	42.9	4.2	0.51	9.8	1.19
Three-piece can side-seam spray	25.3	5.5	0.66	21.7	2.61
End sealing compound	50.3	3.7	0.44	7.4	0.88
<u>Coil Coating</u>					
Prime and topcoat or single coat operation	64.7	2.6	0.31	4.0	0.48
<u>Fabric Coating</u>					
Fabric coating line	60.6	2.9	0.35	4.8	0.58
Vinyl coating line	48.4	3.8	0.45	7.9	0.93

(continued)

TABLE 5. (continued)

Industrial finishing categories	Solvent-borne coating equivalent volume % solids	Lb VOC per gallon of coating less water	Kg VOC per liter of coating less water	Lb VOC per gallon of solids	Kg VOC per liter of solids
Paper Coating					
Coating line	60.6	2.9	0.35	4.8	0.58
Automotive and Light-Duty Truck Assembly Plant					
Primer (electrodeposition) application, flashoff area and oven	83.7	1.2	0.14	1.4	0.17
Surfacer (guide coat) application, flashoff area and oven	62.0	2.8	0.34	4.5	0.55
Topcoat application, flashoff area and oven	62.0	2.8	0.34	4.5	0.55
Final repair application, flashoff area and oven	34.8	4.8	0.58	13.8	1.67
Metal Furniture					
Coating line	59.2	3.0	0.36	5.1	0.61
Magnet Wire Insulation					
Wire coating oven	6.9	1.7	0.20	2.2	0.26

(continued)

TABLE 5. (continued)

Industrial finishing categories	Solvent-borne coating equivalent volume % solids	Lb VOC per gallon of coating less water	Kg VOC per liter of coating less water	Lb VOC per gallon of solids	Kg VOC per liter of solids
Large Appliances					
Prime, single, or topcoat application area, flashoff area and oven	62.0	2.8	0.34	4.5	0.55
Miscellaneous Metal Parts and Products					
Air-dried items	52.4	3.5	0.42	6.7	0.80
Clear-coated items	41.6	4.3	0.52	10.3	1.25
Frequent-color-change items	59.2	3.0	0.36	5.1	0.61
Powder-coated items	95.6	0.4	0.05	0.4	0.05
Extreme performance coatings	52.4	3.5	0.42	6.7	0.80

TABLE 6. EQUIVALENT CTG SOLIDS DEPOSITED LIMITS

	Lb/gal-H_2O (kg/l)	Volume % Solids	Baseline T.E.	Lb/gal solids deposited (kg/l)
Auto and Light-duty Truck*				
Surfacer	2.8 (0.34)	62.0	30	15.1 (1.83)
Topcoat	2.8 (0.34)	62.0	30	15.1 (1.83)
Metal Furniture				
Coating line	3.0 (0.36)	59.2	60	8.4 (1.01)
Large Appliances				
Coating Line	2.8 (0.34)	62.0	60	7.5 (0.91)

*Waterborne equivalence

TABLE 7. METRIC CONVERSION FACTORS

A.

Metric abbrevation	Metric unit	Equivalent English unit
kg	kilogram (10^3 grams)	2.2046 lb
liter	liter	0.2642 gal, 0.353 ft^3
Mg	megagram (10^6 grams)	2,204.6 lb
MT	metric ton (10^6 grams)	2,204.6 lb
dscm	dry standard cubic meters	35.31 dry st. ft^3
scmm	standard cubic meter per min	35.31 ft^3/min

B. Multiply lb/gal x 0.12 to get kg/liter

C. Multiply kg/liter x 8.34 to get lb/gal

D. Temperature: Degrees Celsius or centigrade (°C) can be converted to degrees Fahrenheit (°F) by the following forumla:

$$t°F = 1.8\ (t°C) + 32$$

So, for each gallon of coating solids, 7.4 pounds of VOC are emitted.

$$\frac{3.7 \text{ pounds VOC}}{\text{gallon coating}} \quad X \quad \frac{2 \text{ gallons coating}}{\text{gallon solids}}$$

Thus, emissions from the 50 v/o solids coatings are 66 percent less than from the 25 v/o solids coating when providing an equal amount of solids to the process.

$$\frac{22.0 - 7.4}{22.0} = 0.66$$

° <u>WHAT EMISSION REDUCTION IS NEEDED TO MEET AN EMISSION LIMIT?</u>

This calculation, which <u>must also be done on a solids basis,</u> is the same as that used <u>above to compare emissions from</u> two different coatings.

A coater who uses a 25 v/o solids coating containing 5.5 pounds of VOC per gallon, less water, must reduce emissions by 66 percent to meet an emission limit of 3.7 pounds of VOC per gallon, less water.

° <u>HOW MUCH DO IMPROVEMENTS IN TRANSFER EFFICIENCY HELP A SOURCE TO COMPLY?</u>

The coater may want to use a coating that does not comply with a regulation and compensate by improvements in the transfer efficiency with which the coating is applied to meet an equivalent emission level. In order to calculate credit for VOC reductions which result from improvements in transfer efficiency, <u>calculations should be done using units of:</u>

$$\frac{\text{lb VOC}}{\text{gallon solids deposited}}$$

These units are determined by dividing lb VOC/gallon solids by the transfer efficiency expressed as a decimal fraction. For example, if the starting transfer efficiency is 60 percent, the units would be:

$$\frac{\text{lb VOC}}{\text{gal solids deposited}} = \frac{\text{lb VOC}}{\text{gal solids}} \quad X \quad \frac{\text{1.0 gal solids in coating used}}{\text{0.60 gal solids deposited}}$$

(with the old system) — in coating used

If the same paint were now to be sprayed with 90 percent transfer efficiency, the new value would be:

$$\frac{\text{lb VOC}}{\text{gallon solids deposited}} = \frac{\text{lb VOC}}{\text{gallon solids in coating used}} \quad X \quad \frac{\text{1.0 gal solids in coating used}}{\text{0.90 gal solids deposited}}$$

(with new system)

If both the solvent content of the coating and the transfer efficiency are changed, the situation becomes:

$$\frac{\text{lb VOC}}{\text{gal solids deposited}} = \frac{\text{lb VOC}}{\text{gal solids in new coating used}} \quad X \quad \frac{\text{1.0 gal solids in new coating used}}{T \text{ gal solids deposited}}$$

(with new paint and new transfer efficiency)

where T = the new transfer efficiency expressed as a decimal

Expressed in these units, the emissions from the old and new systems can be directly compared to determine the reduction achieved.

NOTE: For metal furniture and appliance coating, the EPA has recommended* that credit for transfer efficiency be given from a baseline of 60 percent transfer efficiency (TE). For example, if a company goes from 35 percent TE to 85 percent TE, credit should only be given for going from 60 percent TE to 85 percent TE to avoid rewarding a source that has historically had poor transfer efficiency - hence a high emission rate.

The rationale for this is that 60 percent TE is a reasonable transfer efficiency to achieve for these industries, and credit should only be given for exceeding 60 percent TE.

For the automobile industry, the CTG recommendation for baseline transfer efficiency is 30 percent TE for both primer surfacer and topcoat. This is the efficiency at which waterborne coatings were applied at two existing assembly plants.

* Memo from G. T. Helms, Chief, Control Programs Operations Branch, EPA, to Chief, Air Programs Branch, EPA Regions I-X, "Appropriate Transfer Efficiencies for Metal Furniture and Large Appliance Coating", November 28, 1980.

REFERENCES

1. "Compliance with VOC Emission Limitations for Can Coating Operations," 45 FR 80824, dated December 8, 1980.

2. "Glossary for Air Pollution Control of Industrial Coating Operations." Second Edition. Emission Standards and Engineering Division, U.S. Environmental Protection Agency. EPA-450/3-83-013R. December 1983.

3. Memorandum entitled "Appropriate Transfer Efficiencies for Metal Furniture and Large Appliace Coating," from G.T. Helms, Chief, Control Programs Operations Branch, to Chief, Air Programs Branch, Regions I-X, dated November 28, 1980.

4. Memorandum entitled "Appropriate Transfer Efficiency for Water-Borne Equivalence," from R.G. Rhoads, Director, Control Programs Development Division to Director, Air and Hazardous Materials Division, Regions I-X, dated July 3, 1979.

5. Memorandum entitled "Determination of Capture Efficiency," from J. Berry, Chief, Chemical Analysis Section, to D. Cook, EPA Region IV, dated July 7, 1980.

6. Memorandum entitled "Equivalency Calculations with the CTG Recommendations for Surface Coating," from R.G. Rhoads, Director, Control Programs Development Division, to David Kee, Director, Air and Hazardous Materials Division, Region V, dated October 17, 1980.

7. Memorandum entitled "Procedure to Calculate Equivalency with the CTG Recommendations for Surface Coating, from R.G. Rhoads, Director, Control Programs Development Division, to Chief, Air Programs Branch, Regions I-X, dated May 5, 1980.

8. Memorandum entitled "RACT Options for Can Coating Operations," from R.G. Rhoads, Director, Control Programs Development Division to Director, Air and Hazardous Materials Division, Regions I-X, dated November 21, 1978.

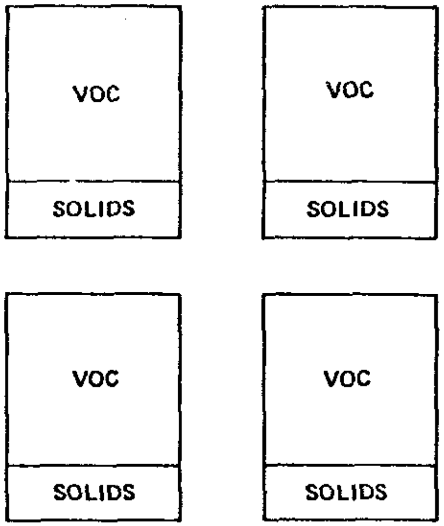
9. Memorandum entitled "Role of Improved Transfer Efficiency in Demonstrating Compliance with the CTG Recommendations for Surface Coating", from G.T. Helms, Chief, Control Programs Operations Branch, to W.S. Baker, Chief, Air Programs Branch, Region II, dated December 2, 1980.

APPENDIX A

GLOSSARY OF TERMS USED IN AIR POLLUTION CONTROL OF EMISSIONS FROM INDUSTRIAL COATING OPERATION EPA PUBLICATION NO. 450/3-83-013R, PAGES 26-29

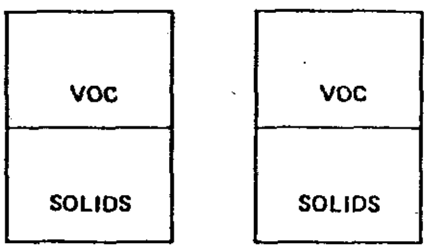
The same volume of coating solids must be deposited on an object to coat it to a desired film thickness regardless of the type of coating or volatile organic compound content of the coating used. Solids make the film. Volatiles (VOC, water, and non-photochemically reactive solvents) evaporate.

Four gallons of a 25 volume percent (v/o) solids coating must be used to get one gallon of coating solids.



A-3

But, only two gallons of a 50 v/o solids coating must be used to get one gallon of coating solids.

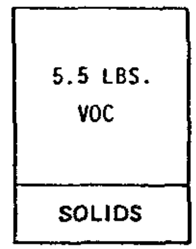


50 v/o solids coating than with a gallon of 25 v/o solids coating. Twice as many gallons of 25 percent solids coating are needed than gallons of 50 percent solids coating to do the same job.

HOW DO EMISSIONS FROM DIFFERENT COATINGS COMPARE?

Comparisons of the percent difference in emissions between two coatings, or between a coating and an emission limit, must be done on a solids basis.

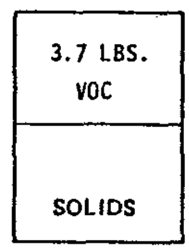
Each gallon of the 25 v/o solids coating contains 5.5 pounds of VOC.



So, for each gallon of coating solids, 22.0 pounds of VOC are emitted.

$$\frac{\text{5.5 pounds VOC}}{\text{gallon coating}} \quad X \quad \frac{\text{4 gallons coating}}{\text{gallon solids}}$$

Each gallon of the 50 v/o solids coating contains 3.7 pounds of VOC.



This report has been reviewed by the Emission Standards and Engineering Division of the Office of Air Quality Planning and Standards, EPA, and approved for publication. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use. Copies of this report are available through the Library Services Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, N.C. 27711, or from the National Technical Information Services, 5285 Port Royal Road, Springfield, Virginia 22161.

APPENDIX B

PROCEDURES FOR CERTIFYING QUANTITY OF VOLATILE ORGANIC COMPOUNDS EMITTED BY PAINT, INK, AND OTHER COATINGS.

Determination of Volatile Matter Content, Density, Volume Solids, and Weight Solids of Surface Coatings," in the Federal Register (45 FR 65958). For the first time the Agency formally specified an analytical method for the VOC content of those coatings that cure by chemical reaction. Even then, the announcement continued to allow the manufacturer's formulation to be used to calculate the VOC content but specified that the analytical technique, RM-24, would be the reference in any conflict between the two.

During 1981 and 1982, as more State and Federal regulations were established, the demand for low-solvent coatings began a continuing increase in the sales volume of reaction-cure coatings. There was some concern voiced by the industry in how appropriate the reference method was for these type coatings. To find out, the Agency began a review of RM-24 to determine the effect of temperature and exposure time on the indicated VOC "content". It was concluded that the maximum effect of those time-temperature combinations that were examined amounted to only about a 10 percent variation. Somewhat more surprising was that the solvent sometimes accounted for only 50 to 70 percent of the total VOC measured by the reference method.

The obvious conclusion was that RM-24 is a better measure of the total organics freed by a coating than is the solvent. This manual implements a policy based on that conclusion. Certification of VOC content on the attached Data Sheets must be based on an analysis using RM-24. No longer will solvent content be permitted as a surrogate for VOC unless a showing is first made that its use is a reasonable alternative or equivalent method of determining the VOC content of that particular coating.

One final comment. Since VOC is not always synonomous with solvent, it follows that the amount of solids in a coating cannot be obtained by subtracting the solvent from the total volume of coating. The original Federal Register proposal for RM-24, published on October 3, 1980, recommended the American Society of Test Materials test Number D2697 as the appropriate method of determining solids content. Subsequent comments from the industry maintained that this test is unreliable. As a result, when promulgated in 1980, RM-24 specified that the solids content of a coating can be obtained only from the manufacturer's formulation of the coating.

Dennis Crumpler

Dennis Crumpler
December 14, 1984

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/3-84-019
December 1984

Air

EPA

Procedures for Certifying Quantity of Volatile Organic Compounds Emitted by Paint, Ink, and Other Coatings

NOTICE

THIS EDITION INCLUDES PAGES III-4
AND III-9 AS REVISED JUNE 19,1986

EPA-450/3-84-019

Procedure for Certifying Quantity of Volatile Organic Compounds Emitted By Paint, Ink, and Other Coatings

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

December 1984

$(W_v)_a$ the weight percent of total volatiles in the coating "as applied"

$(W_v)_s$ the weight percent of total volatiles in the coating "as supplied"

$(W_w)_a$ the weight percent water in the coating "as applied"

$(W_w)_d$ the weight percent water in the dilution solvent

$(W_w)_s$ the weight percent water in the coating "as supplied"

PREFACE

This manual was conceived as a way to provide simple step-by-step instructions for certifying the quantity of volatile organic compounds (VOC) that will be released by a coating. It has not turned out that way. The guidance is here, but in spite of great diligence, the instructions remain imposing.

The manual was prepared for several reasons. First, the coatings industry, as represented by the National Paint and Coatings Association, had requested a certification procedure which would relieve their customers the expense of analysis. Second, the complexity of the calculations necessary to determine compliance, for example, when dilution solvent is added to a coating, continue to confound Federal, State and Local enforcement personnel. Finally, results of a recent review of the Agency's reference method for determining VOC reemphasized the importance of analytical procedures to verify VOC content.

In response to the results of the review of the test methods, this manual reaffirms that Reference Method 24 or its constituent methods developed by the American Society for Testing and Materials (ASTM), are the procedures by which the VOC content of a coating will be determined for compliance with Federal regulations. The earliest guidance was not so specific. In 1977, the first report[1], written to assist States in developing regulations for sources of VOC emissions, provided recommendations for the maximum allowable VOC content for complying coatings in a variety of industries. These values were expressed in mass of VOC per unit volume of coating. In deriving the recommended limitation, the VOC content of a coating was calculated based on the solids content provided by the coating manufacturer. The Agency calculated the mass of VOC in the coating by assuming the VOC had a density of 7.36 pounds per gallon.

Solvent and VOC were used somewhat interchangebly even though it was recognized that organics such as resin monomer, oligimers, and reaction by-products could be released by a coating during the cure. There was no accepted analytical method available for measuring the total VOC which would be released by a coating. The initial guidance[1] provided an analytical method for use only for air-dry coatings, those where all VOC emissions would be expected to come as a result of evaporation of solvent. On a volume basis, air dry coatings constituted the largest catagory of coatings then in use.

The Agency subsequently developed a more general analytical procedure that could be used to determine the total VOC in a coating. On October 3, 1980, the Agency published "Reference Method 24 (RM-24) -

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[1]Control of Volatile Organic Emissions from Stationary Sources - Volume II: Surface Caoting of Cans, Coils, Paper, Fabrics, Automobiles, and Light-duty Trucks, Document No. EPA-450/2-77-008.

TABLE OF CONTENTS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

VOC DATA SHEET:

PROPERTIES OF THE COATING "AS SUPPLIED" BY THE MANUFACTURER

Coating Manufacturer: ____________________

Coating Identification: ____________________

Batch Identification: ____________________

Supplied To: ____________________

Properties of the coating as supplied[1] to the customer:

A. Coating Density $(D_c)_s$: ________ lb/gal ________ kg/l

/__/ ASTM D1475 /__/ Other[2]

B. Total Volatiles $(W_v)_s$: ________ Weight Percent

/__/ ASTM D2369 /__/ Other[2]

C. Water Content: 1. $(W_w)_s$ ________ Weight Percent

/__/ ASTM D3792 /__/ ASTM D4017 /__/ Other[2]

2. $(V_w)_s$ ________ Volume Percent

/__/ Calculated /__/ Other[2]

D. Organic Volatiles $(W_o)_s$: ________ Weight Percent

E. Nonvolatiles Content $(V_n)_s$: ________ Volume Percent

F. VOC Content $(VOC)_s$: 1. ____________ lb/gal coating less water

or ____________ kg/l coating less water

2. ____________ lb/gal solids

or ____________ kg/l solids

Remarks: (use reverse side)

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[1]The subscript "s" denotes each value is for the coating "as supplied" by the manufacturer.

[2]Explain the other method used under "Remarks".

Signed: ____________________ Date ________

GLOSSARY OF TERMS

"As Applied"	the condition of a coating after dilution by the user just prior to application to the substrate.
"As Supplied"	the condition of a coating before dilution, as sold and delivered by the coating manufacturer to the user.
$(D_c)_a$	coating density "as applied"
$(D_c)_s$	coating density, "as supplied"
D_d	density of dilution solvent
$D_d^\dagger$	density of organic solvent/water mixture
D_w	density of water (8.33 lb/gal)
R_d	dilution solvent ratio, equals the volume of VOC added per unit volume of coating "as supplied"
$R_d^\dagger$	equals the volume of premixed water and VOC added per unit volume of coating "as supplied"
$(V_n)_a$	Volume percent solids of coating "as applied"
$(V_n)_s$	Volume percent solids of coating "as supplied"
$(VOC)_a$	VOC content of "as applied" coating, expressed as mass of VOC per unit volume of coating less water or as mass of VOC per unit volume of solids
$(VOC)_s$	VOC content of "as supplied" coating, expressed as mass of VOC per unit volume of coating less water or as mass of VOC per unit volume of solids
$(V_w)_a$	the water content, in volume percent, of coating "as applied"
$(V_w)_d$	the water content, in volume percent, of the dilution solvent added to the "as supplied" coating
$(V_w)_s$	the water content, in volume percent, of the coating "as supplied"
$(W_o)_a$	the organic volatile content, in weight percent, of the coating "as applied"
$(W_o)_s$	the organic volatile content, in weight percent, of the coating "as supplied"

2. The water content, in volume percent, $(V_w)_s$, can be calculated by the equation:

$$(V_w)_s = \frac{(W_w)_s(D_c)_s}{D_w}, \quad \text{II-1}$$

where D_w is the density of water, 8.33 lbs/gal.

D. The organic volatiles content, $(W_o)_s$, i.e., the VOC content expressed as a percent by weight, is determined by the following equation[5]:

$$(W_o)_s = (W_v)_s - (W_w)_s \quad \text{II-2}$$

If the coating contains no water the weight percent of organic volatiles is equal to the weight percent of total volatiles.

In other words:

$$(W_w)_s = 0 \text{ and}$$

$$(W_o)_s = (W_v)_s \quad \text{II-3}$$

E. The volume percent solids (nonvolatiles), $(V_n)_s$, should be derived from the coating formulation using the following equation:

$$(V_n)_s = \sum_{i=1}^{p} (V_n)_{s_i} \quad \text{II-4}$$

where $(V_n)_{s_i}$ denotes the volume percent of each nonvolatile component in an "as supplied" coating, and "p" is the number of nonvolatile components in that coating. (Also see Footnote 1, Pg. II-3.)

[5]The precision limit adjustments permitted by Reference Method 24 for experimentally determined mean W_w and W_v values may be made only by enforcement agencies for determination of compliance. The adjustment is not to be used for the purposes of completing the "AS SUPPLIED" VOC DATA SHEET.

C. The water content is necessary only if the coating has been diluted with a mixture of organic solvent and water.[4,5] If the dilution solvent is 100 percent organic, or if the weight and volume percent water in the mixture is known, proceed directly to Step D.

The weight percent water, $(W_w)_a$, is determined by "ASTM D3792 - Standard Test Method for Water Content of Water-Reducible Paints by Direct Injection Into a Gas Chromatograph," or "ASTM D4017 - Standard Test Method for Water in Paints and Paint Materials by the Karl Fischer Method." (Also see Footnote 3, Pg. III-4.)

The water content, in volume percent, $(V_w)_a$, can be calculated by the equation:

$$(V_w)_a = \frac{(W_w)_a \, (D_c)_a}{D_w} \qquad \text{III-1}$$

where D_w is the density of water, 8.33 lb/gal.

---

[4]Volatile compounds classified by EPA as having negligible photochemical reactivity such as 1,1,1-trichloroethane and methylene chloride, etc., and listed as exempt in the applicable Federal and State VOC regulation, should be treated in the same manner as water. The weight percent of negligibly reactive compounds in the dilution solvent must be known either from the coater's mixing records or the dilution solvent supplier's formulation. The volume percent can then be calculated using Equations III-1 or III-5 when the weight percent and density of the negligibly reactive organics are substituted for those of water. The weight and volume percent of the negligibly reactive compounds can be substituted in all equations where the weight and volume percent water, (W_w) and (V_w), respectively, are used.

[5]The precision limit adjustments permitted by Reference Method 24 for experimentally determined mean weight percent water and total volatiles, W_w and W_v respectively, may be made only by enforcement agencies for determination of compliance. The adjustment is not to be used for the purposes of completing the "AS APPLIED" VOC DATA SHEET.

E. The dilution solvent ratio, R_d, is defined as the volume of photochemically reactive organic solvent, (VOC), added per unit volume of "as supplied" coating. Stated mathematically,

$$R_d = \frac{\text{Volume photochemically reactive dilution solvent added}}{\text{Volume of "as supplied" coating}}$$

1. If the "as supplied" coating is subsequently diluted with water or a solvent which is of negligible photochemical reactivity, the VOC content will be unchanged from that reported on the "AS SUPPLIED" VOC DATA SHEET. This should be reported on the "AS APPLIED" VOC DATA SHEET by entering "0" for the dilution solvent ratio, R_d.

2. In the absence of adequate dilution records, R_d can be calculated from entries on the VOC DATA SHEETS by one of the following equations:

   a. When the dilution solvent consists only of VOC,

$$R_d = \frac{(D_c)_s - (D_c)_a}{(D_c)_a - (D_d)} \qquad \text{III-6}$$

   b. When the dilution solvent is a mixture of water and photochemically reactive organic solvent, Equation III-6 may be expressed as:

$$R_d^{\dagger} = \frac{(D_c)_s - (D_c)_a}{(D_c)_a - (D_d)^{\dagger}} \qquad \text{III-7}$$

where: $R_d^{\dagger}$ is the ratio of the volume of water and organic dilution solvent to the volume of "as supplied" coating to which it is added. (Also see Footnote 4, Pg. III-5.)

The dilution solvent ratio, R_d, may now be calculated from $R_d^{\dagger}$ by the following equation:

$$R_d = R_d^{\dagger} \left[1 - \frac{(V_w)_d}{100\%}\right] \qquad \text{III-8}$$

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

VOC DATA SHEET:

PROPERTIES OF THE COATING "AS APPLIED" TO THE SUBSTRATE

Coating Manufacturer: ____________________

Coating Identification: ____________________

Batch Identification: ____________________

User: ____________________

User's Coating Identification: ____________________

Properties of the coating as applied[1] by the User:

A. Coating Density $(D_c)_a$: ________ kg/l, or ________ lb/gal

/_/ ASTM D1475 /_/ Other[2]

B. Total Volatiles $(W_v)_a$: ________ Weight Percent

/_/ ASTM D2369 /_/ Other[2]

C. Water Content: 1. $(W_w)_a$ ________ Weight Percent

/_/ ASTM D3792 /_/ ASTM D4017 /_/ Other[2]

2. $(V_w)_a$ ________ Volume Percent

/_/ Calculated /_/ Other[2]

D. Weighted Average Density of the dilution solvent $(D_d)^3$: ________ lb/gal

/_/ ASTM D1475 /_/ Handbook /_/ Formulation

(Continued on Reverse Side)

[1]The subscript "a" denotes each value is for the coating "as applied" to the substrate.
[2]Explain the other method used under "Remarks" on reverse side
[3]The subscript "d" denotes values are for the dilution solvent

(2). If the coating contains water the following equation must be used:

$$(VOC)_a = \frac{(W_o)_a \ (D_c)_a}{\cancel{100\%} - (V_w)_a} \qquad \text{III-14}$$

b. Using the VOC content of the "as supplied" coating, (VOC_s), the dilution solvent ratio, and the density of the solvent, the equation is:

$$(VOC)_a = \frac{[(VOC)_s \ (100\% - (V_w)_s)/100\%] + (R_d D_d)}{1 + R_d - (V_w)_s/100\%} \qquad \text{III-15}$$

Where $(VOC)_s$ in this case must be in units of lbs VOC/gal coating less water.

2. The VOC content may also be calculated in terms of mass of VOC per unit volume of solids (nonvolatiles).

a. Using the results obtained by analyzing the coating with EPA Reference Method 24 or its constituent ASTM methods, the equation for both solvent-borne and waterborne coatings, is:

$$(VOC)_a = \frac{(W_o)_a \ (D_c)_a}{(V_n)_a} \qquad \text{III-16}$$

b. Using dilution information and calculation procedures only, the equation is:

$$(VOC)_a = \frac{[(VOC)_s \ (100\% - (V_w)_s)/100\%] + (R_d D_d)}{(V_n)_s/100\%} \qquad \text{III-17}$$

Where $(VOC)_s$ in this case must be in units of lbs VOC/gal coating less water.

3.2. IMPLEMENTING INSTRUCTIONS FOR THE VOC DATA SHEET FOR "AS APPLIED" COATINGS

This DATA SHEET, henceforth referred to as the "AS APPLIED" VOC DATA SHEET, is to be completed by the company which applies a coating. It provides information on the amount of volatile organic compounds (VOC) in the coating "as applied" to the substrate by accounting for the quantity of diluent solvent added to the "as supplied" coating prior to application. If a coating is diluted only with water or a solvent of negligible photochemical reactivity, the user merely doucments the fact (see Step E.1. and also Footnote 4, Pg. III-5.). Otherwise, several avenues exist for the coater to certify the VOC content:
(1) Maintain adequate records of how much organic solvent is added to each coating and use that information and the "AS SUPPLIED" VOC DATA SHEET[2] to calculate the VOC content "as applied." In this case begin with Step D.
(2) If the "AS SUPPLIED" DATA SHEET is available, but dilution records are not, begin the "As Applied" determination with Step A, skip Steps B and C, and proceed to Step D.
(The user may choose to analyze an "As Supplied" coating using Reference Method 24 and complete the "AS SUPPLIED" VOC DATA SHEET rather than have the coating manufacturer complete it. The volume percent solids, however, will necessarily continue to be supplied by the coating manufacturer.)
(3) Analyze each diluted coating with the same method used to generate the data provided by the coating manufacturer on the "AS SUPPLIED" VOC DATA SHEET. (See Chapter 2 of this Manual.) In this case begin with Step A.[1]

A. The "as applied" coating density, $(D_c)_a$[2], is determined using "ASTM D1475-Standard Test Method for Density of Paint, Lacquer, and Related Products."

B. The weight percent of total volatiles in the coating, $(W_v)_a$ is determined by "ASTM D2369-81 Standard Method for Volatile Content of Coatings." The drying conditions to be used are 110°C for 1 hour[3].

[1]EPA's Reference Method 24 (40 C.F.R. Part 60, App. A), contains the ASTM methods referenced in these instructions.

[2]The subscript "a" denotes those parameters of a coating in the "as applied" condition, i.e., after dilution by the user. The subscript "s" denotes the parameters of a coating in the "as supplied" condition, before dilution by the user.

[3]If the manufacturer believes the specified method gives results that are not representative of the VOC released during the normal cure, he may petition the enforcement authority for approval of an alternative analytical method. Any alternate method or alteration to the methods and procedures in these instructions or in any applicable regulation would be subject to review and approval by the appropriate State and/or Federal enforcement agency.

APPENDIX C

REFERENCE METHOD 24

D. If the dilution solvent consists of a single compound the density may be obtained from the literature.

If the dilution solvent is a mixture of organic compounds, the density, D_d[6], can be determined analytically via ASTM D1475, or an average density can be estimated from the solvent formulation as shown below. This estimation assumes that volumes are additive.

$$D_d = \frac{100\%}{\sum_{j=1}^{m} \frac{W_j}{D_j}} \qquad \text{III-2}$$

or

$$= \frac{1}{100\%} \sum_{j=1}^{m} V_j D_j \qquad \text{III-3}$$

where: D_j, W_j, and V_j denote the density, weight percent, and volume percent of each solvent in the dilution solvent mixture and "m" is the number of organic solvents in the dilution solvent mixture.

If the dilution solvent is a mixture of photochemically reactive organics and water, the coater must know the weight percent, $(W_w)_d$, or volume percent, $(V_w)_d$, of water from his mixing records or the supplier's formulation, or he must analytically determine the weight fraction of water in the dilution solvent using ASTM D3792 or ASTM D4017. The density, D_d, of the dilution solvent may then be determined by analytically measuring the density of the organic solvent/water mixture, $D_d^{\dagger}$, using ASTM D1475 and adjusting it for the water content using the following equation. (See also Footnote 4, Pg. III-5.)

$$D_d = D_d^{\dagger} \frac{[100\% - (W_w)_d]}{[100\% - (V_w)_d]} \qquad \text{III-4}$$

Note: If either the weight or volume percent water in the dilution solvent is known, the other can be calculated by the equation:

$$(V_w)_d = \frac{(W_w)_d \; D_d^{\dagger}}{D_w} \qquad \text{III-5}$$

where "D_w" is the density of water.

---

[6]The subscript "d" denotes a parameter that pertains to that solvent used by the coater to dilute the "as supplied" coating.

METHOD 24—DETERMINATION OF VOLATILE MATTER CONTENT, WATER CONTENT, DENSITY, VOLUME SOLIDS, AND WEIGHT SOLIDS OF SURFACE COATINGS

1. Applicability and Principle

1.1 Applicability. This method applies to the determination of volatile matter content, water content, density, volume solids, and weight solids of paint, varnish, lacquer, or related surface coatings.

1.2 Principle. Standard methods are used to determine the volatile matter content, water content, density, volume solids, and weight solids of the paint, varnish, lacquer, or related surface coatings.

2. Applicable Standard Methods

Use the apparatus, reagents, and procedures specified in the standard methods below:

2.1 ASTM D1475-60 (Reapproved 1980), Standard Test Method for Density of Paint, Varnish, Lacquer, and Related Products (incorporated by reference—see § 60.17).

2.2 ASTM D2369-81, Standard Test Method for Volatile Content of Coatings (incorporated by reference—see § 60.17).

2.3 ASTM D3792-79, Standard Test Method for Water Content of Water-Reducible Paints by Direct Injection into a Gas Chromatograph (incorporated by reference—see § 60.17).

2.4 ASTM D4017-81, Standard Test Method for Water in Paints and Paint Materials by the Karl Fischer Titration Method (incorporated by reference—see § 60.17).

3. *Procedure.*

3.1 Volatile Matter Content. Use the procedure in ASTM D2369-81 (incorporated by reference—see § 60.17) to determine the volatile matter content (may include water) of the coating. Record the following information:

W_1 = Weight of dish and sample before heating, g.

W_2 = Weight of dish and sample after heating, g.

W_s = Sample weight, g.

Run analyses in pairs (duplicate sets) for each coating until the criterion in section 4.3 is met. Calculate the weight fraction of the volatile matter (W_v) for each analysis as follows:

$$W_v = \frac{W_1 - W_2}{W_s} \qquad \text{(Eq. 24-1)}$$

Record the arithmetic average (W_v).

3.2 Water Content. For waterborne (water reducible) coatings only, determine the weight fraction of water (W_w) using either "Standard Content Method Test for Water of Water-Reducible Paints by Direct Injection into a Gas Chromatograph" or "Standard Test Method for Water in Paint and Paint Materials by Karl Fischer Method." (These two methods are incorporated by reference—see § 60.17.) A waterborne coating is any coating which contains more than 5 percent water by weight in its volatile fraction. Run duplicate sets of determinations until the criterion in section 4.3 is met. Record the arithmetic average (W_w).

3.3 Coating Density. Determine the density (D_c, kg/liter) of the surface coating using the procedure in ASTM D1475-60 (Reapproved 1980) (incorporated by reference—see § 60.17).

Run duplicate sets of determinations for each coating until the criterion in section 4.3 is met. Record the arithmetic average (D_c).

3.4 Solids Content. Determine the volume fraction (V_s) solids of the coating by calculation using the manufacturer's formulation.

4. Data Validation Procedure

4.1 Summary. The variety of coatings that may be subject to analysis makes it necessary to verify the ability of the analyst and the analytical procedures to obtain reproducible results for the coatings tested. This is done by running duplicate analyses on each sample tested and comparing results with the within-laboratory precision statements for each parameter. Because of the inherent increased imprecision in the determination of the VOC content of waterborne coatings as the weight percent water increases, measured parameters for waterborne coatings are modified by the appropriate confidence limits based on between-laboratory precision statements.

4.2 Analytical Precision Statements. The within-laboratory and between-laboratory precision statements are given below:

	Within-laboratory	Between-laboratory
Volatile matter content, W_v	1.5 pct W_v	4.7 pct W_v
Water content, W_w	2.9 pct W_w	7.5 pct W_w
Density, D_c	0.001 kg/liter	0.002 kg/liter.

4.3 Sample Analysis Criteria. For W_v and W_w, run duplicate analyses until the difference between the two values in a set is less than or equal to the within-laboratory precision statement for that parameter. For D_c run duplicate analyses until each value in a set deviates from the mean of the set by no more than the within-laboratory precision statement. If after several attempts it is concluded that the ASTM procedures

F. The organic volatile content $(W_o)_a$, i.e. the VOC content expressed as a percent by weight of the diluted coating, can now be calculated by either of two ways:

1. From analyses of the coating using the following equation:

$$(W_o)_a = (W_v)_a - (W_w)_a \qquad \text{I}$$

(See Footnotes 4 and 5, Pg. III-5.)

If the coating does not contain water, the weight percent of organic volatiles is equal to the weight percent of total volatiles, or

$$(W_o)_a = (W_v)_a \qquad \text{II}$$

2. By using the data from the "AS SUPPLIED" VOC DATA SHEET, the dilution solvent ratio, and the density of the dilution solvent with the following equation:

$$(W_o)_a = \frac{[(D_c)_s\ (W_o)_s/100\%] + (R_d D_d)}{(D_c)_s + (R_d D_d)} \times 100\% \qquad \text{III}$$

G. The volume percent solids, or nonvolatiles, $(V_n)_a$, must be calculated from the following equation where $(V_n)_s$ is obtained from the "AS SUPPLIED" VOC DATA SHEET.

$$(V_n)_a = \frac{(V_n)_s}{1 + R_d} \qquad \text{II}$$

H. The VOC content of the "as applied" coating $(VOC)_a$, can now be calculated and thereby expressed in terms used in most State or Federal regulations.

1. The mass of VOC per unit volume of coating, less water, is calculated in either of two ways.

a. Using the results obtained by analyzing the coating with EPA Reference Method 24 or its constituent ASTM Methods:

(1). If the coating contains no water the equation is:

$$(VOC)_a = \frac{(W_o)_a\ (D_c)_a}{100\%} \qquad \text{IIII}$$

3.1 Weight Fraction VOC. Calculate the weight fraction volatile organic content W_o using the following equation:

$$W_o = \frac{M_{x1} + M_{cY1} - M_{cY2} - M_{x2}}{M_{cY1} - M_{cY2}}$$

(Eq. 24A-1)

Report the weight fraction VOC $\overline{W}_o$ as the arithmetic average of the three determinations.

3.2 Volume Fraction VOC. Calculate the volume fraction volatile organic content V_o using the following equation:

$$W_o = \frac{M_{x1} + M_{cY1} - M_{cY2} - M_{x2}}{M_{cY1} - M_{cY2}} \qquad \text{Eq.24A-1}$$

$$V_o + \frac{\overline{W}_o \overline{D}_c}{\overline{D}_o} \qquad \text{Eq. 24A-2}$$

4. *Bibliography.*

4.1 Standard Test Method for Density of Paint, Varnish, Lacquer, and Related Products. ASTM Designation D 1475-60 (Reapproved 1980).

4.2 Teleconversation. Wright, Chuck, Inmont Corporation with Reich, R. A., Radian Corporation. September 25, 1979. Gravure Ink Analysis.

4.3 Teleconversation. Oppenheimer, Robert, Gravure Research Institute with Burt, Rick, Radian Corporation, November 5, 1979. Gravure Ink Analysis.

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16. ABSTRACT

The calculation of volatile organic compound emissions from surface coating operations to determine compliance is often a complicated task, sometimes creating confusion with compliance authorities and sources alike. In an attempt to minimize this confusion, EPA (OAQPS) has periodically issued guidance in this area, generally in the form of memoranda to the EPA Regional Offices. The most recent document is entitled "Procedures for Certifying Quantity of Volatile Organic Compounds Emitted by Paint, Ink and Other Coatings," published December 1984, EPA 450/3-84-019.

"A Guideline for Surface Coating Calculations" takes the above guidance process one step further for surface coating operations. Guidance is provided on how to compute existing and allowed emissions based on the above document as well as previously issued Control Technique Guidelines for the individual categories. Example calculations are included for basic emission problems, compliance determinations, equivalency determinations, application of transfer efficiency, and calculations involving complex multiproduct plants. The appropriate data sheets, a list of various equations and notations, and graphs and tables useful in making the above calculations are also included.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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