2001 Architectural Coatings Survey

Final Reactivity Analysis

March 2005

California Environmental Protection Agency

Air Resources Board

State of California
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AIR RESOURCES BOARD

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ARB, Board	Air Resources Board
ASTM	American Society for Testing and Materials
CAS#	Chemical Abstract Service number
CMIR	Composite Maximum Incremental Reactivity
MIR	Maximum Incremental Reactivity
MIRBC	Maximum Incremental Reactivity of the Base Case ROG Mixture
NOx	Nitrogen Oxides
O_3	Ozone
PWMIR	Product Weighted Maximum Incremental Reactivity
RAF	Reactivity Adjustment Factor
RAVOC	Reactivity-Adjusted Volatile Organic Compound Content
ROG	Reactive Organic Gases
RR	Relative Reactivity
RRAC	Reactivity Research Advisory Committee
TOG	Total Organic Gases
TPD	Tons Per Day
U.S. EPA	United States Environmental Protection Agency
SCAQMD	South Coast Air Quality Management District
SCM	Suggested Control Measure
SWA	Sales-Weighted Average
SWAMIR	Sales-Weighted Average Maximum Incremental Reactivity
$SWAMIR_{VOC}$	Sales-Weighted Average Maximum Incremental Reactivity, based on VOCs only
U.S. EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound

Chapter 1 -- Introduction and Background

In July 2001, the Air Resources Board (ARB or Board) conducted a survey of companies that sold architectural coating products in California in 2000. This report contains a detailed analysis of the photochemical reactivity associated with architectural coatings, based on results from that survey. This document is intended to provide different options for evaluating the reactivity of architectural coatings, but it is not a formal regulatory document.

ARB's 2001 Architectural Coating Survey gathered detailed sales information and speciation of VOCs in product formulations, with ingredients reported to the 0.1 weight percent level. Results from this survey are summarized in the "2001 Architectural Coatings Survey, Final Report, October 2003".

When coatings are applied, they release different types of organic compounds that can react in the atmosphere to produce different amounts of ozone. This ozone forming potential is called hydrocarbon reactivity and it is determined by the photochemical reactions in the atmosphere. If a coating contains a small amount of a highly reactive compound, it could have a relatively high reactivity rating even if it has a low level of volatile organic compounds (VOCs). Similarly, a coating that has a high VOC content may have a relatively low reactivity rating, if it contains compounds that aren't very reactive. The following sections contain a detailed description of the chemical reactions that lead to the formation of ozone in the atmosphere.

Section 1.1. Chemistry of Ozone Formation and Reactivity

Tropospheric chemical generation of ozone involves complex interactions among hydrocarbons and oxides of nitrogen (NO_x) under sunlight [1,2,3,4,5]. In the ambient air, the primary process leading to ozone formation is the photolysis of nitrogen dioxide (NO_2).

$$NO_2 + h\nu \rightarrow NO + O(^3P)$$

$$O(^3P) + O_2 + M \rightarrow O_3 + M$$

where
NO_2 = Nitrogen Dioxide
$h\nu$ = Ultraviolet Light
NO = Nitric Oxide
M = A third body, such as N_2
$O(^3P)$ = A ground state oxygen atom

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[1] Carter, W.P.L. "Development of Ozone Reactivity Scales for Volatile Organic Compounds." Journal of the Air and Waste Management Association 44:881-899, 1994.
[2] Silman, S. "The Use of NOy, H2O2, and HNO3 as Indicators for Ozone-NOx-Hydrocarbon Sensitivity in Urban Locations." Journal of Geophysical Research 100:14175-14188, 1995.
[3] Bergin, M.S., Russell, A.G., Carter, W.P.L., Croes, B.E., and Seinfeld, J. "Ozone Control and VOC Reactivity" in Encyclopedia of Environmental Analysis and Remediation. Meyers. R.A. (eds), John Wiley & Sons, Inc. 1998.
[4] National Research Council. "Rethinking the Ozone Problem in Urban and Regional Air Pollution." National Academy Press, Washington, D.C. 1991.
[5] National Research Council. "Ozone Formation Potential of Reformulated Gasoline." National Academy Press, Washington, D.C. 1999.

O_2 = Oxygen
O_3 = Ozone

At photo-equilibrium, the steady state ozone concentration is then given by

$$[O_3]_{steady} = \frac{k_{photo}[NO_2]}{k_1[NO]}$$

where
k_{photo} = the photolysis rate of NO_2
k_1 = the rate constant for the reaction of NO with O_3

It is apparent from this equation that additional processes converting NO to NO_2 can lead to enhanced ozone levels. VOCs are chemicals known to play an important role in such processes.[6] The ability of a VOC to induce ozone formation is known as "reactivity." Under ambient atmospheric conditions, the major reactions involving VOCs can be summarized as follows:

$$VOC + OH \rightarrow RO_2 + products$$

$$RO_2 + \alpha NO \rightarrow \beta NO_2 + radicals$$

$$Radicals \rightarrow \delta OH + products\ (e.g., HCHO)$$

The reaction is initiated by hydroxyl (OH) radicals reacting to form peroxy radicals (RO_2). In the presence of sufficient amounts of NO_x (i.e., NO and NO_2), reactions of peroxy radicals with NO compete effectively with their reactions with other peroxy radicals. This, in turn, leads to NO-to-NO_2 conversions and ultimately results in regeneration of the OH radicals. Therefore, a VOC can enhance the rate of ozone formation via an increase in the amount of NO_2 (β) converted from NO. In addition, the reaction with OH radicals is the major (or in most cases the only) reaction for most VOCs. Therefore, any enhanced production of OH radicals ($\delta > 1$), either by the parent VOC or its products (e.g., formaldehyde (HCHO)), would increase not only its own rate of ozone formation but also increase the rate of ozone formation of other VOCs present.

However, if a radical termination process is present in the VOC's reactions, it will decrease the amount of other VOCs reacting. This affects the total amount of O_3 formed.[7,8] Furthermore, processes like organic nitrate formation (e.g., peroxyacetyl

[6] National Research Council. "Rethinking the Ozone Problem in Urban and Regional Air Pollution." National Academy Press, Washington, D.C. 1991.
[7] Carter, W.P.L. "Development of Ozone Reactivity Scales for Volatile Organic Compounds." Journal of the Air and Waste Management Association 44:881-899, 1994.
[8] Bergin, M.S., Russell, A.G., Carter, W.P.L., Croes, B.E., and Seinfeld, J. "Ozone Control and VOC Reactivity" in Encyclopedia of Environmental Analysis and Remediation. Meyers. R.A. (eds), John Wiley & Sons, Inc. 1998.

nitrate (PAN) from acetaldehyde) can affect the ability of a VOC to form ozone by reducing the amount of NO available (α) to form NO_2.[9]

Hence, the impact of a VOC on ozone formation is a function of:

(1) its reaction rates (i.e., kinetics);
(2) direct mechanistic effects such as the amount of NO-to-NO_2 conversion;
(3) indirect mechanistic effects on other VOCs via processes such as radical initiation; and
(4) the presence of other species in an urban airshed with which the VOCs could potentially react.

Consequently, there is a wide variation in the ability of VOCs to induce ozone formation, and the relative importance of these processes determines whether a VOC has an enhancing (i.e., positive reactivity) or a suppressing effect (i.e., negative reactivity) on ozone formation.

Section 1.2 ARB Reactivity-Based Regulations

The ARB has pioneered the use of reactivity in regulations controlling VOC emissions. In 1991, the Board approved the Low Emission Vehicles and Clean Fuels regulation that allowed for the use of reactivity adjustment factors.[10] In June 2000, the Board approved a reactivity-based regulation for aerosol coatings.[11]

Section 1.3 ARB Suggested Control Measure for Architectural Coatings

Architectural coatings are a large source of VOC emissions. Except for consumer products, it is the largest single source of VOC emissions among all stationary and area sources. In 2000, architectural coatings emitted approximately 130 tons per day of VOCs in California, on an annual average basis. This represents about 10 percent of the VOC emissions from all stationary and area sources combined. Control of emissions from architectural coatings is primarily the responsibility of the local Air Pollution Control Districts and Air Quality Management Districts. To assist Districts in reducing emissions from this source, ARB approved a Suggested Control Measure for Architectural Coatings (SCM) in 1977, and amended it in 1985, 1989, and 2000. These SCMs have been used as models for Districts when adopting and amending their local rules. As of February 2005, 19 local air districts have adopted the architectural coating limits from the 2000 SCM.

[9] Atkinson, R. "Gas-Phase Tropospheric Chemistry of Organic Compounds." Journal of Physical and Chemistry Reference Data. Monograph 2:1-216, 1994.
[10] Air Resources Board. Proposed Regulations for Low-Emission Vehicles and Clean Fuels Staff Report. August 13, 1990.
[11] Air Resources Board. Initial Statement of Reasons for the Proposed Amendments to the Regulation for Reducing Volatile Organic Compound Emissions from Aerosol Coating Products and Proposed Tables of Maximum Incremental Reactivity (MIR) Values, and Proposed Amendments to Method 310, "Determination of Volatile Organic Compounds in Consumer Products." May 5, 2000.

During the June 2000 Board hearing, Board members adopted Resolution 00-23 which directed the ARB staff to work with industry and other stakeholders in assessing the ozone-forming potential (i.e., reactivity) of architectural coatings, and to evaluate the feasibility of developing a reactivity-based control strategy. This evaluation is to include:

(1) assessing the reactivity of individual VOC species in consideration of the best available science;
(2) conducting a comprehensive survey of the architectural coatings industry; and
(3) assessing the extent to which VOCs emitted from architectural coatings contribute to ozone levels.

Testimony at the June 2000 hearing underscored industry's interest in reactivity-based limits and suggested that improved science is a prerequisite to developing reactivity-based limits.

In June 2001, December 2002, and January 2004, ARB staff provided updates to the Board, regarding progress in implementing Resolution 00-23.[12] A brief summary of ARB's progress is provided below:

(1) ARB has funded a $300,000 research project with the University of California, Riverside that includes conducting chamber experiments to verify the chemical mechanisms used to identify the maximum incremental reactivities for some key solvents in architectural coatings. These solvents include Texanol® and six hydrocarbon solvents. The final report for this project was completed in March 2005.
(2) In 2001, ARB conducted a comprehensive survey of the architectural coatings industry. Results from this survey are summarized in the "2001 Architectural Coatings Survey, Final Report, October 2003".
(3) ARB is using the data from the 2001 survey to estimate the reactivity of architectural coatings. The results are summarized in Chapter 2 of this report. The extent to which architectural coatings contribute to ozone levels can be evaluated in a variety of ways. To actually estimate ozone concentrations, it is necessary to conduct detailed air dispersion modeling calculations. Another method for characterizing the relative ozone impacts is to identify the maximum ozone forming potential under MIR conditions. For the purposes of this report, we have chosen the latter approach, because it is a much simpler analysis that still provides a method of comparing relative ozone impacts for different coatings.

ARB staff is continuing the investigation into the feasibility of a reactivity-based architectural coatings regulation, including consideration of the following advantages and disadvantages.

[12] Air Resources Board. Status Report Architectural Coatings Suggested Control Measure. June 2001.
Air Resources Board. Status Report Architectural Coatings Suggested Control Measure. December 2002.
Air Resources Board. Status Report Architectural Coatings Suggested Control Measure. January 2004.

Section 1.4 Advantages of a Reactivity-Based SCM for Architectural Coatings

There are several advantages associated with a reactivity-based control strategy for architectural coatings. Many of the elements of a successful reactivity program are met with architectural coatings. Architectural coatings are a discrete and well-defined emissions source category, which is regularly updated with industry surveys. The reactivities of many VOC ingredients used in architectural coatings are already well characterized. Several manufacturers have expressed an interest in working with ARB on a reactivity-based SCM.

The use of mass-based VOC limits has resulted in significant emission reductions for architectural coatings. However, mass-based emission reductions are becoming more difficult to achieve as VOC limits decline and water-borne coatings increasingly dominate the market (more than 80 percent of the architectural coatings sold are water-borne products). Thus, reactivity-based limits offer a new opportunity to achieve additional ozone reductions. We expect an equal or greater air quality benefit compared to a mass-based strategy, because VOCs with the greatest ozone forming potential will be targeted rather than treating each VOC equally.

Another potential advantage involves the use of exempt compounds. Under a reactivity-based approach, the reactivity of exempt compounds would be included when evaluating the overall reactivity of a coating product. With the current mass-based approach, exempt compounds are completely excluded when determining the VOC level. Theoretically, the use of exempt compounds could increase substantially to meet VOC levels and there would be a non-negligible ozone impact associated with the increased use of exempt compounds. This issue would not be a concern with reactivity-based limits.

The reformulation options may be greater with a reactivity-based strategy, because there is a wide range of VOC species, VOC contents, and alternative technologies available. At the same time, there should be less of a tendency for lower reactive solvents to be replaced with higher reactive or toxic solvents to lower the total VOC content. For example, we would expect to see a decreased use of some toxic compounds, such as xylene and toluene, because of their high reactivity.

There are also advantages associated with enforceability. If reactivity-based limits were developed in the same manner as was done for the aerosol coatings regulation, there would no longer be a need to consider U.S. EPA's and ARB's exempt VOCs based on negligible reactivity, since the reactivity of all VOCs would be counted and nothing would be exempt. Depending on how the reactivity-based limit is defined, the "less water and exempts" calculation for determining the VOC content may cease to be an issue, since limits may be expressed in units other than grams of VOC per liter of coating, less water and exempt compounds.

Section 1.5 Disadvantages of a Reactivity-Based SCM for Architectural Coatings

There are implications for both the regulatory agencies and the manufacturers if we go forward with a reactivity-based SCM for architectural coatings. Architectural coatings are regulated by the local air districts. Since the districts may be implementing a more complex reactivity-based regulation, the ARB will provide assistance as needed. Therefore, this would result in increased resource needs for the local districts and ARB.

Compliance determination under a reactivity-based program differs from that under a traditional mass-based program. The identity and quantity of each VOC and exempt compound in a coating is needed to determine compliance with a reactivity-based limit. This may involve multiple gas chromatography with mass spectrometry (GC/MS) runs. Many districts may need ARB assistance with this type of analysis. This again would result in the need for increased resources.

To verify compliance with a reactivity-based limit, districts would require manufacturers to divulge the individual VOC ingredients in their coatings. As allowed under the Federal Clean Air Act, this emissions-related data could also be released to the public, if requested. Under such a scheme, manufacturers may be concerned about maintaining the confidentially of their product formulas. One option would be that only the reactive, volatile components of the coating would need to be divulged and the non-reactive components such as solids or resins could be lumped together to maintain product confidentially. Such an agreement was reached between the aerosol coatings industry and ARB for the aerosol coatings reactivity-based regulation.

Since more than 80 percent of the market is already water-borne, and relatively low reactive mineral spirits dominate the VOCs in solvent-borne coatings, there may be challenges to reformulating with lower-reactive solvents. In addition, we will need to analyze whether acceptable substitutes are available for the highly reactive solvents used in architectural coatings, if mandatory reactivity-based limits are proposed. This analysis will need to examine technical feasibility, economic impacts, and potential health effects.

Any reactivity-based strategy would evaluate the potential uses of toxic compounds. Some toxic compounds (e.g., methylene chloride and perchloroethylene) have a low reactivity, which could lead to increased usage in coatings that are subject to a reactivity-based limit. Therefore, it may be necessary to cap current uses and potentially prevent or minimize new uses of these toxic chemicals.

Chapter 2 – Reactivity Analysis of Survey Data

Section 2.1 Individual MIR Values

Ozone is created by chemical reactions that occur between organic compounds and nitrogen oxides (NOx), in the presence of sunlight (see Chapter 1). The reactivity of organic compounds varies widely, depending on the specific chemical and the atmospheric conditions. Incremental reactivity is the change in ozone that is caused by adding a small amount of an organic compound to a standard gas mixture. This reactivity can be characterized in a number of ways, using a variety of measurement scales, such as those developed by Dr. William Carter at the University of California, Riverside:

MIR - Maximum Incremental Reactivity

> The MIR scale is based on a scenario derived by adjusting the NOx emissions in a base case scenario to yield the highest incremental reactivity of the Base Case Reactive Organic Gas (ROG) Mixture.[1]
>
> The MIR is the incremental reactivity computed for conditions in which the NO_x concentration would maximize the VOC reactivity. This scenario is typical in air parcels of low VOC-to-NO_x ratios, or air parcels in which ozone is most sensitive to VOC changes. These are typical of urban centers where there are high emissions of NO_x and the atmospheric chemistry is VOC-limited.
>
> MIR values are calculated from a computer box model that is based on the SAPRC chemical mechanism. Environmental chamber experiments have been conducted to verify and refine the SAPRC mechanism. Additional chamber experiments are ongoing and the mechanism is updated accordingly as new data are gathered.

MOIR - Maximum Ozone Incremental Reactivity

> The MOIR scale is based on a scenario derived by adjusting the NOx emissions in a base case scenario to yield the highest peak ozone concentration.
>
> The MOIR is the incremental reactivity computed for conditions that maximize the ozone concentration. The scenario is characterized by moderate VOC-to-NO_x ratios such that the highest ozone concentration is formed. These moderate VOC-to-NO_x ratios are generally encountered as the chemistry is in transition between VOC and NO_x limitations. In this scenario, ozone formation is relatively insensitive to concentrations of VOCs and NO_x, compared to its sensitivity to VOC control in the VOC-limited region and its sensitivity to NO_x control in the

[1] The Base Case ROG mixture is a mixture of reactive organic gases that represents the chemical composition of the air in 39 urban areas throughout the United States. The U.S. Environmental Protection Agency selected a high ozone episode from each of these 39 areas to establish a geographically representative distribution of conditions in ozone nonattainment areas.

NO_x-limited region. The ozone sensitivity to the VOC is studied after the NO_x concentrations are optimized to yield the maximum ozone concentration.

EBIR - Equal Benefit Incremental Reactivity

The EBIR scale is based on a scenario derived by adjusting the NOx emissions in a base case scenario so VOC and NOx reductions are equally effective in reducing ozone.

The EBIR is the incremental reactivity computed for conditions in which ozone sensitivity to VOC is equal to that of NO_x. The scenario is characterized by higher VOC-to-NO_x ratios such that VOC and NO_x controls are equally effective in reducing ozone.

Carter evaluated each of these three scales and concluded that, if only one scale is to be used for regulatory purposes, the MIR scale is the most appropriate for California.[2]

Although the MOIR is computed for conditions that maximize the ozone concentration, the MOIR and EBIR are more representative of lower NO_x and higher VOC conditions. In the grid modeling study conducted by McNair et al., a 3-D model was applied to a 3-day pollution episode in the Los Angeles Air Basin.[3] The results showed that the MIRs derived from the box models did not perform well in predicting peak ozone sensitivities to individual VOCs, but performed reasonably well in predicting the effects of the VOCs on the integrated exposure to ozone over the air quality standard. The MOIR scale did not compare as well as the MIR scale to either the peak ozone concentration or ozone exposure concentrations greater than the air quality standard. In another study, Bergin et al. conducted a more direct comparison with the MIR and MOIR scales.[4,5] The results showed that the metrics compared relatively better with the MIR scale than with the MOIR scale. The results suggest that the MIR scale is most appropriate in areas rich in NO_x, such as the urban areas in California that exceed ozone air quality standards. On the federal level, the Environmental Protection Agency coordinates the Reactivity Research Working Group that is working to improve the scientific basis for reactivity-related regulatory policies.

The ARB is using the MIR scale for regulatory applications because the MIR scale reflects reactivities under environmental conditions that are most sensitive to the effects of VOC controls, such as in the South Coast Air Basin. The scale would be most

[2] Carter, W.P.L. "Development of Ozone Reactivity Scales for Volatile Organic Compounds." Journal of the Air and Waste Management Association 44:881-899, 1994.
[3] McNair, L., A. Russell, and M.T. Odman. "Airshed Calculation of the Sensitivity of Pollutant Formation to Organic Compound Classes and Oxygenates Associated with Alternative Fuels." Journal of the Air and Waste Management Association 42:174-178, 1992.
[4] Bergin, M. S., Russell, A. G., and Milford, J. B. "Quantification of Individual VOC Reactivity Using a Chemically Detailed, Three-Dimensional Photochemical Model." Environmental Science and Technology 29(12):3029-3037, 1995.
[5] Bergin, M.S., A.G. Russell, and J.B. Milford. "Effects of Chemical Mechanism Uncertainties on the Reactivity Quantification of Volatile Organic Compounds Using a Three-Dimensional Air Quality Model." Environmental Science and Technology 32(5):694-703, 1998.

accurate for VOC-limited conditions, in which VOC controls would be most effective. The MIR scale was also found to correlate well to scales based on integrated ozone yields, even in lower NO_x scenarios.[2,3,4] Moreover, the MIR scale tends to predict low reactivities for slowly reacting compounds. The wider range of incremental reactivities in the MIR scale allows better discrimination in a manufacturer's selection of a less reactive compound to substitute for a more reactive compound.

MIR values have been assigned for hundreds of organic compounds, including both VOCs and exempt compounds. ARB uses the term Reactive Organic Gases (ROG) for VOCs only and the term Total Organic Gases (TOG) to include both VOCs and exempt compounds. MIR values are expressed in units of grams ozone per gram TOG (g O_3/g TOG) and these values are updated periodically by Carter.[6] At an Executive Officer hearing in December 2003, ARB approved a formal update of the Tables of MIR Values for the Aerosol Coatings Regulation and any other future reactivity regulations. This update became effective on July 7, 2004.

The MIR scale can be used to assign reactivity values for most of the pure chemicals that are used in architectural coatings. However, hydrocarbon solvents are a major ingredient in architectural coatings and they generally consist of mixtures, rather than pure compounds. For hydrocarbon solvents, ARB developed a bin system in conjunction with the development of the Aerosol Coating regulation.[7] These bins assign MIR values, based on average boiling points and hydrocarbon characteristics (e.g., aromatic content). The bins are similar to the categories contained in the following standards from the American Society for Testing and Materials (ASTM):

D 235: Mineral Spirits (Petroleum Spirits, Hydrocarbon Dry Cleaning Solvent)
D 3734: High-Flash Aromatic Naphthas
D 3735: VM&P Naphthas

ARB worked with paint manufacturers and solvent suppliers to identify the appropriate bin numbers for the hydrocarbon solvents that were reported in the 2001 Architectural Coatings Survey.

Dr. Carter's MIR scale and the ARB hydrocarbon solvent bins provided MIR values for approximately 87 percent by weight of the organic compounds reported in the 2001 survey. For the remaining organic compounds, ARB calculated default MIR values that reflected sales-weighted averages of the MIRs that had been identified. Separate default MIR values were calculated for solventborne and waterborne coatings using the following types of compounds: exempt compounds; hydrocarbon solvents; and other organic compounds (non-exempt, non-hydrocarbon solvent.) These values are listed in Table 2-1.

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[6] The most recent update prepared by Dr. Carter is dated February 5, 2003 and can be obtained at the following website: http://pah.cert.ucr.edu/~carter/reactdat.htm#update02. These February 2003 MIR values were used for ARB's reactivity analysis in this report.

[7] Air Resources Board. Initial Statement of Reasons for the Proposed Amendments to the Regulation for Reducing Volatile Organic Compound Emissions from Aerosol Coating Products and Proposed Tables of Maximum Incremental Reactivity (MIR)Values. May 2000.

Table 2-1: ***Default MIR Values***

Type of Compound	Default MIR Values (g O_3/g TOG)	
	Solventborne	*Waterborne*
Exempt Compounds	0.38	0.42
Hydrocarbon Solvents	1.86	1.82
Other (non-exempt, non-hydrocarbon solvent)	0.35 (100% solids) 4.25	2.25

Note: Default MIR values are sales-weighted averages, based on mass, for reported ingredients that had MIRs assigned by Dr. Carter .

Section 2.2 Product-Weighted MIR Values

The Product-Weighted MIR (PWMIR) represents a compilation of MIR values for all of the individual ingredients in a coating. In one approach, which was used in the ARB's aerosol coatings regulation, the product-weighted MIRs for coatings are calculated as follows:

$$[\text{PWMIR, g } O_3\text{/g product}] = [\text{Wt\%}]_1*[\text{MIR}]_1 + [\text{Wt\%}]_2*[\text{MIR}]_2 + \ldots + [\text{Wt\%}]_n*[\text{MIR}]_n$$

where

$[\text{Wt\%}]_i$ = the weight percent of each ingredient in a coating product (e.g., 0.25 for 25%)
$[\text{MIR}]_i$ = the MIR value of each ingredient in a coating product, g O_3/g TOG
n = the total number of ingredients in a coating product

An example is provided below, based on actual survey data that has been altered slightly to protect manufacturer confidentiality:

Ingredient	CAS #	Wt %	MIR (g O_3/g TOG)	[Wt%]*[MIR]
1,2-Propanediol	57-55-6	4%	2.74	0.110
2,2,4-Trimethyl-1,3-Pentanediol Monoisobutyrate	25265-77-4	2%	0.88	0.018
2-(2-Butoxyethoxy)-Ethanol	112-34-5	4%	2.87	0.115
2-(2-Methoxyethoxy)-Ethanol	111-77-3	3%	2.88	0.086
Water	7732-18-5	54%	0	0
Solids		33%	0	0
	TOTAL =	**100%**		**0.33**
Product-Weighted MIR = **0.33** grams ozone/gram product				

Section 2.3 Sales-Weighted Average MIR Values

To determine sales-weighted average MIR values (SWAMIRs), we used the following equation:

$$\text{SWAMIR} = \frac{[\text{Sales}]_1*[\text{PWMIR}]_1 + [\text{Sales}]_2*[\text{PWMIR}]_2 + \ldots + [\text{Sales}]_n*[\text{PWMIR}]_n}{[\text{Sales}]_1 + [\text{Sales}]_2 + \ldots + [\text{Sales}]_n}$$

where

[Sales, gals]$_i$ = the sales of product "i", gallons
[PWMIR]$_i$ = the Product-Weighted MIR value, grams ozone/gram product
n = the total number of coating products

An example is provided below:

Product	PWMIR (g O3/g product)	Sales (gals)	[PWMIR]*[Sales]
#1	0.75	1,000	750
#2	1.16	12,000	13,920
#3	0.98	3,500	3,430
#4	0.35	500	175
	TOTALS:	**17,000**	**18,275**
Sales-Weighted Avg. MIR = (18,275)/(17,000) = **1.08** grams ozone/gram product			

SWAMIRs were calculated for all of the coating categories based on the 2001 survey data. The survey collected sales data for more than 8,000 products and it also gathered data on the chemical ingredients contained in each product. However, there were approximately 100 products for which no ingredient data were submitted. These 100 products only represent 2.0 percent of the total sales volume. Since ingredient data are required to identify MIRs, we did not include the products with missing ingredient data when calculating sales-weighted average MIR values.

Table 2-2 contains SWAMIRs for the surveyed coating categories, including a breakdown for solventborne and waterborne formulations. It also contains SWAMIRs for compliant and non-compliant coatings, based on the VOC limits contained in ARB's 2000 Architectural Coatings SCM.

Table 2-2: ***SWAMIRs for All Categories***

Coating Category	SCM VOC Limit (g/l)	SWAMIR (grams ozone/gram product)								
		Solventborne Coatings			Waterborne Coatings			All Coatings		
		Compliant w/SCM Limit	Non-Compliant	Overall	Compliant w/SCM Limit	Non-Compliant	Overall	Compliant w/SCM Limit	Non-Compliant	Overall
Antenna	530	0.80	N/A	0.80	0.36	N/A	0.36	0.74	N/A	0.74
Bituminous Roof	300	0.38	0.57	0.39	0.00	0.01	0.00	0.19	0.55	0.20
Bituminous Roof Primer	350	0.65	0.60	0.62	0.20	N/A	0.20	0.29	0.60	0.37
Bond Breakers	350	N/A	N/A	N/A	0.14	0.82	0.16	0.14	0.82	0.16
Clear Brushing Lacquer	680	1.51	N/A	1.51	N/A	N/A	N/A	1.51	N/A	1.51
Concrete Curing Compounds	350	1.32	1.29	1.32	0.14	0.01	0.14	0.19	1.09	0.20
Dry Fog	400	0.36	0.42	0.36	0.11	N/A	0.11	0.24	0.42	0.24
Faux Finishing	350	0.30	0.45	0.43	0.18	0.94	0.22	0.18	0.76	0.23
Fire Resistive	350	N/A	N/A	N/A	0.04	N/A	0.04	0.04	N/A	0.04
Fire Retardant - Clear	650	N/A	N/A	N/A	0.00	N/A	0.00	0.00	N/A	0.00
Fire Retardant - Opaque	350	0.93	1.72	1.00	0.05	N/A	0.05	0.12	1.72	0.13
Flat	**100**	N/A	**0.43**	**0.43**	**0.05**	**0.11**	**0.06**	**0.05**	**0.11**	**0.06**
Floor	250	0.34	0.67	0.40	0.16	0.29	0.16	0.18	0.44	0.19
Flow	420	N/A	N/A	N/A	0.54	N/A	0.54	0.54	N/A	0.54
Form Release Compounds	250	0.31	0.93	0.31	0.03	N/A	0.03	0.27	0.93	0.27
Graphic Arts	500	0.77	0.50	0.77	0.10	N/A	0.10	0.45	0.50	0.45
High Temperature	420	0.72	1.92	0.84	0.31	N/A	0.31	0.72	1.92	0.84
Industrial Maintenance	**250**	**0.44**	**0.85**	**0.77**	**0.17**	**0.63**	**0.21**	**0.33**	**0.85**	**0.69**
Lacquers	**550**	**0.90**	**1.67**	**1.54**	**0.32**	N/A	**0.32**	**0.59**	**1.67**	**1.34**
Low Solids	120	N/A	N/A	N/A	0.17	N/A	0.17	0.17	N/A	0.17
Magnesite Cement	450	2.12	N/A	2.12	N/A	N/A	N/A	2.12	N/A	2.12
Mastic Texture	300	0.11	0.31	0.16	0.08	N/A	0.08	0.09	0.31	0.11
Metallic Pigmented	500	1.67	3.38	1.68	0.09	N/A	0.09	1.38	3.38	1.40

Table 2-2: ***SWAMIRs for All Categories***

Coating Category	SCM VOC Limit (g/l)	SWAMIR (grams ozone/gram product)								
		Solventborne Coatings			Waterborne Coatings			All Coatings		
		Compliant w/SCM Limit	Non-Compliant	Overall	Compliant w/SCM Limit	Non-Compliant	Overall	Compliant w/SCM Limit	Non-Compliant	Overall
Multi-Color	250	N/A	0.43	0.43	0.07	1.22	0.32	0.07	1.19	0.33
Nonflat - High Gloss	**250**	**0.73**	**0.65**	**0.68**	**0.19**	**0.31**	**0.19**	**0.25**	**0.63**	**0.34**
Nonflat - Low Gloss	**150**	N/A	**0.45**	**0.45**	**0.08**	**0.16**	**0.10**	**0.08**	**0.16**	**0.10**
Nonflat - Medium Gloss	**150**	N/A	**0.55**	**0.55**	**0.08**	**0.17**	**0.13**	**0.08**	**0.19**	**0.14**
Other	100	0.04	0.95	0.28	0.00	0.01	0.00	0.00	0.77	0.00
Pre-Treatment Wash Primer [1]	420	0.46	1.43	0.83	0.21	0.44	0.21	0.22	1.43	0.24
Primer, Sealer, and Undercoater	**200**	**0.07** [2]	**0.60**	**0.60**	**0.09**	**0.17**	**0.09**	**0.09**	**0.50**	**0.17**
Quick Dry Enamel	**250**	**0.20** [3]	**0.58**	**0.54**	**0.27**	N/A	**0.27**	**0.22**	**0.58**	**0.53**
Quick Dry Primer, Sealer, and Undercoater	**200**	**0.09** [4]	**0.53** [5]	**0.52**	**0.12**	**0.16**	**0.12**	**0.12**	**0.51**	**0.40**
Recycled	250	N/A	N/A	N/A	0.01	0.03	0.02	0.01	0.03	0.02
Roof	250	0.19	0.75	0.46	0.06	N/A	0.06	0.06	0.75	0.09
Rust Preventative	400	0.51	0.44	0.50	0.14	N/A	0.14	0.43	0.44	0.43
Sanding Sealers	350	N/A	1.33	1.33	0.17	N/A	0.17	0.17	1.33	1.01
Shellacs - Clear	730	1.14	N/A	1.14	N/A	N/A	N/A	1.14	N/A	1.14
Shellacs - Opaque	550	0.74	N/A	0.74	N/A	N/A	N/A	0.74	N/A	0.74
Specialty Primer, Sealer, and Undercoater	350	0.47	0.58	0.56	0.11	N/A	0.11	0.12	0.58	0.14
Stains - Clear/Semitransparent	**250**	**0.37**	**0.67**	**0.66**	**0.07**	**0.24**	**0.15**	**0.10**	**0.61**	**0.55**
Stains - Opaque	**250**	**0.14**	**0.49**	**0.49**	**0.11**	**0.22**	**0.11**	**0.11**	**0.43**	**0.19**
Swimming Pool	340	1.10	1.17	1.11	0.21	N/A	0.21	0.68	1.17	0.71
Swimming Pool Repair and Maintenance	340	N/A	3.56	3.56	N/A	N/A	N/A	N/A	3.56	3.56
Traffic Marking	**150**	**0.19**	**0.57**	**0.23**	**0.04**	**0.11**	**0.04**	**0.07**	**0.45**	**0.08**

Table 2-2: ***SWAMIRs for All Categories***

Coating Category	SCM VOC Limit (g/l)	SWAMIR (grams ozone/gram product)								
		Solventborne Coatings			Waterborne Coatings			All Coatings		
		Compliant w/SCM Limit	Non-Compliant	Overall	Compliant w/SCM Limit	Non-Compliant	Overall	Compliant w/SCM Limit	Non-Compliant	Overall
Varnishes - Clear	350	0.69	0.75	0.73	0.26	0.59	0.32	0.46	0.73	0.59
Varnishes - Semitransparent	350	N/A	0.53	0.53	0.22	0.29	0.22	0.22	0.53	0.51
Waterproofing Concrete/Masonry Sealers	400	0.74	1.79	1.04	0.10	0.08	0.10	0.26	1.79	0.40
Waterproofing Sealers	**250**	**0.50**	**0.82**	**0.77**	**0.06**	**0.14**	**0.10**	**0.14**	**0.56**	**0.41**
Wood Preservatives	350	0.68	1.17	0.73	0.19	0.48	0.20	0.65	1.17	0.70

Bold highlighting indicates major categories that were targeted for lower VOC limits in ARB's 2000 SCM.
"N/A": Not applicable, because there were no coating sales and/or ingredient data reported in this compliance category.

1. These results are questionable because a portion of the sales consists of products that manufacturers chose to categorize as Pretreatment Wash Primers, but could potentially qualify as Specialty PSUs.
2. These results are questionable because more than 95% of the sales volume for compliant solventborne PSUs had incomplete ingredient data and, therefore, was not included in determining the SWAMIR.
3. The low reactivity for this subcategory is due to the fact that all of the sales volume for compliant solventborne QDEs has a weight percent water that is relatively high for a solventborne product.
4. The low reactivity for this subcategory is due to the fact that about half of the sales volume for compliant solventborne QDPSUs consists of 100% solids products and the other half of the sales volume has a relatively high weight percent water.
5. These results are questionable because more than 25% of the sales volume for noncompliant solventborne QDPSUs had incomplete ingredient data and, therefore, was not included in determining the SWAMIR.

Figure 2-1 contains the SWAMIRs and the associated sales for selected categories that were targeted for lower VOC limits in ARB's 2000 Suggested Control Measure.

Figure 2-1: Selected Categories
Sales-Weighted Average MIR and 2000 Sales Data

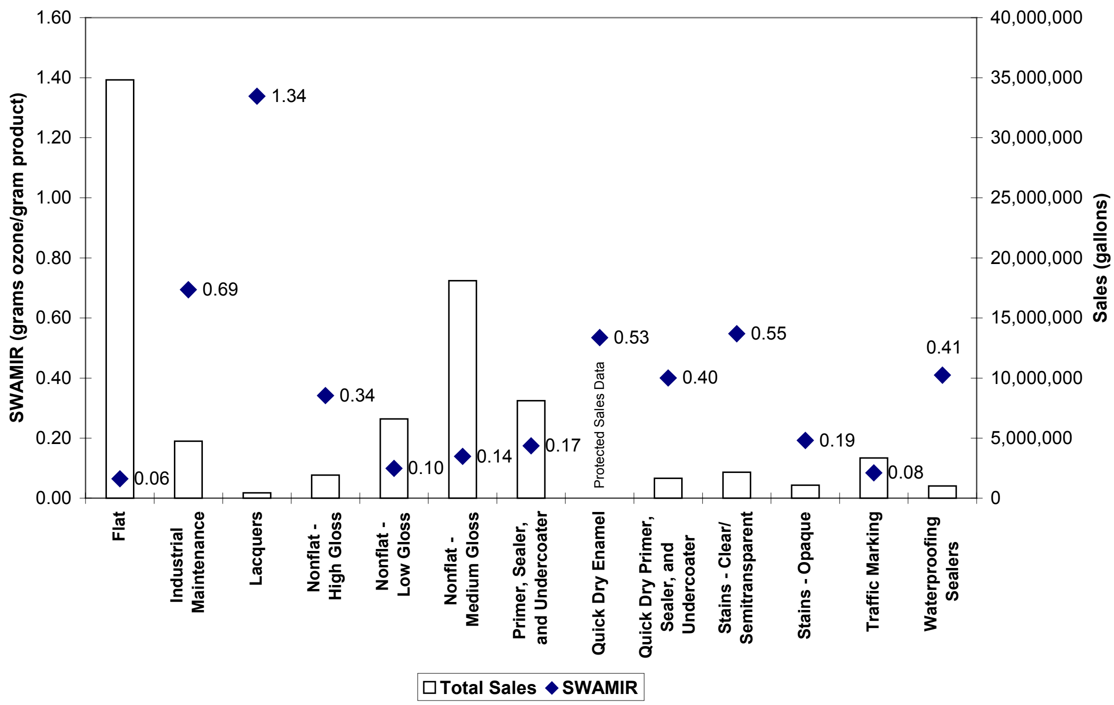
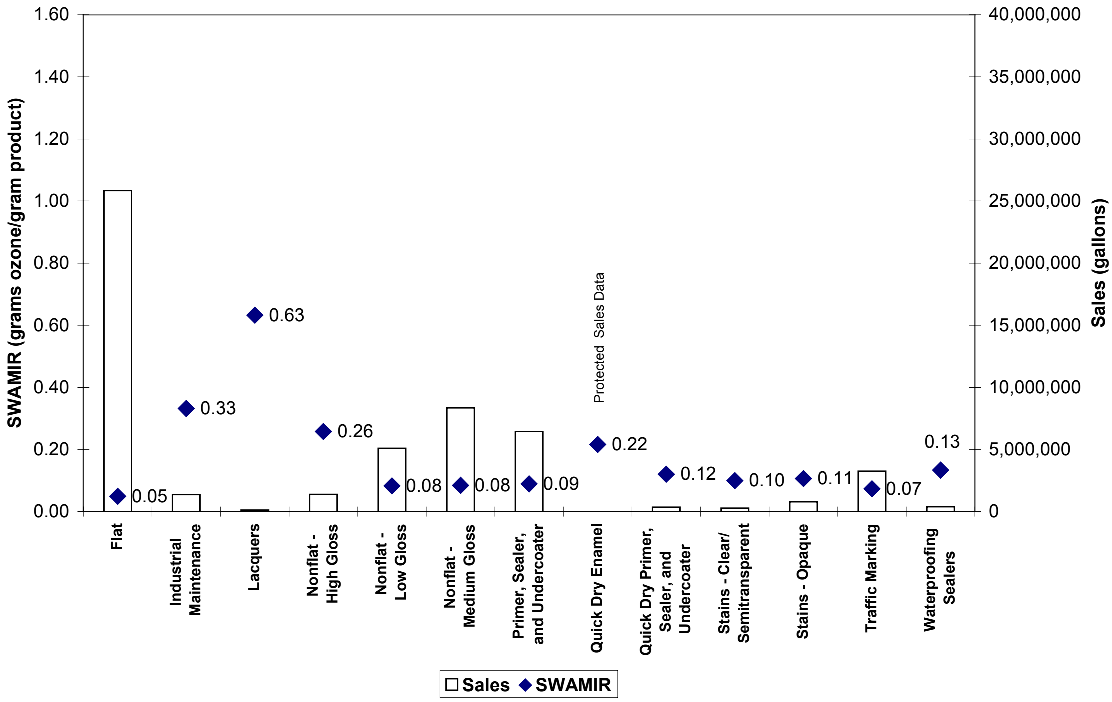


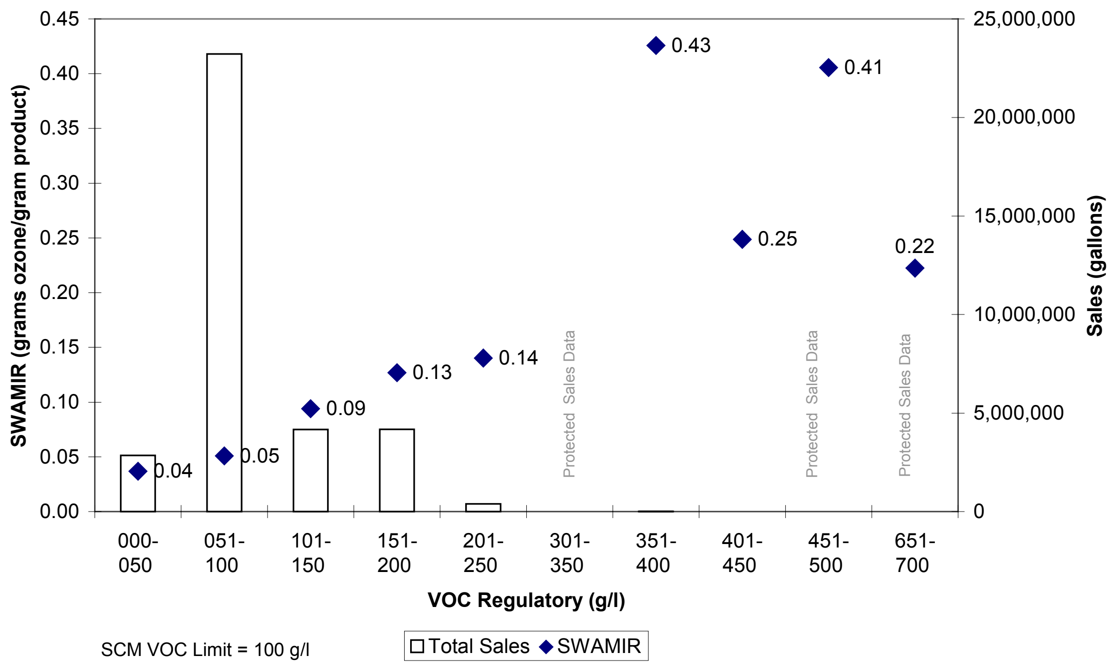
Figure 2-2 contains data similar to Figure 2-1, but it provides SWAMIRs and sales only for those reported coatings that complied with the VOC limits in ARB's 2000 Suggested Control Measure. In addition, Figure 2-2 does not include sales of small containers (one quart or less), because they are exempt from the SCM VOC limits.

Figure 2-2: Selected Categories - Compliant Coatings Only
Sales-Weighted Average MIR & 2000 Sales Data (w/o quarts)



Figures 2-3 to 2-15 contain charts of the SWAMIRs for selected categories in 50-gram/liter (g/l) ranges for VOC Regulatory (i.e., VOC less water, less exempts), along with the associated sales values in each range.

Figure 2-3: Flat
Sales-Weighted Average MIR and 2000 Sales Data



No MIR value could be calculated for Flats in the 301-350 g/l range, because no ingredient data were provided.

Figure 2-4: Industrial Maintenance
Sales-Weighted Average MIR and 2000 Sales Data

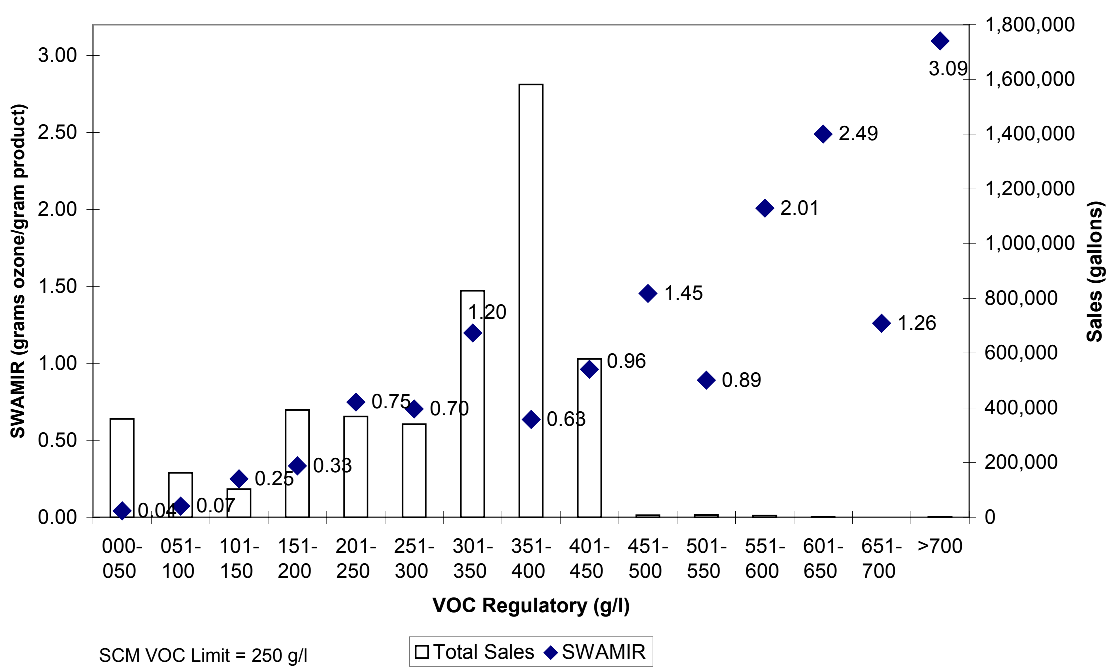


Figure 2-5: Lacquers
Sales-Weighted Average MIR and 2000 Sales Data

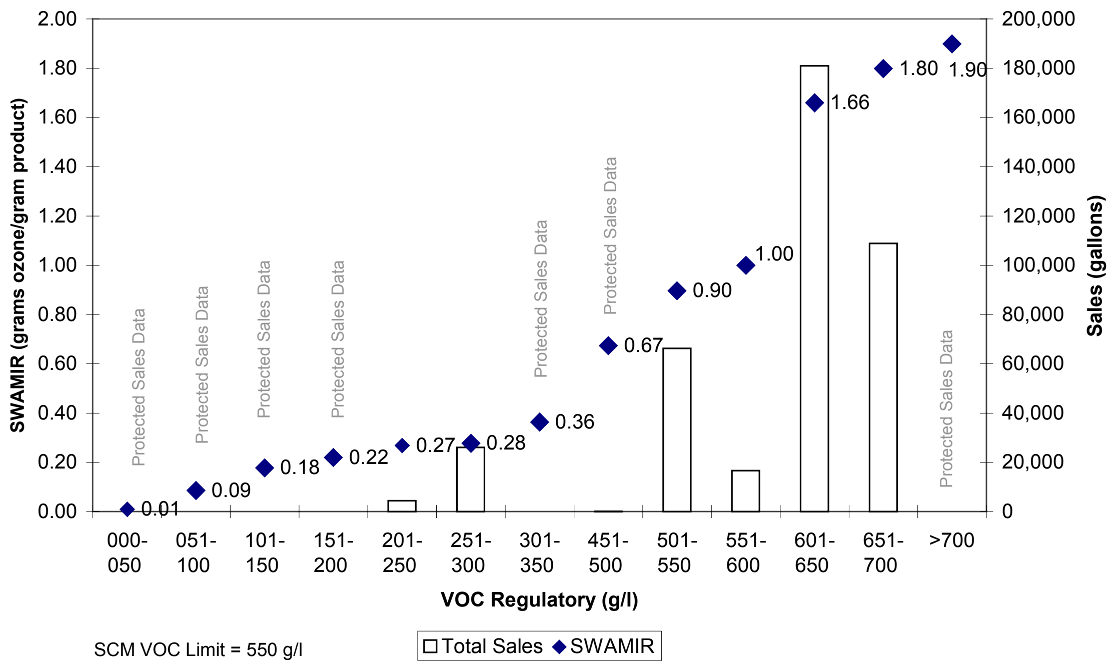


Figure 2-6: Nonflat - High Gloss
Sales-Weighted Average MIR and 2000 Sales Data

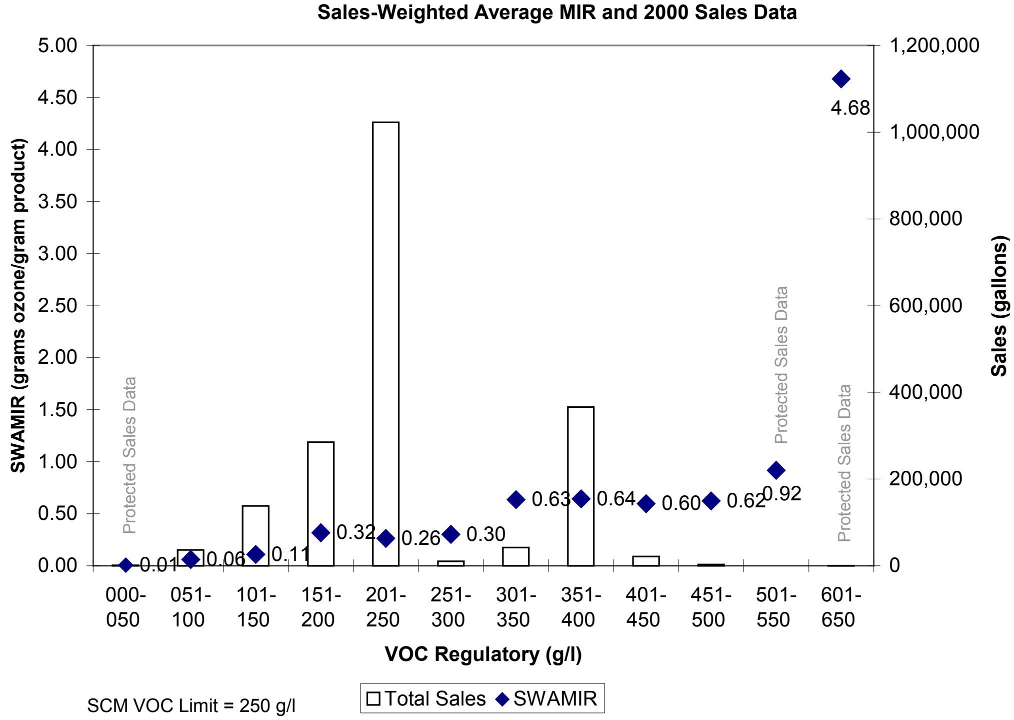


Figure 2-7: Nonflat - Low Gloss
Sales-Weighted Average MIR and 2000 Sales Data

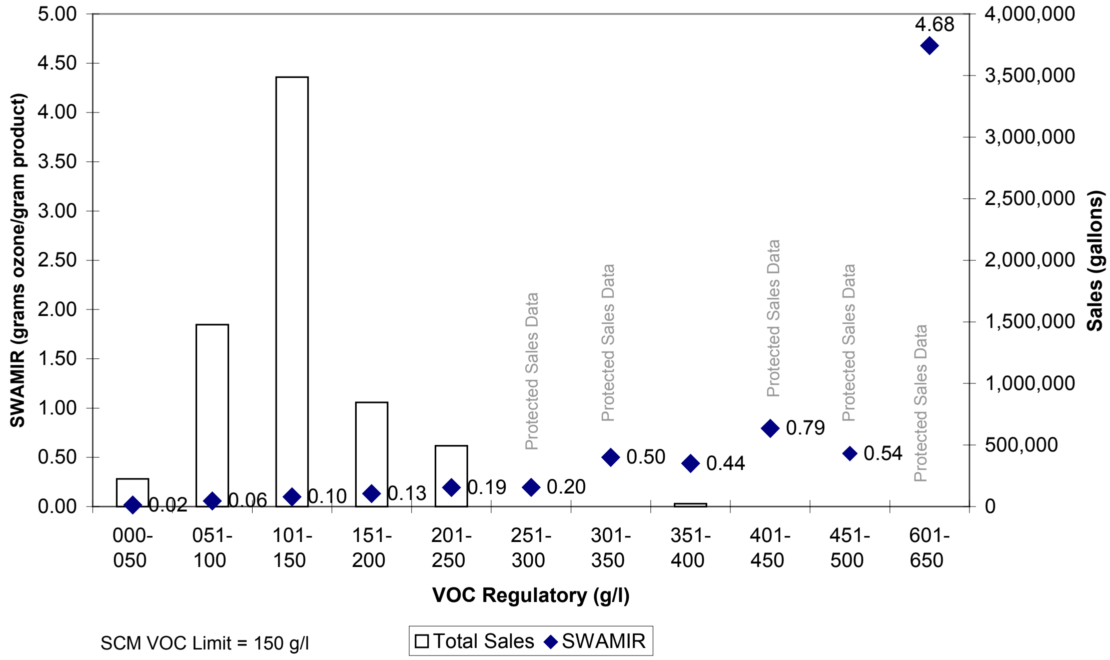


Figure 2-8: Nonflat - Medium Gloss
Sales-Weighted Average MIR and 2000 Sales Data

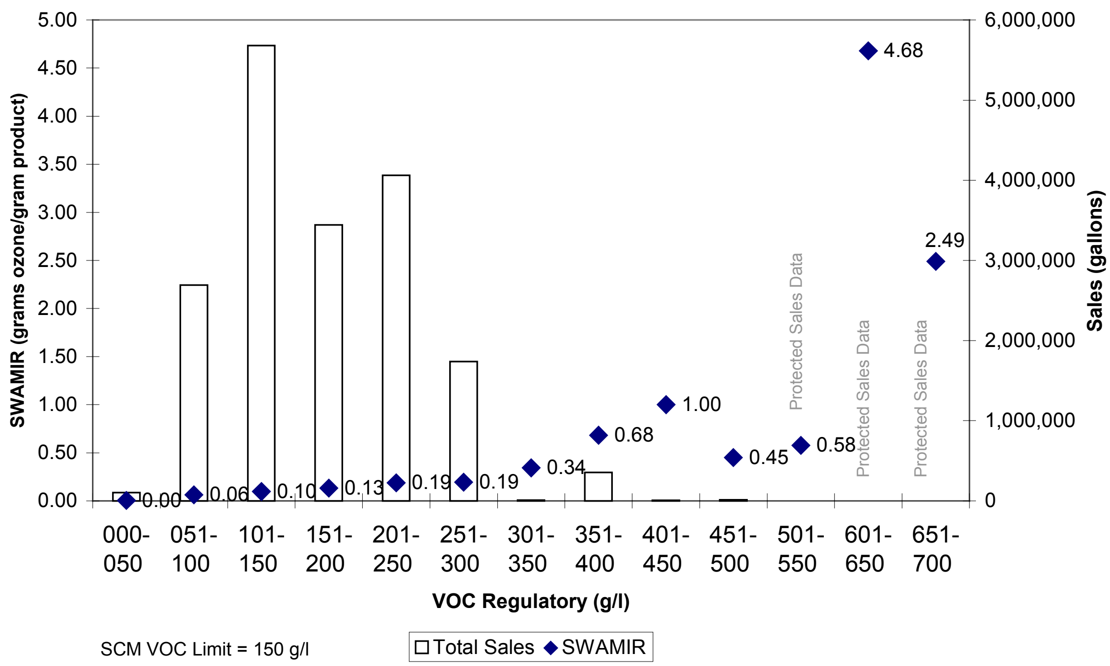


Figure 2-9: Primer, Sealer, Undercoater
Sales-Weighted Average MIR and 2000 Sales Data

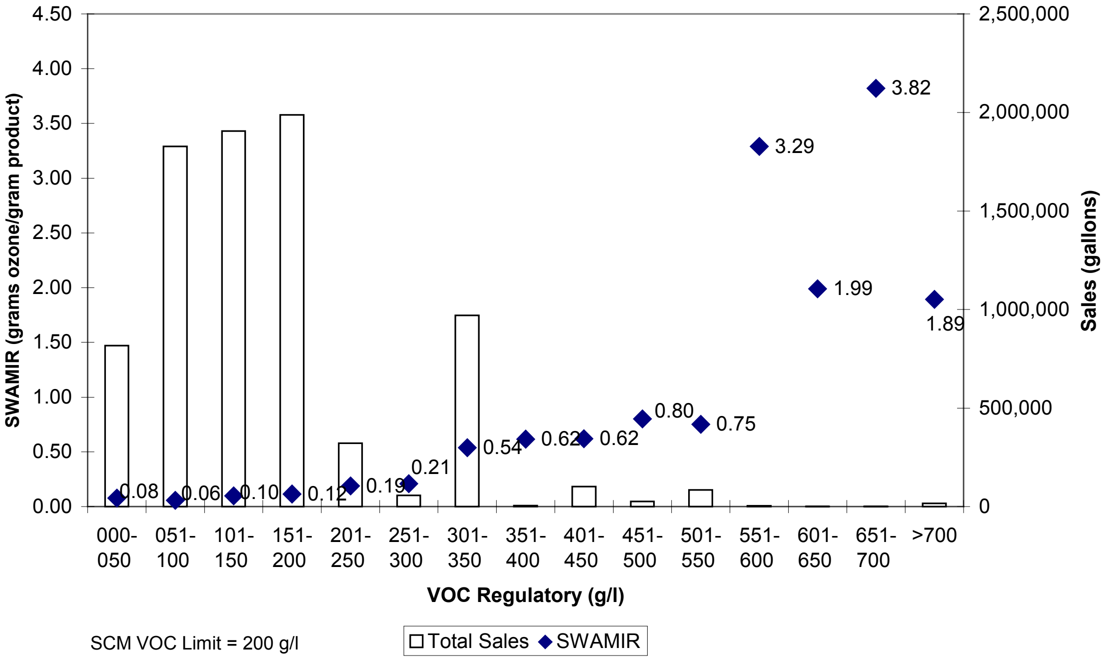


Figure 2-10: Quick Dry Enamel
Sales-Weighted Average MIR and 2000 Sales Data

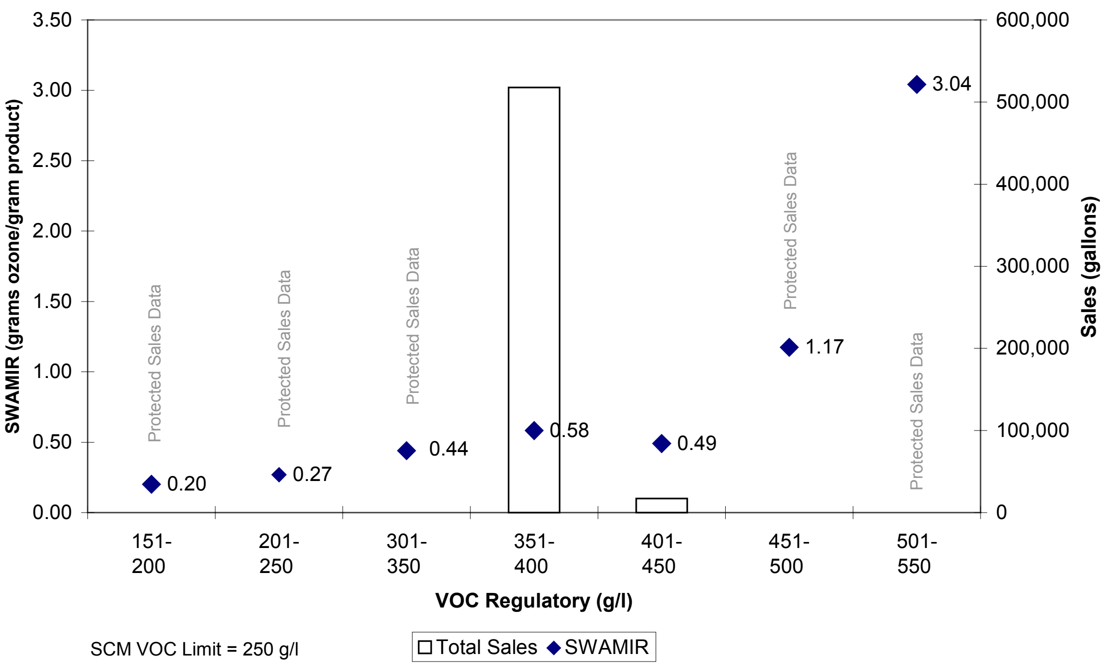


Figure 2-11: Quick Dry Primer, Sealer, Undercoater
Sales-Weighted Average MIR and 2000 Sales Data

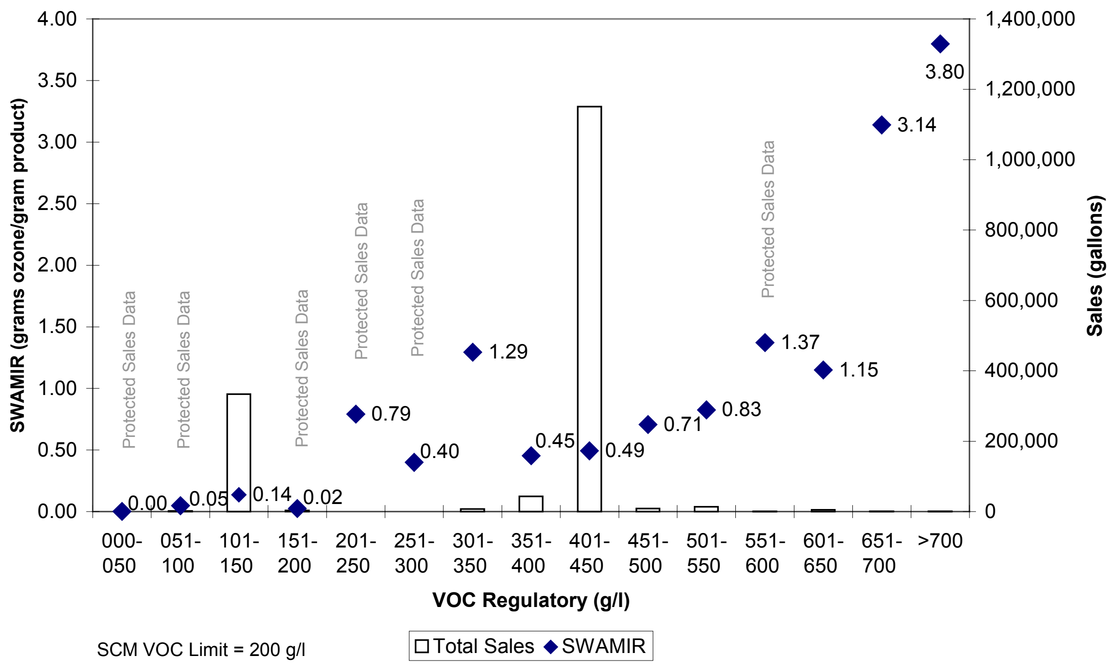


Figure 2-12: Stain - Clear/Semitransparent
Sales-Weighted Average MIR and 2000 Sales Data

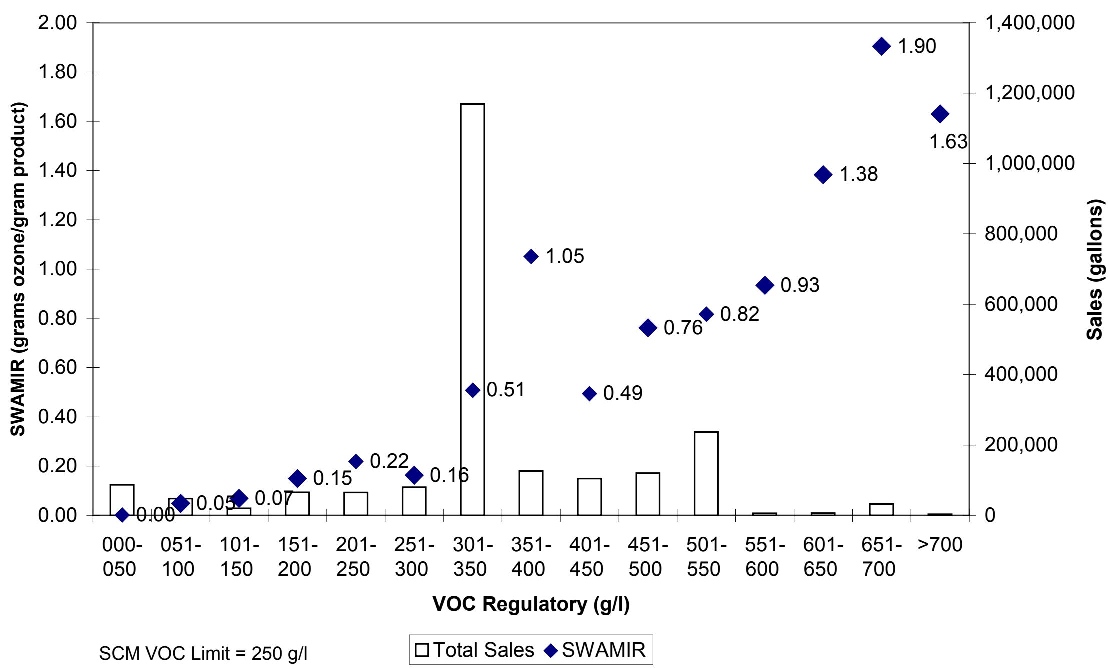


Figure 2-13: Stain - Opaque
Sales-Weighted Average MIR and 2000 Sales Data

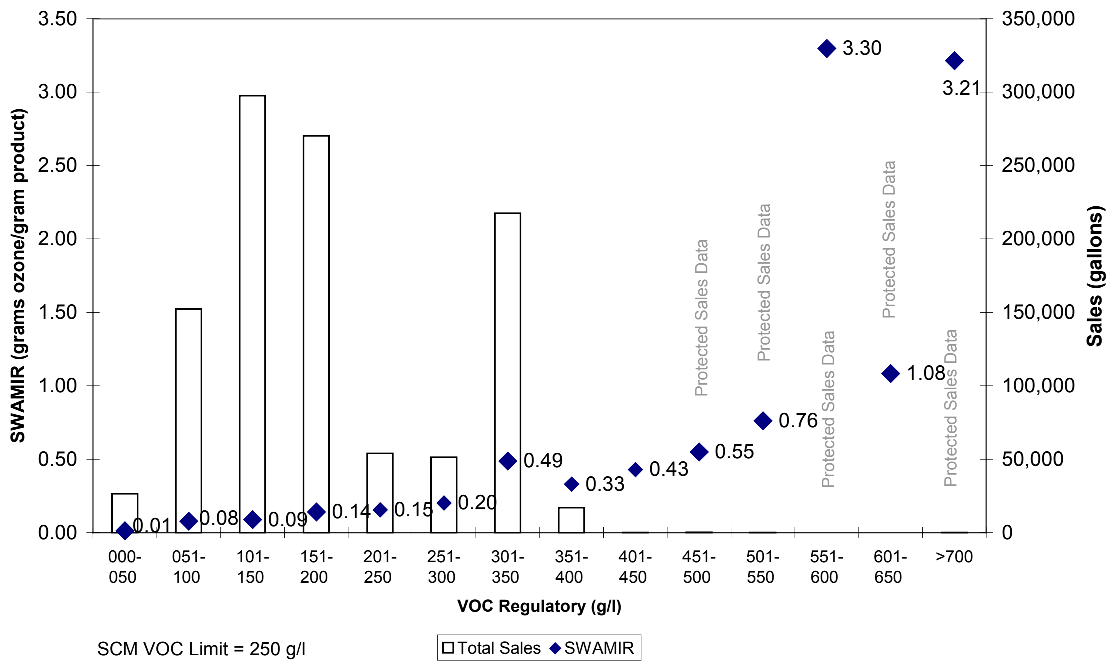


Figure 2-14: Traffic Marking
Sales-Weighted Average MIR and 2000 Sales Data

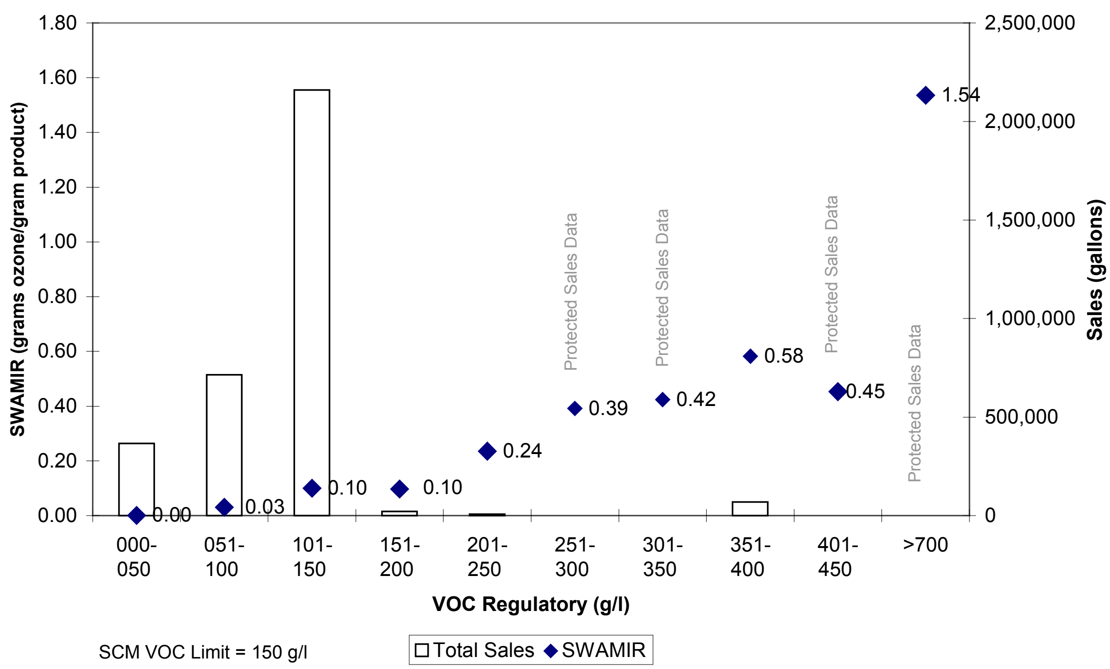
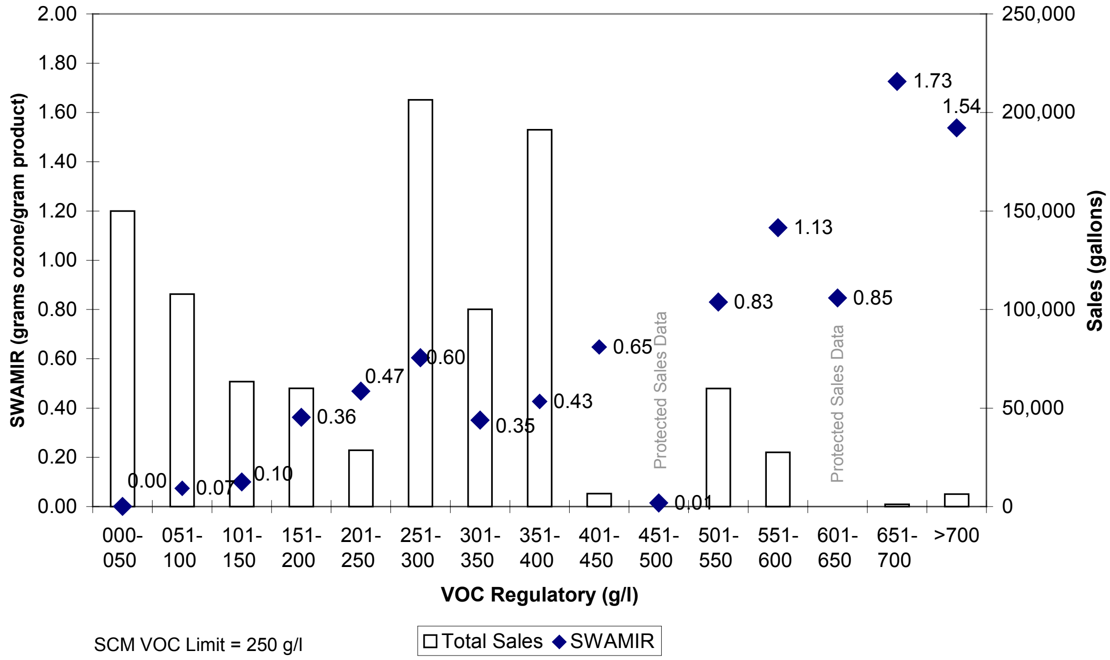


Figure 2-15: Waterproofing Sealers
Sales-Weighted Average MIR and 2000 Sales Data



SCM VOC Limit = 250 g/l

Table 2-3 contains SWAMIRs that were calculated for 50-g/l ranges for all categories. Sales-weighted averages were calculated based on sales volumes (gallons). Tables 2-4 and 2-5 contain this information for solventborne and waterborne coatings, respectively.

Table 2-3: ***Sales-Weighted Average MIR Values in 50-g/l Ranges (grams ozone/gram product)***

Coating Category	VOC Regulatory Ranges (grams/liter)														
	0-50	**51-100**	**101-150**	**151-200**	**201-250**	**251-300**	**301-350**	**351-400**	**401-450**	**451-500**	**501-550**	**551-600**	**601-650**	**651-700**	**> 700**
Antenna						0.36		1.37		0.73					
Bituminous Roof	0.00	0.07	0.14	0.28	0.38	0.50	0.52	0.94		0.43					
Bituminous Roof Primer	0.06			0.20			0.84		0.60						
Bond Breakers		0.08		0.06		0.08	0.19					0.82			
Clear Brushing Lacquer														1.51	
Concrete Curing Compounds	0.06	0.07	0.11	0.21	0.10	0.17	1.12			0.01	0.49	1.35	3.68	5.39	1.66
Dry Fog	0.02	0.04	0.08	0.07		0.25	0.30	0.37	0.40		0.82				
Faux Finishing		0.06	0.10		0.20	0.24	0.23	0.31	0.51					0.78	0.95
Fire Resistive	0.04														
Fire Retardant – Clear	0.00														
Fire Retardant – Opaque	0.02	0.04	0.08		1.09	1.04	0.89			0.98		3.91			4.82
Flat	0.04	0.05	0.09	0.13	0.14			0.43	0.25	0.41				0.22	
Floor	0.17	0.06	0.24	0.16	0.25	0.27	0.27	0.64	0.89	0.50	1.05		1.09		
Flow									0.54						
Form Release Compounds		0.07	0.05	0.40	0.31		0.74		0.94						
Graphic Arts		0.03	0.10	0.22	0.28	0.32	0.30	0.86	0.64		0.50				
High Temperature						0.58	0.52	0.78	0.58	1.23	2.54	2.94	1.85	2.88	
Industrial Maintenance	0.04	0.07	0.25	0.33	0.75	0.70	1.20	0.63	0.96	1.45	0.89	2.01	2.49	1.26	3.09
Lacquers	0.01	0.09	0.18	0.22	0.27	0.28	0.36			0.67	0.90	1.00	1.66	1.80	1.90
Low Solids	0.05	0.23													
Magnesite Cement									2.12						
Mastic Texture	0.01	0.08	0.19	0.17	0.12	0.37		0.31							
Metallic Pigmented		0.25	0.08	0.22	0.35	0.84	0.62	0.92	0.82	1.96	1.15	1.74	2.54	4.49	4.59
Multi-Color		0.02	0.10		0.18					0.24	0.43				2.02

Table 2-3: ***Sales-Weighted Average MIR Values in 50-g/l Ranges (grams ozone/gram product)***

Coating Category	VOC Regulatory Ranges (grams/liter)														
	0-50	**51-100**	**101-150**	**151-200**	**201-250**	**251-300**	**301-350**	**351-400**	**401-450**	**451-500**	**501-550**	**551-600**	**601-650**	**651-700**	**> 700**
Nonflat - High Gloss	0.01	0.06	0.11	0.32	0.26	0.30	0.63	0.64	0.60	0.62	0.92		4.68		
Nonflat - Low Gloss	0.02	0.06	0.10	0.13	0.19	0.20	0.50	0.44	0.79	0.54			4.68		
Nonflat - Medium Gloss	0.00	0.06	0.10	0.13	0.19	0.19	0.34	0.68	1.00	0.45	0.58		4.68	2.49	
Other	0.00	0.18	0.02		0.95	0.42	0.37				0.60	1.68		0.78	
Pre-Treatment Wash Primer [1]	0.07	0.07	0.07				0.29	0.29						1.03	1.83
Primer, Sealer, and Undercoater	0.08	0.06	0.10	0.12	0.19	0.21	0.54	0.62	0.62	0.80	0.75	3.29	1.99	3.82	1.89
Quick Dry Enamel				0.20	0.27		0.44	0.58	0.49	1.17	3.04				
Quick Dry Primer, Sealer, and Undercoater	0.00	0.05	0.14	0.02	0.79	0.40	1.29	0.45	0.49	0.71	0.83	1.37	1.15	3.14	3.80
Recycled					0.03	0.03									
Roof	0.03	0.08	0.18	0.15	0.29	0.64	0.72		1.17						1.79
Rust Preventative		0.04	0.11	0.14	0.22	1.25	1.36	0.41	0.64	0.42					1.34
Sanding Sealers				0.14	0.18	0.20	0.17				0.93	1.80		1.04	2.43
Shellacs – Clear												0.90	1.21	1.12	
Shellacs – Opaque											0.74				
Specialty Primer, Sealer, and Undercoater	0.03	0.11	0.09	0.15	0.23	0.60	0.35		0.58	0.87				1.61	
Stains - Clear/Semitransparent	0.00	0.05	0.07	0.15	0.22	0.16	0.51	1.05	0.49	0.76	0.82	0.93	1.38	1.90	1.63
Stains – Opaque	0.01	0.08	0.09	0.14	0.15	0.20	0.49	0.33	0.43	0.55	0.76	3.30	1.08		3.21
Swimming Pool	0.04	0.08	0.08	0.20	0.45	1.09	1.13		1.19		0.48				
Swimming Pool Repair and Maintenance												3.56			
Traffic Marking	0.00	0.03	0.10	0.10	0.24	0.39	0.42	0.58	0.45						1.54
Varnishes - Clear		0.09	0.16	0.14	0.21	0.31	0.68	0.62	0.69	0.73	0.73	1.16		1.55	1.75
Varnishes - Semitransparent					0.22	0.23	0.18	0.29	0.52	1.11	1.94				
Waterproofing Concrete/Masonry Sealers	0.00	0.08	0.10	0.19	0.85	0.21	0.26	0.75	0.74		0.79	3.99		1.81	1.65

Table 2-3: ***Sales-Weighted Average MIR Values in 50-g/l Ranges (grams ozone/gram product)***

Coating Category	VOC Regulatory Ranges (grams/liter)														
	0-50	51-100	101-150	151-200	201-250	251-300	301-350	351-400	401-450	451-500	501-550	551-600	601-650	651-700	> 700
Waterproofing Sealers	0.00	0.07	0.10	0.36	0.47	0.60	0.35	0.43	0.65	0.01	0.83	1.13	0.85	1.73	1.54
Wood Preservatives	0.06	0.30	0.10	0.11	0.31	0.26	0.68		0.48	0.72	1.22			1.13	1.67

Blank cells indicate that the SWAMIR could not be calculated for this VOC Regulatory range, because there were no sales or the Form 3 ingredient data was incomplete.

1. These results are questionable because a portion of the sales consists of products that manufacturers chose to categorize as Pretreatment Wash Primers, but could potentially qualify as Specialty PSUs.

Table 2-4: ***Sales-Weighted Average MIR Values in 50-g/l Ranges (grams ozone/gram product) – Solventborne Coatings Only***

Coating Category	**VOC Regulatory Ranges (grams/liter)**														
	0-50	**51-100**	**101-150**	**151-200**	**201-250**	**251-300**	**301-350**	**351-400**	**401-450**	**451-500**	**501-550**	**551-600**	**601-650**	**651-700**	**> 700**
Antenna								1.37		0.73					
Bituminous Roof	0.00		0.14	0.28	0.38	0.50	0.52	0.94		0.89					
Bituminous Roof Primer							0.65		0.60						
Clear Brushing Lacquer														1.51	
Concrete Curing Compounds							1.32				0.49	1.35	3.68	5.39	1.66
Dry Fog	0.01					0.25	0.30	0.40	0.40		0.82				
Faux Finishing							0.30	0.31	0.51						
Fire Retardant - Opaque	0.08				1.09	1.04	0.89			0.98		3.91			4.82
Flat					0.18			0.43	0.53	0.41					
Floor	0.02	0.09	1.20	0.74	0.79	0.32	0.45	0.64	0.89	0.50	1.38		1.09		
Form Release Compounds				0.40	0.31		0.74		0.94						
Graphic Arts							0.30	0.86	0.64		0.50				
High Temperature						0.65	0.52	0.78	0.58	1.23	2.54	2.94	1.85	2.88	
Industrial Maintenance	0.04	0.14	0.36	0.47	1.12	0.72	1.21	0.63	0.97	1.46	1.12	3.51	2.49	1.26	3.09
Lacquers										0.67	0.90	1.00	1.66	1.80	1.90
Magnesite Cement									2.12						
Mastic Texture	0.00		0.80		0.11	0.37		0.31							
Metallic Pigmented		0.26		0.70	1.45	0.85	0.62	0.92	0.82	1.96	1.15	1.74	2.54	4.49	4.59
Multi-Color											0.43				
Nonflat - High Gloss				1.95	0.52	0.23	0.82	0.64	0.60	0.62	0.92		4.68		
Nonflat - Low Gloss					0.32		0.50	0.44	0.79	0.54			4.68		
Nonflat - Medium Gloss					0.29	0.27	0.47	0.69	1.00	0.54	0.58		4.68	2.49	
Other	0.03	0.24			1.16	0.42	0.37				0.60	1.68		0.78	
Pre-Treatment Wash Primer [1]							0.46							1.03	1.83
Primer, Sealer, and Undercoater	0.00	0.20	0.09		0.58	0.24	0.55	0.61	0.62	0.81	0.75	3.29	1.99	3.82	1.89
Quick Dry Enamel				0.20			0.44	0.58	0.49	1.17	3.04				
Quick Dry Primer, Sealer, and Undercoater			0.16	0.07	0.80	0.86	1.29	0.45	0.49	0.71	0.83	1.37	1.15	3.14	3.80
Roof	0.00		0.67		0.29	0.64	0.72		1.17						1.79

Table 2-4: ***Sales-Weighted Average MIR Values in 50-g/l Ranges (grams ozone/gram product) – Solventborne Coatings Only***

Coating Category	VOC Regulatory Ranges (grams/liter)														
	0-50	**51-100**	**101-150**	**151-200**	**201-250**	**251-300**	**301-350**	**351-400**	**401-450**	**451-500**	**501-550**	**551-600**	**601-650**	**651-700**	**> 700**
Rust Preventative						1.25	1.36	0.41	0.64	0.42					1.34
Sanding Sealers											0.93	1.80		1.04	2.43
Shellacs - Clear												0.90	1.21	1.12	
Shellacs - Opaque											0.74				
Specialty Primer, Sealer, and Undercoater	0.18			0.30		0.60	0.52		0.58	0.87				1.61	
Stains - Clear/Semitransparent	0.05	0.23	0.24	0.25	0.45		0.52	1.05	0.88	0.76	0.82	0.93	1.38	1.90	1.63
Stains - Opaque				0.14			0.50	0.33	0.43	0.55	0.76	3.30	1.08		3.21
Swimming Pool				0.80	1.04	1.09	1.13		1.19		0.48				
Swimming Pool Repair and Maintenance												3.56			
Traffic Marking	0.00	0.33	0.39		0.26	0.39	0.42	0.58	0.45						1.54
Varnishes - Clear			0.17	0.34	0.16		0.69	0.78	0.69	0.75	0.73	1.23		1.61	1.75
Varnishes - Semitransparent									0.52	1.11	1.94				
Waterproofing Concrete/Masonry Sealers	0.00	0.12		0.41	0.97		1.06	0.75	0.77		0.79	3.99		1.81	1.65
Waterproofing Sealers	0.02	0.40		0.40	0.98	0.62	0.72	1.41	0.97	1.35	0.83	1.13	0.85	1.73	1.89
Wood Preservatives					0.31		0.68			0.72	1.22			1.13	1.67

Blank cells indicate that the SWAMIR could not be calculated for this VOC Regulatory range, because there were no sales or the Form 3 ingredient data was incomplete.

1. These results are questionable because a portion of the sales consists of products that manufacturers chose to categorize as Pretreatment Wash Primers, but could potentially qualify as Specialty PSUs.

Table 2-5: ***Sales-Weighted Average MIR Values in 50-g/l Ranges (grams ozone/gram product) – Waterborne Coatings Only***

Coating Category	VOC Regulatory Ranges (grams/liter)														
	0-50	51-100	101-150	151-200	201-250	251-300	301-350	351-400	401-450	451-500	501-550	551-600	601-650	651-700	> 700
Antenna						0.36									
Bituminous Roof	0.00	0.07								0.01					
Bituminous Roof Primer	0.06			0.20			1.31								
Bond Breakers		0.08		0.06		0.08	0.19					0.82			
Concrete Curing Compounds	0.06	0.07	0.11	0.21	0.10	0.17	0.88			0.01					
Dry Fog	0.02	0.04	0.08	0.07				0.28							
Faux Finishing		0.06	0.10		0.20	0.24	0.23							0.78	0.95
Fire Resistive	0.04														
Fire Retardant - Clear	0.00														
Fire Retardant - Opaque	0.02	0.04	0.08												
Flat	0.04	0.05	0.09	0.13	0.14			0.42	0.16					0.22	
Floor	0.19	0.06	0.08	0.14	0.19	0.27	0.19				0.64				
Flow									0.54						
Form Release Compounds		0.07	0.05		0.07										
Graphic Arts		0.03	0.10	0.22	0.28	0.32									
High Temperature						0.31									
Industrial Maintenance	0.03	0.05	0.14	0.19	0.26	0.40	0.78	0.66	0.51	1.30	0.52	1.32			
Lacquers	0.01	0.09	0.18	0.22	0.27	0.28	0.36								
Low Solids	0.05	0.23													
Mastic Texture	0.02	0.08	0.11	0.17	0.16										
Metallic Pigmented		0.07	0.08	0.15	0.23	0.09									
Multi-Color		0.02	0.10		0.18					0.24					2.02
Nonflat - High Gloss	0.01	0.06	0.11	0.15	0.22	0.30	0.32	0.32							
Nonflat - Low Gloss	0.02	0.06	0.10	0.13	0.19	0.20									
Nonflat - Medium Gloss	0.00	0.06	0.10	0.13	0.18	0.19	0.24	0.18		0.44					
Other	0.00	0.04	0.02		0.00										
Pre-Treatment Wash Primer [1]	0.07	0.07	0.07				0.28	0.29							0.44
Primer, Sealer, and Undercoater	0.08	0.06	0.10	0.12	0.17	0.14	0.19	0.66		0.51		0.41			
Quick Dry Enamel					0.27										

Table 2-5: ***Sales-Weighted Average MIR Values in 50-g/l Ranges (grams ozone/gram product) – Waterborne Coatings Only***

Coating Category	VOC Regulatory Ranges (grams/liter)														
	0-50	**51-100**	**101-150**	**151-200**	**201-250**	**251-300**	**301-350**	**351-400**	**401-450**	**451-500**	**501-550**	**551-600**	**601-650**	**651-700**	**> 700**
Quick Dry Primer, Sealer, and Undercoater	0.00	0.05	0.14	0.02	0.28	0.16									
Recycled					0.03	0.03									
Roof	0.03	0.08	0.12	0.15											
Rust Preventative		0.04	0.11	0.14	0.22		0.31								
Sanding Sealers				0.14	0.18	0.20	0.17								
Specialty Primer, Sealer, and Undercoater	0.03	0.11	0.09	0.14	0.23		0.19								
Stains - Clear/Semitransparent		0.05	0.06	0.15	0.11	0.16	0.29		0.25		0.54				0.64
Stains - Opaque	0.01	0.08	0.09	0.14	0.15	0.20	0.31								
Swimming Pool	0.04	0.08	0.08	0.11	0.28										
Traffic Marking	0.03	0.03	0.04	0.10	0.21			0.49							
Varnishes - Clear		0.09	0.16	0.14	0.22	0.31	0.55	0.46		0.65		1.05		1.16	
Varnishes - Semitransparent					0.22	0.23	0.18	0.29							
Waterproofing Concrete/Masonry Sealers	0.01	0.08	0.10	0.16	0.09	0.21	0.18		0.08						
Waterproofing Sealers	0.00	0.07	0.10	0.11	0.11	0.17	0.16	0.13	0.08	0.01					0.50
Wood Preservatives	0.06	0.30	0.10	0.11		0.26			0.48						

Blank cells indicate that the SWAMIR could not be calculated for this VOC Regulatory range, because there were no sales or the Form 3 ingredient data was incomplete.

1. These results are questionable because a portion of the sales consists of products that manufacturers chose to categorize as Pretreatment Wash Primers, but could potentially qualify as Specialty PSUs.

Some members of the architectural coatings industry have indicated that the PWMIR and SWAMIR approach is appropriate for regulating aerosol coatings, but they do not believe this approach is suitable for architectural coatings. Alternative approaches for reactivity analysis are contained in the Appendix.

Section 2.4 Ozone Formation Potential

Ultimately, VOC emission quantities are used to determine the impact on ozone concentrations. Determining ozone concentrations involves extensive air dispersion modeling, which accounts for emissions from both stationary sources and mobile sources. This type of modeling effort is outside the scope of this project, but it is possible to evaluate the maximum potential ozone impacts associated with the emissions from architectural coatings. For the purposes of this report, we can use the MIR scale to estimate the maximum potential ozone impacts under MIR conditions and then compare the relative contributions from different coating categories. Estimating maximum ozone formation potentials provides a way to identify categories that may be candidates for achieving additional ozone reductions by way of reactivity-based standards.

Total VOC emissions can be converted to ozone quantities by using detailed speciation profiles, based on the results of ARB's Architectural Coating surveys. The profiles contain listings of specific chemicals, which can be associated with reactivity values for the purposes of air quality modeling. A similar exercise involves calculating the maximum potential ozone generated by each ingredient in each coating product, based on the survey data, and then determining the total ozone quantity for each coating category. This can be done, using the following equations:

(1) Calculate the emissions of each VOC and exempt compound in each product:

$$[\text{TOG Emissions, tons/day}]_i = [\text{Sales, gals/yr}]*[\text{Density, lbs/gal}]*[\text{Wt\% TOG}]_i * \frac{[\text{1 ton TOG/2000 lbs TOG}]}{[\text{365 days/yr}]}$$

(2) Calculate the maximum potential ozone generated from each VOC and exempt compound in each product:

$$[\text{Ozone, tpd}]_i = [\text{TOG Emissions, tons/day}]_i *[\text{MIR}_i\text{, g O3/g TOG}] * \frac{[\text{907,185 g TOG/ton TOG}]}{[\text{907,185 g O}_3\text{/ton O}_3]}$$

Note: This value represents the maximum potential ozone that would be formed under MIR conditions.

(3) Add up the maximum potential ozone generated by all VOCs and exempt compounds in all products:

$$[\text{Total Ozone, tpd}] = [\text{Ozone, tpd}]_1 +[\text{Ozone, tpd}]_2 +\ldots+ [\text{Ozone, tpd}]_n$$

where $[\text{TOG Emissions}]_i$ = Emissions of each VOC or exempt compound "i" in a product, tons/day
Sales = Sales of each coating product, gallons/year
Density = Density of each coating product, pounds/gallon
$[\text{Wt\% TOG}]_i$ = Weight percent of each VOC or exempt compound "i" in each product
$[\text{MIR}]_i$ = the MIR of each VOC or exempt compound "i" in a product, grams ozone/gram TOG
$[\text{Ozone}]_i$ = the maximum potential amount of ozone generated under MIR conditions by each VOC or exempt compound "i", tons/day
n = the total number of VOCs and exempt compounds in all coating products

Table 2-6 contains a summary of maximum potential ozone quantities under MIR conditions, based on VOCs only. The survey gathered data for more than 8,000 products. For approximately 100 products (which accounted for 2.0 percent of the total sales volume), no ingredient data were submitted. Therefore, it was not possible to identify individual MIRs for each ingredient in these products. As a result, the total maximum potential ozone quantity provided below is slightly less than it should be, because it doesn't include the contribution from approximately 100 products that have missing ingredient data.

Table 2-6: ***Maximum Ozone Formation Potential Based on Individual Ingredients (VOCs Only)***

Coating Category	SOLVENTBORNE		WATERBORNE		OVERALL	
	Emissions (tpd)	Max. [1] Ozone Potential (tpd)	Emissions (tpd)	Max. Ozone Potential (tpd)	Emissions (tpd)	Max. Ozone Potential (tpd)
Antenna	0.00	0.00	0.00	0.00	0.00	0.00
Bituminous Roof	4.32	7.17	0.01	0.03	4.33	7.20
Bituminous Roof Primer	0.31	0.46	0.05	0.23	0.36	0.70
Bond Breakers	N/A [2]	N/A	0.07	0.17	0.07	0.17
Clear Brushing Lacquer	0.53	1.08	N/A	N/A	0.53	1.08
Concrete Curing Compounds	0.08	0.48	0.29	1.10	0.37	1.58
Dry Fog	0.85	1.47	0.24	0.39	1.10	1.86
Faux Finishing	0.03	0.04	0.18	0.46	0.21	0.51
Fire Resistive	N/A	N/A	0.00	0.00	0.00	0.00
Fire Retardant - Clear	N/A	N/A	0.00	0.00	0.00	0.00
Fire Retardant - Opaque	0.01	0.03	0.01	0.02	0.02	0.06
Flat	0.05	0.08	16.23	34.76	16.28	34.84
Floor	0.25	0.84	1.23	2.88	1.48	3.72
Flow	N/A	N/A	0.00	0.00	0.00	0.00
Form Release Compounds	0.63	0.70	0.00	0.01	0.63	0.71
Graphic Arts	0.06	0.13	0.01	0.02	0.07	0.15
High Temperature	0.08	0.21	0.00	0.00	0.08	0.21
Industrial Maintenance	14.65	44.61	0.64	1.77	15.29	46.39
Lacquers	2.36	6.55	0.10	0.27	2.46	6.83
Low Solids	N/A	N/A	0.01	0.03	0.01	0.03
Magnesite Cement	0.12	0.81	N/A	N/A	0.12	0.81
Mastic Texture	0.40	0.41	0.17	0.49	0.57	0.91
Metallic Pigmented	2.83	11.09	0.07	0.13	2.89	11.22
Multi-Color	0.00	0.00	0.01	0.03	0.01	0.03
Nonflat - High Gloss	2.33	5.45	1.35	3.43	3.68	8.88
Nonflat - Low Gloss	0.10	0.16	3.91	9.20	4.01	9.36
Nonflat - Medium Gloss	2.05	4.36	13.24	30.41	15.29	34.77
Other	0.02	0.06	0.00	0.01	0.03	0.07
Pre-Treatment Wash Primer [2]	0.02	0.04	0.08	0.19	0.10	0.23
Primer, Sealer, and Undercoater	4.92	10.64	3.45	8.47	8.38	19.11
Quick Dry Enamel	2.41	4.36	0.02	0.06	2.43	4.41

Table 2-6: ***Maximum Ozone Formation Potential Based on Individual Ingredients (VOCs Only)***

Coating Category	SOLVENTBORNE		WATERBORNE		OVERALL	
	Emissions (tpd)	Max. [1] Ozone Potential (tpd)	Emissions (tpd)	Max. Ozone Potential (tpd)	Emissions (tpd)	Max. Ozone Potential (tpd)
Quick Dry Primer, Sealer, and Undercoater	4.33	6.77	0.23	0.72	4.57	7.49
Recycled	N/A	N/A	0.04	0.08	0.04	0.08
Roof	0.21	0.57	0.36	0.85	0.57	1.42
Rust Preventative	0.73	1.25	0.03	0.09	0.75	1.34
Sanding Sealers	0.13	0.28	0.01	0.02	0.14	0.29
Shellacs - Clear	0.11	0.19	N/A	N/A	0.11	0.19
Shellacs - Opaque	0.51	0.88	N/A	N/A	0.51	0.88
Specialty Primer, Sealer, and Undercoater	0.10	0.19	0.21	0.60	0.31	0.78
Stains - Clear/Semitransparent	7.24	11.24	0.40	0.83	7.64	12.07
Stains - Opaque	0.88	1.57	0.52	1.37	1.40	2.94
Swimming Pool	0.05	0.23	0.01	0.03	0.06	0.26
Swimming Pool Repair and Maintenance	0.10	0.70	N/A	N/A	0.10	0.70
Traffic Marking	0.66	2.52	2.09	1.82	2.74	4.34
Varnishes - Clear	3.56	5.33	0.52	1.40	4.08	6.73
Varnishes - Semitransparent	0.29	0.32	0.00	0.01	0.30	0.33
Waterproofing Concrete/Masonry Sealers	1.01	2.94	0.28	0.75	1.29	3.69
Waterproofing Sealers	1.68	3.80	0.27	0.60	1.95	4.40
Wood Preservatives	0.65	1.16	0.00	0.02	0.65	1.19
Totals:	**61.6**	**141.2**	**46.3**	**103.8**	**108.0**	**245.0**

"N/A": Not applicable, because there were no coating sales or ingredient data reported in this category.

1. Maximum Potential Ozone formed under MIR conditions.
2. These results are questionable because a portion of the sales consists of products that manufacturers chose to categorize as Pretreatment Wash Primers, but could potentially qualify as Specialty PSUs.

Table 2-7 contains maximum potential ozone quantities for exempt compounds only under MIR conditions, but it only includes those coating categories for which exempt compounds were reported.

Table 2-7: ***Maximum Ozone Formation Potential Based on Individual Ingredients (Exempt Compounds Only)***

Coating Category	SOLVENTBORNE		WATERBORNE		OVERALL	
	Emissions (tpd)	Max. [1] Ozone Potential (tpd)	Emissions (tpd)	Max. Ozone Potential (tpd)	Emissions (tpd)	Max. Ozone Potential (tpd)
Concrete Curing Compounds	0.01	0.01	N/A [2]	N/A	0.01	0.01
Flat	N/A	N/A	0.00	0.00	0.00	0.00
Floor	0.00	0.00	N/A	N/A	0.00	0.00
High Temperature	0.01	0.00	N/A	N/A	0.01	0.00
Industrial Maintenance	0.13	0.02	N/A	N/A	0.13	0.02
Lacquers	0.37	0.16	N/A	N/A	0.37	0.16
Magnesite Cement	0.10	0.04	N/A	N/A	0.10	0.04
Metallic Pigmented	0.00	0.00	N/A	N/A	0.00	0.00
Nonflat - High Gloss	0.04	0.02	0.00	0.00	0.04	0.02
Nonflat - Low Gloss	N/A	N/A	0.00	0.00	0.00	0.00
Nonflat - Medium Gloss	N/A	N/A	0.00	0.00	0.00	0.00
Primer, Sealer, and Undercoater	0.07	0.02	0.00	0.00	0.07	0.02
Quick Dry Enamel	0.00	0.00	N/A	N/A	0.00	0.00
Quick Dry Primer, Sealer, and Undercoater	0.02	0.01	N/A	N/A	0.02	0.01
Roof	0.00	0.00	N/A	N/A	0.00	0.00
Rust Preventative	0.01	0.00	N/A	N/A	0.01	0.00
Sanding Sealers	0.00	0.00	N/A	N/A	0.00	0.00
Stains - Clear/Semitransparent	0.00	0.00	N/A	N/A	0.00	0.00
Stains - Opaque	0.00	0.00	N/A	N/A	0.00	0.00
Swimming Pool Repair and Maintenance	0.00	0.00	N/A	N/A	0.00	0.00
Traffic Marking	1.16	0.50	0.00	0.00	1.16	0.50
Varnishes - Clear	0.02	0.01	N/A	N/A	0.02	0.01
Waterproofing Concrete/Masonry Sealers	0.18	0.05	N/A	N/A	0.18	0.05
Waterproofing Sealers	0.23	0.06	N/A	N/A	0.23	0.06
Totals:	**2.3**	**0.9**	**0.0**	**0.0**	**2.3**	**0.9**

"N/A": Not applicable, because there were no coating sales or ingredient data reported in this category.

1. Maximum Potential Ozone formed under MIR conditions.

As noted above, the maximum potential ozone totals are slightly less than they should be, due to some missing ingredient data from the 2001 survey. To get an estimate of maximum potential ozone quantities for the total volume of coating sales, it's possible to develop a representative reactivity value that can be multiplied by total VOC emissions to yield ozone. A representative reactivity value for this purpose could be a sales-weighted average "Composite MIR" that is based on VOCs only ($CMIR_{VOC}$). Using category-specific $CMIR_{VOC}$ values and VOC emissions data can provide a more complete estimate of the maximum potential ozone generated from coatings reported in the 2001 survey. In addition, developing $CMIR_{VOC}$ values for each coating category provides a mechanism for estimating maximum potential ozone from future emission inventories, based on future VOC emission data. Estimating maximum ozone formation potentials provides a way to identify categories that may be candidates for achieving additional ozone reductions by way of reactivity-based standards.

$CMIR_{VOC}$ values can also be used to characterize the reactivity of the solvents in a coating, but they don't necessarily correspond to the overall reactivity of a coating. If a product only contains a small percentage of a solvent blend that has a high $CMIR_{VOC}$ value, the impact of that solvent blend may be relatively small and the overall reactivity of the coating could still be low.

Calculations for the $CMIR_{VOC}$ values and the maximum potential ozone estimates are described below:

(1) Calculate the VOC emissions for each product:

$$[\text{VOC Emissions, tons/day}] = [\text{Sales, gals/yr}]*[\text{VOC Actual, g/l}]*\frac{[\text{1 lb/gal}]*\ [\text{1 ton VOC/2000 lbs VOC}]}{[\text{120 g/l}]\qquad [\text{365 days/yr}]}$$

where

[VOC Emissions] = Emissions of VOCs only for each coating product, tons VOC/day
Sales = Sales of each coating product, gallons/year
VOC Actual = VOC Actual Content, grams VOC/liter coating

(2) Calculate the total VOC emissions for each coating category:

$$[\text{Total VOC Emissions, tpd}] = [\text{VOC Emissions}]_1 + [\text{ VOC Emissions}]_2 + \ldots + [\text{VOC Emissions}]_n$$

(3) Determine the Composite MIR for VOCs only ($CMIR_{VOC}$), for each coating, using the following equation:

$$[CMIR_{VOC}, \text{g } O_3/\text{g TOG}] = \frac{([MIR]_1*[Wt\%]_1) + ([MIR]_2*[Wt\%]_2) + \ldots + ([MIR]_n*[Wt\%]_n)}{[\text{Total Wt\%}]}$$

where

MIRi = the MIR of each VOC in a product, grams ozone/gram VOC
[Wt%]i = the weight percent of each VOC in a coating
[Total Wt%] = the total weight percent of all VOCs in a product

An example is provided below, based on actual survey data that has been altered slightly to protect manufacturer confidentiality:

n	Ingredient	MIR Value ($g\ O_3/g$ TOG)	$[Wt\%]_i$	$\frac{[MIR]_i*[Wt\%]_i}{[\text{Total Wt\%}]}$
1	Mineral Spirits (Bin 14)	1.21	35	1.01
2	Mineral Spirits (Bin 11)	0.91	4	0.09
3	Propylene Glycol	2.74	2	0.13
4	Xylene	7.48	1	0.18
			Total Wt% = 42%	**$CMIR_{voc}$ = 1.41**

(4) Determine the sales-weighted average Composite MIR for VOCs only ($CMIR_{VOC}$), for each coating category, using the following equation:

$$[SWA\ CMIR_{VOC},\ g\ O_3/g\ TOG] = \frac{([CMIR_{voc}]_1*[VOC\ Emis.]_1) + ([CMIR_{voc}]_2*[VOC\ Emis.]_2) + \ldots + ([CMIR_{voc}]_n*[VOC\ Emis]_n)}{[Total\ VOC\ Emis.]}$$

where

$[CMIR_{voc}]i$ = the Composite MIR of each product based on VOCs only, grams ozone/gram VOC
[VOC Emis.]i = the VOC emissions for each product
[Total VOC Emis.] = the total VOC emissions for a coating category

(5) Calculate the maximum potential ozone generated for each coating category, based on VOC emissions and the SWA $CMIR_{VOC}$:

$$[Ozone,\ tpd] = [SWA\ CMIR_{VOC},\ g\ O_3/g\ VOC]*[Total\ VOC\ Emissions,\ tpd]\frac{*[907{,}185\ g\ VOC/ton\ VOC]}{[907{,}185\ g\ O_3/ton\ O_3]}$$

Note: This value represents the maximum potential ozone that would be formed under MIR conditions.

Table 2-8 contains a summary of maximum potential ozone quantities, based on total VOC emissions and a sales-weighted average Composite MIR for VOCs only. The quantity of ozone in Table 2-8 is very close to the sum of the quantities in Tables 2-6 and 2-7, with a difference of only 1 percent.

Table 2-8: ***Maximum Ozone Formation Potential Based on Total VOC Emissions***

Coating Category	SOLVENTBORNE			WATERBORNE			OVERALL		
	VOC Emissions (tpd) [1]	SWA $CMIR_{voc}$ ($g\ O^3$/ g VOC) [2]	Max. Potential Ozone [3] (tpd)	VOC Emissions (tpd)	SWA $CMIR_{voc}$ ($g\ O^3$/ g VOC) [2]	Max. Potential Ozone [3] (tpd)	VOC Emissions (tpd)	SWA $CMIR_{voc}$ ($g\ O^3$/ g VOC) [2]	Max. Potential Ozone [3] (tpd)
Antenna	0.00	2.44	0.00	0.00	3.27	0.00	0.00	2.47	0.00
Bituminous Roof	4.30	1.66	7.14	0.03	2.36	0.06	4.33	1.66	7.20
Bituminous Roof Primer	0.31	1.50	0.47	0.05	4.49	0.24	0.37	1.93	0.71
Bond Breakers	N/A[4]	N/A	N/A	0.07	2.48	0.17	0.07	2.48	0.17
Clear Brushing Lacquer	0.53	2.03	1.07	N/A	N/A	N/A	0.53	2.03	1.07
Concrete Curing Compounds	0.08	6.20	0.51	0.29	3.67	1.06	0.37	4.23	1.57
Dry Fog	0.85	1.72	1.47	0.25	1.58	0.39	1.10	1.69	1.85
Faux Finishing	0.03	1.27	0.04	0.18	2.54	0.47	0.22	2.36	0.51
Fire Resistive	N/A	N/A	N/A	0.00	2.06	0.00	0.00	2.06	0.00
Fire Retardant - Clear	N/A	N/A	N/A	0.00	2.15	0.00	0.00	2.15	0.00
Fire Retardant - Opaque	0.01	5.04	0.03	0.01	2.21	0.02	0.02	3.35	0.06
Flat	0.05	1.70	0.09	15.55	2.17	33.67	15.60	2.16	33.76
Floor	0.24	3.27	0.77	0.63	2.39	1.52	0.87	2.63	2.29
Flow	N/A	N/A	N/A	0.00	2.87	0.00	0.00	2.87	0.00
Form Release Compounds	0.61	1.12	0.68	0.01	1.88	0.01	0.61	1.13	0.69
Graphic Arts	0.06	2.12	0.14	0.01	2.52	0.02	0.07	2.16	0.16

Table 2-8: ***Maximum Ozone Formation Potential Based on Total VOC Emissions***

Coating Category	SOLVENTBORNE			WATERBORNE			OVERALL		
	VOC Emissions (tpd) [1]	SWA $CMIR_{voc}$ (g O^3/ g VOC) [2]	Max. Potential Ozone [3] (tpd)	VOC Emissions (tpd)	SWA $CMIR_{voc}$ (g O^3/ g VOC) [2]	Max. Potential Ozone [3] (tpd)	VOC Emissions (tpd)	SWA $CMIR_{voc}$ (g O^3/ g VOC) [2]	Max. Potential Ozone [3] (tpd)
High Temperature	0.08	2.56	0.21	0.00	3.25	0.00	0.08	2.56	0.21
Industrial Maintenance	14.81	3.04	45.06	0.63	2.79	1.76	15.44	3.03	46.82
Lacquers	2.40	2.77	6.64	0.10	2.78	0.28	2.50	2.77	6.92
Low Solids	N/A	N/A	N/A	0.01	2.98	0.03	0.01	2.98	0.03
Magnesite Cement	0.12	7.03	0.81	N/A	N/A	N/A	0.12	7.03	0.81
Mastic Texture	0.45	1.04	0.47	0.23	2.98	0.67	0.68	1.69	1.14
Metallic Pigmented	2.75	3.93	10.81	0.06	1.91	0.12	2.81	3.89	10.94
Multi-Color	0.00	1.30	0.00	0.01	4.01	0.03	0.01	3.93	0.03
Nonflat - High Gloss	2.28	2.21	5.03	1.37	2.53	3.47	3.65	2.33	8.50
Nonflat - Low Gloss	0.10	1.60	0.17	3.95	2.35	9.30	4.05	2.33	9.46
Nonflat - Medium Gloss	2.12	2.12	4.49	13.46	2.29	30.89	15.58	2.27	35.38
Other	0.02	2.95	0.06	0.00	2.71	0.00	0.02	2.95	0.06
Pre-Treatment Wash Primer [5]	0.02	1.85	0.04	0.08	2.50	0.19	0.10	2.35	0.23
Primer, Sealer, and Undercoater [6]	5.17	2.14	11.08	3.38	2.46	8.31	8.55	2.27	19.39
Quick Dry Enamel	2.47	1.81	4.47	0.02	2.68	0.05	2.49	1.82	4.53
Quick Dry Primer, Sealer, Undercoater [6]	6.22	1.56	9.73	0.26	3.11	0.82	6.49	1.63	10.55
Roof	0.21	2.80	0.60	0.36	2.32	0.83	0.57	2.50	1.43
Rust Preventative	0.72	1.79	1.29	0.03	3.20	0.09	0.75	1.85	1.38
Sanding Sealers	0.13	2.11	0.27	0.01	2.25	0.02	0.14	2.12	0.29
Shellacs - Clear	0.11	1.69	0.18	N/A	N/A	N/A	0.11	1.69	0.18
Shellacs - Opaque	0.50	1.71	0.86	N/A	N/A	N/A	0.50	1.71	0.86
Specialty Primer, Sealer, Undercoater	0.10	1.89	0.18	0.21	2.89	0.60	0.31	2.57	0.79
Stains - Clear/Semitransparent	7.46	1.59	11.91	0.40	2.08	0.83	7.86	1.62	12.74
Stains - Opaque	0.85	1.78	1.51	0.52	2.63	1.36	1.36	2.10	2.87
Swimming Pool	0.05	4.97	0.23	0.01	3.02	0.03	0.06	4.62	0.26
Swimming Pool Repair and Maintenance	0.10	7.02	0.70	N/A	N/A	N/A	0.10	7.02	0.70
Traffic Marking	0.75	3.94	2.95	2.29	0.87	1.99	3.03	1.63	4.94
Varnishes - Clear	3.52	1.49	5.25	0.51	2.70	1.36	4.03	1.64	6.62
Varnishes - Semitransparent	0.29	1.09	0.32	0.00	2.37	0.01	0.30	1.10	0.33

Table 2-8: ***Maximum Ozone Formation Potential Based on Total VOC Emissions***

Coating Category	SOLVENTBORNE			WATERBORNE			OVERALL		
	VOC Emissions (tpd) [1]	SWA $CMIR_{voc}$ (g O^3/ g VOC) [2]	Max. Potential Ozone [3] (tpd)	VOC Emissions (tpd)	SWA $CMIR_{voc}$ (g O^3/ g VOC) [2]	Max. Potential Ozone [3] (tpd)	VOC Emissions (tpd)	SWA $CMIR_{voc}$ (g O^3/ g VOC) [2]	Max. Potential Ozone [3] (tpd)
Waterproofing Concrete/Masonry Sealers	1.02	2.90	2.97	0.28	2.72	0.75	1.30	2.86	3.72
Waterproofing Sealers	1.65	2.27	3.73	0.27	2.19	0.59	1.92	2.26	4.32
Wood Preservatives	0.68	1.80	1.22	0.00	4.92	0.02	0.68	1.83	1.25
Totals:	**64.2**		**145.7**	**45.5**		**102.0**	**109.7**		**247.7**

1. VOC emissions were calculated as follows: [VOC Emissions, lbs] = [VOC Actual, lbs/gal]*[Sales Volume, gals].
2. The sales-weighted average Composite MIR values were weighted based on the VOC emissions for those products that had complete speciated ingredient data
3. The Max. Potential Ozone represents the maximum ozone formation potential under MIR conditions, calculated using the equation: [Max. Potential Ozone, tpd] = [VOC Emissions, tpd]*[SWA $CMIR_{voc}$, g O^3/g VOC]
4. "N/A": Not applicable, because there were no coating sales or ingredient data reported in this category.
5. These results are questionable because a portion of the sales consists of products that manufacturers chose to categorize as Pretreatment Wash Primers, but could potentially qualify as Specialty PSUs.
6. The PSU and QDPSU categories illustrate why the SWA $CMIR_{voc}$ does not truly reflect the overall reactivity of coating. Solventborne PSUs and QDPSUs contain a much higher percentage of VOCs than waterborne PSUs and QDPSUs. Consequently, the solventborne products have higher VOC emissions and higher reactivity per gallon of coating used when compared to the waterborne products. However, solventborne PSUs and QDPSUs typically contain hydrocarbon solvents which have a lower reactivity than ethylene glycol, which is one of the primary VOCs reported for waterborne PSUs and QDPSUs. Therefore, the composite MIR for the VOCs in solventborne PSUs and QDPSUs is lower than the reactivity for VOCs in waterborne PSUs and QDPSUs.

Chapter 3 – Future Efforts

ARB is investigating whether a reactivity-based approach is feasible for achieving additional ozone reductions from the architectural coatings category. This report represents ARB's initial efforts to document a reactivity baseline for this investigation. It is possible that implementing reactivity-based regulations will provide additional ozone benefits, while providing greater flexibility to coating manufacturers in their formulations. However, it is also possible that the investigation will determine that existing reactivity levels are already so low that the use of a reactivity-based approach would not yield significant reductions. Listed below are the primary components of ARB's continuing investigation.

Section 3.1 Research

This section describes some of the research projects that have been funded by ARB to help expand our understanding of architectural coatings and improve regulatory efforts.

Environmental Chamber Experiments - ARB funded a $300,000 architectural coating reactivity project with UC Riverside that began in 2001. The final report for this project was completed in March 2005. The project includes using a new state-of-the-art environmental chamber to verify the chemical mechanisms used to assess the reactivity of Texanol® and the following hydrocarbon solvents:

Table 3-1: ***Hydrocarbon Solvents Being Tested in Environmental Chamber***

Hydrocarbon Solvent Name	ASTM Designation	Description	ASTM Distillation Range (ºF)	ARB Bin #
Aromatic 100	D3734, Type I	362°F maximum dry point, 95% minimum aromatic content (mostly C9's)	300-355	22
7% Aromatic Mineral Spirits	D235, Type IB	2-8% aromatics, full distillation range	300-415	14
Low Aromatic Mineral Spirits	D235, Type 1C	0-2% aromatic content, full distillation range (300-415°F)	300-415	11
Odorless Mineral Spirits	D235, Type III C-1	0-0.25% maximum aromatic, full distillation range, odorless, low olefins	300-415	12
Stoddard Solvent (15-20% Aromatic Mineral Spirits)	D235, Type 1A	8-22% aromatics, full distillation range (300-415°F)	300-415	15
V M & P Naphtha	D3735, Type IV	0-2% aromatic content, minimum flash point of 40°F	235-310	6

In 2003, SCAQMD provided $200,000 to UC Riverside to conduct additional reactivity research. At least four compounds will be tested in the environmental chamber, and it is likely that two of these compounds will be from water-based coatings (e.g., ethylene glycol and propylene glycol.) This project is scheduled for completion in 2005 as well.

Both of these research projects are being coordinated with the ARB's Reactivity Research Advisory Committee (RRAC), which includes representatives from coating manufacturers, solvent manufacturers, and regulatory agencies.

Solids Content and Hiding as it Relates to the Calculation of VOC Content - In 2001, the ARB initiated a $100,000 research contract with Cal Poly, San Luis Obispo, to determine if there is a consistent relationship between the volume percent of solids in coatings and the coverage, or hiding, of the coatings. The basis for the calculation of VOC content in paint rules ("VOC, less water and less exempts") is that there is a consistent relationship between solids and coverage, or hiding, especially in typical flat and nonflat house paints. In other words, it has been assumed that the higher the solids content by volume in a coating, the better the hiding.

In the final report from this project, dated December 2004, the researchers determined that although for a particular coating the hiding improves as the solids content increases, across different coatings, higher solids content does not necessarily equate to better hiding. In many cases, a 35 percent solids by volume water-based coating hides as well as a 60 percent solids by volume solvent-based coating. Accordingly, since the basis for using "VOC, less water and less exempts" was not supported by this study, this method of calculating the VOC content for house paints does not appear to be the ideal method. The researchers developed a different standard, termed "hiding VOC", which is defined as the amount of VOCs emitted by hiding one square meter with a paint. Using this measure, among the flat and nonflat paints tested, the solvent-borne coatings on average emitted over ten times as much VOC to hide the same area as the water-borne paints did.

Development of Improved VOC Test Method – In January 2005, ARB funded another research contract with Cal Poly, San Luis Obispo. The objective of this $250,000 research project is to develop a unified VOC test method that can be used for all types of architectural coatings and is more accurate than U.S. EPA's Test Method 24, especially for low-VOC coatings. Development of this improved test method will help local air districts improve their compliance and enforcement efforts for architectural coatings. The method could also be used to improve district enforcement of other coating categories (e.g., automotive refinish coatings.) By improving the ability to measure VOC content, we will be better able to verify the manufacturers' listed values and encourage the use of zero- and low-VOC coatings.

Section 3.2 2005 Architectural Coating Survey

In 2005, ARB will be conducting another architectural coating survey to collect sales and ingredient data for calendar year 2004. This survey would reflect the coatings being sold in California after all of the SCM VOC limits have taken effect. It is expected that results from this survey would be finalized during 2006. Data from that survey will be analyzed similarly to how the 2001 survey data were analyzed in this report.

Section 3.3 SCM Revision

After the 2005 Architectural Coating Survey data are analyzed, we will begin the process to revise the 2000 SCM to incorporate lower mass-based VOC limits, or new reactivity-based limits, or some combination of both. We anticipate this process occurring in the 2006-2007 time frame.

APPENDIX

Alternative Approaches for Reactivity Analysis of Survey Data

Alternative Approaches for Reactivity Analysis of Survey Data

ARB worked with coating manufacturers to obtain input on alternative methods for describing the reactivity of architectural coatings. This appendix contains some of the recommended alternative approaches for conducting a reactivity analysis. Some members of the architectural coatings industry have indicated that the PWMIR and SWAMIR approach is appropriate for regulating aerosol coatings, but they do not believe this approach is suitable for architectural coatings. We will continue working with the industry and local air districts as we consider various approaches and methods to evaluate a reactivity-based control measure for architectural coatings.

Section A.1. Composite MIR for VOCs and Exempt Compounds

An alternative type of reactivity analysis that was recommended by one manufacturer involves determining an average composite MIR value for both VOCs and exempt compounds (i.e., all total organic gases or TOGs) that are contained in a coating. This is similar to the composite MIR for VOCs only (CMIRvoc) that was discussed in Section 2.4. The calculations would be similar, but they would be based on all TOGs instead of VOCs only. This type of parameter could be used to estimate the maximum ozone formation potential, if TOG emissions were known. It can also be used to characterize the reactivity of the solvents in a coating, but it doesn't necessarily correspond to the overall reactivity of a coating. If a product only contains a small percentage of a solvent blend that has a high composite MIR, the impact of that solvent blend may be relatively small and the overall reactivity of the coating could still be low.

To determine the Composite MIR for TOGs ($CMIR_{TOG}$), we used the following equation:

$$CMIR_{TOG} = \frac{[MIR]_1 * [Wt\%]_1 + [MIR]_2 * [Wt\%]_2 + \ldots + [MIR]_n * [Wt\%]_n}{[Total\ Wt\%]}$$

where

MIRi = the MIR of each TOG (i.e., VOC or exempt compound) in a product, grams ozone/gram TOG
[Wt%]i = the weight percent of each TOG in a coating
[Total Wt%] = the total weight percent of all TOGs in a product

Table A-1 contains a listing of the sales-weighted average composite average MIR values (SWA $CMIR_{TOG}$) for all TOGs contained in each coating category. The table also lists those compounds that were the primary contributors to the SWA $CMIR_{TOG}$ values, either due to the fact that large quantities of the compound were used or because the compound had a high individual MIR value. The maximum ozone formation potential is included in Table A-1 and it represents the summation of the MIR value multiplied by the emissions for each ingredient in each coating.

[Note: In the draft report, the sales-weighted average was calculated based on the sales volume. In response to comments, we revised the calculation method and determined the sales-weighted average based on the mass of VOCs and exempt compounds contained in the coating. This revised method is more consistent with the approach that was used to estimate the maximum ozone formation potential.]

Table A-1: ***SWA Composite Average MIRs – VOCs & Exempt Compounds Only***

Coating Category	SOLVENTBORNE			WATERBORNE			OVERALL			Primary Contributors	CAS # [1]
	SWA CMIR (g O_3/g TOG)	Emissions (VOCs & Exempts) (tpd)	Max. Ozone (tpd)	SWA CMIR (g O_3/g TOG)	Emissions (VOCs & Exempts) (tpd)	Max. Ozone (tpd)	SWA CMIR (g O_3/g TOG)	Emissions (VOCs & Exempts) (tpd)	Max. Ozone (tpd)		
Antenna	2.44	0.00	0.00	3.27	0.00	0.00	2.47	0.00	0.00	Bin 14 Hydrocarbon Solvent	Bin 14
										Xylene	1330207
										Bin 23 Hydrocarbon Solvent	Bin 23
Bituminous Roof	1.66	4.32	7.17	2.36	0.01	0.03	1.66	4.33	7.20	Bin 14 Hydrocarbon Solvent	Bin 14
										Bin 9 Hydrocarbon Solvent	Bin 9
										Bin 15 Hydrocarbon Solvent	Bin 15
Bituminous Roof Primer	1.50	0.31	0.46	4.49	0.05	0.23	1.93	0.36	0.70	Bin 14 Hydrocarbon Solvent	Bin 14
										Bin 22 Hydrocarbon Solvent	Bin 22
										Bin 10 Hydrocarbon Solvent	Bin 10
Bond Breakers	N/A	N/A	N/A	2.48	0.07	0.17	2.50	0.07	0.17	Morpholine	110918
										Hydrotreated light naphthenic distillate	64742536
										Mineral Spirits	64741419
Clear Brushing Lacquer	2.03	0.53	1.08	N/A	N/A	N/A	2.03	0.53	1.08	Ethylene Glycol Butyl Ether	111762
										Methyl-n-amyl Ketone	110430
										Bin 12 Hydrocarbon Solvent	Bin 12
Concrete Curing Compounds	5.37	0.09	0.49	3.67	0.29	1.10	4.15	0.38	1.59	Bin 22 Hydrocarbon Solvent	Bin 22
										Morpholine	110918
										Bin 14 Hydrocarbon Solvent	Bin 14
Dry Fog	1.72	0.85	1.47	1.58	0.24	0.39	1.69	1.10	1.86	Bin 14 Hydrocarbon Solvent	Bin 14
										Bin 7 Hydrocarbon Solvent	Bin 7
										Bin 9 Hydrocarbon Solvent	Bin 9

Table A-1: ***SWA Composite Average MIRs – VOCs & Exempt Compounds Only***

Coating Category	SOLVENTBORNE			WATERBORNE			OVERALL			Primary Contributors	CAS # [1]
	SWA CMIR (g O_3/g TOG)	Emissions (VOCs & Exempts) (tpd)	Max. Ozone (tpd)	SWA CMIR (g O_3/g TOG)	Emissions (VOCs & Exempts) (tpd)	Max. Ozone (tpd)	SWA CMIR (g O_3/g TOG)	Emissions (VOCs & Exempts) (tpd)	Max. Ozone (tpd)		
Faux Finishing	1.27	0.03	0.04	2.54	0.18	0.46	2.35	0.21	0.51	Propylene Glycol	57556
										Ethylene Glycol	107211
										Bin 14 Hydrocarbon Solvent	Bin 14
Fire Resistive	N/A	N/A	N/A	2.06	0.00	0.00	2.06	0.00	0.00	Petroleum Hydrocarbon	0
										Propylene Glycol	57556
										Ethylene Glycol	107211
Fire Retardant - Clear	N/A	N/A	N/A	2.15	0.00	0.00	2.16	0.00	0.00	Aggregated VOCs < 0.1%	9981
										Isopropyl Alcohol	67630
										Formaldehyde	50000
Fire Retardant - Opaque	5.04	0.01	0.03	2.21	0.01	0.02	3.35	0.02	0.06	Xylene	1330207
										Propylene Glycol	57556
										1,2-Benzenedicarboxylic Acid, Diheptyl Ester, Branched and Linear [2]	68515446
Flat	1.70	0.05	0.08	2.17	16.23	34.76	2.14	16.28	34.84	Ethylene Glycol	107211
										Texanol® Ester Alcohol	25265774
										Propylene Glycol	57556
Floor	3.24	0.25	0.84	2.39	1.23	2.88	2.51	1.48	3.72	Benzyl Alcohol	100516
										Propylene Glycol	57556
										Castor Oil	8001794
Flow	N/A	N/A	N/A	2.87	0.00	0.00	2.87	0.00	0.00	Ethylene Glycol Butyl Ether	111762
										Aggregated VOCs < 0.1%	9981
Form Release Compounds	1.12	0.63	0.70	1.88	0.00	0.01	1.12	0.63	0.71	Bin 11 Hydrocarbon Solvent	Bin 11
										Bin 14 Hydrocarbon Solvent	Bin 14
										Straight-run middle distillate	64741442

Table A-1: ***SWA Composite Average MIRs – VOCs & Exempt Compounds Only***

Coating Category	SOLVENTBORNE			WATERBORNE			OVERALL			Primary Contributors	CAS # [1]
	SWA CMIR (g O_3/g TOG)	Emissions (VOCs & Exempts) (tpd)	Max. Ozone (tpd)	SWA CMIR (g O_3/g TOG)	Emissions (VOCs & Exempts) (tpd)	Max. Ozone (tpd)	SWA CMIR (g O_3/g TOG)	Emissions (VOCs & Exempts) (tpd)	Max. Ozone (tpd)		
Graphic Arts	2.12	0.06	0.13	2.52	0.01	0.02	2.16	0.07	0.15	Bin 14 Hydrocarbon Solvent	Bin 14
										Propylene Glycol	57556
										Bin 11 Hydrocarbon Solvent	Bin 11
High Temperature	2.33	0.09	0.21	3.25	0.00	0.00	2.33	0.09	0.21	Bin 10 Hydrocarbon Solvent	Bin 10
										Xylene	1330207
										Methyl-n-amyl Ketone	110430
Industrial Maintenance	3.01	14.77	44.63	2.79	0.64	1.77	3.01	15.41	46.40	Bin 22 Hydrocarbon Solvent	Bin 22
										Xylene	1330207
										Bin 6 Hydrocarbon Solvent	Bin 6
Lacquers	2.45	2.73	6.71	2.78	0.10	0.27	2.47	2.83	6.99	Toluene	108883
										Xylene	1330207
										Methyl Isobutyl Ketone	108101
Low Solids	N/A	N/A	N/A	2.98	0.01	0.03	2.97	0.01	0.03	Propylene Glycol	57556
										Ethylene Glycol Butyl Ether	111762
										Dipropylene glycol methyl ether	34590948
Magnesite Cement	4.03	0.21	0.85	N/A	N/A	N/A	4.03	0.21	0.85	Bin 22 Hydrocarbon Solvent	Bin 22
										1,2,4-Trimethylbenzene	95636
										Acetone [3]	67641
Mastic Texture	1.04	0.40	0.41	2.98	0.17	0.49	1.59	0.57	0.91	Ethylene Glycol	107211
										Bin 11 Hydrocarbon Solvent	Bin 11
										Bin 22 Hydrocarbon Solvent	Bin 22
Metallic Pigmented	3.93	2.83	11.09	1.91	0.07	0.13	3.88	2.89	11.22	Bin 22 Hydrocarbon Solvent	Bin 22
										Bin 15 Hydrocarbon Solvent	Bin 15
										Xylene	1330207

Table A-1: ***SWA Composite Average MIRs – VOCs & Exempt Compounds Only***											
Coating Category	**SOLVENTBORNE**			**WATERBORNE**			**OVERALL**			**Primary Contributors**	**CAS #** [1]
	SWA CMIR (g O_3/g TOG)	**Emissions (VOCs & Exempts) (tpd)**	**Max. Ozone (tpd)**	**SWA CMIR (g O_3/g TOG)**	**Emissions (VOCs & Exempts) (tpd)**	**Max. Ozone (tpd)**	**SWA CMIR (g O_3/g TOG)**	**Emissions (VOCs & Exempts) (tpd)**	**Max. Ozone (tpd)**		
Multi-Color	1.30	0.00	0.00	4.01	0.01	0.03	3.95	0.01	0.03	Bin 22 Hydrocarbon Solvent	Bin 22
										Bin 14 Hydrocarbon Solvent	Bin 14
										Propylene Glycol	57556
Nonflat - High Gloss	2.27	2.37	5.46	2.53	1.35	3.43	2.39	3.72	8.90	Bin 15 Hydrocarbon Solvent	Bin 15
										Ethylene Glycol	107211
										Bin 10 Hydrocarbon Solvent	Bin 10
Nonflat - Low Gloss	1.60	0.10	0.16	2.35	3.91	9.20	2.34	4.01	9.36	Ethylene Glycol	107211
										Propylene Glycol	57556
										Texanol® Ester Alcohol	25265774
Nonflat - Medium Gloss	2.12	2.05	4.36	2.29	13.24	30.41	2.27	15.29	34.77	Propylene Glycol	57556
										Ethylene Glycol	107211
										Texanol® Ester Alcohol	25265774
Other	2.95	0.02	0.06	2.71	0.00	0.01	2.81	0.03	0.07	Xylene	1330207
										Hexahydro-1,3,5-tris(2-hydroxyethyl)-s-triazine [5]	4719044
										Bin 11 Hydrocarbon Solvent	Bin 11
Pre-Treatment Wash Primer	1.85	0.02	0.04	2.51	0.08	0.19	2.35	0.10	0.23	Propylene Glycol	57556
										Dipropylene Glycol n-Butyl Ether	29911282
										Ethylene Glycol	107211
Primer, Sealer, and Undercoater	2.12	5.00	10.66	2.46	3.45	8.47	2.26	8.45	19.13	Ethylene Glycol	107211
										Bin 14 Hydrocarbon Solvent	Bin 14
										Bin 15 Hydrocarbon Solvent	Bin 15

Table A-1: ***SWA Composite Average MIRs – VOCs & Exempt Compounds Only***											
Coating Category	**SOLVENTBORNE**			**WATERBORNE**			**OVERALL**			**Primary Contributors**	**CAS #** [1]
	SWA CMIR (g O_3/g TOG)	**Emissions (VOCs & Exempts) (tpd)**	**Max. Ozone (tpd)**	**SWA CMIR (g O_3/g TOG)**	**Emissions (VOCs & Exempts) (tpd)**	**Max. Ozone (tpd)**	**SWA CMIR (g O_3/g TOG)**	**Emissions (VOCs & Exempts) (tpd)**	**Max. Ozone (tpd)**		
Quick Dry Enamel	1.81	2.41	4.36	2.68	0.02	0.06	1.82	2.43	4.41	Bin 6 Hydrocarbon Solvent	Bin 6
										Bin 14 Hydrocarbon Solvent	Bin 14
										Bin 11 Hydrocarbon Solvent	Bin 11
Quick Dry Primer, Sealer, and Undercoater	1.56	4.35	6.78	3.11	0.23	0.72	1.64	4.58	7.50	Bin 6 Hydrocarbon Solvent	Bin 6
										Bin 9 Hydrocarbon Solvent	Bin 9
										Bin 11 Hydrocarbon Solvent	Bin 11
Recycled	N/A	N/A	N/A	1.84	0.04	0.08	1.84	0.04	0.08	Propylene Glycol	57556
										Texanol® Ester Alcohol	25265774
										Aggregated VOCs < 0.1%	9981
Roof	2.75	0.21	0.58	2.32	0.36	0.85	2.50	0.57	1.42	Propylene Glycol	57556
										Ethylene Glycol	107211
										Bin 6 Hydrocarbon Solvent	Bin 6
Rust Preventative	1.73	0.73	1.25	3.20	0.03	0.09	1.76	0.76	1.34	Bin 22 Hydrocarbon Solvent	Bin 22
										Bin 11 Hydrocarbon Solvent	Bin 11
										Bin 12 Hydrocarbon Solvent	Bin 12
Sanding Sealers	2.10	0.13	0.28	2.25	0.01	0.02	2.11	0.14	0.29	Bin 15 Hydrocarbon Solvent	Bin 15
										Bin 14 Hydrocarbon Solvent	Bin 14
										Xylene	1330207
Shellacs - Clear	1.69	0.11	0.19	N/A	N/A	N/A	1.69	0.11	0.19	Ethanol	64175
										Methyl Isobutyl Ketone	108101
										Isopropanol	67630
Shellacs - Opaque	1.71	0.51	0.88	N/A	N/A	N/A	1.71	0.51	0.88	Ethanol	64175
										Isopropanol	67630
										Aggregated VOCs < 0.1%	9981

Table A-1: ***SWA Composite Average MIRs – VOCs & Exempt Compounds Only***

Coating Category	SOLVENTBORNE			WATERBORNE			OVERALL			Primary Contributors	CAS # [1]
	SWA CMIR (g O_3/g TOG)	Emissions (VOCs & Exempts) (tpd)	Max. Ozone (tpd)	SWA CMIR (g O_3/g TOG)	Emissions (VOCs & Exempts) (tpd)	Max. Ozone (tpd)	SWA CMIR (g O_3/g TOG)	Emissions (VOCs & Exempts) (tpd)	Max. Ozone (tpd)		
Specialty Primer, Sealer, and Undercoater	1.89	0.10	0.19	2.89	0.21	0.60	2.56	0.31	0.78	Diethylene Glycol Butyl Ether	112345
										Ethylene Glycol	107211
										Bin 14 Hydrocarbon Solvent	Bin 14
Stains - Clear/Semitransparent	1.59	7.24	11.24	2.08	0.40	0.83	1.58	7.64	12.07	Bin 14 Hydrocarbon Solvent	Bin 14
										Bin 11 Hydrocarbon Solvent	Bin 11
										Bin 15 Hydrocarbon Solvent	Bin 15
Stains - Opaque	1.78	0.88	1.57	2.63	0.52	1.37	2.10	1.40	2.94	Aliphatic Hydrocarbons	8052413
										Ethylene Glycol	107211
										Bin 14 Hydrocarbon Solvent	Bin 14
Swimming Pool	4.97	0.05	0.23	3.02	0.01	0.03	4.62	0.06	0.26	Xylene	1330207
										Bin 22 Hydrocarbon Solvent	Bin 22
										n-Butyl Alcohol	71363
Swimming Pool Repair and Maintenance	6.97	0.10	0.70	N/A	N/A	N/A	6.97	0.10	0.70	Xylene	1330207
										Bin 14 Hydrocarbon Solvent	Bin 14
										1,2,4-Trimethylbenzene	95636
Traffic Marking	1.68	1.81	3.02	0.87	2.09	1.82	1.24	3.90	4.84	Methanol	67561
										Acetone [4]	67641
										Xylene	1330207
Varnishes - Clear	1.49	3.58	5.33	2.70	0.52	1.40	1.64	4.10	6.73	Bin 14 Hydrocarbon Solvent	Bin 14
										Bin 15 Hydrocarbon Solvent	Bin 15
										Aliphatic Hydrocarbons	8052413
Varnishes - Semitransparent	1.09	0.29	0.32	2.37	0.00	0.01	1.10	0.30	0.33	Bin 11 Hydrocarbon Solvent	Bin 11
										Bin 14 Hydrocarbon Solvent	Bin 14
										Stoddard Solvent	8052413

Table A-1: *SWA Composite Average MIRs – VOCs & Exempt Compounds Only*											
Coating Category	**SOLVENTBORNE**			**WATERBORNE**			**OVERALL**			**Primary Contributors**	**CAS #** [1]
	SWA CMIR (g O_3/g TOG)	**Emissions (VOCs & Exempts) (tpd)**	**Max. Ozone (tpd)**	**SWA CMIR (g O_3/g TOG)**	**Emissions (VOCs & Exempts) (tpd)**	**Max. Ozone (tpd)**	**SWA CMIR (g O_3/g TOG)**	**Emissions (VOCs & Exempts) (tpd)**	**Max. Ozone (tpd)**		
Waterproofing Concrete/Masonry Sealers	2.51	1.19	2.99	2.72	0.28	0.75	2.55	1.47	3.74	Bin 22 Hydrocarbon Solvent	Bin 22
										Ethylene Glycol	107211
										Toluene	108883
Waterproofing Sealers	2.02	1.91	3.86	2.19	0.27	0.60	2.04	2.18	4.46	Bin 6 Hydrocarbon Solvent	Bin 6
										Hydrotreated light naphthenic distillate	64742536
										Aliphatic Hydrocarbons	8052413
Wood Preservatives	1.80	0.65	1.16	4.92	0.00	0.02	1.82	0.65	1.19	Aliphatic Hydrocarbons	8052413
										Mineral Spirits	64475850
										Hydrotreated heavy naphthenic distillate	64742525
Totals:		**64.0**	**142.1**		**46.3**	**103.8**		**110.3**	**245.8**		

"N/A": Not applicable, because there were no coating sales and/or ingredient data reported in this category.

Footnotes:
1. A blank cell indicates that no CAS number is available for this ingredient.
2. This compound (1,2-Benzenedicarboxylic Acid, Diheptyl Ester, Branched and Linear) was only reported in a small number of products, but one of those products had a high reported sales volume for the Fire Retardant-Opaque category. As a result, it ranked fourth highest in VOC emissions for this category behind Texanol®, but it was considered a bigger potential ozone contributor than Texanol® because it was assigned a default MIR value that was higher than the MIR value for Texanol®.
3. Acetone had the highest emissions for VOCs or exempt compounds in the Magnesite Cement category. Therefore, it was a primary contributor even though the MIR value is relatively low.
4. Acetone had the second highest emissions for VOCs or exempt compounds in the Traffic Marking category. Therefore, it was a primary contributor even though the MIR value is relatively low.
5. This compound (Hexahydro-1,3,5-tris(2-hydroxyethyl)-s-triazine) had the second highest emissions for VOCs or exempt compounds in the Other category, due to its use in driveway sealer products.

Section A.2 Reactivity-Adjusted VOC Values – Based on VOC Regulatory

One option presented by one manufacturer involves a reactivity-adjusted VOC content, which is a VOC content that has been adjusted to account for the reactivity of the individual VOCs and exempt compounds that are contained in a coating. If a coating has a large amount of highly reactive compounds, the reactivity-adjusted VOC content could be higher than the traditional VOC content. An advantage of this approach is the retention of measurement units (grams/liter or lbs/gal) that are already familiar to manufacturers and coating users. One manufacturer suggested that the reactivity-adjusted VOC content be based on the relative reactivity of the VOCs contained in the coating, as reflected in the VOC content value.

The use of relative reactivity has been presented by various researchers. For the development of ozone control strategies, Hakami et. al. conclude that it is the relative magnitude of individual reactivities, as opposed to their absolute values, that are meaningful[1]. In a 1994 paper, Carter stated that the ratios of incremental reactivities are of greater relevance than the incremental reactivities themselves[2]. Russell et. al. found that VOC control strategies based on relative reactivity appear to be robust with respect to nationwide variations in environmental conditions and uncertainties in atmospheric chemistry[3].

Relative reactivity could be defined as the ratio of the reactivity for a VOC species to the reactivity for a defined standard (e.g., the Base Case ROG Mixture or ethane.) Selection of the defined standard affects the absolute value of the result, but the relative results are the same, regardless of the standard. If the Base Case ROG Mixture is selected for the defined standard, the reactivity adjustment will usually be less than one, because most architectural coating VOCs have an MIR that is lower than the MIR for the Base Case ROG Mixture. On the other hand, if ethane were chosen as the defined standard, the reactivity adjustment will usually be greater than one, because most architectural coating VOCs have an MIR that is higher than the MIR for ethane. After determining this relative reactivity adjustment, one can multiply a coating's VOC Regulatory value by the relative reactivity to obtain a reactivity-adjusted VOC content, as described below.

To determine Reactivity-Adjusted VOCs (RAVOCs), we used the following equations:

1) Calculate the relative reactivity for each VOC and exempt compound in a coating:

   [Relative Reactivity (RRi)] = [MIRi]/[MIRBC]

   where

   MIRi = the MIR of each VOC or exempt compound in a product, grams ozone/gram TOG
   MIRBC = the MIR of the Base Case ROG Mixture = 3.71 grams ozone/gram TOG, under MIR conditions

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[1] Hakami, A, R.A. Harley, J.B. Milford, M. Odman, and A.G. Russell. "Regional, three-dimensional assessment of the ozone formation potential of organic compounds." Atmospheric Environment 38: 121-134, 2004.
[2] Carter, W.P.L. "Development of Ozone Reactivity Scales for Volatile Organic Compounds." Journal of the Air and Waste Management Association 44:881-899, 1994.
[3] Russell, A, J. Milford, M.S. Bergin, S. McBride, L. McNair, Y. Yang, W.R. Stockwell, B. Croes. "Urban Ozone Control and Atmospheric Reactivity of Organic Gases." Science 269:491-495, 1995.

2) Determine the Reactivity Adjustment Factor (RAF) for the coating:

$$RAF = \frac{[RR]_1 * [Wt\%]_1 + [RR]_2 * [Wt\%]_2 + \ldots + [RR]_n * [Wt\%]_n}{[Total\ Wt\%]}$$

where

[RR]i = the relative reactivity of each VOC or exempt compound in a coating
[Wt%]i = the weight percent of each VOC or exempt compound in a coating
[Total Wt%] = the total weight percent of all VOCs and exempt compounds in a product

3) Calculate the Reactivity-Adjusted VOC (RAVOC) for a coating:

[RAVOC, g/l] = [VOC Regulatory Content, g/l]*[RAF]

An example is provided below, based on actual survey data that has been altered slightly to protect manufacturer confidentiality:

n	Ingredient	MIR Value ($g\ O_3/g$ TOG)	RRi	$[Wt\%]_i$	$\frac{[RR]_i*[Wt\%]_i}{[Total\ Wt\%]}$
1	Mineral Spirits (Bin 14)	1.21	0.33	35	0.27
2	Mineral Spirits (Bin 11)	0.91	0.25	4	0.02
3	Propylene Glycol	2.74	0.74	2	0.04
4	Xylene	7.48	2.02	1	0.05
				Total Wt% = 42%	**RAF = 0.38**
VOC Regulatory Content = 550 g/l **RAVOC** = [0.38]*[550 g/l] = **208 g/l**					

Determining the reactivity-adjusted VOC content can provide a mechanism for identifying coatings that contain highly reactive VOCs, but it doesn't really reflect the overall reactivity of a coating because it does not account for the presence of water and solids. Focusing only on VOCs can make a coating seem highly reactive, when it contains a relatively small quantity of VOCs. Consider the following example for two coatings, one solventborne and one waterborne, that both have a VOC Regulatory value of 280 g/l. If the reactivity adjustment factor is based only on VOCs and exempt compounds, it appears that the waterborne coating has a significantly higher RAVOC than the solventborne coating. However, if the reactivity adjustment factor is based on all of the ingredients in the coating, the solventborne coating has a higher RAVOC than the waterborne coating, as shown below:

	Reactivity Adjustment Factor		**VOC Reg. (g/l)**	VOC Actual (g/l)	**Reactivity Adjusted VOC**	
	Based on VOCs & Exempts Only	Based on All Ingredients			Based on VOCs & Exempts Only	Based on All Ingredients
Solventborne	0.45	0.14	280	280	126	39
Waterborne	0.89	0.10	280	135	250	28

Details of this analysis are provided in the following summaries, which are based on actual survey data that has been altered slightly to protect manufacturer confidentiality:

Solventborne Coating: Reactivity Adjusted VOC – Based on VOCs and Exempts Only

n	Ingredient	MIR Value ($g\ O_3/g$ TOG)	RRi	$[Wt\%]_i$	$[RR]_i*[Wt\%]_i$ / [Total Wt%]
1	HC Solvent (Bin 14)	1.21	0.33	19.3	0.21
2	Aromatic 100	7.51	2.02	1.3	0.09
3	HC Solvent (Bin unknown)	1.86	0.50	9.2	0.15
				Total Wt% = 29.8%	**RAF = 0.45**
VOC Regulatory Content = 280 g/l **RAVOC** = [0.45]*[280 g/l] = **126 g/l**					

Solventborne Coating: Reactivity Adjusted VOC – Based on All Ingredients

n	Ingredient	MIR Value ($g\ O_3/g$ TOG)	RRi	$[Wt\%]_i$	$[RR]_i*[Wt\%]_i$ / [Total Wt%]
1	HC Solvent (Bin 14)	1.21	0.33	19.3	0.06
2	Aromatic 100	7.51	2.02	1.3	0.03
3	HC Solvent (Bin unknown)	1.86	0.50	9.2	0.05
4	Solids	0	0	70.2	0
				Total Wt% = 100%	**RAF = 0.14**
VOC Regulatory Content = 280 g/l **RAVOC** = [0.14]*[280 g/l] = **39 g/l**					

Waterborne Coating: Reactivity Adjusted VOC – Based on VOCs and Exempts Only

n	Ingredient	MIR Value ($g\ O_3/g$ TOG)	RRi	$[Wt\%]_i$	$[RR]_i*[Wt\%]_i$ / [Total Wt%]
1	2-Propoxyethanol	3.50	0.94	5.7	0.48
2	2-Butoxyethanol	2.88	0.78	4.4	0.31
3	Toluene	3.97	1.07	1.0	0.10
				Total Wt% = 11.1%	**RAF = 0.89**
VOC Regulatory Content = 280 g/l **RAVOC** = [0.89]*[280 g/l] = **250 g/l**					

Waterborne Coating: Reactivity Adjusted VOC – Based on All Ingredients

n	Ingredient	MIR Value ($g\ O_3/g$ TOG)	RRi	$[Wt\%]_i$	$[RR]_i*[Wt\%]_i$ / [Total Wt%]
1	2-Propoxyethanol	3.50	0.94	5.7	0.05
2	2-Butoxyethanol	2.88	0.78	4.4	0.03
3	Toluene	3.97	1.07	1.0	0.01
4	Water	0	0	37.3	0
5	Solids	0	0	51.6	0
				Total Wt% = 100%	**RAF = 0.10**
VOC Regulatory Content = 280 g/l **RAVOC** = [0.10]*[280 g/l] = **28 g/l**					

Table A-2 contains a listing of the sales-weighted average VOC Regulatory values and the corresponding Reactivity-Adjusted VOC values for each coating category. The RAVOC has been calculated using two different methods. For one method, the reactivity adjustment factor is calculated based on VOCs and exempt compounds only. The other method uses a reactivity adjustment factor that is based on all of the ingredients in the coating, which results in a value that reflects the overall reactivity of the coatings.

When calculating RAVOC, based on VOCs and exempt compounds only, the value is almost always less than the standard VOC Regulatory content. This is due to the fact that the reactivity adjustment factor includes the ratio of individual chemical MIRs to the MIR for the Base Case ROG Mixture. The MIR value for the Base Case ROG Mixture is 3.71 grams ozone/gram ROG, which is generally higher than the MIR values for the ingredients that are most commonly used in architectural coatings. Therefore, the ratio is usually less than one and the resulting RAVOC is less than the VOC Regulatory content.

Table A-2: ***SWA Reactivity-Adjusted VOCs for All Categories***

Coating Category	SOLVENTBORNE			WATERBORNE			OVERALL		
		SWA RAVOC (g/l)			SWA RAVOC (g/l)			SWA RAVOC (g/l)	
	SWA VOC Reg (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients	SWA VOC Reg (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients	SWA VOC Reg (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients
Antenna	452	297	95	280	247	27	431	291	87
Bituminous Roof	240	107	28	2	1	0	120	54	14
Bituminous Roof Primer	391	158	65	85	106	14	211	127	35
Bond Breakers				244	194	15	244	194	15
Clear Brushing Lacquer	667	366	271	N/A	N/A	N/A	667	366	271
Concrete Curing Compounds	350	588	128	135	128	8	145	149	13
Dry Fog	346	161	36	160	68	9	258	117	23
Faux Finishing	404	138	47	255	175	24	261	173	25
Fire Resistive	N/A	N/A	N/A	45	25	0	45	25	0
Fire Retardant - Clear	N/A	N/A	N/A	4	2	0	4	2	0
Fire Retardant - Opaque	257	349	82	80	47	2	95	73	8
Flat	373	171	44	96	55	2	96	55	2
Floor	139	119	27	96	62	5	100	67	7
Flow	N/A	N/A	N/A	412	319	60	412	319	60
Form Release Compounds	238	72	20	41	21	1	213	66	17
Graphic Arts	413	236	85	125	85	3	274	163	46
High Temperature	401	259	96	261	229	22	401	259	96
Industrial Maintenance	315	258	72	179	134	14	298	242	64
Lacquers	622	419	262	282	211	25	567	385	223
Low Solids	N/A	N/A	N/A	59	47	3	59	47	3
Magnesite Cement	443	481	253	N/A	N/A	N/A	443	481	253
Mastic Texture	229	64	11	85	68	2	133	67	5

Table A-2: ***SWA Reactivity-Adjusted VOCs for All Categories***

Coating Category	SOLVENTBORNE			WATERBORNE			OVERALL		
		SWA RAVOC (g/l)			SWA RAVOC (g/l)			SWA RAVOC (g/l)	
	SWA VOC Reg (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients	SWA VOC Reg (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients	SWA VOC Reg (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients
Metallic Pigmented	469	497	222	134	69	3	409	420	182
Multi-Color	526	185	61	224	240	56	227	239	56
Nonflat - High Gloss	338	200	60	203	138	11	245	157	26
Nonflat - Low Gloss	372	160	46	128	82	4	129	82	4
Nonflat - Medium Gloss	329	188	52	166	103	6	171	105	8
Other	117	95	26	0	0	0	1	1	0
Pre-Treatment Wash Primer	486	243	136	238	164	16	252	168	23
Primer, Sealer, and Undercoater	339	209	62	118	79	3	154	100	13
Quick Dry Enamel	361	176	55	234	169	17	358	176	54
Quick Dry Primer, Sealer, and Undercoater	434	180	61	146	121	5	345	162	44
Recycled	N/A	N/A	N/A	204	65	1	204	65	1
Roof	211	157	40	56	35	1	69	45	4
Rust Preventative	381	177	51	177	156	7	339	172	42
Sanding Sealers	557	316	204	245	148	12	471	270	151
Shellacs - Clear	600	273	185	N/A	N/A	N/A	600	273	185
Shellacs - Opaque	538	248	107	N/A	N/A	N/A	538	248	107
Specialty Primer, Sealer, and Undercoater	400	203	62	103	79	3	120	86	7
Stains - Clear/Semitransparent	387	167	74	215	137	12	349	160	60
Stains - Opaque	331	159	45	141	101	5	180	113	13
Swimming Pool	321	430	97	215	168	13	274	315	60

Table A-2: ***SWA Reactivity-Adjusted VOCs for All Categories***

Coating Category	SOLVENTBORNE			WATERBORNE			OVERALL		
		SWA RAVOC (g/l)			SWA RAVOC (g/l)			SWA RAVOC (g/l)	
	SWA VOC Reg (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients	SWA VOC Reg (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients	SWA VOC Reg (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients
Swimming Pool Repair and Maintenance	573	1,077	552	N/A	N/A	N/A	573	1,077	552
Traffic Marking	103	50	13	120	29	1	116	34	4
Varnishes - Clear	432	173	86	266	195	27	375	181	66
Varnishes - Semitransparent	439	129	62	270	173	16	431	131	60
Waterproofing Concrete/Masonry Sealers	426	307	143	108	80	4	210	153	48
Waterproofing Sealers	342	189	78	181	112	7	256	148	40
Wood Preservatives	356	174	74	164	231	11	345	177	70

"N/A": Not applicable, because there were no coating sales or ingredient data reported in this category.

Section A.3 Reactivity-Adjusted VOC Values – Based on Alternative VOC_{exempt}

In the previous section, we calculated a reactivity adjustment based on the VOC Regulatory value (a.k.a., VOC content less water and exempt compounds.) VOC Regulatory is calculated as shown below:

$$\text{VOC Regulatory} = \frac{Wvm - Ww - We}{Vc - Vw - Ve}$$

where

Wvm = total weight of volatile materials (VOC+water+exempt compounds) in the coating, grams
Ww = weight of water in the coating, grams
We = weight of exempt compounds in the coating, grams
Vc = total volume of the coating, liters
Vw = volume of water in the coating, liters
Ve = volume of exempt compounds in the coating, liters

One manufacturer recommended using an alternative VOC value to determine a reactivity-adjusted VOC content. Instead of performing a reactivity adjustment on the VOC regulatory value, it was suggested that we use an alternative VOC value that includes the contribution from exempt compounds. An Alternative VOC that includes exempt compounds could be calculated as shown below:

$$\text{Alternative } VOC_{exempt} = \frac{Wvm - Ww}{Vc - Vw}$$

where

Wvm = total weight of volatile materials (VOC+water+exempt compounds) in the coating, grams
Ww = weight of water in the coating, grams
Vc = total volume of the coating, liters
Vw = volume of water in the coating, liters

Table A-3 summarizes the sales-weighted average Alternative VOC_{exempt} values and the reactivity-adjusted Alternative VOC_{exempt} values. These data can be compared to Table A-2 to see where differences occur due to the use of Alternative VOC_{exempt} vs. VOC Regulatory. For waterborne coatings, there is no difference between the values in Table A-2 and Table A-3, because exempt compounds are not used extensively in waterborne coatings. For solventborne coatings, the biggest differences are found in Traffic Marking, Magnesite Cement, and Waterproofing Sealers. These categories have a relatively high usage of exempt compounds as compared to the quantity of non-exempt VOCs contained in the coatings. For all other categories, the differences between Table A-2 and A-3 are less than ten percent.

Table A-3: ***SWA Reactivity-Adjusted Alternative VOC_{exempt} for All Categories***

Coating Category	SOLVENTBORNE			WATERBORNE			OVERALL		
		SWA RAVOC (g/l)			SWA RAVOC (g/l)			SWA RAVOC (g/l)	
	SWA Alt. VOC_{exempt} (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients	SWA Alt. VOC_{exempt} (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients	SWA Alt. VOC_{exempt} (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients
Antenna	452	297	95	280	247	27	431	291	87
Bituminous Roof	240	107	28	2	1	0	120	54	14
Bituminous Roof Primer	391	158	65	85	106	14	211	127	35
Bond Breakers	N/A	N/A	N/A	244	194	15	244	194	15
Clear Brushing Lacquer	667	366	271	N/A	N/A	N/A	667	366	271
Concrete Curing Compounds	365	591	130	135	128	8	146	149	13
Dry Fog	346	161	36	160	68	9	258	117	23
Faux Finishing	404	138	47	255	175	24	261	173	25
Fire Resistive	N/A	N/A	N/A	45	25	0	45	25	0
Fire Retardant - Clear	N/A	N/A	N/A	4	2	0	4	2	0
Fire Retardant - Opaque	257	349	82	80	47	2	95	73	8
Flat	376	171	44	96	55	2	96	55	2
Floor	140	119	27	96	62	5	101	67	7
Flow	N/A	N/A	N/A	412	319	60	412	319	60
Form Release Compounds	238	72	20	41	21	1	213	66	17
Graphic Arts	413	236	85	125	85	3	274	163	46
High Temperature	426	268	100	261	229	22	426	268	100
Industrial Maintenance	318	258	72	179	134	14	300	242	64
Lacquers	647	428	268	282	211	25	588	392	228
Low Solids	N/A	N/A	N/A	59	47	3	59	47	3
Magnesite Cement	563	612	322	N/A	N/A	N/A	563	612	322
Mastic Texture	229	64	11	85	68	2	133	67	5

Table A-3: ***SWA Reactivity-Adjusted Alternative VOC$_{exempt}$ for All Categories***

Coating Category	SOLVENTBORNE			WATERBORNE			OVERALL		
		SWA RAVOC (g/l)			SWA RAVOC (g/l)			SWA RAVOC (g/l)	
	SWA Alt. VOC$_{exempt}$ (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients	SWA Alt. VOC$_{exempt}$ (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients	SWA Alt. VOC$_{exempt}$ (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients
Metallic Pigmented	469	497	222	134	69	3	409	420	182
Multi-Color	526	185	61	224	240	56	227	239	56
Nonflat - High Gloss	348	213	65	203	138	11	248	161	28
Nonflat - Low Gloss	372	160	46	128	82	4	129	82	4
Nonflat - Medium Gloss	329	188	52	166	103	6	171	105	8
Other	117	95	26	0	0	0	1	1	0
Pre-Treatment Wash Primer	486	243	136	238	164	16	252	168	23
Primer, Sealer, and Undercoater	342	210	63	118	79	3	154	100	13
Quick Dry Enamel	362	176	55	234	169	17	358	176	54
Quick Dry Primer, Sealer, and Undercoater	436	181	62	146	121	5	347	163	44
Recycled	N/A	N/A	N/A	204	65	1	204	65	1
Roof	214	159	41	56	35	1	69	45	4
Rust Preventative	381	177	51	177	156	7	339	172	42
Sanding Sealers	558	316	204	245	148	12	471	270	151
Shellacs - Clear	600	273	185	N/A	N/A	N/A	600	273	185
Shellacs - Opaque	538	248	107	N/A	N/A	N/A	538	248	107
Specialty Primer, Sealer, and Undercoater	400	203	62	103	79	3	120	86	7
Stains - Clear/Semitransparent	387	167	74	215	137	12	349	160	60
Stains - Opaque	331	159	45	141	101	5	180	113	13
Swimming Pool	321	430	97	215	168	13	274	315	60

Table A-3: ***SWA Reactivity-Adjusted Alternative VOC_{exempt} for All Categories***

Coating Category	SOLVENTBORNE			WATERBORNE			OVERALL		
		SWA RAVOC (g/l)			SWA RAVOC (g/l)			SWA RAVOC (g/l)	
	SWA Alt. VOC_{exempt} (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients	SWA Alt. VOC_{exempt} (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients	SWA Alt. VOC_{exempt} (g/l)	Based on VOCs & Exempts Only	Based on All Ingredients
Swimming Pool Repair and Maintenance	575	1,080	553	N/A	N/A	N/A	575	1,080	553
Traffic Marking	208	94	24	120	29	1	141	44	7
Varnishes - Clear	434	174	86	266	195	27	376	181	66
Varnishes - Semitransparent	439	129	62	270	173	16	431	131	60
Waterproofing Concrete/Masonry Sealers	468	317	150	108	80	4	223	156	51
Waterproofing Sealers	371	202	88	181	112	7	269	154	45
Wood Preservatives	356	174	74	164	231	11	345	177	70

"N/A": Not applicable, because there were no coating sales or ingredient data reported in this category.