2005 Architectural Coatings Survey

FINAL Reactivity Analysis

February 2008

California Environmental Protection Agency

Air Resources Board

State of California
California Environmental Protection Agency
AIR RESOURCES BOARD

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ARB, Board	Air Resources Board
ASTM	American Society for Testing and Materials
CAS#	Chemical Abstract Service number
MIR	Maximum Incremental Reactivity
NOx	Nitrogen Oxides
O_3	Ozone
RRAC	Reactivity Research Advisory Committee
SCAQMD	South Coast Air Quality Management District
SCM	Suggested Control Measure
SWA	Sales-Weighted Average
SWAMIR	Sales-Weighted Average Maximum Incremental Reactivity
TPD	Tons Per Day
U.S. EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound

Executive Summary

In April 2005, the Air Resources Board (ARB or Board) conducted a survey of companies that sold architectural coating products in California in 2004 (ARB, 2007.) The survey gathered detailed ingredient information for the volatile compounds contained in each coating product. ARB staff used these ingredient data to analyze the photochemical reactivity (i.e., ozone-forming potential) associated with architectural coatings. This document is intended to provide different options for evaluating the reactivity of architectural coatings, but it is not a formal regulatory document.

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 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 (ARB, 1990.) In June 2000, the Board approved a reactivity-based regulation for aerosol coatings (ARB, 2000.) This regulation was approved by the United States Environmental Protection Agency (U.S. EPA) in 2005 (U.S. EPA, 2005.)

In 2005, the U.S. EPA published a guidance document regarding the use of innovative reactivity-based approaches to achieve ozone reduction (U.S. EPA, 2005a.) This guidance encourages states to consider photochemical reactivity when developing control measures for state implementation plans (SIPs). U.S. EPA provided the following ways that reactivity could be addressed during the SIP development process:

- Develop speciated emission inventories to help identify the most reactive VOCs.
- Prioritize control measures based on reactivity.
- Target emissions of highly reactive VOCs with specific control measures.
- Encourage VOC substitution using reactivity-weighted emission limits.

U.S. EPA's guidance document supports the approach in ARB's Aerosol Coatings Regulation, which establishes reactivity limits based on individual ingredients rather than total VOC mass-based limits.

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 2004, architectural coatings and associated solvents emitted approximately **95** tons per day from coatings only and more than **20** tons per day from thinning/cleanup/additives, for a total of **115** tons per day, on an annual average basis.

The **95** tons per day from coatings represent about **8%** of the total stationary and area source VOC emissions, and about **4%** of all VOC emissions statewide. Control of emissions from architectural coatings is primarily the responsibility of the local Air Pollution Control Districts and Air Quality Management Districts (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, 2000, and 2007. These SCMs have been used as models for districts when adopting and amending their local rules. As of January 2008, **20** local air districts have adopted the architectural coating limits from the 2000 SCM.

During the June 2000 Board hearing, Board members approved the 2000 SCM and adopted Resolution 00-23. This Resolution 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. In June 2001, December 2002, and January 2004, ARB staff provided updates to the Board, regarding progress in implementing Resolution 00-23 (ARB, 2001; ARB, 2002; ARB, 2004.) This progress is summarized below:

Reactivity Evaluation Tasks	**ARB Accomplishments**
• Assess the reactivity of individual VOC species in consideration of the best available science.	• ARB funded a $300,000 research project with the University of California, Riverside to assess the reactivity of key solvents in architectural coatings, including Texanol® and six hydrocarbon solvents. The final report for this project was completed in March 2005.
• Conduct a comprehensive survey of the architectural coatings industry.	• In 2001 and 2005, ARB conducted architectural coatings surveys. Results from these surveys are summarized in the "2001 Architectural Coatings Survey, Final Report, October 2003" and the "2005 Architectural Coatings Survey, Final Report, December 2007".
• Assess the extent to which VOCs emitted from architectural coatings contribute to ozone levels.	• ARB used data from the architectural coating surveys to estimate the potential amount of ozone that is generated by architectural coatings. The ozone estimates from the 2001 survey were contained in the "2001 Architectural Coatings Survey, Final Reactivity Analysis, March 2005". The ozone estimates from the 2005 survey are summarized in Chapter 2 of this report.

In Spring 2006, ARB staff began working with stakeholders to develop an updated version of the 2000 SCM. During the development process, staff evaluated the potential for replacing mass-based VOC limits with reactivity-based limits. Staff also considered using a reactivity-based approach to create a new exemption for products that exceed mass-based limits. During 2006 and 2007, staff worked with districts and industry representatives to investigate reactivity-based options. Since districts are responsible for architectural coatings rules, district personnel would be responsible for enforcing reactivity-based limits. Districts expressed concerns that implementation of a reactivity-based rule would require additional resources for enforcement. If district personnel wanted to determine the reactivity of a product for enforcement purposes, they would need to obtain detailed chemical formulation data to identify all of the volatile ingredients contained in the product. They would then need to identify the appropriate maximum incremental reactivity (MIR) value for each of these ingredients, so they could calculate the overall reactivity for the product. District personnel would also need to develop a system for updating MIR values to accommodate changes that result from research studies.

Only some industry representatives were supportive of a reactivity-based approach. ARB staff met with industry groups in the Spring and Fall of 2006 to discuss reactivity. In addition, ARB conducted several meetings with individual coating manufacturers and raw material suppliers to discuss their concerns. No consensus regarding reactivity-based limits could be achieved among coating manufacturers.

ARB staff concluded that many districts have insufficient resources to implement and enforce reactivity-based limits or exemptions. In addition, the U.S. EPA had concerns regarding the implementation and enforcement of a reactivity-based exemption. Based on the lack of district resources, U.S. EPA's response, and the lack of industry consensus, staff decided to propose mass-based VOC limits for the updated SCM.

During the October 2007 Board meeting, Board members approved the updated SCM with mass-based VOC limits and adopted Resolution 07-46. This Resolution directed ARB staff to continue to work with industry and other stakeholders on assessing the ozone-forming potential (reactivity) of architectural coatings. This analysis is to include:

- Assessing the reactivity of individual VOC species in consideration of the best available science;
- Assessing the extent to which VOC s emitted from architectural coatings contribute to ozone levels; and
- Conducting a comprehensive survey of the architectural coatings industry.

Staff currently plans to conduct another architectural coatings survey in 2011 to gather data from calendar year 2010. Staff expects the survey to be similar to the survey conducted in 2005 to gather data from calendar year 2004. This survey will reflect the products that have been reformulated to meet the VOC limits effective in the South Coast Air Quality Management District (SCAQMD) from 2005 to 2008, and the proposed SCM limits that take effect in 2010. Data from the survey will be analyzed to assess the reactivity of architectural coatings.

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. Carter evaluated a variety of scales and concluded that the Maximum Incremental Reactivity (MIR) scale is the most appropriate for California (Carter, 1994.) The ARB uses the MIR scale for regulatory applications because it reflects reactivities under environmental conditions that are most sensitive to the effects of VOC controls, such as in the South Coast Air Basin.

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 (ARB, 2000.) These bins assign MIR values, based on average boiling points and hydrocarbon characteristics (e.g., aromatic content).

MIR values and VOC emission quantities can be used to estimate the amount of ozone that could potentially be formed under MIR conditions (i.e., the maximum ozone formation potential). Estimating actual atmospheric ozone concentrations involves the use of complicated computer modeling programs that analyze emission data, meteorological data, MIR values, and other information. This type of modeling effort is outside the scope of this reactivity analysis. For the purposes of this report, we use the maximum ozone formation potential to provide a comparison of the relative contributions from different coating categories and identify categories that may be candidates for achieving additional ozone reductions.

After determining the maximum ozone formation potential, it is necessary to normalize the values in a way that allows comparison between the different coating categories. In this report we considered the following possible approaches:

- Maximum Ozone Per Pound of Coating
- Maximum Ozone Per Gallon of Coating
- Maximum Ozone Per Pound of Solids
- Maximum Ozone Per Gallon of Solids

Table E-1 contains a summary of maximum potential ozone quantities under MIR conditions. The table also contains the maximum potential ozone per gallon of coating. As shown below, the amount of potential ozone generated by each gallon of solventborne coating is generally higher than the amount generated by each gallon of waterborne coating. However, the overall quantity of maximum potential ozone (tons/day) is sometimes higher in the waterborne column, because waterborne coatings dominate the architectural coating market. The data in Table E-1 is based on the official MIR values published in ARB's Aerosol Coatings regulation, as updated in July 2004 (CCR, 2004). Following Table E-1 is Table E-2, which contains similar information but is based on draft updated MIR values that have not yet been officially adopted (Carter, 2007).

Table E-1: ***Maximum Ozone Formation Potential (official MIRs)***

Coating Category	Maximum Ozone (tons/day)			[Maximum Ozone, lbs] per [Gallon Coating]		
	SB	WB	All	SB	WB	All
Bituminous Roof	1.05	0.07	1.12	5.75	0.04	0.56
Bituminous Roof Primer	0.48	0.02	0.50	5.88	1.67	5.38
Bond Breakers	0.01	0.75	0.77	10.80	2.94	2.97
Clear Brushing Lacquer	1.06	0.00	1.06	11.16	NA	11.16
Concrete Curing Compounds	0.72	0.84	1.57	12.09	0.82	1.44
Driveway Sealer	0.04	0.04	0.08	6.68	0.01	0.02
Dry Fog	1.51	0.21	1.72	5.90	0.79	3.32
Faux Finishing	0.03	0.94	0.97	4.71	2.29	2.32
Fire Resistive	0.04	0.00	0.04	6.06	0.19	2.56
Fire Retardant - Clear	0.02	0.00	0.02	19.58	NA	19.58
Fire Retardant - Opaque	0.90	0.00	0.91	3.65	0.15	3.31
Flat	0.10	36.61	36.72	18.23	0.72	0.72
Floor	1.00	5.25	6.25	10.23	3.40	3.80
Form Release Compounds	1.29	0.03	1.32	3.31	0.50	2.97
Graphic Arts	0.02	0.00	0.02	4.29	2.39	3.92
High Temperature	0.14	0.00	0.14	8.66	NA	8.66
Industrial Maintenance	13.24	1.66	14.90	6.94	1.76	5.23
Lacquers	8.51	0.74	9.25	6.62	1.53	5.23
Low Solids	0.00	0.10	0.10	NA	1.17	1.17
Magnesite Cement	0.72	0.00	0.72	20.12	NA	20.12
Mastic Texture	0.27	0.73	1.00	1.64	0.96	1.08
Metallic Pigmented	5.80	0.25	6.06	9.75	1.40	7.79
Multi-Color	0.00	0.01	0.01	5.67	0.31	0.42
Nonflat - High Gloss	0.27	3.54	3.81	4.84	1.50	1.58
Nonflat - Low Gloss	0.03	18.56	18.59	4.73	1.13	1.13
Nonflat - Medium Gloss	0.46	29.18	29.64	4.31	1.07	1.08
Other	0.07	0.01	0.08	18.95	0.09	0.63
Pre-Treatment Wash Primer	0.02	0.00	0.02	13.42	0.74	3.51
Primer, Sealer, and Undercoater	1.22	17.17	18.39	3.95	1.23	1.29
Quick Dry Enamel	4.45	0.17	4.61	4.55	2.44	4.41
Quick Dry Primer, Sealer, and Undercoater	1.69	0.01	1.69	5.58	0.15	4.94
Roof	0.43	0.72	1.15	7.32	0.38	0.60
Rust Preventative	15.31	0.20	15.52	5.58	1.63	5.41
Sanding Sealers	0.50	0.04	0.53	5.99	1.17	4.62
Shellacs - Clear	0.55	0.00	0.55	7.66	NA	7.66
Shellacs - Opaque	1.28	0.00	1.28	6.40	NA	6.40
Specialty Primer, Sealer, and Undercoater	11.09	0.56	11.64	5.28	0.85	4.23
Stains - Clear/Semitransparent	8.11	0.70	8.81	4.05	1.34	3.49
Stains - Opaque	0.15	1.24	1.39	5.38	0.96	1.06
Swimming Pool	0.19	0.03	0.22	14.24	1.90	7.85

Table E-1: *Maximum Ozone Formation Potential (official MIRs)*

Coating Category	Maximum Ozone (tons/day)			[Maximum Ozone, lbs] per [Gallon Coating]		
	SB	WB	All	SB	WB	All
Swimming Pool Repair and Maintenance	0.11	0.00	0.11	36.41	NA	36.41
Traffic Marking	2.35	1.90	4.24	5.20	0.74	1.40
Varnishes - Clear	4.70	0.84	5.54	4.95	2.21	4.17
Varnishes - Semitransparent	0.42	0.00	0.43	3.57	1.15	3.49
Waterproofing Concrete/Masonry Sealers	7.17	1.48	8.65	5.51	1.19	3.40
Waterproofing Sealers	1.32	2.12	3.43	4.93	1.17	1.66
Wood Preservatives	0.95	0.01	0.96	4.21	1.07	4.04
TOTALS:	**99.8**	**126.7**	**226.5**	**5.60**	**0.95**	**1.50**

Notes:
1. NA = Not Applicable. No sales were reported for this subcategory.
2. The values in this table are based on the official MIR values published in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions", California Code of Regulations, Title 17, sections 94700 and 94701, as updated July 7, 2004.
3. This table does not include sales-weighted average values. The "[Maximum Ozone] per [Gallon Coating]" reflects the sum of the maximum ozone formation potential for all products in a category divided by the total sales volume for all products in that category.
4. This table includes small containers (one quart or less).
5. For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.

Table E-2: *Maximum Ozone Formation Potential (draft updated MIRs)*

Coating Category	Maximum Ozone (tons/day)			[Maximum Ozone, lbs] per [Gallon Coating]		
	SB	WB	All	SB	WB	All
Bituminous Roof	1.05	0.06	1.11	5.75	0.04	0.56
Bituminous Roof Primer	0.48	0.02	0.50	5.88	1.50	5.35
Bond Breakers	0.01	0.30	0.31	10.80	1.16	1.21
Clear Brushing Lacquer	0.98	0.00	0.98	10.37	NA	10.37
Concrete Curing Compounds	0.65	0.73	1.38	10.88	0.71	1.27
Driveway Sealer	0.04	0.03	0.07	6.68	0.01	0.02
Dry Fog	1.43	0.16	1.60	5.59	0.63	3.09
Faux Finishing	0.03	0.73	0.76	4.28	1.79	1.82
Fire Resistive	0.04	0.00	0.04	5.97	0.16	2.51
Fire Retardant - Clear	0.02	0.00	0.02	19.47	NA	19.47
Fire Retardant - Opaque	0.89	0.00	0.89	3.58	0.12	3.24
Flat	0.10	23.25	23.35	18.71	0.46	0.46
Floor	0.99	3.88	4.88	10.20	2.51	2.97
Form Release Compounds	1.29	0.03	1.31	3.30	0.50	2.96
Graphic Arts	0.02	0.00	0.02	4.28	2.13	3.86
High Temperature	0.14	0.00	0.14	8.48	NA	8.48
Industrial Maintenance	13.08	1.44	14.52	6.86	1.52	5.09
Lacquers	7.66	0.65	8.31	5.96	1.35	4.70
Low Solids	0.00	0.08	0.08	NA	0.93	0.93
Magnesite Cement	0.72	0.00	0.72	20.13	NA	20.13

Table E-2: ***Maximum Ozone Formation Potential (draft updated MIRs)***

Coating Category	Maximum Ozone (tons/day)			[Maximum Ozone, lbs] per [Gallon Coating]		
	SB	**WB**	**All**	**SB**	**WB**	**All**
Mastic Texture	0.23	0.58	0.81	1.38	0.76	0.87
Metallic Pigmented	5.81	0.07	5.88	9.76	0.36	7.56
Multi-Color	0.00	0.01	0.01	5.67	0.28	0.39
Nonflat - High Gloss	0.25	2.10	2.35	4.50	0.89	0.97
Nonflat - Low Gloss	0.02	13.82	13.84	4.26	0.84	0.84
Nonflat - Medium Gloss	0.43	22.94	23.38	4.06	0.84	0.85
Other	0.07	0.01	0.08	19.01	0.08	0.62
Pre-Treatment Wash Primer	0.02	0.00	0.02	12.03	0.68	3.16
Primer, Sealer, and Undercoater	1.14	11.30	12.45	3.71	0.81	0.87
Quick Dry Enamel	4.13	0.15	4.28	4.23	2.24	4.10
Quick Dry Primer, Sealer, and Undercoater	1.57	0.00	1.57	5.20	0.12	4.60
Roof	0.28	0.59	0.87	4.73	0.32	0.45
Rust Preventative	14.53	0.18	14.71	5.29	1.44	5.12
Sanding Sealers	0.48	0.03	0.52	5.85	1.04	4.49
Shellacs - Clear	0.47	0.00	0.47	6.53	NA	6.53
Shellacs - Opaque	1.09	0.00	1.09	5.48	NA	5.48
Specialty Primer, Sealer, and Undercoater	10.24	0.44	10.68	4.88	0.68	3.88
Stains - Clear/Semitransparent	7.92	0.57	8.49	3.96	1.09	3.36
Stains - Opaque	0.15	0.93	1.08	5.24	0.72	0.82
Swimming Pool	0.19	0.02	0.22	14.14	1.72	7.71
Swimming Pool Repair and Maintenance	0.11	0.00	0.11	37.61	NA	37.61
Traffic Marking	2.32	1.72	4.05	5.15	0.67	1.33
Varnishes - Clear	4.39	0.66	5.05	4.62	1.73	3.80
Varnishes - Semitransparent	0.40	0.00	0.40	3.39	0.99	3.31
Waterproofing Concrete/Masonry Sealers	7.27	1.24	8.51	5.59	0.99	3.34
Waterproofing Sealers	1.33	1.60	2.93	4.98	0.89	1.42
Wood Preservatives	0.94	0.01	0.95	4.17	1.14	4.00
TOTALS:	**95.4**	**90.4**	**185.8**	**5.35**	**0.68**	**1.23**

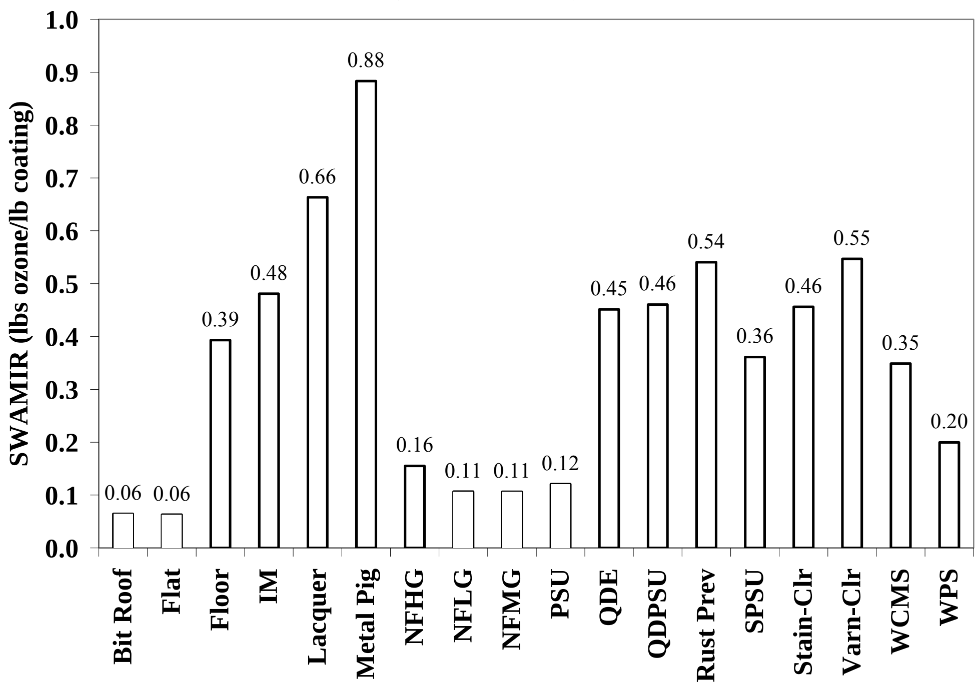
Notes:

1. NA = Not Applicable. No sales were reported for this subcategory.
2. The values in this table are based on draft updated MIR values that have not yet been officially adopted in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions". These draft updated values have been determined by Dr. William Carter for the research project titled "Reactivity Estimates for Selected Consumer Product Compounds" under Contract No. 06-408. The draft updated values were current as of December 24, 2007, and they are subject to change.
3. This table does not include sales-weighted average values. The "[Maximum Ozone] per [Gallon Coating]" reflects the sum of the maximum ozone formation potential for all products in a category divided by the total sales volume for all products in that category.
4. This table includes data small containers (one quart or less).
5. For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.

Sales-weighted average MIR values (SWAMIRs) provide another way to characterize the overall reactivity of a given category. Sales-weighting assigns greater importance to products that have higher sales volumes. Therefore, if a category has a particularly dominant product, the SWAMIR for that category will be more reflective of the dominant product.

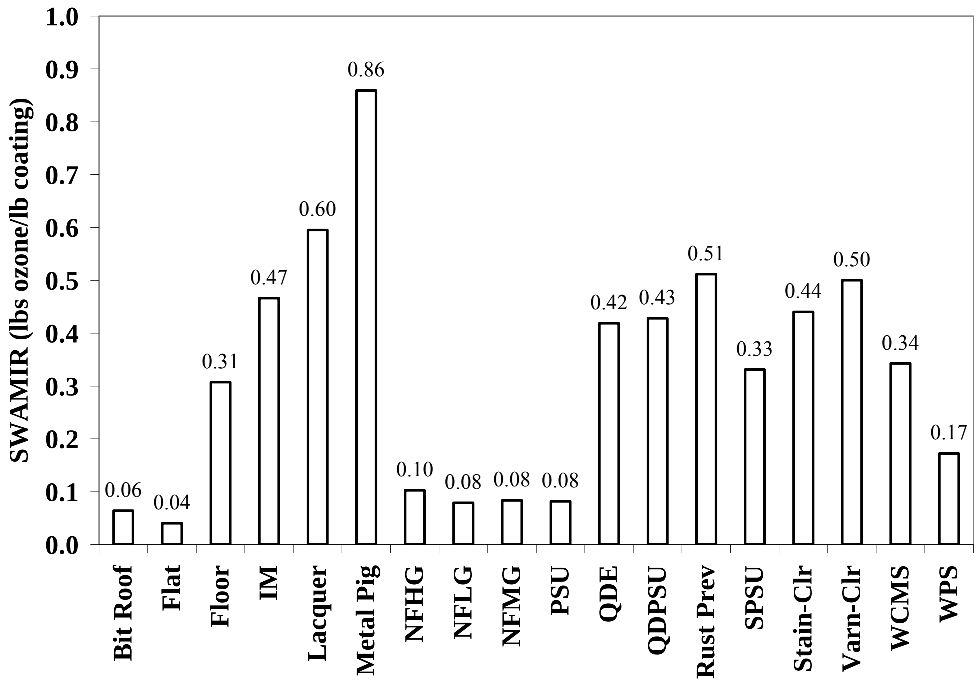
Figure E-1 contains SWAMIRs for selected coating categories. Data are provided in units of [Lb Ozone/Lb Coating], which corresponds to the approach that ARB used in the reactivity-based Aerosol Coatings regulation. The data in Figure E-1 is based on the official MIR values for ARB's Aerosol Coatings regulation that were updated in 2004 (CCR, 2004). Following Figure E-1 is Figure E-2, which contains similar information but is based on draft updated MIR values that have not yet been officially adopted (Carter, 2007).

Figure E-1: Sales-Weighted Average MIR – [Lb Ozone/Lb Coating]
(official MIRs)



Notes:
1. [Lb Ozone]/[Lb Coating] = [Maximum Ozone Formation Potential]/[Total Coating Mass]
2. [Maximum Ozone Formation Potential] = ∑ [Ingredient Emissions, lbs]*[MIR, g Ozone/g Ingredient]
3. [Total Coating Mass] = ∑ [Coating Sales Volume, gals]*[Coating Density, lb/gal]
4. This figure includes data from small containers (1 quart or less).
5. This figure includes ozone generated from all volatile emissions, including VOCs and exempt compounds.
6. Bit Roof = Bituminous Roof; IM = Industrial Maintenance; Metal Pig = Metallic Pigmented; NFHG = Nonflat – High Gloss; NFLG = Nonflat – Low Gloss; NFMG = Nonflat – Medium Gloss; PSU = Primer, Sealer, Undercoater; QDPSU = Quick Dry Primer, Sealer, Undercoater; Rust Prev = Rust Preventative; Stain – Clr = Stains – Clear/Semitransparent; Varn – Clr = Varnishes – Clear; WCMS = Waterproofing Concrete/Masonry Sealers; WPS = Waterproofing Sealers.
7. For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.
8. The values in this table are based on the official MIR values published in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions", California Code of Regulations, Title 17, sections 94700 and 94701, as updated July 7, 2004.

Figure E-2: Sales-Weighted Average MIR – [Lb Ozone/Lb Coating]
(draft updated MIRs)



Notes:
1. [Lb Ozone]/[Lb Coating] = [Maximum Ozone Formation Potential]/[Total Coating Mass]
2. [Maximum Ozone Formation Potential] = ∑ [Ingredient Emissions, lbs]*[MIR, g Ozone/g Ingredient]
3. [Total Coating Mass] = ∑ [Coating Sales Volume, gals]*[Coating Density, lb/gal]
4. This figure includes data from small containers (1 quart or less).
5. This figure includes ozone generated from all volatile emissions, including VOCs and exempt compounds.
6. Bit Roof = Bituminous Roof; IM = Industrial Maintenance; Metal Pig = Metallic Pigmented; NFHG = Nonflat – High Gloss; NFLG = Nonflat – Low Gloss; NFMG = Nonflat – Medium Gloss; PSU = Primer, Sealer, Undercoater; QDPSU = Quick Dry Primer, Sealer, Undercoater; Rust Prev = Rust Preventative; Stain – Clr = Stains – Clear/Semitransparent; Varn – Clr = Varnishes – Clear; WCMS = Waterproofing Concrete/Masonry Sealers; WPS = Waterproofing Sealers.
7. For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.
8. The values in this table are based on draft updated MIR values that have not yet been officially adopted in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions". These draft updated values have been determined by Dr. William Carter for the research project titled "Reactivity Estimates for Selected Consumer Product Compounds" under Contract No. 06-408. The draft updated values were current as of December 24, 2007, and they are subject to change.

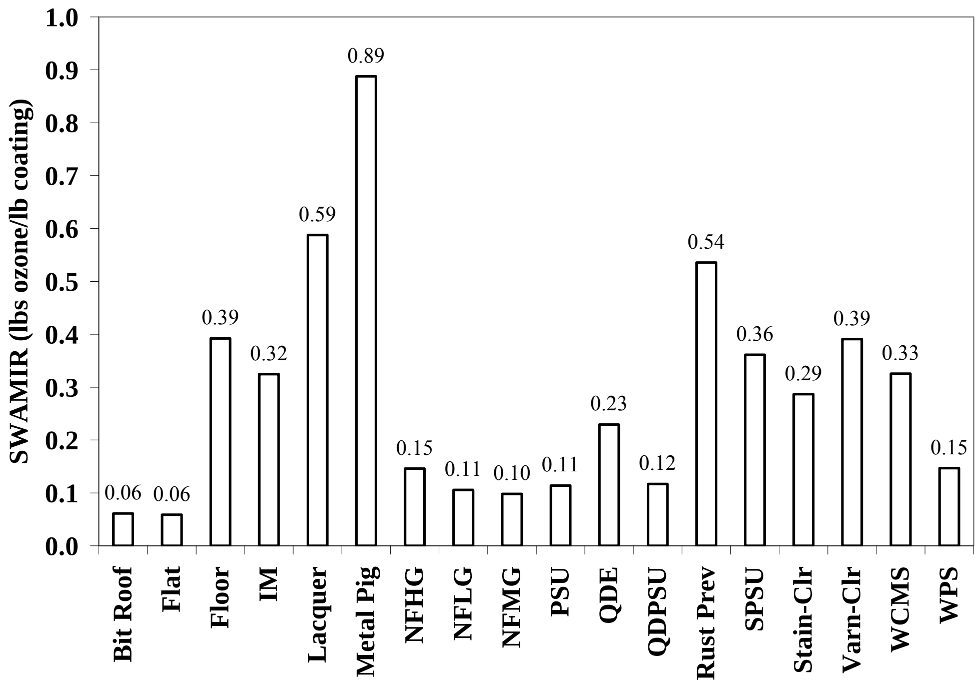
Detailed SWAMIR data for all coating categories are contained in Appendix B, including a breakdown for solventborne and waterborne formulations. Appendix B also contains SWAMIRs for compliant and non-compliant coatings, based on the VOC limits contained in ARB's 2000 Architectural Coatings SCM and the SCAQMD VOC limits that will take effect in or before 2008.

Figure E-3 contains data similar to Figure E-1, but it provides SWAMIRs only for those reported coatings that complied with the VOC limits in ARB's 2000 Suggested Control

Measure. In addition, Figure E-3 does not include sales of small containers (one quart or less), because they are exempt from the SCM VOC limits. When comparing Figure E-1 (all coatings) to Figure E-3 (compliant coatings only), the SWAMIRs are similar for most of the categories. However, the SWAMIRs on Figure E-3 are significantly lower for compliant coatings in the following categories: Industrial Maintenance; Quick Dry Enamel; Quick Dry Primer, Sealer, Undercoater; Stains – Clear/Semitransparent; and Varnishes - Clear.

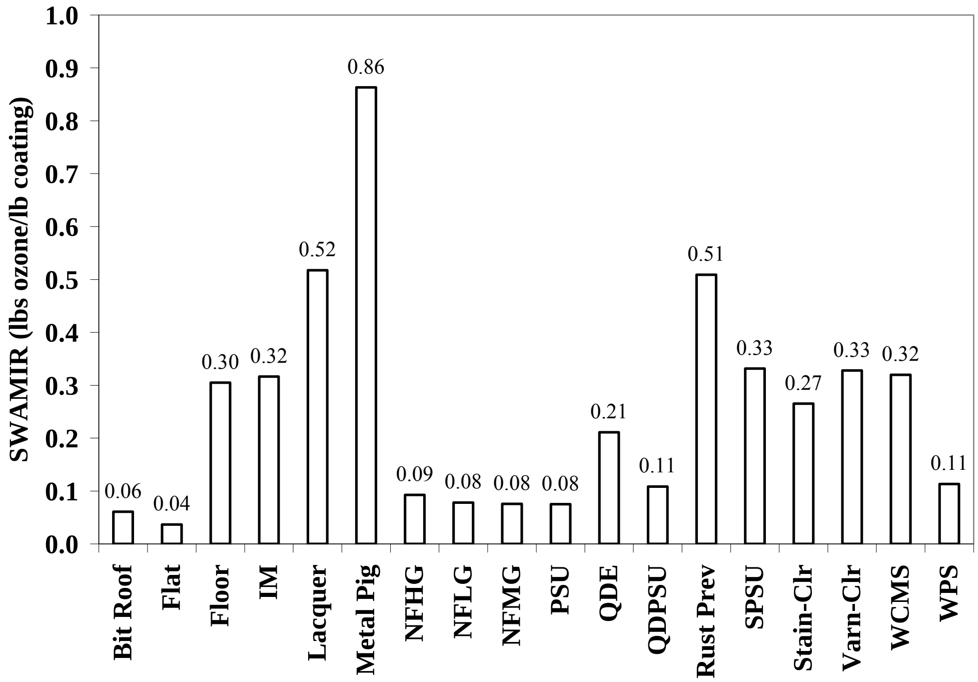
The data in Figure E-3 are based on the official MIR values for ARB's Aerosol Coatings regulation that were updated in 2004 (CCR, 2004). Following Figure E-3 is Figure E-4, which contains similar information but is based on draft updated MIR values that have not yet been officially adopted (Carter, 2007).

Figure E-3: Sales-Weighted Average MIR – [Lb Ozone/Lb Coating]
(Only Includes Compliant Coatings in Large Containers, Official MIRs)



Notes:
1. [Lb Ozone]/[Lb Coating] = [Maximum Ozone Formation Potential]/[Total Coating Mass]
2. [Maximum Ozone Formation Potential] = ∑ [Ingredient Emissions, lbs]*[MIR, g Ozone/g Ingredient]
3. [Total Coating Mass] = ∑ [Coating Sales Volume, gals]*[Coating Density, lb/gal]
4. This figure only includes data for coatings that comply with the VOC limits in the 2000 SCM.
5. This figure does not include data from small containers (1 quart or less).
6. This figure includes ozone generated from all volatile emissions, including VOCs and exempt compounds.
7. For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.
8. The values in this table are based on the official MIR values published in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions", California Code of Regulations, Title 17, sections 94700 and 94701, as updated July 7, 2004.

Figure E-4: Sales-Weighted Average MIR – [Lb Ozone/Lb Coating]
(Only Includes Compliant Coatings in Large Containers, Draft Updated MIRs)



Notes:
1. [Lb Ozone]/[Lb Coating] = [Maximum Ozone Formation Potential]/[Total Coating Mass]
2. [Maximum Ozone Formation Potential] = ∑ [Ingredient Emissions, lbs]*[MIR, g Ozone/g Ingredient]
3. [Total Coating Mass] = ∑ [Coating Sales Volume, gals]*[Coating Density, lb/gal]
4. This figure only includes data for coatings that comply with the VOC limits in the 2000 SCM.
5. This figure does not include data from small containers (1 quart or less).
6. This figure includes ozone generated from all volatile emissions, including VOCs and exempt compounds.
7. For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.
8. The values in this table are based on draft updated MIR values that have not yet been officially adopted in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions". These draft updated values have been determined by Dr. William Carter for the research project titled "Reactivity Estimates for Selected Consumer Product Compounds" under Contract No. 06-408. The draft updated values were current as of December 24, 2007, and they are subject to change.

To identify opportunities for ozone reductions, it is important to know which ingredients contribute the most to a category's potential ozone creation. The following table focuses on the ingredients that are the primary contributors to either VOC emissions or maximum potential ozone totals for selected categories. Table E-3 only lists ingredients that represent more than 10% of the total maximum potential ozone for a category or ingredients that represent more than 10% by weight of the total volatile ingredients (excluding water). It highlights categories where it may be possible to replace a more reactive ingredient with one that is less reactive. The data in Table E-3 are based on the official MIR values for ARB's Aerosol Coatings regulation that were updated in 2004 (CCR, 2004).

Table E-3: ***Ingredients That Contribute the Most to Emissions and Potential Ozone (official MIRs)***

Category	CAS	Ingredient	MIR (g O^3/ g ingr)	Ingred. Qty. (tpd)	Max. Ozone (tpd)	% of Total Volatiles For Category	% of Total Max. Ozone From Category
Bituminous Roof		Bin 15 Hydrocarbon Solvent	1.82	0.32	0.59	78%	52%
		Bin 22 Hydrocarbon Solvent	7.51	0.06	0.44	14%	39%
Flat	107211	Ethylene Glycol	3.63	3.48	12.65	25%	34%
	124685	2-Amino-2-Methyl-1-Propanol	15.08	0.61	9.19	4%	25%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.89	6.46	5.75	47%	16%
	57556	Propylene Glycol	2.75	1.84	5.05	13%	14%
Floor	9986	Unknown	2.73	1.36	3.72	63%	59%
		Bin 22 Hydrocarbon Solvent	7.51	0.12	0.88	5%	14%
	29911271	Dipropylene Glycol Monopropyl Ether	2.13	0.24	0.51	11%	8%
Industrial Maintenance	1330207	Xylene	7.48	0.67	5.01	15%	34%
		Bin 11 Hydrocarbon Solvent	0.91	0.59	0.54	14%	4%
Lacquers	67641	Acetone	0.43	4.02	1.73	55%	19%
	1330207	Xylene	7.48	0.18	1.34	2%	15%
	111762	2-Butoxy Ethanol	2.90	0.33	0.94	4%	10%
	123864	Butyl Acetate, 1-	0.89	0.87	0.78	12%	8%
Metallic Pigmented		Bin 15 Hydrocarbon Solvent	1.82	1.35	2.45	62%	40%
		Bin 22 Hydrocarbon Solvent	7.51	0.32	2.43	15%	40%
Nonflat - High Gloss	107211	Ethylene Glycol	3.63	0.35	1.26	26%	33%
	124685	2-Amino-2-Methyl-1-Propanol	15.08	0.05	0.79	4%	21%
	57556	Propylene Glycol	2.75	0.17	0.48	13%	13%
	5444757	2-Ethylhexyl Benzoate	2.73	0.17	0.46	13%	12%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.89	0.33	0.30	25%	8%

Table E-3: ***Ingredients That Contribute the Most to Emissions and Potential Ozone (official MIRs)***

Category	CAS	Ingredient	MIR (g O^3/ g ingr)	Ingred. Qty. (tpd)	Max. Ozone (tpd)	% of Total Volatiles For Category	% of Total Max. Ozone From Category
Nonflat - Low Gloss	107211	Ethylene Glycol	3.63	2.61	9.47	39%	51%
	57556	Propylene Glycol	2.75	0.93	2.56	14%	14%
	124685	2-Amino-2-Methyl-1-Propanol	15.08	0.15	2.26	2%	12%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.89	1.94	1.72	29%	9%
Nonflat - Medium Gloss	107211	Ethylene Glycol	3.63	3.31	12.02	28%	41%
	57556	Propylene Glycol	2.75	2.70	7.41	23%	25%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.89	3.83	3.41	33%	12%
Primer, Sealer, and Undercoater	107211	Ethylene Glycol	3.63	2.59	9.41	40%	51%
	124685	2-Amino-2-Methyl-1-Propanol	15.08	0.24	3.68	4%	20%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.89	1.67	1.48	26%	8%
		Bin 11 Hydrocarbon Solvent	0.91	0.76	0.69	12%	4%
Quick Dry Enamel		Bin 11 Hydrocarbon Solvent	0.91	2.33	2.12	72%	46%
		Bin 10 Hydrocarbon Solvent	2.03	0.34	0.70	11%	15%
Quick Dry Primer, Sealer, and Undercoater		Bin 6 Hydrocarbon Solvent	1.41	0.63	0.89	62%	53%
		Bin 11 Hydrocarbon Solvent	0.91	0.22	0.20	22%	12%
Rust Preventative		Bin 10 Hydrocarbon Solvent	2.03	1.87	3.79	21%	24%
		Bin 11 Hydrocarbon Solvent	0.91	3.86	3.51	44%	23%
		Bin 15 Hydrocarbon Solvent	1.82	1.21	2.20	14%	14%
	1330207	Xylene	7.48	0.25	1.88	3%	12%
Specialty Primer, Sealer, and Undercoater		Bin 22 Hydrocarbon Solvent	7.51	0.62	4.66	10%	40%
		Bin 11 Hydrocarbon Solvent	0.91	4.45	4.05	74%	35%
Stains - Clear/ Semitransparent		Bin 11 Hydrocarbon Solvent	0.91	3.87	3.52	59%	40%
Varnishes - Clear		Bin 11 Hydrocarbon Solvent	0.91	2.77	2.52	70%	46%
		Bin 15 Hydrocarbon Solvent	1.82	0.41	0.75	10%	14%

Table E-3: ***Ingredients That Contribute the Most to Emissions and Potential Ozone (official MIRs)***

Category	CAS	Ingredient	MIR (g O3/ g ingr)	Ingred. Qty. (tpd)	Max. Ozone (tpd)	% of Total Volatiles For Category	% of Total Max. Ozone From Category
Waterproofing Concrete/Masonry Sealers		Bin 22 Hydrocarbon Solvent	7.51	0.39	2.95	10%	34%
		Bin 6 Hydrocarbon Solvent	1.41	0.65	0.92	16%	11%
	67641	Acetone	0.43	0.55	0.24	14%	3%
	98566	4-Chlorobenzotrifluoride	0.11	0.58	0.06	14%	1%
Waterproofing Sealers		Bin 11 Hydrocarbon Solvent	0.91	0.61	0.55	38%	16%
	34590948	Dipropylene Glycol Methyl Ether	2.46	0.20	0.48	12%	14%
	107211	Ethylene Glycol	3.63	0.12	0.45	8%	13%

Notes:

1. The values in this table are based on the official MIR values published in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions", California Code of Regulations, Title 17, sections 94700 and 94701, as updated July 7, 2004.
2. This table includes data from small containers (1 quart or less).
3. This table includes ozone generated from all volatile emissions, including VOCs and exempt compounds.

For comparison, Table E-4 contains similar information as Table E-3, but Table E-4 is based on draft updated MIR values that have not yet been officially adopted (Carter, 2007).

Table E-4: ***Ingredients That Contribute the Most to Emissions and Potential Ozone (draft updated MIRs)***

Category	CAS	Ingredient	MIR (g O3/ g ingr)	Ingred. Qty. (tpd)	Max. Ozone (tpd)	% of Total Volatiles For Category	% of Total Max. Ozone From Category
Bituminous Roof		Bin 15 Hydrocarbon Solvent	1.82	0.32	0.59	78%	53%
		Bin 22 Hydrocarbon Solvent	7.51	0.06	0.44	14%	40%
Flat	107211	Ethylene Glycol	3.03	3.48	10.56	25%	45%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.75	6.46	4.87	47%	21%
	57556	Propylene Glycol	2.50	1.84	4.59	13%	20%
Floor	9986	Unknown	1.93	1.36	2.64	63%	54%
		Bin 22 Hydrocarbon Solvent	7.51	0.12	0.88	5%	18%
	29911271	Dipropylene Glycol Monopropyl Ether	1.89	0.24	0.45	11%	9%
Industrial Maintenance	1330207	Xylene	7.72	0.67	5.17	15%	36%
		Bin 22 Hydrocarbon Solvent	7.51	0.19	1.46	4%	10%
		Bin 11 Hydrocarbon Solvent	0.91	0.59	0.54	14%	4%

Table E-4: ***Ingredients That Contribute the Most to Emissions and Potential Ozone (draft updated MIRs)***

Category	CAS	Ingredient	MIR (g O^3/ g ingr)	Ingred. Qty. (tpd)	Max. Ozone (tpd)	% of Total Volatiles For Category	% of Total Max. Ozone From Category
Lacquers	67641	Acetone	0.35	4.02	1.42	55%	17%
	1330207	Xylene	7.72	0.18	1.39	2%	17%
	111762	2-Butoxy Ethanol	2.80	0.33	0.91	4%	11%
	123864	Butyl Acetate, 1-	0.77	0.87	0.68	12%	8%
Metallic Pigmented		Bin 15 Hydrocarbon Solvent	1.82	1.35	2.45	62%	42%
		Bin 22 Hydrocarbon Solvent	7.51	0.32	2.43	15%	41%
Nonflat - High Gloss	107211	Ethylene Glycol	3.03	0.35	1.05	26%	45%
	57556	Propylene Glycol	2.50	0.17	0.43	13%	19%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.75	0.33	0.25	25%	11%
	5444757	2-Ethylhexyl Benzoate	0.92	0.17	0.16	13%	7%
Nonflat - Low Gloss	107211	Ethylene Glycol	3.03	2.61	7.90	39%	57%
	57556	Propylene Glycol	2.50	0.93	2.33	14%	17%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.75	1.94	1.46	29%	11%
Nonflat - Medium Gloss	107211	Ethylene Glycol	3.03	3.31	10.03	28%	43%
	57556	Propylene Glycol	2.50	2.70	6.74	23%	29%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.75	3.83	2.89	33%	12%
Primer, Sealer, and Undercoater	107211	Ethylene Glycol	3.03	2.59	7.86	40%	63%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.75	1.67	1.26	26%	10%
		Bin 11 Hydrocarbon Solvent	0.91	0.76	0.69	12%	6%
Quick Dry Enamel		Bin 11 Hydrocarbon Solvent	0.91	2.33	2.12	72%	50%
		Bin 10 Hydrocarbon Solvent	2.03	0.34	0.70	11%	16%
Quick Dry Primer, Sealer, and Undercoater		Bin 6 Hydrocarbon Solvent	1.41	0.63	0.89	62%	57%
		Bin 11 Hydrocarbon Solvent	0.91	0.22	0.20	22%	13%
Rust Preventative		Bin 10 Hydrocarbon Solvent	2.03	1.87	3.79	21%	26%
		Bin 11 Hydrocarbon Solvent	0.91	3.86	3.51	44%	24%
		Bin 15 Hydrocarbon Solvent	1.82	1.21	2.20	14%	15%
	1330207	Xylene	7.72	0.25	1.94	3%	13%
Specialty Primer, Sealer, and Undercoater		Bin 22 Hydrocarbon Solvent	7.51	0.62	4.66	10%	44%
		Bin 11 Hydrocarbon Solvent	0.91	4.45	4.05	74%	38%
Stains - Clear/ Semitransparent		Bin 11 Hydrocarbon Solvent	0.91	3.87	3.52	59%	41%

Table E-4: ***Ingredients That Contribute the Most to Emissions and Potential Ozone (draft updated MIRs)***

Category	CAS	Ingredient	MIR (g O^3/ g ingr)	Ingred. Qty. (tpd)	Max. Ozone (tpd)	% of Total Volatiles For Category	% of Total Max. Ozone From Category
Varnishes - Clear		Bin 11 Hydrocarbon Solvent	0.91	2.77	2.52	70%	50%
		Bin 15 Hydrocarbon Solvent	1.82	0.41	0.75	10%	15%
Waterproofing Concrete/Masonry Sealers		Bin 22 Hydrocarbon Solvent	7.51	0.39	2.95	10%	35%
		Bin 6 Hydrocarbon Solvent	1.41	0.65	0.92	16%	11%
	67641	Acetone	0.35	0.55	0.20	14%	2%
	98566	4-Chlorobenzotrifluoride	0.12	0.58	0.07	14%	1%
Waterproofing Sealers		Bin 11 Hydrocarbon Solvent	0.91	0.61	0.55	38%	19%
	34590948	Dipropylene Glycol Methyl Ether	2.18	0.20	0.43	12%	15%
	107211	Ethylene Glycol	3.03	0.12	0.37	8%	13%
		Bin 23 Hydrocarbon Solvent	8.07	0.04	0.32	3%	11%

Notes:

1. The values in this table are based on draft updated MIR values that have not yet been officially adopted in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions". These draft updated values have been determined by Dr. William Carter for the research project titled "Reactivity Estimates for Selected Consumer Product Compounds" under Contract No. 06-408. The draft updated values were current as of December 24, 2007, and they are subject to change.
2. This table includes data from small containers (1 quart or less).
3. This table includes ozone generated from all volatile emissions, including VOCs and exempt compounds.

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Chapter 1 -- Introduction and Background

In April 2005, the Air Resources Board (ARB or Board) conducted a survey of companies that sold architectural coating products in California in 2004. The survey gathered detailed ingredient information for the volatile compounds contained in each coating product (ARB, 2006.) ARB staff used these ingredient data to analyze the photochemical reactivity (i.e., ozone-forming potential) associated with architectural coatings. This document is intended to provide different options for evaluating the reactivity of architectural coatings, but it is not a formal regulatory document.

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 (Bergin, 1998; Carter, 1994; NRC, 1991; NRC, 1999; Silman, 1995.) 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
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 (NRC, 1991.) 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:

$$VOC + OH \rightarrow RO_2 + \text{products}$$

$$RO_2 + \alpha NO \rightarrow \beta NO_2 + \text{radicals}$$

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

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 (Bergin, 1998; Carter, 1994.) Furthermore, processes like organic nitrate formation (e.g., peroxyacetyl 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 (Atkinson, 1994.)

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 (ARB, 1990.) In June 2000, the Board approved a reactivity-based regulation for aerosol coatings, based on the Maximum Incremental Reactivity (MIR) scale (ARB, 2000.) ARB's Aerosol Coating Regulation is provided in Appendix A. This regulation was approved by the United States Environmental Protection Agency (U.S. EPA) in 2005 (U.S. EPA, 2005.)

Section 1.3 Federal Policy on Reactivity-Based Regulations

In 2005, the U.S. EPA published a guidance document regarding the use of innovative reactivity-based approaches to achieve ozone reduction (U.S. EPA, 2005a.) This guidance encourages states to consider photochemical reactivity when developing control measures for state implementation plans (SIPs). U.S. EPA provided the following ways that reactivity could be addressed during the SIP development process:

- Develop speciated emission inventories to help identify the most reactive VOCs.
- Prioritize control measures based on reactivity.
- Target emissions of highly reactive VOCs with specific control measures.
- Encourage VOC substitution using reactivity-weighted emission limits.

U.S. EPA's guidance document supports the approach in ARB's Aerosol Coatings Regulation, which establishes reactivity limits based on individual ingredients rather than total VOC mass-based limits.

Section 1.4 ARB Suggested Control Measure for Architectural Coatings

Architectural coatings are a large source of VOC emissions. In 2004, architectural coatings and associated solvents emitted almost **95** tons per day from coatings only and more than **20** tons per day from thinning/cleanup/additives, for a total of **115** tons per day, on an annual average basis. The **95** tons per day from coatings represent about **8%** of the total stationary and area source VOC emissions, and about **4%** of all VOC emissions statewide. 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, 2000, and 2007. These SCMs have been used as models for Districts when adopting and amending their local rules. As of January 2008, **20** local air districts had adopted the architectural coating limits from the 2000 SCM.

During the June 2000 Board meeting, Board members approved an SCM update and adopted Resolution 00-23. This Resolution 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. In June 2001, December 2002, and January 2004, ARB staff provided updates to the Board, regarding progress in implementing Resolution 00-23 (ARB, 2001; ARB, 2002; ARB, 2004.) A brief summary of ARB's progress is provided below:

(1) ARB funded a $300,000 research project with the University of California, Riverside that included conducting chamber experiments to verify the chemical mechanisms used to identify the maximum incremental reactivities for some key solvents in architectural coatings. These solvents included Texanol® and six hydrocarbon solvents. The final report for this project was completed in March 2005.
(2) In 2001 and 2005, ARB conducted comprehensive surveys of the architectural coatings industry. Results from these surveys are summarized in the "2001 Architectural Coatings Survey, Final Report, October 2003" and the "2005 Architectural Coatings Survey, Final Report, December 2007".
(3) ARB used the data from these surveys to estimate the reactivity of architectural coatings. The results from the 2001 survey were contained in the "2001 Architectural Coatings Survey, Final Reactivity Analysis, March 2005". The results from the 2005 survey 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.

In Spring 2006, ARB staff began working with stakeholders to develop an updated version of the 2000 SCM. During the development process, staff evaluated the potential for replacing mass-based VOC limits with reactivity-based limits. Staff also considered using a reactivity-based approach to create a new exemption for products that exceed mass-based limits. During 2006 and 2007, staff worked with districts and industry representatives to investigate reactivity-based options. Since districts are responsible for architectural coatings rules, district personnel would be responsible for enforcing reactivity-based limits. Districts expressed concerns that implementation of a reactivity-based rule would require additional resources for enforcement. If district personnel wanted to determine the reactivity of a product for enforcement purposes, they would need to obtain detailed chemical formulation data to identify all of the volatile ingredients contained in the product. They would then need to identify the appropriate maximum incremental reactivity (MIR) value for each of these ingredients, so they could calculate the overall reactivity for the product. District personnel would also need to develop a system for updating MIR values to accommodate changes that result from research studies.

Only some industry representatives were supportive of a reactivity-based approach. ARB staff met with industry groups in the Spring and Fall of 2006 to discuss reactivity. In addition, ARB conducted several meetings with individual coating manufacturers and raw material suppliers to discuss their concerns. No consensus regarding reactivity-based limits could be achieved among coating manufacturers.

ARB staff concluded that many districts have insufficient resources to implement and enforce reactivity-based limits or exemptions. In addition, the U.S. EPA had concerns regarding the implementation and enforcement of a reactivity-based exemption. Based on the lack of district resources, U.S. EPA's concerns, and the lack of industry consensus, staff decided to propose mass-based VOC limits for the updated SCM.

During the October 2007 Board meeting, Board members approved the updated SCM with mass-based VOC limits and adopted Resolution 07-46. This Resolution directed ARB staff to continue to work with industry and other stakeholders on assessing the ozone-forming potential (reactivity) of architectural coatings. This analysis is to include:

- Assessing the reactivity of individual VOC species in consideration of the best available science;
- Assessing the extent to which VOC s emitted from architectural coatings contribute to ozone levels; and
- Conducting a comprehensive survey of the architectural coatings industry.

Staff currently plans to conduct another architectural coatings survey in 2011 to gather data from calendar year 2010. Staff expects the survey to be similar to the survey conducted in 2005 to gather data from calendar year 2004. This survey will reflect the products that have been reformulated to meet the VOC limits effective in the SCAQMD from 2005 to 2008, and the proposed SCM limits that take effect in 2010. Data from the survey will be analyzed to assess the reactivity of architectural coatings.

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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 (Carter, 1994.)

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 (McNair, 1992.) 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 (Bergin, 1995; Bergin, 1998a.) 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 U.S. Environmental Protection Agency participated in the Reactivity Research Working Group that worked 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 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 (Carter, 1994; McNair, 1992; Bergin, 1995.) 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 (Carter, 2003.) 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 (ARB, 2004; CCR, 2004.) For water and solid ingredients, ARB staff used an MIR value of zero.

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 (ARB, 2000.) 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 2005 Architectural Coatings Survey.

Dr. Carter's MIR scale and the ARB hydrocarbon solvent bins provided MIR values for **95** percent by weight of the organic compounds reported in the 2005 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.

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

Type of Compound	**Default MIR Values (g Ozone/g TOG)**	
	Solventborne	*Waterborne*
Exempt Compounds	0.36	0.43
Hydrocarbon Solvents	1.59	2.00
Other (non-exempt, non-hydrocarbon solvent VOCs)	3.86	2.73

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

Section 2.2 Maximum Ozone Formation Potential

MIR values and VOC emission quantities can be used to estimate the amount of ozone that could potentially be formed under MIR conditions (i.e., the maximum ozone formation potential). Since the goal of the architectural coatings regulations is ozone reduction, it is important to identify which products and categories may create the most ozone. Estimating actual atmospheric ozone concentrations involves the use of complicated computer modeling programs that analyze emission data, meteorological data, MIR values, and other information. This type of modeling effort is outside the scope of this reactivity analysis. For the purposes of this report, we use the maximum ozone formation potential to provide a comparison of the relative contributions from different coating categories and identify categories that may be candidates for achieving additional ozone reductions.

Emissions data can be converted to maximum ozone formation potentials by using the ingredient information collected in ARB's Architectural Coating Surveys. The surveys gather data on the weight percentages of each ingredient in each coating and the density of each coating. Using this information, we can determine the mass of each ingredient in each product. This mass can then be multiplied by the MIR value for each ingredient to yield the maximum ozone formation potential, as described in the following equations:

(1) Calculate the mass of each ingredient in each product:

$$[\text{Ingredient Mass, lbs}]_i = [\text{Sales, gals}]*[\text{Density, lbs/gal}]*[\text{Ingredient Weight \%}]_i$$

(2) Calculate the maximum potential ozone generated from each ingredient in each product:

$$[\text{Ozone from Ingredient, lbs}]_i = [\text{Ingredient Mass, lbs}]_i *[\text{MIR, gram Ozone/gram ingred.}]_i$$

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 ingredients in all products:

$$[\text{Total Ozone, lbs}] = [\text{Ozone from Ingred., lbs}]_1 +[\text{Ozone from Ingred., lbs}]_2 +\ldots+ [\text{Ozone from Ingred., lbs}]_n$$

where $[\text{Ingredient Mass}]_i$ = The amount of each ingredient "i" in each coating product, pounds
Sales = Sales of each coating product, gallons
Density = Density of each coating product, pounds/gallon
$[\text{Ingredient Weight \%}]_i$ = Weight percent of each ingredient "i" in each coating product
$[\text{MIR}]_i$ = the MIR of each ingredient "i" in each coating product, grams ozone/gram ingredient
(Note: For solids and water, the MIR is zero.)
$[\text{Ozone from Ingredient}]_i$ = the maximum potential amount of ozone generated under MIR conditions by each ingredient "i" in each coating product, pounds
n = the total number of ingredients in all coating products

Table 2-2 contains a summary of maximum potential ozone quantities under MIR conditions. The survey gathered data for more than **11,200** products and product groupings. For approximately **80** products (which accounted for only **0.2** 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 the products with missing ingredient data.

Table 2-2 contains two types of information: (1) Data based on the official MIR values published in ARB's Aerosol Coatings regulation, as updated in July 2004 (CCR, 2004); and (2) Data based on draft updated MIR values that have not yet been officially adopted (Carter, 2007). For some key ingredients in architectural coatings, the draft updated MIRs used in Table 2-2 provide more accurate results.

Table 2-2: ***Maximum Ozone Formation Potential (Tons/Day)***

	Official MIRs			Draft Updated MIRs		
Coating Category	**SB**	**WB**	**All**	**SB**	**WB**	**All**
Bituminous Roof	1.05	0.07	1.12	1.05	0.06	1.11
Bituminous Roof Primer	0.48	0.02	0.50	0.48	0.02	0.50
Bond Breakers	0.01	0.75	0.77	0.01	0.30	0.31
Clear Brushing Lacquer	1.06	NA	1.06	0.98	NA	0.98
Concrete Curing Compounds	0.72	0.84	1.57	0.65	0.73	1.38
Driveway Sealer	0.04	0.04	0.08	0.04	0.03	0.07
Dry Fog	1.51	0.21	1.72	1.43	0.16	1.60
Faux Finishing	0.03	0.94	0.97	0.03	0.73	0.76
Fire Resistive	0.04	0.00	0.04	0.04	0.00	0.04
Fire Retardant - Clear	0.02	NA	0.02	0.02	NA	0.02
Fire Retardant - Opaque	0.90	0.00	0.91	0.89	0.00	0.89
Flat	0.10	36.61	36.72	0.10	23.25	23.35
Floor	1.00	5.25	6.25	0.99	3.88	4.88
Form Release Compounds	1.29	0.03	1.32	1.29	0.03	1.31
Graphic Arts	0.02	0.00	0.02	0.02	0.00	0.02
High Temperature	0.14	NA	0.14	0.14	NA	0.14
Industrial Maintenance	13.24	1.66	14.90	13.08	1.44	14.52
Lacquers	8.51	0.74	9.25	7.66	0.65	8.31
Low Solids	NA	0.10	0.10	NA	0.08	0.08
Magnesite Cement	0.72	NA	0.72	0.72	NA	0.72
Mastic Texture	0.27	0.73	1.00	0.23	0.58	0.81
Metallic Pigmented	5.80	0.25	6.06	5.81	0.07	5.88
Multi-Color	0.00	0.01	0.01	0.00	0.01	0.01
Nonflat - High Gloss	0.27	3.54	3.81	0.25	2.10	2.35
Nonflat - Low Gloss	0.03	18.56	18.59	0.02	13.82	13.84
Nonflat - Medium Gloss	0.46	29.18	29.64	0.43	22.94	23.38
Other	0.07	0.01	0.08	0.07	0.01	0.08
Pre-Treatment Wash Primer	0.02	0.00	0.02	0.02	0.00	0.02
Primer, Sealer, and Undercoater	1.22	17.17	18.39	1.14	11.30	12.45
Quick Dry Enamel	4.45	0.17	4.61	4.13	0.15	4.28
Quick Dry Primer, Sealer, and Undercoater	1.69	0.01	1.69	1.57	0.00	1.57
Recycled	0	0	0	0	0	0
Roof	0.43	0.72	1.15	0.28	0.59	0.87
Rust Preventative	15.31	0.20	15.52	14.53	0.18	14.71

Table 2-2: ***Maximum Ozone Formation Potential (Tons/Day)***

	Official MIRs			Draft Updated MIRs		
Coating Category	**SB**	**WB**	**All**	**SB**	**WB**	**All**
Sanding Sealers	0.50	0.04	0.53	0.48	0.03	0.52
Shellacs - Clear	0.55	NA	0.55	0.47	NA	0.47
Shellacs - Opaque	1.28	NA	1.28	1.09	NA	1.09
Specialty Primer, Sealer, and Undercoater	11.09	0.56	11.64	10.24	0.44	10.68
Stains - Clear/Semitransparent	8.11	0.70	8.81	7.92	0.57	8.49
Stains - Opaque	0.15	1.24	1.39	0.15	0.93	1.08
Swimming Pool	0.19	0.03	0.22	0.19	0.02	0.22
Swimming Pool Repair and Maintenance	0.11	NA	0.11	0.11	NA	0.11
Traffic Marking	2.35	1.90	4.24	2.32	1.72	4.05
Varnishes - Clear	4.70	0.84	5.54	4.39	0.66	5.05
Varnishes - Semitransparent	0.42	0.00	0.43	0.40	0.00	0.40
Waterproofing Concrete/Masonry Sealers	7.17	1.48	8.65	7.27	1.24	8.51
Waterproofing Sealers	1.32	2.12	3.43	1.33	1.60	2.93
Wood Preservatives	0.95	0.01	0.96	0.94	0.01	0.95
Totals:	**99.8**	**126.7**	**226.5**	**95.4**	**90.4**	**185.8**

Notes:

1. This table contains Maximum Potential Ozone formed under MIR conditions.
2. "Official MIRs": Data based on the official MIR values published in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions", California Code of Regulations, Title 17, sections 94700 and 94701, as updated July 7, 2004
3. "Draft Updated MIRs": Data based on draft updated MIR values that have not yet been officially adopted by ARB. These draft values have been determined by Dr. William Carter for the research project titled "Reactivity Estimates for Selected Consumer Product Compounds" under Contract No. 06-408. The draft updated values were current as of December 24, 2007, and they are subject to change.
4. "NA": Not applicable, because no coating sales were reported in this subcategory.
5. For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.
6. For Recycled coatings, maximum potential ozone is zero because it is assumed that the ozone should be associated with the sales of the original product, prior to recycling.
7. This table includes data from small containers (1 quart or less).
8. This table includes ozone generated from all volatile emissions, including VOCs and exempt compounds.

The breakdown between solventborne and waterborne ozone is graphically illustrated in Figure 2-1. Solventborne coatings only account for 12% of the total coating sales in California, but they represent 44% of the potential ozone. This is due to the fact that solventborne coatings generally contain more pounds of VOC per gallon than waterborne coatings. Overall, this higher level of VOCs results in solventborne coatings generating more potential ozone per gallon than waterborne coatings. Figure 2-1 is based on the official MIR values published in ARB's Aerosol Coatings regulation, as updated in July 2004 (CCR, 2004).

Figure 2-1
Waterborne and Solventborne Maximum Potential Ozone

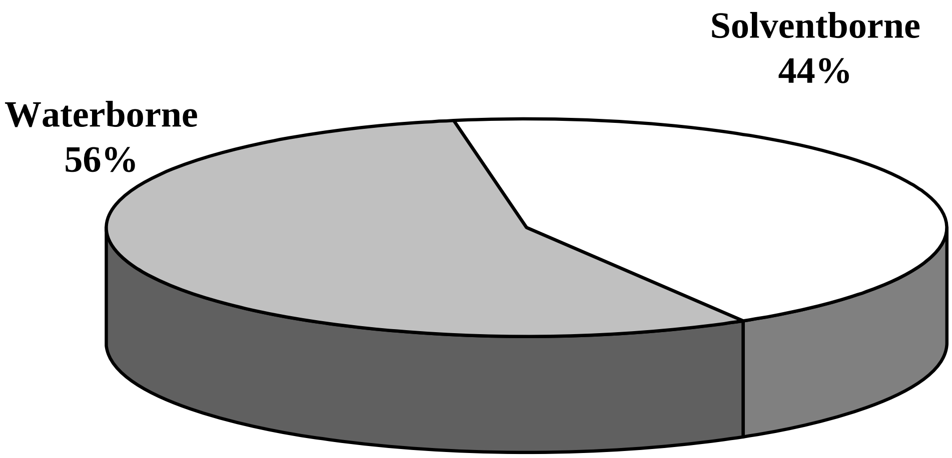


Figure 2-2 is a chart that highlights the top ten coating categories, based on maximum potential ozone formed under MIR conditions. Ten categories account for 76% of the potential ozone, while the remaining 38 categories account for 24%. Flat coatings represent 1/3 of total architectural coating sales, but Flat coatings only generate 1/6 of the potential ozone. Figure 2-2 is based on the official MIR values published in ARB's Aerosol Coatings regulation, as updated in July 2004 (CCR, 2004).

Figure 2-2
Top 10 Categories for Maximum Potential Ozone

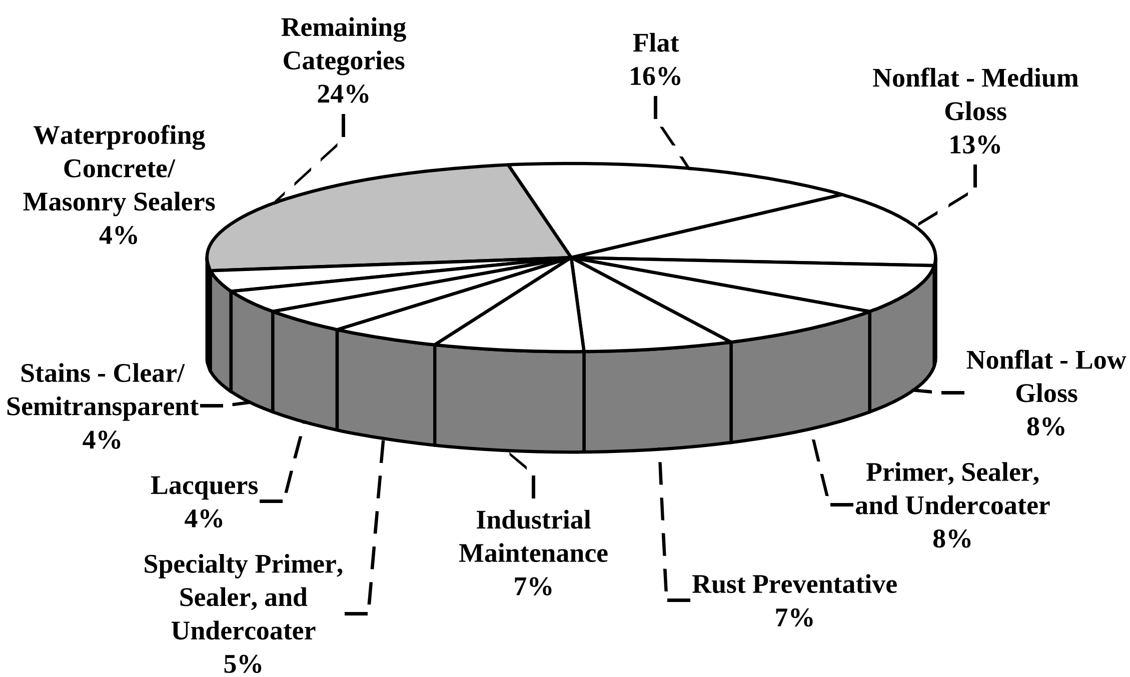
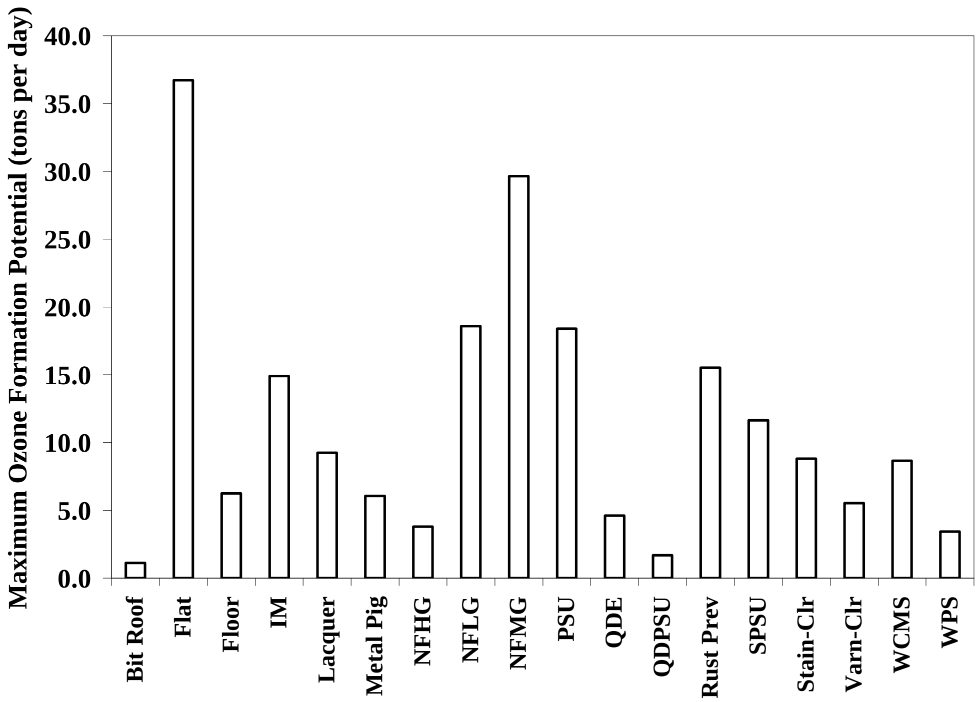


Figure 2-3 illustrates the "Maximum Ozone Formation Potential" for selected categories. Detailed data for all categories are provided in Table 2-2. Figure 2-3 is based on the official MIR values published in ARB's Aerosol Coatings regulation, as updated in July 2004 (CCR, 2004).

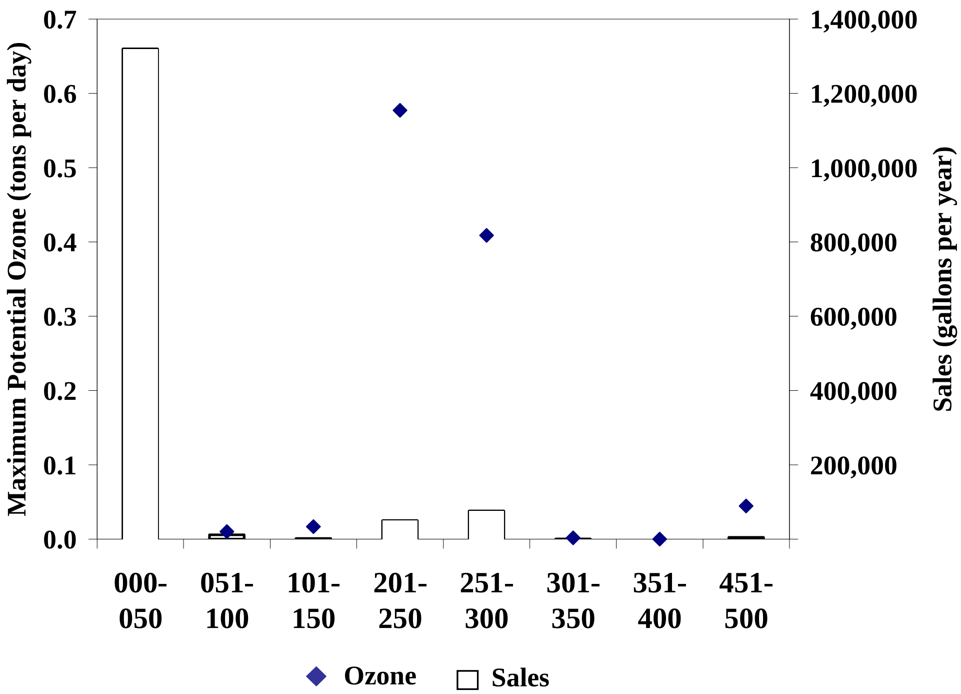
Figure 2-3
Maximum Ozone Formation Potential by Category



Notes:
1. [Maximum Ozone Formation Potential] = ∑ [Ingredient Emissions, tons/day]*[MIR, g Ozone/g Ingredient]
2. This figure includes data from small containers (1 quart or less).
3. This figure includes ozone generated from all volatile emissions, including VOCs and exempt compounds.
4. For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.

Figures 2-4 to 2-21 plot "Maximum Ozone Formation Potential" (tons/day) against "VOC Regulatory" values in 50-gram/liter increments. The figures also contain "Sales" (gallons/year) plotted against "VOC Regulatory". Figure 2-4 to 2-21 are based on the official MIR values published in ARB's Aerosol Coatings regulation, as updated in July 2004 (CCR, 2004). The figures include data from small containers and they represent ozone generated by emissions from all volatile compounds, including VOCs and exempt compounds. Figures are only included for selected categories. Detailed data for all categories are provided in Appendix B.

Figure 2-4
Bituminous Roof



This figure shows that the majority of the sales for this category had a low VOC content (< 50 g/l) and these low-VOC products generated a relatively small amount of potential ozone. Products in the mid-range (200-300 g/l) generated most of the potential ozone, even though their sales were relatively small. This indicates that these mid-range products contained much more reactive solvents on a per-gallon basis as compared to the low-VOC products.

This figure is not typical of the ozone/sales figures in this chapter, as is shown on subsequent charts. In most cases, high amounts of ozone correspond to high sales volumes and low amounts of ozone correspond to low sales volumes. For those cases where the ozone diamond is much higher than the sales bar, that indicates products with relatively high reactivity per gallon. For those cases where the ozone diamond is far below the top of the sales bar, that indicates products with relatively low reactivity per gallon.

Figure 2-5
Flat

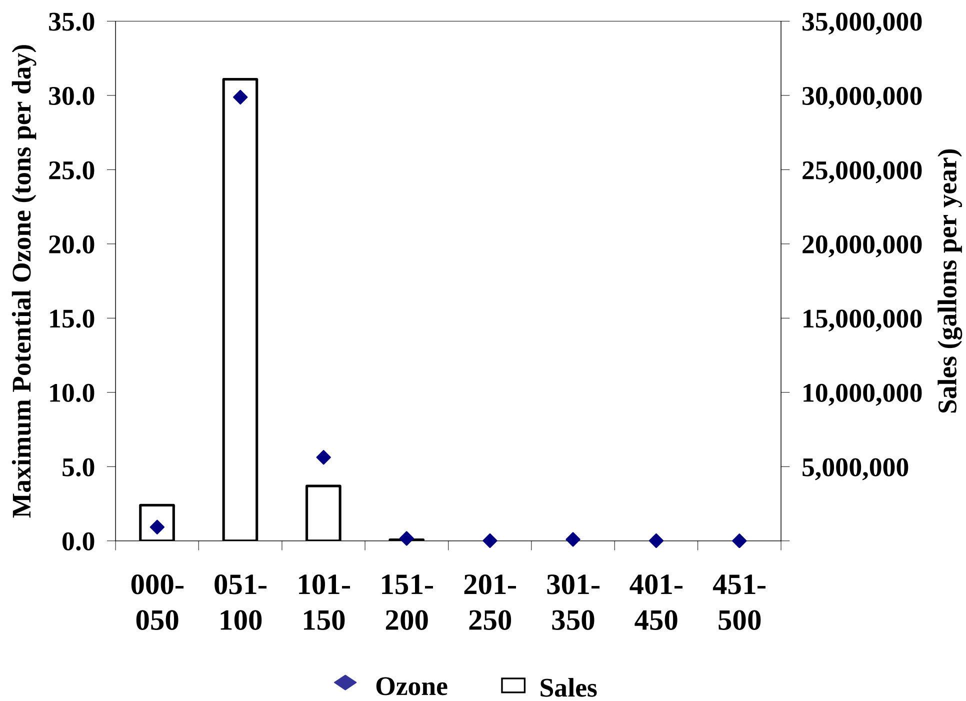
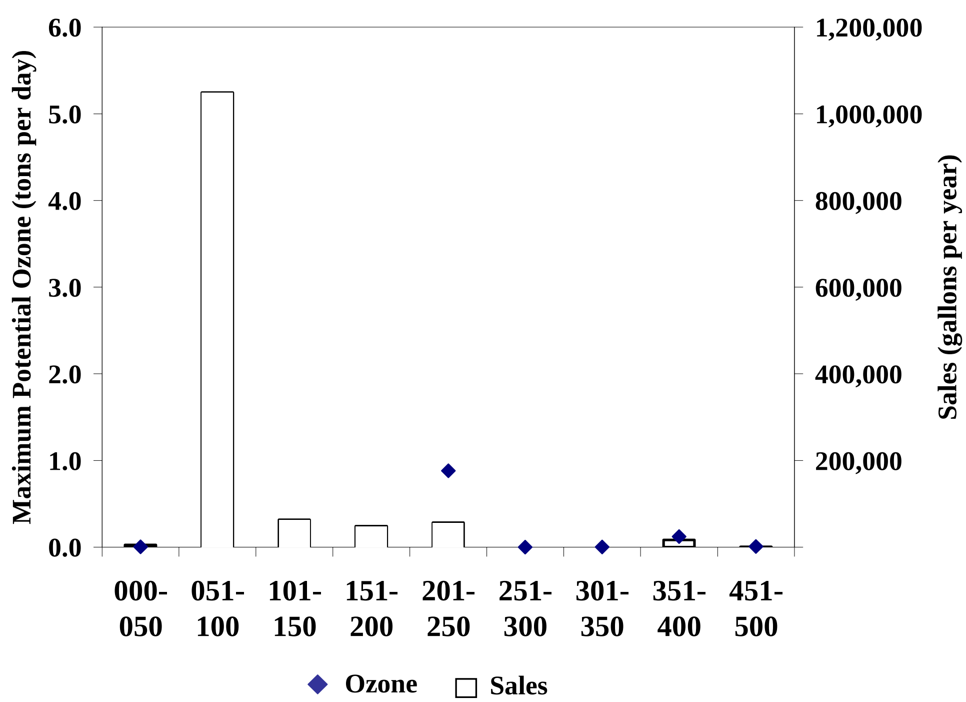


Figure 2-6
Floor



For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.

Figure 2-7
Industrial Maintenance

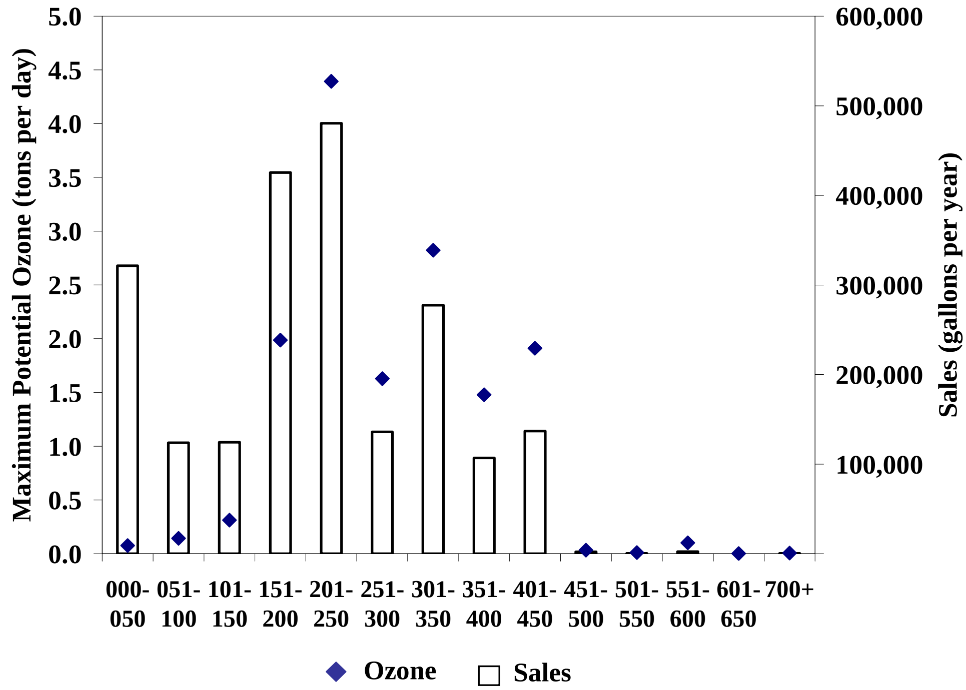


Figure 2-8
Lacquers

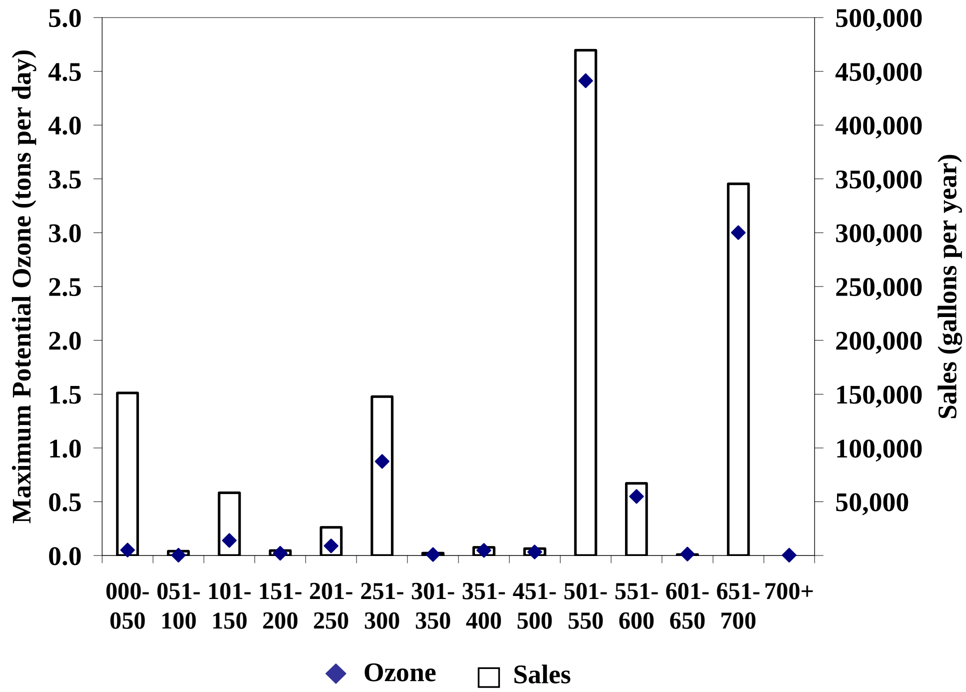


Figure 2-9
Metallic Pigmented

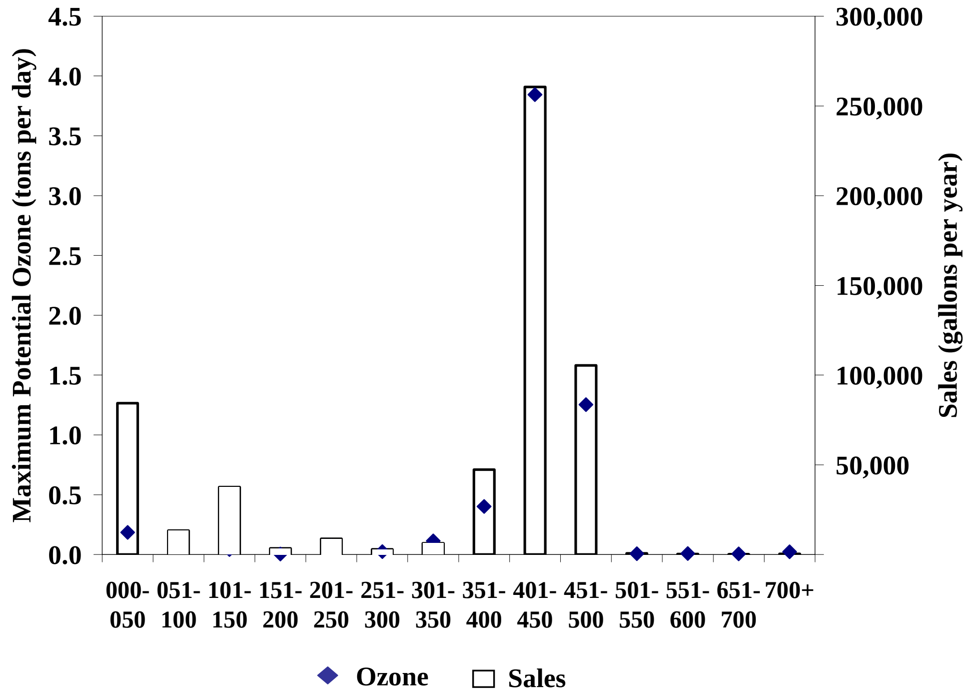


Figure 2-10
Nonflat – High Gloss

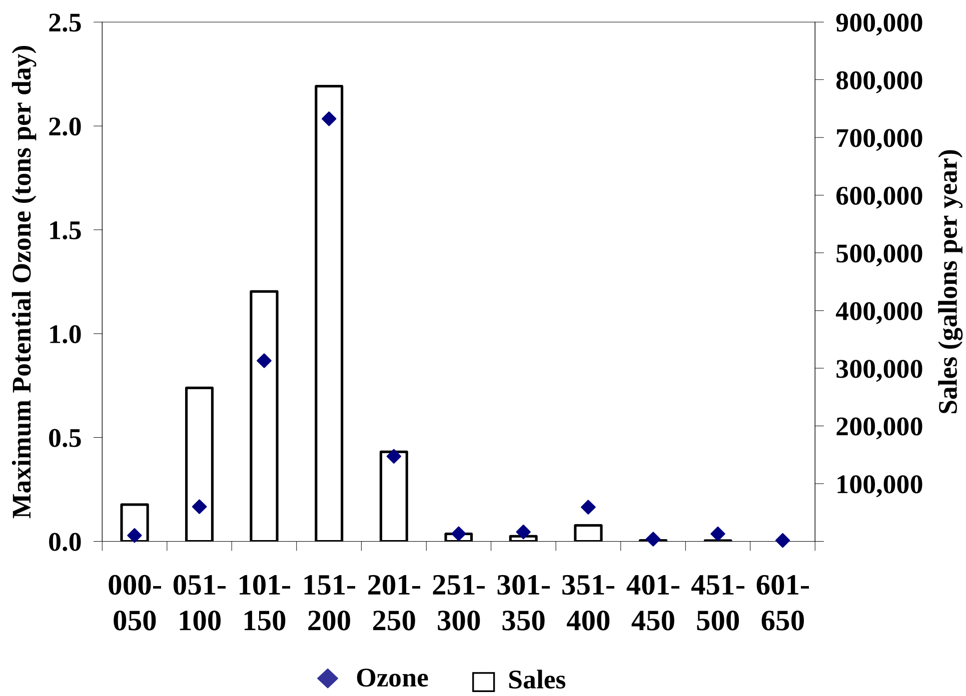


Figure 2-11
Nonflat – Low Gloss

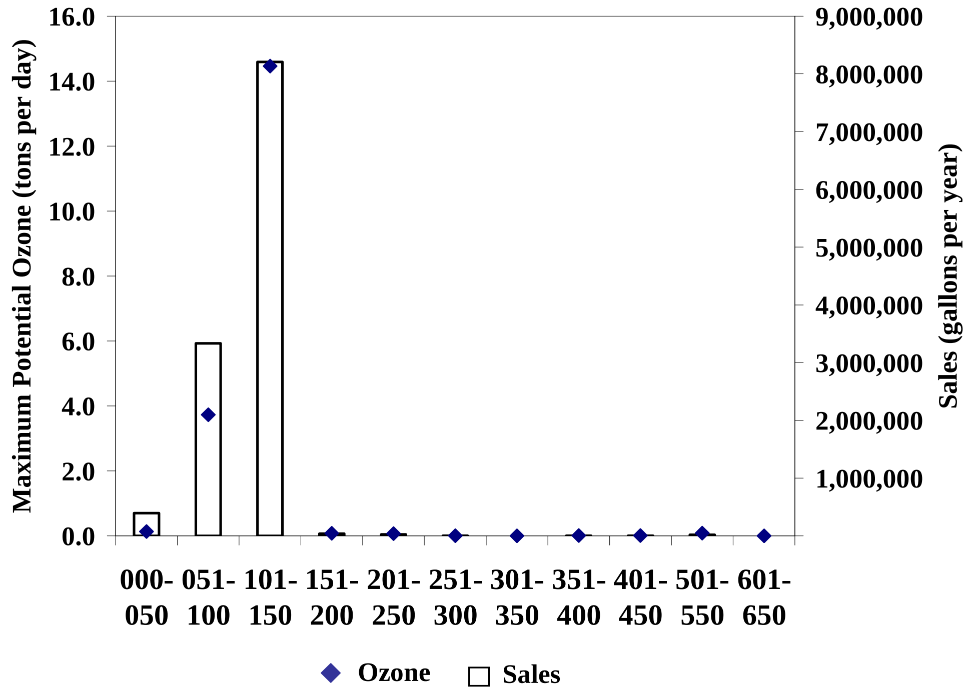


Figure 2-12
Nonflat – Medium Gloss

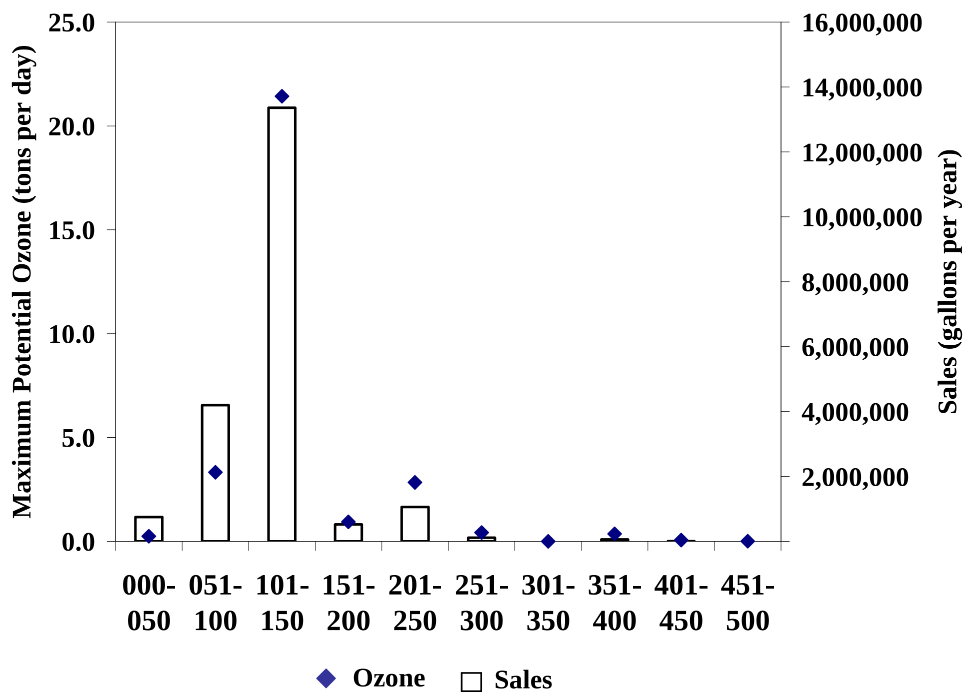


Figure 2-13
Primer, Sealer, Undercoater

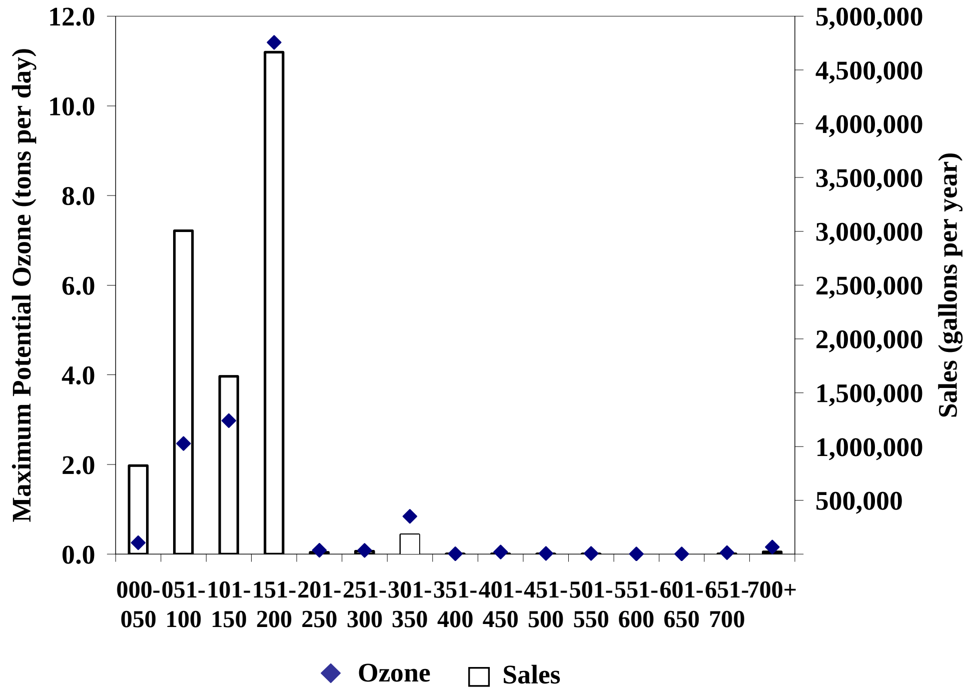


Figure 2-14
Quick Dry Enamel

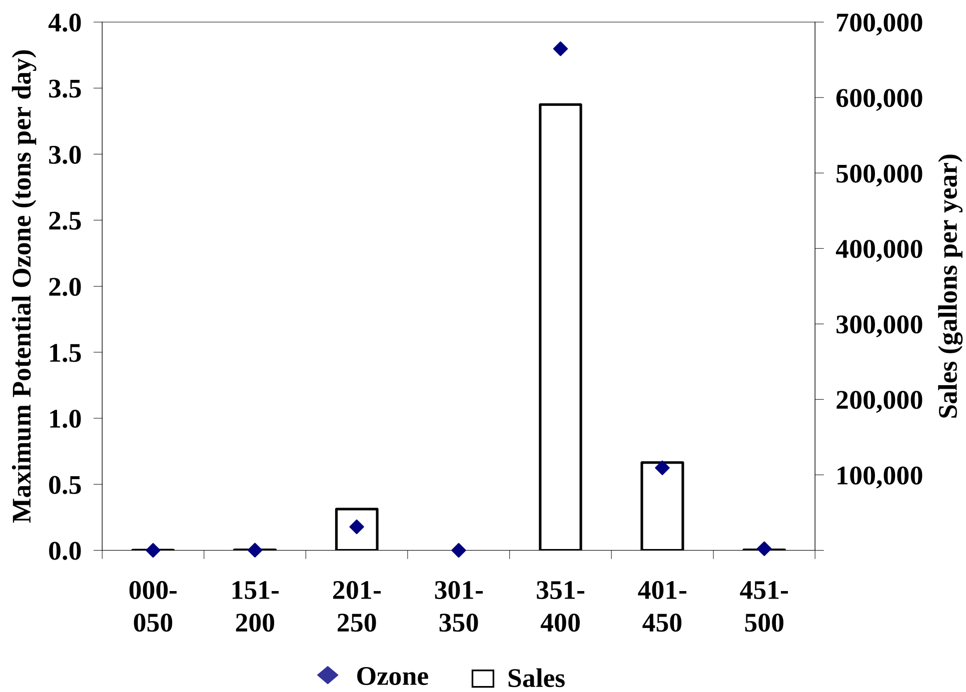


Figure 2-15
Quick Dry Primer, Sealer, Undercoater

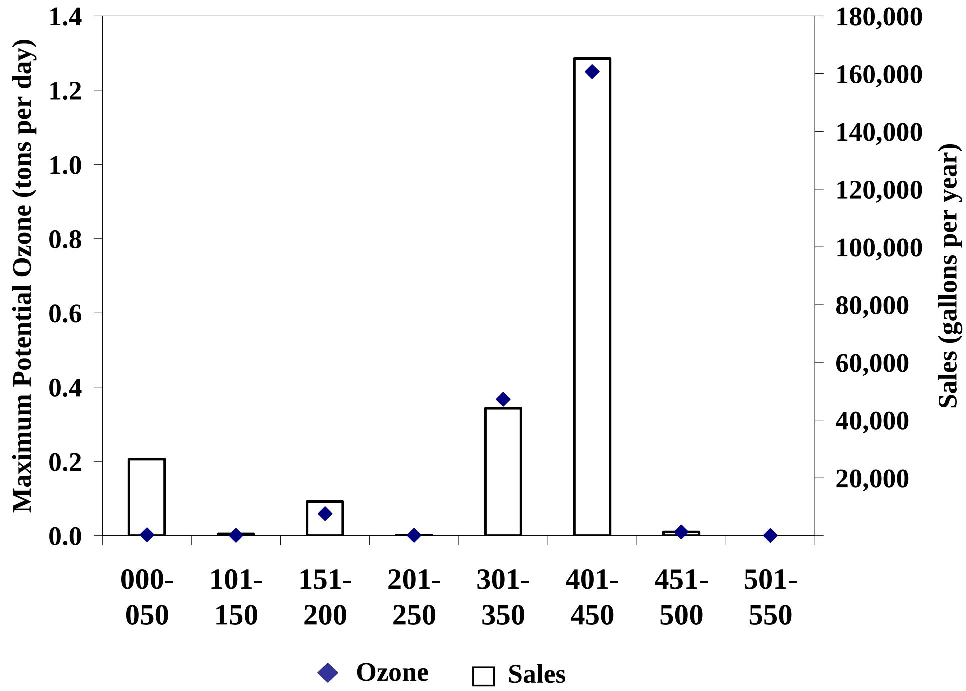


Figure 2-16
Rust Preventative

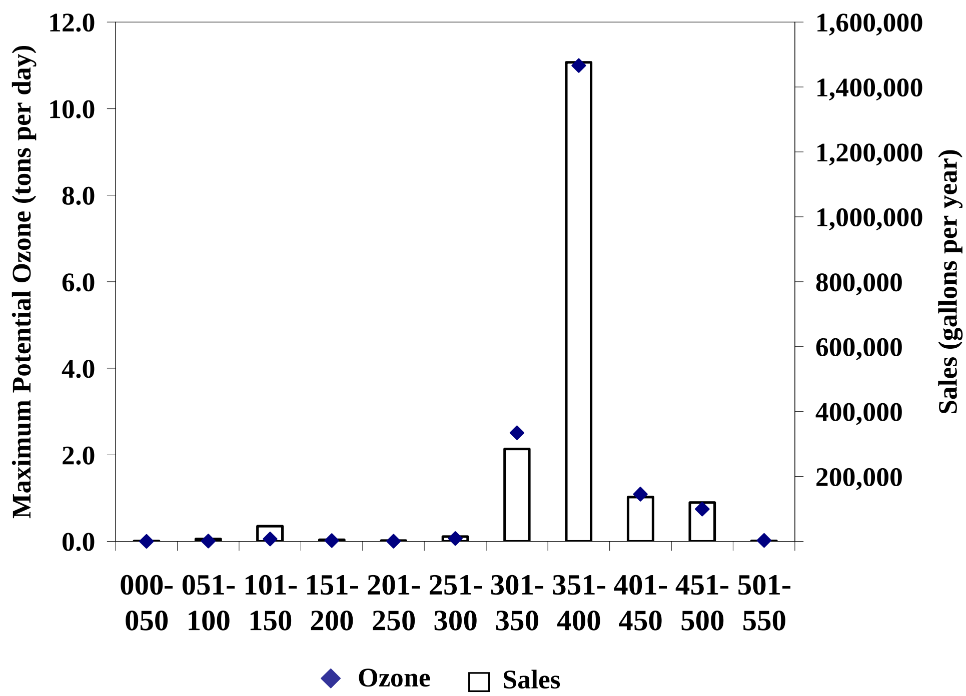


Figure 2-17
Specialty Primer, Sealer, Undercoater

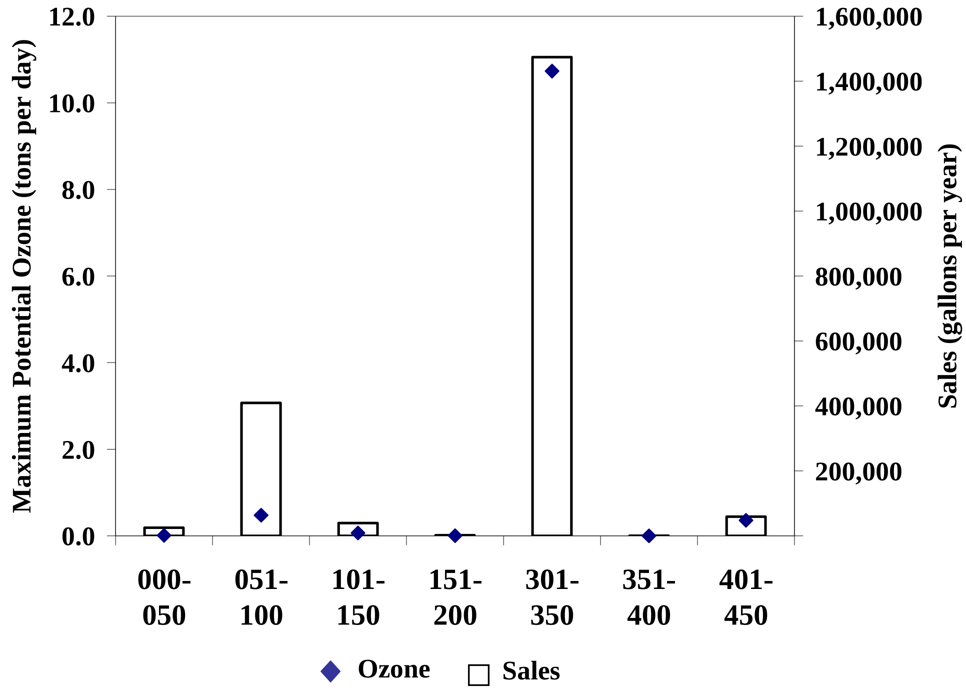


Figure 2-18
Stains – Clear/Semitransparent

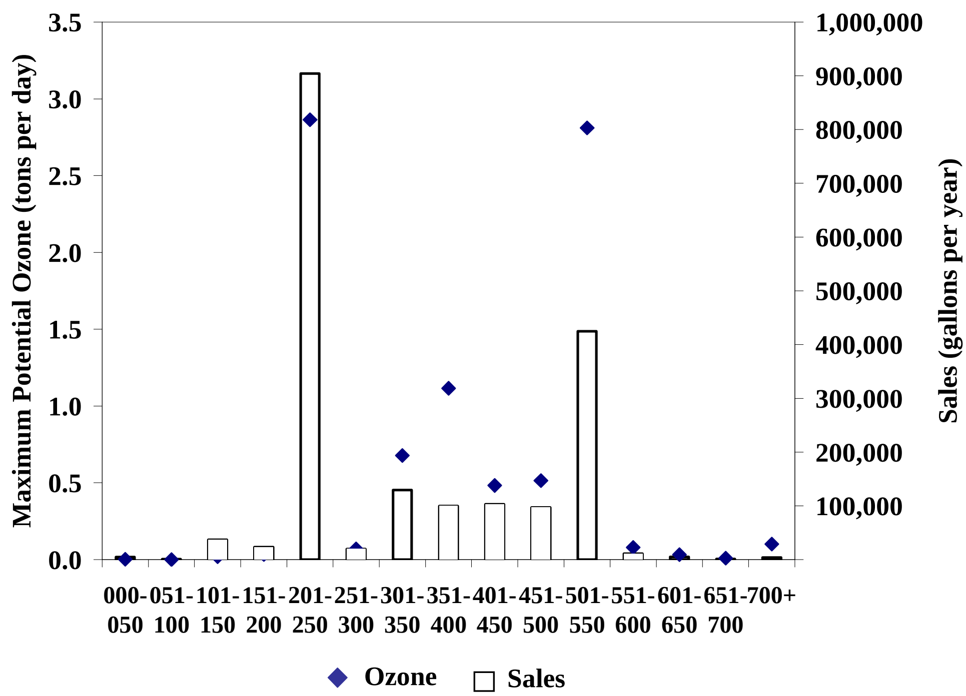


Figure 2-19
Varnishes - Clear

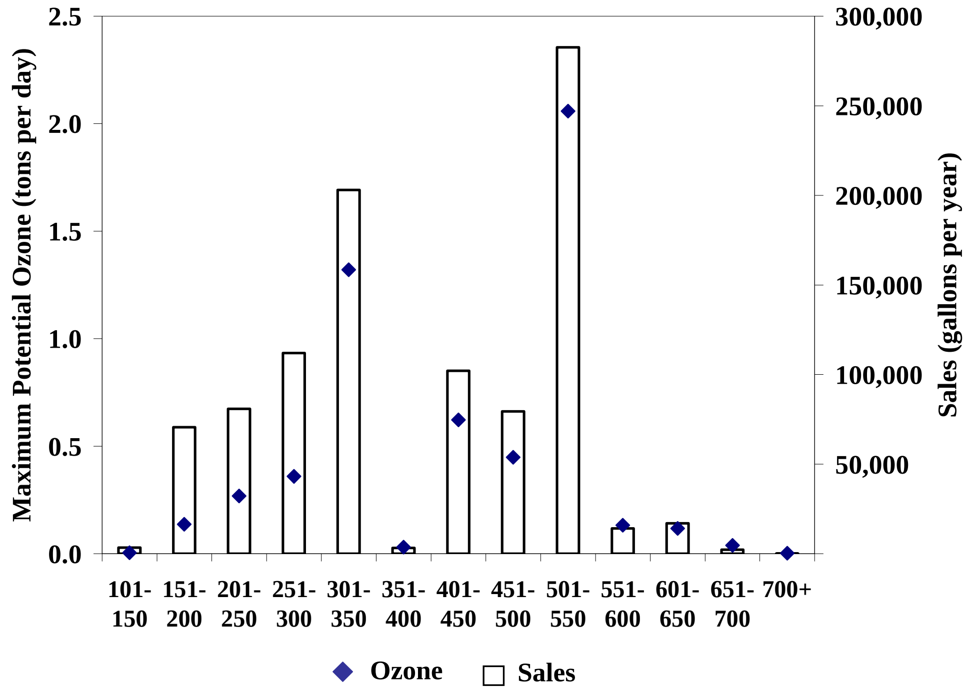


Figure 2-20
Waterproofing Concrete/Masonry Sealers

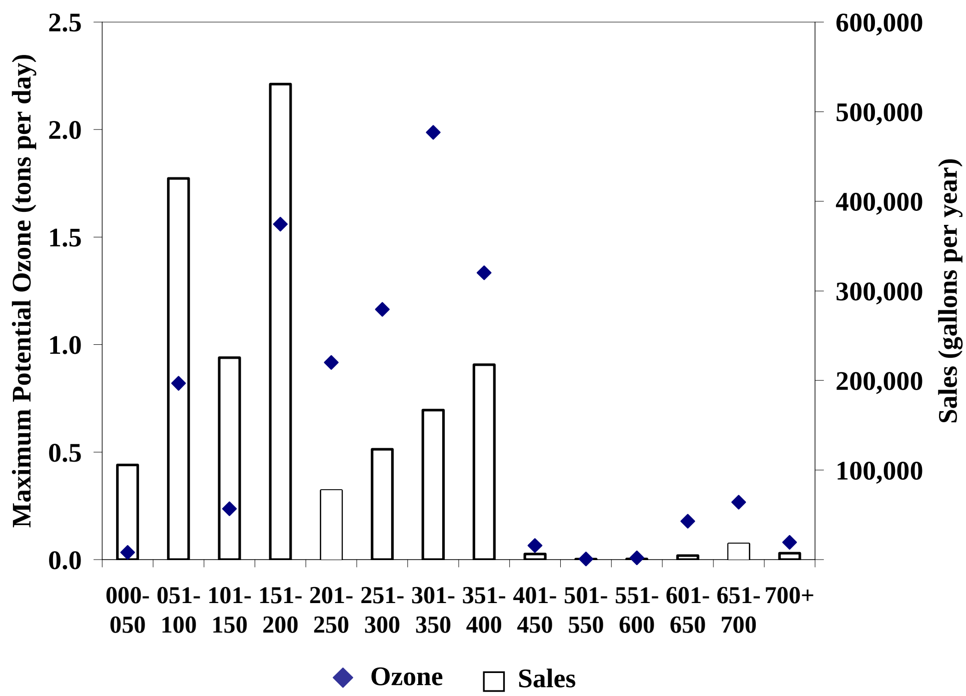
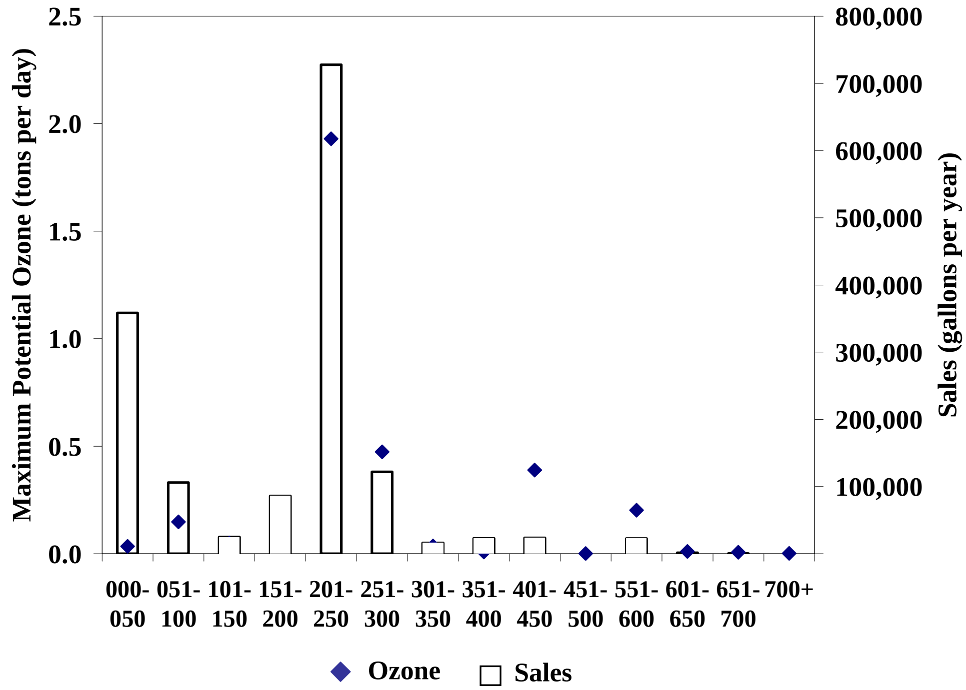


Figure 2-21
Waterproofing Sealers



Section 2.3 Possible Reactivity Formats

After determining the maximum ozone formation potential, it is necessary to normalize the values in a way that allows comparison between the different coating categories. In this section we will be considering the following possible approaches:

- Ozone Per Pound of Coating
- Ozone Per Gallon of Coating
- Ozone Per Pound of Solids
- Ozone Per Gallon of Solids

"Ozone Per Pound of Coating" is equivalent to the format that is used in ARB's Aerosol Coatings Regulation. For aerosol coatings, ARB has defined a "Product-Weighted MIR" (PWMIR) in units of grams ozone per gram product. The advantage of using a similar format would be consistency between aerosol coatings and architectural coatings reactivity-based regulations. In addition, U.S. EPA has already approved ARB's Aerosol Coatings Regulation. Therefore, using a similar approach would be helpful in obtaining U.S. EPA approval if districts adopted reactivity-based architectural coatings regulations. "Ozone Per Pound of Coating" was calculated as shown below:

[Ozone Per Pound of Coating] = [Total Ozone, lbs]/[Coating Mass, lbs]

[Coating Mass, lbs] = [Coating Sales, gallons]*[Coating Density, lb/gal]

These equations yield the same format as the Aerosol Coating Product-Weighted MIR which is calculated as follows:

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

where

$[Wt\%]_i$ = the weight percent of each ingredient in a coating product (e.g., 0.25 for 25%)
$[MIR]_i$ = 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:

Coating Sales = 5,000 gals
Coating Density = 9 lbs/gal
Coating Mass = [5,000 gals]*[9 lbs/gal] = 45,000 lbs

Ingredient	**CAS #**	**Wt %**	**Ingr. Mass (lbs ingred)**	**MIR (gram O_3/ gram ingred)**	**Maximum Potential Ozone (lbs O3)**
1,2-Propanediol	57-55-6	4%	1,800	2.74	4,932
2,2,4-Trimethyl-1,3-Pentanediol Monoisobutyrate	25265-77-4	2%	900	0.88	792
2-(2-Butoxyethoxy)-Ethanol	112-34-5	4%	1,800	2.87	5,166
2-(2-Methoxyethoxy)-Ethanol	111-77-3	3%	1,350	2.88	3,888
Water	7732-18-5	54%	24,300	0	0
Solids		33%	14,850	0	0
	TOTAL =	**100%**	**45,000 lbs**		**14,778 lbs O3**
Lbs Ozone Per Lb Coating = [14,778]/[45,000] = **0.33**					

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				

"Ozone Per Gallon of Coating" is similar to the format of "VOC Actual" which expresses "VOC Emissions Per Gallon of Coating". It's also similar to the format of emission factors for coatings which can be used to develop emission inventories. "Ozone Per Gallon of Coating" was calculated as shown below:

[Ozone Per Gallon of Coating] = [Total Ozone, lbs]/[Coating Sales, gallons]

"Ozone Per Pound of Solids" is similar to the format that U.S. EPA uses for wood coatings rules. The National Emission Standards for Hazardous Air Pollutants (NESHAPs) for Wood Furniture Manufacturing includes emission limits in units of "lb VHAP/lb solids" (i.e., pounds of volatile hazardous air pollutant per pound of solids). According to U.S. EPA, "…The traditional method for coatings of g/L less water is not appropriate for HAP's because there is not always a direct relationship between the HAP content of a coating and the solids content of a coating..." (U.S. EPA, 1995) For the sake of consistency, U.S. EPA used similar units for their Control Techniques Guidelines (CTG) for wood furniture manufacturing operations which has emission limits in units of "lb VOC/lb solids" (i.e., pounds of volatile organic compounds per pound of solids) (U.S. EPA, 1996.) U.S. EPA also considered units of "lb VOC/gallon solids", but they were concerned that there was no U.S. EPA test method available to accurately measure the volume of solids.

[Ozone Per Pound of Solids] = [Total Ozone, lbs]/[Solids Mass, lbs]

[Solids Mass, lbs] = [Coating Sales, gallons]*[Coating Density, lb/gal]*[Weight % Solids]

"Ozone Per Gallon of Solids" is a format that some consider to be the most appropriate format, because it is based on the volume of coating film that actually remains on the substrate after all of the volatiles have evaporated. In addition, volume of solids corresponds to coverage and dry film thickness, which are critical parameters for many coatings.

[Ozone Per Gallon of Solids] = [Total Ozone, lbs]/[Solids Volume, gallons]

[Solids Volume, gals] = [Coating Sales, gallons]*[Volume % Solids]

Table 2-3 summarizes the various formats for each coating category. Detailed data are contained in Appendix B for the following formats: Ozone Per Pound of Coating; Ozone Per Gallon of Coating; and Ozone Per Gallon of Solids. The data in Table 2-3 are based on the official MIR values published in ARB's Aerosol Coatings regulation, as updated in July 2004 (CCR, 2004). For comparison purposes, Table 2-4 contains data that are based on draft updated MIR values that have not yet been officially adopted (Carter, 2007). For some key ingredients in architectural coatings, the draft updated MIRs used in Table 2-4 provide more accurate results.

Table 2-3: ***Possible Ozone Reactivity Formats (official MIRs)***

	Lb Ozone Per Lb Coating			*Lb Ozone Per Gal Coating*			*Lb Ozone Per Lb Solids*			*Lb Ozone Per Gal Solids*		
Coating Category	**SB**	**WB**	**All**	**SB**	**WB**	**All**	**SB**	**WB**	**All**	**SB**	**WB**	**All**
Bituminous Roof	0.7	0.0	0.1	5.8	0.0	0.6	0.9	0.0	0.1	8.3	0.1	1.1
Bituminous Roof Primer	0.8	0.2	0.7	5.9	1.7	5.4	1.3	0.5	1.2	10.0	4.7	9.6
Bond Breakers	1.5	0.4	0.4	10.8	2.9	3.0	9.9	2.2	2.2	98.0	16.7	16.9
Clear Brushing Lacquer	1.5	NA	1.5	11.2	NA	11.2	5.7	NA	5.7	59.8	NA	59.8
Concrete Curing Compounds	1.5	0.1	0.2	12.1	0.8	1.4	3.6	0.5	0.8	48.8	4.8	8.3
Driveway Sealer	0.9	0.0	0.0	6.7	0.0	0.0	1.8	0.0	0.0	13.4	0.0	0.1
Dry Fog	0.5	0.1	0.3	5.9	0.8	3.3	0.7	0.1	0.4	12.9	2.1	7.9
Faux Finishing	0.5	0.2	0.2	4.7	2.3	2.3	0.8	0.6	0.6	10.4	7.9	8.0
Fire Resistive	0.6	0.0	0.3	6.1	0.2	2.6	0.7	0.0	0.4	8.0	0.4	4.4
Fire Retardant - Clear	2.3	NA	2.3	19.6	NA	19.6	4.6	NA	4.6	50.6	NA	50.6
Fire Retardant - Opaque	0.3	0.0	0.3	3.7	0.1	3.3	0.4	0.0	0.4	6.6	0.4	6.2
Flat	1.7	0.1	0.1	18.2	0.7	0.7	2.3	0.1	0.1	29.9	2.0	2.0
Floor	1.1	0.3	0.4	10.2	3.4	3.8	1.4	0.7	0.8	14.2	9.8	10.3
Form Release Compounds	0.4	0.1	0.4	3.3	0.5	3.0	0.6	0.4	0.6	4.6	3.2	4.6
Graphic Arts	0.4	0.3	0.4	4.3	2.4	3.9	0.5	0.5	0.5	8.6	6.1	8.2
High Temperature	0.8	NA	0.8	8.7	NA	8.7	1.4	NA	1.4	20.2	NA	20.2
Industrial Maintenance	0.6	0.2	0.5	6.9	1.8	5.2	0.8	0.4	0.7	9.7	4.5	8.6
Lacquers	0.9	0.1	0.6	6.6	1.5	5.2	2.9	0.3	1.8	30.7	4.7	21.2
Low Solids	NA	0.1	0.1	NA	1.2	1.2	NA	1.5	1.5	NA	13.6	13.6
Magnesite Cement	2.3	NA	2.3	20.1	NA	20.1	4.7	NA	4.7	60.3	NA	60.3
Mastic Texture	0.2	0.1	0.1	1.6	1.0	1.1	0.3	0.1	0.2	3.1	1.8	2.1

Table 2-3: ***Possible Ozone Reactivity Formats (official MIRs)***

	Lb Ozone Per Lb Coating			*Lb Ozone Per Gal Coating*			*Lb Ozone Per Lb Solids*			*Lb Ozone Per Gal Solids*		
Coating Category	**SB**	**WB**	**All**	**SB**	**WB**	**All**	**SB**	**WB**	**All**	**SB**	**WB**	**All**
Metallic Pigmented	1.1	0.1	0.8	9.8	1.4	7.8	1.7	0.3	1.5	18.6	3.9	16.1
Multi-Color	0.7	0.0	0.0	5.7	0.3	0.4	2.6	0.1	0.1	34.5	1.4	1.8
Nonflat - High Gloss	0.5	0.1	0.2	4.8	1.5	1.6	0.8	0.3	0.3	9.3	4.3	4.5
Nonflat - Low Gloss	0.4	0.1	0.1	4.7	1.1	1.1	0.6	0.2	0.2	9.9	3.2	3.2
Nonflat - Medium Gloss	0.4	0.1	0.1	4.3	1.1	1.1	0.6	0.2	0.2	8.0	3.2	3.2
Other	2.0	0.0	0.1	18.9	0.1	0.6	3.8	0.0	0.2	54.8	0.5	3.2
Pre-Treatment Wash Primer	1.8	0.1	0.4	13.4	0.7	3.5	10.5	0.2	1.3	170.4	3.3	18.4
Primer, Sealer, and Undercoater	0.4	0.1	0.1	4.0	1.2	1.3	0.5	0.2	0.2	7.8	3.7	3.9
Quick Dry Enamel	0.5	0.2	0.5	4.6	2.4	4.4	0.7	0.5	0.7	9.1	7.3	9.0
Quick Dry Primer, Sealer, and Undercoater	0.5	0.0	0.5	5.6	0.1	4.9	0.8	0.0	0.7	12.9	0.4	11.6
Roof	0.7	0.0	0.1	7.3	0.4	0.6	0.9	0.1	0.1	10.3	0.9	1.3
Rust Preventative	0.5	0.2	0.5	5.6	1.6	5.4	0.8	0.4	0.8	10.7	4.9	10.6
Sanding Sealers	0.8	0.1	0.6	6.0	1.2	4.6	2.0	0.5	1.6	18.0	4.2	14.6
Shellacs - Clear	1.0	NA	1.0	7.7	NA	7.7	3.7	NA	3.7	36.6	NA	36.6
Shellacs - Opaque	0.7	NA	0.7	6.4	NA	6.4	1.2	NA	1.2	20.4	NA	20.4
Specialty Primer, Sealer, and Undercoater	0.4	0.1	0.4	5.3	0.9	4.2	0.6	0.1	0.5	9.6	2.1	8.2
Stains - Clear/Semitransparent	0.5	0.2	0.4	4.0	1.3	3.5	0.9	0.7	0.9	7.8	6.9	7.7
Stains - Opaque	0.5	0.1	0.1	5.4	1.0	1.1	0.7	0.2	0.2	9.2	2.7	3.0
Swimming Pool	1.2	0.2	0.7	14.2	1.9	7.9	1.6	0.3	1.1	22.1	5.7	16.3

Table 2-3: ***Possible Ozone Reactivity Formats (official MIRs)***

	Lb Ozone Per Lb Coating			*Lb Ozone Per Gal Coating*			*Lb Ozone Per Lb Solids*			*Lb Ozone Per Gal Solids*		
Coating Category	**SB**	**WB**	**All**	**SB**	**WB**	**All**	**SB**	**WB**	**All**	**SB**	**WB**	**All**
Swimming Pool Repair and Maintenance	3.5	NA	3.5	36.4	NA	36.4	6.6	NA	6.6	105.3	NA	105.3
Traffic Marking	0.4	0.1	0.1	5.2	0.7	1.4	0.5	0.1	0.1	9.5	1.3	2.5
Varnishes - Clear	0.7	0.3	0.5	4.9	2.2	4.2	1.4	0.9	1.3	11.7	7.9	10.9
Varnishes - Semitransparent	0.5	0.1	0.5	3.6	1.1	3.5	0.9	0.7	0.9	8.3	6.7	8.3
Waterproofing Concrete/Masonry Sealers	0.6	0.1	0.3	5.5	1.2	3.4	0.8	0.2	0.6	8.7	3.4	6.8
Waterproofing Sealers	0.6	0.1	0.2	4.9	1.2	1.7	1.1	0.5	0.6	8.7	4.8	5.8
Wood Preservatives	0.6	0.1	0.6	4.2	1.1	4.0	0.9	1.2	0.9	7.0	10.1	7.1

Notes:

1. "Lb Ozone": Maximum Ozone Formation Potential under MIR conditions.
2. "Lb Ozone Per Lb Coating": Total pounds of ozone for a category divided by the total pounds of coating for the category.
3. "Lb Ozone Per Gal Coating": Total pounds of ozone for a category divided by the total gallons of coating for the category.
4. "Lb Ozone Per Lb Solids": Total pounds of ozone for a category divided by the total pounds of solids for the category.
5. "Lb Ozone Per Gal Solids": Total pounds of ozone for a category divided by the total gallons of solids for the category.
6. "Official MIRs": Data based on the official MIR values published in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions", California Code of Regulations, Title 17, sections 94700 and 94701, as updated July 7, 2004
7. "NA": Not Applicable because no coating sales were reported or inadequate data were reported.
8. This table includes data from small containers (1 quart or less).
9. This table includes ozone generated from all volatile emissions, including VOCs and exempt compounds.
10. For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.

Table 2-4: ***Possible Ozone Reactivity Formats (draft updated MIRs)***

	Lb Ozone Per Lb Coating			*Lb Ozone Per Gal Coating*			*Lb Ozone Per Lb Solids*			*Lb Ozone Per Gal Solids*		
Coating Category	**SB**	**WB**	**All**	**SB**	**WB**	**All**	**SB**	**WB**	**All**	**SB**	**WB**	**All**
Bituminous Roof	0.7	0.0	0.1	5.8	0.0	0.6	0.9	0.0	0.1	8.3	0.1	1.1
Bituminous Roof Primer	0.8	0.2	0.7	5.9	1.5	5.4	1.3	0.5	1.2	10.0	4.2	9.5
Bond Breakers	1.5	0.1	0.1	10.8	1.2	1.2	9.9	0.9	0.9	98.0	6.6	6.9
Clear Brushing Lacquer	1.4	NA	1.4	10.4	NA	10.4	5.3	NA	5.3	55.6	NA	55.6
Concrete Curing Compounds	1.3	0.1	0.1	10.9	0.7	1.3	3.3	0.4	0.7	43.9	4.2	7.3
Driveway Sealer	0.9	0.0	0.0	6.7	0.0	0.0	1.8	0.0	0.0	13.4	0.0	0.0
Dry Fog	0.5	0.1	0.3	5.6	0.6	3.1	0.7	0.1	0.4	12.2	1.7	7.4
Faux Finishing	0.5	0.2	0.2	4.3	1.8	1.8	0.7	0.5	0.5	9.5	6.2	6.3
Fire Resistive	0.5	0.0	0.3	6.0	0.2	2.5	0.7	0.0	0.4	7.9	0.4	4.3
Fire Retardant - Clear	2.3	NA	2.3	19.5	NA	19.5	4.6	NA	4.6	50.3	NA	50.3
Fire Retardant - Opaque	0.3	0.0	0.3	3.6	0.1	3.2	0.4	0.0	0.4	6.5	0.3	6.0
Flat	1.7	0.0	0.0	18.7	0.5	0.5	2.4	0.1	0.1	30.7	1.3	1.3
Floor	1.1	0.2	0.3	10.2	2.5	3.0	1.4	0.5	0.6	14.2	7.2	8.0
Form Release Compounds	0.4	0.1	0.4	3.3	0.5	3.0	0.6	0.4	0.6	4.6	3.2	4.6
Graphic Arts	0.4	0.2	0.3	4.3	2.1	3.9	0.5	0.5	0.5	8.6	5.5	8.1
High Temperature	0.8	NA	0.8	8.5	NA	8.5	1.4	NA	1.4	19.8	NA	19.8
Industrial Maintenance	0.6	0.2	0.5	6.9	1.5	5.1	0.8	0.3	0.7	9.5	3.9	8.4
Lacquers	0.8	0.1	0.6	6.0	1.3	4.7	2.6	0.3	1.6	27.6	4.1	19.1
Low Solids	NA	0.1	0.1	NA	0.9	0.9	NA	1.2	1.2	NA	10.8	10.8
Magnesite Cement	2.3	NA	2.3	20.1	NA	20.1	4.7	NA	4.7	60.4	NA	60.4

Table 2-4: ***Possible Ozone Reactivity Formats (draft updated MIRs)***

	Lb Ozone Per Lb Coating			***Lb Ozone Per Gal Coating***			***Lb Ozone Per Lb Solids***			***Lb Ozone Per Gal Solids***		
Coating Category	**SB**	**WB**	**All**	**SB**	**WB**	**All**	**SB**	**WB**	**All**	**SB**	**WB**	**All**
Mastic Texture	0.1	0.1	0.1	1.4	0.8	0.9	0.2	0.1	0.1	2.6	1.5	1.7
Metallic Pigmented	1.1	0.0	0.8	9.8	0.4	7.6	1.7	0.1	1.4	18.7	1.0	15.6
Multi-Color	0.7	0.0	0.0	5.7	0.3	0.4	2.6	0.1	0.1	34.5	1.2	1.7
Nonflat - High Gloss	0.5	0.1	0.1	4.5	0.9	1.0	0.7	0.2	0.2	8.7	2.6	2.8
Nonflat - Low Gloss	0.4	0.1	0.1	4.3	0.8	0.8	0.6	0.2	0.2	8.9	2.4	2.4
Nonflat - Medium Gloss	0.4	0.1	0.1	4.1	0.8	0.9	0.5	0.2	0.2	7.5	2.5	2.5
Other	2.0	0.0	0.1	19.0	0.1	0.6	3.8	0.0	0.2	55.0	0.4	3.1
Pre-Treatment Wash Primer	1.6	0.1	0.4	12.0	0.7	3.2	9.5	0.2	1.2	152.7	3.1	16.6
Primer, Sealer, and Undercoater	0.3	0.1	0.1	3.7	0.8	0.9	0.5	0.2	0.2	7.3	2.4	2.6
Quick Dry Enamel	0.4	0.2	0.4	4.2	2.2	4.1	0.7	0.5	0.6	8.5	6.7	8.4
Quick Dry Primer, Sealer, and Undercoater	0.5	0.0	0.4	5.2	0.1	4.6	0.7	0.0	0.6	12.0	0.3	10.8
Roof	0.5	0.0	0.0	4.7	0.3	0.5	0.6	0.1	0.1	6.7	0.7	1.0
Rust Preventative	0.5	0.1	0.5	5.3	1.4	5.1	0.7	0.3	0.7	10.2	4.3	10.0
Sanding Sealers	0.8	0.1	0.6	5.9	1.0	4.5	2.0	0.4	1.6	17.6	3.8	14.2
Shellacs - Clear	0.9	NA	0.9	6.5	NA	6.5	3.2	NA	3.2	31.3	NA	31.3
Shellacs - Opaque	0.6	NA	0.6	5.5	NA	5.5	1.1	NA	1.1	17.4	NA	17.4
Specialty Primer, Sealer, and Undercoater	0.4	0.1	0.3	4.9	0.7	3.9	0.5	0.1	0.5	8.8	1.7	7.5
Stains - Clear/Semitransparent	0.5	0.1	0.4	4.0	1.1	3.4	0.9	0.6	0.9	7.6	5.6	7.4
Stains - Opaque	0.5	0.1	0.1	5.2	0.7	0.8	0.6	0.1	0.2	9.0	2.1	2.3

Table 2-4: ***Possible Ozone Reactivity Formats (draft updated MIRs)***

	Lb Ozone Per Lb Coating			***Lb Ozone Per Gal Coating***			***Lb Ozone Per Lb Solids***			***Lb Ozone Per Gal Solids***		
Coating Category	**SB**	**WB**	**All**	**SB**	**WB**	**All**	**SB**	**WB**	**All**	**SB**	**WB**	**All**
Swimming Pool	1.2	0.1	0.7	14.1	1.7	7.7	1.5	0.3	1.0	21.9	5.2	16.0
Swimming Pool Repair and Maintenance	3.6	NA	3.6	37.6	NA	37.6	6.8	NA	6.8	108.8	NA	108.8
Traffic Marking	0.4	0.0	0.1	5.1	0.7	1.3	0.5	0.1	0.1	9.4	1.2	2.4
Varnishes - Clear	0.6	0.2	0.5	4.6	1.7	3.8	1.3	0.7	1.1	11.0	6.2	10.0
Varnishes - Semitransparent	0.4	0.1	0.4	3.4	1.0	3.3	0.9	0.6	0.8	7.9	5.8	7.8
Waterproofing Concrete/Masonry Sealers	0.6	0.1	0.3	5.6	1.0	3.3	0.8	0.2	0.6	8.8	2.8	6.7
Waterproofing Sealers	0.7	0.1	0.2	5.0	0.9	1.4	1.1	0.4	0.5	8.8	3.6	5.0
Wood Preservatives	0.6	0.1	0.5	4.2	1.1	4.0	0.9	1.3	0.9	7.0	10.7	7.0

Notes:

1. "Lb Ozone": Maximum Ozone Formation Potential under MIR conditions.
2. "Lb Ozone Per Lb Coating": Total pounds of ozone for a category divided by the total pounds of coating for the category.
3. "Lb Ozone Per Gal Coating": Total pounds of ozone for a category divided by the total gallons of coating for the category.
4. "Lb Ozone Per Lb Solids": Total pounds of ozone for a category divided by the total pounds of solids for the category.
5. "Lb Ozone Per Gal Solids": Total pounds of ozone for a category divided by the total gallons of solids for the category.
6. "Draft Updated MIRs": Data based on draft updated MIR values that have not yet been officially adopted by ARB. These draft values have been determined by Dr. William Carter for the research project titled "Reactivity Estimates for Selected Consumer Product Compounds" under Contract No. 06-408. The draft updated values were current as of December 24, 2007, and they are subject to change.
7. "NA": Not Applicable because no coating sales were reported or inadequate data were reported.
8. This table includes data from small containers (1 quart or less).
9. This table includes ozone generated from all volatile emissions, including VOCs and exempt compounds.
10. For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.

Section 2.4 Sales-Weighted Average MIR Values

Sales-weighted average MIR values (SWAMIRs) provide another way to characterize the overall reactivity of a given category. In most cases, SWAMIRs are similar to the category-wide ozone values shown in Table 2-3 that don't include any sales-weighting. However, it is important to note that SWAMIRs can sometimes be quite different than the values in Table 2-3, because they are based on inherently different calculations. Sales-weighting assigns greater importance to products that have higher sales volumes, while the values in Table 2-3 are based on total ingredients without consideration of which ingredients are in high volume products. Therefore, if a category has a particularly dominant product, the SWAMIR for that category will be more reflective of the dominant product.

To determine SWAMIRs, we used the following equation:

$$\text{SWAMIR} = \frac{[\text{Sales}]_1 * [\text{Lb O3/Lb Coating}]_1 + [\text{Sales}]_2 * [\text{Lb O3/Lb Coating}]_2 + \ldots + [\text{Sales}]_n * [\text{Lb O3/Lb Coating}]_n}{[\text{Sales}]_1 + [\text{Sales}]_2 + \ldots + [\text{Sales}]_n}$$

where

$[\text{Sales, gals}]_i$ = the sales of product "i", gallons

$[\text{Lb O3/Lb Coating}]_i$ = the [Maximum Ozone Formation Potential, lbs]/[Mass of Coating, lbs] for each product

n = the total number of coating products

An example is provided below:

Product	[Lb O3/Lb Coating]	Sales (gals)	[Lb O3/Lb Coating]*[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** lbs ozone/lb coating			

SWAMIRs were calculated for all of the coating categories based on the 2005 survey data. The survey collected sales data for more than 11,000 products and it also gathered data on the chemical ingredients contained in each product. However, there were approximately 80 products for which no ingredient data were submitted. These 80 products only represent 0.2 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.

SWAMIRs were not calculated for the units of [Lb Ozone/Gal Coating], because the individual sales volumes cancel out in the sales-weighted average equation, as shown below:

$$\text{SWAMIR} = \frac{[\cancel{\text{Sales}}]_1 * [\text{Lb O3}/\cancel{\text{Sales}}]_1 + [\cancel{\text{Sales}}]_2 * [\text{Lb O3}/\cancel{\text{Sales}}]_2 + \ldots + [\cancel{\text{Sales}}]_n * [\text{Lb O3}/\cancel{\text{Sales}}]_n}{[\text{Sales}]_1 + [\text{Sales}]_2 + \ldots + [\text{Sales}]_n}$$

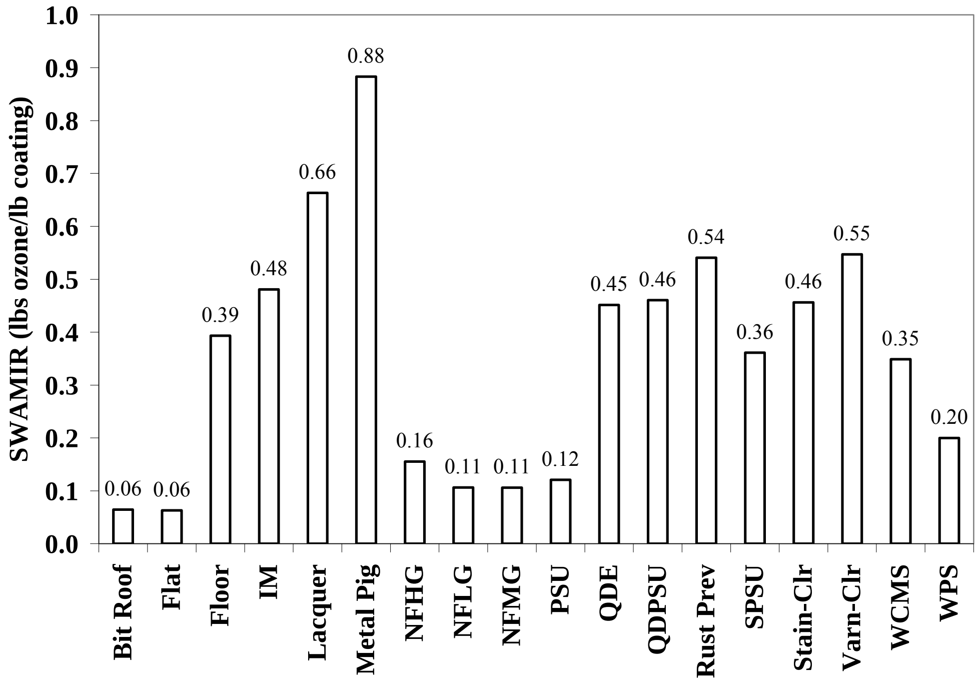
where

- $[\text{Sales, gals}]_i$ = the sales of product "i", gallons
- $[\text{Lb O3/Sales}]_i$ = the [Maximum Ozone Formation Potential, lbs]/[Sales, gals] for each product
- n = the total number of coating products

Since sales-weighting is not possible for the units of [Lb Ozone/Gal Coating], we've provided the total ozone over the total gallons in Table 2-3.

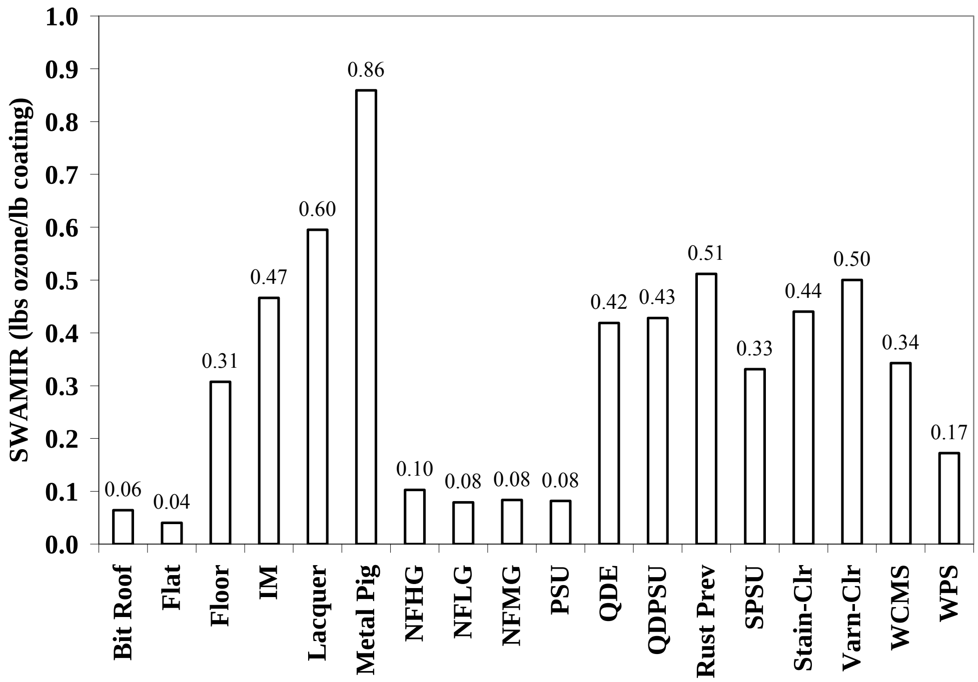
Figure 2-22 contains SWAMIRs for selected coating categories. Data are provided in units of [Lb Ozone/Lb Coating], which corresponds to the approach that ARB used in the reactivity-based Aerosol Coatings Regulation. The data in Figure 2-22 are based on the official MIR values published in ARB's Aerosol Coatings regulation, as updated in July 2004 (CCR, 2004). For comparison purposes, Figure 2-23 contains data that are based on draft updated MIR values that have not yet been officially adopted (Carter, 2007). For some key ingredients in architectural coatings, the draft updated MIRs used in Figure 2-23 provide more accurate results.

Figure 2-22
Sales-Weighted Average MIR – [Lb Ozone/Lb Coating]
(official MIRs)



Notes:
1. [Lb Ozone]/[Lb Coating] = [Maximum Ozone Formation Potential]/[Total Coating Mass]
2. [Maximum Ozone Formation Potential] = ∑ [Ingredient Emissions, lbs]*[MIR, g Ozone/g Ingredient]
3. [Total Coating Mass] = ∑ [Coating Sales Volume, gals]*[Coating Density, lb/gal]
4. This figure includes data from small containers (1 quart or less).
5. This figure includes ozone generated from all volatile emissions, including VOCs and exempt compounds.
6. Bit Roof = Bituminous Roof; IM = Industrial Maintenance; Metal Pig = Metallic Pigmented; NFHG = Nonflat – High Gloss; NFLG = Nonflat – Low Gloss; NFMG = Nonflat – Medium Gloss; PSU = Primer, Sealer, Undercoater; QDPSU = Quick Dry Primer, Sealer, Undercoater; Rust Prev = Rust Preventative; Stain – Clr = Stains – Clear/Semitransparent; Varn – Clr = Varnishes – Clear; WCMS = Waterproofing Concrete/Masonry Sealers; WPS = Waterproofing Sealers.
7. For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.
8. The values in this table are based on the official MIR values published in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions", California Code of Regulations, Title 17, sections 94700 and 94701, as updated July 7, 2004.

Figure 2-23: Sales-Weighted Average MIR – [Lb Ozone/Lb Coating]
(draft updated MIRs)



Notes:
1. [Lb Ozone]/[Lb Coating] = [Maximum Ozone Formation Potential]/[Total Coating Mass]
2. [Maximum Ozone Formation Potential] = ∑ [Ingredient Emissions, lbs]*[MIR, g Ozone/g Ingredient]
3. [Total Coating Mass] = ∑ [Coating Sales Volume, gals]*[Coating Density, lb/gal]
4. This figure includes data from small containers (1 quart or less).
5. This figure includes ozone generated from all volatile emissions, including VOCs and exempt compounds.
6. Bit Roof = Bituminous Roof; IM = Industrial Maintenance; Metal Pig = Metallic Pigmented; NFHG = Nonflat – High Gloss; NFLG = Nonflat – Low Gloss; NFMG = Nonflat – Medium Gloss; PSU = Primer, Sealer, Undercoater; QDPSU = Quick Dry Primer, Sealer, Undercoater; Rust Prev = Rust Preventative; Stain – Clr = Stains – Clear/Semitransparent; Varn – Clr = Varnishes – Clear; WCMS = Waterproofing Concrete/Masonry Sealers; WPS = Waterproofing Sealers.
7. For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.
8. The values in this table are based on draft updated MIR values that have not yet been officially adopted in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions". These draft updated values have been determined by Dr. William Carter for the research project titled "Reactivity Estimates for Selected Consumer Product Compounds" under Contract No. 06-408. The draft updated values were current as of December 24, 2007, and they are subject to change.

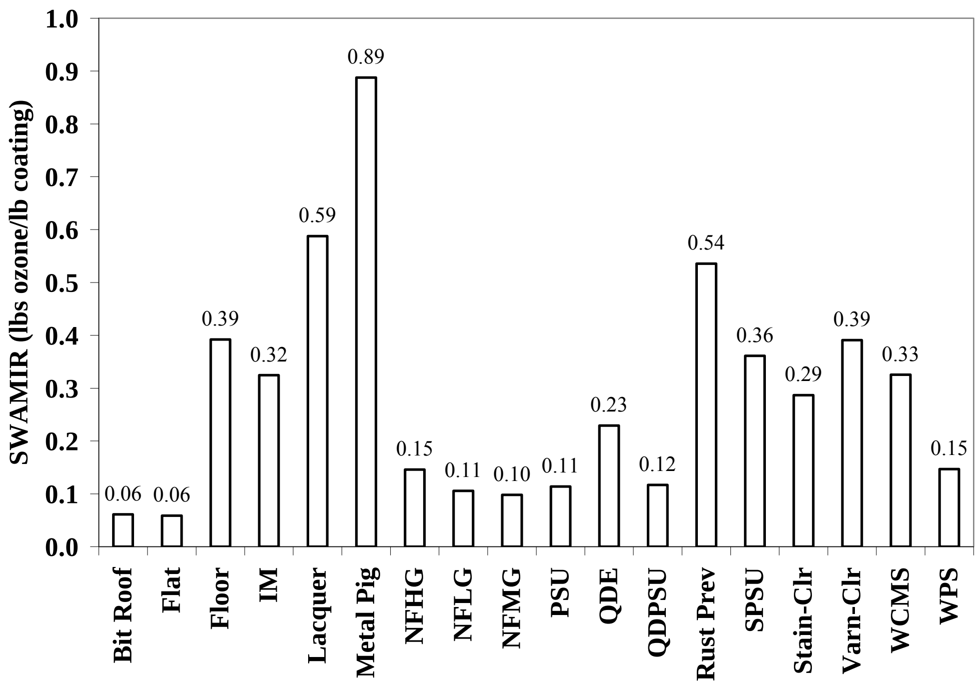
Detailed SWAMIR data for all coating categories are contained in Appendix B, including a breakdown for solventborne and waterborne formulations. Appendix B also contains SWAMIRs for compliant and non-compliant coatings, based on the VOC limits contained in ARB's 2000 Architectural Coatings SCM and the SCAQMD VOC limits that will take effect in or before 2008.

Figure 2-24 contains data similar to Figure 2-22, but it provides SWAMIRs only for those reported coatings that complied with the VOC limits in ARB's 2000 Suggested Control Measure. In addition, Figure 2-24 does not include sales of small containers (one quart or less), because they are exempt from the SCM VOC limits. When comparing

Figure 2-22 (all coatings) to Figure 2-24 (compliant coatings only), the SWAMIRs are similar for most of the categories. However, the SWAMIRs on Figure 2-24 are significantly lower for compliant coatings in the following categories: Industrial Maintenance; Quick Dry Enamel; Quick Dry Primer, Sealer, Undercoater; Stains – Clear/Semitransparent; and Varnishes - Clear.

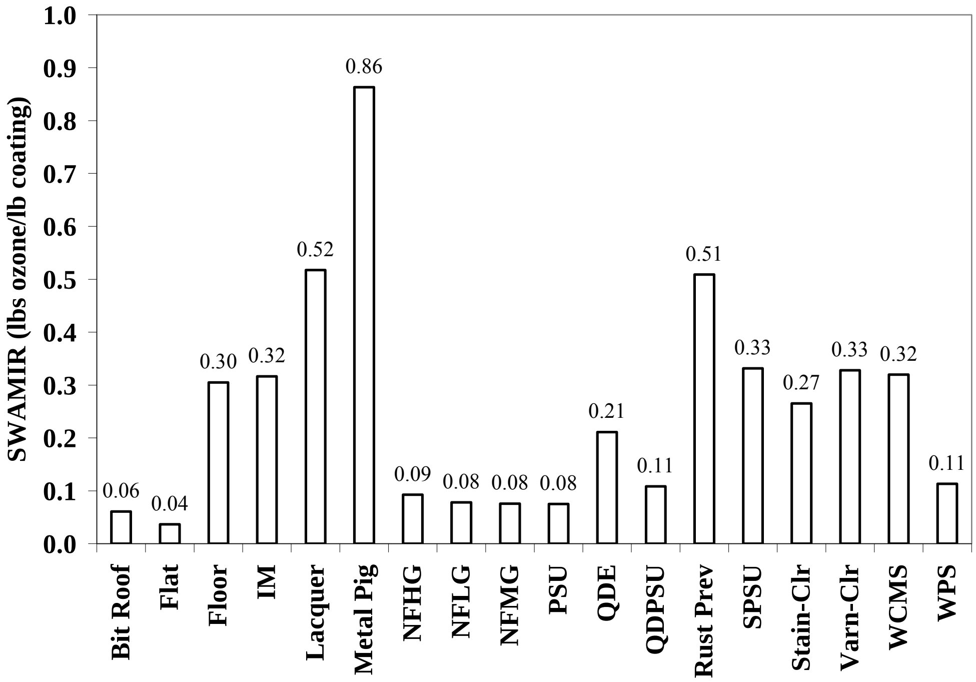
The data in Figure 2-24 are based on the official MIR values published in ARB's Aerosol Coatings regulation, as updated in July 2004 (CCR, 2004). Following Figure 2-24 is Figure 2-25, which contains similar information but is based on draft updated MIR values that have not yet been officially adopted (Carter, 2007). For some key ingredients in architectural coatings, the draft updated MIRs used in Figure 2-25 provide more accurate results.

Figure 2-24
Sales-Weighted Average MIR – [Lb Ozone/Lb Coating]
(Only Includes Compliant Coatings in Large Containers, Official MIRs)



Notes:
1. [Lb Ozone]/[Lb Coating] = [Maximum Ozone Formation Potential]/[Total Coating Mass]
2. [Maximum Ozone Formation Potential] = ∑ [Ingredient Emissions, lbs]*[MIR, g Ozone/g Ingredient]
3. [Total Coating Mass] = ∑ [Coating Sales Volume, gals]*[Coating Density, lb/gal]
4. This figure only includes data for coatings that comply with the VOC limits in the 2000 SCM.
5. This figure does not include data from small containers (1 quart or less).
6. This figure includes ozone generated from all volatile emissions, including VOCs and exempt compounds.
7. For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.
8. The values in this table are based on the official MIR values published in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions", California Code of Regulations, Title 17, sections 94700 and 94701, as updated July 7, 2004.

Figure 2-25
Sales-Weighted Average MIR – [Lb Ozone/Lb Coating]
(Only Includes Compliant Coatings in Large Containers, Draft Updated MIRs)



Notes:
1. [Lb Ozone]/[Lb Coating] = [Maximum Ozone Formation Potential]/[Total Coating Mass]
2. [Maximum Ozone Formation Potential] = ∑ [Ingredient Emissions, lbs]*[MIR, g Ozone/g Ingredient]
3. [Total Coating Mass] = ∑ [Coating Sales Volume, gals]*[Coating Density, lb/gal]
4. This figure only includes data for coatings that comply with the VOC limits in the 2000 SCM.
5. This figure does not include data from small containers (1 quart or less).
6. This figure includes ozone generated from all volatile emissions, including VOCs and exempt compounds.
7. For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.
8. The values in this table are based on draft updated MIR values that have not yet been officially adopted in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions". These draft updated values have been determined by Dr. William Carter for the research project titled "Reactivity Estimates for Selected Consumer Product Compounds" under Contract No. 06-408. The draft updated values were current as of December 24, 2007, and they are subject to change.

Figures 2-26 to 2-61 contain charts of the SWAMIRs for selected categories in 50-gram/liter (g/l) ranges for VOC Regulatory. For each of the selected categories, two SWAMIR formats are provided: [Pounds Ozone per Pound Coating] and [Pounds Ozone per Gallon Solids]. The data in these figures are based on the official MIR values published in ARB's Aerosol Coatings regulation, as updated in July 2004 (CCR, 2004). Appendix B contains similar SWAMIR data for all categories. Appendix B also contains [Pounds Ozone per Gallon Coating] for all categories in 50-g/l ranges.

Figure 2-26
Bituminous Roof (lb O^3/lb coating)

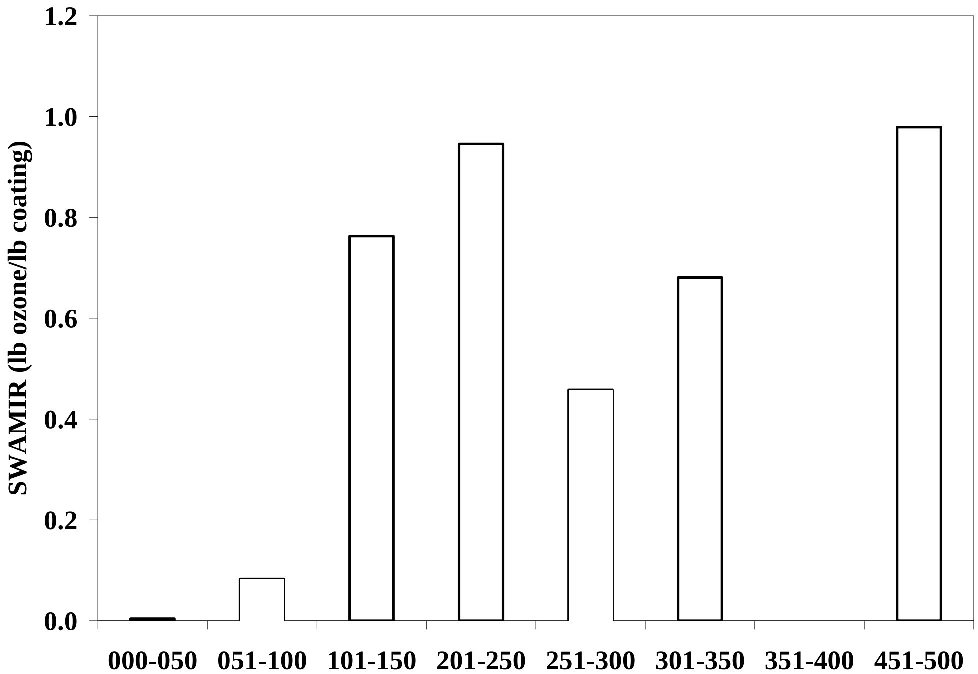


Figure 2-27
Bituminous Roof (lb O^3/gallon solids)

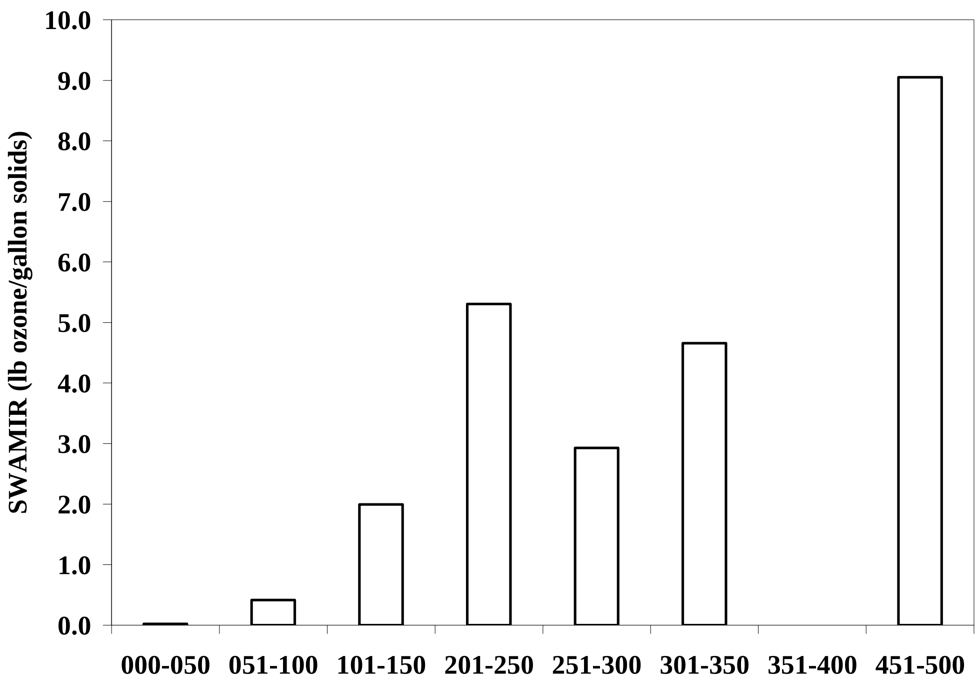


Figure 2-28

Flat (lb O^3/lb coating)

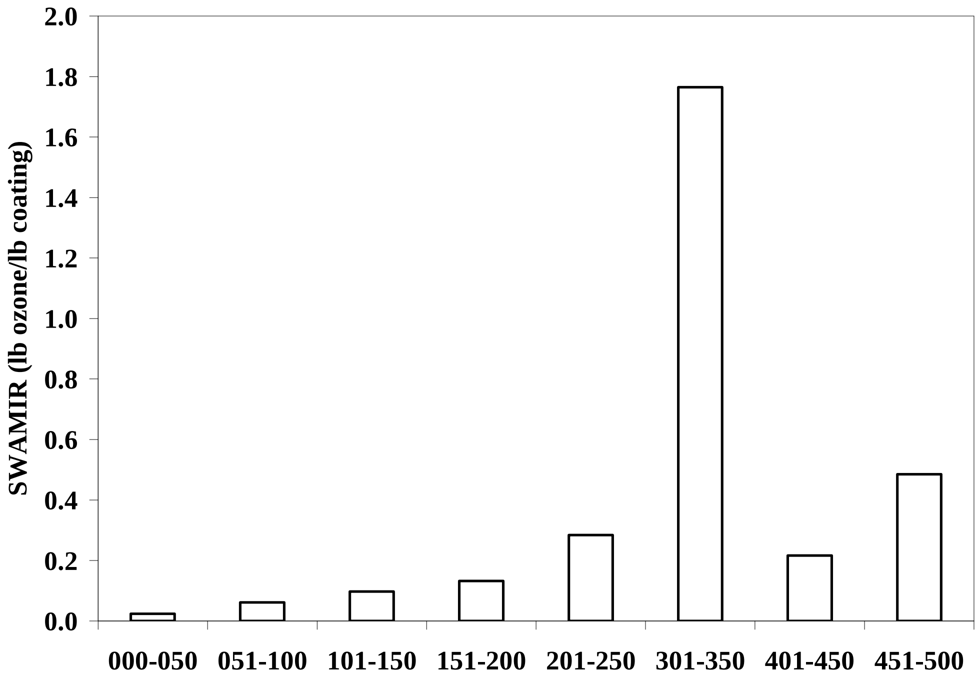


Figure 2-29

Flat (lb O^3/gallon solids)

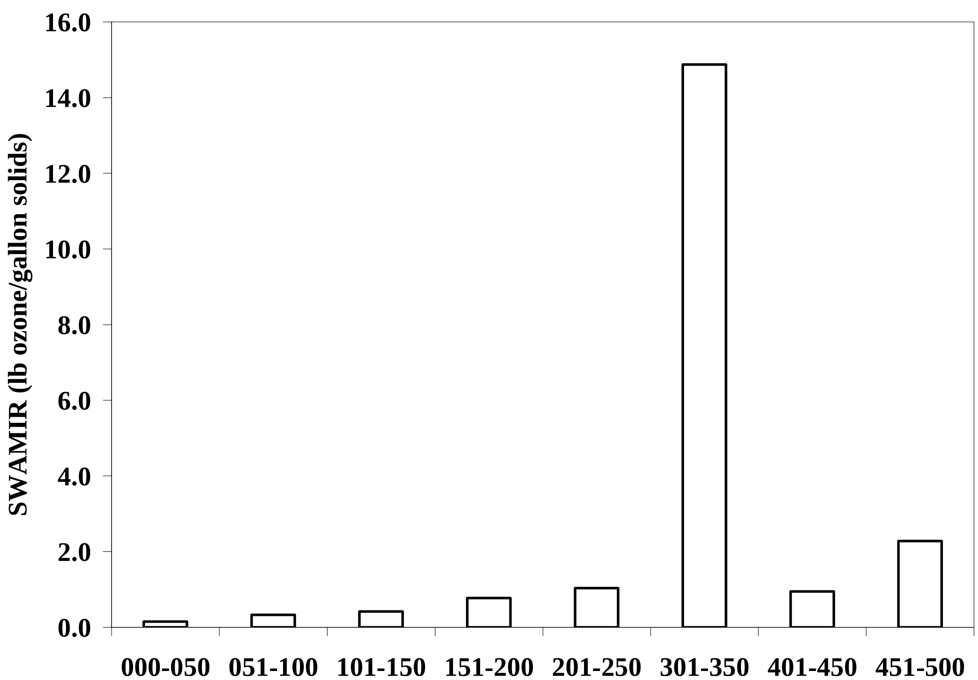


Figure 2-30
Floor (lb O3/lb coating)

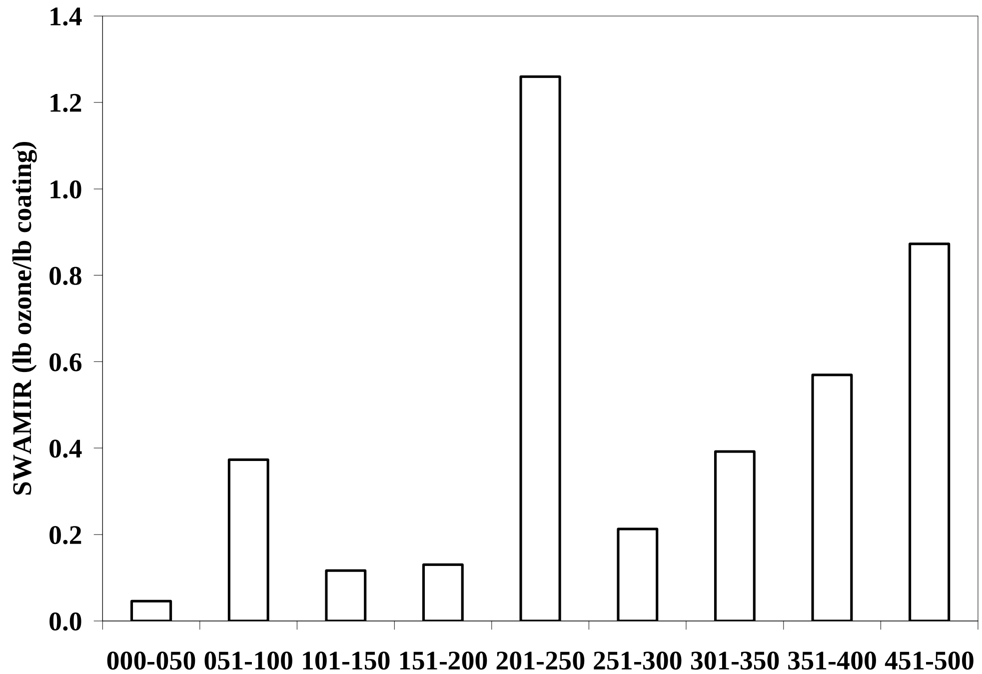
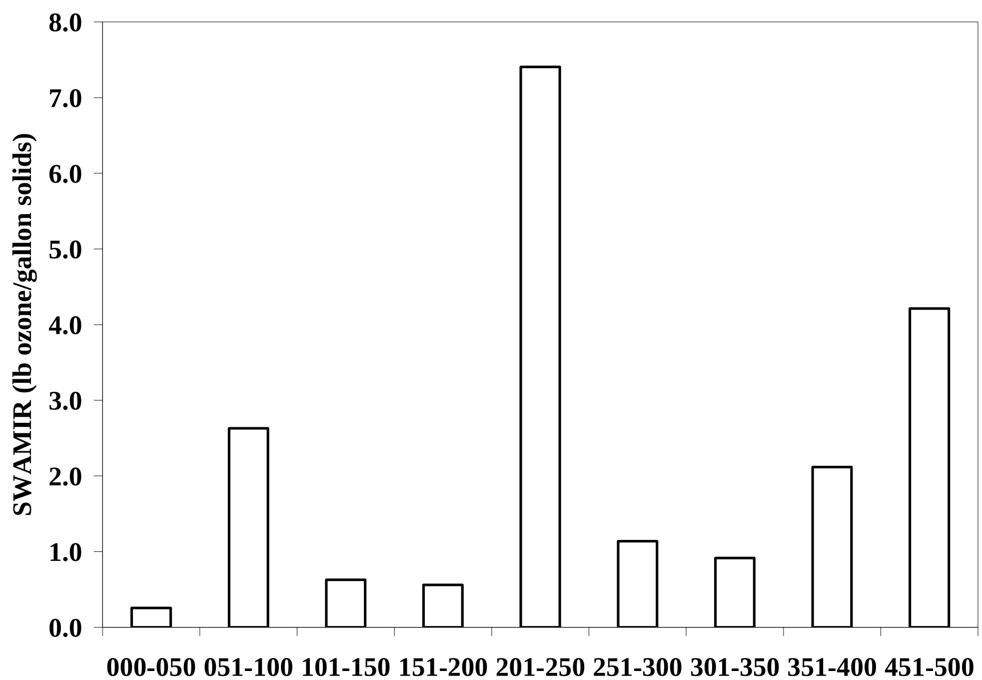


Figure 2-31
Floor (lb O3/gallon solids)



For the Floor category, ARB staff considers the data to be questionable because a significant portion of the reactivity is based on an unknown ingredient.

Figure 2-32

Industrial Maintenance (lb O3/lb coating)

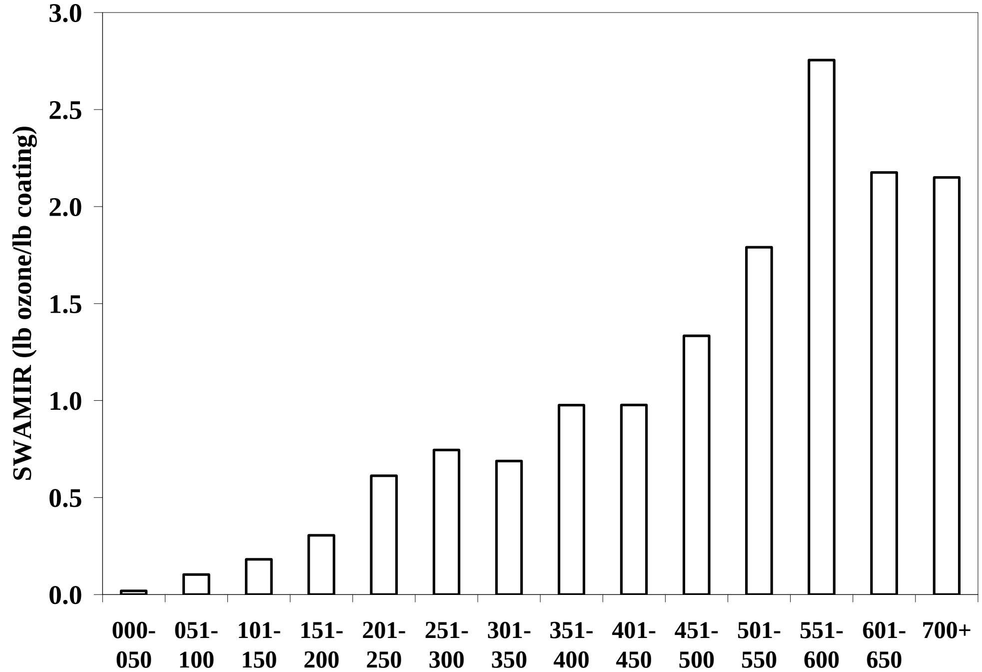
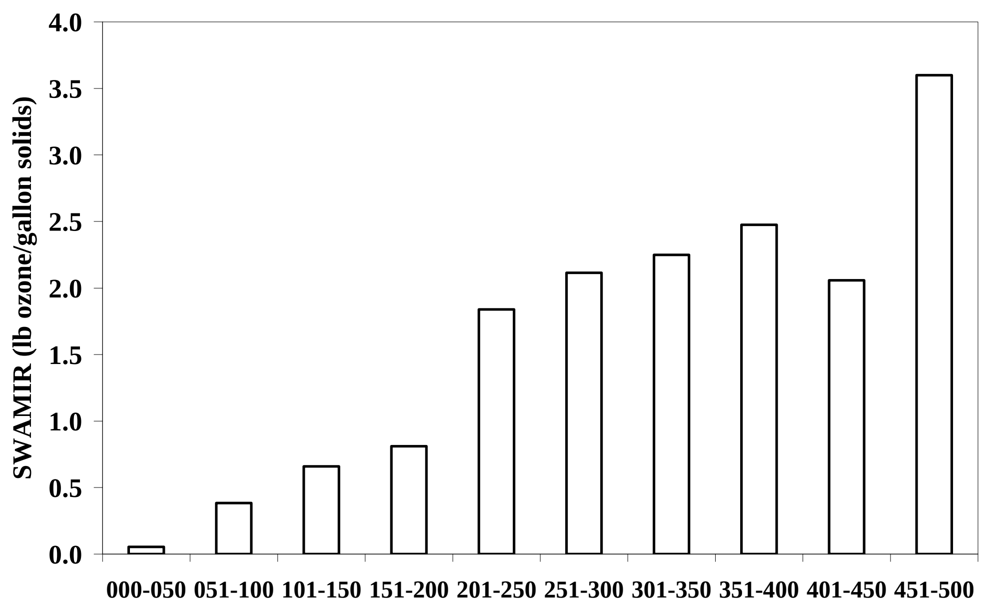


Figure 2-33

Industrial Maintenance (lb O3/gallon solids)



***Note: This chart does not include all products in this category. To improve chart resolution, upper VOC ranges with high SWAMIR values are not shown. Please refer to the Appendix to see the complete data for this category.**

Figure 2-34
Lacquers (lb O^3/lb coating)

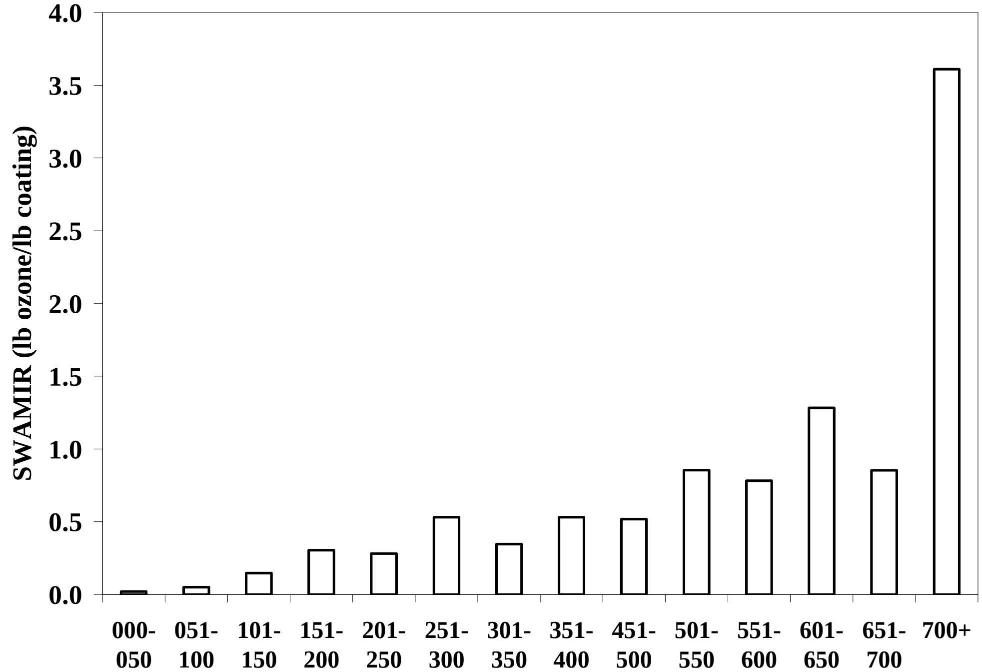
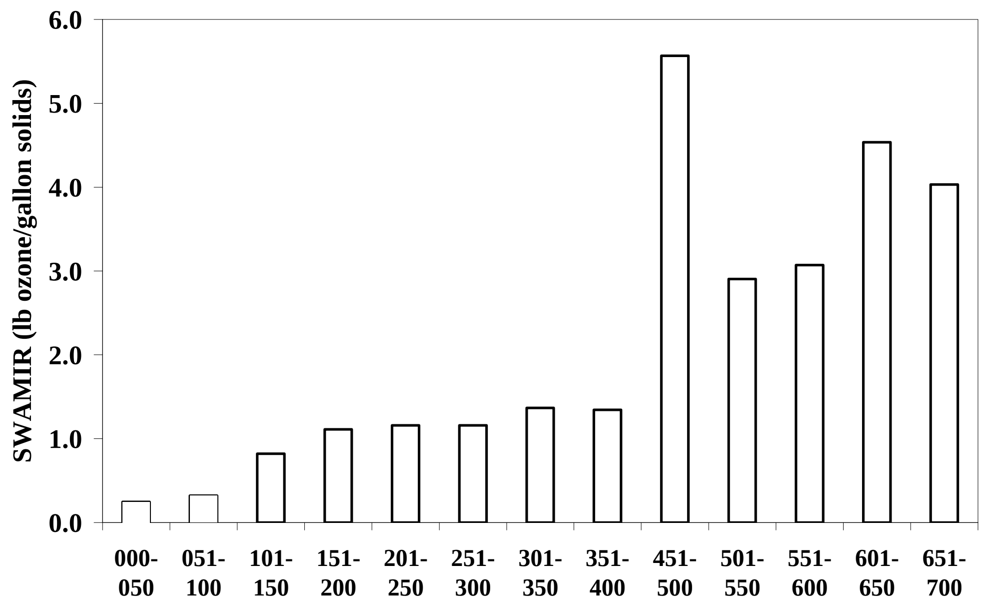


Figure 2-35
Lacquers (lb O^3/gallon solids)



***Note: This chart does not include all products in this category. To improve chart resolution, upper VOC ranges with high SWAMIR values are not shown. Please refer to the Appendix to see the complete data for this category.**

Figure 2-36
Metallic Pigmented (lb O3/lb coating)

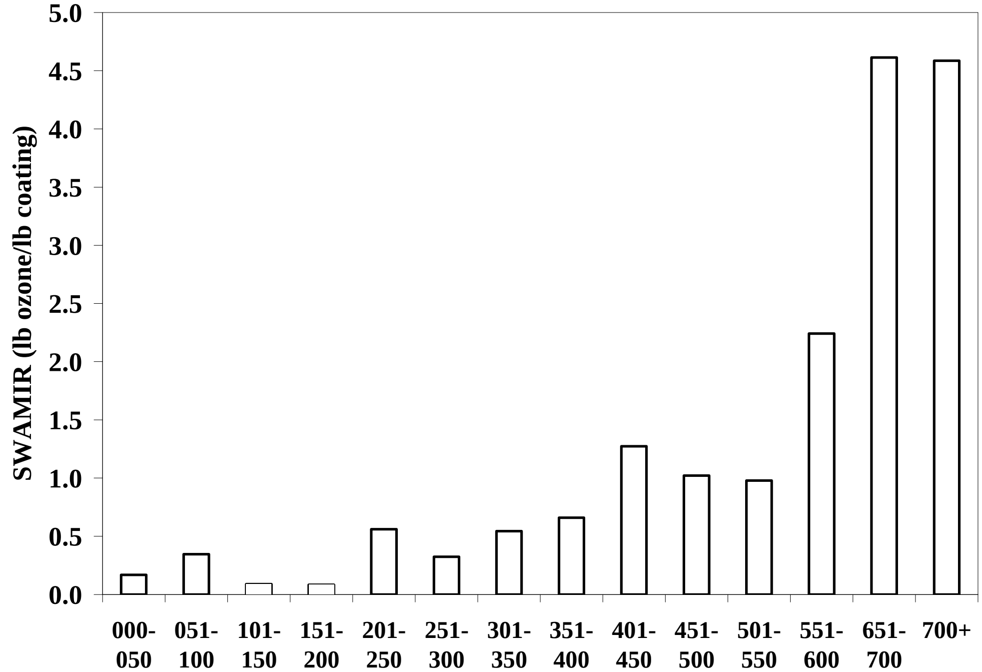
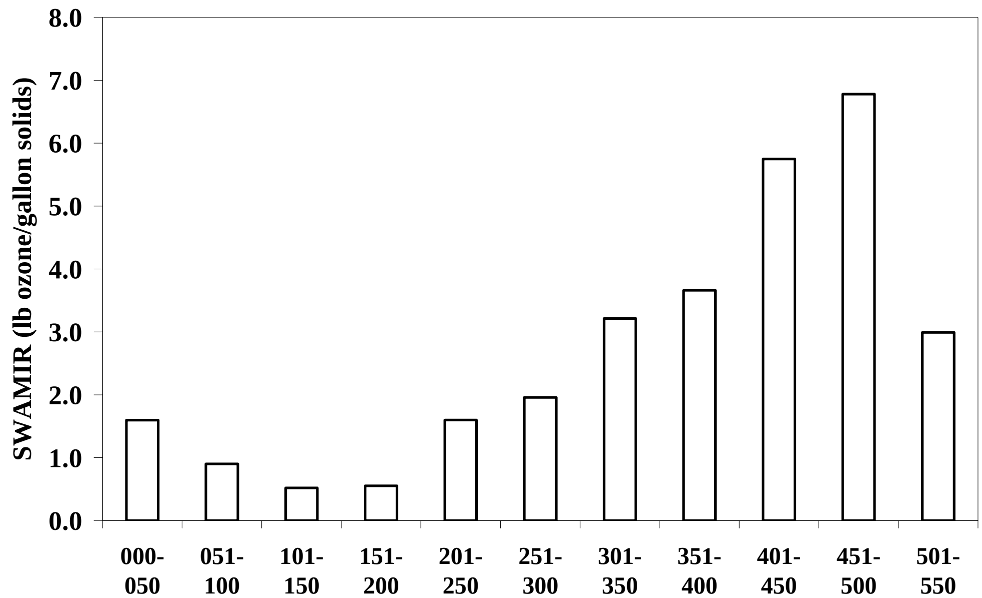


Figure 2-37
Metallic Pigmented (lb O3/gallon solids)



***Note: This chart does not include all products in this category. To improve chart resolution, upper VOC ranges with high SWAMIR values are not shown. Please refer to the Appendix to see the complete data for this category.**

Figure 2-38
Nonflat – High Gloss (lb O^3/lb coating)

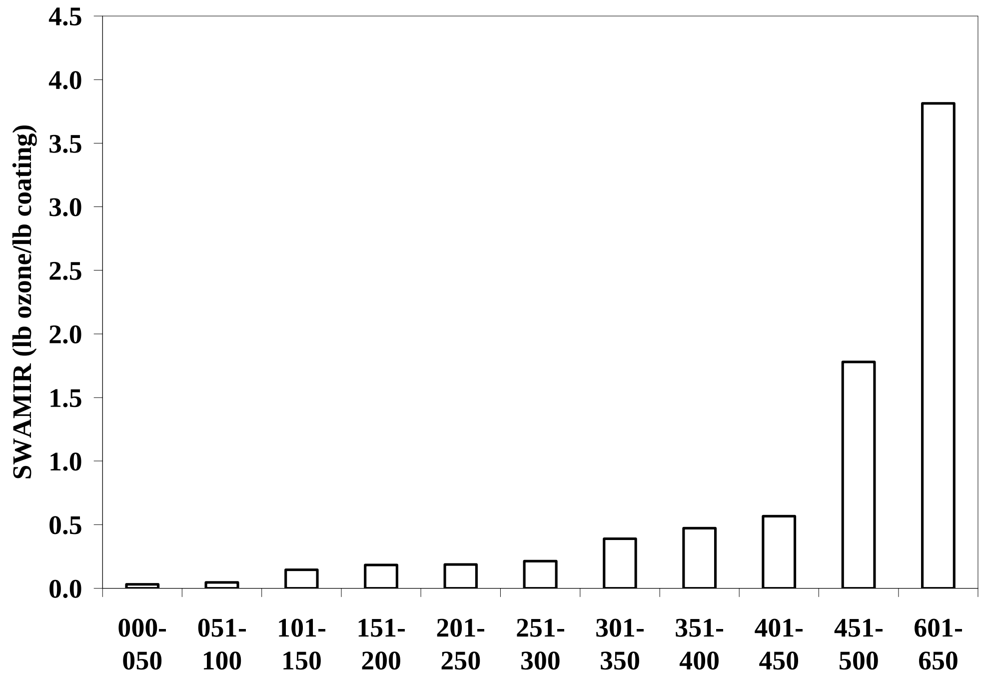
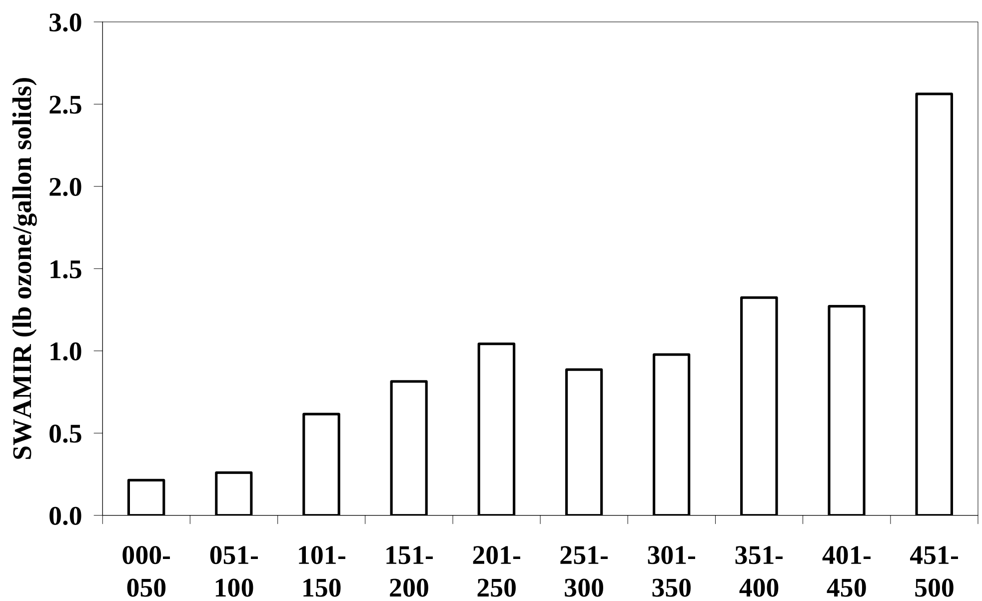


Figure 2-39
Nonflat – High Gloss (lb O^3/gallon solids)



***Note: This chart does not include all products in this category. To improve chart resolution, upper VOC ranges with high SWAMIR values are not shown. Please refer to the Appendix to see the complete data for this category.**

Figure 2-40
Nonflat – Low Gloss (lb O^3/lb coating)

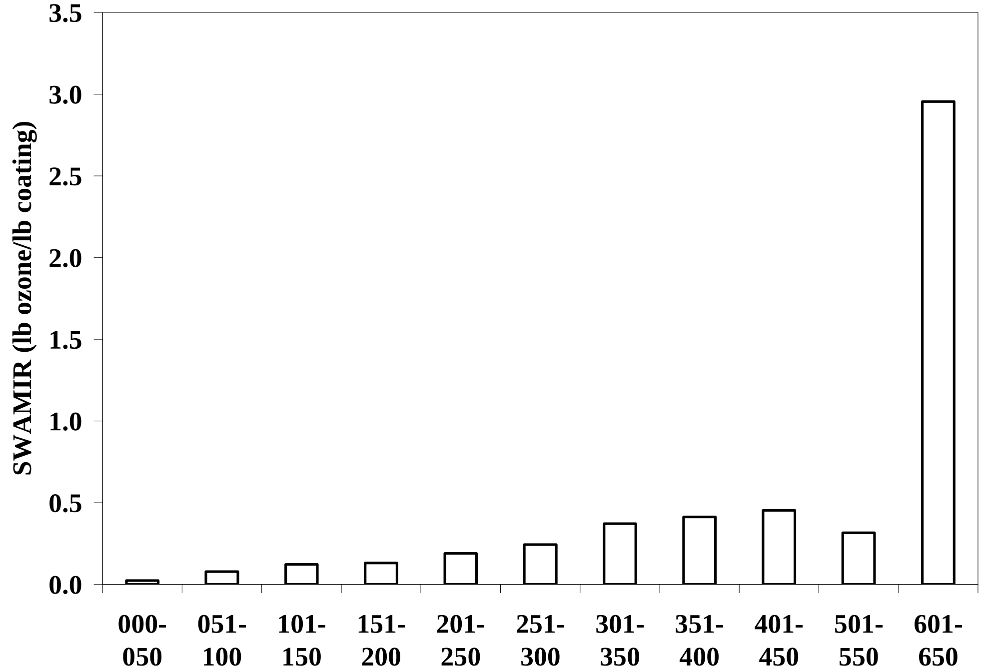
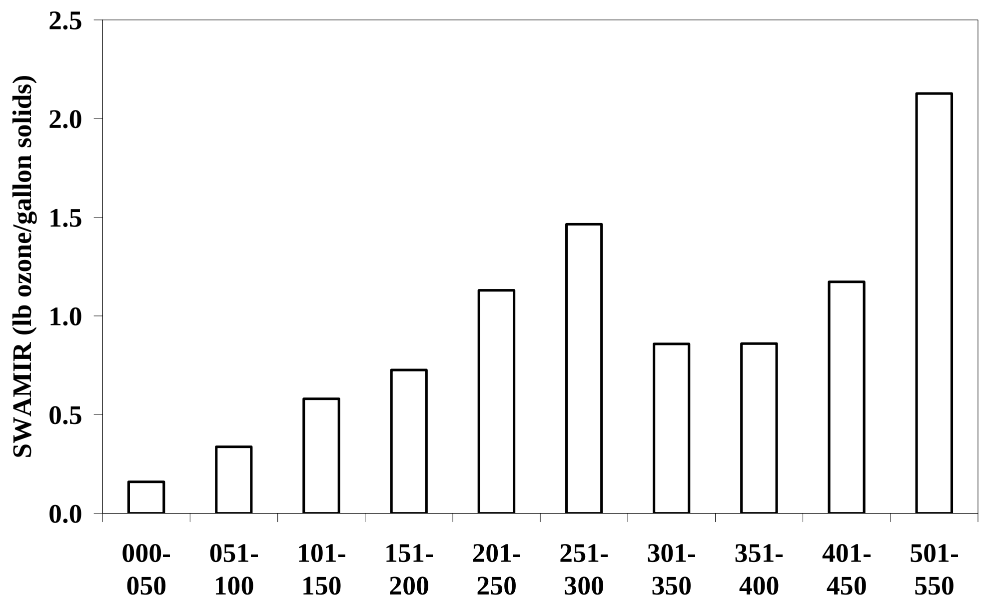


Figure 2-41
Nonflat – Low Gloss (lb O^3/gallon solids)



***Note: This chart does not include all products in this category. To improve chart resolution, upper VOC ranges with high SWAMIR values are not shown. Please refer to the Appendix to see the complete data for this category.**

Figure 2-42
Nonflat – Medium Gloss (lb O^3/lb coating)

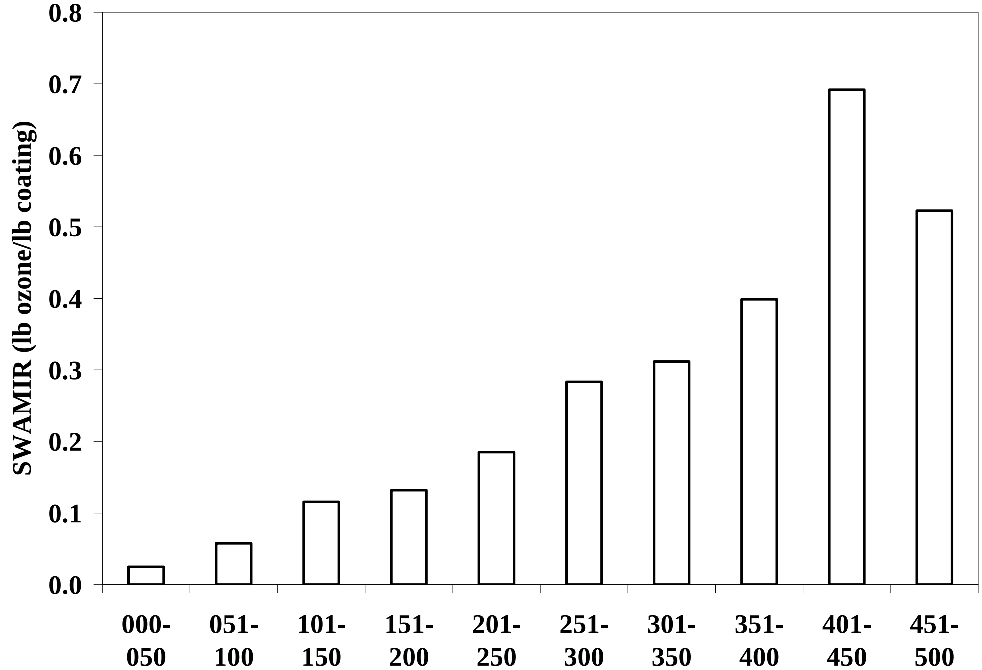


Figure 2-43
Nonflat – Medium Gloss (lb O^3/gallon solids)

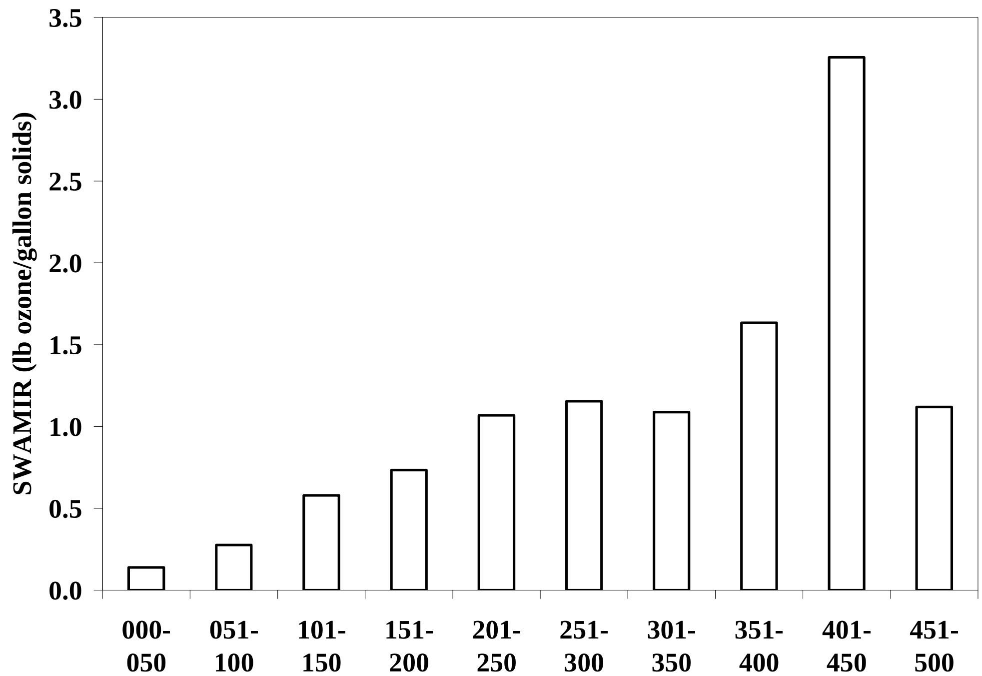


Figure 2-44
Primer, Sealer, Undercoater (lb O3/lb coating)

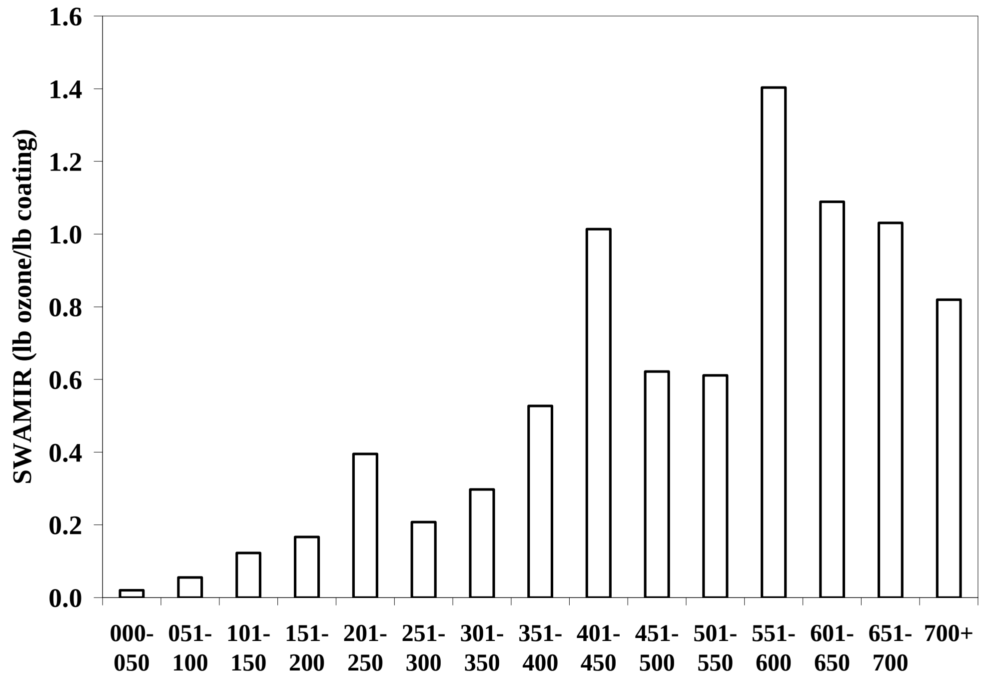
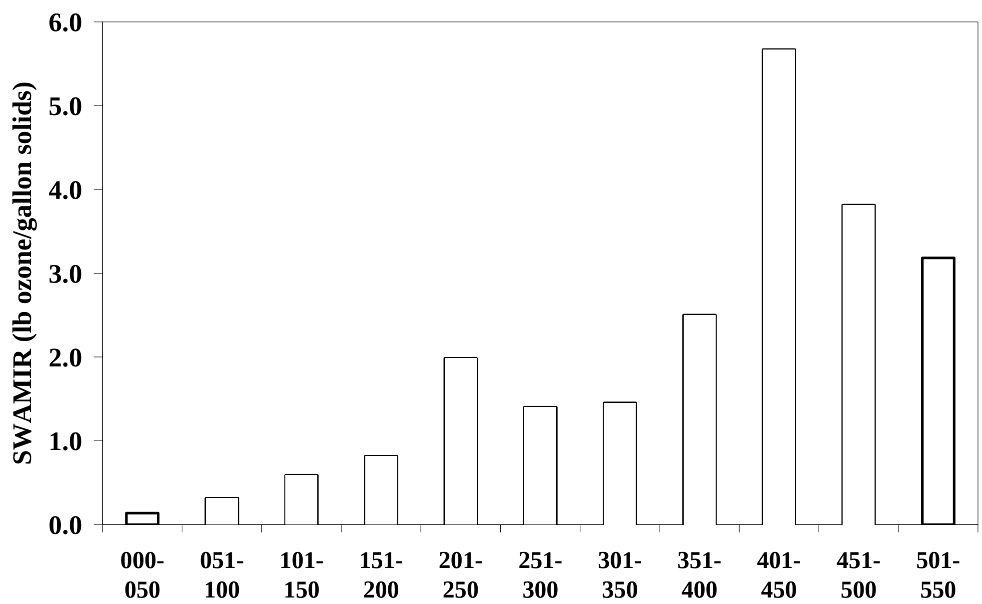


Figure 2-45
Primer, Sealer, Undercoater (lb O3/gallon solids)



***Note: This chart does not include all products in this category. To improve chart resolution, upper VOC ranges with high SWAMIR values are not shown. Please refer to the Appendix to see the complete data for this category.**

Figure 2-46
Quick Dry Enamel (lb O3/lb coating)

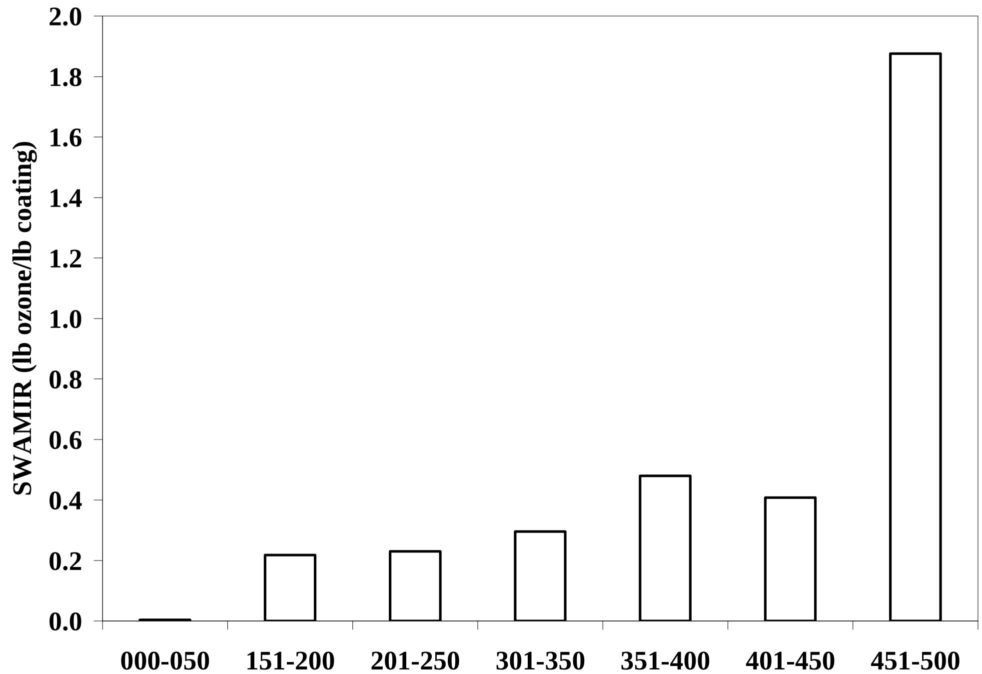


Figure 2-47
Quick Dry Enamel (lb O3/gallon solids)

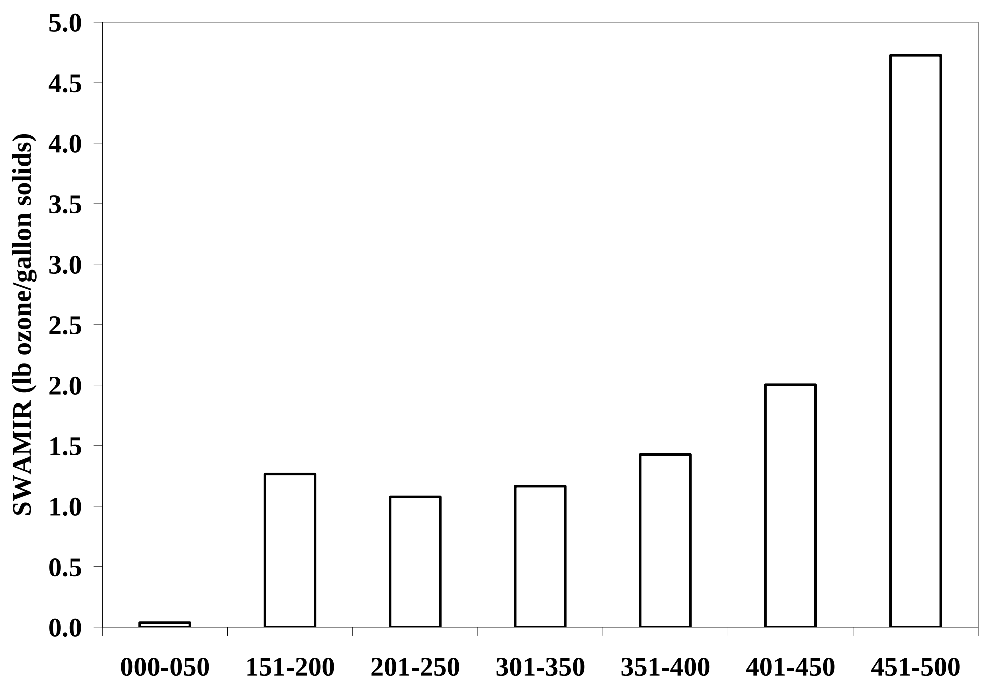


Figure 2-48
Quick Dry Primer, Sealer, Undercoater (lb O3/lb coating)

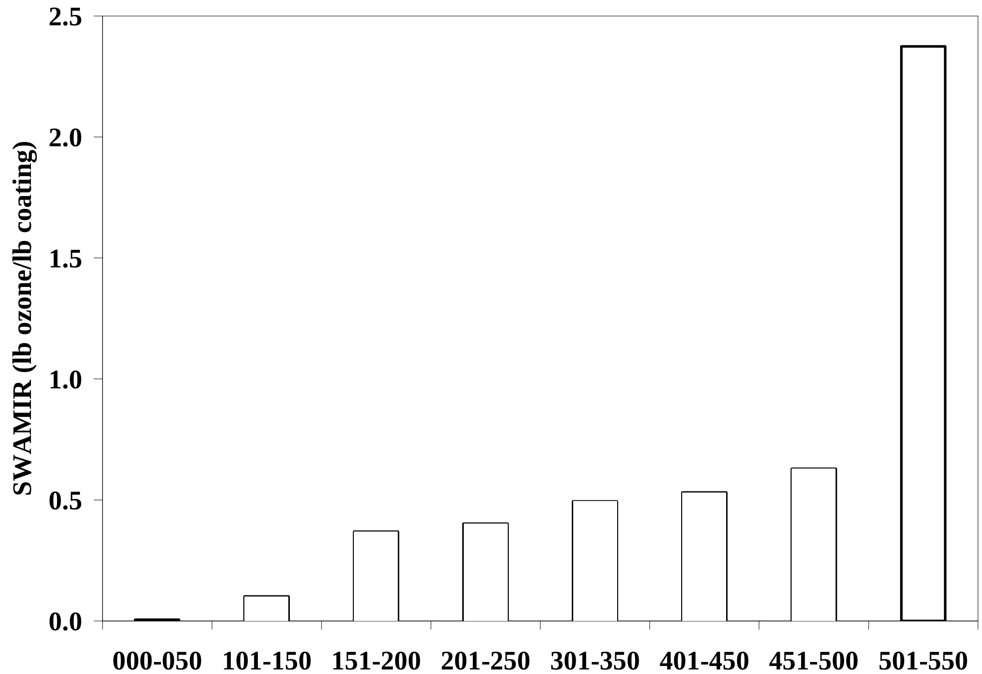
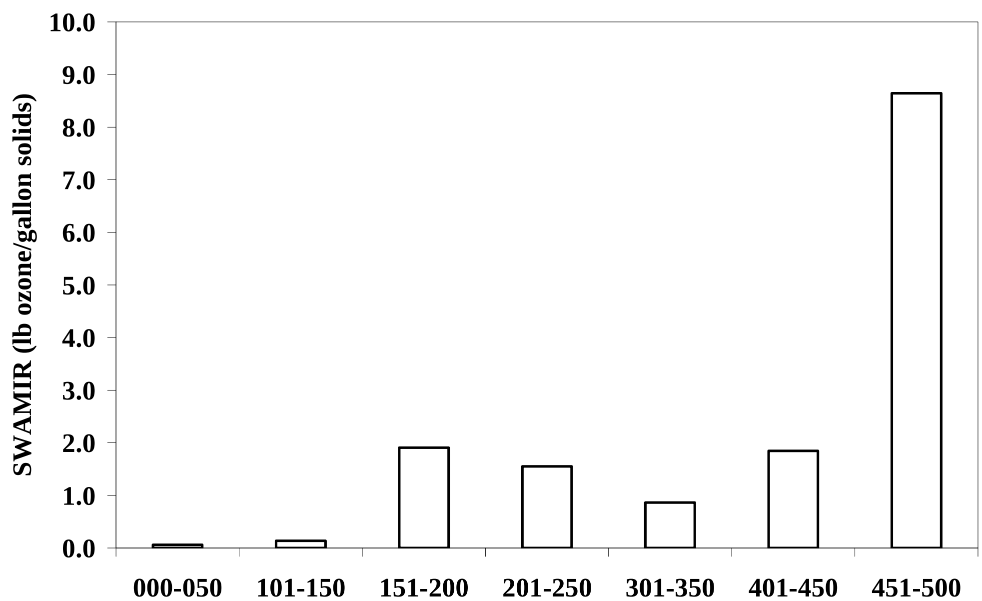


Figure 2-49
Quick Dry Primer, Sealer, Undercoater (lb O3/gallon solids)



***Note: This chart does not include all products in this category. To improve chart resolution, upper VOC ranges with high SWAMIR values are not shown. Please refer to the Appendix to see the complete data for this category.**

Figure 2-50
Rust Preventative (lb O3/lb coating)

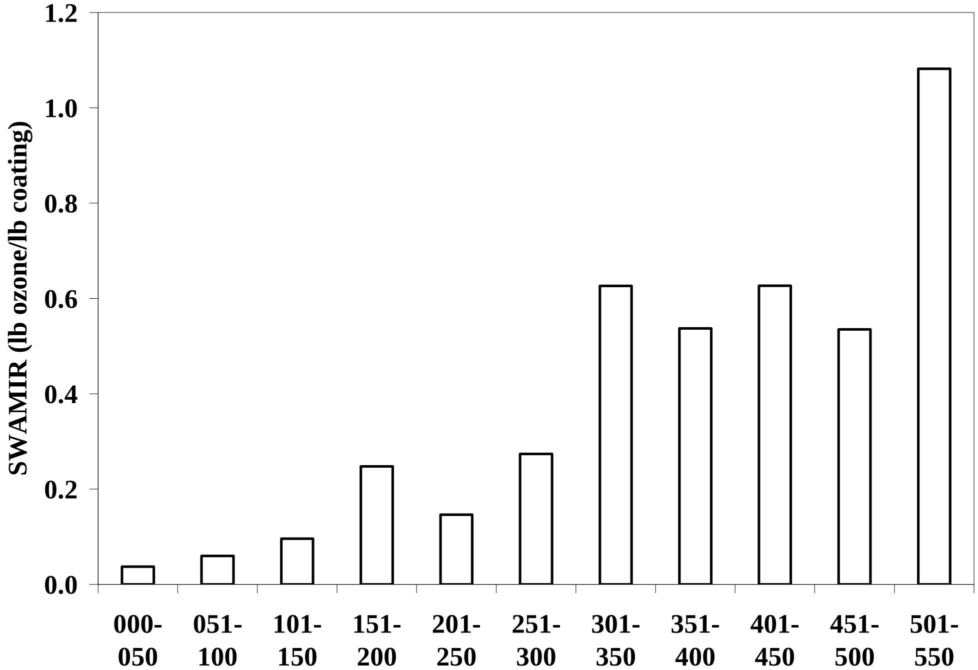


Figure 2-51
Rust Preventative (lb O3/gallon solids)

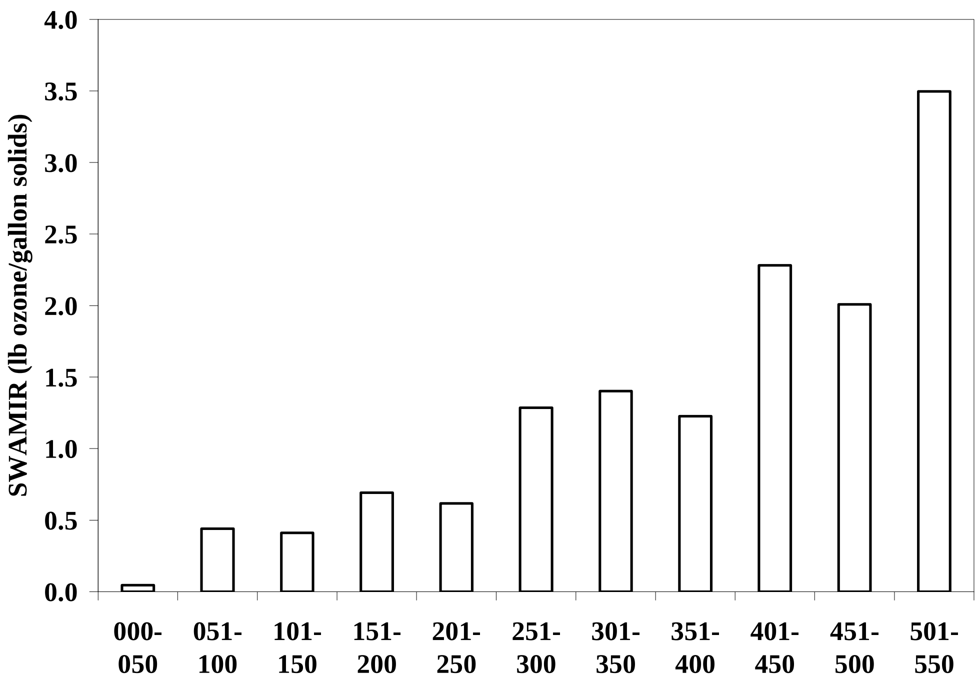


Figure 2-52

Specialty Primer, Sealer, Undercoater (lb O3/lb coating)

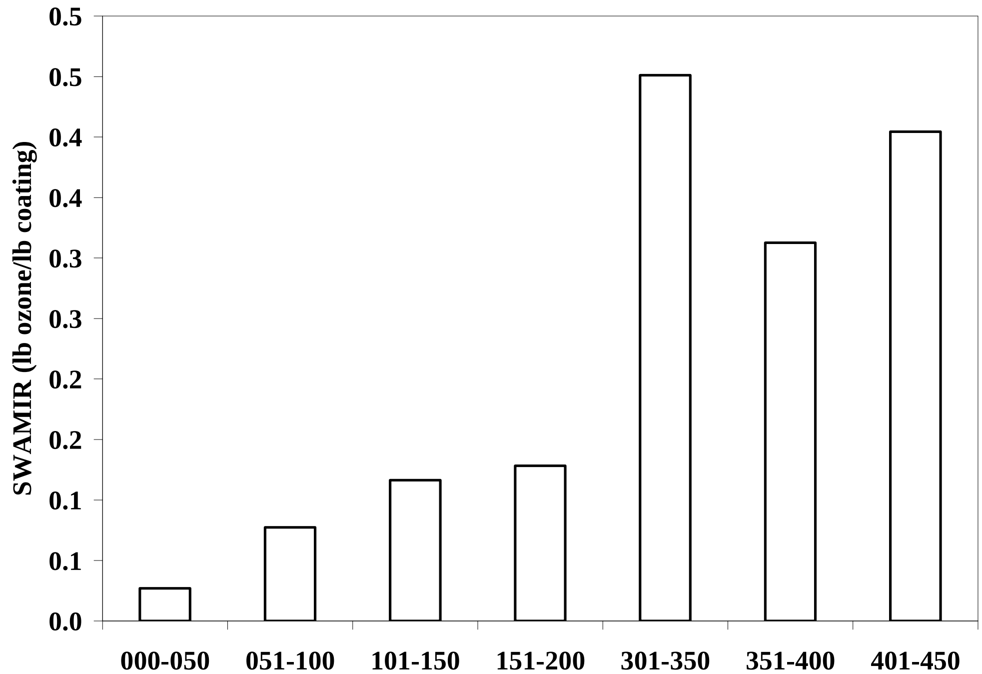


Figure 2-53

Specialty Primer, Sealer, Undercoater (lb O3/gallon solids)

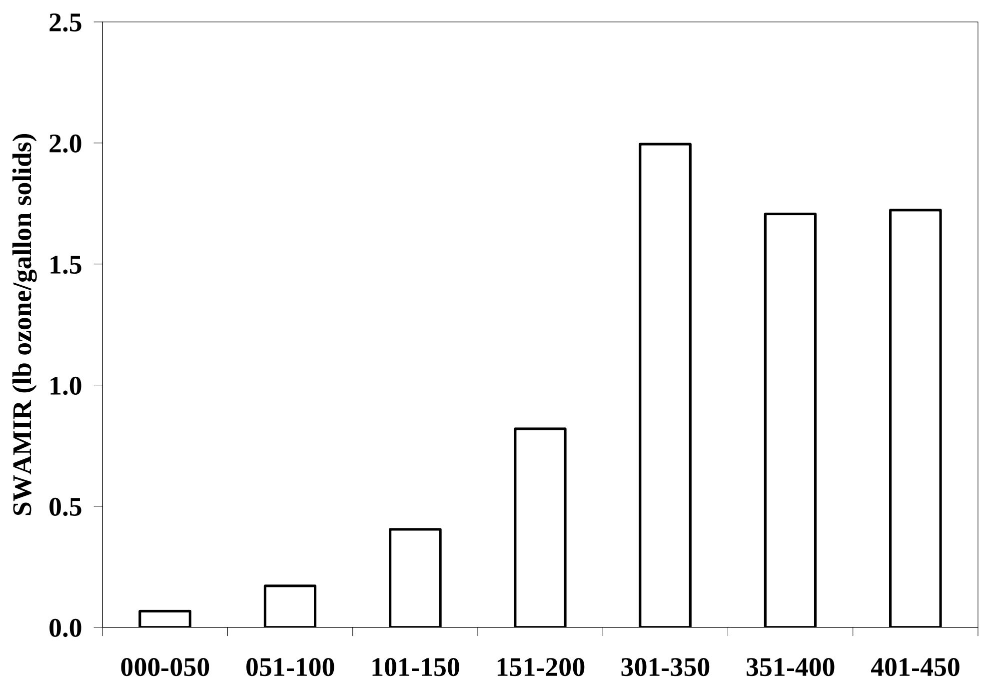


Figure 2-54

Stains – Clear/Semitransparent (lb O^3/lb coating)

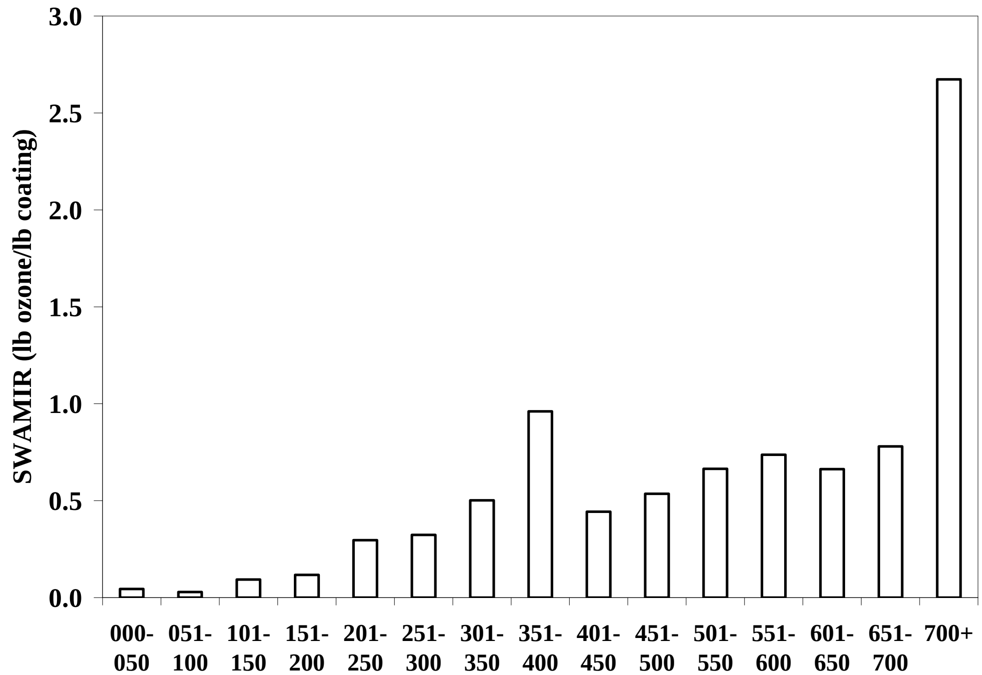
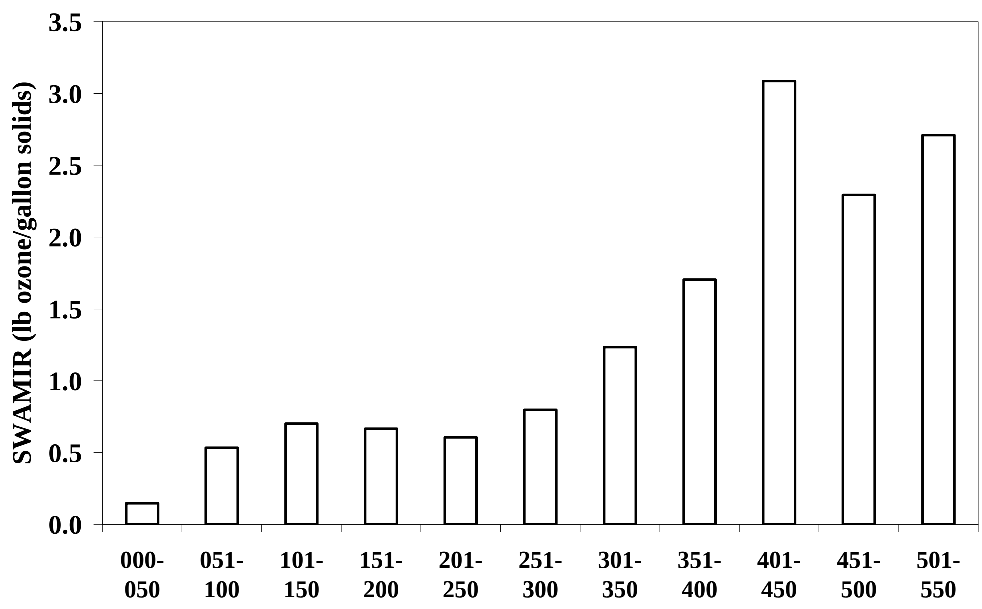


Figure 2-55

Stains – Clear/Semitransparent (lb O^3/gallon solids)



***Note: This chart does not include all products in this category. To improve chart resolution, upper VOC ranges with high SWAMIR values are not shown. Please refer to the Appendix to see the complete data for this category.**

Figure 2-56
Varnishes – Clear (lb O3/lb coating)

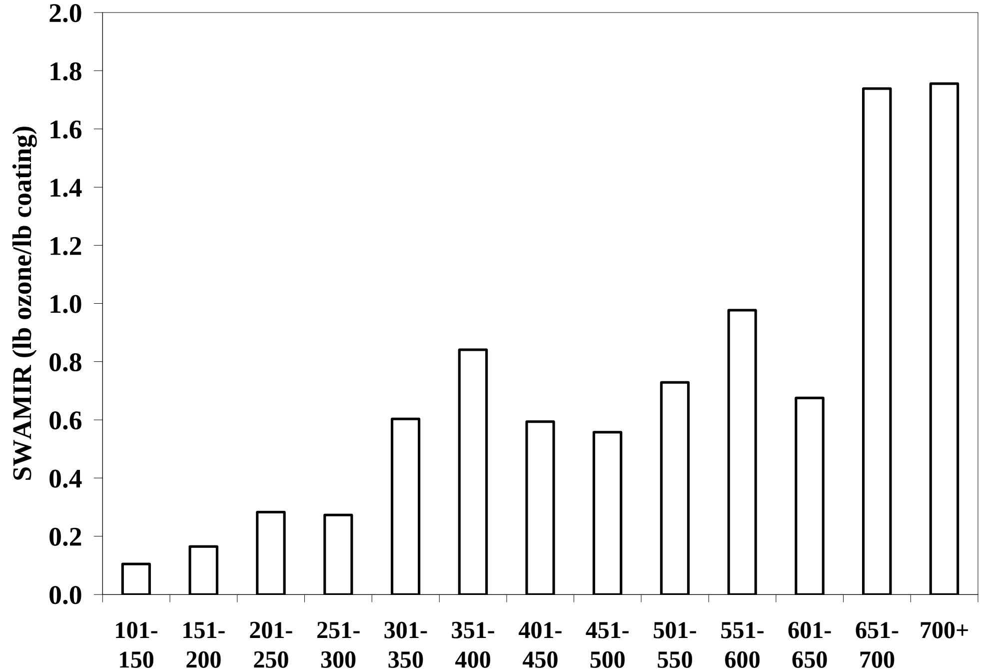
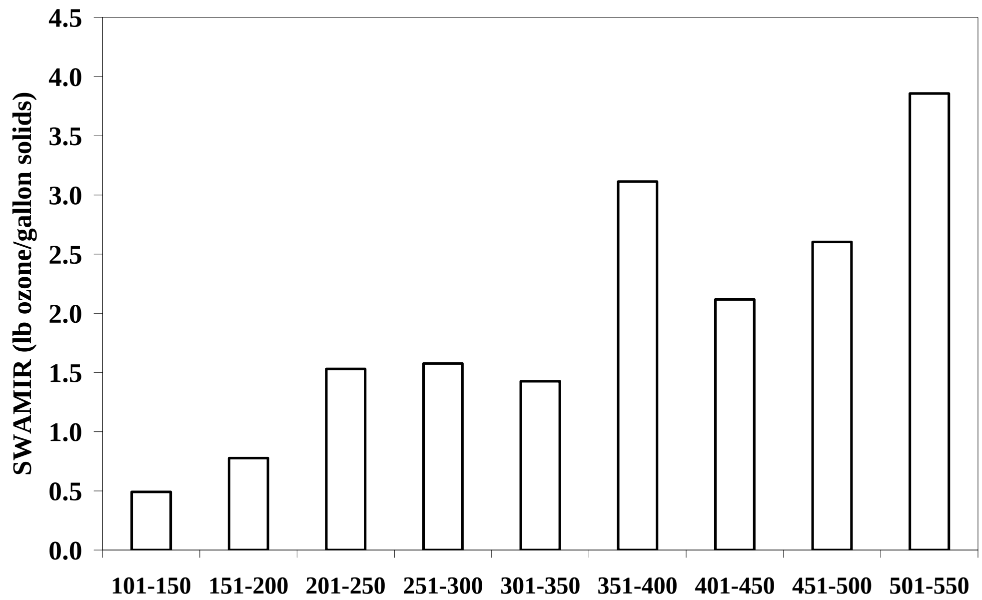


Figure 2-57
Varnishes – Clear (lb O3/gallon solids)



***Note: This chart does not include all products in this category. To improve chart resolution, upper VOC ranges with high SWAMIR values are not shown. Please refer to the Appendix to see the complete data for this category.**

Figure 2-58
Waterproofing Concrete/Masonry Sealers (lb O3/lb coating)

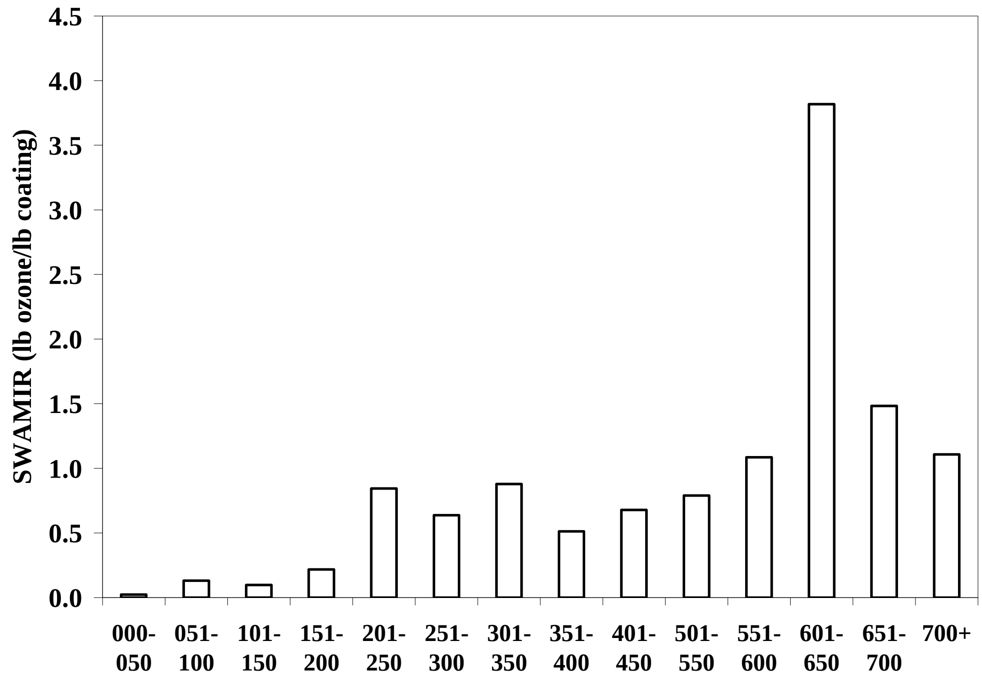
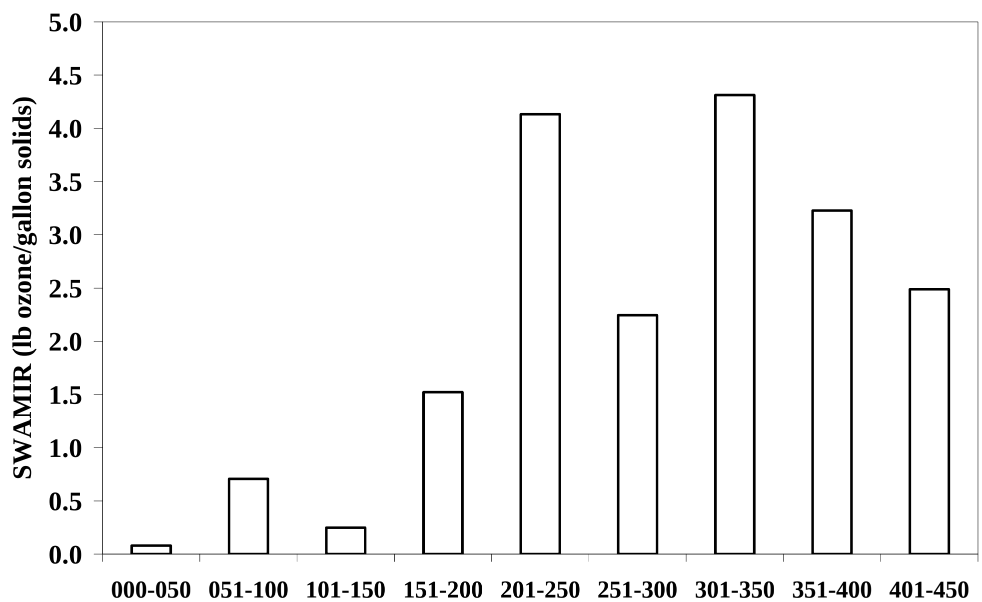


Figure 2-59
Waterproofing Concrete/Masonry Sealers (lb O3/gallon solids)



***Note: This chart does not include all products in this category. To improve chart resolution, upper VOC ranges with high SWAMIR values are not shown. Please refer to the Appendix to see the complete data for this category.**

Figure 2-60

Waterproofing Sealers (lb O3/lb coating)

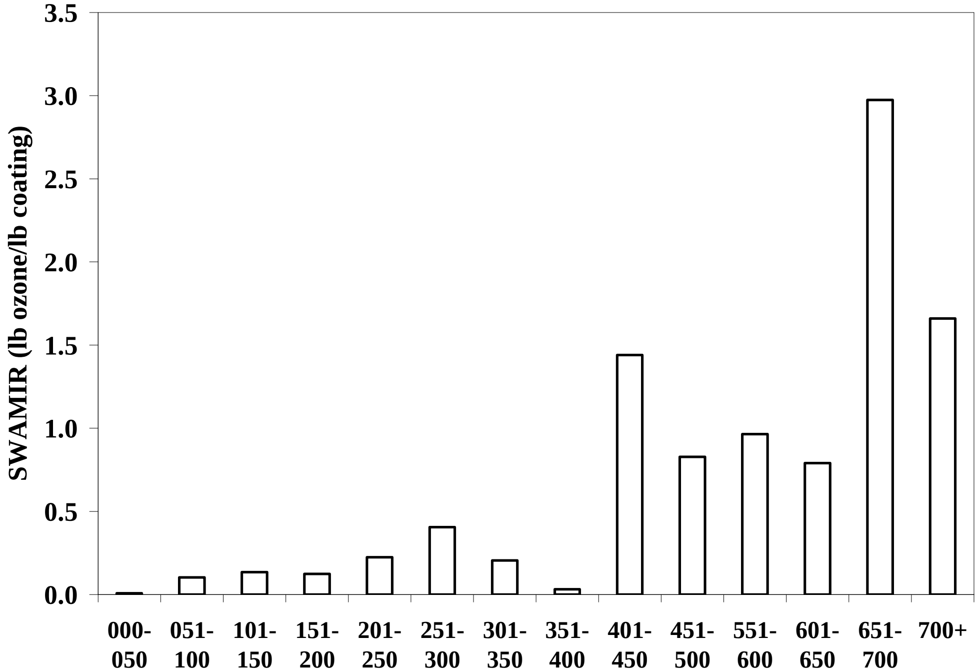
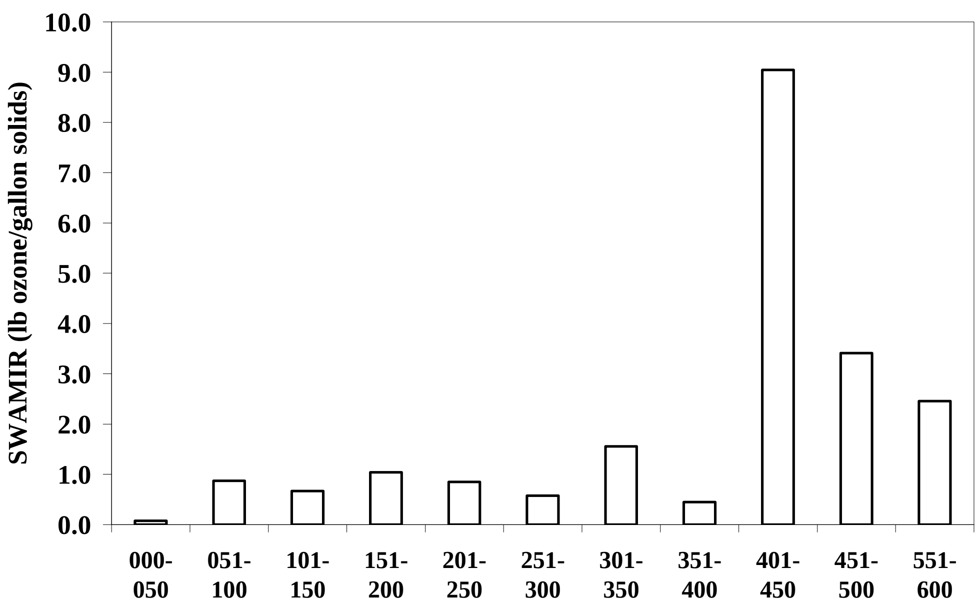


Figure 2-61

Waterproofing Sealers (lb O3/gallon solids)



***Note: This chart does not include all products in this category. To improve chart resolution, upper VOC ranges with high SWAMIR values are not shown. Please refer to the Appendix to see the complete data for this category.**

Section 2.5 Ingredient Contributions To Reactivity

To identify opportunities for ozone reductions, it is important to know which ingredients contribute the most to a category's potential ozone creation. The following table focuses on the ingredients that are the primary contributors to either VOC emissions or maximum potential ozone totals for selected categories. Table 2-5 only lists ingredients that represent more than 10% of the total maximum potential ozone for a category or ingredients that represent more than 10% by weight of the total volatile ingredients (excluding water). It highlights categories where it may be possible to replace a more reactive ingredient with one that is less reactive. The data in Table 2-5 are based on the official MIR values published in ARB's Aerosol Coatings regulation, as updated in July 2004 (CCR, 2004).

Table 2-5: ***Ingredients That Contribute the Most to Emissions and Potential Ozone (official MIRs)***

Category	CAS	Ingredient	MIR (g O^3/ g ingr)	Ingred. Qty. (tpd)	Max. Ozone (tpd)	% of Total Volatiles For Category	% of Total Max. Ozone From Category
Bituminous Roof		Bin 15 Hydrocarbon Solvent	1.82	0.32	0.59	78%	52%
		Bin 22 Hydrocarbon Solvent	7.51	0.06	0.44	14%	39%
Flat	107211	Ethylene Glycol	3.63	3.48	12.65	25%	34%
	124685	2-Amino-2-Methyl-1-Propanol	15.08	0.61	9.19	4%	25%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.89	6.46	5.75	47%	16%
	57556	Propylene Glycol	2.75	1.84	5.05	13%	14%
Floor	9986	Unknown	2.73	1.36	3.72	63%	59%
		Bin 22 Hydrocarbon Solvent	7.51	0.12	0.88	5%	14%
	29911271	Dipropylene Glycol Monopropyl Ether	2.13	0.24	0.51	11%	8%
Industrial Maintenance	1330207	Xylene	7.48	0.67	5.01	15%	34%
		Bin 11 Hydrocarbon Solvent	0.91	0.59	0.54	14%	4%
Lacquers	67641	Acetone	0.43	4.02	1.73	55%	19%
	1330207	Xylene	7.48	0.18	1.34	2%	15%
	111762	2-Butoxy Ethanol	2.90	0.33	0.94	4%	10%
	123864	Butyl Acetate, 1-	0.89	0.87	0.78	12%	8%
Metallic Pigmented		Bin 15 Hydrocarbon Solvent	1.82	1.35	2.45	62%	40%
		Bin 22 Hydrocarbon Solvent	7.51	0.32	2.43	15%	40%
Nonflat - High Gloss	107211	Ethylene Glycol	3.63	0.35	1.26	26%	33%
	124685	2-Amino-2-Methyl-1-Propanol	15.08	0.05	0.79	4%	21%
	57556	Propylene Glycol	2.75	0.17	0.48	13%	13%
	5444757	2-Ethylhexyl Benzoate	2.73	0.17	0.46	13%	12%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.89	0.33	0.30	25%	8%

Table 2-5: ***Ingredients That Contribute the Most to Emissions and Potential Ozone (official MIRs)***

Category	CAS	Ingredient	MIR (g O^3/ g ingr)	Ingred. Qty. (tpd)	Max. Ozone (tpd)	% of Total Volatiles For Category	% of Total Max. Ozone From Category
Nonflat - Low Gloss	107211	Ethylene Glycol	3.63	2.61	9.47	39%	51%
	57556	Propylene Glycol	2.75	0.93	2.56	14%	14%
	124685	2-Amino-2-Methyl-1-Propanol	15.08	0.15	2.26	2%	12%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.89	1.94	1.72	29%	9%
Nonflat - Medium Gloss	107211	Ethylene Glycol	3.63	3.31	12.02	28%	41%
	57556	Propylene Glycol	2.75	2.70	7.41	23%	25%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.89	3.83	3.41	33%	12%
Primer, Sealer, and Undercoater	107211	Ethylene Glycol	3.63	2.59	9.41	40%	51%
	124685	2-Amino-2-Methyl-1-Propanol	15.08	0.24	3.68	4%	20%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.89	1.67	1.48	26%	8%
		Bin 11 Hydrocarbon Solvent	0.91	0.76	0.69	12%	4%
Quick Dry Enamel		Bin 11 Hydrocarbon Solvent	0.91	2.33	2.12	72%	46%
		Bin 10 Hydrocarbon Solvent	2.03	0.34	0.70	11%	15%
Quick Dry Primer, Sealer, and Undercoater		Bin 6 Hydrocarbon Solvent	1.41	0.63	0.89	62%	53%
		Bin 11 Hydrocarbon Solvent	0.91	0.22	0.20	22%	12%
Rust Preventative		Bin 10 Hydrocarbon Solvent	2.03	1.87	3.79	21%	24%
		Bin 11 Hydrocarbon Solvent	0.91	3.86	3.51	44%	23%
		Bin 15 Hydrocarbon Solvent	1.82	1.21	2.20	14%	14%
	1330207	Xylene	7.48	0.25	1.88	3%	12%
Specialty Primer, Sealer, and Undercoater		Bin 22 Hydrocarbon Solvent	7.51	0.62	4.66	10%	40%
		Bin 11 Hydrocarbon Solvent	0.91	4.45	4.05	74%	35%
Stains - Clear/ Semitransparent		Bin 11 Hydrocarbon Solvent	0.91	3.87	3.52	59%	40%
Varnishes - Clear		Bin 11 Hydrocarbon Solvent	0.91	2.77	2.52	70%	46%
		Bin 15 Hydrocarbon Solvent	1.82	0.41	0.75	10%	14%

Table 2-5: ***Ingredients That Contribute the Most to Emissions and Potential Ozone (official MIRs)***

Category	CAS	Ingredient	MIR (g O^3/ g ingr)	Ingred. Qty. (tpd)	Max. Ozone (tpd)	% of Total Volatiles For Category	% of Total Max. Ozone From Category
Waterproofing Concrete/Masonry Sealers		Bin 22 Hydrocarbon Solvent	7.51	0.39	2.95	10%	34%
		Bin 6 Hydrocarbon Solvent	1.41	0.65	0.92	16%	11%
	67641	Acetone	0.43	0.55	0.24	14%	3%
	98566	4-Chlorobenzotrifluoride	0.11	0.58	0.06	14%	1%
Waterproofing Sealers		Bin 11 Hydrocarbon Solvent	0.91	0.61	0.55	38%	16%
	34590948	Dipropylene Glycol Methyl Ether	2.46	0.20	0.48	12%	14%
	107211	Ethylene Glycol	3.63	0.12	0.45	8%	13%

Notes:

1. The values in this table are based on the official MIR values published in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions", California Code of Regulations, Title 17, sections 94700 and 94701, as updated July 7, 2004.
2. This table includes data from small containers (1 quart or less).
3. This table includes ozone generated from all volatile emissions, including VOCs and exempt compounds.

For comparison, Table 2-6 contains similar information as Table 2-5, but Table 2-6 is based on draft updated MIR values that have not yet been officially adopted (Carter, 2007).

Table 2-6: ***Ingredients That Contribute the Most to Emissions and Potential Ozone (draft updated MIRs)***

Category	CAS	Ingredient	MIR (g O^3/ g ingr)	Ingred. Qty. (tpd)	Max. Ozone (tpd)	% of Total Volatiles For Category	% of Total Max. Ozone From Category
Bituminous Roof		Bin 15 Hydrocarbon Solvent	1.82	0.32	0.59	78%	53%
		Bin 22 Hydrocarbon Solvent	7.51	0.06	0.44	14%	40%
Flat	107211	Ethylene Glycol	3.03	3.48	10.56	25%	45%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.75	6.46	4.87	47%	21%
	57556	Propylene Glycol	2.50	1.84	4.59	13%	20%
Floor	9986	Unknown	1.93	1.36	2.64	63%	54%
		Bin 22 Hydrocarbon Solvent	7.51	0.12	0.88	5%	18%
	29911271	Dipropylene Glycol Monopropyl Ether	1.89	0.24	0.45	11%	9%
Industrial Maintenance	1330207	Xylene	7.72	0.67	5.17	15%	36%
		Bin 22 Hydrocarbon Solvent	7.51	0.19	1.46	4%	10%
		Bin 11 Hydrocarbon Solvent	0.91	0.59	0.54	14%	4%

Table 2-6: *Ingredients That Contribute the Most to Emissions and Potential Ozone (draft updated MIRs)*

Category	CAS	Ingredient	MIR (g O3/ g ingr)	Ingred. Qty. (tpd)	Max. Ozone (tpd)	% of Total Volatiles For Category	% of Total Max. Ozone From Category
Lacquers	67641	Acetone	0.35	4.02	1.42	55%	17%
	1330207	Xylene	7.72	0.18	1.39	2%	17%
	111762	2-Butoxy Ethanol	2.80	0.33	0.91	4%	11%
	123864	Butyl Acetate, 1-	0.77	0.87	0.68	12%	8%
Metallic Pigmented		Bin 15 Hydrocarbon Solvent	1.82	1.35	2.45	62%	42%
		Bin 22 Hydrocarbon Solvent	7.51	0.32	2.43	15%	41%
Nonflat - High Gloss	107211	Ethylene Glycol	3.03	0.35	1.05	26%	45%
	57556	Propylene Glycol	2.50	0.17	0.43	13%	19%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.75	0.33	0.25	25%	11%
	5444757	2-Ethylhexyl Benzoate	0.92	0.17	0.16	13%	7%
Nonflat - Low Gloss	107211	Ethylene Glycol	3.03	2.61	7.90	39%	57%
	57556	Propylene Glycol	2.50	0.93	2.33	14%	17%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.75	1.94	1.46	29%	11%
Nonflat - Medium Gloss	107211	Ethylene Glycol	3.03	3.31	10.03	28%	43%
	57556	Propylene Glycol	2.50	2.70	6.74	23%	29%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.75	3.83	2.89	33%	12%
Primer, Sealer, and Undercoater	107211	Ethylene Glycol	3.03	2.59	7.86	40%	63%
	25265774	2,2,4-Trimethyl-1,3-Pentanediol Isobutyrate	0.75	1.67	1.26	26%	10%
		Bin 11 Hydrocarbon Solvent	0.91	0.76	0.69	12%	6%
Quick Dry Enamel		Bin 11 Hydrocarbon Solvent	0.91	2.33	2.12	72%	50%
		Bin 10 Hydrocarbon Solvent	2.03	0.34	0.70	11%	16%
Quick Dry Primer, Sealer, and Undercoater		Bin 6 Hydrocarbon Solvent	1.41	0.63	0.89	62%	57%
		Bin 11 Hydrocarbon Solvent	0.91	0.22	0.20	22%	13%
Rust Preventative		Bin 10 Hydrocarbon Solvent	2.03	1.87	3.79	21%	26%
		Bin 11 Hydrocarbon Solvent	0.91	3.86	3.51	44%	24%
		Bin 15 Hydrocarbon Solvent	1.82	1.21	2.20	14%	15%
	1330207	Xylene	7.72	0.25	1.94	3%	13%
Specialty Primer, Sealer, and Undercoater		Bin 22 Hydrocarbon Solvent	7.51	0.62	4.66	10%	44%
		Bin 11 Hydrocarbon Solvent	0.91	4.45	4.05	74%	38%
Stains - Clear/ Semitransparent		Bin 11 Hydrocarbon Solvent	0.91	3.87	3.52	59%	41%

Table 2-6: ***Ingredients That Contribute the Most to Emissions and Potential Ozone (draft updated MIRs)***

Category	CAS	Ingredient	MIR (g O^3/ g ingr)	Ingred. Qty. (tpd)	Max. Ozone (tpd)	% of Total Volatiles For Category	% of Total Max. Ozone From Category
Varnishes - Clear		Bin 11 Hydrocarbon Solvent	0.91	2.77	2.52	70%	50%
		Bin 15 Hydrocarbon Solvent	1.82	0.41	0.75	10%	15%
Waterproofing Concrete/Masonry Sealers		Bin 22 Hydrocarbon Solvent	7.51	0.39	2.95	10%	35%
		Bin 6 Hydrocarbon Solvent	1.41	0.65	0.92	16%	11%
	67641	Acetone	0.35	0.55	0.20	14%	2%
	98566	4-Chlorobenzotrifluoride	0.12	0.58	0.07	14%	1%
Waterproofing Sealers		Bin 11 Hydrocarbon Solvent	0.91	0.61	0.55	38%	19%
	34590948	Dipropylene Glycol Methyl Ether	2.18	0.20	0.43	12%	15%
	107211	Ethylene Glycol	3.03	0.12	0.37	8%	13%
		Bin 23 Hydrocarbon Solvent	8.07	0.04	0.32	3%	11%

Notes:

1. The values in this table are based on draft updated MIR values that have not yet been officially adopted in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions". These draft updated values have been determined by Dr. William Carter for the research project titled "Reactivity Estimates for Selected Consumer Product Compounds" under Contract No. 06-408. The draft updated values were current as of December 24, 2007, and they are subject to change.
2. This table includes data from small containers (1 quart or less).
3. This table includes ozone generated from all volatile emissions, including VOCs and exempt compounds.

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Chapter 3 – Reactivity Analysis Comparison

This section compares, where possible, the data from ARB's 2001 survey (2000 sales) with the 2005 survey (2004 sales). Data in this chapter include sales of small containers (one quart or less). As shown in Table 3-1, from 2000 to 2004, the coating sales volume increased 12 percent, but the maximum ozone formation potential (OFP) declined 8 percent.

Table 3-1: ***Summary Comparison Between 2001 and 2005 Surveys (official MIRs)***

	2001 Survey (2000 Sales, including quarts)	2005 Survey (2004 Sales, including quarts)	Percent Change
COATING SALES VOLUME DATA			
Total Sales Volume Reported (gallons)	**98,455,172**	**110,407,721**	**12%**
Water-borne Coating Sales Volume	81,548,961	97,354,686	19%
Solvent-borne Coating Sales Volume	16,906,211	13,053,035	-23%
Percent Water-borne Sales	83%	88%	
Percent Solvent-borne Sales	17%	12%	
Coating Sales Volume Per Capita (gals per person)	2.9	3.0	
MAXIMUM OZONE FORMATION POTENTIAL (OFP) – COATINGS ONLY			
Total Maximum OFP (tons ozone/day)	**246**	**227**	**-8%**
Water-borne Coating OFP	103.8	126.7	22%
Solvent-borne Coating OFP	142.1	99.8	-30%
Percent Water-borne OFP	42%	56%	
Percent Solvent-borne OFP	58%	44%	
OFP per capita (lbs ozone per person)	5.3	4.6	
SALES-WEIGHTED AVERAGE MIR (SWAMIR) – COATINGS ONLY			
Overall SWAMIR (lbs ozone/lb coating)	**0.19**	**0.15**	**-21%**
Water-borne Coating SWAMIR	0.09	0.09	0%
Solvent-borne Coating SWAMIR	0.67	0.60	-10%
MAXIMUM OZONE PER POUND – COATINGS ONLY (not sales-weighted)			
Total Max. OFP Per Lb (lbs ozone/lb coating)	**0.17**	**0.14**	**-18%**
Water-borne Coating OFP Per Pound	0.09	0.09	0%
Solvent-borne Coating OFP Per Pound	0.62	0.58	-6%
MAXIMUM OZONE PER GALLON – COATINGS ONLY (not sales-weighted)			
Total Max. OFP Per Gallon (lbs ozone/gal)	**1.82**	**1.50**	**-18%**
Water-borne Coating OFP Per Gallon	0.93	0.95	2%
Solvent-borne Coating OFP Per Gallon	6.13	5.60	-9%

Notes:

1. Reference for the 2001 Maximum Ozone Formation Potential: ARB's "2001 Architectural Coatings Survey, Final Reactivity Analysis", Tables 2-6 and 2-7, dated March 2005.
2. CA Population in 2000 = 33,871,648 people. CA Population in 2004 = 35,893,799 people
3. The values in this table are based on the official MIR values published in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions", California Code of Regulations, Title 17, sections 94700 and 94701, as updated July 7, 2004

The decline in ozone shown in Table 3-1 is a result of the shift of products from solventborne formulations to waterborne formulations that have a lower reactivity. In addition, the overall reactivity of solventborne products declined from 2000 to 2004. The data in Table 3-1 are based on the official MIR values published in ARB's Aerosol Coatings regulation, as updated in July 2004 (CCR, 2004). For comparison purposes, Table 3-2 contains data that are based on draft updated MIR values that have not yet been officially adopted (Carter, 2007). For some key ingredients in architectural coatings, the draft updated MIRs used in Table 3-2 provide more accurate results.

Table 3-2: ***Summary Comparison Between 2001 and 2005 Surveys (draft updated MIRs)***

	2001 Survey (2000 Sales, including quarts)	2005 Survey (2004 Sales, including quarts)	Percent Change
COATING SALES VOLUME DATA			
Total Sales Volume Reported (gallons)	**98,455,172**	**110,407,721**	**12%**
Water-borne Coating Sales Volume	81,548,961	97,354,686	19%
Solvent-borne Coating Sales Volume	16,906,211	13,053,035	-23%
Percent Water-borne Sales	83%	88%	
Percent Solvent-borne Sales	17%	12%	
Coating Sales Volume Per Capita (gals per person)	2.9	3.0	
MAXIMUM OZONE FORMATION POTENTIAL (OFP) – COATINGS ONLY			
Total Maximum OFP (tons ozone/day)	**231**	**186**	**-20%**
Water-borne Coating OFP	90.7	90.4	0%
Solvent-borne Coating OFP	140.5	95.4	-32%
Percent Water-borne OFP	39%	49%	
Percent Solvent-borne OFP	61%	51%	
OFP per capita (lbs ozone per person)	5.0	3.8	
SALES-WEIGHTED AVERAGE MIR (SWAMIR) – COATINGS ONLY			
Overall SWAMIR (lbs ozone/lb coating)	**0.18**	**0.13**	**-29%**
Water-borne Coating SWAMIR	0.08	0.07	-15%
Solvent-borne Coating SWAMIR	0.66	0.57	-14%
MAXIMUM OZONE PER POUND – COATINGS ONLY (not sales-weighted)			
Total Max. OFP Per Lb (lbs ozone/lb coating)	**0.16**	**0.12**	**-28%**
Water-borne Coating OFP Per Pound	0.08	0.06	-16%
Solvent-borne Coating OFP Per Pound	0.62	0.56	-10%
MAXIMUM OZONE PER GALLON – COATINGS ONLY (not sales-weighted)			
Total Max. OFP Per Gallon (lbs ozone/gal)	**1.71**	**1.23**	**-28%**
Water-borne Coating OFP Per Gallon	0.81	0.68	-16%
Solvent-borne Coating OFP Per Gallon	6.07	5.35	-12%

Notes:
1. CA Population in 2000 = 33,871,648 people. CA Population in 2004 = 35,893,799 people
2. The values in this table are based on draft updated MIR values that have not yet been officially adopted by ARB. These draft values have been determined by Dr. William Carter for the research project titled "Reactivity Estimates for Selected Consumer Product Compounds" under Contract No. 06-408. The draft updated values were current as of December 24, 2007, and they are subject to change.

Table 3-3 provides a comparison between the reactivity analyses for the 2001 and 2005 surveys. For most coating categories, it was possible to make a direct comparison. However, in some cases, it was not possible to make a direct comparison because data were not available for both survey years. If it was not possible to make a comparison, the category was not listed in Table 3-3. In some categories, there were significant changes in sales volume and ozone formation potential. Table 3-4 summarizes the primary reasons for these changes. The data in Table 3-3 are based on the official MIR values published in ARB's Aerosol Coatings regulation, as updated in July 2004 (CCR, 2004).

Table 3-3: ***Detailed Comparison of Reactivity Analyses for the 2001 and 2005 Surveys (official MIRs)***

Coating Category	*Sales Volume (gallons)*			*Maximum Ozone Formation Potential (tons per day)*			*Sales-Weighted Average MIR (SWAMIR) (lbs ozone/lbs product)*			*Maximum OFP Per Gallon (lbs ozone/gal product)*		
	2000 Sales	*2004 Sales*	*% change*	*2000*	*2004*	*% change*	*2000*	*2004*	*% change*	*2000*	*2004*	*% change*
Bituminous Roof	3,245,397	1,464,326	-55%	7.20	1.12	-84%	0.20	0.06	-67%	1.62	0.56	-65%
Bituminous Roof Primer	170,520	68,092	-60%	0.70	0.50	-29%	0.37	0.71	90%	2.98	5.38	80%
Bond Breakers	93,896	187,785	100%	0.17	0.77	346%	0.16	0.36	121%	1.33	2.97	123%
Clear Brushing Lacquer	PD	PD	PD	1.08	1.06	-2%	1.51	1.49	-2%	11.33	11.16	-1%
Concrete Curing Compounds	692,419	793,566	15%	1.59	1.57	-1%	0.20	0.17	-13%	1.68	1.44	-14%
Dry Fog	459,756	377,707	-18%	1.86	1.72	-7%	0.24	0.28	17%	2.95	3.32	13%
Faux Finishing	173,737	303,810	75%	0.51	0.97	91%	0.23	0.26	11%	2.12	2.32	9%
Fire Resistive	PD	12,577	PD	0.00	0.04	6226%	0.04	0.24	521%	0.41	2.56	531%
Fire Retardant - Clear	PD	PD	PD	0.00	0.02	35299%	0.00	2.20	64279%	0.04	19.58	51895%
Fire Retardant - Opaque	29,055	200,150	589%	0.06	0.91	1519%	0.13	0.29	113%	1.41	3.31	135%
Flat	**34,810,257**	**37,264,874**	**7%**	**34.84**	**36.72**	**5%**	**0.06**	**0.06**	**-2%**	**0.73**	**0.72**	**-2%**
Floor	1,425,064	1,239,892	-13%	3.72	*6.25*	*68%*	0.19	*0.39*	*108%*	1.90	*3.80*	*100%*
Form Release Compounds	255,724	323,612	27%	0.71	1.32	85%	0.27	0.40	46%	2.03	2.97	46%
Graphic Arts	26,389	PD	PD	0.15	0.02	-85%	0.45	0.35	-21%	4.26	3.92	-8%
High Temperature	18,632	11,736	-37%	0.21	0.14	-34%	0.84	0.82	-3%	8.22	8.66	5%
Industrial Maintenance	**4,740,079**	**2,137,772**	**-55%**	**46.40**	**14.90**	**-68%**	**0.69**	**0.48**	**-31%**	**7.15**	**5.23**	**-27%**
Lacquers	**447,352**	**1,291,571**	**189%**	**6.99**	**9.25**	**32%**	**1.34**	**0.66**	**-50%**	**11.40**	**5.23**	**-54%**
Low Solids	13,413	65,680	390%	0.03	0.10	289%	0.17	0.14	-20%	1.47	1.17	-21%
Magnesite Cement	PD	PD	PD	0.85	0.72	-16%	2.12	2.26	7%	18.92	20.12	6%
Mastic Texture	628,590	677,063	8%	0.91	1.00	10%	0.11	0.10	-5%	1.05	1.08	3%
Metallic Pigmented	625,944	570,977	-9%	11.22	6.06	-46%	1.40	0.88	-37%	13.08	7.79	-40%
Multi-Color	**7,580**	**13,635**	**80%**	**0.03**	**0.01**	**-73%**	**0.33**	**0.05**	**-86%**	**2.78**	**0.42**	**-85%**
Nonflat - High Gloss	1,926,436	1,760,459	-9%	8.90	3.81	-57%	0.34	0.16	-55%	3.37	1.58	-53%
Nonflat - Low Gloss	**6,594,890**	**12,023,079**	**82%**	**9.36**	**18.59**	**99%**	**0.10**	**0.11**	**7%**	**1.04**	**1.13**	**9%**
Nonflat - Medium Gloss	**18,102,739**	**20,072,832**	**11%**	**34.77**	**29.64**	**-15%**	**0.14**	**0.11**	**-24%**	**1.40**	**1.08**	**-23%**

Table 3-3: ***Detailed Comparison of Reactivity Analyses for the 2001 and 2005 Surveys (official MIRs)***

Coating Category	*Sales Volume (gallons)*			*Maximum Ozone Formation Potential (tons per day)*			*Sales-Weighted Average MIR (SWAMIR) (lbs ozone/lbs product)*			*Maximum OFP Per Gallon (lbs ozone/gal product)*		
	2000 Sales	*2004 Sales*	*% change*	*2000*	*2004*	*% change*	*2000*	*2004*	*% change*	*2000*	*2004*	*% change*
Other	1,510,316	89,473	-94%	0.07	0.08	7%	0.00	0.07	1781%	0.04	0.63	1699%
Pre-Treatment Wash Primer	75,342	4,959	-93%	0.23	0.02	-90%	0.24	0.45	87%	2.26	3.51	55%
Primer, Sealer, and Undercoater	**8,125,823**	**10,402,018**	**28%**	**19.13**	**18.39**	**-4%**	**0.17**	**0.12**	**-31%**	**1.72**	**1.29**	**-25%**
Quick Dry Enamel	**623,666**	**763,266**	**22%**	**4.41**	**4.61**	**5%**	**0.53**	**0.45**	**-16%**	**5.17**	**4.41**	**-15%**
Quick Dry Primer, Sealer, and Undercoater	**1,660,227**	**249,710**	**-85%**	**7.50**	**1.69**	**-77%**	**0.40**	**0.46**	**15%**	**3.30**	**4.94**	**50%**
Roof	1,137,354	1,406,889	24%	1.42	1.15	-19%	0.09	0.06	-38%	0.91	0.60	-35%
Rust Preventative	209,899	2,095,500	898%	1.34	15.52	1059%	0.43	0.54	26%	4.66	5.41	16%
Sanding Sealers	28,268	84,273	198%	0.29	0.53	83%	1.01	0.62	-39%	7.52	4.62	-39%
Shellacs - Clear	PD	PD	PD	0.19	0.55	195%	1.14	1.03	-9%	8.45	7.66	-9%
Shellacs – Opaque	PD	PD	PD	0.88	1.28	46%	0.74	0.66	-11%	7.32	6.40	-13%
Specialty Primer, Sealer, and Undercoater	376,521	2,009,464	434%	0.78	11.64	1390%	0.14	0.36	163%	1.52	4.23	179%
Stains - Clear/Semitransparent	**2,171,595**	**1,865,237**	**-14%**	**12.07**	**8.81**	**-27%**	**0.55**	**0.46**	**-17%**	**4.06**	**3.49**	**-14%**
Stains – Opaque	**1,087,373**	**957,506**	**-12%**	**2.94**	**1.39**	**-53%**	**0.19**	**0.10**	**-47%**	**1.97**	**1.06**	**-46%**
Swimming Pool	22,086	20,364	-8%	0.26	0.22	-15%	0.71	0.68	-5%	8.54	7.85	-8%
Swimming Pool Repair and Maintenance	**15,266**	**PD**	**PD**	**0.70**	**0.11**	**-84%**	**3.56**	**3.49**	**-2%**	**33.39**	**36.41**	**9%**
Traffic Marking	3,338,918	2,214,451	-34%	4.84	4.24	-12%	0.08	0.11	27%	1.06	1.40	32%
Varnishes - Clear	1,087,860	970,695	-11%	6.73	5.54	-18%	0.59	0.55	-7%	4.52	4.17	-8%
Varnishes - Semitransparent	61,505	89,303	45%	0.33	0.43	31%	0.51	0.45	-12%	3.87	3.49	-10%
Waterproofing Concrete/Masonry Sealers	707,921	1,908,378	170%	3.74	8.65	131%	0.40	0.35	-13%	3.86	3.40	-12%
Waterproofing Sealers	**1,017,611**	**1,511,911**	**49%**	**4.46**	**3.43**	**-23%**	**0.41**	**0.20**	**-51%**	**3.20**	**1.66**	**-48%**

Table 3-3: ***Detailed Comparison of Reactivity Analyses for the 2001 and 2005 Surveys (official MIRs)***

Coating Category	*Sales Volume (gallons)*			*Maximum Ozone Formation Potential (tons per day)*			*Sales-Weighted Average MIR (SWAMIR) (lbs ozone/lbs product)*			*Maximum OFP Per Gallon (lbs ozone/gal product)*		
	2000 Sales	*2004 Sales*	*% change*	*2000*	*2004*	*% change*	*2000*	*2004*	*% change*	*2000*	*2004*	*% change*
Wood Preservatives	177,444	173,846	-2%	1.19	0.96	-19%	0.70	0.55	-21%	4.89	4.04	-17%

Notes:
1. PD = Protected Data. Fewer than three companies reported sales.
2. Bold highlighting indicates categories for which lower limits were implemented in 2003 and 2004.
3. For the Floor category, the 2004 data are questionable because a significant portion of the reactivity is based on an unknown ingredient.
4. The values in this table are based on the official MIR values published in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions", California Code of Regulations, Title 17, sections 94700 and 94701, as updated July 7, 2004.
5. Sales volumes contained in this table include sales of small containers (1 quart or less).

ARB staff investigated the causes for changes between the ozone data from the 2001 and 2005 surveys for the categories summarized in Table 3-4. In almost all cases, the SWAMIR declined from 2000 to 2004 for those categories that had lower VOC limits due to rule changes. However, for some of the smaller categories, the SWAMIR actually increased from 2000 to 2004, even though there were no changes to VOC limits.

Table 3-4: ***Reasons for Significant Changes in the Sales-Weighted Average MIR and Ozone Formation Potential***

Coating Category	**Major Reasons for Changes in SWAMIR (lbs O_3/lb product) and Normalized OFP (lbs O_3/gal)**	**Major Reasons for Changes in Total OFP (tons O_3/day)**
Bituminous Roof	SWAMIR and normalized OFP decreased for these reasons - In 2000, a significant portion of Bituminous Roof coatings were solventborne products that had a relatively high ozone formation potential. Sales of solventborne products declined significantly in 2004.	Total OFP decreased for these reasons - The total sales volume and VOC emissions declined in 2004, because quality control was improved and adhesives/cements were removed from survey responses.

Table 3-4: ***Reasons for Significant Changes in the Sales-Weighted Average MIR and Ozone Formation Potential***

Coating Category	Major Reasons for Changes in SWAMIR (lbs O_3/lb product) and Normalized OFP (lbs O_3/gal)	Major Reasons for Changes in Total OFP (tons O_3/day)
Bituminous Roof Primer	SWAMIR and normalized OFP increased for these reasons - In 2000, there was a relatively even distribution between solventborne and waterborne products. In 2004, this distribution changed and solventborne products with a higher ozone formation potential became much more dominant. This change in products occurred even though there was no change in the VOC limit for the Bituminous Roof Primer category.	Total OFP decreased for these reasons - The total sales volume and VOC emissions declined in 2004.
Bond Breakers	SWAMIR and normalized OFP increased for these reasons - In 2004, the sales volume increased substantially for products that were reformulated with a more reactive hydrocarbon solvent and 2-amino-2-methyl-1-propanol (AMP). Since the official MIR for AMP is a high upper limit value, it resulted in a substantial increase of the SWAMIR and the normalized OFP. However, when the draft updated MIR is used, the SWAMIR and the normalized OFP decrease, as shown in Table 3-5. This change in formulation occurred even though there was no change in the VOC limit for the Bond Breakers category.	Total OFP increased for these reasons - The total sales volume and VOC emissions increased in 2004.
Dry Fog	SWAMIR and normalized OFP increased for these reasons - A small number of high-volume solventborne products were reformulated with a more reactive hydrocarbon solvent. This reformulation occurred even though there was no change in the VOC limit for the Dry Fog category.	Total OFP decreased for these reasons - The total sales volume and VOC emissions declined in 2004.
Faux Finishing	SWAMIR and normalized OFP increased for these reasons - In 2004, there was an increase in the use of 2-amino-2-methyl-1-propanol (AMP). Since the official MIR for AMP is a high upper limit value, it resulted in a slight increase of the SWAMIR and the normalized OFP. However, when the draft updated MIR is used, the SWAMIR and the normalized OFP decrease, as shown in Table 3-5. This reformulation occurred even though there was no change in the VOC limit for the Faux Finishing category.	Total OFP increased for these reasons - The total sales volume and VOC emissions increased significantly in 2004.

Table 3-4: ***Reasons for Significant Changes in the Sales-Weighted Average MIR and Ozone Formation Potential***

Coating Category	Major Reasons for Changes in SWAMIR (lbs O_3/lb product) and Normalized OFP (lbs O_3/gal)	Major Reasons for Changes in Total OFP (tons O_3/day)
Fire Resistive	SWAMIR and normalized OFP increased for these reasons - In 2000, all of the reported Fire Resistive coatings were waterborne products. In 2004, some of the Fire Resistive coatings were solventborne products that had higher ozone formation potentials. This change occurred even though there was no change in the VOC limit for the Fire Resistive category.	Total OFP increased for these reasons - The VOC content and VOC emissions increased in 2004.
Fire Retardant – Clear	SWAMIR and normalized OFP increased for these reasons - In 2000, all of the sales volume consisted of waterborne products, none of which were reported in the subsequent survey. In 2004, all of the sales volume consisted of solventborne coatings with higher ozone formation potential.	Total OFP increased for these reasons - The VOC content and VOC emissions increased in 2004.
Fire Retardant – Opaque	SWAMIR and normalized OFP increased for these reasons - In 2004, some companies re-classified Quick Dry Enamel or Industrial Maintenance alkyd coatings as Fire Retardant coatings. These re-classified alkyd products had a higher ozone formation potential than the products that were classified as Fire Retardant products in 2000.	Total OFP increased for these reasons - The VOC content and VOC emissions increased in 2004.
Flat	SWAMIR and normalized OFP decreased for these reasons - In 2004, manufacturers reduced the amount of VOC in Flat coatings.	Total OFP increased for these reasons - The total sales volume and VOC emissions increased in 2004.
Floor	2004 data are considered questionable for these reasons - In 2000, the Floor category contained some high-solids products that were suitable for industrial uses and had low ozone formation potential. In 2004, staff improved quality control procedures and moved these industrial floor coatings to the Industrial Maintenance category. The products remaining in the Floor category were porch, deck, stair, and garage floor coatings. Unfortunately, one of the highest volume products in the Floor category for 2004 contained an unknown ingredient that was assigned a relatively high default MIR value. Since a significant portion of the reactivity for the Floor category is based on an unknown ingredient, ARB staff considers the results to be invalid for 2004.	2004 data are considered questionable for these reasons - A significant portion of the reactivity for the Floor category is based on an unknown ingredient.

Table 3-4: ***Reasons for Significant Changes in the Sales-Weighted Average MIR and Ozone Formation Potential***

Coating Category	Major Reasons for Changes in SWAMIR (lbs O_3/lb product) and Normalized OFP (lbs O_3/gal)	Major Reasons for Changes in Total OFP (tons O_3/day)
Form Release Compounds	SWAMIR and normalized OFP increased for these reasons - In 2004, there was an increase in the use of hydrocarbon solvents that were not assigned a Bin Number. These hydrocarbon solvents were assigned a relatively high default MIR value.	Total OFP increased for these reasons - The total sales volume and VOC emissions increased in 2004.
Industrial Maintenance (IM)	SWAMIR and normalized OFP decreased for these reasons - In 2004, companies re-classified IM coatings as Rust Preventative and Waterproofing Concrete/Masonry Sealers. The products that remained in the IM category had less VOC and a lower ozone formation potential.	Total OFP decreased for these reasons - The total sales volume and VOC emissions declined in 2004, because companies re-classified IM coatings as Rust Preventative and Waterproofing Concrete/Masonry Sealers.
Lacquers	SWAMIR and normalized OFP decreased for these reasons - In 2004, Lacquer coatings contained less VOC which resulted in a lower ozone formation potential.	Total OFP increased for these reasons – The total sales volume and VOC emissions increased significantly in 2004, because new products were introduced and new companies/divisions submitted survey data.
Metallic Pigmented	SWAMIR and normalized OFP decreased for these reasons - In 2004, Metallic Pigmented coatings contained less VOC which resulted in a lower ozone formation potential.	Total OFP decreased for these reasons - The total sales volume and VOC emissions declined in 2004.
Nonflat – High Gloss	SWAMIR and normalized OFP decreased for these reasons - In 2004, Nonflat – High Gloss coatings had less VOC which resulted in a lower ozone formation potential.	Total OFP decreased for these reasons - The total sales volume and VOC emissions declined in 2004.
Nonflat – Low Gloss	SWAMIR and normalized OFP increased for these reasons - In 2004, there was an increase in the use of 2-amino-2-methyl-1-propanol (AMP). Since the official MIR for AMP is a high upper limit value, it results in a slight increase of the SWAMIR and the normalized OFP. However, when the draft updated MIR is used, the SWAMIR and the normalized OFP decrease, as shown in Table 3-5.	Total OFP increased for these reasons – The total sales volume and VOC emissions increased significantly in 2004, because new products were introduced.

Table 3-4: ***Reasons for Significant Changes in the Sales-Weighted Average MIR and Ozone Formation Potential***

Coating Category	Major Reasons for Changes in SWAMIR (lbs O_3/lb product) and Normalized OFP (lbs O_3/gal)	Major Reasons for Changes in Total OFP (tons O_3/day)
Nonflat – Medium Gloss	SWAMIR and normalized OFP decreased for these reasons - In 2004, there was a significant decline in the sales volume for solventborne Nonflat – Medium Gloss products and an increase in waterborne products with a lower ozone formation potential.	Total OFP decreased for these reasons - The VOC content and VOC emissions decreased in 2004.
Other	SWAMIR and normalized OFP increased for these reasons - In 2000, the majority of the "Other" category consisted of waterborne driveway sealer emulsions with very low VOC levels. In 2004, driveway sealers were given their own category. The products remaining in the "Other" category had a higher ozone formation potential than driveway sealers.	Total OFP increased for these reasons – The VOC content and VOC emissions increased in 2004.
Pre-Treatment Wash Primer	SWAMIR and normalized OFP increased for these reasons - In 2000, waterborne products dominated the Pre-Treatment Wash Primer category. In 2004, solventborne products accounted for a larger portion of the sales volume and these products contained more reactive ingredients. This change occurred even though there was no reduction in the VOC limit for the Pre-Treatment Wash Primer category.	Total OFP decreased for these reasons - The total sales volume and VOC emissions declined in 2004.
Primer, Sealer, and Undercoater (PSU)	SWAMIR and normalized OFP decreased for these reasons - In 2004, sales of solventborne PSUs declined significantly and they were replaced by waterborne products with a lower ozone formation potential.	Total OFP decreased for these reasons - VOC emissions declined in 2004.
Quick Dry Primer, Sealer, Undercoater (QDPSU)	SWAMIR and normalized OFP increased for these reasons - In 2004, companies re-classified QDPSUs as Specialty PSUs, Rust Preventative, and PSUs. The remaining sales volume included more solventborne products with a higher ozone formation potential. In addition, more than half of the QDPSU sales volume exceeded VOC limits because products were included in an averaging program.	Total OFP decreased for these reasons - The total sales volume and VOC emissions declined in 2004.
Roof	SWAMIR and normalized OFP decreased for these reasons - In 2004, sales of solventborne Roof coatings declined and they were replaced by waterborne products with a lower ozone formation potential. In addition, the high volume waterborne products had a lower ozone formation potential in 2004.	Total OFP decreased for these reasons - The VOC content and VOC emissions decreased in 2004.

Table 3-4: ***Reasons for Significant Changes in the Sales-Weighted Average MIR and Ozone Formation Potential***

Coating Category	Major Reasons for Changes in SWAMIR (lbs O_3/lb product) and Normalized OFP (lbs O_3/gal)	Major Reasons for Changes in Total OFP (tons O_3/day)
Rust Preventative	SWAMIR and normalized OFP increased for these reasons - In 2004, companies re-classified IM coatings as Rust Preventative coatings and new products were introduced. This shift increased the percentage of solventborne products with higher VOC contents and higher ozone formation potentials.	Total OFP increased for these reasons – The total sales volume and VOC emissions increased significantly in 2004.
Specialty Primer, Sealer, Undercoater	SWAMIR and normalized OFP increased for these reasons - In 2004, companies re-classified PSUs and QDPSUs as Specialty PSUs and new products were introduced. This shift increased the percentage of solventborne products with higher VOC contents and higher ozone formation potentials.	Total OFP increased for these reasons – The total sales volume and VOC emissions increased significantly in 2004.
Stains - Clear/ Semitransparent	SWAMIR and normalized OFP decreased for these reasons - In 2004, some products were reformulated with less reactive ingredients and some solventborne products were replaced by waterborne products with lower ozone formation potential.	Total OFP decreased for these reasons – The total sales volume and VOC emissions declined in 2004.
Stains - Opaque	SWAMIR and normalized OFP decreased for these reasons - In 2004, sales of solventborne products declined and they were replaced by waterborne products with a lower ozone formation potential.	Total OFP decreased for these reasons - The total sales volume and VOC emissions declined in 2004.
Traffic Marking	SWAMIR and normalized OFP increased for these reasons - In 2004, there was an increase in the use of xylene, ethylene glycol butyl ether, and ethylene glycol.	Total OFP decreased for these reasons - The total sales volume and VOC emissions declined in 2004.
Varnishes – Clear	SWAMIR and normalized OFP decreased for these reasons - In 2004, less reactive hydrocarbon solvents were used.	Total OFP decreased for these reasons - The total sales volume and VOC emissions declined in 2004.
Varnishes - Semitransparent	SWAMIR and normalized OFP decreased for these reasons - In 2004, less reactive hydrocarbon solvents were used.	Total OFP increased for these reasons - The total sales volume and VOC emissions increased in 2004.

Table 3-4: ***Reasons for Significant Changes in the Sales-Weighted Average MIR and Ozone Formation Potential***

Coating Category	Major Reasons for Changes in SWAMIR (lbs O_3/lb product) and Normalized OFP (lbs O_3/gal)	Major Reasons for Changes in Total OFP (tons O_3/day)
Waterproofing Concrete/Masonry Sealer	SWAMIR and normalized OFP decreased for these reasons - In 2004, companies re-classified IM coatings as Waterproofing Concrete/Masonry Sealers and new products were introduced. Also, there was a significant increase in the use of exempt compounds.	In spite of a decline in the SWAMIR, total OFP increased for these reasons - The total sales volume and VOC emissions increased in 2004, because companies re-classified products and new products were introduced.
Waterproofing Sealers	SWAMIR and normalized OFP decreased for these reasons - In 2004, sales of solventborne products declined and they were replaced by waterborne products with a lower ozone formation potential.	Total OFP decreased for these reasons - The VOC content and VOC emissions decreased in 2004.

For comparison purposes, Table 3-5 provides data similar to Table 3-3, but Table 3-5 is based on draft updated MIR values that have not yet been officially adopted (Carter, 2007). For some key ingredients in architectural coatings, the draft updated MIRs provide more accurate results. As shown in Table 3-5, more coating categories had declines in the Sales-Weighted Average MIR from 2000 to 2004, when using the draft updated MIRs.

Table 3-5: ***Detailed Comparison of Reactivity Analyses for the 2001 and 2005 Surveys (draft updated MIRs)***

Coating Category	*Sales Volume (gallons)*			*Maximum Ozone Formation Potential (tons per day)*			*Sales-Weighted Average MIR (SWAMIR) (lbs ozone/lbs product)*			*Maximum OFP Per Gallon (lbs ozone/gal product)*		
	2000 Sales	*2004 Sales*	*% change*	*2000*	*2004*	*% change*	*2000*	*2004*	*% change*	*2000*	*2004*	*% change*
Bituminous Roof	3,245,397	1,464,326	-55%	7.20	1.11	-85%	0.20	0.06	-67%	1.62	0.56	-66%
Bituminous Roof Primer	170,520	68,092	-60%	0.69	0.50	-28%	0.37	0.70	91%	2.95	5.35	82%
Bond Breakers	93,896	187,785	100%	0.17	0.31	82%	0.16	0.15	-9%	1.32	1.21	-9%
Clear Brushing Lacquer	PD	PD	PD	1.00	0.98	-2%	1.40	1.38	-2%	10.54	10.37	-2%
Concrete Curing Compounds	692,419	793,566	15%	1.56	1.38	-12%	0.19	0.15	-22%	1.64	1.27	-23%
Dry Fog	459,756	377,707	-18%	1.76	1.60	-9%	0.23	0.26	15%	2.80	3.09	10%
Faux Finishing	173,737	303,810	75%	0.45	0.76	69%	0.21	0.20	-2%	1.88	1.82	-3%

Table 3-5: ***Detailed Comparison of Reactivity Analyses for the 2001 and 2005 Surveys (draft updated MIRs)***

Coating Category	*Sales Volume (gallons)*			*Maximum Ozone Formation Potential (tons per day)*			*Sales-Weighted Average MIR (SWAMIR) (lbs ozone/lbs product)*			*Maximum OFP Per Gallon (lbs ozone/gal product)*		
	2000 Sales	*2004 Sales*	*% change*	*2000*	*2004*	*% change*	*2000*	*2004*	*% change*	*2000*	*2004*	*% change*
Fire Resistive	PD	12,577	PD	0.00	0.04	6530%	0.04	0.24	550%	0.38	2.51	562%
Fire Retardant - Clear	PD	PD	PD	0.00	0.02	35008%	0.00	2.18	63711%	0.04	19.47	51469%
Fire Retardant - Opaque	29,055	200,150	589%	0.05	0.89	1520%	0.13	0.28	113%	1.38	3.24	135%
Flat	**34,810,257**	**37,264,874**	**7%**	**30.12**	**23.35**	**-22%**	**0.06**	**0.04**	**-28%**	**0.63**	**0.46**	**-28%**
Floor	1,425,064	1,239,892	-13%	3.58	4.88	36%	0.18	0.31	69%	1.83	2.97	62%
Form Release Compounds	255,724	323,612	27%	0.71	1.31	85%	0.27	0.40	46%	2.03	2.96	46%
Graphic Arts	26,389	PD	PD	0.16	0.02	-86%	0.46	0.35	-24%	4.35	3.86	-11%
High Temperature	18,632	11,736	-37%	0.20	0.14	-33%	0.81	0.80	-1%	7.95	8.48	7%
Industrial Maintenance	**4,740,079**	**2,137,772**	**-55%**	**46.00**	**14.52**	**-68%**	**0.69**	**0.47**	**-32%**	**7.08**	**5.09**	**-28%**
Lacquers	**447,352**	**1,291,571**	**189%**	**6.77**	**8.31**	**23%**	**1.30**	**0.60**	**-54%**	**11.04**	**4.70**	**-57%**
Low Solids	13,413	65,680	390%	0.02	0.08	344%	0.12	0.11	-8%	1.03	0.93	-9%
Magnesite Cement	PD	PD	PD	0.92	0.72	-22%	2.28	2.26	-1%	20.35	20.13	-1%
Mastic Texture	628,590	677,063	8%	0.84	0.81	-4%	0.10	0.08	-17%	0.98	0.87	-11%
Metallic Pigmented	625,944	570,977	-9%	11.21	5.88	-48%	1.40	0.86	-38%	13.08	7.56	-42%
Multi-Color	**7,580**	**13,635**	**80%**	**0.03**	**0.01**	**-73%**	**0.31**	**0.04**	**-86%**	**2.61**	**0.39**	**-85%**
Nonflat - High Gloss	1,926,436	1,760,459	-9%	8.37	2.35	-72%	0.32	0.10	-70%	3.17	0.97	-69%
Nonflat - Low Gloss	**6,594,890**	**12,023,079**	**82%**	**8.23**	**13.84**	**68%**	**0.09**	**0.08**	**-10%**	**0.91**	**0.84**	**-8%**
Nonflat - Medium Gloss	**18,102,739**	**20,072,832**	**11%**	**31.35**	**23.38**	**-25%**	**0.13**	**0.08**	**-33%**	**1.26**	**0.85**	**-33%**
Other	1,510,316	89,473	-94%	0.07	0.08	4%	0.00	0.07	1734%	0.04	0.62	1651%
Pre-Treatment Wash Primer	75,342	4,959	-93%	0.20	0.02	-89%	0.21	0.41	96%	1.94	3.16	63%
Primer, Sealer, and Undercoater	**8,125,823**	**10,402,018**	**28%**	**18.03**	**12.45**	**-31%**	**0.16**	**0.08**	**-50%**	**1.62**	**0.87**	**-46%**
Quick Dry Enamel	**623,666**	**763,266**	**22%**	**4.38**	**4.28**	**-2%**	**0.53**	**0.42**	**-21%**	**5.13**	**4.10**	**-20%**
Quick Dry Primer, Sealer, and Undercoater	**1,660,227**	**249,710**	**-85%**	**7.17**	**1.57**	**-78%**	**0.38**	**0.43**	**12%**	**3.15**	**4.60**	**46%**
Roof	1,137,354	1,406,889	24%	1.27	0.87	-31%	0.08	0.04	-48%	0.81	0.45	-44%
Rust Preventative	209,899	2,095,500	898%	1.32	14.71	1015%	0.42	0.51	21%	4.59	5.12	12%

Table 3-5: ***Detailed Comparison of Reactivity Analyses for the 2001 and 2005 Surveys (draft updated MIRs)***

Coating Category	*Sales Volume (gallons)*			*Maximum Ozone Formation Potential (tons per day)*			*Sales-Weighted Average MIR (SWAMIR) (lbs ozone/lbs product)*			*Maximum OFP Per Gallon (lbs ozone/gal product)*		
	2000 Sales	*2004 Sales*	*% change*	*2000*	*2004*	*% change*	*2000*	*2004*	*% change*	*2000*	*2004*	*% change*
Sanding Sealers	28,268	84,273	198%	0.29	0.52	81%	0.99	0.60	-39%	7.40	4.49	-39%
Shellacs - Clear	PD	PD	PD	0.16	0.47	192%	0.98	0.88	-10%	7.28	6.53	-10%
Shellacs - Opaque	PD	PD	PD	0.77	1.09	43%	0.65	0.56	-13%	6.39	5.48	-14%
Specialty Primer, Sealer, and Undercoater	376,521	2,009,464	434%	0.70	10.68	1424%	0.12	0.33	169%	1.36	3.88	186%
Stains - Clear/Semitransparent	**2,171,595**	**1,865,237**	**-14%**	**11.90**	**8.49**	**-29%**	**0.54**	**0.44**	**-18%**	**4.00**	**3.36**	**-16%**
Stains - Opaque	**1,087,373**	**957,506**	**-12%**	**2.78**	**1.08**	**-61%**	**0.18**	**0.08**	**-56%**	**1.87**	**0.82**	**-56%**
Swimming Pool	22,086	20,364	-8%	0.25	0.22	-14%	0.69	0.67	-4%	8.29	7.71	-7%
Swimming Pool Repair and Maintenance	**15,266**	**PD**	**PD**	**0.72**	**0.11**	**-84%**	**3.67**	**3.61**	**-2%**	**34.35**	**37.61**	**9%**
Traffic Marking	3,338,918	2,214,451	-34%	4.60	4.05	-12%	0.08	0.10	27%	1.01	1.33	33%
Varnishes - Clear	1,087,860	970,695	-11%	6.38	5.05	-21%	0.56	0.50	-11%	4.28	3.80	-11%
Varnishes - Semitransparent	61,505	89,303	45%	0.32	0.40	28%	0.49	0.43	-14%	3.76	3.31	-12%
Waterproofing Concrete/Masonry Sealers	707,921	1,908,378	170%	3.63	8.51	134%	0.39	0.34	-12%	3.74	3.34	-11%
Waterproofing Sealers	**1,017,611**	**1,511,911**	**49%**	**4.55**	**2.93**	**-36%**	**0.42**	**0.17**	**-59%**	**3.26**	**1.42**	**-57%**
Wood Preservatives	177,444	173,846	-2%	1.19	0.95	-20%	0.70	0.55	-22%	4.89	4.00	-18%

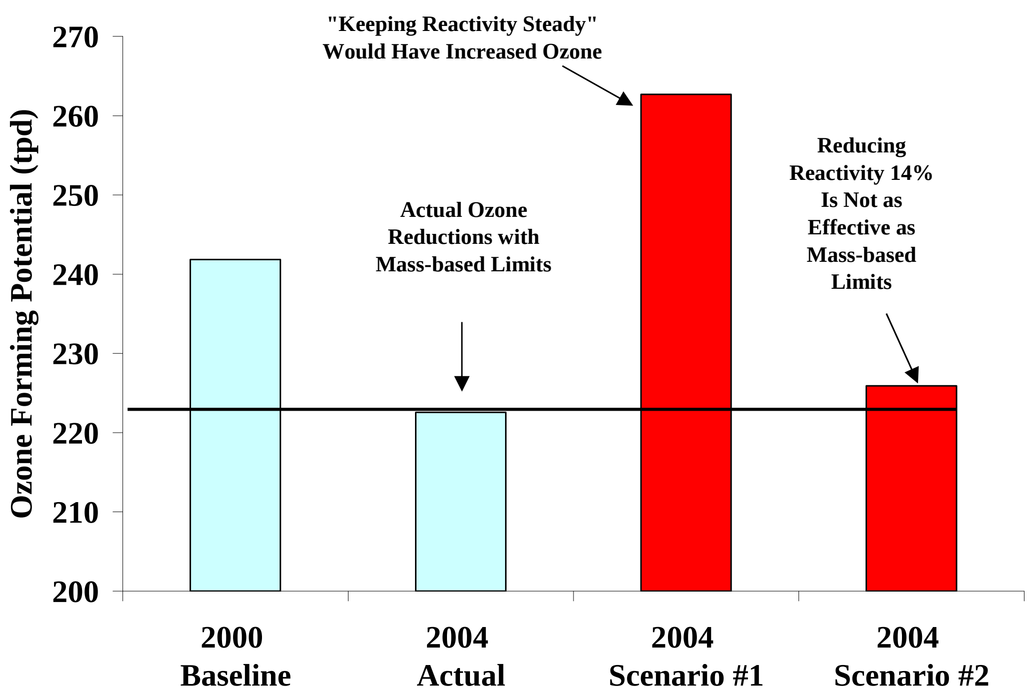
Notes:

1. PD = Protected Data. Fewer than three companies reported sales.
2. Bold highlighting indicates categories for which lower limits were implemented in 2003 and 2004.
3. For the Floor category, the 2004 data are questionable because a significant portion of the reactivity is based on an unknown ingredient.
4. The values in this table are based on draft updated MIR values that have not yet been officially adopted in ARB's "Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions". These draft updated values have been determined by Dr. William Carter for the research project titled "Reactivity Estimates for Selected Consumer Product Compounds" under Contract No. 06-408. The draft updated values were current as of December 24, 2007, and they are subject to change.
5. Sales volumes contained in this table include sales of small containers (1 quart or less).

Some industry representatives believe that ozone trends should be analyzed on the basis of "pounds ozone per pound VOC". ARB staff does not believe that "pounds ozone per pound VOC" is a valid parameter for analysis, because it only focuses on a portion of the ingredients and does not account for the overall reactivity of the coating as applied. For example, a coating could contain a small amount of a highly reactive chemical, but the overall coating reactivity may be low if most of the ingredients have a low reactivity. Also, using the term "pounds ozone per pound VOC" without regard for sales volume provides misleading results. For example, an increase in the total ozone formation potential could be caused by an increase in sales volume, rather than an increase in the reactivity of coatings. Finally, using the term "pounds ozone per pound VOC" provides misleading results. Some industry representatives used "pounds ozone per pound VOC" to argue that better ozone reductions could be achieved by keeping reactivity steady at 2000 levels or by reducing reactivity 14% from 2000 levels. ARB staff analyzed these two scenarios and found that mass-based VOC limits achieved more ozone reductions than either of the two scenarios, as illustrated in Figure 3-1. The data in Figure 3-1 are based on the official MIR values published in ARB's Aerosol Coatings regulation, as updated in July 2004 (CCR, 2004).

Figure 3-1

Ozone Reductions from 2000 to 2004: Mass-Based Limits vs. Reactivity-Based Scenarios



Notes:

1. This figure only includes categories for which there were sales data from three or more companies for both 2000 and 2004.
2. "2000 Baseline" and "2004 Actual" are based on the data reported in ARB surveys.
3. "2004 Scenario #1" is a prediction of ozone levels if the SWAMIR values from 2000 remained the same in 2004. This scenario uses the reported sales volumes for 2004.
4. "2004 Scenario #2" is a prediction of ozone levels if the SWAMIR values from 2000 were reduced 14% in 2004. This scenario uses the reported sales volumes for 2004.

ARB's Aerosol Coatings regulation uses a reactivity-based approach and it contains limits based on "product-weighted MIR" with units of "grams ozone per gram product". The "product-weighted MIR" is comparable to the SWAMIR (lbs ozone per lb product) in this report (see Tables 3-3 and 3-5). As shown in these tables, the SWAMIR declined for most categories, particularly those that had lower VOC limits implemented in 2003 and 2004.

The data in Tables 3-3 and 3-5 demonstrate that reducing VOC limits has been an effective method for reducing ozone. If VOC limits had remained unchanged from 2000 to 2004, it is expected that VOC emissions and ozone formation potential would have increased, because sales volume increased. Instead, VOC limit reductions caused manufacturers to develop reformulated products that reduced VOC emissions and ozone formation potential, in spite of increases in sales volume.

REFERENCES

Carter, 2007. Carter, W.P.L. "Reactivity Estimates For Selected Consumer Product Compounds". Draft Final Report. Contract No. 06-408. December 24, 2007.

CCR, 2004. California Code of Regulations. "Tables of Maximum Incremental Reactivity (MIR) Values". CCR, section 94700, title 17. July 2004. http://ccr.oal.ca.gov

Chapter 4 – Reactivity-Related Research Projects

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. These research projects were coordinated with the ARB's Reactivity Research Advisory Committee (RRAC), which includes representatives from coating manufacturers, solvent manufacturers, and regulatory agencies.

Section 4.1 ARB-Funded Research

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 (http://www.arb.ca.gov/research/apr/past/00-333.pdf). Researchers used a state-of-the-art environmental chamber to verify the chemical mechanisms that determine the reactivity of Texanol® and several hydrocarbon solvents that are commonly used in architectural coatings. Table 4-1 describes the hydrocarbon solvents that were tested during the project.

Table 4-1: ***Hydrocarbon Solvents Tested in Environmental Chamber***

Solvent	ASTM Designation	Aromatic Content	ASTM Distillation Range (°F)	ARB Bin #	Description
VM&P Naphtha	D3735, Type IV	0.1%	235-310	6	Primarily C7-C9 Mixed Alkanes. Petroleum Distillate Derived.
Dearomatized Mineral Spirits	D235, Type IC	0%	300-415	11	Primarily C10-C12 Mixed Alkanes. Petroleum Distillate Derived.
Reduced Aromatics Mineral Spirits	D235, Type IB	6%	300-415	14	Primarily C10-C12 Mixed Alkanes. Petroleum Distillate Derived.
Regular Mineral Spirits	D235, Type IA	19%	300-415	15	Primarily C10-C12 Mixed Alkanes. Petroleum Distillate Derived.
Aromatic 100	D3734, Type I	100%	300-355	22	Primarily C9-C10 Alkylbenzenes. Petroleum Distillate Derived.
Synthetic Isoparaffinic Alkanes	D235, Type III C-1	0%	300-415	12	Primarily C10-C12 Branched Alkanes. Synthetic Mixture.

Table 4-2 contains the baseline MIR values and the MIR values that resulted from the research project. For hydrocarbon solvents, baseline MIR values were obtained from ARB's Aerosol Coatings Regulation and the hydrocarbon solvent bin system (California Code of Regulations, Title 17, Section 94701.) For most of the solvents tested, the results of the research confirmed the baseline MIR values. However, the research indicated that the baseline MIR may be too low for the Synthetic Isoparaffinic Alkanes (i.e., Odorless

Mineral Spirits) in Bin 12. Additional research may be needed to improve the computer modeling for synthetic hydrocarbons. At this time, ARB has not proposed a change to the MIR table to adjust for Bin 12 synthetic hydrocarbons.

Table 4-2: *Results of ARB-Funded Reactivity Research Project*

Solvent	Baseline MIR	MIR Based on Research Project
Isobutyrate Monoesters of 2,2,4-Trimethyl-1,3-Pentanediol (Texanol®)	0.88	0.88
VM&P Naphtha (D3735, Type IV)	1.41	1.35
Dearomatized Mineral Spirits (D235, Type IC)	0.91	0.96
Reduced Aromatics Mineral Spirits (D235, Type IB)	1.21	1.26
Regular Mineral Spirits (D235, Type IA)	1.82	1.97
Aromatic 100 (D3734, Type I)	7.51	7.70
Synthetic Isoparaffinic Alkanes (D235, Type III C-1)	0.81	1.1-1.5

ARB provided $150,000 to UC Riverside to update the chemical mechanisms for airshed models. The final report for this project titled "Development of the SAPRC-07 Chemical Mechanism and Updated Ozone Reactivity Scales" was completed in August 2007 (http://www.arb.ca.gov/research/reactivity/saprc07.pdf). Dr. William Carter updated the SAPRC-99 chemical mechanisms used in airshed models for predicting photochemical air pollution. Dr. Carter reviewed and updated the rate constants and reactions for the base mechanisms, reformulated the aromatics mechanisms, added chlorine chemistry, improved the capability of Secondary Organic Aerosol prediction, added mechanisms for more VOC types, evaluated the mechanism against chamber data, and updated the reactivity scales for approximately 1,100 VOC types.

ARB provided $50,000 to UC Riverside for Dr. William Carter to update SAPRC-07 reactivity scales to include 45 additional compounds for the Consumer Products program (Contract No. 06-408). Included in these 45 compounds are several amines which are important in architectural coatings. The draft final report for this project, titled "Reactivity Estimates for Selected Consumer Product Compounds", was completed in December 2007, but the final report is not yet available on ARB's website.

Section 4.2 SCAQMD-Funded Research

In 2003, SCAQMD provided $200,000 to UC Riverside to conduct additional reactivity research. Table 4-3 lists the four compounds that were tested in the environmental chamber, including two that are major ingredients in water-based coatings (ethylene glycol and propylene glycol.) The final report for this project was completed in July 2005 (http://pah.cert.ucr.edu/~carter/coatings/SCAQcham.pdf).

Table 4-3: ***Results of SCAQMD-Funded Reactivity Research Project***

Solvent	Baseline MIR	MIR Based on Research Project
Ethylene Glycol	3.36	3.63
Propylene Glycol	2.74	2.74
2-(2-Butoxyethoxy)-Ethanol (Diethylene Glycol Monobutyl Ether)	2.86	2.86
Benzyl Alcohol	none	4.89