CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

AIR RESOURCES BOARD

Initial Statement of Reasons for the Proposed Amendments to the Regulation for Reducing Volatile Organic Compound Emissions from Aerosol Coating Products and Proposed Tables of Maximum Incremental Reactivity (MIR) Values, and Proposed Amendments to Method 310, "Determination of Volatile Organic Compounds in Consumer Products"

Release Date: May 5, 2000

State of California
AIR RESOURCES BOARD

INITIAL STATEMENT OF REASONS FOR THE PROPOSED RULEMAKING

Public Hearing To Consider

Proposed Amendments to the Regulation for Reducing Volatile Organic Compound Emissions from Aerosol Coating Products and Proposed Tables of Maximum Incremental Reactivity (MIR) Values, and Proposed Amendments to Method 310, "Determination of Volatile Organic Compounds in Consumer Products"

To be considered by the Air Resources Board on June 22 or 23, 2000, at:

Air Resources Board
Board Hearing Room, Lower Level
2020 L Street
Sacramento, California

Air Resources Board
P.O. Box 2815
Sacramento, CA 95812

STATE OF CALIFORNIA
AIR RESOURCES BOARD

Initial Statement of Reasons for the Proposed Amendments to the Regulation for Reducing Volatile Organic Compound Emissions from Aerosol Coating Products and Proposed Tables of Maximum Incremental Reactivity (MIR) Values, and Adoption of Proposed Amendments to Method 310, "Determination of Volatile Organic Compounds in Consumer Products"

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Initial Statement of Reasons for the Proposed Amendments to the Regulation for Reducing Volatile Organic Compound Emissions from Aerosol Coating Products and Proposed Tables of Maximum Incremental Reactivity (MIR) Values, and of Proposed Amendments to Method 310, “Determination of Volatile Organic Compounds in Consumer Products”

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STATE OF CALIFORNIA
AIR RESOURCES BOARD

EXECUTIVE SUMMARY

INITIAL STATEMENT OF REASONS FOR THE PROPOSED AMENDMENTS TO THE REGULATION FOR REDUCING VOLATILE ORGANIC COMPOUND EMISSIONS FROM AEROSOL COATING PRODUCTS,
AND
PROPOSED TABLES OF MAXIMUM INCREMENTAL REACTIVITY (MIR)VALUES,
AND
PROPOSED AMENDMENTS TO METHOD 310, "DETERMINATION OF VOLATILE ORGANIC COMPOUNDS IN CONSUMER PRODUCTS"

Executive Summary

A. Introduction

To reduce excess ozone concentrations in non-attainment areas, control of ozone precursors such as volatile organic compounds (VOCs) and oxides of nitrogen (NO_x) is needed. As part of California's abatement strategy, we have been successfully implementing mass-based VOC emission controls for aerosol coating products. To further refine the current regulatory approach, in this rulemaking the Air Resources Board (ARB) staff is recommending using photochemical reactivity as the basis for regulating emissions from aerosol coatings.

The proposed amendments presented here recognize that each VOC has a different ability to induce ambient ozone in the air once emitted. This concept is known as photochemical reactivity. By understanding the differences in VOCs' potentials to form ozone, and by using that knowledge in regulatory applications, a more effective and cost efficient control strategy can be established that, rather than limiting the total mass of VOCs, limits the amount of ozone produced by the VOCs. We believe this control approach has the potential to provide more flexibility to manufacturers, at less cost than traditional mass-based VOC controls, while achieving equivalent or greater air quality benefits.

Therefore, in this rulemaking staff is proposing to amend the Aerosol Coatings Regulation (section 94520-94528, Title 17, California Code of Regulations) by replacing the January 1, 2002, VOC limits for aerosol coatings with reactivity limits that achieve an equivalent air quality result. At its November 19, 1998, hearing the ARB adopted VOC content limits that are more stringent than the existing limits which became effective January 8, 1996. These more stringent limits become effective on January 1, 2002. At that hearing, recognizing that some of the limits were technologically challenging, the Board directed staff to return to them with an alternative reactivity-based compliance option for aerosol coatings. To that end, staff has been working with the affected industry on voluntary reactivity provisions for this regulation.

However, during development of the voluntary reactivity regulation proposal, staff and several representatives of the aerosol coating industry came to the conclusion that it was preferable to pursue replacing the VOC content limits with mandatory reactivity-based VOC limits. In making the request, the industry representatives indicated that reactivity-based VOC limits may provide more flexibility, while efficiently reducing the ozone formed from aerosol coatings. With agreement from the majority of the aerosol coating industry, staff began working on a proposal for mandatory reactivity-based VOC limits. These proposed amendments are described here and in greater detail in the Technical Support Document.

We also note that a commitment was included to consider incorporating reactivity into our consumer products regulations (including aerosol coatings) when the ARB adopted the 1994 State Implementation Plan (SIP) for Ozone. Since 1995, ARB staff has been working with the affected consumer products stakeholders on approaches to include reactivity within our regulations. This proposal for aerosol coatings is the result of that work. This proposal is intended to be a "pilot project" which provides a model for additional reactivity-based control measures.

In accordance with Government Code section 11346.2(a)(1), this Executive Summary, contains an overview, in plain language, of the staff's proposal to amend the Aerosol Coatings Regulation. The overview is provided in a question and answer format. We also explain the rationale for this proposal. A more detailed description of all the proposed regulatory changes, in plain English, is included in Chapter VI of the Technical Support Document.

B. Summary of Proposed Rulemaking

What amendments are being proposed to the Aerosol Coatings Regulation?

We are proposing to amend the Aerosol Coatings Regulation by replacing the January 1, 2002, VOC limits with reactivity-based limits that achieve equivalent air quality benefits. By restricting the reactivity of the VOCs, rather than the total mass of the VOCs, staff believes these reactivity-based limits will provide more reformulation options at potentially less cost. In developing the proposed reactivity limits, our goal was to propose limits that ensure that the ozone reduction commitment from the existing mass-based VOC limits would not be compromised. The limits are based on the maximum incremental reactivity (MIR) scale developed by Dr. William Carter of the University of California, Riverside. To implement the reactivity provisions we are also proposing to add a new Subchapter 8.6 that would contain the MIR values. The proposed reactivity limits are shown in Table 1. Other amendments to the Aerosol Coatings Regulation are proposed to implement the reactivity limits.

What specific amendments to Method 310 are proposed?

We are proposing revisions to ARB Method 310 so that it can be used to verify and provide discreet results for aerosol coating product ingredients. These proposed amendments will aid in enforcing the proposed amendments to the Aerosol Coatings Regulation.

Although analytical procedures exist for identifying individual chemical species, currently, ARB applies Method 310 for determining the overall VOC content of aerosol coating products. In this reactivity-based regulation, chemical ingredient information (in percent by weight) is needed for determining the ozone formation potential of aerosol coating products. Hence, amendments to the regulatory language are proposed to allow Method 310 to be used in this application.

TABLE 1
PROPOSED LIMITS FOR AEROSOL COATING PRODUCTS

	Reactivity Limit g O_3 / g product
General Coatings	**Effective Date : 06/01/02**
Clear Coatings	1.54
Flat Paint Products	1.21
Fluorescent Coatings	1.77
Metallic Coatings	1.93
Nonflat Paint Products	1.40
Primers	1.11
Specialty Coatings	**Effective Date : 01/01/03**
Art Fixatives or Sealants	1.80
Auto Body Primers	1.57
Automotive Bumper and Trim Products	1.75
Aviation or Marine Primers	1.98
Aviation Propeller Coatings	2.47
Corrosion Resistant Brass, Bronze or Copper Coatings	1.78
Exact Match Finishes	
Engine Enamel	1.72
Automotive	1.77
Industrial	2.07
Floral Sprays	1.68
Glass Coatings	1.42
Ground Traffic/Marking Coatings	1.18
High Temperature Coatings	1.83
Hobby/Model/Craft Coatings	
Enamel	1.47
Lacquer	2.70
Clear or Metallic	1.60
Marine Spar Varnishes	0.87
Photograph Coatings	0.99
Pleasure Craft Finish Primers, Surfacers or Undercoaters	1.05
Pleasure Craft Topcoats	0.59
Shellac Sealers	
Clear	0.98
Pigmented	0.94
Slip-Resistant Coatings	2.41
Spatter/Multicolor Coatings	1.07
Vinyl/Fabric/Leather/Polycarbonate Coatings	1.54
Webbing/Veil Coatings	0.83
Weld-Through Primers	0.98
Wood Stains	1.38
Wood Touch-Up, Repair or Restoration Coatings	1.49

When will the reactivity limits become effective?

The current mass-based VOC limits became effective on January 8, 1996, with more stringent limits scheduled to become effective on January 1, 2002. The reactivity limits are intended to replace the January 1, 2002, VOC limits. However, to allow adequate time to reformulate aerosol coatings, staff is proposing to extend the date that the reactivity limits would become effective. We are proposing to bifurcate the effective dates for the reactivity limits, with the general coating category limits becoming effective on June 1, 2002, and the specialty coating category limits becoming effective on January 1, 2003. By providing the additional seven months to comply with the specialty coating category limits manufacturers will be able to focus first on reformulation efforts for the general coating categories, which will provide the greatest air quality benefit.

Extending the effective dates would result in a delay of the reductions of ozone precursors for up to one year. However, the general coatings categories constitute about 78 percent of the total ozone formation potential of the aerosol coatings category, and, by requiring compliance by June 1, 2002, most of the planned ozone reductions will be achieved concurrent with the 2002 ozone season. For an additional seven months there will be an ozone shortfall of 1.7 tpd from the specialty coating categories. We believe the extension of the effective date is necessary to prevent disruptions in the aerosol coating market place and to minimize the possibility of an economic hardship for aerosol coating manufacturers. This proposal also ensures that efficacious products will continue to be available to the consumer in all 35 categories. We believe that these considerations override the relatively small short-term air quality disbenefit.

C. Background and Staff Proposal

What is reactivity?

The photochemical reactivity (or reactivity) of a VOC is a measure of its potential to enhance ozone formation in the air once emitted. In the presence of sunlight, VOCs in the air react with oxides of nitrogen (NO_x) to form ozone. Of the many different VOCs released into the atmosphere, each reacts at a different rate and through a different chemical reaction mechanism. The VOCs with high reactivity have a greater potential to form ozone, while other VOCs react slowly in the atmosphere, and are less likely to form ozone.

In the current Aerosol Coatings Regulation and virtually all other VOC regulations, total VOC content is limited on a percent-by-weight basis, without consideration of the differences in VOC reactivity. In this type of control strategy all VOCs are treated similarly, or in some cases (exemptions), form very low amounts of ozone such that their contribution to ambient ozone concentrations is not considered. Therefore, a reactivity-based control strategy could be viewed as a “refinement” of mass-based control strategies, because each VOC is considered with its respective ozone formation potential. This type of control has the potential to lead to more efficient ozone reductions by targeting substitutions of highly reactive compounds with lower reactive compounds. For example, the ozone formed from one gram of toluene is over seven times more than that formed from one gram of propane (Carter, 2000). The reactivity-based approach proposed here relies primarily on VOC substitution rather than VOC reduction. A reduction in the total VOC content may not always be necessary.

How can we compare the reactivities of VOCs?

Research on VOC reactivities over the last several decades has led to the development of scales to serve as tools to compare one VOC's reactivity to another. One such scale is the MIR scale developed by Dr. William P. L. Carter at the University of California at Riverside. This scale provides a numerical value to each VOC's potential to form ozone based on modeling analyses and other data derived from smog chamber studies. The higher the MIR value, the more ozone likely to be formed by a compound. We are proposing to use the MIR scale as the basis for setting reactivity limits.

Why has the MIR scale been selected as the most appropriate scale?

For ozone control strategies, the reactivity scale selected should be designed for the best overall air quality benefit. At the request of ARB, Dr. Carter studied 18 different methods of ranking the reactivity of individual VOCs in the atmosphere using a single-cell trajectory model with the SAPRC90 chemical mechanism (Carter, 1994). Dr. Carter concluded that if only one scale is to be used for regulatory purposes in California, the MIR scale is the most appropriate.

Based on this recommendation, the ARB is proposing to use the MIR scale for the Aerosol Coatings Regulation. The MIR scale appears to be most accurate for VOC-limited conditions, such as in the South Coast Air Basin, in which VOC controls would be most effective. We also note that the MIR scale is currently used to derive reactivity adjustment factors in the Low Emission Vehicle/Clean Fuels Regulations.

Will the MIR scale change?

Although we expect the MIR scale to gradually change as more data become available, we do not expect the qualitative ranking of VOC reactivities to change appreciably. As discussed below over 80 percent of compounds used in aerosol coatings are well-characterized, and another 17 percent are fairly well-characterized, such that their MIR values are expected to remain stable. However, if significant changes in MIRs occur the ARB is committed to reevaluate the reactivity limits to ensure that they continue to achieve the required ozone reduction. Should the limits change, manufacturers would be given adequate reformulation time to comply. Staff is continuing to evaluate an appropriate process to update MIR values and limits, and may propose additional changes at the Board hearing.

How is MIR value uncertainty addressed?

In providing MIR values for VOCs, Dr. Carter, based on his technical expertise, indicates the degree of uncertainty associated with each value. To describe the reliability of reactivity estimates Dr. Carter developed six bins. Bins one and two include compounds with reaction mechanisms that are well-characterized. Bins three and four include compounds with limited data, and bins five and six contain compounds for which very little data exist. We are proposing to use these bins as a mechanism to account for MIR value uncertainty.

Staff acknowledges that MIR values may decrease as well as increase. However, to ensure the air quality benefits, in designing this proposal staff has only considered that MIR values may increase. We are proposing that compounds in bins one and two be multiplied by an uncertainty factor of "1.0," in other words, no adjustment. For compounds contained in bin three we are proposing to adjust their MIR values by a factor of "1.25;" compounds in bin four would be adjusted by a factor of "1.5;" compounds in bins five and six by a factor of "2.0." We are also proposing to adjust hydrocarbon solvent MIR values by a factor of "1.15." These adjustment factors are assigned based on Dr. Carter's evaluations on the amount of experimental data available and MIR mechanistic uncertainty (see also Chapter II). These factors are proposed such that, if MIR values change due to new or improved data becoming available, the ozone reduction commitment would not be compromised. The uncertainty factors, under this proposal, would be applied to the MIR values prior to calculating the target ozone reduction. By addressing uncertainty within development of the proposed limit, manufacturers selecting solvents for reformulation would be able to use the MIR values without adjustment.

We have reviewed the VOCs currently used in aerosol coatings, and the uncertainty bins in which they fall. This analysis showed that over 80 percent on a by-weight basis of the VOCs used in aerosol coatings fall into bins one and two, and no MIR value adjustment would be necessary. Only two percent of compounds used fall into bin three, and less than one percent of compounds in bin four are currently used. About 17 percent of compounds used are hydrocarbon solvents and MIR values would be adjusted by 1.15. The remaining compounds used, less than one percent, fall into bins five and six. Because over 95 percent of compounds are fairly well-characterized we are able to propose reactivity limits for aerosol coating products at this time.

How do you convert a mass-based VOC reduction commitment into an equivalent ozone reduction?

In developing the proposed reactivity limits, our goal was to propose limits that ensure that the ozone reductions that would result from the mass limits would be preserved. Each proposed reactivity limit for a coating category is therefore based on the ozone reduction that would have been realized with the mass limits for each category of aerosol coatings. This required fairly extensive calculations based on product formulation data obtained from an industry survey. As mentioned above, uncertainty factors were incorporated into the reactivity limits.

How was a hydrocarbon solvent reactivity classification scheme developed?

Typical hydrocarbon solvents include VOC solvents such as mineral spirits, and naphtha. These solvents are not composed of a single chemical component, but rather many hydrocarbon constituents. Because of this, we developed a method to assign MIR values to hydrocarbon solvents based on average boiling points, alkane, and aromatic contents. Solvents with similar average boiling point and alkane and aromatic content are assigned to a group, and an MIR value is assigned to each group. Our approach for assigning MIR values to hydrocarbon solvents is included in Chapter IV and Appendix C of the Technical Support Document.

What information is needed to establish a reactivity program?

To establish reactivity-based limits, product sales and VOC speciation data are needed. These data are available from the 1997 survey of aerosol coatings.

How were the reactivity limits set?

Typically, when VOC limits are proposed, the available technologies, cost, total VOC content, and complying marketshares are used as guiding factors to determine technologically and commercially feasible VOC limits. This was the case when the staff proposed, and the Board adopted the January 1, 2002, revised VOC limits for aerosol coatings. These mass-based VOC limits are designed to achieve a reduction in VOC emissions of about 3.1 tons per day (tpd). In developing the proposed reactivity limits, our goal was to propose limits that ensure that the ozone reduction associated with the mass limits would be preserved. Therefore, each proposed reactivity limit is based on the VOC emission reduction commitment for each category of aerosol coatings. The VOC reduction is converted into an ozone reduction using the MIR scale. The ozone reduction target is adjusted for uncertainty, and this becomes the target reduction that the reactivity limits must achieve. Through an iterative process, reactivity limits are derived that achieve the necessary ozone reduction. A complete description of how the limits are calculated is included in Chapter IV of this report.

Is there any ongoing or planned research on reactivity?

Research on reactivity is ongoing. The ARB continues to fund research to improve analytical techniques to estimate VOC reactivities.

What is the role of the Reactivity Scientific Advisory Committee (RSAC)?

In April 1996, the ARB established the RSAC. The committee is made up of independent, respected scientists who have the responsibility to provide advice on the use of hydrocarbon reactivity in ARB programs. At their August 26, 1998, meeting the RSAC approved of our regulatory approach for a reactivity-based regulation for aerosol coatings, but suggested that the basis for the regulation, the MIR scale, should undergo peer review before using it in regulatory applications.

Based on this advice, the ARB contracted with Dr. William Stockwell of the Desert Research Institute to conduct the review of Dr. Carter's MIR scale. The result of that review was shared with the RSAC at their October 8, 1999, meeting. They expressed overwhelming support for the review and commented that the MIR scale, and the mechanism from which it is derived, represented the "state-of-the-science."

Are there other reactivity-based programs at the ARB and/or in the United States?

The proposed amendments would be the first reactivity-based ARB regulation proposed for non-mobile sources. However, the ARB has taken the lead in considering reactivity principles as a means to control ozone formation. In 1990, the ARB adopted the Low Emissions Vehicle and Clean Fuels Regulations. These regulations first used the MIR scale developed by Dr. Carter to determine the ozone-forming potential of vehicle exhaust by utilizing reactivity adjustment factors (RAF). A RAF is the ratio of the reactivity of exhaust emissions, from an alternatively fueled vehicle, to the reactivity of exhaust emissions from a conventional gasoline fueled vehicle. The ozone reactivity for the exhaust emissions is calculated using the MIRs for the individual VOCs found in the emissions. By making a reactivity adjustment to the emissions, an alternatively fueled vehicle is able to emit more mass emissions, as long as they are less reactive than those from a gasoline fueled vehicle.

Does the SIP require use of reactivity?

When the ARB adopted the 1994 State Implementation Plan for Ozone we included a commitment to consider reactivity when developing control strategies for consumer products (including aerosol coatings). We included reactivity as a potential control strategy in recognition that the 85 percent overall VOC emission reduction may be difficult to achieve on a mass-based approach alone. Since 1995 the ARB staff has been working with the affected consumer products stakeholders on approaches to include reactivity within our regulations, and this proposal was designed to meet the commitments made when the 1994 SIP was adopted.

Why are we proposing reactivity as a control strategy for aerosol coatings products?

As mentioned above, the ARB committed to investigate the use of reactivity in consumer products control strategies. Also, at its November 19, 1998, hearing the ARB adopted VOC content limits that are more stringent than the existing limits which became effective January 8, 1996. These more stringent limits become effective on January 1, 2002. At that hearing, recognizing that some of the limits were technologically challenging, the Board directed staff to return to them with an alternative reactivity-based compliance option for aerosol coatings. To that end, staff has been working with the affected industry on a voluntary reactivity regulation. However, during development of the voluntary proposal, staff and several representatives of the aerosol coating industry came to the conclusion that it was preferable to pursue replacing the VOC content limits with mandatory reactivity-based VOC limits. With agreement from the majority of the aerosol coating industry, the proposal that is the subject of this rulemaking would replace the January 1, 2002, VOC content limits with mandatory reactivity limits.

The aerosol coating category was selected for the first reactivity-based regulation because it is a well-defined, discreet consumer product category. We also have detailed speciation data from a recent survey. These data indicate that the VOCs used are well-characterized. We also note that aerosol coating manufacturers agreed to work with us early on to see if reactivity could be a viable control strategy. As such the regulation will act as a pilot for other potential reactivity-based regulations.

Will VOCs that are currently considered exempt continue to be exempt if the proposed amendments to the Aerosol Coatings Regulation are adopted?

In these amendments staff is proposing to eliminate the exemptions for low and negligibly reactive compounds. Currently, the Aerosol Coatings Regulation contains exemptions for negligibly reactive VOCs such as methane, and low reactive VOCs, such as acetone. This approach assumes these compounds do not contribute to ozone formation. However, under a reactivity-based strategy the potential ozone formation of all VOCs is considered. Using the MIR scale we are able to distinguish individual VOCs including acetone, by their characteristic reactivity values. The negligibly reactive and low reactive VOCs do make small contributions to ozone formation once they are emitted, they are just much less potent in forming ozone. However, staff believes that because these compounds have comparatively very low reactivity values, industry will still have strong incentives to use these compounds, where they are otherwise a desirable component in aerosol coatings.

What are the potential benefits of the proposed amendments to the Aerosol Coatings Regulation?

We believe there are several benefits to adopting the proposed amendments. First of all, we believe the proposed amendments will ensure that ozone reduction benefits are achieved from aerosol coatings. At present, total VOC content is limited on a percent-by-weight basis, without consideration of the differences in VOC reactivity. To comply with these more stringent VOC content limits, manufacturers would reduce the total VOC content. However in some instances manufacturers may choose to use more reactive VOC solvents, thus reducing the air quality benefit. Limiting the reactivity of the VOCs in a product helps ensure that ozone reductions are achieved as products are reformulated.

Secondly, we believe the proposed amendments may provide manufacturers more reformulation options. Manufacturers may be able to maintain the same overall VOC content as in their current formulations, however they will have to use VOC solvents that have lower ozone formation potentials. This approach should allow manufacturers more reformulation options and, as our economic impact analysis shows, may be a more cost effective compliance mechanism.

Another benefit that may result from the proposed amendments is a reduction in the use of toxic compounds such as toluene and xylenes due to their higher photochemical reactivity compared to other solvents.

Finally, the ARB will also benefit through this pilot project by using it as an example for future reactivity-based control strategies.

D. Effects of the Proposed Rulemaking

What products will be affected by the proposed rulemaking?

Thirty-five categories of aerosol coating products will be affected. These products are primarily aerosol paints, but also include aerosol clear coatings and aerosol stains.

Who would be affected by the proposed rulemaking?

The proposed rulemaking would affect any person who sells, supplies, offers for sale, applies, or manufactures for use in California any aerosol coating product subject to the regulation. This includes manufacturers, distributors, wholesalers, retailers, and aerosol paint users. The regulation is intended to apply to both household and industrial uses of aerosol paints. However, it should be noted that the regulation contains a specific exemption for noncommercial application of aerosol coatings. This exemption was provided to avoid enforcement actions against home use of noncomplying aerosol coatings.

The primary impact would be on manufacturers and marketers of aerosol coatings, which will have to reformulate some of their products. There would also be an impact on distributors and retailers, who must ensure that they are selling or supplying complying products. In addition, because some products will have to be reformulated, suppliers of chemicals, propellants, containers, valves, and other components may be impacted, depending on whether there is an increased or decreased demand for their products. Finally, consumers may have to pay more for some aerosol coating products, or may have to make some adjustments in their use of the reformulated products.

Will the performance of aerosol coatings products be affected?

There may be some changes in the characteristics of the reformulated aerosol coating products because their formulations will change. However, we do not expect significant impacts on product performance.

The regulation specifies different limits for each of the 35 categories of products to ensure that each type of product can be successfully reformulated and continue to be available to consumers. There are already complying products in nearly all of the 35 categories (in most cases representing a significant marketshare).

We expect the performance of water-based aerosol coatings to be unchanged. This is because these products currently are formulated with lower reactive solvents that have less ozone formation potential. Therefore, these products, formulated with water and dimethyl ether, already comply with the proposed limits.

How will the proposed changes to ARB Method 310 affect aerosol coating manufacturers?

We do not expect that the proposed amendments to ARB Method 310 will have an impact on aerosol coating manufacturers. Analytical data and other necessary information may be required from aerosol coating manufacturers to assist with the determination of chemical ingredients by Method 310, but this information should be readily available.

E. Regulatory Development Process and Evaluation of Alternatives

How did ARB staff develop the proposed amendments?

This rulemaking was developed in cooperation with the aerosol coating industry, solvent manufacturers, and other interested stakeholders. We began the process of determining if reactivity could be a useful control strategy for consumer products by establishing the Reactivity Subgroup within our Consumer Products Working Group in 1995. This group has met nine times. Findings from meetings of the Reactivity Subgroup, showing reactivity to be a viable control strategy, led us to begin developing a concept for a reactivity-based control regulation for aerosol coatings. Development of the regulation began in early 1998 and was originally proposed as an optional compliance strategy to the mass-based limits for aerosol coatings.

In developing the proposal, we have conducted eight public workshops, with the first held in November of 1997. At the first workshop we presented general regulatory concepts. Our most recent public workshop was held on April 11, 2000, at which time we presented the mandatory reactivity limit proposal. During the workshops, ARB staff discussed the proposed amendments, the limits, and other elements of the proposal necessary to establish the limits. Also, in the fall of 1999 we formed the Aerosol Coating Workgroup that is comprised of aerosol coatings manufacturers. Through this group we have exchanged information on the elements of the proposal. This workgroup has met or held teleconferences five times. In addition to these more formal meetings, ARB staff has held meetings with individual aerosol coatings manufacturers.

Who has been most active in the process?

Aerosol coating manufacturers and marketers, and trade associations have been most active in the process. The trade associations include the National Paint and Coatings Association (NPCA), the National Aerosol Association (NAA), and the Chemical Manufacturers Association (CMA). ARB staff maintains a comprehensive mailing list of companies and interested parties, which received information throughout the development of the proposed rulemakings. Information has also been made available on the ARB's Internet site.

Did ARB staff evaluate any alternatives?

As originally proposed, the reactivity regulation would have been an alternative means to comply with the Aerosol Coatings Regulation. However, with this mandatory proposal manufacturers would no longer have an option. Staff does believe that this proposal provides more flexibility and more reformulation options than the mass-based VOC limits by requiring manufacturers to focus on ozone reductions rather than mass reductions. We also note again, that aerosol coatings industry representatives made the request of ARB staff to consider establishing mandatory reactivity limits.

It should also be noted that the option of complying through use of the Alternative Control Plan will no longer be available. This regulation is not currently designed to average reactivity adjusted emissions. However, in the future we will be considering updating the Alternative Control Plan to include reactivity considerations.

F. Compliance with the Proposed Amendments

How will manufacturers comply with the proposed reactivity limits?

Manufacturers of noncomplying products will need to replace higher reactive VOC solvents or propellants in their formulations with lower reactive VOC ingredients and/or fewer VOCs. To comply with the proposed reactivity limits the most effective way to lower the reactivity would be to find comparable lower reactive substitutes for the highest reactive solvents in their products.

Are the proposed reactivity limits technologically and commercially feasible?

As explained in Chapter VII and VIII of the Technical Support Document, we believe the proposed reactivity limits are technologically and commercially feasible. The proposed amendments specify limits for 35 individual categories of coating products to ensure that each type of product can be successfully reformulated and continue to be available for consumer use. For all but two of the proposed VOC limits, there are currently complying products being sold.

The two categories that do not currently have complying products are “glass coating” and “corrosion resistant brass, bronze, or copper coatings.” We believe, that given the availability of a variety of lower reactive solvents, there are numerous reformulation options that can be used by manufacturers to reformulate their products. Products in these categories may also be successfully reformulated by using technologies employed in other product categories with significant complying marketshares.

TABLE 2
PROPOSED REACTIVITY LIMITS AND COMPLYING MARKETSHARES

Product Category	Proposed Reactivity Limit (g O_3/g product)	Number Complying Products	Percent Complying Products	Complying Marketshare (Percent)
Clear Coatings	1.54	45	38	45
Flat Paint Products	1.21	26	22	11
Fluorescent Coatings	1.77	44	86	64
Metallic Coatings	1.93	54	33	27
Nonflat Paint Products	1.40	302	38	36
Primers	1.11	31	20	29
Art Fixatives or Sealants	1.80	7	47	47
Auto Body Primers	1.57	12	63	64
Automotive Bumper and Trim Products	1.75	34	49	73
Aviation or Marine Products	1.98	<10	100	100
Aviation Propeller Coatings	2.47	<10	100	100
Corrosion Resistant Brass, Bronze, or Copper Coatings	1.78	0	0	0
Exact Match Finishes: Engine Enamel	1.72	8	28	72
Exact Match Finishes: Automotive	1.77	276	87	62
Exact Match Finishes: Industrial	2.07	30	94	99
Floral Sprays	1.68	13	81	87
Glass Coatings	1.42	0	0	0
Ground Traffic/Marking Coatings	1.18	64	58	24
High Temperature Coatings	1.83	28	43	42
Hobby/Model/Craft Coatings: Enamel	1.47	32	94	94
Hobby/Model/Craft Coatings: Lacquer	2.70	<10	40	60
Hobby /Model Craft Coatings: Clear or Metallic	1.60	13	76	34

(continued on next page)

TABLE 2 (Continued)
PROPOSED REACTIVITY LIMITS AND COMPLYING MARKETSHARES

Product Category	Proposed Reactivity Limit (g O_3/g product)	Number Complying Products	Percent Complying Products	Complying Marketshare (Percent)
Marine Spar Varnishes	0.87	<10	100	100
Photograph Coatings	0.99	<10	50	39
Pleasure Craft Finish Primers, Surfacers or Undercoaters	1.05	<10	100	100
Pleasure Craft Topcoats	0.59	<10	100	100
Shellac Sealers: Clear	0.98	<10	100	100
Shellac Sealers: Pigmented	0.94	<10	100	100
Slip-Resistant Coatings	2.41	7	100	100
Spatter/Multicolor Coatings	1.07	12	55	89
Vinyl/Fabric/Leather/ Polycarbonate	1.54	16	80	31
Webbing/Veil Coatings	0.83	<10	100	100
Weld-Through Primers	0.98	<10	38	67
Wood Stains	1.38	<10	100	100
Wood Touch-Up, Repair or Restoration Coatings	1.49	<10	> 60	> 90

What is the ozone reduction from the proposed amendments?

The proposed limits are expected to reduce the ozone formation potential of aerosol coatings by about 9.6 tpd. This is the equivalent ozone reduction that would be expected from the mass-based VOC reduction commitment of about 3.1 tpd. The six general coating categories and the ground traffic/marking coating category account for about 80 percent of the ozone formation potential, while the other 28 categories account for the remaining 20 percent of the ozone formation potential from aerosol coatings.

G. Economic Impacts

What are the expected economic impacts of the proposed amendments to the Aerosol Coatings Regulation on businesses?

Overall, we believe the proposed amendments to establish reactivity-based limits would result in cost savings for aerosol coatings manufacturers compared to the estimated cost to comply with the mass-based VOC limits. We conducted an analysis of the costs manufacturers would incur to reformulate their existing products to meet the proposed reactivity limits. We compared this cost with the costs estimated for compliance with the mass-based VOC limits adopted on November 19, 1998. Our analysis showed that reformulating to meet the reactivity limits will result in cost savings compared to compliance with the mass-based VOC limits.

We conducted an economic impacts analysis when we proposed the amendments to the mass-based VOC limits that were adopted by the Board on November 19, 1998 (ARB, 1998a). For this complete analysis the reader is referred to "Initial Statement of Reasons for the Proposed Amendments to Regulations for Reducing Volatile Organic Compound Emissions from Aerosol Coatings, Antiperspirants and Deodorants, and Consumer Products" (ARB, 1998a).

Because our cost analysis for these proposed reactivity limits is less than was predicted for the mass limits we believe that the conclusions of that economic impacts analysis would still apply for this rulemaking. We previously evaluated the potential impacts on profitability and other aspects of businesses subject to the proposed limits (with particular attention to California businesses), the cost-effectiveness of the limits, and the estimated cost impacts to consumers. To conduct our analysis, prior to adopting the mass-based VOC limits, we relied on a combination of publicly available financial databases (Dun and Bradstreet, *Ward's Business Directory of U.S. Manufacturing Industries*), the 1997 ARB Aerosol Coatings Survey (ARB, 1998b), industry journals/literature, and discussions with industry representatives.

Based on our earlier analysis, we expect most manufacturers to be able to absorb the added costs of the proposed rulemaking without an adverse impact on their profitability. We also found that the proposed rulemaking is cost-effective relative to similar ARB regulations or measures, and the impacts to consumers based on changes to raw materials cost are consistent with existing ARB regulations.

In the analysis conducted for the mass-based VOC limits, we estimated the change in "return on owner's equity" (ROE) as an indicator of the standards' potential impacts on business profitability. The cost to comply with the proposed regulation, due to increased research and development, materials costs, equipment purchases and other investment costs, is presumed to impact a business' ROE and therefore its profitability. The cost to reformulate noncomplying products for a typical small, medium and large company was used to determine the total annual reformulation costs. At that time, our analysis indicated that the estimated change in ROE can vary from essentially no change to slightly over an eight percent change. The average change in ROE was about two percent, relative to the pre-regulatory ROE. This estimated change in ROE is well within the change in ROE estimated for ARB's existing consumer products regulations. Given that the costs estimated from our analysis of costs to comply with the reactivity limits are lower, we expect the change in ROE to be no more, and likely less, than was estimated for the mass-based VOC limits.

Our ROE analysis for the mass-based VOC limits may have overestimated the impact on businesses because it assumes that manufacturers will absorb all of the compliance costs. In reality, we expect at least some of the investment costs to be passed on to consumers. The analysis also did not quantify the extent of cost mitigation from "technology-transfer" among product lines and from third-party manufacturers (i.e., contract fillers) who fill essentially equivalent products for a number of competing businesses.

In our earlier analysis, we also determined that most businesses would be able to absorb the costs to comply without significant adverse impacts on their profitability. This same conclusion can be drawn for manufacturers reformulating to meet the reactivity limits because the costs to reformulate products are less than those calculated to meet the mass-based VOC limits.

However, we also conclude that there is the possibility that some individual businesses may be adversely affected by this regulatory action. It is possible that some aerosol coatings manufacturers had begun to incur costs as they worked toward meeting the mass-based limits. Our analysis did not consider these costs, so in some instances the costs estimated here to comply with the reactivity limits may be underestimated. Therefore, it is possible that these proposed amendments may have a significant adverse impact on some businesses that are not in a market position to invest monies to develop new lower reactive products as well as other manufacturers, or to absorb the increased cost resulting from their compliance with the proposed rulemaking.

Again, based on our earlier analysis, we do not expect these proposed amendments to have a significant impact on employment, or business creation, elimination, or expansion. We also do not expect the proposed amendments to have a significant impact on the competitiveness of California businesses compared with those outside of California. This is because all companies that sell aerosol coating products in California would have to meet the proposed requirements, whether located in or outside of California.

The proposed reactivity limits will primarily impact aerosol coating manufacturers and marketers (companies which contract out the manufacturing of their products). However, we recognize that other industries could also be impacted to a lesser amount, which is difficult to quantify. These industries include distributors, retailers, and “upstream” suppliers who supply containers, valves, solvents, propellants, and other chemicals used in aerosol coatings.

Distributors and retailers could be impacted if some manufacturers decide to carry a dual inventory of products (one for California and one for the rest of the nation). Another potential cost to distributors or retailers would be the implementation of procedures to ensure that noncomplying products are not sold past the three year “sell-through period.” However, based on retail sell-through data obtained during the development of ARB’s existing consumer product regulations, we believe the existing three year sell-through period should provide ample time to allow for the sale of noncomplying aerosol coating products.

Upstream suppliers could be impacted because manufacturers will be purchasing some different solvents, propellants, and other materials for their reformulated products. They may also purchase different containers, valves, or other components for their reformulated products. However, we do not expect these changes to result in a major impact on the affected industries because chemical companies generally supply many different industries, and because many of the upstream suppliers also provide the alternative products which will be used in the reformulated products. In fact, we expect some upstream suppliers will benefit since the proposed reactivity limits are likely to create new or increased demand for materials to be used in compliant formulations.

Will the proposed rulemaking be cost-effective?

Cost-effectiveness is one measure of a regulation’s efficiency in reducing a given amount of pollutant (often reported in “dollars (to be) spent per pound of VOC reduced”). The determination of cost-effectiveness is well-established and often used to compare a proposed regulation’s cost-efficiency with those of other regulations. To conduct our analyses, we relied on specific formulation data from the 1997 ARB Aerosol Coatings Survey, industry journals/literature, and discussions with industry representatives. Our analyses considered separately the impacts on the cost-effectiveness from nonrecurring, investment costs (as an annualized cost) and the impacts from recurring costs (primarily changes in raw material ingredients).

It is important to keep in mind that in these amendments we are proposing limits that will reduce the amount of ozone formed rather than reduce the total amount of VOC emissions. However, because traditionally cost-effectiveness is based on cost per pound of VOC reduced, we are presenting our analysis in the same units. We estimate the cost-effectiveness of the proposed amendments to the aerosol coatings regulation to range from no cost to about $1.67 per pound of VOC reduced, with a sales-weighted average of about $0.74. When the mass-based VOC limits were adopted by the Board on November 19, 1998, we estimated the cost-effectiveness of those amendments to range from $0.93 to $3.19, with an overall average cost-effectiveness of $1.57 per pound of VOC reduced. These data for the proposed reactivity limits support our conclusion that reformulating to meet reactivity limits is a more cost-effective compliance alternative and are consistent or lower than other existing ARB regulations and control measures.

Will consumers have to pay more for aerosol coatings subject to the rulemaking?

We estimate the cost per unit to range by category from no cost to an increase of about $0.11 per unit. The average cost per unit increase is expected to be about $0.05. These values compare favorably to the cost increase predicted from compliance with the mass-based VOC limits (about $0.10). To the extent manufacturers pass these costs along to the consumer, the actual retail price changes may be higher or lower than indicated by this analysis. Chapter XI and Appendix I of the Technical Support Document contain the detailed analyses of our estimated range in unit cost increases.

What are the expected economic impacts of the proposed modifications to Method 310?

We do not expect that the proposed amendments to Method 310 will result in any costs to manufacturers. Even though we would require manufacturers to supply formulation data if their products are selected for testing, this is information that is readily available and should not pose any cost burden.

H. Environmental Impacts

What are the expected environmental benefits of the proposed amendments?

The proposed amendments are designed to provide an equivalent air quality benefit as would be achieved upon implementation of the January 1, 2002, VOC content limits. The primary intent of this rulemaking is to reduce the total amount of ozone formed from aerosol coating product emissions, rather than reduce the total mass of VOC emissions. The mass-based VOC reductions, upon implementation in 2002, would achieve a VOC reduction of 3.1 tpd. In this rulemaking, we are converting the commitment of 3.1 tpd of VOC emissions reductions into 9.6 tpd of ozone reductions.

Another benefit that may result from the proposed amendments is a reduction in the use of toxic compounds such as toluene and xylenes due to their higher photochemical reactivity compared to other solvents.

In addition, VOCs have also been found to contribute to the formation of $PM_{2.5}$ (minute particulate matter of 2.5 micrometers or less equivalent aerodynamic diameter). Results of aerosol formation studies suggest that reactive aromatic compounds and aromatic-containing hydrocarbon solvents used in aerosol coatings, such as toluene, xylenes, and naphthas, may have high $PM_{2.5}$ formation potentials. To comply with the reactivity limits the most efficient ozone reductions would be achieved by reducing the amounts of these highly reactive compounds**.** Because of this we believe the proposed rulemaking may have an additional positive impact on $PM_{2.5}$ formation (see below also).

How would the proposed rulemaking reduce the risk to public health?

It has long been known that exposure to ground level ozone and $PM_{2.5}$ have adverse impacts on public health. These potential health impacts include respiratory problems, aggravated asthma, and impairment of the immune system. Therefore, by reducing the ozone and, potentially, $PM_{2.5}$ concentrations, this regulation would reduce the health risks posed by exposure to these pollutants.

Another benefit that may result from the proposed amendments is a reduction in the amounts of toxic compounds such as toluene and xylenes due to their higher photochemical reactivity compared to other solvents.

Are there any potential negative environmental impacts from the proposed reactivity limits?

We are proposing to delay the effective date of the reactivity limits from January 1, 2002, to June 1, 2002, and January 1, 2003, for general coatings and specialty coatings, respectively. Because of this a short-term shortfall of 9.6 tpd of ozone will occur for five months. However, the general coatings categories constitute 78 percent of the total ozone formation potential. By requiring compliance by June 1, 2002, 7.9 tpd, or 82 percent of the ozone reductions will be achieved concurrent with the 2002 ozone season. For an additional seven months there will be an ozone shortfall of 1.7 tpd. We believe the extension of the effective date is necessary to prevent disruptions in the aerosol coating market place and to minimize the possibility of an economic hardship for aerosol coating manufacturers. This proposal also ensures that efficacious products will continue to be available to the consumer in all 35 categories. We believe that these considerations override the short-term air quality disbenefit.

Both high molecular weight VOCs (or solvent) and aromatics are expected to contribute to the formation of aerosols. While the heavier organic compounds are less reactive, they may have higher potentials to form $PM_{2.5}$ than their light weight counterparts. A similar situation is also found for aromatic compounds and solvents used in aerosol coating products. However, the extent that manufacturers would reformulate using these high aerosol forming VOC or aromatic species is difficult to predict. Hence, we will continue to monitor implementation of the regulation to ensure that there is no adverse impact as a result of the proposed rulemaking.

We did identify one other potential adverse impact from implementation of the proposed amendments. Methylene chloride has been identified as a toxic air contaminant by the ARB. Because methylene chloride is a negligibly reactive VOC and also has desirable solvent qualities, its use could potentially increase as products are reformulated to meet the reactivity limits. Because of this, we are proposing a "no new use" provision for methylene chloride to prohibit increased uses. As proposed, if an existing product already uses methylene chloride, no additional methylene chloride could be added when the product is reformulated. Any product that does not currently contain methylene chloride, could not reformulate using methylene chloride. Our complete analysis is contained in Chapter X and Appendix G.

As explained further in Chapter X of the Technical Support Document, we do not expect any other adverse environmental impacts to result from the proposed amendments. We examined the potential effect of the proposed regulation on global warming, stratospheric ozone depletion, the use of Toxic Air Contaminants, and the impacts on water quality and solid waste disposal.

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Recommendation

We recommend that the Board adopt the proposed amendments to the Aerosol Coatings Regulation, the proposed Tables of MIR values, and the proposed amendments to ARB Method 310. Adoption of the proposed amendments would put in place the first reactivity-based regulation for consumer products. These amendments, if adopted, could be used as a model for additional reactivity-based regulations.

State of California
AIR RESOURCES BOARD

Technical Support Document

Initial Statement of Reasons for the

Proposed Amendments to the Regulation for Reducing Volatile Organic Compound Emissions from Aerosol Coating Products,
and
Proposed Tables of Maximum Incremental Reactivity (MIR)Values,
and
Proposed Amendments to Method 310, “Determination of Volatile Organic Compounds in Consumer Products”

I.

Introduction

A. Overview

This Initial Statement of Reasons (ISOR), describes the Air Resources Board (ARB) staff's proposal and justification for amending the Aerosol Coatings Regulation contained in sections 94520-94528 of Title 17 in the California Code of Regulations (CCR). In these amendments ARB staff is proposing a new way to regulate volatile organic compound (VOC) emissions from aerosol coatings. Using the science of VOC photochemical reactivity (reactivity), ARB staff is proposing amendments that would replace the January 1, 2002, VOC limits with reactivity-based limits that achieve an equivalent air quality result. To implement the reactivity-based amendments we are also proposing a new Subchapter 8.6 that would include maximum incremental reactivity (MIR) values, and are proposing amendments to ARB Method 310, "Determination of Volatile Organic Compounds in Consumer Products."

At present the Aerosol Coatings Regulation contains limits that specify the maximum amount, on a percent-by-weight basis, of VOCs that can be contained in an aerosol coating product. These mass-based VOC standards do not take into consideration the differences in a VOC's potential to form ozone once emitted. However, not all VOCs react in the atmosphere to form equivalent amounts of ozone. Some VOCs make very little ozone while others are likely to form an order of magnitude more. "Reactivity" is the concept that allows us to consider these differences in each VOC's potential to form ozone. Based on this science, staff is proposing amendments that, rather than limiting the total amount of VOCs, would limit the total amount of ozone that could be formed from the VOCs contained in aerosol coatings. The MIR values in the newly proposed Subchapter would be used to assign reactivity values to VOCs. The proposed amendments to Method 310 are necessary to aid in enforcing the reactivity portions of the Aerosol Coatings Regulation. Our proposal and information on the science and use of photochemical reactivity is explained in Chapters II and IV of this Technical Support Document.

B. Legislative History

ARB authority to regulate aerosol coatings and other consumer products is contained in Health and Safety Code section 41712. Section 41712 was originally enacted by the Legislature as part of the California Clean Air Act of 1988. In enacting section 41712, the Legislature gave the ARB new authority to control emissions from consumer products, an area that had previously been subject to very few air pollution control regulations.

Section 41712 has been amended a number of times since it was originally enacted in 1988. The current language of section 41712 requires the ARB to adopt regulations to achieve the maximum feasible reduction in VOCs emitted by consumer products. In addition, all consumer products regulations adopted by the ARB must be: (1) based on adequate data; (2) technologically and commercially feasible; (3) necessary to attain state and federal ambient air quality standards; and (4) not result in the elimination of a product form.

As originally enacted, section 41712 gave ARB the authority to regulate VOC emissions from “consumer products.” But the term “consumer products” was defined to specifically exclude “paint.” Because aerosol coatings are considered to be “paint,” the ARB initially did not have any authority to regulate aerosol coatings. The authority to regulate aerosol coatings was vested in the local air pollution control and air quality management districts.

All this changed in 1992 and 1993. In 1992, the Legislature enacted Assembly Bill 2783 (AB 2783, Sher; Stats. 1992, Chapter 945). AB 2783 gave ARB the authority to regulate aerosol paints. It did this by amending the definition of “consumer products” in section 41712 to include “aerosol paints" as a consumer product to be regulated by the ARB.

In 1993, the Legislature further amended Health and Safety Code section 41712 by enacting AB 1890 (AB 1890, Sher; Stats. 1993, Chapter 1028). Among other things, the AB 1890 amendments required ARB to achieve a 60 percent emission reduction from the use of aerosol paints by December 31, 1999. However, ARB was required to conduct a public hearing on or before December 31, 1998, on the technological or commercial feasibility of achieving full compliance with the final limits by December 31, 1999. The law also allowed ARB to grant an extension of time not to exceed five years if it was determined that the 60 percent reduction was not technologically or commercially feasible by December 31, 1999.

The AB 1890 amendments also clarified the intent of the Legislature with respect to the regulation of aerosol paints by requiring, with one exception, that limits on the emissions of reactive organic compounds from aerosol paints be set solely by the state board to ensure uniform standards are applicable on a statewide basis. The only exception to this requirement is any regulation that has been adopted by a district pursuant to an order of a federal court. The only district regulation that meets this criterion is the Rule 49 of the Bay Area Air Quality Management District, which was adopted in June 1990 in response to a federal court order.

Senate Bill 987 (SB 987, Sher; Stats. 1997, Chapter 568) is the most recent amendment to section 41712 affecting aerosol paints. Senate Bill 987 specifies that acetone be included among the VOCs in the 1989 baseline year measurement used for the calculation of the 60 percent emission reductions from the use of aerosol coating products. This amendment was necessary because in 1989 acetone was still considered a regulated VOC. Since that time acetone qualified for an exemption from consideration as a VOC due to its comparatively low (compared to ethane) photochemical reactivity.

To fulfill the requirements of state law, on November 19, 1998, the ARB conducted a public hearing on the feasibility of achieving the required 60 percent reduction in emissions from aerosol coatings. Staff determined, and the Board concurred, that the limits that would achieve the 60 percent reduction were neither technologically nor commercially feasible (ARB, 1998a). Because of this, at the hearing the Board adopted revised VOC limits to ensure that consumer-acceptable products would continue to be available in the marketplace. The Board also extended the compliance deadline to January 1, 2002, to achieve the newly adopted VOC limits. However, at the hearing, the Board also recognized that some of the limits would be technically challenging and directed staff to return to them with a voluntary regulatory compliance option based on reactivity.

C. Background

1. Consumer Product Regulations Adopted to Date

To date, the ARB has taken several actions to fulfill the legislative mandate set forth in Health and Safety Code section 41712. Three regulations have been adopted that limit the VOC content of 47 consumer product categories and 35 categories of aerosol paints. In addition, two voluntary regulations have been adopted to provide compliance flexibility to companies.

On November 8, 1989, the ARB adopted a regulation for reducing VOC emissions from antiperspirants and deodorants (the "antiperspirant and deodorant regulation;" sections 94500-94506.5, Title 17, CCR) (ARB, 1989a; 1989b).

The ARB then adopted a more comprehensive regulation for reducing VOC emissions from 46 additional categories of consumer products, which was adopted by the ARB in four phases (the "consumer products regulation;" sections 94507-95417, Title 17, CCR) (ARB, 1990; 1990a; 1990b; 1991; 1991a; 1991b; 1997b, 1999a). Phase I was adopted on October 11, 1990, Phase II was adopted on January 9, 1992, and Phase III was approved on July 24, 1997. The Phase III amendments, referred to as the Mid-term Measures, became legally effective on August 16, 1998. To complete our Mid-term Measures commitment additional amendments were approved by the Board at its October 28, 1999, hearing. These regulations reduce VOC emissions primarily through specification of maximum allowable VOC content limits (by weight percent) for individual product categories (ARB, 1999a).

On September 22, 1994, the ARB adopted the first voluntary regulation, the "Alternative Control Plan Regulation for Consumer Products" (the "ACP") (ARB, 1994; 1994a). The ACP is a market-based regulation that employs the concept of an aggregate emissions cap or "bubble" This program supplements existing regulations by providing consumer products and aerosol coatings manufacturers additional flexibility when formulating consumer products. This regulation is contained in Title 17, CCR sections 94540-94555.

The ARB adopted a third regulation on March 23, 1995, the "Regulation to Reduce Volatile Organic Compound Emissions from Aerosol Coating Products and Amendments to the Alternative Control Plan for Consumer Products" (ARB, 1995; 1995a). This regulation limits the VOC content of 35 categories of aerosol coatings. At the same time, the ACP was amended to make it possible for aerosol coatings to average their emissions to provide a compliance option. The aerosol coatings regulation is contained in Title 17, CCR, sections 94520-94528.

On November 13, 1997, the ARB approved the second voluntary regulation, the Hairspray Credit Program (ARB, 1997c), which allows hairspray manufacturers and marketers to generate emission reduction credits if they comply early with the second-tier VOC standard for hairspray. The Hairspray Credit Program regulation became legally effective on August 24, 1998, and is contained in Title 17, CCR, sections 94560-94574.

On November 19, 1998, the Board adopted amendments to the aerosol coatings regulation, the consumer products regulation, and the antiperspirant and deodorant regulation (ARB, 1998a). The amendments modified the December 31, 1999, VOC limits in the aerosol coatings regulation, and the effective dates for these VOC limits. Minor changes were also made to the definitions and administrative requirements in the aerosol coatings regulation. Finally, methyl acetate was added to the list of compounds exempt from the VOC definitions in these three regulations. The amendments became legally effective on June 24, 1999.

As mentioned above, on October 28, 1999, the Board approved the Midterm Measures II amendments that affected 17 consumer product categories. These included two new categories and 15 previously regulated categories for which more stringent limits were approved. Also some product categories were expanded to include some additional types of products. These amendments were proposed to partially fulfill a lawsuit settlement for failure to implement specific measures contained in the 1994 State Implementation Plan for Ozone (ARB 1994b).

2. The State Implementation Plan

On November 15, 1994, the ARB adopted the State Implementation Plan (SIP) for ozone (ARB, 1994b). The SIP serves as California's overall long-term plan for attainment of the federal ambient air quality standard for ozone. Together with significant reductions from stationary industrial facilities, mobile sources (e.g. cars, trains, boats), and other area sources (e.g. architectural and industrial maintenance coatings), the emission reduction commitments in the consumer products element of the SIP are an essential part of California's effort to attain both the National and State ambient air quality standards for ozone. The VOC reductions from consumer products are also needed to help several local air pollution control districts meet rate-of-progress requirements in the federal Clean Air Act (CAA).

Our current commitment in the SIP is to reduce consumer product emissions by 85 percent by the year 2010 (including the adopted regulations). This reduction is necessary for the South Coast Air Basin, among others, to attain the federal ozone standard and meet the rate-of-progress requirements under the CAA. To meet the emission reductions committed to in the SIP, we developed a multi-faceted program comprised of "near-term," "mid-term," and "long-term" control measures. The aerosol coating limits adopted on November 19, 1998, are an important component of the near-term measures goal to reduce VOC emissions from consumer products by 30 percent.

Listed below is a breakdown of how our SIP commitment for an 85 percent reduction in emissions from consumer products will be achieved:

- 30 percent from near-term measures;
- 25 percent from mid-term measures;
- 30 percent from long-term measures.

Additionally, in the SIP, we committed to consider photochemical reactivity principles for the control of VOCs from consumer products. As part of the Consumer Products Working Group, on April 11, 1995, we also formed the "Reactivity Subgroup" to help in the investigation and development of reactivity-based consumer product regulations. Since its inception, the Reactivity Subgroup has met nine times to discuss concepts and principles for reactivity-based control strategies.

It is important to mention here that ARB has begun to evaluate the current 85 percent emission reduction commitment for consumer products. This evaluation is part of the ARB's plan to revise and update the SIP in early 2001. From these evaluations we have determined that additional reductions from consumer products are achievable, but at a lower level of effectiveness than called for in the current SIP. However, we plan to continue to aggressively pursue every feasible emission reduction from consumer products, including aerosol coatings. These emission reduction measures may include additional reactivity-based control strategies.

3. Comparable Federal Regulations

The U.S. EPA Administrator signed the final approval for the enactment of the National Volatile Organic Compound Emissions Standards for Consumer Products on August 14, 1998. The U.S. EPA published the final rule in the September 11, 1998 Federal Register, Volume 63, No. 176, pages 48819-48847 (U.S. EPA, 1998). The standard effective date for all the categories in the U.S. EPA rule was December 10, 1998.

The U.S. EPA's rule is similar to that of the ARB's consumer product regulations, although some differences do exist. Of particular importance for this rulemaking is that there is no current U.S. EPA proposal to reduce VOC emissions from aerosol coating products. There also are no federal reactivity-based regulations for consumer products or aerosol coatings. We do note that according to current schedule, the U.S. EPA is scheduled promulgate a regulation to reduce aerosol coating emissions in 2001.

4. Use of Photochemical Reactivity as a VOC Control Strategy

As mentioned at the beginning of this Chapter, the photochemical reactivity of a VOC is a measure of its potential to form ozone once it is emitted into the atmosphere. By using reactivity-based scales, such as the MIR scale, we can compare the reactivity of one VOC to the reactivity of another, and use these differences to develop control approaches that target reductions from VOCs that have higher ozone formation potentials. In this report, staff is proposing to regulate aerosol coating products by limiting the reactivity of the emissions, rather than the total mass of emissions. Specifically, we are proposing to replace the VOC standards adopted by the Board on November 19, 1998, with reactivity limits that will achieve an equivalent air quality benefit.

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II.

Background on the Science of Volatile Organic Compound Photochemical Reactivity

A. Introduction

To reduce excess ozone concentrations in non-attainment areas, control of ozone precursors such as volatile organic compounds (VOC) and oxides of nitrogen (NO_x), is needed. As part of California's ozone control strategy, we have been successfully implementing mass-based VOC emission controls for aerosol coating products. To further refine the current regulatory approach, in this rulemaking Air Resources Board (ARB) staff is proposing to use photochemical reactivity as the basis for regulating emissions from aerosol coatings. We believe this control approach has the potential to provide more flexibility to manufacturers, and could lead to a more effective and cost efficient ozone control strategy.

It has been known for several decades that individual VOCs vary in the amount of ozone potentially formed once emitted into the air. This concept is referred to as "reactivity." In the current Aerosol Coatings Regulation, total VOC content is limited on a percent-by-weight basis, without consideration of the differences in VOC reactivity. However, the science of reactivity now allows us to more effectively control VOC emissions by targeting reductions from VOCs that have a higher potential to form ozone.

Therefore, we are proposing to amend the Aerosol Coatings Regulation by replacing the January 1, 2002, mass-based limits with equivalent reactivity-based limits. The following sections provide background on the science of reactivity, and how the reactivity of VOCs is measured.

B. Background on the Science of Reactivity

The photochemical reactivity of a VOC is a measure of its potential to impact ozone levels. Years of research has led to our understanding that VOCs vary in their ability to contribute to ozone formation because they react at different rates and *via* different chemical mechanisms. In other words, the difference in the chemistry of each VOC, or its reactivity, determines its impact on ozone formation. These differences can be quantified and used in approaches to control emissions of VOCs.

The science of photochemical reactivity, or reactivity, has been evolving and expanding for several decades. Beginning in 1952, it was discovered that different organic compounds have different potentials to form ozone (Haagen-Smit *et al.*, 1952). The formation of ozone involves complex chemical interactions of VOCs with oxides of nitrogen, or NO_x , in the air. Within these interactions, it was discovered that VOCs differ in their abilities to form ozone. The variability in ozone-formation potentials was later verified by smog chamber experiments (Carter and Atkinson, 1989). In smog chamber studies a known amount of a VOC is injected into an experimental chamber under conditions that would generate the maximum amount of ozone. The reaction products of the chemical reactions and their amounts are measured and analyzed to help understand the chemical reaction rate and mechanism by which the VOC reacts. These smog chamber experiments yielded important information on the chemistry of VOCs. To account for the differences in the VOCs' abilities to form ozone, reactivity scales were developed (for example, Dodge, 1984; Bufalini et al., 1976). The United States Environmental Protection Agency (U.S. EPA), as early as 1977, recognized the variability of VOCs' ozone-forming potential and created a two-class reactivity scale for the regulatory control of VOCs: "negligibly reactive" and "reactive." California also applies this strategy in its consumer products regulations.

C. Development of Methods to Compare VOC Reactivities

To use the concept of reactivity a method is needed to quantify the impact of each VOC on ozone formation. One tool that allows for ozone measurement is a reactivity scale. Many scales have been proposed to quantify the ozone formation potential of VOCs. The complexity of these scales range from one considering only the hydroxyl (OH) radical reaction rate constant (see, for example, Darnall *et al.*, 1976) to those that incorporate detailed effects of ozone chemistry and ambient conditions using a box model or the more sophisticated three-dimensional Eulerian model (Carter, 1994; Harley *et al.*, 1993).

One of the earlier scales to measure VOC reactivity was based on the reaction of hydrocarbons with OH radicals (Darnall *et al.*, 1976). The scale proposed to account for the differences in reactivities by the VOC's chemical reaction rate constant. The chemical reaction rate constant (or how fast the initial reaction occurs) of the VOC with OH radical is important because it is the predominant reaction in the lower troposphere (the lowest 15 kilometer layer of atmosphere in which we live) and the OH radical is critical to the formation of photochemical smog. For many VOCs, reaction with the OH radical is the only atmospheric loss process. Thus, the reaction rate constant, k_{OH}, is the measurement of how rapidly the initial VOC reaction takes place. In addition, the k_{OH} rate constant is available for a large number of VOCs. However, because of the intricacies of the VOC-NO_x-air-irradiation system, there are significant inherent differences in the reaction mechanisms, which affect how much ozone is formed after the VOC has reacted with the OH radical. Because these differences have not been accounted for, the k_{OH} scale is considered insufficient for the ranking of rapidly reacting VOCs, and of ozone impacts of the VOCs with similar k_{OH} values.

In 1991, Derwent and Jenkin of the United Kingdom developed the Photochemical Ozone Creating Potential (POCP) (Derwent and Jenkin, 1991), which was defined by subtracting the emissions of a particular VOC from a 69-component mixture and re-running the photochemical model calculation. The POCP model was defined relative to ethene as the reference compound. This model showed that aromatic and olefinic compounds yielded the highest POCP values, while aliphatic hydrocarbons showed POCP values that increased steadily in multi-day trajectories. However, the Harwell mechanism used in the POCP scale was not validated against results from smog chamber experiments and therefore, may not be appropriate for evaluating the reactivities of VOCs in the atmosphere. Later, Andersson-Skold *et al.* (1992) refined several parameters of the POCP model and found that the maximum ozone difference and the 96-hour average ozone concentration gave the most consistent POCP values. On a 96-hour average, ethene and acrolein were found to be very efficient ozone producers, followed by higher alkenes, aromatics, alkanes, and ethers. Alcohols and ketones were found to be weaker ozone producers.

In 1984, Dodge studied the organic reactivities of VOC present in an urban air mixture (Dodge, 1984). A chemical mechanism was developed and tested against smog chamber experiments. This mechanism was found to have a reasonable fit to the available experimental data. VOC reactivity was expressed as the percent increase in maximum ozone per amount of hydrocarbon added to the urban mixture, and the calculations were performed based on the ratio of the concentration of the VOC to the concentration of the NO_x (also known as the VOC/NO_x ratio), characteristic of the air basin, and on the atmospheric composition. The differences in reactivity among the VOC tested were greater at lower VOC/NO_x ratios (<3-4), but the differences in reactivity decreased as the VOC/NO_x ratio increased. Thus, the use of hydroxyl rate constant, k_{OH}, is a good measure of reactivity at low VOC/NO_x ratios, but not at high ratios.

Since 1989, Carter and co-workers at Statewide Air Pollution Research Center (SAPRC) (and now continuing at the College of Engineering Center for Environmental Research and Technology) (Carter and Atkinson, 1989; Carter, 1994; 1996; 1999b; 2000; Carter *et al.*, 1995) have been conducting the most extensive studies of incremental reactivities using smog chamber experiments and computer modeling. Carter defines the incremental reactivity as the maximum amount of ozone formed by the addition of a test hydrocarbon to the base reactive organic gas mixture, divided by the infinitesimal amount of the test hydrocarbon added. Data from these experiments have shown that the ozone formation potential of the VOCs depends significantly on the nature of their reaction mechanisms and the characteristics of the environment in which they react, with NO_x availability being the most important environmental factor. In general, VOCs are found to have the highest effects on ozone formation under relatively high NO_x conditions (i.e., low ROG/NO_x as in urban conditions), and to have low impact on ozone formation under limited NO_x conditions, which lead to high ROG/NO_x ratios.

The MIR, maximum ozone incremental reactivity (MOIR), and equal benefits incremental reactivity (EBIR) are three incremental reactivity scales developed by Carter from box models of 39 U.S. urban areas (selection based on conditions described by the U.S. EPA) (Bauges, 1990; Carter, 1994). Incremental reactivity is expressed as the number of additional grams of ozone formed per gram of VOC compound added to the base organic mixture. Incremental reactivity conveniently computes the ozone formation potential of a VOC when it is readily available for reaction in the troposphere.

The MIR is the incremental reactivity computed for conditions in which the NO_x concentration would maximize the base ROG reactivity. This scenario is typical in air parcels of low VOC-to-NO_x ratios such as urban centers, or air parcels in which ozone is most sensitive to VOC changes. These are typical of urban centers in where there are high emissions of NO_x and the chemistry is VOC-limited.

Because of the complexity of the atmosphere and nonlinear interactions of ozone precursors (Carter, 1996), computer models are used to calculate the general trends in reactivity of organic compounds. Accordingly, the reliability of such calculations would depend on the accuracy of the model's descriptions of the physical as well as chemical environment of the "real world." The MIR scale that would be used in these proposed amendments was developed using a simple zero-dimensional ("box") photochemical model with a detailed chemical mechanism developed at the SAPRC (hereafter referred to as the SAPRC mechanism) (Carter, 1990; 2000).

The SAPRC mechanism is a "lumped molecule" mechanism, which is a modeling approach utilizing generalized species and reactions with parameters derived from the compound(s) being represented (Carter, 1990). This mechanism is designed to assess the differences in atmospheric impacts of individual VOCs and has been extensively evaluated against environmental chamber data (Carter *et al*., 1995). Despite having less detail to represent different physical processes (for example, pollutant transport) in the atmosphere, a box model allows a comprehensive evaluation of the ozone forming chemistry of an organic chemical based upon finite computer resources.

Studies have also addressed the appropriateness of using a simplified, zero-dimensional box model, to quantify the reactivities of VOCs. These studies involved comparing the MIR to other reactivity scales (such as peak ozone level) derived by using more sophisticated photochemical models such as a three-dimensional Eulerian model (3D Model) (see, for example, McNair *et al*., 1992; Bergin *et al,* 1998). Unlike the box model, a 3D model has a more comprehensive representation of different atmospheric physical processes such as multi-day transport, spatial and temporal variations of emissions. The results of these studies indicated that the box-model calculated MIR scale, using the SAPRC mechanism, is in agreement with other reactivity scales derived using more sophisticated models (Bergin *et al.*, 1995; 1998) and chemical mechanisms (Derwent *et al.*, 1998; Bergin *et al.*, 1998). Therefore, we conclude that the MIR scale provides a reliable description of hydrocarbon reactivities and, therefore, can be utilized for ozone control strategy decisions.

D. Appropriateness of the MIR Scale

In the previous section we discussed the chemical mechanism from which the MIR scale is derived, and concluded that the SAPRC mechanism reliably predicts the reactivities of VOCs. However, we also need to address the appropriateness of using the MIR scale in California's ozone control strategies. For ozone control strategies, the reactivity scale selected should be designed for the best overall air quality benefit. At the request of ARB, Dr. Carter studied 18 different methods (including MIR, MOIR, and EBIR) of ranking the reactivity of individual VOCs in the atmosphere using a single-cell trajectory model with the SAPRC90 chemical mechanism (Carter, 1994). Dr. Carter concluded that if only one scale is to be used for regulatory purposes in California, the MIR scale is the most appropriate.

Based on this recommendation, the ARB is proposing to use the MIR scale for the proposed amendments to the Aerosol Coatings Regulation. The MIR scale appears to be most accurate for VOC-limited conditions, such as in the South Coast Air Basin, 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 (McNair *et al.*, 1992; Bergin *et al.*, 1995; 1998). Currently, the MIR scale is used to derive reactivity adjustment factors in the Low Emission Vehicle/Clean Fuels regulations. (ARB, 1990c). The wider range of VOC incremental reactivities in the MIR scale also allows more choices in a manufacturer's selection of a lower-reactive VOC substitution for a relatively higher-reactive VOC solvent.

As further evidence of the MIR scale being appropriate for California, the VOC/NO_x ratios used for deriving the scale are observed throughout the state of California including such cities as San Diego, Los Angeles, Sacramento, and San Francisco (Carter, 1994).

To further validate the use of the MIR scale, at the suggestion of our Reactivity Scientific Advisory Committee (RSAC) and industry, ARB contracted with Dr. William Stockwell at the Desert Research Institute to conduct a review of the base mechanism (SAPRC99) from which the MIR scale is derived. The result of the review was encouraging. Stockwell concluded that Carter's mechanism represents "state of the science for air quality models" (Stockwell, 1999). The RSAC concurred with Stockwell at its October 8, 1999, meeting and found that SAPRC99 represents the most thoroughly reviewed and best documented chemical mechanism available.

E. Uncertainty of MIR Values

As mentioned above, the science of reactivity is still evolving and improving. Therefore, before assessing whether a reactivity-based control strategy is viable, a clear understanding of the VOCs used, the amount of each VOC used, and the reliability and completeness of the reactivity data available for those VOCs, in a given source category, is essential. Even though the aerosol category is well-defined, in light of gradual refinement of hydrocarbon reactivities in the future, we believe consideration for uncertainty needs to be made when using MIR values in regulatory applications (Carter, 2000). In the following paragraph, we provide information on the type of uncertainties that exist. In Chapter IV, we provide our proposal to address the uncertainty.

As mentioned above, the MIR scale is calculated using the SAPRC chemical mechanism. This chemical mechanism includes experimentally determined or estimated reaction rate constants, as well as product yield (mechanistic) parameters of several thousand reactions. A previous version of the SAPRC mechanism, SAPRC90, was peer-reviewed (Gery, 1991) and the factors contributing to MIR uncertainty were identified (Stockwell *et al*., 1994; Yang *et al.*, 1995; 1996; Yang and Milford, 1996). Since the development of SAPRC90, significant progress in atmospheric chemistry has been made (Atkinson, 1994; 1997; 2000). To reflect the latest developments in the science of hydrocarbon reactivity, the MIR scale was calculated using the SAPRC99 mechanism (Carter, 2000). The SAPRC99 mechanism is an extension of SAPRC90, which incorporates the latest information on atmospheric chemistry of various reactive organic compounds (ROC) and computational techniques.

Although the MIR values are calculated using a “state-of-the-science” chemical mechanism, the reactivity estimates of some ROC classes are still uncertain. This is partly because of some inconclusive scientific data (see, for example, Atkinson, 2000). To understand the uncertainties, it is important to note that the model calculated MIR value of a chemical is determined using both the base mechanism (in this case SAPRC-99), as well as the mechanism by which an individual compound reacts in the atmosphere. The base mechanism describes the reactions of inorganics and common products formed during the photo-oxidation of ROC. Because this base mechanism is used for calculating the reactivity of all chemicals, any change to the base mechanism is likely to have a “global” effect on MIR values. In other words, the uncertainty associated with changes to the base mechanism would likely be similar for all compounds. On the other hand, improvements in understanding how an individual compound reacts in the atmosphere, and what its reaction products are, would tend to change the MIR value for that compound only.

To assist us with understanding the amount and type of uncertainty associated with some MIR values, uncertainty classification “bins” for ROC reactivity were developed by Dr. Carter (Table II-1 below) (see also Appendix F). This Table provides a qualitative description on the nature of the mechanistic uncertainties of different individual organic compounds, and is reproduced from the documentation titled “Documentation for the SAPRC-99 Chemical Mechanism: An Updated VOC Reactivity Scale” (Carter, 2000).

Table II-1 Uncertainty Ranking and Description

Uncertainty Ranking	Description
1	Considered to be relatively certain, or some uncertainties but reactivity is not expected to change significantly.
2	Uncertain mechanism may change somewhat if refined, but change is expected to be less than a factor of two. If the compound is predicted to inhibit O_3, changes are not expected to affect predicted inhibition, but may affect magnitude of inhibition. This code is also used for compounds whose reactivities are expected to be highly sensitive to ambient conditions or to changes in the base mechanism.
3	Uncertain and may change if compound is studied (or studied further) or estimation methods are updated. Change in MIR could be as much as a factor of two. This code is also used for (1) compounds whose reactivities are expected to be sensitive to the representation of the reactive products, whose accuracy is difficult to test experimentally and (2) compounds whose reactivities are expected to be highly sensitive to ambient conditions or to changes in the base mechanism.
4	Uncertain and is expected to change if compound is studied or estimation methods are updated. It is recommended that uncertainty adjustments be employed in regulatory applications.
5	Non-negligible chance of the estimate being incorrect in significant respects. It is recommended that uncertainty adjustments be employed in regulatory applications.
6	Current mechanism is probably incorrect, but biases in atmospheric reactivity predictions are uncertain. It is recommended that uncertainty adjustments be employed in regulatory applications.
A	The reactivity of this compound is expected to be sensitive to ambient conditions and/or changes in the base mechanism.
B	Some uncertainty due to differences in reactivities of compounds represented by this class. Look at differences among compounds in this class for the magnitude of this uncertainty.
C	Parameterized mechanism used, with uncertain portions adjusted to fit chamber data for representative compounds.
D	Highly simplified “Placeholder” mechanism used to represent the approximate range of reactivity of this compound. Mechanism does not represent an estimate of the actual mechanism of the compound.
E	The current version of this mechanism does not represent these compounds, but based on previous studies they are expected to be O_3 inhibitors under all conditions.

The ARB also contracted with Dr. William Stockwell at the Desert Research Institute in Reno, Nevada, to conduct a peer-review of the documentation for SAPRC-99. This review was conducted to ensure that both the mechanism and MIR scale derived from it are of high scientific quality (Stockwell, 1999). As part of the peer-review of the SAPRC-99 mechanism Stockwell was asked to review MIR value uncertainty and the “bins” developed by Dr. Carter. The final report was approved on November 29, 1999, by the RSAC.

Both Carter and Stockwell came to the conclusion that some adjustment is necessary to account for uncertainty of MIR values, however they differed on how uncertainty should be addressed (Carter, 2000; Stockwell, 1999). Carter's more qualitative assessment based on compound specific uncertainty, suggests that MIR value adjustments are needed for compounds in uncertainty bin numbers four or above. However, the quantitative approach of Stockwell indicated that all MIR values needed to be adjusted, with a slightly higher adjustment to the "less certain" chemicals. To reconcile their conclusions ARB staff reviewed the data to determine how best to apply uncertainty factors in the proposed amendments.

Stockwell performed an analysis of the previously published and the latest MIR values (Carter, 1994; 2000) and found that there was an increase in calculated hydrocarbon reactivities among uncertainty groups. However, no significant relationship was found between the MIR variability (as measured by the coefficients of variation) and assigned uncertainty groups. This observation suggests that common mechanistic factor(s) may be involved in contributing to the MIR uncertainty of all groups and is consistent with the "global effect" of the based mechanism update (see above). In addition, the MIR coefficients of variation reported in Stockwell's analyses are in agreement with those in a Wang and Milford study, in which MIR uncertainties were analyzed based on uncertainties in product yields and chemical rate parameters using Monte Carlo procedures (Yang *et al.*, 1995; Stockwell, 1999).

An additional analysis conducted by Stockwell (1999) showed that the percentage change in MIRs increased with Carter's uncertainty bin assignments. Because MIR values for well-studied chemicals are expected to be relatively "stable" (i.e., small percentage change in MIR value), is an indication that significant improvements have been made, especially, in studying the chemistry of individual "uncertain" VOCs. This interpretation is consistent with Carter's evaluation of compound specific mechanistic uncertainties (as shown in Table II-1) due to available experimental data.

These uncertainties do not need to preclude regulatory development, as long as the source category considered for regulation consists of compounds that have been well-characterized, such that the MIR values are "certain." To deal with uncertainty, within the regulation, adjustment factors can be applied to MIR values for compounds that have not been extensively studied. In this way even if MIR values change, as more data become available, the air quality benefit would be preserved. Our proposal to account for the uncertainties is described in Chapter IV of this Technical Support Document.

F. ARB's Commitment to Reactivity-based Control Strategies

The ARB is committed to evaluating the feasibility of reactivity-based regulations for certain source categories. As evidence of the Board's commitment, the ARB has funded research projects to improve and refine the science of VOC photochemical reactivity. A partial listing of reactivity research funded by ARB is shown below:

- Development of Reactivity Scales Via 3-D Grid Modeling of California Ozone Episodes. 98-309: University of California, Berkeley.

- Improvement of Speciation Profiles for Aerosol Coatings. 98-306: California Polytechnic State University Foundation, San Luis Obispo.

- Linkages Between Measurements of Multifunctional and Polar Organics in Chamber Studies and the Ambient Environment. 98-311: University of California, Davis.

- Atmospheric Chemistry of Selected Linear, Branched, and Cyclic C_{10} Alkane Components of Mineral Spirits. 97-312: University of California, Riverside.

- Development and Application of Improved Methods for Measurement of Ozone Formation Potentials of Volatile Organic Compounds. 97-314: University of California, Riverside.

- Uncertainty Analyses of Chemical Mechanisms Derived from Environmental Chamber Data. 95-331: University of California, Riverside.

- Investigation of Atmospheric Reactivities of Selected Stationary Source VOCs. 95-308: University of California, Riverside.

- Development And Application of an Updated Photochemical Mechanism for VOC Reactivity Assessment. 92-329: University of California, Riverside.

- Product Studies of the Atmospherically Important Reactions of Alkenes and Aromatic Hydrocarbons. 94-311: Statewide Air Pollution Research Center, University of California, Riverside.

- Experimental Studies of Atmospheric Reactivities of Volatile Organic Compounds. A032-096: University of California, Riverside.

- Experimental Investigation of the Atmospheric Chemistry of Aromatic Hydrocarbons and Long-Chain Alkanes. A032-067: University of California, Riverside.

- Development and Application of an Up-To-Date Photochemical Mechanism for Airshed Modeling and Reactivity Assessments. A932-094: University of California, Riverside.

- Review of the Updated Maximum Incremental Reactivity Scale of Dr. William Carter. 98-401: Desert Research Institute; Reno, Nevada.

In addition to funding research, the ARB established the RSAC to advise the ARB on the science of reactivity. The RSAC is an independent panel of scientists with various areas of expertise in the field of atmospheric chemistry. The RSAC has met four times.

Another advisory group, the Reactivity Research Advisory Committee (RRAC), has also been formed. The RRAC is comprised of consumer product manufacturers, raw material suppliers, and other interested stakeholders. The purpose of the RRAC has been to identify important VOCs used in consumer products that warrant further reactivity characterization. The goal has been to ensure that reactivity regulations being developed for consumer products are based on sound VOC reactivity data. This group has met seven times and has provided valuable input on commercially important VOCs to study further to reliably assess their reactivity. Based on their suggestions, additional research was funded by ARB and completed (ARB, 1998).

G. ARB’s Current Use of Reactivity

The research funded by the ARB has led to incorporation of VOC reactivity into regulatory strategies. In fact, the ARB was the first regulatory agency to enact a regulation which uses reactivity in a more complex manner than U.S. EPA’s “bright-line” approach in their VOC exemption process (ARB, 1990c).

The Low Emission Vehicle/Clean Fuels (LEV/CF) Regulations (ARB, 1990c) established increasingly stringent standards for emissions of nonmethane organic gases (NMOG), NO_x, carbon monoxide, and formaldehyde. As part of the regulation, to encourage use of alternatively fueled vehicles (AFV), the ARB established a process to account for the differences in reactivity of the NMOG emissions. The regulation allows AFVs to have a higher mass of NMOG emissions as long as the ozone formation potential of the AFV emissions are no more than those of a conventionally fueled vehicle (CFV). Emissions are compared through the use of reactivity adjustment factors (RAFs). A RAF is defined as the ratio of the exhaust reactivity (per gram) of an AFV to the exhaust reactivity of a comparable CFV. For an AFV, the mass emission rates of NMOG exhaust are adjusted by the RAF prior to comparison with the emission standards specified in the regulation (ARB, 1990c).

It is important to note that the LEV/CF Regulations established the MIR scale as the most appropriate for use in California regulations. To determine the reactivity of exhaust, the emission rate of each NMOG species is converted to mass of ozone using the MIR scale. These are then summed to estimate the reactivity of the entire exhaust sample (ARB, 1990c).

H. A Reactivity-based Regulation for Aerosol Coatings

The ARB began regulating the VOC emissions from consumer products in 1989 when they adopted the Antiperspirants and Deodorants Regulation. This regulation has been followed with the adoption of mass-based VOC limits for 47 categories of consumer products and 35 categories of aerosol coatings. The current State Implementation Plan (SIP) commitment for consumer products, including aerosol coatings, calls for an additional 30 percent reduction in VOC emissions. In 1995, however, when the SIP was approved, we recognized that reaching this target emission reduction, solely on a mass basis, would be difficult to achieve. In light of that, ARB committed to investigate reactivity-based control strategies for consumer products.

To that end, ARB staff has been working with consumer product stakeholders through the Reactivity Subgroup (see Chapter V for further information) since 1995. This work has culminated in the reactivity-based proposal for aerosol coatings that is the subject of this rulemaking. This effort is viewed as a pilot project to determine the feasibility of additional reactivity-based measures for other source categories.

The ARB adopted revised limits (effective January 1, 2002) for aerosol coatings in 1998 (ARB, 1998a). At that time, the Board recognized that the mass-based limits presented particularly difficult reformulation challenges for water-based aerosol coatings, and directed staff to come back to them with an alternative voluntary reactivity-based proposal. A voluntary reactivity-based regulation would provide a viable compliance path for water-based coatings, given their comparatively low reactivity. However, during development of the voluntary reactivity regulation proposal, staff and several representatives of the aerosol coating industry came to the conclusion that it was preferable to pursue a proposal to replace the January 1, 2002, mass-based VOC content limits with equivalent mandatory reactivity-based limits.

Developing a reactivity-based regulation for chemically formulated products presents new challenges, and may not prove viable for all source categories. Staff also recognizes that the science of reactivity is still evolving and further improvements will need to be made. It is also true that, at present time, not all VOCs have been thoroughly studied to reliably assess their reactivity (Carter, 1999b). For a given consumer products category, such as aerosol coatings, over 100 different VOC ingredients are used in formulations. Therefore, to develop a successful reactivity program for chemically formulated products, the following elements are required:

- an inventory of completely speciated VOC data for individual products within the source category;

- a scale that allows a comparison of VOC reactivities based on appropriate atmospheric conditions;

- an inventory that consists largely of VOCs that have well-characterized reactivities;

- product sales data that allow weighting of VOC reactivities; and,

- a method to establish limits that achieves an equivalent ozone reduction benefit.

The aerosol coatings category was selected for development of the first consumer product reactivity-based regulation because the above elements are available. A recent survey provided detailed speciated VOC data and sales information. A review of the aerosol coatings data also showed that, on a mass basis, over 80 percent by weight of VOCs reported have been sufficiently studied to allow reliable MIR estimates.

A further challenge is to ensure that the already-committed to mass-based VOC reduction is preserved. Therefore, the first step is to convert the VOC tonnage commitment, on a category-by-category basis, into an equivalent ozone reduction. The methodology to calculate reactivity limits, including conversion to an equivalent ozone reduction is discussed in Chapter IV of this Technical Support Document.

ARB staff intends to use this proposed regulation as a pilot project which provides a model for additional reactivity-based regulations.

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III.

Ozone Formation from Aerosol Coating Emissions

As stated in the previous Chapter, the proposed amendments present a new approach to regulate the emissions from aerosol coating products. Using the concepts of reactivity, staff is proposing to replace the January 1, 2002, volatile organic compound (VOC) content limits with reactivity limits that achieve an equivalent air quality result. To do this, it is necessary to quantify the ozone reduction that would be associated with the VOC limits and set reactivity limits that achieve that ozone reduction target. In this way the proposed reactivity limits should ensure an equal air quality benefit.

To set reactivity-based limits, information on the amounts and types of reactive organic compounds emitted, as well as aerosol coating product sales are needed. These data are readily available from the 1997 Aerosol Coating Survey (ARB, 1998b). These same data were used as the basis for setting the January 1, 2002, VOC limits. In this Chapter, we provide a summary of the data on the VOC emissions and sales of aerosol coatings. In addition, the product category reactivities, VOC reductions and the corresponding ozone reduction commitments are shown on a category-by-category basis.

A. Emissions from Aerosol Coating Products Contribute to the Formation of Ozone in the Troposphere

The use of aerosol coating products results in VOC emissions which originate from the propellants and solvents contained in them (Dunn, 1993; Fortmann *et al.,* 1998). Once in the air, these compounds, in the presence of sunlight, react with nitrogen oxides to form ozone. Hence, we have been regulating VOC emissions from aerosol coatings as part of our ozone control strategy.

When aerosol coatings are used outdoors or in well ventilated areas, the VOCs have a direct route to ambient air after they have vaporized. The propellants used in aerosol coatings, such as isobutane, propane, and dimethyl ether, are gases at room temperature. These gases are emitted when an aerosol coating is sprayed and are immediately available for transport to the atmosphere. The solvents used in aerosol coatings evaporate during the application and drying processes of the paint. Typically, a solvent-blend of fast evaporating and slow to medium evaporating solvents is used in the formulation, to provide the correct drying time for the paint film. The evaporation of the solvents takes place in two stages, with the initial loss of solvent (up to 80 percent) being dependent on the vapor pressure of the fast evaporating solvent. After the initial loss of solvent, the polymer film is formed. The remaining solvent loss is caused by a slower diffusion-controlled process (ICAG, 1987). The nonvolatile portion of the coating remains in the cured coating film and, under normal use conditions, is not emitted to the atmosphere.

B. Air Resources Board Emissions Survey

The emission inventory was developed for aerosol coatings based on a survey questionnaire sent out to 313 potential responsible parties and manufacturers of aerosol coatings. Among other information, manufacturers and responsible parties supplied information on product formulation and product sales. Data were received from 137 responsible parties and 53 manufacturers. These data accounted for at least 90 percent of the sales of aerosol paint in California during 1997. A further discussion of survey development and the information supplied is contained in the "Initial Statement of Reasons for the Proposed Amendments to the Regulations for Reducing Volatile Organic Compound Emissions from Aerosol Coatings, Antiperspirants and Deodorants, and Consumer Products" (ARB, 1998a).

C. Summary of the Data from the 1997 Aerosol Coatings Survey

To interpret the data in the following tables, we begin by defining some reactivity-related terms. It is also important to note the distinction we are making between VOC and reactive organic compound (ROC). "VOC," as defined in the mass-based regulation does not include the exempted compounds such as acetone. In our reactivity-based regulation, we are proposing to use the term "ROC" to clarify that all VOCs, including exempt compounds such as acetone, are considered for evaluating products' reactivities. This distinction explains the difference between VOC and ROC emissions reported in Table III-1.

Reactivity related terms used in the following tables:

- $SWA\text{-}MIR_{prod}$ is the sales-weighted average maximum incremental reactivity (MIR) of the products reported in an aerosol coating category.

- $SWA\text{-}MIR_{VOC}$ is the sales-weighted average maximum incremental reactivity of the products ($SWA\text{-}MIR_{prod}$) divided by the sales-weighted average VOC content of the product category, as explained in Chapter IV. The $SWA\text{-}MIR_{VOC}$ is used to calculate the equivalent ozone reduction. The tpd VOC reduction commitment is based on reductions of VOCs (not including acetone).

- Total Ozone Formation is the potential amount of ozone (reported here in tpd) formed from emissions of the VOCs in the aerosol coating category.

- Unadjusted Equivalent Ozone Reduction is the equivalent ozone reduction expected to be achieved from the tpd VOC reduction commitment. The unadjusted ozone reduction is calculated by multiplying the tpd VOC reduction by the $SWA\text{-}MIR_{VOC.}$

- Adjusted $SWA\text{-}MIR_{VOC}$ is the $SWA\text{-}MIR_{VOC}$ adjusted for mechanistic uncertainty of ingredient MIR values.

- Adjusted Equivalent Ozone Reduction is the ozone reduction calculated by multiplying the tpd VOC reduction commitment by the adjusted $SWA\text{-}MIR_{VOC}$. This is the amount of ozone reduction that needs to be achieved by the proposed reactivity limit.

Table III-1 summarizes product sales and VOC and ROC emissions calculated from the survey data. As shown from Table III-1, sales from all coating categories were about 34.3 tpd, with VOC emissions of 19 tpd. Adjusting for survey coverage (which is an approximate 10 percent adjustment), VOC emissions were estimated to be 21 tpd in California in 1997. Data shown in Tables 1and 2 are based on actual reported emissions. Total ROC emissions were reported as 26.5 tpd. Based on the survey data, the six “general” aerosol coating categories account for approximately 77 percent of the total ROC emissions and 78 percent of the total amount of ozone formed from aerosol coating emissions in California in 1997. The remaining 23 percent of ROC emissions and 22 percent of total ozone formed can be attributed to the combined emissions from the 29 “specialty” aerosol coating categories. Among all categories, nonflat (“glossy”) coatings are 43 percent of the ROC emissions and represent almost 46 percent of the total ozone formation.

Table III-2 summarizes our estimates of VOC emission reductions and the corresponding ozone reduction (i.e. unadjusted equivalent ozone reduction) that would have occurred upon implementation of the VOC standards adopted by the Board on November 19, 1998. As detailed in Chapter IV, not all VOC have been thoroughly studied. In these instances, uncertainty factors are applied to the ingredient MIR values prior to determining what the “ozone reduction target” should be. After accounting for MIR value uncertainty, the adjusted SWA-MIR$_{VOC}$ is multiplied by the VOC reduction commitment (in tpd). This ozone reduction target is shown in Table III-2 as “adjusted equivalent ozone reduction.” Nevertheless, these adjustments are rather insignificant (up to 10 percent), suggesting that the compounds used in aerosol coating products are reasonably well studied (see also Chapter IV).

As shown in Table III-2, the VOC standards would have achieved reductions of 3.1 tpd from VOC emissions totaling 19 tpd. The total VOC emissions and VOC emission reductions shown in Tables III-1 and 2 are different from those reported in the October 2, 1998, staff report (ARB, 1998a). Upon further quality checks of the data, data entry errors were found in the ground traffic and marking coating category. After correcting the data, the VOC emissions and VOC reductions from the ground traffic and marking category are 1.7 tpd and 0.28 tpd, respectively. Previously we reported emissions of 2.83 tpd and a reduction of 0.74 tpd.

TABLE III-1
SUMMARY OF DATA FROM THE 1997 AEROSOL COATING SURVEY

Aerosol Coating Category	California Sales (tons per day)	VOC Emissions (tons per day)	ROC Emissions (tons per day)	SWA-MIR_{prod} (g O_3/g product)	Total Ozone Formation (tons per day)
General Categories					
Clear Coatings	1.59	0.96	1.36	1.66	2.64
Flat Paint Products	3.04	1.54	2.36	1.52	4.62
Fluorescent Coatings	0.36	0.24	0.25	1.63	0.59
Metallic Coatings	2.33	1.65	1.88	2.09	4.87
Nonflat Paint Products	15.13	8.13	12.09	1.62	24.51
Primers	3.56	1.82	2.59	1.33	4.73
Specialty Categories					
Art Fixatives or Sealants	0.33	0.23	0.28	1.56	0.51
Auto Body Primers	0.50	0.25	0.37	1.69	0.85
Auto Bumper and Trim	0.35	0.30	0.32	1.59	0.56
Exact Match Finishes: Engine Enamel	0.38	0.18	0.32	1.52	0.58
Exact Match Finishes: Automotive	0.72	0.39	0.64	1.68	1.21
Ground/Traffic/Marking	3.20	1.70	1.81	1.35	4.32
High Temperature Coatings	0.70	0.48	0.60	2.04	1.43
Vinyl/Fabric/Leather/ Polycarbonate	0.33	0.25	0.31	1.67	0.55
All Other Coating Categories	1.74	0.89	1.36	N/A	1.66
Totals	34.25	18.99	26.54	N/A	53.63

N/A : not applicable

TABLE III-2
SUMMARY OF VOC EMISSIONS AND TARGET OZONE REDUCTIONS

Aerosol Coating Category	VOC Reduction (tons per day)	Unadjusted [a]SWA-MIR$_{VOC}$ (g O_3/g VOC)	Adjusted [a]SWA-MIR$_{VOC}$ (g O_3/g VOC)	Unadjusted Equivalent Ozone Reduction (tons per day)	Adjusted Equivalent Ozone Reduction (tons per day)
General Categories					
Clear Coatings	0.17	2.75	3.00	0.47	0.52
Flat Paint Products	0.33	3.00	3.21	0.99	1.06
Fluorescent Coatings	0.03	2.45	2.63	0.07	0.07
Metallic Coatings	0.21	2.95	3.07	0.62	0.66
Nonflat Paint Products	1.37	3.01	3.26	4.12	4.46
Primers	0.41	2.60	2.77	1.07	1.13
Specialty Categories					
Art Fixatives or Sealants	0.04	2.24	2.35	0.09	0.10
Auto Body Primers	0.04	3.35	3.62	0.13	0.13
Auto Bumper and Trim	0.04	1.89	1.97	0.07	0.08
Exact Match Finishes: Engine Enamel	0.01	3.13	3.42	0.03	0.04
Exact Match Finishes: Automotive	0.04	3.11	3.17	0.12	0.14
Ground/Traffic/Marking	0.28	2.54	2.78	0.71	0.78
High Temperature Coatings	0.07	3.01	3.15	0.21	0.22
Vinyl/Fabric/Leather/ Polycarbonate	0.03	2.27	2.34	0.07	0.08
All Other Coating Categories*	0.03	N/A	N/A	0.04	0.06
Totals	3.11	N/A	N/A	8.82	9.56

[a]SWA-MIR$_{VOC}$ = SWA-MIR$_{prod}$ / SWA-VOC
N/A : not applicable

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IV.

Use of Photochemical Reactivity as an Ozone Control Approach

A. Introduction

In this Chapter, we provide a description of how we propose to use the science of photochemical reactivity to control reactive organic compound (ROC) emissions from aerosol coatings. In Chapter II of this report, we provided background on the science of photochemical reactivity and the development of numerical scales that allow us to compare the differences in individual ROC reactivity. The potential of using reactivity as a ROC control approach has also been evaluated (Croes *et al*., 1992), and we believe the scientific foundation needed for using reactivity is well-established and readily available. In fact, hydrocarbon reactivity already serves as the basis for a portion of California's Low Emission Vehicle and Clean Fuels Regulation (LEV/CF) (ARB, 1990c). Research has also shown that reactivity-based control strategies have the potential to be a cost-effective approach to improve air quality (Russell *et al*., 1995; McBride *et al*., 1997).

The amendments proposed here would be the first reactivity-based regulation for non-mobile sources. To implement this reactivity-based regulation, we have developed a number of methods to apply the science of photochemical reactivity. These proposals are:

- Using the Maximum Incremental Reactivity (MIR) Scale
- Including Reactive Organic Compounds (ROC) that are Considered "Exempt" in Mass-Based Regulations
- Calculating Upper Limit MIR Values
- Calculating Group MIR Values for Hydrocarbon Solvent Mixtures
- Addressing Uncertainty in the Maximum Incremental Reactivity Scale
- Calculating "Equal Air Quality Benefit" Reactivity Limits

Our goal is to ensure that these amendments will achieve an ozone reduction equivalent to that which would be expected from implementation of the mass-based volatile organic compound (VOC) limits, while providing manufacturers with additional flexibility to achieve our air quality goals.

B. Program Elements

1. Using the Maximum Incremental Reactivity (MIR) Scale

As described in Chapter II, under a given environmental condition, organic compounds differ in their ozone forming abilities. In addition, individual chemicals are emitted into the atmosphere in the presence of other ROCs. These "background" organic compounds may have a modifying effect on a chemical's ozone forming potential (Bowman and Seinfield, 1994; Carter, 1994). In other words, a ROC not only contributes but also affects other compounds' abilities to react to form ozone. Therefore, to control emissions of ROCs, based on their potentials to form ozone, the air quality impact of an individual chemical as well as its effects on other ROCs needs to be assessed. To do this, in these amendments we are proposing to use the concept of MIR. The MIR is a numerical quantity that describes the change in peak ozone levels due to the addition of an organic compound under simulated atmospheric conditions. (Carter, 1994; 1998) (see also Chapter II).

Unlike the reactivity scales derived using the assumption that hydrocarbons occur singly in the atmosphere (see, for example, Bufalini et al., 1976), the MIR approach allows characterization of an individual organic compound's ability to form ozone, as well as its effect on other hydrocarbons (Carter, 1994; 2000). For this rulemaking, a list of over six hundred MIR values of ROC (in units of gram O_3 per gram organic compound) and representative chemical species (for example, branched C7 alkanes) has been compiled. These MIR values combined with emission data can be used to determine the ozone contribution of an individual chemical.

Under this proposal, manufacturers will need to assess the reactivity of their products by using the MIR scale. To do this, each ingredient in an aerosol coating formulation would be assigned its corresponding MIR value (non-ROCs are assigned MIR values of zero). The weight fraction of each ingredient is multiplied by the MIR value to get the "weighted reactivity" of an ingredient. The weighted reactivities of all ingredients are summed to get the product's weighted MIR (in grams ozone/gram product). The "product-weighted" MIR would then be compared to the reactivity limit to determine compliance. To comply, the product-weighted reactivity must be no more than the reactivity limit for the aerosol coating category. An example of how a product's weighted reactivity is calculated is provided in Appendix D.

2. Including "Exempt" Organic Compounds in Reactivity-based Regulations

The current Aerosol Coatings Regulation contains exemptions for "low reactive" VOCs, such as acetone, ethane, perchloroethylene, and parachlorobenzotrifluoride (PCBTF). This regulation essentially uses a reactivity scale of "zero" and "one" i.e. a compound is either exempt or assumed to have the same potential to form ozone as all other VOC compounds. This approach is consistent with that used by the United States Environmental Protection Agency (U.S. EPA) which classifies all VOCs as either "reactive" or "negligibly reactive" (Dimitriades, 1996). This "bright line" approach is practical for the implementation of mass-based regulations, but does not provide the level of detail to assess all ozone impacts of emitted VOCs.

Although the ability of organic compounds to induce ozone varies over several orders of magnitude (Carter, 2000), significant emissions of a "negligibly reactive" or "exempted VOC" under the current mass-based regulation may have a non-negligible air quality impact. An analysis of the 1997 Aerosol Coating Survey data indicate that the acetone (a "low reactive" exempt VOC) contained in aerosol coatings can change the reactivity of a product by 10 percent or more (ARB, 1998b). This provides evidence that in a reactivity program, the reactivities of low reactive VOCs should be considered with their respective smaller impacts on ozone formation. Hence, in this proposed regulation, all organic ingredients are included in evaluating the ozone forming potential of aerosol coating products.

3. Calculating Upper Limit MIR Values

The majority of ingredients used in aerosol coating products have MIR values available. However, there are several compounds currently used in aerosol coatings for which no published MIR value exists. To allow continued use of these ROCs a methodology for calculating upper limit MIRs was developed (Carter, 2000). This method for estimating the upper maximum incremental reactivity limit has been reviewed by the Reactivity Scientific Advisory Committee (RSAC) and is detailed in Appendix E of this report.

Briefly, the estimation procedure is based on deriving the upper limits of kinetic and mechanistic reactivities. Both of these factors play a critical role in determining the ozone impact of a compound in an air pollution episode (Carter and Atkinson, 1989). Kinetic reactivity is the fraction of a compound that reacts due to different atmospheric loss processes. Its upper limit, which has a maximum value of one, can be estimated using the rates of chemical reactions with different reactive species in the atmosphere (e.g. hydroxyl (OH) radicals). The number of ozone molecules formed for each molecule of ROC reacted is known as mechanistic reactivity. For determining the upper limit mechanistic reactivity of both photo- and non photo-reactive compounds, empirical relationships based on carbon number of a molecule or its hydroxyl radical reaction rate constant are established (Carter, 2000). The maximum incremental reactivity can be obtained by multiplying the upper limit estimates of kinetic reactivity and mechanistic reactivity.

4. Calculating Group MIR Values for Hydrocarbon Solvent Mixtures

Hydrocarbon solvents (HCS) are complex mixtures of organic compounds, which include alkanes, branched alkanes, cycloalkanes, and aromatics. Because different processes are used in their productions, these HCS have different compositions (CMA, 1997). Based on their chemical ingredients, HCS can be classified into aromatic and aliphatic solvents. Aromatic HCS are solvent mixtures containing approximately 100 percent of substituted monocyclic (i.e. single ring) and/or polycyclic (multiple rings) aromatic compounds. Aliphatic HCS are predominately saturated hydrocarbons, with maximum aromatic contents ranging from 2 to 22 percent by volume (see, for example, ASTM, 1995, CMA, 1997). Depending on their applications, different generic names are given to these aliphatic HCS, with "mineral spirit" being among the most commonly used name for those used in coatings industries (ASTM, 1995). Therefore, for evaluating the ozone formation potential of aerosol coating products, the ability to understand the reactivity of HCS is needed.

The reactivity of complex mixtures, such as HCS, can be calculated by combining each ingredient's MIR and its corresponding weight percentage (see for example, Chang and Rudy, 1990; McNair *et al.*, 1992). While computational methods exist for determining the MIR value of a chemical (see above), the detailed chemical speciation (i.e. ingredients) data needed for such a calculation may not be available for all HCS. To overcome this, if solvents can be assigned to a group, speciation profiles of selected or "typical" solvents may then be used for calculating a group reactivity. At present, however, there is no solvent categorization method available, although grouping criteria such as chemical abstract service (CAS) number, boiling ranges, and aromatic contents have been proposed.

To address the need, we have developed a categorization ("binning") methodology for hydrocarbon solvents. The procedure is detailed in the manuscript titled "Methods for Estimating Maximum Incremental Reactivity (MIR) of Hydrocarbon Solvents and Their Classification" (Kwok *et al.*, 2000) and is included as Appendix C of this report. Briefly, the hydrocarbon solvent classification scheme was developed by assuming that the overall HCS MIR can be estimated by summing the reactivity contribution from individual chemical classes. For hydrocarbon solvent mixtures composed of *n*-alkanes, branched alkanes, cycloalkanes, and mono-, di-, poly-substituted benzenes, the total MIR of a solvent mixture is then given by:

HCS MIR = Sum of % Wt MIR of all straight-chain alkanes
+ Sum of % Wt MIR of all branched alkanes
+ Sum of % Wt MIR of all cycloalkanes
+ Sum of % Wt MIR of all mono-substituted benzenes
+ Sum of % Wt MIR of all di-substituted benzenes
+ Sum of % Wt MIR of all poly-substituted benzenes

where % Wt = percent composition weighted.

To simplify the above equation, data suggest that for a given carbon number, the MIR values are relatively insensitive to the position of the substituent groups (see, for example, Carter, 2000). In addition, MIR values of C_{n-1}, C_n, and C_{n+1} homologs are similar (Carter, 2000), and hydrocarbon solvent mixtures have rather narrow carbon number distributions (see for example, Carter *et al*., 1997). Hence, the composition weighted (% Wt.) MIR of all compounds can be approximated by, for example, for branched (Br) alkanes:

Sum of % Wt MIR of all branched alkanes
= MIR of a Br-alkane
x total Wt % of Br-alkanes in the mixture

In other words, for a chemical class, the reactivity of all chemical species is similar, and a single species can be used to determine the reactivity contribution of the entire chemical class. Thus, the MIR of a complex HCS mixture can be calculated by using a simple n-alkane-branched-alkane-cycloalkane-aromatics mixture (i.e. surrogate mixture). Results from our analysis indicated that, in general, carbon number distribution of a HCS peaks at its average-boiling point, which is defined as the sum of initial boiling point (IBP) plus dry point (DP) divided by two. This relationship was used to identify the surrogate species of each chemical class. To validate these assumptions, solvent reactivities calculated using the surrogate mixture approach were tested against the HCS reactivity data reported by the solvent manufacturing industry. Based on this comparison, over 90 percent of the solvents tested have estimated and reported reactivity values that mostly differed by no more than a factor of 15 percent. This result shows that a surrogate mixture can be used for representing complex HCS for reactivity determinations.

In developing a way to group HCS of similar reactivity, it is important to ensure that the MIR value assigned for the group reliably reflects the reactivity of a particular HCS mixture within the group. Using the surrogate mixture procedure developed, calculations were performed to determine the effects of hydrocarbon composition (i.e. relative percentages of *n*-alkanes, branched alkanes, cycloalkanes, and aromatics) and carbon number (as a function of boiling point) on a mixture's MIR value. Our results indicate that, up to a certain temperature range, solvent composition has only a minor effect on the mixture MIR value. Using a surrogate mixture MIR's coefficients of variation of 15 percent as a grouping criterion, we have developed four HCS reactivity groups over the average boiling point of 80-580 ^{o}F. This temperature range is consistent with the existing HCS data. Within each group, five different sub-groups are defined according to their dominant chemical ingredients. The aromatic content of these solvents is classified according to the American Society of Testing and Materials method (ASTM, 1995).

To assist aerosol coating formulators with applying this HCS classification scheme, typical solvent sales specification data such as mid-boiling range, percent total alkanes and isoalkanes, cyclolkanes and aromatics are used as categorization criteria. Table IV-1 lists all twenty aliphatic hydrocarbon solvent bins and their corresponding group MIR values. In most cases (~70 percent), the assigned MIR is approximately ± 15 percent of the reported values, and only a few (~ 7 percent) have a discrepancy between the assigned and reported values greater than 30 percent.

TABLE IV-1
PROPOSED DRAFT APPROACH FOR ASSIGNING MIR VALUES TO ALIPHATIC HYDROCARBON SOLVENTS

Average BP (oF)	CRITERIA	MIR (g O3/g Organics)	BIN NO.
80-205	ALKANES (< 2% AROMATICS)	2.08	1
	N- & ISO-ALKANES (≥ 90% & < 2% AROMATICS)	1.59	2
	CYCLO-ALKANES (≥ 90% & < 2% AROMATICS)	2.52	3
	ALKANES (2 to < 8% AROMATICS)	2.24	4
	ALKANES (8 to 22% AROMATICS)	2.56	5
> 205-340	ALKANES (< 2% AROMATICS)	1.41	6
	N- & ISO-ALKANES (≥ 90% & < 2% AROMATICS)	1.17	7
	CYCLO-ALKANES (≥ 90% & < 2% AROMATICS)	1.65	8
	ALKANES (2 to < 8% AROMATICS)	1.62	9
	ALKANES (8 to 22% AROMATICS)	2.03	10
> 340-460	ALKANES (< 2% AROMATICS)	0.91	11
	N- & ISO-ALKANES (≥ 90% & < 2% AROMATICS)	0.81	12
	CYCLO-ALKANES (≥ 90% & < 2% AROMATICS)	1.01	13
	ALKANES (2 to < 8% AROMATICS)	1.21	14
	ALKANES (8 to 22% AROMATICS)	1.82	15
> 460-580	ALKANES (< 2% AROMATICS)	0.57	16
	N- & ISO-ALKANES (≥ 90% & < 2% AROMATICS)	0.51	17
	CYCLO-ALKANES (≥ 90% & < 2% AROMATICS)	0.63	18
	ALKANES (2 to < 8% AROMATICS)	0.88	19
	ALKANES (8 to 22% AROMATICS)	1.49	20

TABLE IV-2
PROPOSED DRAFT APPROACH FOR ASSIGNING MIR VALUES TO AROMATIC HYDROCARBON SOLVENTS

Boiling Range (oF)	CRITERIA	MIR (g O3/g Organics)	BIN NO.
280-290	100% AROMATICS	7.37	21
320-350	100% AROMATICS	7.51	22
355-420	100% AROMATICS	8.07	23
450-535	100% AROMATICS	5.00	24

For aromatic hydrocarbon solvents, the speciation data are scarce, and the surrogate mixture approach was not used for determining the solvent reactivity. Hence, the aromatic HCS classification scheme was constructed based on the boiling range and is presented in Table IV-2 (Bin 21-24).

5. Addressing Uncertainty in the Maximum Incremental Reactivity Scale

As described in Chapter II, there are uncertainties associated with reactivity scales such as the MIR. Therefore, to apply reactivity as a control approach, we believe that most of the ROCs used in the category proposed for regulation need to consist of well-characterized compounds (i.e. with "certain" MIR values). In addition, a method to account for MIR value uncertainty is needed. In the aerosol coatings category, over 80 percent of ROCs used are well-studied and an additional 17 percent of the inventory (i.e. hydrocarbon solvents) would need only a minor adjustment for uncertainty. In other words, over 95 percent of the ROCs used in aerosol coatings are fairly well-characterized in terms of their reactivity. Nevertheless, to ensure that the total air quality benefit is achieved, we believe uncertainty factors should still be applied when appropriate. Below we describe our proposal for using uncertainty "factors" in the proposed amendments.

Based on the analysis in Chapter II, we concluded that for regulatory applications uncertainty adjustments should be tied to the individual compound. Therefore, following the recommendation of Dr. Carter and using his uncertainty "bin" assignments, we are proposing to apply uncertainty factors to individual compounds. For our proposed amendments to the Aerosol Coatings Regulation, we propose to apply an uncertainty factor of 1.0 to compounds classified within uncertainty bins one and two; a factor of 1.25 to compounds in bin three; a factor of 1.5 to compounds in bin four; and a factor of 2.0 for compounds in bins five and six.

Organic compounds in uncertainty bins one and two are compounds which have been studied extensively (in most cases) in the laboratory, and their ozone forming ability can be reasonably described by the chemical mechanism developed. Hence, no adjustment is recommended for bin one and two chemicals. As mentioned previously, over 80 percent (on a weight basis) of ROCs used in aerosol coatings would fall into bins one and two. Bin three chemicals, constitute two percent of compounds used in aerosol coatings (ARB, 1998b). These chemicals, in general, have lesser amounts of experimental data available, and a slight change to the MIR value could occur when the chemical mechanism is refined in the future. Because of this, an adjustment factor of 1.25 is proposed.

Bin four chemicals, include "generic" species representing the reactivity of a group of chemicals. The higher adjustment factor recommended for bin four chemicals (i.e. 1.5 compared to 1.25 for bin three) is consistent with the lack of experimental data for this group. However, less than one percent of compounds reported in the 1997 survey would fall into bin four (ARB, 1998b). Although some chemicals in bins five and six have been tested under laboratory conditions, the modeling results are not conclusive.

Hence, an uncertainty factor of 2.0 is proposed. Less than one percent of aerosol coating ROCs reported in the survey fall into bins five and six (ARB, 1998b).

For hydrocarbon solvent MIRs shown in Table IV-1 and II, an uncertainty factor of 1.15 is proposed. By proposing this factor, we are assuming that the HCS table MIR values provide a reliable description of the "true" solvent's reactivity. The adjustment factor proposed is to account for the need to "bin" HCS into groups as described earlier. For estimated MIR values (i.e. upper limit MIRs), no adjustment factor is proposed as the method used infers the highest reactivity of the chemical.

ARB staff recognizes that for compounds with uncertain MIR values it is likely that, upon further study, the MIR value for an individual compound may increase or may decrease. However, to ensure the air quality benefit, staff is proposing to increase the reported MIR value by multiplying it by the uncertainty factor. This conservative approach preserves the air quality benefit.

Uncertainty factors can be applied in two ways. MIR values can be adjusted when calculating the reactivity limit or can be adjusted when manufacturers determine the reactivity of their products. Either approach should preserve the air quality benefit. Both proposals were presented to the aerosol coatings industry and their preference was to apply uncertainty factors to calculation of the reactivity limit. In this way manufacturers can determine the reactivity of their products by using the MIR values as they appear in the Tables of MIR values.

6. Calculating "Equal Air Quality Benefit" Reactivity Limits

In this rulemaking, we are proposing to replace the January 1, 2002, mass-based aerosol coating VOC limits with equivalent reactivity limits. For aerosol coatings, because a mass-based reduction has already been claimed we need to ensure this commitment will be met. Hence, a common basis is needed to compare the air quality benefit from mass-based versus reactivity-based control, which in this case, is the amount of ozone reduction to be achieved. Based on the premise of providing an equal air quality benefit, the proposed methodology is designed to develop a reactivity limit that will match the amount of ozone reductions associated with implementation of the mass-based standards.

The calculation involves two simple steps. Step one is to determine the amount of ozone reduction that would be achieved from the mass-based VOC reduction. The reactivity limit is then set using an iterative process until the target ozone reduction is matched. The sales and VOC content data relied upon for this rulemaking are obtained from the Air Resources Board 1997 Aerosol Coating Product Survey (ARB, 1998b). These procedures are detailed below.

To calculate the ozone reduction achieved by the mass-based limits, we assumed that the average reactivity of all VOCs used in a particular aerosol coating product category could be represented by an overall sales-weighted average maximum incremental reactivity ($SWA\text{-}MIR_{VOC}$) (in units of g O_3/g organics). In other words, this metric describes the ozone formation potential contributed by the VOCs. This can be expressed in the following equation:

$$SWA\text{-}MIR_{VOC} = SWA\text{-}MIR_{prod} / SWA\text{-}VOC, \qquad (1)$$

Where:

$SWA\text{-}MIR_{prod}$ = Sales-weighted average product MIR

= Summation of the products' individual reactivities multiplied by their individual sales divided by the summation of the sales in the product category

SWA-VOC = Sales-weighted average VOC

= Summation of the products' individual VOC contents multiplied by their individual sales divided by the summation of the sales in the product category.

Under the mass-based regulation, ozone reductions would only be achieved from the reduction of non-exempted VOC emissions. The total amount of ozone reduction from the mass-based control then, would be equal to the $SWA\text{-}MIR_{VOC}$ multiplied by the total amount of non-exempted VOCs ($VOC_{non\text{-}exempt}$) exceeding the particular VOC limit (VOC_{limit}).

Ozone Reduction from an Aerosol Coatings Product Category

$$= SWA\text{-}MIR_{VOC} \times (VOC_{non\text{-}exempt} - VOC_{limit}) \qquad (2)$$

In the calculation described above, the MIR values of individual ROCs have been adjusted for uncertainty based on our proposal described earlier in this Chapter. We believe that the application of adjustment factors in determining the target ozone reduction is a necessary conservative approach to ensure that the full ozone reduction is achieved.

Once the target ozone reduction is determined, the reactivity limit is calculated using the following procedures. The existing product reactivity (PWMIR) (in units of g O_3/g product) is calculated using its ingredient information and the unadjusted MIR values of all ingredients (non-ROC s are assigned MIR values of zero). A trial or arbitrary limit is then set. For those products with reactivity greater than the trial limit, the amount of ozone reduced due to the "reactivity reduction" is calculated by the following equation:

$$\text{Ozone Reduction} = (\text{PWMIR} - \text{"Limit"}) \times \text{Sales} \qquad (3)$$

This step is then repeated for all "non-complying" products, and the expected ozone reduction from the trial limit applied to each product are summed. The total ozone reduction is calculated for each trial limit (i.e. iteration) and is repeated until it equals the mass-based target ozone reduction. The VOC reduction, adjusted SWA-MIR_{VOC}, and target ozone reduction (i.e. adjusted equivalent ozone reduction) for all categories are listed in Chapter IX, Tables IX-1 through IX-16.

The advantage of this "trial-and-error" method is that it allows products with more reactive organic compounds to be "selectively" controlled. This is because the product's reactivity is evaluated based on its entire formulation. This is believed to be a more appropriate method for evaluating air quality benefits using ROC substitution (Carter, 1999). In addition, using this method, no assumptions are made regarding future product ingredients and ROC contents in this computational exercise. Therefore, the results obtained will reliably reflect the air quality benefit expected from the reactivity-based regulation.

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V.

Process for Development of the Proposed Amendments to the Aerosol Coating Products Regulation, Proposed Tables of Maximum Incremental Reactivity (MIR) Values, and Proposed Amendments to Air Resources Board Method 310

A. Introduction

We began the process of investigating using photochemical reactivity as an ozone control approach five years ago. This effort began with the formation of the Reactivity Subgroup within the Consumer Products Working Group (CPWG) on April 11, 1995. Since that time the subgroup has met nine times to discuss the science and use of reactivity concepts for consumer products and aerosol coatings. Staff has conducted eight public workshops on regulatory proposals. In addition to these formal meetings staff has held several individual meetings, and teleconferences with the aerosol coating industry, and discussed the regulatory concepts twice with the air districts. Staff also presented reactivity regulatory concepts for aerosol coatings at the United States Environmental Protection Agency (U.S. EPA) sponsored Photochemical Reactivity Workshop held in Durham, North Carolina, on May 12-14, 1998. We also received valuable input from the Reactivity Scientific Advisory Committee and presented concepts for developing a reactivity-based control strategy to them. Another group, the Reactivity Research Advisory Committee was also formed to provide valuable input on important compounds to study further to obtain reliable reactivity estimates. In the fall of 1999, we also formed the Aerosol Coatings Working Group. This group has been useful for rapid exchange of information and ideas. Appendix H contains copies of the meeting notices.

B. Role of the Reactivity Subgroup

In the February 14, 1995, State Implementation Plan for Ozone (SIP) we committed to investigate the feasibility of incorporating a reactivity control strategy into the existing consumer products program. Our efforts began with formation of a reactivity subgroup at the CPWG meeting on April 11, 1995. The group consists of representatives from the consumer products industry, U.S. EPA, Air Resources Board (ARB) and local air districts.

At the initial meetings of the Reactivity Subgroup we established the goals of the group, and focused on education. To improve our understanding, technical forums were provided by leading researchers Dr. William P.L. Carter of the University California at Riverside, Dr. Armistead Russell of the Georgia Institute of Technology, and Dr. Jana Milford of the University of Colorado at Boulder. At the October 29, 1996, meeting draft concepts were presented for regulatory control strategies. Working with the subgroup we also conducted a reactivity pilot project. Four manufacturers participated and the results were discussed with the subgroup. Based on the results we determined that reactivity-based strategies have the potential to achieve significant reductions in ozone while providing compliance flexibility. We intend to continue meeting with the Reactivity Subgroup to explore additional reactivity based control strategies. The meetings of the Reactivity Subgroup are detailed in Table V-1.

TABLE V-1
CHRONOLOGY OF REACTIVITY SUBGROUP MEETINGS

Date	Meeting/Workshop	Location
April 11-12, 1995	1st Consumer Products Working Group (CPWG) Meeting - Formation of Reactivity Subgroup	Sacramento, CA
July 11, 1995	1st Reactivity Subgroup Meeting	Sacramento, CA
October 17, 1995	2nd Reactivity Subgroup Meeting	Sacramento, CA
January 18, 1996	3rd Reactivity Subgroup Meeting	Sacramento, CA
June 19, 1996	4th Reactivity Subgroup Meeting	Sacramento, CA
October 29, 1996	5th Reactivity Subgroup Meeting	Sacramento, CA
February 4, 1997	6th Reactivity Subgroup Meeting	Sacramento, CA
May 20, 1997	7th Reactivity Subgroup Meeting	Sacramento, CA
January 15, 1998	8th Reactivity Subgroup Meeting	Sacramento, CA
February 11, 1998	9th Reactivity Subgroup Meeting	Sacramento, CA

C. Reactivity Research Advisory Committee (RRAC)

In March 1996, the ARB established a scientific group, the Reactivity Research Advisory Committee (RRAC). This committee is comprised of consumer product manufacturers, raw material suppliers, and other interested stakeholders. The purpose of the RRAC has been to identify important volatile organic compounds (VOCs) used in consumer products that warrant further reactivity characterization. The goal has been to ensure that reactivity regulations developed for consumer products are based on sound VOC reactivity data. This group has met seven times and has provided valuable input on commercially important VOCs to study further to reliably assess their reactivity. Based on their suggestion, additional research was funded by ARB and completed. Meetings of the RRAC are not shown in these tables.

D. Reactivity Scientific Advisory Committee (RSAC)

In March 1996, the ARB established a scientific advisory group, the Reactivity Scientific Advisory Committee (RSAC). The committee is made up of independent, respected scientists who make recommendations to the ARB on the science related to hydrocarbon reactivity. At the first meeting, the RSAC approved the use of the maximum incremental reactivity (MIR) scale, developed by Dr. Carter, as appropriate for use in developing reactivity-based control strategies for California. At the February 24, 1997, meeting ARB staff presented regulatory concepts based on the MIR scale. The RSAC supported the use of reactivity concepts in regulatory control strategies.

On August 26, 1998, we presented a draft voluntary reactivity regulation to the RSAC for their concurrence. While they supported the regulatory concept they suggested that the basis for the MIR scale undergo peer review prior to use in the proposed regulation. We agreed and contracted with Dr. William Stockwell to conduct the review. We presented the final report on the review of the mechanism from which the MIR scale is derived to the RSAC on October 8, 1999. They overwhelmingly approved of the review and Dr. Carter's documentation supporting the MIR scale. The RSAC meeting dates are summarized in Table V-2. We plan to hold another RSAC meeting on this proposal before mid-June 2000.

TABLE V-2
CHRONOLOGY OF RSAC MEETINGS

February 3, 1997	1st Meeting Reactivity Scientific Advisory Committee (RSAC)	Pasadena, CA
February 24, 1998	2nd Meeting RSAC	Sacramento, CA
August 26, 1998	3rd Meeting RSAC- Teleconference	Riverside, CA
October 8, 1999	4th Meeting RSAC	Riverside, CA

E. Public Workshops, Aerosol Coatings Workgroups and Other Meetings

Staff also conducted eight public workshops on reactivity-related proposals. The first workshop on November 19, 1997, focused on general regulatory concepts.

During the second workshop in May of 1998, we discussed a voluntary reactivity regulation for aerosol coatings. We continued to develop this compliance option and held additional five workshops as we refined the voluntary regulation, with the last workshop on the voluntary proposal held on January 26, 2000.

In February 2000, during development of the voluntary reactivity regulation proposal, staff and several representatives of the aerosol coating industry came to the conclusion that it was preferable to pursue replacing the VOC content limits with mandatory reactivity-based VOC limits. In reaching this conclusion, the industry representatives indicated that reactivity-based VOC limits may provide more flexibility, while efficiently reducing the ozone formed from aerosol coatings. We presented the first mandatory proposal to the Aerosol Coatings Workgroup in late February 2000. As we developed this proposal we met or held telephone conferences with the Aerosol Coatings Working Group five times. We held a public workshop on the mandatory reactivity limits for aerosol coatings on April 11, 2000.

At each public workshop and Aerosol Coatings Workgroup Meeting, the MIR values were discussed.

The proposed amendments to ARB Method 310 were discussed with the Aerosol Coatings Workgroup, and were presented at the April 11, 2000, public workshop. These meetings are detailed in Table V-3 below.

TABLE V-3
CHRONOLOGY OF OTHER REACTIVITY MEETINGS

November 19, 1997	1st Reactivity Public Workshop	Sacramento, CA
February 10, 1998	1st Meeting with National Paint and Coatings Association	San Francisco, CA
March 30, 1998	1st Meeting with Air Districts	Sacramento, CA
May 5, 1998	2 nd Reactivity Public Workshop	Sacramento, CA
May 19, 1998	3rd Reactivity Public Workshop	Sacramento, CA
May 21, 1998	2nd Meeting with Air Districts	Sacramento, CA
June 23, 1998	1st Meeting with Aerosol Coatings Industry	Sacramento, CA
July 9, 1998	2nd Meeting with Aerosol Coatings Industry	Sacramento, CA
July 23, 1998	4th Reactivity Public Workshop	Sacramento, CA
August 19, 1998	5th Reactivity Public Workshop	Sacramento, CA
February 22, 1999	2nd Meeting with National Paint and Coatings Association	San Francisco, CA
March 18, 1999	6th Reactivity Public Workshop	El Monte, CA
September 27, 1999	1st Meeting with Aerosol Coatings Workgroup	Washington, D.C.
January 26, 2000	7th Reactivity Public Workshop	Sacramento, CA
February 29, 2000	2nd Meeting with Aerosol Coatings Workgroup	Sacramento, CA
March 15, 2000	3rd Meeting with Aerosol Coatings Workgroup	Sacramento, CA
April 4, 2000	4th Meeting with Aerosol Coatings Workgroup (Conference Call)	Sacramento, CA
April 6, 2000	1st Conference Call with Chemical Manufacturers Association	Sacramento, CA
April 11, 2000	5th Meeting with Aerosol Coatings Workgroup	Sacramento, CA
April 11, 2000	8th Reactivity Public Workshop	Sacramento, CA

VI.

Proposed Amendments to the Aerosol Coating Products Regulation, Proposed Tables of Maximum Incremental Reactivity (MIR) Values, and Proposed Amendments to Air Resources Board Method 310

A. Introduction

In this Chapter, the Air Resources Board (ARB) staff provides a description, in plain language, of the proposed amendments to the Aerosol Coatings Regulation, the proposed Tables of Maximum Incremental Reactivity (MIR) Values, and the proposed amendments to ARB Method 310. The reasons for proposing the amendments are also explained. The description in plain language satisfies the requirements of Government Code section 11343.2, which requires that a noncontrolling, "plain English" summary of the regulation be made available to the public.

To begin with a distinction between the terms volatile organic compounds (VOC) and reactive organic compound (ROC) is necessary. The term VOC refers to the compounds regulated by the mass-based limits. Under our current mass-based regulations, the VOC definition does not include exempted compounds such as acetone. ROC is a new term we are proposing here and refers to the compounds that would be regulated by the proposed reactivity limits. ROC includes all organic compounds such as acetone. As explained in Chapter II and IV low reactive compounds that have been exempted in the VOC definition, are included as ROC. These low reactive compounds do make small amounts of ozone. Therefore, it is appropriate to include them in a reactivity-based control approach. When the term VOC is used, we are referring to the mass-based portion of the regulation, when we use the term ROC we are referring to the reactivity provisions proposed here.

The proposed amendments presented here recognize that each ROC has a different potential to form ozone once emitted into the air. This concept is known as "reactivity." By understanding the differences in ROCs' potentials to form ozone, a control approach can be established to limit the amount of ozone produced by the ROCs contained in aerosol coatings products. This type of control approach has the potential to provide more flexibility to manufacturers, at less cost than traditional mass-based VOC controls, while achieving an equivalent air quality benefit. Using the concepts of reactivity, staff is proposing to establish reactivity limits for aerosol coatings to replace the January 1, 2002, mass-based VOC limits presently contained in the regulation. As the basis for setting reactivity limits, staff is proposing to use the MIR scale. The concepts of ROC photochemical reactivity are discussed in detail in Chapter II of this report.

At present, the Aerosol Coatings Regulation requires reductions in emissions of VOCs by specifying the total amount, or mass, of VOCs (on a percent by weight basis) that can be contained in an aerosol coating product. The first reductions in VOC content became effective in January 1996. Further reductions in total VOC content are required beginning in January 1, 2002. The amendments proposed here would replace 2002 VOC content limits with reactivity limits that provide an equivalent air quality benefit. Reactivity limits for the general coatings categories would become effective on June 1, 2002, and limits for the specialty coatings categories would become effective on January 1, 2003. To establish equivalent limits, staff has quantified the ozone reductions associated with the mass-based VOC limits and calculated a reactivity limit that ensures an equal air quality benefit. The new Subchapter containing the MIR values is proposed to serve as the basis for implementing the reactivity provisions.

Staff is also proposing amendments to Method 310 to specify its use for determining compliance with the proposed reactivity limits. These changes would allow Method 310 to be used with manufacturers' formulation data to determine the amount and type of each ROC ingredient in an aerosol coating product.

B. Proposed Amendments to the Aerosol Coatings Regulation

1. Introduction

Air Resources Board staff is proposing amendments to the Regulation for Reducing Volatile Organic Compound Emissions from Aerosol Coatings Products (Aerosol Coatings Regulation), contained in Title 17, California Code of Regulations (CCR), sections 94520-94528. As mentioned above, the major change being proposed is to replace the existing January 1, 2002, mass-based VOC content limits with reactivity limits that provide an equivalent air quality benefit. However, the current (1996) mass-based limits will continue to be in effect. Hence, we are proposing that the structure of the regulation be changed to continue to include all of the requirements necessary to comply with the January 1996 VOC content limits, and we are adding additional provisions that would be necessary for compliance after the effective date of the reactivity limits. To do this, as proposed, many provisions contained in the regulation would be bifurcated into parts one and two. Part one would contain the mass-based requirements, and be labeled as products subject to the limits in section 94522(a)(2). Part two would contain the reactivity-based requirements, and be labeled as products subject to the limits in section 94522(a)(3).

As described in more detail below, staff is proposing amendments to sections 94521-94524, and section 94526 of the Aerosol Coatings Regulation, Title 17, CCR, sections 94520-94528. The proposed amendments to the Aerosol Coatings Regulation are shown in Appendix A of this Technical Support Document. We are also proposing to change the title of the regulation to the "Regulation for Reducing the Ozone Formed from Aerosol Coatings Product Emissions." This title change reflects the change to a reactivity-based control approach.

2. Proposed Amendments to Definitions, section 94521

In section 94521 definitions are provided for terms used in the regulation which are not self-explanatory. We are proposing to amend section 94521(a) to add a number of reactivity-related terms. Each definition proposed for addition follows:

Base Reactive Organic Gas (Base ROG):

The "base reactive organic gas (Base ROG)" is a term to describe the mixture of gases used to derive the MIR scale. It is a mixture of the gases contained in ambient air in 39 urban centers in the United States, including the California cities of Los Angeles, San Diego, San Francisco, and Sacramento.

Ingredient:

An ingredient is any component of an aerosol coating product. The weight fraction of each ingredient of an aerosol coating product, including reactive organic gases and solids must be known to accurately determine the weighted reactivity of a product.

Maximum Incremental Reactivity (MIR):

"Maximum Incremental Reactivity (MIR)" is a numerical value that describes the change in the weight of ozone formed by adding a specific amount of a ROC ingredient to the base ROG mixture. The units associated with a MIR value are grams of ozone formed per gram of ROC.

Ozone:

Ozone is a toxic pollutant formed in the troposphere by reactions of nitrogen oxides and ROCs in the presence of sunlight. It is a molecule consisting of three oxygen atoms.

Product-Weighted MIR (PWMIR):

The "Product-Weighted MIR (PWMIR)" is the total reactivity of a product expressed as grams of ozone per gram of product. The PWMIR is the sum of each MIR value multiplied by the weight fraction of each ingredient in the product. For compliance, the PWMIR must be less than or equal to the reactivity limit for that product category.

Reactivity Limit:

The "reactivity limit" is the maximum reactivity allowed for an aerosol coating product, expressed as grams ozone per gram product. The reactivity limit is calculated to achieve the same ozone reduction as was estimated to be achieved from the previously adopted mass-based VOC limit. A complete description of the method used to calculate the reactivity limits is found in Chapter IV.

Reactive Organic Compound (ROC):

A reactive organic compound is a compound that has the potential to contribute to ozone formation in the troposphere once emitted. In general, all VOCs [as defined in section 94521] are ROCs. The definition is proposed to clarify that all VOCs, including compounds defined as low reactive, contribute to ozone formation and are considered in determining the total reactivity of aerosol coating products. Under a reactivity-based control strategy we are proposing that VOC compounds such as acetone and methyl acetate would no longer qualify as exempt compounds after the effective date of the reactivity limits.

Upper Limit Kinetic Reactivity (ULKR):

The "Upper Limit Kinetic Reactivity (ULKR)" refers to maximum percentage of an emitted ROC ingredient that has reacted in the atmosphere. The ULKR used is one hundred percent and is used to compute an upper limit MIR (ULMIR) value. A further description of kinetic reactivity is included in Chapter IV.

Upper Limit Mechanistic Reactivity (ULMR):

The "Upper Limit Mechanistic Reactivity (ULMR)" means the maximum gram of ozone formed per gram of ROC ingredient reacting. The MR value is used to compute a upper limit MIR (ULMIR) value. A further description of mechanistic reactivity is included in Chapter IV.

Upper Limit MIR (ULMIR):

The "Upper Limit MIR (ULMIR)" is a numerical value calculated by ARB staff that estimates the maximum reactivity for ROCs that do not have a published MIR value. The method to calculate an ULMIR was developed by Dr. Carter (Carter, 2000). The ULMIR value is calculated by multiplying the upper limit kinetic reactivity by the upper limit mechanistic reactivity. ULMIR values are expressed in units of grams of ozone per gram of ROC. The proposed approach to calculate ULMIRs is described in Appendix E. ULMIRs were only calculated for ROCs reported in the aerosol coating survey that do not have a published MIR value.

Weight Fraction:

The weight fraction is the weight of an ingredient divided by the total weight of the product expressed to thousandths. The weight fraction of an ingredient is multiplied by its MIR value to obtain the weighted reactivity of an ingredient in a product. The reactivity of all ingredients is summed to get the total product-weighted reactivity.

3. Proposed Amendments to Standards and Requirements for Aerosol Coating Products, section 94522

We are proposing a number of amendments to sections 94522. First of all, we are proposing to delay the effective date to comply with the reactivity limits. This is necessary to allow manufactures adequate time to reformulate their products. Our proposal is to amend the effective date for the “general coating” aerosol coatings categories from January 1, 2002, to June 1, 2002. The general coating categories are: Clear Coatings, Flat Paint Products, Fluorescent Coatings, Metallic Coatings, Nonflat Paint Products, and Primers.

We are also proposing to delay the compliance date for the remaining “specialty categories” from January 1, 2002, to January 1, 2003. This additional extension would allow manufacturers to focus first on reformulation efforts for the “general coating” categories, which will provide the greatest air quality benefit.

However, delaying the effective date will result in a short term ozone shortfall of 9.6 tons per day (tpd). However, by requiring compliance from the general coating categories by June 1, 2002, 7.9 tpd, or 82 percent of the ozone reductions will be achieved concurrent with the 2002 ozone season (based on VOC reduction commitment of 2.53 tpd). For an additional seven months there will be a shortfall of 1.7 tpd of ozone (based on a VOC reduction commitment of 0.6 tpd).

We believe the delay of the effective date is necessary to prevent disruptions in the aerosol coating market place and to minimize the possibility of an economic hardship for aerosol coating manufacturers. This proposal also ensures that efficacious products will continue to be available to the consumer in all 35 categories. We believe that these considerations override the short-term air quality disbenefit. Because 82 percent of the required reduction will be achieved as the ozone season begins in 2002, we believe the overall proposal will have a minimal impact on air quality.

a. Compliance with Limits, section 94522(a)(1)

We are proposing to add new subsection 94522(a)(1) to ensure that manufacturers who comply with the reactivity limits prior to the effective dates would not be found to be out of compliance. At present aerosol coatings manufacturers are required to include information on the applicable product category, the applicable limit, and the date of manufacture.

As proposed in new section 94522(a)(1), if products are labeled with the reactivity limit rather than the VOC limit, then the product would meet all the requirements for products manufactured to meet the reactivity limit, and would no longer be subject to the requirements for the mass-based VOC limits contained in section 94522(a)(2).

b. Limits for Aerosol Coatings Products, sections 94522(a)(2) and 94522(a)(3)

Section 94522(a)(2) contains standards that limit the VOC content of 35 categories of aerosol coatings and the dates when the standards take effect. We are proposing to delete the mass-based VOC standards that become effective on January 1, 2002, and replace them with new reactivity limits that are contained in the Table of Limits in proposed new section 94522(a)(3). The January 8, 1996, VOC limits found in section 94522(a)(1), would continue to be effective, however. The proposed reactivity limits are shown in Table VI-1.

TABLE VI-1
PROPOSED TABLE OF REACTIVITY LIMITS

	Weighted Product Reactivity g O_3 / g product
General Coatings	**06/01/02**
Clear Coatings	1.54
Flat Paint Products	1.21
Fluorescent Coatings	1.77
Metallic Coatings	1.93
Nonflat Paint Products	1.40
Primers	1.11
Specialty Coatings	**01/01/03**
Art Fixatives or Sealants	1.80
Auto Body Primers	1.57
Automotive Bumper and Trim Products	1.75
Aviation or Marine Primers	1.98
Aviation Propeller Coatings	2.47
Corrosion Resistant Brass, Bronze or Copper Coatings	1.78
Exact Match Finishes	
Engine Enamel	1.72
Automotive	1.77
Industrial	2.07
Floral Sprays	1.68
Glass Coatings	1.42
Ground Traffic/Marking Coatings	1.18
High Temperature Coatings	1.83
Hobby/Model/Craft Coatings	
Enamel	1.47
Lacquer	2.70
Clear or Metallic	1.60
Marine Spar Varnishes	0.87
Photograph Coatings	0.99
Pleasure Craft Finish Primers, Surfacers or Undercoaters	1.05
Pleasure Craft Topcoats	0.59
Shellac Sealers	
Clear	0.98
Pigmented	0.94
Slip-Resistant Coatings	2.41
Spatter/Multicolor Coatings	1.07
Vinyl/Fabric/Leather/Polycarbonate Coatings	1.54
Webbing/Veil Coatings	0.83
Weld-Through Primers	0.98
Wood Stains	1.38
Wood Touch-Up, Repair or Restoration Coatings	1.49

It should also be noted that when the reactivity limits become effective, products would no longer be able to participate in the Alternative Control Plan or the Hairspray Credit Program. Neither of these programs is presently designed to include products complying with reactivity limits. The provision clarifying that the Alternative Control Plan can no longer be used is specified in new subsection 94522(a)(6).

c. Sell-Through of Products, subsection 94522(b)

We are proposing to modify subsection 94522(b), to specify that products would have a three-year sell through period if the products were manufactured prior to the effective dates of the reactivity limits and contain a date or a code indicating the date the product was manufactured. Of course, these products would still be required to be in compliance with the January 8, 1996, VOC limits.

d. Products Containing Methylene Chloride, subsection 94522(c)(2)

Proposed new subsection 94522(c)(2) would limit the use of methylene chloride in aerosol coatings because methylene chloride has been identified as a toxic air contaminant (TAC). In the existing Aerosol Coatings Regulation, methylene chloride use is restricted by requiring that the percent by weight of methylene chloride in an aerosol coating be added to the total VOC content to determine compliance. However, when calculating the total reactivity of a product this type of provision does not provide the same restriction because methylene chloride is negligibly-reactive, and has a low MIR value. Therefore, to limit methylene chloride use we are proposing a “no new use” provision. As proposed, if an existing product already uses methylene chloride, no additional methylene chloride could be added when the product is reformulated. The baseline would be established based on the 1997 survey data. Any product that does not currently contain methylene chloride, could not reformulate using methylene chloride.

Our complete analysis and health risk assessment which serve as our justification for this provision is in included in Appendix G. The provision is also discussed in Chapter X, section E, Emission Reductions and Other Potential Environmental Impacts.

e. Products Containing Perchloroethylene or Ozone Depleting Substances, subsection 94522(d)(2)

Proposed new subsection 94522(d)(2) would restrict the use of perchloroethylene and ozone depleting substances in products meeting the reactivity limits, in the same way (“no new use”) their use is restricted for products manufactured to meet the mass-based VOC limits in section 94522(a)(2). However, products could only continue to use, but not increase use of perchloroethylene or an ozone depleting substance, if the product contained perchloroethylene or an ozone depleting substance in calendar year 1997.

f. Multicomponent Kits, section 94522(e)(2)

In proposed new subsection (e)(2) we are proposing a method to calculate the reactivity of “multicomponent kits,” to determine compliance with the reactivity limits. A multicomponent kit is a system in which two or more aerosol coatings are sold together in one package, and both coatings are necessary to produce the finished coating. We are proposing that the total reactivity of multicomponent kits must be less than or equal to the total of all the reactivity limits had each product individually met the reactivity limits. This means that the products in the kit can be "averaged" with a product above the reactivity limit being offset with a product below the reactivity limit. An equation is provided to aid in determining compliance with this provision. This is similar to the provision for products complying with the mass-based VOC limits.

g. Products Assembled by Adding Bulk Paint to Aerosol Containers of Propellant, section 94522(f)

In section 94222(f) we are proposing language to clarify that aerosol coating products assembled by adding bulk paint to aerosol cans of propellants must meet either the mass limits or the reactivity limits, whichever are currently effective.

h. Requirements for Lacquer Aerosol Coatings Products Subject to the VOC Limits Specified in 94522(a)(2), section 94522(g)

We are proposing that the provisions currently in place for lacquer aerosol coatings apply only to the mass-based VOC limits contained in section 94522(a)(2). This provision allowed lacquer aerosol coatings to continue to be sold until January 1, 1998, that had a combined VOC and methylene chloride content of up to 80 percent by weight. Although this provision has expired, products that were manufactured prior to January 1, 1998, can continue to sold, supplied, offered for sale, or applied until January 1, 2001, due to sell-through provisions. However, once the reactivity limits become effective, this provision would no longer be needed.

i. Assignment of Maximum Incremental Reactivity (MIR) Values, Proposed New subsection 94522(h)

In new proposed subsection 94522(h) the procedures for assigning MIR values for aerosol coatings ingredients are specified. Non-ROC ingredients such as resins, pigments, plasticizers, and fillers, as well as ingredients that do not contain carbon, would be assigned MIR values of zero. Each ROC would be assigned its respective MIR value using Tables of MIR Values and MIR Values for Hydrocarbon Solvents contained in newly proposed Subchapter 8.6, sections 94700-94701. As proposed in new subpart D, only ROCs in the tables of MIR Values can be used in aerosol coatings to comply with the reactivity limits in section 94522(a)(3).

To determine the product weighted MIR (PWMIR), the weight fraction of each ingredient in an aerosol coating is multiplied by the MIR value. The weighted reactivity of all ingredients is then summed to get the PWMIR. This value, in grams ozone per gram of product, is compared to the reactivity limit contained in section 94522(a)(3). If the calculated PWMIR of the aerosol coating product is greater than the category reactivity limit, the product does not comply and would need to be reformulated. If the PWMIR of the aerosol coating is less than or equal to the category reactivity limit, the product is in compliance.

4. Exemptions, section 94523

We are proposing to amend subsections (c) and (d) to clarify that the exemptions would apply to products meeting either the VOC content standards or the reactivity limits. Subsection (c) provides that the requirements of the Aerosol Coatings Regulation do not apply to products that are intended for sale or use outside of California. Subsection (d) provides that the requirements prohibiting the use of non-complying aerosol coatings applies only to commercial application of aerosol coating products. This means that a household consumer using a non-complying product would not be in violation of the regulatory requirements.

5. Administrative Requirements, section 94524

a. Most Restrictive Limit, subsection (a)

We are proposing to amend subsection (a), the "most restrictive limit" clause. Currently, if any representation is made that an aerosol coating could be used as a product for which a lower limit is specified, the aerosol coating product would be subject to the lower limit. The amendment would clarify that the "most restrictive limit" provision would continue to apply after the reactivity limits become effective.

b. Labeling Requirements, new subsection (b)(1)(B)

We are proposing to add a new subpart (1)(B) to clarify that manufacturers would be required to display the reactivity limit, the coating category, and the date or a code indicating when the product was manufactured after the limits become effective. At present, for products manufactured to meet the mass-based VOC limits specified in 94522(a)(2), manufacturers are required to include the VOC content limit on cans of aerosol coatings. The provisions in renumbered subparts (1)(A)(3.) and (4.), which require manufacturers to list the aerosol coating category, and the date or a code indicating when the product was manufactured on their products, would continue to apply.

c. Reporting Requirements, subsection (c)

We are proposing that all of the current reporting requirements would continue to apply once the reactivity limits become effective. An amendment is proposed to subpart (c)(2)(F) to clarify that after the reactivity limits in section 94522(a)(3) become effective, products would have to supply, within 90 days written notice, the product weighted MIR, and the weight fraction of all ingredients in the aerosol coating product. A further amendment is proposed to part (H) to clarify that the Executive Officer may ask for any information to help determine the reactivity of emissions from aerosol coatings.

d. Special Reporting Requirements for Perchloroethylene-Containing Aerosol Coatings, subsection (e)

We are proposing amendments to the perchloroethylene reporting requirements to specify that the reporting requirements will continue to apply after the reactivity limits become effective.

We are also proposing to delete subsection (e)(2)(C), which requires manufacturers to report the applicable product form of their perchloroethylene-containing aerosol coatings. This provision is unnecessary because all products subject to the rule are aerosol product forms.

6. Test Methods, section 94526

a. Testing for Products Manufactured to Meet the Reactivity Limits in section 94522(a)(3)

All of the test methods currently used to determine compliance with the aerosol coating regulation would continue to apply. However, we are proposing to add a new subsection (b) to specify testing procedures and requirements for products meeting the reactivity limits after the proposed effective dates. In subpart (b)(1) we specify that ARB Method 310, Determination of Volatile Organic Compounds in Consumer Products, can be used to determine the ingredients and the amount of each ingredient in an aerosol coating product. Note that we are also proposing amendments to Method 310 to accommodate testing for compliance with the reactivity limits. These amendments are described below in section eight of this Chapter.

In proposed new subpart (b)(2), manufacturers would be required to supply formulation data, the product category, and any other information necessary to verify the product weighted MIR. The information would be required to be supplied within 10 working days of receiving written notification from the Executive Officer that their product(s) have been selected for compliance testing. Requiring formulation data at the time of testing will speed the analysis and enforcement processes. We are still working to determine an appropriate de minimus level for ingredient impurities and may present a proposal at the Board hearing.

Other modifications to section 94526 would reletter the remaining subsections. We are also proposing to amend relettered subsection (c) to indicate that testing for exempt compounds applies only to products manufactured to meet the mass-based VOC limits [section 94522(a)(2)]. After the effective date of the Reactivity Limits, no compounds would be considered exempt, however, it should be noted that ingredients that do not form ozone are assigned MIR values of zero.

C. Proposed New Subchapter 8.6, sections 94700-94701, Tables of MIR Values

The proposed Tables of MIR Values for compounds and hydrocarbon solvents are contained in sections 94700 and 94701, respectively, of new Subchapter 8.6. These tables are also included in Appendix A of this Technical Support Document. The MIR values are used to calculate both the reactivity limits and a product’s total reactivity (PWMIR). The MIR values contained in section 94700 are also used to establish the MIR values for hydrocarbon solvents contained in section 94701. A more detailed description of the MIR scale is contained in Chapters II of this report. Section 94700 lists each ROC by name, its respective MIR value, and the effective date. This is the revised list of MIR values dated April 11, 2000, and is based upon the research of Dr. William Carter at the University of California, Riverside.

Proposed section 94701 would contain the MIR values for hydrocarbon solvents. Hydrocarbon solvents are not composed of a single chemical component, but rather many different hydrocarbon constituents. As described further in Chapter IV, they are produced from the fractionation of a broader distillation range petroleum stream. For this reason, we are proposing to group hydrocarbon solvents that have similar characteristics, such as average boiling range, alkane content, and aromatic content. The proposed groupings were based on the methodology described in Chapter IV, and using the MIR values found in the Table of Compounds.

Because we recognize that the MIR values may change as more data become available, we also believe a process needs to be put in place to allow regular updates to the Tables of MIRs and to allow for additions of compounds not currently on the list. We believe it would be appropriate to review the Table of MIRs periodically and make changes as recommended. We also believe it would be appropriate to review the reactivity limits periodically to determine if any changes to the MIRs would have a significant impact on any of the limits. If, upon review, changes to the limits were warranted, to protect air quality, we would propose the necessary changes to the Board in a regulatory rulemaking. We are still working on a process for updating MIR values and limits and may propose additional changes at the Board hearing.

D. Proposed Amendments to ARB Method 310, Determination of Volatile Organic Compounds in Consumer Products

The ARB Method 310 is designed to determine the total VOC content in consumer products. The method incorporates procedures from the American Society of Testing and Materials (ASTM), the United States Environmental Protection Agency (U.S. EPA), and the National Institute for Occupational Safety and Health (NIOSH), all of which are referenced in section 94526 of Title 17, CCR, Division 3, Chapter 1, Subchapter 8.5, Article 3, sections 94520-94528.

At present, ARB uses Method 310 for analysis of the overall VOC content of aerosol coating products. In addition to general chemical analyses, Method 310 allows the determination of specific chemical ingredients (for example, NIOSH Method 1400). If necessary, separation of a complex mixture can also be performed by the gas chromatography-mass spectrometry (GC/MS) procedures specified in Method 310 such as U. S. EPA methods 8240B and 8260B. The proposed amendments would require chemical ingredient information (in percent by weight) for determining whether the product meets the reactivity limit. Hence, amendments are proposed to allow Method 310 to be used for ROC determination. The proposed amendments are included as Appendix B of this Technical Support Document. We are also proposing to change the name of the method to Air Resource Board Method 310: Determination of Volatile Organic Compounds (VOC) in Consumer Products. This change is proposed to reflect that Method 310 can be used to verify and provide discreet results for the ingredients contained in aerosol coatings.

REFERENCES

Carter, W.P.L. (2000). The SAPRC-99 Chemical Mechanism and Updated VOC Reactivity Scales, Draft Version. Revised April, 11, 2000. Prepared for the California Air Resources Board Contracts Nos. 92-329 and 95-308. Appendix D, pp. D-1 to D-33. http://www.cert.ucr.edu/~carter/reactdat.htm

VII.

Technological and Commercial Feasibility of the Proposed Reactivity Limits

In this Chapter, Air Resources Board (ARB) staff explains the statutory requirements regarding technological and commercial feasibility and our rationale for why we believe the proposed amendments meet these criteria. Health and Safety Code section 41712 requires all consumer product regulations adopted by the Board to be "technologically and commercially feasible." Before providing our interpretation of the statutory criteria regarding technological and commercial feasibility, and why we believe the proposed limits will result in products that meet these criteria, we describe the process to set the proposed limits.

A. Process of Setting Proposed Reactivity Limits

Typically, when volatile organic compound (VOC) limits are proposed for a particular consumer product category, the available technologies, cost, total VOC content, and complying marketshares are used as guiding factors to determine technologically and commercially feasible VOC limits. This was the case when the staff proposed, and the Board adopted the January 1, 2002, revised VOC limits for aerosol coatings. These mass-based VOC limits are designed to achieve a reduction in VOC emissions of about 3.1 tons per day. However, at that time, it was acknowledged that the limits did present a particularly difficult reformulation challenge for water-based coatings (ARB, 1998a).

We are now proposing to amend the Aerosol Coatings Regulation by replacing the January 1, 2002, VOC limits with reactivity-based limits that achieve an equivalent air quality benefit. In developing the proposed reactivity limits, our goal was to propose limits that ensure that the ozone reduction associated with the mass limits would be preserved, while maintaining the already demonstrated technological and commercial feasibility of them. Overall, staff believes this proposal achieves this goal at potentially less cost.

B. Technological and Commercial Feasibility

1. Technologically Feasible

Health and Safety Code section 41712(d) requires the Board to adopt consumer product regulations that are "technologically feasible." Technological feasibility is a different concept than "commercial feasibility," and does not take into account the cost of the complying product. The staff believes that a proposed limit is technologically feasible if it meets at least one of the following criteria: (1) the limit is already being met by at least one product within the same category, or (2) the limit can reasonably be expected to be met in the time frame provided through additional research and development efforts.

The proposed limits result in significant complying marketshares in all aerosol coatings categories except corrosion resistant brass, bronze, or copper coatings; and glass coatings. As compared to the January 1, 2002, mass-based VOC limits, in 14 categories the complying marketshares increased over those determined for the mass-based VOC limits. For an additional 15 categories the complying marketshares are the same as for the January 1, 2002, mass-based VOC limits. However, lower complying marketshares were determined for four "specialty coating" categories: 1) vinyl, fabric, leather, polycarbonate coatings; 2) metallic coatings; 3) floral coatings; and, 4) hobby, model craft coatings: clear or metallic. In these categories the complying marketshares for products meeting the reactivity limits range from 23 to 87 percent, indicating that the proposed limits are still technologically feasible. We also note that in most cases water-based aerosol coating products, defined as formulated with water and dimethyl ether, easily comply with the proposed reactivity limits.

As mentioned above, two categories currently have no complying products. However, in the case of glass coatings, products representing 65 percent of the market are within about 10 percent of being able to comply with the proposed reactivity limit. In the case of corrosion resistant brass, bronze, or copper coatings; we note that there were no complying products in this category when the January 1, 2001, VOC limits were adopted. However, by using "cross-over technology" from other categories with significant complying marketshares, we believe the limits appear to be feasible. The flexibility allowed by "substituting" rather than "replacing" VOCs should allow multiple reformulation options for these categories. We are proposing to delay the effective date for the "specialty coating categories until January 1, 2003. This additional time should also aid in allowing efficacious products to be developed.

Given the reasonable complying marketshares in most categories, staff concludes that the criterion to set "technologically" feasible limits has been met. Table VII-1 shows the number of complying products and complying marketshares at the proposed reactivity limit for each aerosol coating category.

2. Commercially Feasible

Health and Safety Code section 41712(d) also requires the Board to adopt consumer product regulations that are "commercially feasible." The term "commercially feasible" is not defined in State law. In interpreting this term, staff has utilized the reasoning employed by the United States Court of Appeals for the District of Columbia in interpreting the federal Clean Air Act. In the leading case of International Harvester Company *vs.* Ruckelshaus, (D.C. Cir. 1973) 478 F. 2d 615, the Court held that the United States Environmental Protection Agency could promulgate technology-forcing motor vehicle emission limits which might result in fewer models and a more limited choice of engine types for consumers, as long as the basic market demand for new passenger automobiles could be generally met.

Following this reasoning, the staff has concluded that a regulation is "commercially feasible" as long as the "basic market demand" for a particular aerosol coating product can be met. "Basic market demand" is the underlying need of consumers for a product to fulfill a basic, necessary function. This must be distinguished from consumer "preference," which may be towards specific attributes of a particular product.

We believe our proposed reactivity limits meet the criteria for commercial feasibility because:

1. complying products, using both water-based and solvent-based technologies, are already available in nearly all of the product categories, as stated above;
2. several compliance options are available to the industry, providing flexibility to manufacturers when reformulating their products;
3. the reformulation options are cost-effective, as explained in detail in Chapter XI; and
4. we are proposing 35 individual limits such that the different types of aerosol coatings will continue to be available to consumers.

Given the reasonable complying marketshares in most categories, and the variety of products that are able to comply using various solvent systems and technologies, staff believes the proposed reactivity limits to be both technologically and commercially feasible. Multiple reformulation options allow flexibility in the design of compliant products, ensuring that efficacious, cost-effective products will continue to be sold and used in California. General reformulation options are explained in Chapter VIII.

TABLE VII-1
PROPOSED REACTIVITY LIMITS AND COMPLYING MARKETSHARES

Product Category	Proposed Reactivity Limit (g O_3/g product)	Number Complying Products	Percent Complying Products	Complying Marketshare (Percent)
Clear Coatings	1.54	45	38	45
Flat Paint Products	1.21	26	22	11
Fluorescent Coatings	1.77	44	86	64
Metallic Coatings	1.93	54	33	27
Nonflat Paint Products	1.40	302	38	36
Primers	1.11	31	20	29
Art Fixatives or Sealants	1.80	7	47	47
Auto Body Primers	1.57	12	63	64
Automotive Bumper and Trim Products	1.75	34	49	73
Aviation or Marine Products	1.98	<10	100	100
Aviation Propeller Coatings	2.47	<10	100	100

(continued on next page)

TABLE VII-1 Continued
PROPOSED REACTIVITY LIMITS AND COMPLYING MARKETSHARES

Product Category	Proposed Reactivity Limit (g O_3/g product)	Number Complying Products	Percent Complying Products	Complying Marketshare (Percent)
Corrosion Resistant Brass, Bronze, or Copper Coatings	1.78	0	0	0
Exact Match Finishes: Engine Enamel	1.72	8	28	72
Exact Match Finishes: Automotive	1.77	276	87	62
Exact Match Finishes: Industrial	2.07	30	94	99
Floral Sprays	1.68	13	81	87
Glass Coatings	1.42	0	0	0
Ground Traffic/Marking Coatings	1.18	64	58	24
High Temperature Coatings	1.83	28	43	42
Hobby/Model/Craft Coatings: Enamel	1.47	32	94	94
Hobby/Model/Craft Coatings: Lacquer	2.70	<10	40	60
Hobby /Model Craft Coatings: Clear or Metallic	1.60	13	76	34
Marine Spar Varnishes	0.87	<10	100	100
Photographic Coatings	0.99	<10	50	39
Pleasure Craft Finish Primers, Surfacers or Undercoaters	1.05	<10	100	100
Pleasure Craft Topcoats	0.59	<10	100	100
Shellac Sealers: Clear	0.98	<10	100	100
Shellac Sealers: Pigmented	0.94	<10	100	100
Slip-Resistant Coatings	2.41	7	100	100
Spatter/Multicolor Coatings	1.07	12	55	89
Vinyl/Fabric/Leather/ Polycarbonate	1.54	16	80	31
Webbing/Veil Coatings	0.83	<10	100	100
Weld-Through Primers	0.98	<10	38	67
Wood Stains	1.38	<10	100	100
Wood Touch-Up, Repair or Restoration Coatings	1.49	<10	>60	>90

REFERENCES

California Air Resources Board (1998a). Initial Statement of Reasons for the Proposed Amendments to the Regulations for Reducing Volatile Organic Compound Emissions from Aerosol Coatings, Antiperspirants and Deodorants, and Consumer Products. October 2, 1998.

VIII.

Reformulation Options to Meet the Proposed Reactivity Limits

In this Chapter, Air Resources Board (ARB) staff provides information on methods a manufacturer may employ to reduce the overall reactivity of an aerosol coating to comply with the proposed limits. However, no specific "formulas" are suggested as to how a currently non-complying product would reformulate to comply with the proposed reactivity limits. ARB staff recognizes that an aerosol coating is a "package" and simply suggesting a lower reactive solvent for a currently used higher reactive solvent is inappropriate. Properly formulated aerosol coatings must provide for adequate solvency of the particular resin system and pigments. In addition, a combination of slower and faster evaporating solvents is required to allow for proper film formation once the product is applied. The propellant system must also maintain constant pressure such that the entire product can be expelled uniformly.

Rather than suggesting specific "formulas," or solvent substitutions, ARB staff provides information on the wide range of reactivities of propellants, as well as, slower and faster evaporating solvents that could be used to reduce the reactivity of aerosol coating products. An abbreviated list is provided here, but manufacturers have the option of choosing from several hundred reactive organic compounds (ROC) in the Tables of Maximum Incremental Reactivity (MIR) Values contained in proposed new Subchapter 8.6, sections 94700-94701, and also included as part of Appendix A of this Technical Support Document.

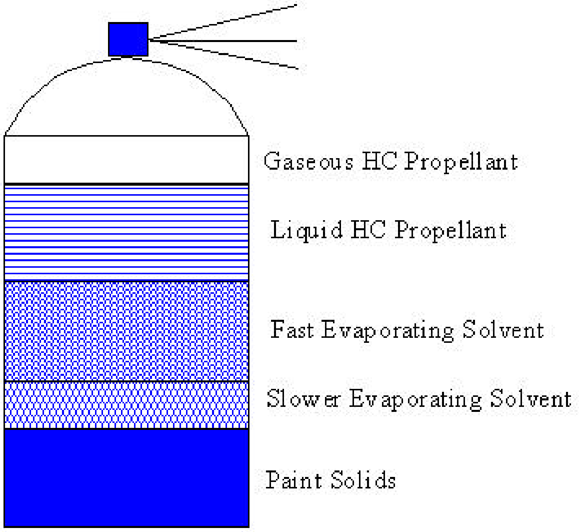
The proposed reactivity limits may not necessarily require reductions in total ROC content, but likely will require lower reactive ROCs to be used to reduce the ozone formed from products. Of course, reductions in product reactivity can also be achieved by increasing the coatings "solids," which in turn leads to reductions in the total amount of ROC contained in a product. By requiring products to reduce their overall reactivity, rather than total mass of VOCs, the proposed reactivity limits provide an equivalent air quality benefit as would be associated with the mass-based VOC limits, and provide more reformulation options at potentially less cost.

Before discussing the variety of solvents and propellants available, basic information on aerosol coating product design is provided.

A. Product Formulation of Solvent-based Aerosol Coatings

Shown below is a schematic diagram of an aerosol coating and the types of ingredients contained.

FIGURE VIII-1 SOLVENT-BASED AEROSOL COATING PRODUCT



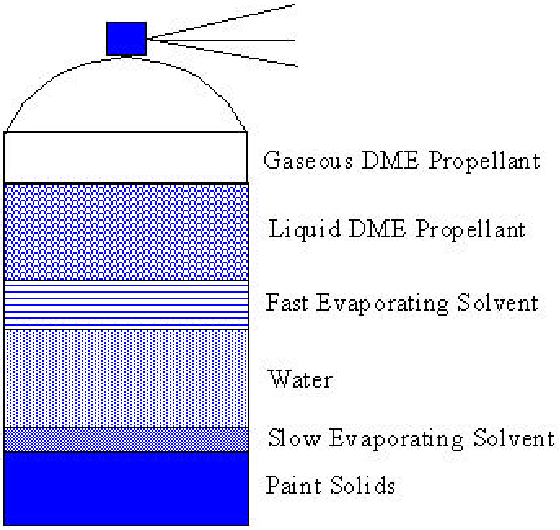
As shown in Figure VIII-1, solvent-based aerosol coatings consist primarily of propellants (which exist in an equilibrium state between the gaseous and liquid forms), fast and slower evaporating solvents, and coating solids. All of the ingredients, except the gas phase propellant, are in a single homogeneous phase after the product is shaken to evenly distribute the coating solids. The hydrocarbon propellants and solvents are the ROCs, while the solids account for the non-ROC ingredients. The propellants are almost without exception hydrocarbon blends including propane, n-butane, or isobutane. A wide variety of solvents are used including ketones (primarily acetone), esters, alcohols, aliphatic and aromatic hydrocarbons. Generally, a balance of fast and slower evaporating solvents is used, with a larger proportion of fast evaporating solvent.

B. Product Formulation of Water-based Aerosol Coatings

Water-based aerosol coatings account for about five percent of the aerosol coatings market. These products are formulated differently than solvent-based products, and generally are lower in reactivity than solvent-based products.

As shown in Figure VIII-2, water-based aerosol coatings consist primarily of propellant (which exists in an equilibrium state between the gaseous and liquid forms), water, fast and slower evaporating water-miscible solvents, and coating solids. Figure VIII-2 does not show ingredients used in small amounts such as surfactants, solvents used as carriers for resins, drying agents, wetting agents, and thickeners. The propellant in water-based products is almost always dimethyl ether (DME) because it is water-soluble, unlike the hydrocarbon propellants. DME also serves as a cosolvent in water-based coatings. The faster evaporating solvents are typically alcohols such as ethyl or propyl alcohol, while the slower evaporating (coalescing) solvents are generally glycols or glycol ethers.

FIGURE VIII-2 WATER-BASED AEROSOL COATING PRODUCT



In "water-reducible" water-based aerosol coatings, all the ingredients except the gas phase propellant are in a single homogeneous phase (after the product is shaken to evenly distribute the coating solids). In most "emulsion" or "dispersion" water-based systems, the resin and carrier solvent are dispersed in tiny "droplets" within the "continuous" phase of water, water soluble solvents, and liquid DME propellant. The original aerosol coatings staff report provides a detailed discussion of the different types of water-based aerosol coatings (ARB, 1995).

C. Reactivity-based Reformulation Strategies

The most likely path non-complying products would take to reformulate to meet the proposed reactivity limits is to substitute lower reactive ROC solvents for the higher reactive solvents currently used in their products. Other options include use of lower reactive propellants and increasing coating solids (which likely leads to reduced ROC content). It should be noted, that reducing total ROC content may also be a path to reduce product reactivity and ozone formation potential. The path that manufacturers choose to reformulate their products will be based on maintaining the proper balance of slower and faster evaporating solvents. Staff believes that by requiring "substitution," rather than "reductions," efficacious products will continue to be available.

Provided in Table VIII-1, is an abbreviated listing of ROCs and their respective MIR values. For our purposes here ROCs are divided into propellants, fast evaporating and slow evaporating solvents. Commonly evaporation rate is compared relative to that of n-butyl acetate, which has a value of 1.0. Slower and faster evaporating ROCs are categorized by having evaporation rates of < 0.8 to 3.0; and > 3.0, respectively. In addition to considering evaporation rate we suggest that manufacturers consider any potential toxics impacts.

TABLE VIII-1
CLASSES OF ROCS AND THEIR MIRS

	ROC	MIR
Propellants	HFC-152a	0.00
	Dimethyl Ether	0.93
	Propane	0.56
	n-Butane	1.33
	Isobutane	1.35
Faster-evaporating Solvents	Acetone	0.43
	Methyl Acetate	0.07
	Ethyl Acetate	0.64
	Isopropanol	0.71
	Ethanol	1.69
	2-Butanol	1.60
Slower-evaporating Solvents	Para-Xylene	4.25
	Xylene Isomers Mixture	7.37
	Meta-Xylene	10.61
	Toluene	3.97
	Ethylbenzene	2.79
	PCBTF	0.11
	t-Butyl Acetate	0.22
	Isobutyl Isobutyrate	0.64
	Isobutyl Acetate	0.67
	n-Propyl Acetate	0.87
	n-Butyl Acetate	0.89
	n-Butyl Propionate	0.89
	1-Methoxy-2-Propyl Acetate (PGME Acetate)	1.71
	Ethyl 3-Ethoxy Propionate	3.61
	Isobutyl Isobutyrate	0.64
	VM & P Naphtha	2.03
	Odorless Mineral Spirits	0.91
	Methyl Ethyl Ketone	1.49
	Methyl Propyl Ketone	3.07
	Methyl Isobutyl Ketone	4.31
	Methyl Amyl Ketone	2.80
	Methyl Isoamyl Ketone	2.80
	1-Methoxy-2-Propanol	2.62
	3-Methoxy-1-Butanol	0.97
	Diacetone Alcohol	0.68

1. Solvent-based Products

a. Propellants

Regarding propellants, the current hydrocarbon propellants used are moderately reactive. However, propane (MIR = 0.56) is considerably less reactive than butane (MIR = 1.33) or isobutane (MIR = 1.35). Using a propellant blend with more propane, such as an A-70 blend (51 percent propane, 49 percent isobutane) or an A-108 blend (100 percent propane), may be an effective means to reduce product reactivity. Another option would be to replace all or part of the hydrocarbon propellant with hydrofluorocarbon-152a (HFC-152a) (MIR= 0).

b. Faster-Evaporating ROCs

For the current mass-based VOC limits, increased use of acetone was suggested as a likely reformulation option (ARB, 1998a). The same could very well be true for reformulating to meet the proposed reactivity limits. As the faster evaporating solvent constituent, acetone is currently the solvent of choice in aerosol coatings. Acetone is also low reactive (MIR = 0.43). To the extent that acetone content could be increased to replace a higher reactive solvent, the product’s reactivity would be lowered. Another solvent with similar properties to acetone, with even lower reactivity, is methyl acetate (MIR = 0.07). However, there are limitations to these options, because a balance must be maintained between fast evaporating solvents and slower evaporating solvents. Too much of a fast evaporating solvent such as acetone can produce defects such as bubbles, pinholes, or “blushing” (Hydrosol; Plasti-kote; Raabe; Seymour of Sycamore).

c. Slower-Evaporating ROCs

However, to efficiently reduce the product’s overall reactivity, it is likely that lower reactive substitutes would need to be found for the slower-evaporating solvents. Slower-evaporating aromatic solvents, such as xylene and toluene are currently used. These aromatic ROCs are also among the most reactive ingredients used in aerosol coatings. Depending on the resin system used, other reformation options include consideration of n-butyl acetate, isobutyl acetate, ethyl acetate, isobutyl isobutyrate, methyl isobutyl ketone, methyl ethyl ketone, 1-methoxy-2-propyl acetate (propylene glycol monomethyl ether acetate), or ethyl-3-ethoxy propionate (EEP).

N-butyl acetate can be used as solvent for acrylics, nitrocellulose, and most modified alkyds (Eastman, 2000). Although the evaporation rate for n-butyl acetate is higher than that for xylenes, solvents like 1-methoxy-2-propyl acetate, methyl amyl ketone, n-butyl propionate, methyl isoamyl ketone, or isobutyl isobutyrate can be blended with the n-butyl acetate to slow its evaporation rate (Eastman, 2000). Although these solvents may or may not be used in a one-to-one by-weight mass substitution for the relatively higher reactive solvents, a combination of one or more of the lower reactive ones may be considered.

2. Water-based Products

For this discussion, we define “water-based” aerosol coatings as products formulated with a blend of water and DME. Water-based aerosol coatings, as stated above, are all formulated very similarly with the primary ROC being DME, which serves as both propellant and co-solvent. The DME serves as the faster-evaporating solvent. Dimethyl ether is moderately reactive with an MIR value of 1.02, significantly lower than the weighted reactivity of the ROCs used in solvent-based products. The other ROCs used in water-based products include smaller amounts of alcohol and other oxygenated solvents such as glycol ethers or glycols. Alcohols are typically faster while the glycol ethers are the coalescing slower-evaporating solvents.

In a typical water-based aerosol coating, the amount of DME is equivalent to the amount of water, which is approximately 35 percent-by-weight. There is generally 5 percent-by-weight of a secondary alcohol, such as 2-butanol, and 5 percent-by-weight of a glycol ether, such as 2-butoxy-ethanol. The remaining percentage is composed of solids. Thus, the overall reactivity profile of the water-based ROC emissions yields a lower ozone-formation potential.

There are water-based products in four of the general coating categories of aerosol coatings. One hundred percent of these current water-based products would comply with the proposed reactivity limits.

D. Conclusion

This proposal presents a new approach of regulating the emissions from aerosol coating products. Under a mass-based VOC reduction, all VOCs are treated equally in terms of ozone formation potential, or in some cases (exemptions), form so low an amount of ozone that they are not regulated. Therefore, a reactivity-based control strategy could be viewed as a “refinement” of mass-based control approaches. The reactivity-based approach proposed here relies primarily on ROC substitution rather than ROC reduction, yet still preserves the ozone reduction benefits of the previously adopted mass-based VOC limits. A reduction in the total VOC content may not be necessary. By requiring “substitution” rather than “reduction” of ROCs, staff believes that reformulation to meet the reactivity limits, as explained in Chapter XI, Economic Impacts, will be more cost-effective.

Given the wide variety of ROCs available that can serve as propellants and slower or faster evaporating solvents and their wide range in reactivities, staff believes that the proposed reactivity limits are feasible for both solvent-based and water-based aerosol coatings. As was shown in Chapter VII, in almost all categories a significant complying marketshare exists for both solvent-based and water-based aerosol coatings. In fact, for water-based coatings we note that all reported products currently comply with the proposed limits.

REFERENCES

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IX.

Description of Aerosol Coatings Categories and Proposed Reactivity Limits

Included in this chapter is a description of the aerosol coatings categories, with particular emphasis on the six 'general coating' categories and the ground traffic and marking coating category. For each of these seven categories, a brief description of the types of products included is provided. However, product category descriptions for the remaining 28 specialty coatings categories are not included in this report. Interested readers should consult the document titled "Initial Statement of Reasons for a Proposed Statewide Regulation to Reduce the Volatile Organic Compound Emissions from Aerosol Coatings and Amendments to the Alternative Control Plan for Consumer Products" (ARB, 1995) for an in depth discussion of individual product categories.

For all categories, we provide relevant data on numbers of products, sales, volatile organic compound (VOC) emissions, sales-weighted product category maximum incremental reactivity (SWA-MIR$_{prod}$) value, and total ozone formation. Because in these amendments we are proposing to achieve an ozone reduction equivalent to that associated with the previously adopted mass-based VOC limits (ARB, 1998a), we provide the VOC tons per day (tpd) reduction commitment and the corresponding ozone reduction. We also describe the proposed reactivity limits, the number of complying products, and complying marketshares. The general coatings categories and ground traffic marking coating category account for 86 percent of the total ozone formation from aerosol coatings. Together, the remaining 28 specialty coatings account for 14 percent of the total ozone formation.

In this Chapter , there is no detailed discussion on reformulation options. However, general reformulation options were described in Chapter VIII. ARB staff recognizes that an aerosol coatings product is a "package" and simply suggesting a lower reactive solvent for a currently used higher reactive solvent is inappropriate. As described in Chapter VIII, properly formulated aerosol coatings must provide for adequate solvency of the particular resin system and pigments. In addition, a combination of slower and faster evaporating solvents is required to allow for proper film formation once the product is applied. The propellant system must also be able to maintain pressure to expel the entire can contents.

However, even though specific reformulation options are not suggested here, as explained in Chapter VIII, given the wide variety and reactivities of the solvents and propellants available, staff concludes that the proposed limits are feasible. In fact, staff concluded that the proposed reactivity limits provide more reformulation options, at potentially less cost, by not necessarily requiring a reduction in total VOC content, but rather a reduction of the reactivity of the VOCs used (i.e. a reduction in the ozone formed from the VOCs). A further indication of the feasibility of the proposed reactivity limits is included in the following sections where we provide data on complying marketshares and the number of products that would currently comply with the proposed limits.

A. Description of the Seven Major Categories

Before providing a brief description of the six ‘general coating’ categories and the ground traffic and marking coating category, we begin by defining some of the terms used within this chapter. These definitions are reproduced from Chapter III for convenience. It is also important to remember the distinction we are making between VOC and reactive organic compound (ROC). “VOC,” as defined in the mass-based regulation does not include the exempted compounds such as acetone. In our reactivity-based amendments, we are proposing to use the term “ROC” to clarify that all VOCs, including exempt compounds such as acetone, are considered for evaluating products’ reactivities.

Reactivity related terms used in the following tables:

- SWA-MIR_{prod} is the sales-weighted average maximum incremental reactivity of the products reported in an aerosol coatings category.

- SWA-MIR_{VOC} is the sales-weighted average maximum incremental reactivity of the products (SWA-MIR_{prod}) divided by the sales-weighted average VOC content of the product category, as explained in Chapter IV. The SWA-MIR_{VOC} is used to calculate the equivalent ozone reduction. The tpd VOC reduction commitment is based on reductions of VOCs (not including acetone).

- Total Ozone Formation is the potential amount of ozone (reported here in tpd) formed from emissions of the VOCs in the aerosol coatings category.

- Unadjusted Equivalent Ozone Reduction is the equivalent ozone reduction associated with the VOC reduction commitment. The unadjusted ozone reduction is calculated by multiplying the tpd VOC reduction by the SWA-$MIR_{VOC.}$

- Adjusted SWA-MIR_{VOC} is the SWA-MIR_{VOC} adjusted for the mechanistic uncertainty of ingredient MIR values.

- Adjusted Equivalent Ozone Reduction is the ozone reduction calculated by multiplying the tpd VOC reduction commitment by the adjusted SWA-MIR_{VOC}. This is the amount of ozone reduction that needs to be achieved by the proposed reactivity limit.

The data included in this section regarding sales and emissions reflect those reported in the 1997 ARB Aerosol Coatings Survey (ARB, 1998b).

1. Clear Coatings:

Product Category Description

Aerosol clear coatings are general use coatings that are colorless and contain resins, but no pigments or fillers other than flatting agents. Flatting agents (also called flatting pigments), may be included in the formulation to decrease the gloss of a clear coating without adding color to the film (for example to produce a flat, or "satin" clear finish).

Clear coating products are formulated as both solvent-based and water-based formulations. A variety of resin types are used, including alkyds, polyurethanes, acrylic and nitrocellulose lacquers. Although coating properties vary with individual formulations, certain resin types generally yield particular coating characteristics. For instance, polyurethane resins generally yield coatings that are hard and resistant to scratches and abrasion, while acrylic lacquers are known for their resistance to "yellowing."

The aerosol clear coatings category is the sixth largest aerosol coating category in terms of sales and VOC emissions according to the 1997 ARB Aerosol Coatings Survey. The category accounts for approximately five percent of the emissions from aerosol paints. Table IX-1 shows that the clear coatings category has a SWA-MIR$_{prod}$ of 1.66 grams ozone per gram of product. The 0.96 tpd of VOCs emitted from sales of 1.59 tpd of clear coatings (see Table IX-1) have the potential to produce 2.64 tpd of ozone (ARB, 1998b).

TABLE IX-1
CLEAR COATINGS*

Number of Products	Category Sales (tons/day)	VOC Emissions (tons/day)	SWA-MIR$_{prod}$ (g O_3/g product)	SWA-MIR$_{VOC}$ (g O_3/gVOC)	Total Ozone Formation (tons/day)
120	1.59	0.96	1.66	2.75	2.64

* Based on ARB 1997 Aerosol Coatings Survey.

Proposed Reactivity Limit

As shown in Table IX-2, the mass-based VOC reduction commitment is 0.17 tpd. After adjusting for MIR value uncertainty (adjusted SWA-MIR$_{VOC}$), the calculated ozone reduction (i.e. the adjusted equivalent ozone reduction) is 0.52 tpd. To achieve this adjusted ozone reduction commitment, for clear coatings, the proposed reactivity limit is 1.54 grams ozone per gram product.

TABLE IX-2
CLEAR COATINGS PROPOSAL*

VOC Reduction (tons/day)	Adjusted SWA-MIR$_{VOC}$ (gO$_3$/g VOC)	Adjusted Equivalent Ozone Reduction (tons/day)	Reactivity Limit** (g O$_3$/g product)	Number of Complying Products	Complying Market Share (%)
0.17	3.00	0.52	1.54	45	45

* Based on ARB 1997 Aerosol Coatings Survey
** Proposed Effective Date is June 1, 2002.

Table IX-2 also show that there are currently 45 products that comply with the proposed reactivity limit. These 45 clear coating products represent a 45 percent complying marketshare (ARB, 1998b). The 45 products that currently would comply with the proposed limit include both solvent-based and water-based products (ARB, 1998b). In fact, the survey data show that all water-based (formulated with water and dimethyl ether (DME)) clear coatings are currently able to comply with this proposed limit. Given the significant complying marketshare and the variety of solvents available for reformulation, staff concludes that the proposed limit is feasible.

2. Flat Paint Products:

Product Category Description:

Flat aerosol coating products are aerosol coatings with a low gloss level, as described below, or products that are labeled as flat coatings, whether or not they meet the gloss level criterion for a flat coating. Flat aerosol coating products are primarily general use aerosol coatings that do not fall under one of the other coating categories. However, special-use flat paints would also fall under the flat paint category.

A coating must register a specular gloss level that is less than or equal to 15 on an 85^o meter, or less than or equal to 5 on a 60^o meter, to qualify as a “flat.” The gloss level is measured by a special gloss meter which measures the amount of light reflected off the coating specimen. The gloss meter consists of a light source that directs a beam at the coating and measures the reflected light in the mirror direction. The degree of the angle used to describe the meter (e.g. 85^o meter) refers to the angle of the light beam which is reflected off the coating surface. The gloss value is a relative value compared to a known standard such as black glass.

Flat aerosol coating formulations vary with the intended use of the product, cost, and the individual color. One of the key components of the formulation, in terms of its effect on the properties of the dried paint film, is the resin. There are several types of resins that are used in flat aerosol paints. These include alkyds, acrylic and nitrocellulose lacquers, epoxies, polyurethanes, and various combinations of these resins. Alkyd resins are used most often and are usually “modified” with chemical groups which enhance particular properties such as drying time or hardness.

The flat aerosol coating category is the fourth largest aerosol paint category in terms of sales, and the fifth largest category in terms of VOC emissions. The category accounts for approximately eight percent of the emissions from aerosol paints. Table IX-3 shows that flat paint products category has a SWA-MIR$_{prod}$ of 1.52 grams ozone per gram of product. The 1.54 tpd of VOCs emitted from sales of 3.04 tpd of flat paint products (see Table IX-3) have the potential to produce 4.62 tpd of ozone (ARB, 1998b).

TABLE IX-3
FLAT PAINT PRODUCTS*

Number of Products	Category Sales (tons/day)	VOC Emissions (tons/day)	SWA-MIR$_{prod}$ (g O_3/g product)	SWA-MIR$_{VOC}$ (gO_3/gVOC)	Total Ozone Formation (tons/day)
117	3.04	1.54	1.52	3.00	4.62

* Based on ARB 1997 Aerosol Coatings Survey.

Proposed Reactivity Limit

As shown in Table IX-4, the mass-based VOC reduction commitment is 0.33 tpd. After adjusting for MIR value uncertainty (adjusted SWA-MIR$_{VOC}$), the calculated ozone reduction (i.e. adjusted equivalent ozone reduction) is 1.06 tpd. To achieve this adjusted ozone reduction commitment, for flat paint products, the proposed reactivity limit is 1.21 grams ozone per gram product.

TABLE IX-4
FLAT PAINT PRODUCTS PROPOSAL*

VOC Reduction (tons/day)	Adjusted SWA-MIR$_{VOC}$ (gO_3/g VOC)	Adjusted Equivalent Ozone Reduction (tons/day)	Reactivity Limit** (g O_3/g product)	Number of Complying Products	Complying Market Share (%)
0.33	3.21	1.06	1.21	26	11

* Based on ARB 1997 Aerosol Coatings Survey.
** Proposed Effective Date is June 1, 2002.

Table IX-4 also show that there are currently 26 products that comply with the proposed reactivity limit. These 26 flat paint products represent a complying marketshare of 11 percent (ARB, 1998b). The 26 products that currently would comply with the proposed limit include both solvent-based and water-based products (ARB, 1998b). In fact, the survey data show that all water-based (formulated with water and DME) flat paint products are currently able to comply with this proposed limit. Given the reasonable complying marketshare and the variety of solvents available for reformulation, staff concludes that the proposed limit is feasible.

3. Fluorescent Coatings:

Product Category Description:

Fluorescent coatings are highly visible coatings which convert absorbed incident light energy into emitted light of a different hue. Ambient light contains electromagnetic radiation, including the short wavelength, high energy, nonvisible light known as ultraviolet (UV) radiation, the longer wavelength visible light, and the even longer wavelength, lower energy, nonvisible infrared radiation. The visible region contains the spectrum of colors ranging through violet, indigo, blue, green, yellow, orange and red. The dyes in fluorescent coatings absorb light in the UV and visible regions and emit it in a narrow range of longer wavelengths in the visible region. This light, when added to the normally reflected light, gives articles their color and makes them appear to glow in the daylight.

Fluorescent coatings are used for decorative purposes, as marking paints for construction and surveying, for safety uses, and in "upside-down" ground marking or striping paints. However, it should be noted that upside-down marking paints, whether fluorescent or not, fall under the ground traffic marking paint coating category rather than the fluorescent coating category.

The dyes used in fluorescent coatings provide the fluorescent quality of the coating, while the resin (acrylic or alkyd) acts as a binder and helps contribute to the color stability of the product. Fluorescent pigments used in aerosol paints are made by incorporating fluorescent dyes into an insoluble matrix, which is then ground to the desired particle size (Radiant Color).

Fluorescent paints are not used as protective coatings. The intense color of the coating is relatively short lived, as the pigments show poor durability in paint and fade quickly. Fluorescent coatings are low gloss and the resins in solvent-borne coatings are usually acrylic lacquers. Resins used in water-borne coatings include water reducible alkyds.

The aerosol fluorescent coatings category is the eleventh largest aerosol paint category in terms of sales and VOC emissions according to the 1997 ARB Aerosol Coatings Survey (ARB, 1998b). The category accounts for approximately one percent of the emissions from aerosol paints. Table IX-5 shows that the fluorescent coatings category has a SWA-MIR$_{prod}$ of 1.63 grams ozone per gram of product. The 0.24 tpd of VOCs emitted from sales of 0.36 tpd of fluorescent coatings (see Table IX-5) have the potential to produce 0.59 tpd of ozone (ARB, 1998b).

TABLE IX-5
FLUORESCENT COATINGS*

Number of Products	Category Sales (tons/day)	VOC Emissions (tons/day)	SWA-MIR$_{prod}$ (g O_3/g product)	SWA-MIR$_{VOC}$ (gO_3/gVOC)	Total Ozone Formation (tons/day)
51	0.36	0.24	1.63	2.45	0.59

* Based on ARB 1997 Aerosol Coatings Survey.

Proposed Reactivity Limit

As shown in Table IX-6, the mass-based VOC reduction commitment is 0.03 tpd. After adjusting for MIR value uncertainty (adjusted SWA-MIR$_{VOC}$), the adjusted ozone reduction is 0.07 tpd. To achieve this adjusted ozone reduction commitment, for fluorescent coatings, the proposed reactivity limit is 1.77 grams ozone per gram product.

TABLE IX-6
FLUORESCENT COATINGS PROPOSAL*

VOC Reduction (tons/day)	Adjusted SWA-MIR$_{VOC}$ (gO$_3$/g VOC)	Adjusted Equivalent Ozone Reduction (tons/day)	Reactivity Limit** (g O$_3$/g product)	Number of Complying Products	Complying Market Share (%)
0.03	2.63	0.07	1.77	44	64

* Based on ARB 1997 Aerosol Coatings Survey.
** Proposed Effective Date is June 1, 2002.

Table IX-6 also show that there are currently 44 products that comply with the proposed reactivity limit. These 44 fluorescent coatings represent a complying marketshare of 64 percent (ARB, 1998b). Given the significant complying marketshare and the variety of solvents available for reformulation, staff concludes that the proposed limit is feasible.

4. Metallic Coatings:

Product Category Description:

Metallic coatings are defined as topcoats which contain at least 0.5 percent elemental metallic pigment by weight and are labeled as “metallic,” or with the name of a specific metallic finish such as “gold,” “silver,” or “bronze.” Metallic coatings are defined as coatings containing at least 0.5 percent elemental metallic pigment because most metallic coatings have a metallic pigment content above this level. Below this level, coatings may have appearances more like a typical nonflat coating.

There are two forms of metallic coatings. One form, the “leafing” metallics, contain elemental metal as the sole pigment in the coating. Leafing refers to the distribution of the metallic pigment within the coating. In leafing pigments, the metallic pigment is carried to the surface of the paint film during drying and gives the appearance of an almost continuous film of metal. These coatings are designed to create the impression that the object coated is composed of gold, silver, brass, copper or aluminum.

The second form of metallic coating is known as “nonleafing.” In nonleafing paints the metallic pigments do not form a continuous metallic layer on the surface of the coating. Rather, they are distributed within the paint film and produce a polychrome effect, when used in conjunction with semi-transparent colored pigments. The metallic pigment contained within the semi-transparent color causes the coating to sparkle. These colored metallics are often formulated to exactly match automobile finishes, and therefore fall into the exact match category. However, there are some nonleafing metallics that are not formulated as exact match coatings. If these coatings have an elemental metallic pigment content greater than 0.5 percent, and are labeled “metallic,” or with the name of a specific metallic finish such as “gold,” “silver,” or “bronze,” then they are categorized as metallics. Otherwise, they fall under the general flat or nonflat coatings.

As mentioned in the section on primers, “zinc-rich primers” (also called “galvanizing coatings”) may contain greater than 0.5 percent elemental metallic pigment, but are not classified as “metallic” coatings because they are not labeled “metallic,” or with the name of a specific metallic finish. These coatings are used for rust prevention and are very different from the decorative topcoats in the metallic category.

Metallic coating formulations are essentially all solvent-based formulations which differ from other types of aerosol paints in that the primary or sole pigment is elemental metal, rather than the standard colored pigments. Manufacturers of leafing metallics achieve the leafing effect by coating the metallic pigments with stearic acid, which serves as a lubricant to aid in bringing the metallic flake to the surface of the coating. Copper metallics are formulated using 100 percent copper, while bronze, brass and gold metallics are prepared by varying the ratios of copper and zinc in the metallic alloy pigment. Since copper tarnishes upon weathering, copper metallics and those metallics made with copper alloy pigments are not durable and are used primarily for interior applications. However, aluminum metallics have excellent durability and can be used for interior and exterior applications.

Metallic coatings are a significant segment of the aerosol paint market, as they are the fifth largest category in terms of sales and the fourth largest in terms of VOC emissions according to the 1997 Aerosol Coatings Survey. The category accounts for approximately nine percent of the emissions from aerosol paints. Table IX-7 shows that the metallic coatings category has a SWA-MIR$_{prod}$ of 2.09 grams ozone per gram of product. The 1.65 tpd of VOCs emitted from sales of 2.33 tpd of metallic coatings (see Table IX-7) have the potential to produce 4.87 tpd of ozone (ARB, 1998b).

TABLE IX-7
METALLIC COATINGS*

Number of Products	Category Sales (tons/day)	VOC Emissions (tons/day)	SWA-MIR$_{prod}$ (g O_3/g product)	SWA-MIR$_{VOC}$ (gO_3/gVOC)	Total Ozone Formation (tons/day)
162	2.33	1.65	2.09	2.95	4.87

* Based on ARB 1997 Aerosol Coatings Survey.

Proposed Reactivity Limit

As shown in Table IX-8, the mass-based VOC reduction commitment is 0.21 tpd. After adjusting for MIR value uncertainty (adjusted SWA-MIR$_{VOC}$), the adjusted ozone reduction is

0.66 tpd. To achieve this adjusted ozone reduction commitment, for metallic coatings, the proposed reactivity limit is 1.93 grams ozone per gram product.

TABLE IX-8
METALLIC COATINGS PROPOSAL*

VOC Reduction (tons/day)	Adjusted SWA-MIR$_{VOC}$ (gO$_3$/g VOC)	Adjusted Equivalent Ozone Reduction (tons/day)	Reactivity Limit** (g O$_3$/g product)	Number of Complying Products	Complying Market Share (%)
0.21	3.07	0.66	1.93	54	27

*   Based on ARB 1997 Aerosol Coatings Survey.
** Proposed Effective Date is June 1, 2002.

Table IX-8 also show that there are currently 54 products that comply with the proposed reactivity limit. These 54 metallic coatings represent a complying marketshare of 27 percent (ARB, 1998b). Given the significant complying marketshare and the variety of solvents available for reformulation, staff concludes that the proposed limit is feasible.

5. <u>Non-Flat Paints</u>:

<u>Product Category Description</u>:

Non-flat (or gloss) aerosol coating products are aerosol coatings with a specular gloss level greater than 15 on an 85° meter, or greater than 5 on a 60° meter (see the section on flat paint products for a description of gloss measurements). Aerosol paints labeled as “high gloss” paints do not qualify as non-flat unless the gloss criteria listed above are met. Non-flat aerosol paint products are primarily general use aerosol paints that do not fall under one of the other coating categories. However, special-use non-flat paints that exhibit the gloss level specified above, and do not fall under one of the other coating categories in the regulation, would also fall under the non-flat paint category.

Non-flat aerosol paints are primarily general-use products employed for a wide variety of purposes where a glossy finish is desired. Some typical uses include protecting objects from rust and corrosion, “touching-up” finishes, and coating small objects or objects that would be hard to coat with a brush, such as wicker. Some are sold as general, all-purpose products, while others have specific qualities such as rust protection, unique decorator colors, water-borne formulas, specific resin types, such as epoxies or polyurethanes, or quick dry times.

Non-flat aerosol paint formulations are very similar to the formulations of flat aerosol paint products, as discussed previously. However, non-flat paints have a higher concentration of resin relative to the total paint solids content. This higher concentration of resin gives non-flat paints higher gloss than flat paint products. The higher concentration of resin may also account for the somewhat higher VOC levels and lower total solids levels relative to non-flat aerosol paints, since resins contribute greater viscosity to paint formulations than other paint solids.

The non-flat aerosol paint category is by far the largest category of aerosol paints with respect to sales and emissions according to the 1997 ARB Aerosol Coatings Survey. The category accounts for approximately 44 percent of the emissions from aerosol paints. Table IX-9 shows that the non-flat paints category has a SWA-MIR$_{prod}$ of 1.62 grams ozone per gram of product. The 8.13 tpd of VOCs emitted from sales of 15.13 tpd of non-flat coatings (see Table IX-9) have the potential to produce 24.51 tpd of ozone (ARB, 1998b).

TABLE IX-9
NON-FLAT PAINTS*

Number of Products	Category Sales (tons/day)	VOC Emissions (tons/day)	SWA-MIR$_{prod}$ (g O_3/g product)	SWA-MIR$_{VOC}$ (gO_3/gVOC)	Total Ozone Formation (tons/day)
805	15.13	8.13	1.62	3.01	24.51

* Based on ARB 1997 Aerosol Coatings Survey.

Proposed Reactivity Limit

As shown in Table IX-10, the mass-based VOC reduction commitment is 1.37 tpd. After adjusting for MIR value uncertainty (adjusted SWA-MIR$_{VOC}$), the adjusted ozone reduction is 4.46 tpd. To achieve this adjusted ozone reduction commitment, for non-flat paints, the proposed Reactivity limit is 1.40 grams ozone per gram product.

TABLE IX-10
NON-FLAT PAINTS PROPOSAL*

VOC Reduction (tons/day)	Adjusted SWA-MIR$_{VOC}$ (gO_3/g VOC)	Adjusted Equivalent Ozone Reduction (tons/day)	Reactivity Limit** (g O_3/g product)	Number of Complying Products	Complying Market Share (%)
1.37	3.26	4.46	1.40	302	36

* Based on ARB 1997 Aerosol Coatings Survey.
** Proposed Effective Date is June 1, 2002.

Table IX-10 also show that there are currently 302 products that comply with the proposed reactivity limit. These 302 non-flat paint products represent a complying marketshare of 36 percent (ARB, 1998b). The 302 products that currently would comply with the proposed limit include both solvent-based and water-based products (ARB, 1998b). In fact, the survey data show that all water-based (formulated with water and DME) non-flat paints are currently able to comply with this proposed limit. Given the significant complying marketshare and the variety of solvents available for reformulation, staff concludes that the proposed limit is feasible.

6. Primer Coatings:

Product Category Description:

A primer is a coating formulated to be applied to a surface to provide a bond between that surface and subsequent coats. As such, primers contribute to the overall effectiveness of an entire coating system. Primers bond the substrate to subsequent coatings by providing a rough, slightly porous surface which adheres to both slick surfaces and glossy topcoats. An aerosol paint must be labeled as a “primer” to fall under this category.

Due to differences in formulation and function, auto body primers are specifically excluded from the general primer category. General primers reportedly cannot be topcoated with automotive topcoats because the solvents in these topcoats will cause “lifting” of general purpose primers.

Primers can fulfill a variety of functions. Depending on the type of product, primers must be able to protect against deterioration such as flaking, peeling, blistering, and corrosion from chemicals and environmental conditions. Primers can also help fill and level irregular substrates prior to subsequent coats such as basecoats or topcoats. In addition, primers can provide good hiding power for subsequent recoating of a substrate.

Primers are formulated similar to flat paint products. General primers often utilize some type of modified alkyd resin system and often have a higher solids content compared with other coatings to provide better hiding and build. Some primers with specialized functions have unique formulations. For example, zinc-rich primers (or galvanizing coatings) are generally very high solids formulations containing zinc pigments. These primers can provide protection against corrosion for iron or steel surfaces.

The primer coating category is the second largest category in terms of sales and emissions according to the 1997 ARB Aerosol Coatings Survey. The category accounts for approximately 10 percent of the emissions from aerosol paints. Table IX-11 shows that the primer coatings category has a SWA-MIR$_{prod}$ of 1.33 grams ozone per gram of product. The 1.82 tpd of VOCs emitted from sales of 3.56 tpd of primer coatings (see Table IX-11) have the potential to produce 4.73 tpd of ozone (ARB, 1998b)

TABLE IX-11
PRIMER COATINGS*

Number of Products	Category Sales (tons/day)	VOC Emissions (tons/day)	SWA-MIR$_{prod}$ (g O_3/g product)	SWA-MIR$_{VOC}$ (gO_3/gVOC)	Total Ozone Formation (tons/day)
153	3.56	1.82	1.33	2.60	4.73

* Based on ARB 1997 Aerosol Coatings Survey.

Proposed Reactivity Limit

As shown in Table IX-12, the mass-based VOC reduction commitment is 0.41 tpd. After adjusting for MIR value uncertainty (adjusted SWA-MIR_{VOC}), the adjusted ozone reduction is 1.13 tpd. To achieve this adjusted ozone reduction commitment, for primer coatings, the proposed reactivity limit is 1.11 grams ozone per gram product.

TABLE IX-12
PRIMER COATINGS PROPOSAL*

VOC Reduction (tons/day)	Adjusted SWA-MIR_{VOC} (gO_3/g VOC)	Adjusted Equivalent Ozone Reduction (tons/day)	Reactivity Limit** (g O_3/g product)	Number of Complying Products	Complying Market Share (%)
0.41	2.77	1.13	1.11	31	29

* Based on ARB 1997 Aerosol Coatings Survey.
** Proposed Effective Date is June 1, 2002.

Table IX-12 also show that there are currently 31 products that comply with the proposed reactivity limit. These 31 primer coating products represent a complying marketshare of 29 percent (ARB, 1998b). Given the significant complying marketshare and the variety of solvents available for reformulation, staff concludes that the proposed limit is feasible.

7. Ground Traffic/Marking Paints:

Product Category Description:

Ground traffic or marking paints are used to apply striping or marking to outdoor surfaces such as streets, golf courses, parking lots, athletic fields, and construction sites. Paints included in this category are often labeled as traffic paints, marking paints, athletic paints, and marking chalk. The individual names refer to the applications for which the products were designed. As an example, traffic paint is designed to give long-lasting marking of traffic lanes or parking lots, whereas athletic paint is primarily for temporary use at recreational sites such as golf courses or soccer fields. All of these paints are commonly referred to as “upside-down” paints because they are applied in an inverted spray position. Unlike “regular” spray paints, upside-down spray paints do not have a dip tube. Lack of a dip tube allows for the inverted spray position. All upside-down paints can be applied either by hand or with a striping machine, a simple pushing device that allows accurate striping of surfaces and has an adjustable spray width. Traffic and other marking paints come in many different colors, including fluorescent colors, and are available as water- and solvent-based formulations.

Ground traffic or marking paints are used by utility locators, forestry workers, landscapers, contractors, surveyors, and others whose work requires marking of surfaces or objects. Upside-down paints can be applied to a variety of surfaces including asphalt, concrete, steel, grass, soil, wood and other surfaces. Depending upon the purpose of the marking and the type of surface, the applicator needs to choose a suitable upside-down paint. For example, applying traffic striping on high traffic concrete or asphalt streets requires a paint that withstands the wear from tires, rain, sun, and other environmental factors for a considerable period of time. A product used for the striping of a soccer field, on the other hand, may only need to last several weeks or months and should be formulated to not harm the grass or turf upon which it is applied. Generally speaking, paints marked as traffic paints are for more permanent applications whereas marking and athletic stripe paints or chalks are chosen for more temporary jobs, such as the marking of power cables or gas lines at a construction side or the outlines of a landscape design. Although they are typically used for less permanent markings, athletic and marking paints often have to withstand environmental factors such as rain and sun for several months.

Ground traffic or marking paints are available as solvent-based and water-based formulations, and as fluorescent and nonfluorescent paints. Water-based traffic and marking paint can be formulated as emulsions (using hydrocarbon propellants), or as solutions (using dimethyl ether propellant). For a description of fluorescent paints, please refer to the "fluorescent paint" category discussion in this chapter. Ground traffic marking paints are typically high in solids to prevent them from being absorbed into porous substrates.

The ground traffic/marking paints category is the third largest aerosol paint category in terms of sales and VOC emissions according to the 1997 ARB Aerosol Coatings Survey. The category accounts for approximately nine percent of the emissions from aerosol paints. Table IX-13 shows that ground traffic/marking paints category has a SWA-MIR$_{prod}$ of 1.35 grams ozone per gram of product. The 1.70 tpd of VOCs emitted from sales of 3.2 tpd of ground traffic/marking paints (see Table IX-13) have the potential to produce 4.32 tpd of ozone (ARB 1998b).

TABLE IX-13
GROUND TRAFFIC/MARKING PAINTS*

Number of Products	Category Sales (tons/day)	VOC Emissions (tons/day)	SWA-MIR$_{prod}$ (g O_3/g product)	SWA-MIR$_{VOC}$ (gO_3/gVOC)	Total Ozone Formation (tons/day)
111	3.20	1.70	1.35	2.55	4.32

* Based on ARB 1997 Aerosol Coatings Survey.

Proposed Reactivity Limit

As shown in Table IX-14, the mass-based VOC reduction commitment is 0.28 tpd. After adjusting for MIR value uncertainty (adjusted SWA-MIR$_{VOC}$), the adjusted ozone reduction is 0.78 tpd. To achieve this adjusted ozone reduction commitment, for ground traffic/marking paints, the proposed reactivity limit is 1.18 grams ozone per gram product.

TABLE IX-14
GROUND TRAFFIC/MARKING PAINTS PROPOSAL*

VOC Reduction (tons/day)	Adjusted SWA-MIR$_{VOC}$ (gO$_3$/g VOC)	Adjusted Equivalent Ozone Reduction (tons/day)	Reactivity Limit** (g O$_3$/g product)	Number of Complying Products	Complying Market Share (%)
0.28	2.78	0.78	1.18	64	24

* Based on ARB 1997 Aerosol Coatings Survey.
** Proposed Effective Date is January 1, 2003.

Table IX-14 also show that there are currently 64 products that comply with the proposed reactivity limit. These 64 ground traffic/marking paints products represent a complying marketshare of 24 percent (ARB, 1998b). Given the significant complying marketshare and the variety of solvents available for reformulation, staff concludes that the proposed limit is feasible.

B. Description of Remaining Specialty Categories

Product Category Description:

Table IX-15 summarizes the following information for each of the remaining 28 aerosol specialty coating categories as reported in the ARB Aerosol Coating Survey:

- the number of products;
- the sales (in tpd);
- the VOC emissions (in tpd);
- the sales-weighted average MIR, for the product category;
- the sales-weighted average MIR of the VOCs ; and
- the ozone formation potential.

The 28 specialty coating categories shown in Table IX-15 account for about 14 percent of the total emissions from aerosol paints. As shown in Table IX-15, the VOC emissions from many of these categories are very small. To maintain the confidentiality of proprietary data, we do not provide the estimated sales and emissions for categories with fewer than four products reported in the survey. We do not discuss each of these 28 categories in detail as we did with the seven categories in the previous section . However, detailed discussions of each of these categories (including product description, use, marketing, and formulation) are provided in the ARB staff report entitled "Initial Statement of Reasons for a Proposed Statewide Regulation to Reduce Volatile Organic Compound Emissions from Aerosol Coating Products and Amendments to the Alternative Control Plan Regulation for Consumer Products," February 3, 1995 (ARB, 1995).

TABLE IX-15
EMISSIONS SUMMARY FOR 28 SPECIALTY CATEGORIES*

Category	Number of Products	Category Sales (tons/day)	VOC Emissions (tons/day)	SWA-MIR$_{prod}$ (g O_3/g product)	SWA-MIR$_{VOC}$ (g O_3/g VOC)	Total Ozone Formation (tons/day)
Art Fixatives or Sealants	15	0.33	0.23	1.56	2.24	0.51
Auto Body Primers	19	0.50	0.25	1.69	3.35	0.85
Automotive Bumpers & Trim Products	70	0.35	0.30	1.59	1.89	0.56
Aviation or Marine Primers	< 10	**	**	**	**	**
Aviation Propeller Coatings	< 10	**	**	**	**	**
Corrosion Resistant Brass, Bronze, or Copper Coatings	< 10	**	**	**	**	**
Exact Match Finishes, Engine Enamel	29	0.38	0.18	1.52	3.13	0.58
Exact Match Finishes, Automotive	316	0.72	0.39	1.68	3.11	1.21
Exact Match Finishes, Industrial	32	0.14	0.07	1.18	2.50	0.17
Floral Sprays	16	0.55	0.23	0.78	1.84	0.43
Glass Coatings	4	**	**	**	**	**
High Temperature Coatings	65	0.70	0.48	2.04	3.01	1.43
Hobby/Model/Craft Coatings, Enamel	34	0.15	0.10	1.10	1.59	0.17
Hobby/Model/Craft Coatings, Lacquer	5	0.01	<0.01	2.48	3.37	0.02
Hobby/Model/Craft Coatings, Clear or Metallic	17	0.14	0.11	1.56	2.00	0.22
Marine Spar Varnishes	< 10	**	**	**	**	**
Photograph Coatings	< 10	**	**	**	**	**
Pleasure Craft Finish Primers/Surfacers/Undercoaters	< 10	**	**	**	**	**
Pleasure Craft Topcoats	< 10	**	**	**	**	**
Shellac Sealers, Clear	< 10	**	**	**	**	**
Shellac Sealers, Pigmented	< 10	**	**	**	**	**
Slip-Resistant Coatings	7	0.01	0.01	1.15	2.82	0.01
Spatter/Multicolor Coatings	22	0.21	0.10	0.77	1.56	0.16
Vinyl/Fabric/Leather/Polycarbonate	20	0.33	0.25	1.67	2.27	0.55
Webbing/Veiling Coatings	4	**	**	**	**	**
Weld-Through Primers	8	0.05	0.02	1.16	2.49	0.06
Wood Stains	4	**	**	**	**	**
Wood Touch-Up/Repair/ Restoration Coatings	<10	**	**	**	**	**
Total	710	5.06	2.96	1.45***	2.48***	7.34

* Based on ARB 1997 Aerosol Coatings Survey.

** Information not provided to protect confidentiality of proprietary information.

*** Calculated value based on total ozone formation, VOC emissions, and sales data.

Proposed Reactivity Limits and Compliance:

Table IX-16 summarizes the following information for each of the remaining 28 aerosol specialty coating categories:

- VOC reduction commitment in tpd;
- the adjusted sales-weighted average MIR value using the data reported in the ARB Aerosol Coatings survey;
- the adjusted ozone reduction in tpd;
- the proposed January 1, 2003, reactivity limits;
- number of products that comply with the proposed January 1, 2003, limits using the data reported in the ARB Aerosol Coatings Survey; and
- complying market share at the proposed limits using the data reported in the ARB Aerosol Coatings survey.

TABLE IX-16
PROPOSED REACTIVITY LIMITS AND COMPLIANCE FOR 28 SPECIALTY CATEGORIES*

Category	VOC Reduction (tons/day)	Adjusted SWA-MIR$_{VOC}$ (gO_3/g VOC)	Adjusted Equivalent Ozone Reduction (tons/day)	Reactivity Limit** (g O_3/g product)	Number of Complying Products	Complying Market Share (%)
Art Fixatives or Sealants	0.04	2.35	0.10	1.80	7	47
Auto Body Primers	0.04	3.62	0.13	1.57	12	64
Automotive Bumpers and Trim Products	0.04	1.97	0.08	1.75	34	73
Aviation or Marine Primers	0.00	3.28	0.00	1.98	< 10	100
Aviation Propeller Coatings	0.00	2.76	0.00	2.47	< 10	100
Corrosion Resistant Brass, Bronze, or Copper Coatings	<0.01	2.83	0.00	1.78	0	0
Exact Match Finishes: Engine Enamel	0.01	3.42	0.04	1.72	8	72
Exact Match Finishes: Automotive	0.04	3.17	0.14	1.77	276	62
Exact Match Finishes: Industrial	<0.01	2.67	0.00	2.07	30	99
Floral Sprays	0.01	1.95	0.01	1.68	13	87

* Proposed effective date for speciality coating is January 1, 2003.

TABLE IX-16 (Continued)
PROPOSED REACTIVITY LIMITS AND COMPLIANCE FOR 28 SPECIALTY CATEGORIES*

Category	VOC Reduction (tons/day)	Adjusted SWA-MIR$_{VOC}$ (gO_3/g VOC)	Adjusted Equivalent Ozone Reduction (tons/day)	Reactivity Limit** (g O_3/g product)	Number of Complying Products	Complying Market Share (%)
Glass Coatings	<0.01	2.49	0.00	1.42	0	0
High Temperature Coatings	0.07	3.15	0.22	1.83	28	42
Hobby/Model/Craft Coatings: Enamel	<0.01	1.73	0.01	1.47	32	94
Hobby/Model/Craft Coatings: Lacquer	<0.01	3.65	< 0.01	2.70	< 10	60
Hobby/Model/Craft Coatings: Clear or Metallic	<0.01	2.13	0.02	1.60	13	34
Marine Spar Varnishes	0.00	1.90	< 0.01	0.87	< 10	100
Photograph Coatings	<0.01	1.31	< 0.01	0.99	< 10	39
Pleasure Craft Finish Primers/Surfacers/ Undercoaters	0.00	2.10	0.00	1.05	< 10	100
Pleasure Craft Topcoats	0.00	0.62	0.00	0.59	< 10	100
Shellac Sealers: Clear	0.00	1.71	0.00	0.98	< 10	100
Shellac Sealers: Pigmented	0.00	1.89	0.00	0.94	< 10	100
Slip-Resistant Coatings	0.00	2.89	0.00	2.41	7	100
Spatter/Multicolor Coatings	<0.01	1.74	< 0.01	1.07	12	89
Vinyl/Fabric/Leather/ Polycarbonate	0.03	2.34	0.08	1.54	16	31
Webbing/Veiling Coatings	0.00	1.03	0.00	0.83	< 10	100
Weld-Through Primers	<0.01	2.55	0.01	0.98	< 10	67
Wood Stains	0.00	1.71	0.00	1.38	< 10	100
Wood touch-Up/Repair/Restoration Coatings	<0.01	1.38	< 0.01	1.49	< 10	> 90
Total	0.31	N/A	0.86	N/A	N/A	N/A

* Proposed effective date for speciality coating is January 1, 2003.

We believe the proposed reactivity limits for many of these categories may function as a cap, and will require less reformulation efforts than the seven larger categories mentioned previously. Given the high complying marketshares in almost all categories, staff concludes that the proposed reactivity limits are feasible.

REFERENCES

ARB. (1995), Initial Statement of Reasons for a Proposed Statewide Regulation to Reduce the Volatile Organic Compound Emissions from Aerosol Coatings and Amendments to the Alternative Control Plan for Consumer Products. February 3, 1995.

ARB. (1998a), Initial Statement of Reasons for the Proposed Amendments to the Regulations for Reducing Volatile Organic Compound Emissions from Aerosol Coatings, Antiperspirants and Deodorants, and Consumer Products. October 2, 1998.

ARB. (1998b) Air Resources Board Aerosol Coatings Survey. November 25, 1997.

Radiant Color. Telephone conversation with ARB staff. May 18, 1998. (Radiant Color)

X.

Environmental Impacts

A. Summary of Environmental Impacts

In this rulemaking, we are proposing to amend both the Aerosol Coatings Regulation and Air Resources Board (ARB) Method 310 "Determination of Volatile Organic Compounds (VOCs) in Consumer Products." To support the implementation of the proposal, Tables of MIR values would be contained in proposed new Subchapter 8.6. However, the ARB staff is only focusing on the potential environmental impacts of the proposed amendments to the Aerosol Coating Regulation. This is because the amendments to ARB Method 310 and the MIR Tables are based on existing scientific information and would not themselves impose any requirements leading to a physical change in the environment. Overall, the result of this analysis shows that, upon full implementation, the proposed rulemaking would have neither a positive nor adverse environmental impact. This is because staff is proposing to replace existing VOC content limits for aerosol coatings with reactivity-based VOC limits that achieve an equivalent air quality benefit. Therefore, the proposal would achieve the same ozone reduction benefit as would have been associated with implementation of the mass-based VOC limits. The mass-based VOC limits adopted by the Board on November 19, 1998, would reduce VOC emissions by about 3.1 tons per day (tpd). These proposed amendments would reduce the ozone formed from aerosol coating emissions by about 9.6 tpd.

Staff has identified a short-term negative environmental impact of the proposed amendments, a temporary ozone shortfall totaling 9.6 tpd. Under this proposal, aerosol coating manufacturers would have an additional five months, until June 1, 2002, to comply with the "general coating" category limits. At that time 7.9 tpd ozone reductions would be achieved. A smaller negative impact would continue for another seven months (1.7 tpd ozone shortfall), until January 1, 2003, when the remaining 29 "specialty coating" categories would comply. However, we believe this additional time is warranted to allow manufacturers the needed time to reformulate consumer-acceptable products. We also believe that the need to ensure viable products are available in the marketplace overrides the short-term negative environmental impact.

Reductions in particulate matter with aerodynamic diameters less than 2.5 micrometers are also anticipated to be similar to those expected from implementation of the mass-based VOC limits. Potential impacts on global warming, stratospheric ozone depletion, and water quality and landfill loading were also considered. No significant negative impacts were identified. We also examined the possibility of increased use of toxics. While we did find that there was a slight chance for an adverse impact due to the use of the toxic air contaminant, methylene chloride, we are proposing a provision that should eliminate this potential impact. The environmental analysis in Sections D, and E below discusses the impacts associated with the proposed rulemaking and provides the basis for our findings.

B. Legal Requirements Applicable to the Analysis

The California Environmental Quality Act (CEQA) and ARB policy require an analysis to determine the potential adverse environmental impacts of proposed regulations. Because the ARB's program involving the adoption of regulations has been certified by the Secretary of Resources (Public Resources Code, Section 21080.5, Exemption of specified regulatory programs), the CEQA environmental analysis requirements are allowed to be included in the ARB Staff Report or Technical Support Document in lieu of preparing an environmental impact report or negative declaration. In addition, the ARB will respond in writing to all significant environmental points raised by the public during the public review period or at the Board hearing. These responses will be contained in the Final Statement of Reasons for the proposed rulemaking for aerosol coating products.

Public Resources Code Section 21159 (Analysis of methods of compliance) requires that the environmental impact analysis conducted by ARB include the following: (1) an analysis of the reasonably foreseeable environmental impacts of the methods of compliance, (2) an analysis of reasonably foreseeable feasible mitigation measures, and (3) an analysis of reasonably foreseeable alternative means of compliance with the rule or regulation.

Our analysis of the reasonably foreseeable environmental impacts of the methods of compliance is presented in Sections D and E below. Except for a slight chance for an adverse impact due to the use of the toxic air contaminant, methylene chloride, in the proposed amendments, no significant adverse environmental impacts associated with the proposed rulemaking were identified. While there is a potential impact from the use of methylene chloride, we are proposing a provision that should eliminate this potential impact. We will also continue to monitor implementation of the amendments to ensure that no other adverse impacts occur in the future.

C. Compliance Alternatives

Alternative means to comply with the Aerosol Coatings Regulation, which limits total VOC content on a weight basis have been studied. To provide alternatives to these mass-based VOC limits, staff has been working with the consumer products industry since 1995 to develop alternative methods of compliance that could achieve equivalent air quality benefits, yet provide compliance flexibility at potentially less cost. As a result, an optional reactivity-based VOC regulatory program was initiated. However, during development of the voluntary reactivity regulation proposal, staff and several representatives of the aerosol coating industry came to the conclusion that it was preferable to pursue replacing the VOC content limits with mandatory reactivity-based VOC limits. In reaching this conclusion, the industry representatives indicated that reactivity-based VOC limits may provide more flexibility, while efficiently reducing the ozone formed from aerosol coatings. At the same time, the analysis conducted by ARB staff indicated that it would be difficult to preserve the ozone reduction associated with the mass-based regulation using a combined mass and reactivity based regulatory program. The analysis is detailed as follows.

Reactivity control approaches have the potential to be more cost-effective in protecting air quality because the ozone formation potential of each chemical is evaluated. In theory, a combined mass and reactivity (i.e. voluntary reactivity) based control approach would achieve the same air quality benefit as if there was only a mass-based control measure. However, a hidden problem in the optional reactivity-based regulation is that a product using the mass-based versus reactivity-based reformulation paths may not yield the same ozone reduction, and any lesser ozone reduction from the reactivity control would constitute a shortfall. In addition, it is difficult to predict the preference of a manufacturer to choose reactivity over the mass-based compliance path (or vice versa). Any shortfall potentially created could only be remedied by imposing more stringent reactivity limits for the remaining products. Given this unpredictability, creating a usable voluntary reactivity program while preserving the air quality benefit may not be possible. This concept is further illustrated in the Figure below.

Figure X-1 shows the impact of the reactivity compliance option to the target ozone reduction commitment for the clear coating category. Depending on the reformulation pathway, as well as a manufacturer’s choice of reformulation path, a combined reactivity-based and mass-based reformulation strategy could yield either a negative or positive impact on ozone reductions. While the actual ozone reduction loss or gain can not be known for certain, their upper limits can be estimated. The maximum percent ozone reduction loss (PORL) is defined as the sum of all potential ozone reduction losses divided by the target ozone reduction commitment based on the mass limit. In other words, if the amount of ozone reduction obtained from the mass-limit is higher than that of the reactivity limit, the difference in ozone reduction from a product would be considered as a loss (i.e. reactivity-based control is less efficient than that of the mass). The sum of all potential ozone reduction losses would be considered as the worst case scenario if the less efficient path is chosen whenever possible. Similarly, the maximum percent ozone reduction gain (PORG) can be defined as the sum of all potential ozone reduction gains divided by the mass-based target ozone reduction commitment. The percent “missing” ozone reduction (PMOR) is calculated based on the amount of ozone reduction that would have been achieved from the reformulation of non-complying products if there was no reactivity compliance option available. As can be seen in Figure X-1, at a particular reactivity limit, there could be up to 40 percent loss of total target ozone reduction. While stringent reactivity limits could be used to minimize the potential ozone reduction loss, the increasing maximum percent

FIGURE X-1 IMPACT OF REACTIVITY COMPLIANCE OPTION ON TARGET OZONE REDUCTION ozone reduction gain suggests that significant technological advances would be required to achieve these reactivity limits.

Based on the aforementioned reasons and with agreement from the majority of the aerosol coating industry, staff began working on a proposal for mandatory reactivity-based VOC limits. The result of those efforts is the subject of this rulemaking. While these reactivity limits would become mandatory, our analysis shows that compliance with the reactivity limits provides more flexibility, at less cost, than the mass-based limits. In addition, as detailed in Chapter IV, the methodology for deriving the reactivity limit is designed to preserve the ozone reduction associated with the mass-based regulation, and no assumptions on the type of ingredients or organic compounds that would be used to reformulate are made in the limit calculation. Therefore, we believe that the proposed amendments will preserve the air quality benefit to be achieved with the mass-based VOC limits.

Staff does note that one former compliance alternative would no longer be available to aerosol coating manufacturers, the Alternative Control Plan (ACP) Regulation. The ACP Regulation, Title 17, California Code of Regulations, Sections 94540-94555, is a voluntary market-based regulation that utilizes the concept of an aggregate emission cap, or "bubble." Until such time as the ACP is amended to allow emissions averaging on a reactivity-weighted basis, manufacturers would no longer be able to comply by means of the ACP. We also note, however, that no aerosol coating manufacturer is currently using the ACP to comply.

At this time, other than maintaining the mass-based VOC limits in the current regulation, ARB staff is unaware of any other scenarios that would serve as an alternative to the proposed amendments to the aerosol coatings regulation.

D. Potential Environmental Impacts

1. Impact on Ground-Level Ozone

Overall, the proposed amendment to the Aerosol Coatings Regulation, upon full implementation, will have neither a positive nor adverse environmental impact because staff is proposing to replace existing VOC content limits for aerosol coatings with reactivity-based VOC limits that provide an equivalent air quality benefit. Therefore, the proposal would achieve the same ozone reduction benefit as would have been associated with implementation of the mass-based VOC limits. The mass-based VOC limits adopted by the Board on November 19, 1998, would reduce VOC emissions by about 3.1 tpd. These proposed amendments would reduce the ozone formed from aerosol coating emissions by about 9.6 tpd.

However, to allow manufacturers the needed time to reformulate to meet the reactivity limits, there will be a short-term negative environmental impact. We are proposing that the limits for the general coating categories become effective June 1, 2002, a five month delay. On

June 1, 2002, 7.9 tpd of ozone reductions, or 82 percent of the overall reduction commitment would be achieved. A smaller negative impact (1.7 tpd ozone shortfall) would exist for an additional seven months, until January 1, 2003, when the remaining specialty categories would comply. However, we believe there are overriding considerations to the short-term negative impact. The intent of the proposed amendments is to ensure that commercial and technological feasible aerosol coatings are available such that basic market demand can be met. Without providing additional time, many manufacturers would experience adverse economic impacts and disruption of the aerosol coatings market. The postponement of the effective date will help ensure that manufacturers will be able to develop consumer-accepted, cost-effective products. We believe this consideration overrides the short-term adverse impacts that may occur as a result of these amendments.

Enhanced tropospheric ozone formation involves the interaction between VOCs and oxides of nitrogen (NO_x) in the presence of sunlight. It is now known that VOCs vary dramatically in their ability to form ozone (Carter, 1994). Thus the most effective ozone control strategy would be to limit the use of VOCs that are likely to produce the most ozone once emitted. Currently, aerosol coating products are required to reduce their mass of VOC emissions. For this control approach, it is possible that, during product reformulation, more reactive solvents (i.e. solvents that form more ozone on per gram basis) could be used, thus reducing the air quality benefit. The amendments proposed in this rulemaking would require manufacturers to reduce their product's ozone formation potential (i.e. reactivity). Reducing a product's reactivity would likely require use of compounds that have lower potentials to produce ozone when emitted from aerosol coatings. Therefore, reformulating to meet the reactivity limits should ensure ozone reductions are achieved aerosol coating products are reformulated.

2. Impact on Particulate Matter (Aerosols)

Overall, our analysis found that the proposed rulemaking would not have significant environmental impact on formation of particulate matter (PM). However, as detailed below, in the absence of secondary organic aerosol (SOA) formation data of certain ingredients, and the uncertainty associated with the reformulation approaches the manufacturers of aerosol coatings will use, it is difficult to determine definitively the full impacts that the implementation of the proposed reactivity limits would have on ambient PM concentrations. Hence, we will continue to monitor implementation of the regulation and reassess the impacts as more data become available.

Fine PM is prevalent in the urban atmosphere (see, for example, Pandis *et al.*, 1992), and ambient PM, especially those with aerodynamic diameters less than two and a half micrometers ($PM_{2.5}$) is known to have negative impacts on human health (Schwartz *et al.*,1996; Moolgavkar and Luebeck, 1996). Like ozone, PM can be formed via atmospheric oxidation of organic compounds (Finlayson-Pitts and Pitts, 2000). According to the results from several recent studies, photochemically derived PM (i.e. secondary organic aerosol) could contribute up to 80 percent of the fine particle burden observed in severe air pollution episodes (Pandis *et al.*, 1992; Turpin and Huntzicker, 1991; 1995). In urban PM, these secondary organic aerosols could produce effects such as visibility degradation and toxicity (see, for example Aktinson, *et al.*, 1994). Hence, it is necessary to assess the likelihood of a potential adverse impact resulting from implementation of the proposed rulemaking.

In the past decade, significant advances have been made in the theoretical and the experimental studies of the formation of secondary organic aerosols (SOA) (Pankow, 1994a, 1994b; Odum *et al.*, 1996; Seinfeld and Pandis,1998; Harner and Bildeman, 1998; Leach, *et al.*, 1999; Kleindienst, *et al.*, 1999; Yu *et al.*, 1999). In addition, modeling techniques to determine the amount of ozone as well as the amount of aerosol formed from a VOC have been established (Bowman *et al.*, 1995), and the concept similar to maximum incremental reactivity is being applied to quantitatively assess the aerosol formation potential of a VOC (i.e. incremental aerosol reactivity) (Griffin *et al.*, 1999). Based on the results of these studies, we now know that there is a mechanistic linkage between the ozone formation and SOA formation of a VOC. Because of this relationship, the proposed amendment may also affect the SOA formation potential of aerosol coating products. The analysis is detailed below.

Although most organic compounds contribute to ozone formation (Carter, 2000), secondary organic aerosol is usually formed from photooxidation of organic compounds with carbon numbers equal to seven or more (Grosjean and Seinfeld, 1989; Wang *et al.*, 1992). This observation is consistent with the fact that both reactivity and product's volatility need to be considered for evaluating the aerosol formation potential of a VOC (Odum *et al.*, 1997). In other words, only chemicals which react fast enough in the atmosphere will generate sufficient amounts of low volatility products for forming aerosols. Based on our 1997 Aerosol Coating Survey data, except hydrocarbon solvents and substituted aromatics, the majority of the compounds used (i.e. ~ 60-70 percent of the inventory) are either "solids" (for example, alkyd resin) or have less than seven carbon atoms in the molecule (ARB, 1998b). Accordingly, substituting less reactive compounds with less than seven carbon atoms for more reactive compounds is likely to have a negligible impact on SOA formation of aerosol coating products. Hence, our discussion of SOA potential of aerosol coating products will focus on how the proposed amendments may potentially affect aromatics and hydrocarbon solvents content. In addition, our assumption is that manufacturers would most likely target reductions of the most reactive VOCs to meet the reactivity limits.

Aerosol formation potential of aromatics has been studied extensively (Izumi and Fukuyama, 1990; Odum *et al.*, 1996; Odum *et al.*, 1997). Toluene, xylenes, trimethylbenzenes and other alkyl-substituted benzenes are commonly found in formulations of aerosol coating products (ARB, 1998b). Using the gas-to-particle partition theory of Pankow (1994a, 1994b), experimental studies of Odum *et al.* (1997) indicated that aerosol yields of toluene and ethylbenzene are higher than those of xylenes and trimethylbenzenes. To comply with the proposed reactivity limits, aerosol manufacturers would most likely substitute lower reactive VOCs for the higher reactive VOCs in their products. This would involve either substituting a less reactive aromatic for a more reactive one, and/or replacing the aromatics by non-aromatic species. The reactivity ranking of aromatics is: toluene < xylenes < trimethylbenzenes

(Carter, 2000). Hence, the replacement of xylenes by toluene would have a negative impact on PM formation (i.e. enhancement of PM formation potential of the aerosol coating products) as toluene has a higher SOA formation potential of xylenes. However, we believe that the xylenes-to-toluene substitution is a less desirable reformulation option because toluene is classified under a list of carcinogen and reproductive toxicants of the Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65). On the other hand, if product reformulation involves the substitution of an aromatic by a non-aromatic species, the SOA formation potential of the product is likely to be reduced. This is because the aerosol yield of aromatics are known to be the highest among all chemical classes (i.e. alkanes, cycloalkanes, and alkenes) (Grosjean, 1992).

As detailed in Chapter IV, hydrocarbon solvent mixtures used in manufacturing aerosol coatings can be classified into two major groups: aliphatic and aromatic. Aromatic solvents contain 100 percent of aromatic compounds, and they have higher potentials to form ozone as well as SOA (see above). Hence, by reducing the aromatic solvent content, both the reactivity and SOA formation potential of an aerosol coating product would be reduced. In aliphatic hydrocarbon solvents, the carbon number distribution of solvent ingredients varies from five to sixteen. In addition to alkanes (i.e. n-alkanes and isoalkanes) and cycloalkanes, these solvents may have up to 22 percent of aromatic content (ASTM, 1995). Based on the hydrocarbon solvent classification scheme developed (see Chapter IV), at a given average boiling range, the reactivity of aromatic containing hydrocarbon solvents is higher than that of their aliphatic counterparts (Kwok *et al.*, 2000). In addition, aliphatic hydrocarbon solvents that consist of high molecular weight ingredients (as indicated by their relatively high average boiling range) are less reactive than the those with “lighter” alkanes and cycloalkanes. Because most potent aerosol precursors are aromatic hydrocarbons (Grosjean, 1992), aromatic containing hydrocarbon solvents are expected to have a higher SOA formation potential. Therefore, a product reformulated by using solvent with low and/or no aromatic content would likely decrease its aerosol formation yield. However, if the product’s reactivity is reduced by replacing a “light” solvent (i.e. containing mainly light weight ingredients) by the heavier one, SOA formation potential of the product may increase. This expectation is consistent with the fact that higher molecular weight alkanes and cycloalkanes are important aerosol forming precursors (Grosjean, 1992). We will continue to monitor implementation of the regulation and reassess the impacts as more data become available.

3. Impact on Global Warming

We do not expect the proposed rulemaking to have an adverse impact on global warming. The theory of global warming is based on the premise that emissions of anthropogenic pollutants, together with other naturally-occurring gases, absorb infrared radiation in the atmosphere, thereby increasing the overall average global temperature (U.S. EPA, 1995a). To comply with the reactivity limits proposed for aerosol coatings, manufacturers may choose to replace or blend the typical hydrocarbon propellants. Options for propellant replacement include using hydrofluorocarbon (HFC) compounds such as HFC-152a. Because HFC-152a has a very low potential to form ozone, it may be used to reduce the overall reactivity of an aerosol coating product. However, we do not believe that this is a likely reformulation path. Current hydrocarbon propellants used in aerosol coatings are only moderately reactive. Hence, replacement of hydrocarbon propellant with HFC-152a is not necessarily an efficient way to reduce a product's reactivity. Nevertheless, if HFC-152a is chosen to replace all or a portion of the hydrocarbon propellant there may be a slight impact on global warming. However, we have determined that even if all aerosol coating products were reformulated to use HFC-152a, the impact on global warming would be negligible.

Hydrofluorocarbons are non-chlorinated methane and ethane derivatives, which contain hydrogen and fluorine. The most likely HFC to be chosen to replace hydrocarbon propellants is HFC-152a (Applegate, 1995). Hydrofluorocarbons absorb infrared energy and therefore can contribute to global warming (Wallington, 1994). The global warming potential (GWP) of HFC-152a is 50 times greater than hydrocarbon propellants and 150 times greater than carbon dioxide. Because HFC-152a is most likely to be considered as a propellant replacement, our analysis is based on its use (Applegate, 1995; Du Pont, 1992). Based on the ARB 1997 Aerosol Coatings Survey (ARB, 1998b), about 10 tpd of hydrocarbon propellant is emitted each day. Therefore, the emissions of HFC-152a would increase by no more than 10.5 tons per day. This small increase in HFC-152a emissions would have a negligible impact on global warming.

As mentioned above, carbon dioxide is the primary man-made greenhouse gas of concern. However, the ARB 1997 Aerosol Coatings Survey data indicate that, currently, carbon dioxide is not used in these products even though it is used to some degree as a replacement propellant in other consumer products (ARB, 1998b). Although carbon dioxide is non-reactive, we do not expect it to be used in aerosol coatings. Aerosol products using CO_2 as propellant have rather coarse spray patterns (Sanders, 1987), which is not likely to be acceptable for aerosol coating product applications. Therefore, its use in aerosol coating products due to the proposed amendments would have little or no impact on global warming. In addition, most of the carbon dioxide that is used as propellant is a recycled by-product of existing processes and therefore would not contribute to the net increase in global warming (ARB, 1995b).

4. Impact on Stratospheric Ozone Depletion

The ARB staff has determined that the proposed rulemaking would have minimal, if any, impact on stratospheric ozone depletion. The stratospheric ozone layer shields the earth from harmful ultraviolet (UV) radiation (U.S. EPA, 1995b). Depletion of the earth's ozone layer allows a higher penetration of UV radiation to the earth's surface (U.S. EPA, 1995b). The increase in UV radiation penetration leads to a greater incidence of skin cancer, cataracts, and impaired immune systems (UNEP, 1996). Reduced crop yields and diminished ocean productivity are also anticipated (U.S. EPA, 1995b; UNEP, 1996). Because the chemical reactions which form tropospheric ozone are driven by UV radiation, it is conceivable that a reduction in stratospheric ozone may also result in an increase in the formation of photochemical smog because of the increased levels of UV radiation on the earth's surface (ARB, 1995a).

Compounds such as CFCs and halocarbons (e.g. halons, 1,1,1-trichloroethane (TCA), and carbon tetrachloride) cause the destruction of the stratospheric ozone (U.S. EPA, 1995b). These compounds are generally very stable and do not degrade appreciably in the troposphere (Wallington, 1994; U.S. EPA, 1995b). Instead, they gradually diffuse into the stratosphere where they release chlorine or bromine atoms. Bromine atoms released from halons are even more reactive than chlorine atoms and therefore have a greater affect on the degradation of the stratospheric ozone layer (U.S. EPA, 1995b).

The regulation currently contains a provision that limits the amount of ozone-depleting compounds used in aerosol coatings to ensure that manufacturers do not switch to them when they are reformulating aerosol coating products to lower reactivity. However, the provision does allow any ozone-depleting compound to be present as an impurity in an aerosol coating in a combined amount with perchloroethylene equal to or less than 0.01 percent, by weight, of the product.

Because it lacks chlorine, HFC-152a probably contributes only slightly to ozone depletion (Wallington, 1994). As evidence of this, HFC-152a is not included on the list of compounds that are scheduled for phase-out under the federal Clean Air Act requirements. If manufacturers choose HFC-152a as a replacement for hydrocarbon propellants, no additional decrease in stratospheric ozone is expected (ARB, 1995b; Daly, 1993). However, as previously stated, HFC-152a is not currently used and we do not expect the use of HFC-152a to be the reformulation option of choice.

5. Impacts on Water Quality and Solid Waste Disposal

We do not expect an adverse impact on water quality or solid waste disposal from the proposed rulemaking. We do not expect consumers to convert to the use of brush-on paints because the proposed rulemaking allows compliance flexibility for a variety of reformulations to be pursued in each aerosol coating category. Without the need to convert to brush-on paints there would be no impact resulting from the use of cleanup equipment or products such as brushes, paint thinner, mineral spirits, various containers, water, and water disposal. Because of this, we do not anticipate any changes in packaging or disposal of aerosol coating products due to the proposed rulemaking.

E. Other Potential Environmental Impacts

1. Impact from Use of Toxic Air Contaminants

Pursuant to Health and Safety Code Section 39650 et seq., the ARB is required to identify and control toxic air contaminants (TACs). The Health and Safety Code defines a TAC as "... an air pollutant which may cause or contribute to an increase in mortality or in serious illness, or which may pose a hazard to human health." A number of chemicals currently used in aerosol coating product formulations have been identified as TACs. In accordance with the California Environmental Quality Act, we are required to mitigate potential adverse environmental impacts that may occur as a result of our regulations. An increased use in TACs in aerosol coating products could lead to a potential adverse environmental impact.

Solvents commonly used in aerosol coating products that have been identified as TACs, include xylene, toluene and methylene chloride. Because of the potential for increased use of these TACs, we have performed an analysis to determine if there would be any potential health impacts from an increased use of them. We also performed a health risk assessment on emissions of methylene chloride and determined that a provision to restrict its use is necessary to avoid any potential adverse impact.

a. Xylene and Toluene

Physical Characteristics (Xylene)

Mixed xylenes are colorless liquids that are insoluble in water and miscible with alcohol, ether, and many other organic solvents. The commercial mixed xylenes are composed of the three isomers, with the meta-, and para-isomers predominating. For our particular purposes, the isomers may be separated (ARB, 1997a). Xylenes are widely used as solvents in numerous aerosol coatings products.

Health Effects (Xylene)

Exposure to xylene vapors may cause eye, nose, throat, and respiratory tract irritation. It is a central nervous system depressant. Acute exposure may cause gastrointestinal effects such as vomiting, and gastric irritation. Exposure may also injure the kidneys. The toxicological endpoints for acute toxicity are the eye and respiratory irritation, whereas the toxicological endpoints for chronic toxicity are the nervous system and respiratory system (OEHHA, 1999a; 2000).

Physical Characteristics (Toluene)

Toluene is a colorless, flammable, non-corrosive liquid with a benzene-like odor. It is insoluble in water and soluble in acetone, absolute alcohol, ether, chloroform, benzene, petroleum ether, glacial acetic acid, and carbon disulfide. As a solvent, toluene is used for paints, coatings, gums, and resins (ARB, 1997a).

Health Effects (Toluene)

Exposure to toluene may cause mild eye and respiratory tract irritation. The central nervous system is the primary target organ for chronic and acute exposures. It is a central nervous system depressant. At exposures to high concentrations, liver and kidney injury may occur. Chronic exposures to toluene may also cause reproductive/developmental effects (OEHHA, 1999a; 2000).

Potential Impact

To comply with the proposed limits, manufacturers will need to reduce the overall reactivity of their product formulations. To do this, we believe the most efficient way to reduce a product's reactivity is to reduce the amount of the most highly reactive VOCs which include xylene, toluene, and other aromatic solvents. Therefore, we do not expect manufacturers would increase--and are much more likely to decrease--the amount of these higher reactive compounds in their reformulated products. We conclude that compliance with the proposed reactivity limits will have a dual benefit: efficient ozone reductions and a reduction in use of TACs. For these reasons we expect an overall positive environmental impact. Hence no further mitigation measure to limit the use of xylene, toluene, or other aromatics is necessary.

b. Methylene Chloride

Methylene chloride is used in a limited number of aerosol coating products. However, when it is used, the amount can be quite high (up to 50 percent). Some of its relevant properties are that it is inexpensive, it is a reasonably strong solvent, and it is a negligibly reactive compound. Because of its negligible reactivity, there is a potential for increased usage in products complying with the proposed regulation. The analysis as to why we believe a provision to restrict its use is warranted is described below with further detail in Appendix G. The proposed amendments should not result in any increased use of this compound.

Physical Characteristics

Methylene chloride, also known as dichloromethane, is a colorless, volatile liquid that is currently used in some aerosol coating products. It is a chlorinated hydrocarbon solvent that is non-flammable. It is slightly soluble in water and miscible with alcohol, ether, and dimethylformamide (Merck, 1989). In the absence of moisture, at ordinary temperatures, methylene chloride is relatively stable. In dry air, it decomposes at temperatures exceeding 120 degrees Celsius. It evaporates relatively quickly from water (ARB, 1997a).

Health Effects

Methylene chloride is irritating to the eyes, respiratory tract, and skin. Methylene chloride is also a central nervous system depressant, and exposure may result in decreased visual and auditory functions, and may also cause headache, nausea, or vomiting. At high exposures, methylene chloride can cause pulmonary edema, cardiac arrhythmias, and loss of consciousness. Chronic exposure can lead to bone marrow, hepatic, and renal toxicity (ARB, 1997a). Methylene chloride also has been shown to increase tumor rates in the mouse liver and lung and the rat mammary gland at concentrations ranging from 1,000 to 4,000 parts per million (ppm) (ARB, 1997a). As a result of these studies, methylene chloride was declared a B2 substance, a probable human carcinogen, by the U.S. EPA (U.S. EPA, 1994). Furthermore, the International Agency for Research on Cancer has classified methylene chloride in Group 2B; which lists possible human carcinogens based on limited animal evidence (ARB, 1997d).

Based on available data, the Occupational Safety and Health Administration (OSHA) first established a standard for methylene chloride exposure in the workplace in 1970. The limit was recently lowered to 25 ppm for an 8-hour time-weighted average (TWA) (OSHA, 1997). The State of California Occupational Safety and Health Administration has also established 25 ppm for an 8-hour TWA as a standard for exposure to methylene chloride in the workplace in California (California Code of Regulations (CCR), 1997). The State of California under the Assembly Bill 1807 TAC Identification and Control Program and Proposition 65 has listed methylene chloride as a carcinogen and as a TAC (ARB, 1989; CCR, 1996). The inhalation potency factor that has been used as a basis for regulatory action in California is 1×10^{-6} (microgram per cubic meter)$^{-1}$ $(\mu g/m^3)^{-1}$ (OEHHA, 1999b). In other words, the potential excess cancer risk for a person exposed over a lifetime to 1 microgram per cubic meter of methylene chloride is estimated to be no greater than one in one million.

Methylene Chloride Use in Aerosol Coating Products

In 1998, the ARB conducted a survey of aerosol coating products sold in California in 1997. The information requested included product formulation data and sales data and was used to estimate VOC emissions from spray paints in California. The survey results provide us with the information necessary to determine, among other things, pounds of aerosol coatings sold which contain methylene chloride, weight percentage of methylene chloride in these products, and total methylene chloride emissions for each aerosol coating category. The survey data show that approximately 38 tons per day of aerosol coating products were sold. Of this amount, 1200 pounds per day of aerosol coating products containing methylene chloride were sold. This results in approximately 380 pounds per day of methylene chloride emissions, which represents 0.5 percent of the inventory (ARB, 1998b).

Methylene chloride was reported in 10 of the 35 categories. Table X-1 presents the categories containing methylene chloride, and the methylene chloride emissions for each category. According to these data, automotive bumper and trim products are the second largest contributor to methylene chloride emissions, accounting for 44 percent of total methylene chloride emissions. (The largest contributor was the total emissions from five other categories.) The lowest methylene chloride concentration reported was less than 1 percent and the highest was 52 percent, with an average methylene chloride concentration of 24 percent (ARB, 1998b).

TABLE X-1
METHYLENE CHLORIDE EMISSIONS PER CATEGORY

Paint Category	1997 Methylene Chloride Emissions (pounds/year) x 1000	Percent of Total Methylene Chloride Emissions per Category
Clear coatings	9.7	7
Metallic coatings	2.1	2
Nonflat paint products	1.8	1
Automotive bumper & trim products	60.1	44
Other categories	63.9	46
TOTAL	**137.6**	**100%**

Summary of Potential Health Effects

To determine if an adverse impact would result if methylene chloride use would increase we conducted a health risk assessment using the above data. The complete analysis is contained in Appendix G of this report. In summary, the results of the analysis, as shown in Table X-2, shows that a worst-case scenario for an aerosol coating product containing 50 percent methylene chloride does not pose a significant risk for acute and chronic noncancer effects. However, the risk assessment analysis shows that there is a potential to increase the cancer risk if there is an increased use of an aerosol coating product containing methylene chloride, or if there is an increase in the content of methylene chloride in the aerosol coating product. Therefore, because of the potential for an increased cancer risk and because methylene chloride is already listed as a TAC, in the aerosol coating regulation we are proposing a provision to restrict the amount of methylene chloride that can be used in an aerosol coating product.

TABLE X-2
RESULTS OF SCREEN3 MODELING (MAXIMUM EXPOSED INDIVIDUAL (MEI) AT 20 METERS)

Health Criteria	Worst-Case Scenario
Methylene Chloride Emission Rate (lb/day)	0.81
Max. 1-hour Concentration (ug/m^3)	169.1
Max. Annual Average Concentration (ug/m^3)	3.33
Individual Cancer Risk (per million)	3.33
Acute Hazard Index	0.012
Chronic Hazard Index	0.33

Proposed Provision to Limit the Use of Methylene Chloride

In the existing aerosol coating regulation, methylene chloride use is restricted by requiring that the weight percent of methylene chloride in an aerosol coating product be added to the total VOC content to determine compliance with the mass-based VOC limits. For the proposed reactivity limits, however, when calculating the total reactivity of a product this type of provision does not provide the same restriction. This is because methylene chloride is negligibly reactive and hence has a low MIR value. Methylene chloride is a strong solvent that could be used as a replacement for more reactive solvents. From the results of the analysis conducted in Appendix G, we conclude that there is a potential for an increased risk in cancer.

Therefore, to limit methylene chloride use we are proposing a “no new use” provision. As proposed, if an existing product already uses methylene chloride, no additional methylene chloride could be added when the product is reformulated. The baseline would be established based on 1997 sales data. Any product not currently formulated with methylene chloride, could not reformulate using methylene chloride. This proposal is similar to a provision in the existing aerosol coating regulation, which restricts new uses of perchloroethylene and ozone-depleting substances. This provision would become effective on the same date as the limits become effective. With this provision we can ensure that emissions of methylene chloride from aerosol coatings will not increase.

F. Impacts on the State Implementation Plan for Ozone

1. Background

The Federal Clean Air Act amendments of 1990 require an ozone attainment plan from every area unable to meet the national ambient air quality standard for ozone. To assist California air districts to meet the challenge of attaining the ozone standard, the ARB and air districts developed the California State Implementation Plan (SIP) for Ozone (ARB, 1994b). State law provides the legal authority to ARB to develop regulations affecting a variety of mobile sources, fuels, and consumer products. The regulations that are already adopted, and measures proposed for adoption constitute the ARB's portion of the SIP. The SIP is California's plan to attain and maintain the national ambient air quality standard for ozone. The SIP was submitted to the U.S. EPA on November 15, 1994, and the consumer products element was formally approved on August 21, 1995.

The consumer products element of the SIP is comprised of near-term, mid-term, and long-term measures. The current consumer products element of the SIP requires an overall 85 percent reduction in VOC emissions relative to the 1990 emissions baseline by 2010. The SIP commitment for aerosol paints was a 60 percent reduction from the 1989 baseline by 2005 (ARB, 1994c). However, when the Board adopted the amendments to the Aerosol Coatings Regulation on November 19, 1998, it was determined that a 60 percent reduction in VOC emissions from aerosol coatings was not currently technologically and commercially feasible. Therefore, higher VOC limits were adopted for twelve product categories, and more stringent VOC limits were adopted for eleven product categories. The effective date was also extended from December 31, 1999, to January 1, 2002, to provide adequate time for manufacturers to reformulate their products. In the proposed amendments to the Aerosol Coatings Regulation, reactivity limits would replace the 2002 VOC limits.

2. Summary of Findings

Upon full implementation, in terms of emission reduction commitments, the proposed amendments do not affect our SIP commitment. This is because the reactivity limits are designed to provide the same ozone reduction benefit as would be associated with the current mass-based VOC limits. To do this, the ton per day VOC reduction is converted to an equivalent ozone reduction using the MIR scale. A reactivity limit is then set that achieves that ozone reduction target. This should ensure that reductions are preserved.

However, delaying the compliance dates for compliance with the reactivity-based limits from January 1, 2002 to June 1, 2002 and January 1, 2003, for general coatings and specialty coatings, respectively, will result in a short-term shortfall.

A short-term shortfall of 9.6 tpd of ozone reductions will occur for 5 months. By requiring the general coating categories to comply by June 1, 2002, 7.9 tpd, or 82 percent, of the ozone reductions will be achieved concurrent with the 2002 ozone season. For an additional seven months there will be a shortfall of 1.7 tpd ozone. By achieving 82 percent of the reductions near the beginning of the ozone season we believe the air quality impacts of delaying the effective dates of the reactivity limits will be minimal.

We believe the extension of the effective date is necessary to prevent disruptions in the aerosol coating market place and to minimize the possibility of an economic hardship for aerosol coating manufacturers. This proposal also ensures that efficacious products will continue to be available to the consumer in all 35 categories. We believe that these considerations override the short-term air quality disbenefit.

The proposed amendments satisfy our SIP commitment to consider reactivity when developing control strategies for consumer products (including aerosol coatings). We included reactivity as a potential control strategy in recognition that the 85 percent overall VOC emission reduction would be difficult to achieve on a mass-based approach alone. Since 1995 the ARB staff has been working with the affected consumer products stakeholders on approaches to include reactivity within our regulations. This proposal for aerosol coatings is the result of that work. This proposal is intended to be a “pilot project” which provides a model for additional reactivity-based controls.

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XI.

Economic Impacts

A. Introduction

In this Chapter, we describe the economic impacts that would be expected from implementation of the proposed amendments to the Aerosol Coatings Regulation, proposed amendments to Method 310, and the proposed Table of Maximum Incremental Reactivity (MIR) Values. Our analysis found no economic impacts from the proposed amendments to Method 310 and the proposed Table of Maximum Incremental Reactivity (MIR) Values; thus, we are focusing on the Aerosol Coatings Regulation in this Chapter. However, because we believe that the proposed reactivity limits offer manufacturers more flexibility in reformulating products, the proposed amendments represent a cost-savings relative to the costs estimated to comply with the January 1, 2002, mass-based volatile organic compound (VOC) limits in the existing regulation. However, we realize that manufacturers will incur costs to comply with the proposed limits. Therefore, this analysis focuses on the costs incurred by manufacturers to meet the proposed reactivity limits, including the impacts on aerosol paint manufacturers, other industries associated with aerosol paints, and consumers. Our analysis also estimates the cost-effectiveness of the proposed regulation. The proposed amendments require a reduction in the ozone formed from aerosol coating emissions rather than requiring VOC reductions. However, because cost-effectiveness is traditionally based on cost per pound of VOC reduced, we are presenting our analysis in the same metric.

In our economic impact analysis we quantified the economic impacts to the extent feasible, although some projections are necessarily qualitative and based on general observations and facts about the aerosol coatings industry. The impacts analysis, therefore, serves to provide a general picture of the economic impacts typical businesses might encounter. We recognize individual companies may experience different impacts than projected.

The overall impacts are first summarized in Section B, followed by a more detailed discussion of specific aspects of the economic impacts in the sections listed below:

(C) Economic Impacts Analysis on California Businesses as Required by the California Administrative Procedure Act (APA);
(D) Analysis of Potential Impacts to California State or Local Agencies
(E) Analysis of the Cost-Effectiveness and the Impacts on Per-Unit Cost of the Proposed Limits
(F) Analysis of the Impacts to Raw Materials Cost

(G) Analysis of the Combined Impacts on Per-Unit Cost from Recurring and Nonrecurring Costs

It is important to note that we conducted the economic impacts analysis shown in this report to meet legal requirements under the APA. The economic impacts analysis was prepared in consultation with the Air Resources Board's (ARB's) Economic Studies Section (section) of the Research Division. The section is staffed with professionals who carry out a broad range of assignments for the ARB and other organizations, including the Governor's Office; California Environmental Protection Agency (Cal/EPA) boards, offices and departments; and local air pollution control agencies. The section manages extramural research contracts; develops methodologies; collects, analyzes and distributes economic and financial data; conducts economic and financial analyses, including the economic impact analyses of the Board's regulations; oversees the economic impact analyses of the regulations promulgated by all Cal/EPA boards, offices and departments; and carries out other related tasks as needed by the ARB. The staff hold Ph.D, J.D., M.B.A., M.A., and B.S. degrees in economics, business, chemical engineering, microbiology, and environmental resource science. Members of the section have taught economics, accounting, finance, and computer science at the university level; have given invited talks and presented technical papers to major universities, academic associations, and government agencies; and have worked in the private sector in credit analysis, accounting, auditing, production control, environmental consulting, and business law.

B. Summary of Findings

Because the proposed amendments are designed to provide manufacturers more reformulation flexibility, we believe this will likely result in potential cost savings to manufacturers. For perspective, we compare the estimated cost-effectiveness of the proposed reactivity limits to the cost-effectiveness of other ARB regulations and control measures, with particular emphasis on comparison to the 1998 Amendments to the Aerosol Coatings Regulation (mass-based VOC limits).

Overall, most affected businesses will be able to absorb the costs of the proposed regulation with no significant adverse impacts on their profitability. This finding is indicated by the staff's estimated change in "return on owner's equity" (ROE) analysis. The analysis found that the overall change in ROE ranges from negligible to a decline of about eight percent. However, the proposed measures may impose economic hardship on some businesses with small or no margin of profitability. These businesses, if hard pressed, can seek relief under the variance provision of the Aerosol Coatings Regulation for extensions to their compliance dates. Such extensions may provide sufficient time to minimize the cost impacts to these businesses. Because the proposed measures would not alter significantly the profitability of most businesses, we do not expect a noticeable change in employment; business creation, elimination or expansion; and business competitiveness in California. We also found no significant adverse economic impacts on any local or State agencies.

The cost-effectiveness of the reactivity limits appears to be comparable, or in some cases an improvement over, the cost-effectiveness of previous ARB consumer product regulations. In our consumer products regulations, as well as the Aerosol Coatings Regulation, the limits are all mass-based VOC reductions. The higher cost estimate in our past rulemaking for aerosol coatings (ARB, 1998a) was mostly attributable to substitution of 1,1-difluoroethane (HFC-152a) for hydrocarbon propellants in the recurring costs. In the analysis conducted for the mass-based regulations in 1998, the cost-effectiveness ranges from less than $1.00 to slightly over $3.00 per pound of VOC reduced, with a sales-weighted average for all proposed limits of $1.57 per pound of VOC reduced. For the proposed reactivity limits, our analysis shows that the cost-effectiveness of the proposed regulation ranges from about $0.00 to $1.67 per pound of VOC reduced. The overall cost-effectiveness across all categories of aerosol coatings is $0.74 per pound of VOC reduced. However, we acknowledge that some formulators may have already initiated reformulation efforts to meet the 2002 mass-based VOC limits, thereby incurring higher costs than estimated in this analysis. At this present time, information is not available as to the number of such companies, and as to how many resources each of these companies might have incurred to comply with the 2002 mass-based VOC limits in the existing regulation.

C. Economic Impacts Analysis on California Businesses as Required by the California Administrative Procedure Act (APA)

The following analysis was completed for the Amendments to the Aerosol Coatings Regulation in 1998, which became legally effective in June, 1999. Because our current proposed reactivity-based amendments are designed to provide an equivalent air quality benefit to the mass-based VOC limits and our estimated costs are lower, we believe that the following section C is still applicable.

1. <u>Legal Requirements</u>

Section 11346.3 of the Government Code requires State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment shall include a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination or creation, and the ability of California business to compete with businesses in other states.

Also, State agencies are required to estimate the cost or savings to any state or local agency and school district in accordance with instructions adopted by the Department of Finance. The estimate shall include any nondiscretionary cost or savings to local agencies and the cost or savings in federal funding to the state.

2. Findings

a. Potential Impact on California Businesses

Our findings show that most California businesses will be able to absorb the costs of the proposed amendments with no significant adverse impacts on their profitability. However, the proposed measures may impose economic hardship on some businesses with small or no margin of profitability. These businesses, if hard pressed, can seek relief under the variance provision of the aerosol coatings regulation for extensions to their compliance dates. Such extensions may provide sufficient time to minimize the cost impacts to these businesses. Because the proposed measures would not alter significantly the profitability of most businesses, we do not expect a noticeable change in employment; business creation, elimination or expansion; and business competitiveness in California.

Discussion

This portion of the economic impacts analysis is based on a comparison of the return on owner's equity (ROE) for affected businesses before and after inclusion of the cost to comply with the proposed amendments. The data used in this analysis were obtained from publicly available sources, the ARB's 1997 Aerosol Coatings Survey, and the staff's 1998 cost-effectiveness analysis discussed later in this chapter.

Affected Businesses

Any business which manufacturers or markets aerosol coating products can be directly affected. Also potentially affected are businesses which supply raw materials or equipment to these manufacturers or marketers and distribute or retail aerosol coating products. The focus of this analysis, however, will be on manufacturers or marketers of aerosol coating products.

Of the 115 responsible parties who reported product information in the Aerosol Coatings survey, a total of 66 made or sold products in 1997 which would not comply with our proposed limits (ARB, 1998b). Four of the companies that made or sold non-complying products are California-based. The total number of noncomplying products reported was 1143 out of 2238 speciated products.

Study Approach

The approach used in evaluating the potential economic impact of the proposed measures on these businesses is outlined as follows:

(1) Affected businesses which responded to the survey were classified by the size of their sales in order to select a typical business.
(2) Compliance cost was estimated for a typical business.
(3) Estimated cost was adjusted for federal and state taxes.
(4) The three-year average ROE was calculated for the typical business by averaging the ROEs for 1994 through 1996. ROE is calculated by dividing the net profit by the net worth. The adjusted cost was then subtracted from net profit data. The adjusted ROE was then compared with the ROE prior to inclusion of the compliance cost to determine the potential impact on the profitability of the business. The adjusted cost to determine the potential impact on the profitability of the business. A reduction of more than ten percent in profitability is considered to indicate a potential for significant adverse economic impacts.

The threshold value of ten percent has been used consistently by the ARB staff to determine impact severity (ARB, 1991; ARB, 1995). This threshold is consistent with the thresholds used by the United States Environmental Protection Agency and others.

Assumptions

The ROEs before and after the subtraction of the adjusted compliance costs were calculated based on the following assumptions:

(1) A typical business on a nationwide basis in the aerosol coatings industry is representative of a typical California business in the aerosol coatings industry;
(2) All affected businesses were subject to federal and state tax rates of 35 percent and 9.3 percent, respectively; and
(3) Affected businesses are neither able to increase the prices of their products, nor able to lower their costs of doing business through short-term cost-cutting measures.

Given the limitation of the available data, staff believes these assumptions are reasonable for most businesses at least in the short run; however, they may not be applicable to all businesses.

Results

Typical California businesses are affected by the proposed limits to the extent that the implementation of these requirements would change their profitability. Using ROE to measure profitability, we found that of the three California manufacturers making noncomplying aerosol coatings, the change in ROE varied from a negligible effect to a drop of about eight percent (with an average of two percent) in the 1998 analysis. This represents a minor change in the average profitability of a California business. However, because we believe that the proposed reactivity limits offer manufacturers more flexibility in reformulating products, the proposed amendments represent a cost-savings relative to the costs estimated to comply with the VOC limits in the 1998 analysis.

The estimated potential impacts to businesses' ROEs may be high because affected businesses probably would not absorb all of the increase in their costs of doing business. They might be able to pass some of the cost on to consumer in the form of higher prices, reduce their costs, or do both.

b. Potential Impact on the Consumer

The potential impact of the proposed measures on consumer depends upon the ability of affected businesses to pass on the cost increases to consumers. In the short run, competitive market forces may prevent businesses from passing their cost increases on to consumers. Thus, we do not expect a significant change in retail prices in the short run. In the long run, however, if businesses are unable to bring down their costs of doing business, they could pass their cost increases on to consumers. In such a case, we estimate that price increases would be less than seven percent, as calculated later in this chapter, which represents a minor impact on consumers.

The proposed measures may also affect consumers adversely if they result in reduced performance attributes of the products. However, this scenario is unlikely to occur for the following reasons. First, for most categories, there are complying products already available on the market; in fact, many categories have 100 percent complying marketshares. Thus, industry already has technology to manufacture the compliant products that meet consumer expectation. Second, marketers are unlikely to introduce a product which does not meet their consumer expectations. This is because such an introduction would be damaging not only to the product sale, but also to the sale of other products sold under the same brand name (impairing so-called "brand equity"). Finally, the Board has provided, under its existing consumer products program, flexibility to businesses whose situations warrant an extension to their compliance dates. For companies which can justify such variances, the additional time may afford more opportunity to explore different formulation, cost-cutting, performance-enhancing, or other marketing strategies which can help make the transition to new complying products nearly transparent to consumers.

c. Potential Impact on Employment

The proposed measures are not expected to cause a noticeable change in California employment and payroll. According to *Ward's Business Directory of U.S. manufacturing industries*, California employment in businesses classified under Standard Industrial Code (SIC) 2851, which includes the aerosol paint industry, totaled less than 600 employees in 1994, well under one percent of the total manufacturing jobs in California. These employees generated about $18 million in payroll, accounting for less than 0.1 percent of the total California manufacturing payroll in 1994.

d. Potential Impact on Business Creation, Elimination or Expansion

The proposed measures would have no noticeable impact on the status of California businesses. This is because the reformulation costs are not expected to impose a significant impact on the profitability of businesses in California. However, some small businesses with little or no margin of profitability may lack the financial resources to reformulate their products in a timely manner. Should the proposed measures impose significant hardship on these businesses, temporary relief in the form of a compliance date extension under the variance provision may be warranted.

While some individual businesses may be impacted, the proposed measures may provide business opportunities for other California businesses or result in the creation of new businesses. California businesses which supply raw materials and equipment or provide consulting services to affected industries may benefit from increased industry spendings on reformulation.

e. Potential Impact on Business Competitiveness

The proposed measures would have no significant impact on the ability of California's businesses to compete with businesses in other states. Because the proposed measures would apply to all businesses that manufacture or market aerosol coatings regardless of their location, the proposed measures should not present any economic disadvantages specific to California businesses.

D. Analysis of Potential Impacts to California State or Local Agencies

We have determined that the proposed amendments to the Aerosol Coatings Regulation, the proposed amendments to Method 310, and the proposed Tables of Maximum Incremental Reactivity (MIR) Values will not create costs or savings, as defined in Government Code section 11346.5 (a)(6), to any State agency or in federal funding to the State, costs or mandate to any local agency or school district whether or not reimbursable by the State pursuant to Part 7 (commencing with section 17500, Division 4, Title 2 of the Government Code), or other nondiscretionary savings to local agencies.

E. Analysis of the Cost-Effectiveness and the Impacts on Per-Unit Cost of the Proposed Limits

1. Introduction

For the following analysis, we evaluated the anticipated cost-effectiveness of the proposed reactivity limits to compare the efficiency of the proposed limits in reducing a pound of VOC relative to other existing regulatory programs. The proposed amendments require a reduction in the ozone formed from aerosol coating emissions rather than requiring VOC reductions. However, because cost-effectiveness is traditionally based on cost per pound of VOC reduced, we are presenting our analysis in the same metric. In this analysis, we applied a well-established methodology for converting compliance costs, both nonrecurring and recurring, to an annual basis. We then report the ratio of the annualized costs to the annual emission reductions in terms of "dollars (to be) spent per pound of VOC reduced." For perspective, we compared the estimated cost-effectiveness of the proposed limits to the cost-effectiveness of other ARB regulations and control measures, with particular emphasis on comparison to the 1998 Amendments to the Aerosol Coatings Regulation.

2. Methodology

The cost-effectiveness of a limit is generally defined as the ratio of total dollars to be spent to comply with the limit (as an annual cost) to the mass reduction of the pollutant(s) to be achieved by complying with that limit (in annual pounds). Annual costs include annualized nonrecurring fixed costs (e.g., total research and development (R&D), product and consumer testing, equipment purchases/modifications, etc.) and annual recurring costs (e.g., raw materials, labeling, packaging, etc.).

This approach was used to evaluate the cost-effectiveness for the proposed amendments to the Aerosol Coatings Regulation in October, 1998 (ARB, 1998a). In this analysis, staff considers that intracompany technology/research-and-development (T/R&D) transfers among product lines and other cost mitigating efforts are undertaken by companies to reduce costs. To provide consistency in this analysis, staff generally used the same assumptions for the cost analysis as performed for the rulemaking for the amendments to the Aerosol Coatings Regulation in 1998 (ARB, 1998a).

In determining the fixed and recurring costs for each category and subcategory with a proposed limit, we conducted a total of 25 individual cost-effectiveness analyses. Cost analyses were completed for each category and subcategory with the details from the best available technical information. While staff is required to protect the confidentiality of proprietary product information in some categories, particularly for the specialty categories (for groups of products of four or less), a surrogate example derived from non-flat paint category is used in its place.

We annualized nonrecurring fixed costs using the Capital Recovery Method, as recommended under guidelines issued by the Cal/EPA. Using this method, we multiplied the estimated total fixed costs to comply with each limit by the Capital Recovery Factor (CRF) to convert these costs into equal annual payments over a project horizon (i.e., the projected useful life of the investment) at a discount rate (Cal/EPA, 1996). We then summed the annualized fixed costs with the annual recurring costs and divided that sum by the annual emission reductions to calculate the cost-effectiveness of each limit, as shown by the following general equation (example shown is for calculating cost-effectiveness from pre-regulatory to the proposed limit):

$$(1) \qquad \text{Cost-Effectiveness} = \frac{(\text{Annualized Fixed Costs})^{\text{Pre-Reg}}_{\text{Reactivity Limit}} + (\text{Annual Recurring Costs})^{\text{Pre-Reg}}_{\text{Reactivity Limit}}}{(\text{Annual Mass Reduction in VOC})^{\text{Pre-Reg}}_{\text{VOC Limit}}}$$

where:

$$(2) \qquad \text{Annualized Fixed Costs} = (\text{Fixed Costs}) \text{ x } \frac{i\,(1+i)^n}{(1+i)^n - 1}$$

$i(1+i)^n/((1+i)^n-1)$ = Capital Recovery Factor (CRF)
i = discount interest rate over project horizon, %
n = number of years in project horizon
Fixed Costs = total nonrecurring cost per product category

As shown by the 25 raw materials cost analyses in Appendix I, a convenient Method for estimating the annual recurring cost portion of overall cost-effectiveness (C.E.) is to separate Equation (1) into two fractions, one for the nonrecurring costs and one for the recurring costs. It can then be shown that the C.E. fraction for recurring costs can be simplified and calculated as follows:

(3) Annual Recurring Costs C.E.

$$= \frac{\text{(Compliant Materials Cost) - (Baseline Materials Cost)}}{\text{(Baseline VOC Content) - (Compliant VOC Content)}}$$

where:

Baseline Materials Cost = cost of raw materials for product before reformulation to the proposed reactivity limit, \$/lb product
Baseline VOC Content = product VOC weight fraction before reformulation to the 2002 mass-based limit, lb VOC/lb product
Compliant Materials Cost = cost of raw materials for reactivity-compliant product, \$/lb product
Compliant VOC Content = product VOC weight fraction at the 2002 mass-based limit, lb VOC/lb product.

To use Equation (3), we determined the product-weighted MIR of both compliant and noncompliant products in each of the 25 product categories/subcategories, based on sales data and the speciated formulations as reported by manufacturers in the ARB's 1997 Aerosol Coatings Survey (ARB, 1998b). To the extent feasible, we then determined the detailed formulations which most closely reflect the "typical" (i.e., sales-weighted average) compliant and noncompliant reactive organic compound (ROC) contents. These formulations, in turn, were designated as compliant and baseline formulations, respectively.

For most ingredients, we used the most recent, distributor-level bulk prices from *Chemical Market Reporter* (March 6, 2000), or from discussions with industry representatives, to calculate the baseline and compliant material costs based on these designated formulations. Unspecified ingredients or ingredients for which prices were unknown were grouped into an "all others" classification and assigned a default cost of \$3.50 per pound, respectively (ARB, 1997a). These analyses are shown in Appendix I and discussed in more detail in "Raw Materials Cost Impacts Analysis" later in this section.

3. Assumptions

We calculated the cost-effectiveness with an assumed project horizon of five years to be consistent with the mass-based regulation. However, a more commonly cited period for an investment's useful lifetime in the chemical processing industry is ten years. We also assumed a fixed interest rate of 10 percent (up from 7.5 percent in the 1998 analysis) throughout the project horizon. These assumptions are conservative considering that a ten-year horizon is standard practice in cost-effectiveness analyses of air pollution regulations, including previous consumer product rulemakings. Based on these assumptions, the CRF is 0.2638.

In this analysis, we report the California-apportioned (by population) annualized fixed cost divided by the California-apportioned emission reductions. To illustrate, a manufacturer may need to install \$10 million worth of equipment to produce its national sales volume of products compliant with the proposed limits. However, if the company were to produce a

California and 49-state product, the company may only need to install $1 million worth of equipment to produce unit sales sufficient for the smaller California market. Using this approach, we discounted the total fixed costs for producing national sales volumes by the California-apportionment factor (i.e., the current ratio of California to U.S. population, or 13%), which we then divided by the California-only emission reductions.

Similar to the cost analysis performed in the Amendments to the Aerosol Coatings Regulation (ARB, 1998), the following methodology was used to calculate the fixed costs:

- Determine the manufacturers that make the non-complying products;
- Determine total complying and non-complying sales of these manufacturers;
- If total sales of these manufacturers are less than 33,000 lbs per year (100 cans per day), then research and development will be done by existing staff;
- If total sales are greater than 33,000 lbs per year, then two chemists would be hired for one year at a cost of $100,000 per chemist for research and development;
- If a manufacturers non-complying sales represent less than 10 percent of their total sales, then research and development will be handled by existing staff as part of on-going product development;
- Each manufacturer's fixed cost is apportioned over the categories in which it sells non-complying products by the percentage of its non-complying sales in that category relative to its total non-complying sales;
- Total fixed costs for each category are the sum of the apportioned fixed costs for each manufacturer of non-complying products in that category.

The assumptions used in this methodology differ from the one conducted in 1998 in two aspects. In this analysis, a new propellant tank is not required because propellant HFC-152a (1,1-difluoroethane) is not used in the analysis to calculate reformulation recurring costs. Given the greater flexibility that manufacturers have to reformulate to comply with the reactivity limits, it is not assumed that the manufacturer must reformulate with HFC-152a to meet the reactivity limits. Thus, the purchase of a new propellant tank, should the manufacturer choose to undertake this approach, is considered part of the company’s ongoing product development and not considered in this analysis. Secondly, this analysis assumes that the manufacturer hires two chemists, instead of one. Given the shorter amount of time that manufacturers have to undertake reformulation efforts to comply with the reactivity limits, an additional chemist is hired as part of the reformulation efforts. As in the previous cost analysis, $100,000 per year is the estimate for a chemist’s salary.

For the annual recurring costs, we assumed compliant reformulations would result in cost changes as a result of changes in a product’s raw materials and their associated prices. Changes in packaging, labeling, distribution and other recurring costs were assumed to be negligible relative to baseline levels of these costs. This assumption is based on our previous regulatory experiences. To illustrate, we conducted a comprehensive technical assessment of the 55 percent VOC hairspray limit, which required extensive reformulations and revolutionary changes to existing products (ARB, 1997a). The hairspray limit is generally considered to be among the most challenging of the consumer product limits; it likely resulted in more changes to the regulated product, relative to pre-regulatory products, than any other VOC limit. However, our assessment found that changes to recurring costs other than hairspray raw material costs were expected to be negligible (ARB, 1997a). Based on this finding and because the proposed new limits are designed to preserve product forms, we believe our assumptions regarding the recurring costs are reasonable.

4. Results

Table XI-1 shows our estimates for per-product and total annualized nonrecurring costs for each of the 25 product categories/subcategories subject to the proposed limits. As shown, the estimated overall annualized fixed cost to industry to reformulate all non-compliant products is projected to be about $1,316,985.

Table XI-2 shows the overall results of our cost-effectiveness analysis, with separate cost-effectiveness fractions representing the annualized nonrecurring and annual recurring costs. In general, Table XI-2 shows that the raw materials costs (i.e., annual recurring cost) have a generally larger impact on overall cost-effectiveness for the affected categories. The annualized nonrecurring fixed costs (i.e., R&D, product testing, etc.) have a relatively smaller impact on the overall cost-effectiveness. Table XI-2 shows that the estimated cost-effectiveness ranges from a low of $0.00 (net savings or no cost for several categories) to a high of about $1.67 per pound VOC for weld-through primers.

Another useful quantity to report is the emission reductions-weighted average (ERWA) cost-effectiveness. This value is the sum of the products of the emission reductions for each limit and its associated cost-effectiveness, divided by the sum of the total emission reductions for all the proposed limits. In contrast to a simple arithmetic mean of the reported cost-effectiveness values, the ERWA cost-effectiveness accounts for the relative magnitude of emission reductions and the relative efficiency of each limit in achieving those reductions. Thus, the ERWA cost-effectiveness is, in theory, a better indicator of the true average cost-effectiveness for achieving a pound of reduction under the proposed limits. As shown in Table XI-2, the ERWA cost-effectiveness is about $0.74 per pound of VOC reduced. These costs compare favorably to the analysis conducted in 1998, in which the cost-effectiveness was estimated to range from less than $1.00 to slightly over $3.00 per pound of VOC reduced, with a sales-weighted average for all proposed limits of $1.57 per pound of VOC reduced.

Based on the average cost of $0.74 to comply with the reactivity limits, the total industry-wide annual compliance cost would be $1.7 million. However, in the 1998 cost analysis for aerosol coatings no California apportionment was made. To compare more directly with this analysis, if we assume no California apportionment, our costs are estimated to be $2.8 million each year for five years. $4.1 million was estimated in the 1998 analysis; this proposal therefore represents a cost savings of $1.3 million per year. We conclude that these proposed amendments are more cost-effective based on the foregoing analysis.

TABLE XI-1
ESTIMATED TOTAL ANNUALIZED NON-RECURRING FIXED COSTS TO COMPLY WITH PROPOSED LIMITS

TABLE XI-2
ESTIMATED COST-EFFECTIVENESS FOR PROPOSED LIMITS

Table XI-3 shows a comparison of the cost-effectiveness for the proposed limits relative to other ARB consumer product regulations and control measures. As shown, the cost-effectiveness range of the staff's proposal is consistent with the cost-effectiveness of other ARB regulations and programs.

TABLE XI-3
COMPARISON OF COST-EFFECTIVENESS FOR PROPOSED LIMITS AND OTHER ARB CONSUMER PRODUCT REGULATIONS/MEASURES
(ADJUSTED TO 1998 DOLLARS)

Regulation/Control Measure	Cost-Effectiveness (Dollars per Pound VOC Reduced)
Aerosol Coating Products Reactivity Regulation	\$0.00 to \$1.67 (\$0.74 avg.)
Mid-Term Measures II Consumer Products Regulation[1]	\$0.00 to \$6.30 (\$0.40 avg.)
Aerosol Coating Products Tier II Regulation[2]	\$0.93 to \$3.19 (\$1.57 avg.)
Mid-Term Measures Consumer Products Regulation[3]	\$0.00 to \$7.10 (\$0.25 avg.)
Hairspray Regulation[4]	\$2.10 to \$2.50 (\$2.25 avg.)
Aerosol Coating Products Regulation[5]	\$2.85 to \$3.20
Phase II Consumer Products Regulation[6]	<\$0.01 to \$1.10
Phase I Consumer Products Regulation[7]	net savings to \$1.80
Antiperspirants and Deodorants Regulation[8]	\$0.54 to \$1.30

Cost-effectiveness values for previous years adjusted to 1997 dollars using the following *Chemical Engineering* Plant Cost indices: 383.4 (1997), 381.1 (1995), 361.3 (1991), and 357.6 (1989-1990); *Chem. Eng.*, April 1996/1997.

[1] ARB, 1999.
[2] ARB, 1998.
[3] Range reported as min./max. for each individual Phase III limit; average C.E. of \$0.25/lb reduced reported as an emission reductions-weighted average cost-effectiveness.
[4] Reported as sales-wtd average, incremental 2nd-tier cost-effectiveness (80% VOC to 55% VOC); ARB, 1997a.
[5] ARB, 1995.
[6] ARB, 1991.
[7] ARB, 1990.
[8] ARB, 1989.

F. Analysis of the Impacts to Raw Materials Cost

1. Introduction

In this analysis, we evaluated the anticipated cost impacts from the proposed limits on raw material costs. As stated previously, the raw material costs generally constitute a little or negligible portion of the compliance costs for most categories, since the manufacturer has greater flexibility in their selection of solvents, ingredients, and compounds. However, evaluating the impacts to raw material costs provides only an indicator of possible impacts to the retail prices of the affected products (assuming the cost impacts are passed on partially or fully to consumers). Because of unpredictable factors such as the competitive nature of the market, it is not possible to accurately predict the final retail price of products that will comply with the proposed limits when they become effective. To the extent the cost impacts are passed on to consumers, the final retail prices may be lower or higher than suggested by this analysis.

2. Methodology

As discussed previously, we determined the detailed formulations which most closely reflect the "typical" (sales-weighted average) compliant and noncompliant products. These formulations, in turn, were designated as compliant and baseline formulations, respectively. Distributor-level ingredient prices from *Chemical Market Reporter* (March 6, 2000) or from discussions with industry representatives were used to calculate the baseline and compliant material costs for these formulations. Other sources of cost information were used for selected ingredients as discussed previously. Unspecified ingredients or ingredients for which prices were unknown were grouped into an "all others" classification and assigned a default cost of $3.50 per pound (ARB, 1997a, *op cit*. at Volume II, p.56). These analyses and the detailed formulations evaluated (with individual weight fractions and unit prices per pound) are shown as cost spreadsheets in Appendix I. While these formulations may not reflect the exact composition of existing noncompliant products and compliant products that will be marketed, we believe they are reasonably representative for the purposes of this analysis.

3. Assumptions

As noted previously, we assumed changes in packaging, labeling, distribution and other recurring costs to be negligible relative to baseline levels of these costs (ARB, 1997a). Consistent with the goals of the proposed amendments, we believe that the formulators have more flexibility to select the types of solvents or compounds to comply with the proposed reactivity limits. With this flexibility, the substitution of lower-reactive ingredients for higher-reactive ingredients does not necessarily constitute higher costs; their costs can be almost the same. We also believe that the companies would undertake every effort to mitigate costs.

4. Results

As shown in Table XI-4, the anticipated raw materials cost changes range from no cost (net savings or no cost) to about $0.09 increase per unit (automotive bumper and trim products).

TABLE XI-4
ESTIMATED IMPACTS TO RAW MATERIALS COST PER UNIT ($/UNIT OF PRODUCT)

Table XI-5 shows a comparison of the impacts to raw materials cost under the proposed limits relative to those of other ARB consumer product regulations. As shown, the raw materials cost impacts under the proposed limits are comparable to those of other ARB regulations.

TABLE XI-5.
COMPARISON OF RAW MATERIALS COST IMPACTS FOR THE PROPOSED LIMITS AND OTHER ARB CONSUMER PRODUCT REGULATIONS (UNADJUSTED DOLLARS)

Regulation	Cost Impacts (Dollars per Unit of Product)
Aerosol Coating Products Reactivity Regulation	$0.00 to $0.09
Mid-Term Measures II Consumer Products Regulation[1]	$0.00 to $0.25
Aerosol Coating Products Tier II Regulation[2]	$0.00 to $0.10
Mid-Term Measures Consumer Products Regulation[3]	$0.00 to $0.60
Hairspray Regulation[4]	($0.10) to $0.45
Aerosol Coating Products Regulation[5]	$0.30 to $0.34
Phase II Consumer Products Regulation[6]	<$0.01 to $0.60
Phase I Consumer Products Regulation[7]	net savings to $0.25
Antiperspirants and Deodorants Regulation[8]	$0.25

[1] ARB, 1999.

[2] ARB, 1998.

[3] Phase III Staff Report; ARB, 1997b·

[4] $0.45/unit reported as a worst-case scenario using high-level of HFC-152a as propellant in “premium” products.

[5] ARB, 1995.

[6] ARB, 1991.

[7] ARB, 1990.

[8] Estimate based on assumption of using HFC-152a to replace HC propellants and meet the 0% HVOC limit.

G. Analysis of the Combined Impacts on Per-Unit Cost from Recurring and Nonrecurring Costs

1. Introduction

In this analysis, we evaluated the combined impacts of both recurring (i.e., raw materials costs) and nonrecurring costs from the proposed limits on per-unit costs. Although the non-recurring fixed costs constitute the major portion of the compliance costs, in some categories, on a per unit basis, the recurring cost was the major contributor. In performing this analysis, we used the fixed costs, raw material costs, assumptions, and other facts discussed previously.

2. Methodology

This Method differs from the raw-materials-cost-only analysis in the previous section in that the nonrecurring cost in this analysis is assumed to be "spread out" (i.e., recouped) through the entire California sales volume of each product category. Thus, the total annual recurring and annualized nonrecurring costs reported previously is divided by the number of units sold in California per year to estimate the per-unit cost increase. The California sales volume for a product category is estimated by dividing the total VOC emissions (pounds of VOC per year) for that category by the category's sales-weighted average VOC content (pounds of VOC per pound of product).

3. Results

As shown in Table XI-6, the combined fixed and raw material cost changes to per-unit production costs ranged from no cost increase (net savings or no cost for various categories) to about $0.11 per unit (photographic coatings). Averaged over the sales volume for each category, the unit sales-weighted average cost increase is about $0.05 per unit. The cost per unit to comply with the mass-based VOC limits proposed in 1998 was estimated on average to be less than $0.10 per unit.

TABLE XI-6
ESTIMATED PER-UNIT COST INCREASES FROM BOTH ANNUALIZED NON-RECURRING AND ANNUAL RECURRING COSTS

REFERENCES

California Air Resources Board. (1989). Technical Support Document for a Proposed Regulation to Reduce Volatile Organic Compound Emissions from Antiperspirants and Deodorants. September 1989. Appendix C, pp. C.1-C.62.

California Air Resources Board. (1990). Technical Support Document for a Proposed Regulation to Reduce Volatile Organic Compound Emissions from Consumer Products. Pp. 67 - 71 and Appendix E. August 1990.

California Air Resources Board. (1991). Technical Support Document for Proposed Amendments to the Statewide Regulation to Reduce Volatile Organic Compound Emissions From Consumer Products – Phase II. October 1991. pp. VI.1-VI.6 and Appendix D.

California Air Resources Board. (1995). Initial Statement of Reasons for a Proposed Statewide Regulation to Reduce Volatile Organic Compound Emissions from Aerosol Coating Products and Amendments to the Alternative Control Plan for Consumer Products. February 3, 1995. Volume II, pp. VIII.1-VIII.20, X.1-X.13, and Appendix G.

California Air Resources Board. (1997a). Initial Statement of Reasons for Proposed Amendments Pertaining to Hairspray in the California Consumer Products Regulation. February 7, 1997. Volume II, pp. 44-59.

California Air Resources Board. (1997b). Initial Statement of Reasons for Proposed Amendments to the California Consumer Products Regulation. June 6, 1997. Volume II, Chapter VIII, pp. 11 - 24.

California Air Resources Board. (1998a). Initial Statement of Reasons for the Proposed Amendments to the Regulations for Reducing Volatile Organic Compound Emissions from Aerosol Coatings, Antiperspirants and Deodorants, and Consumer Products. October 2, 1998. Pp. 88-93.

California Air Resources Board. (1998b). Aerosol Coating Product Survey. November 25, 1997.

California Air Resources Board. (1999). Initial Statement of Reasons for Proposed Amendments to the California Consumer Products Regulation. September 10, 1999. Volume II, pp. 206-221.

California Environmental Protection Agency. (1996) Memorandum "Economic Analysis Requirements for the Adoption of Administrative Regulations" to Cal/EPA Executive Officers and Directors from Peter M. Rooney, Undersecretary. December 6, 1996. Appendix C "Cal/EPA Guidelines for Evaluating Alternatives to Proposed Major Regulations. pp. 5 - 6.

Chemical Market Reporter (2000). Chemical Prices. March 6, 2000.
http://www.chemexpo.com/cmronline/stories/03_06_00/47_03_06_00.cfm

XII.

Future Activities

In the near future, Air Resources Board (ARB) staff will begin working on an update to the consumer product element of the 1994 State Implementation Plan (SIP) for ozone. We have already begun discussions with affected stakeholders on the 1997 emission inventory that would be used as the basis for determining feasible emission reduction strategies. After approval of the mobile source emission inventory (EMFAC2000) and the quantification of the carrying capacity for the South Coast Air Basin and the San Joaquin Valley in mid-2000, staff will begin discussions with stakeholders on concepts for consumer products control measures to include in the SIP. We anticipate conducting public workshops on the proposed consumer products SIP element in the fall and winter of 2000. The draft proposed statewide control plan would be released prior to consideration by the Board in early 2001.

In developing concepts for the consumer products portion of the statewide control plan, we will be analyzing the 1997 emission inventory on a category-by-category basis to determine additional feasible control measures. These categories will include both currently regulated and unregulated categories. We will be looking at potential emission reductions through new technologies, mass-based limits, reactivity-based limits, market incentive programs, and pollution prevention and education programs.

In the fall of 2000, ARB staff will be proposing amendments to the Antiperspirant and Deodorant Regulation. These amendments are necessary to ensure that efficacious aerosol forms of antiperspirants will continue to be available to the consumer.

ARB staff will also begin working on amending the Alternative Control Plan (ACP) Regulation. The ACP Regulation allows participating companies to sell a high-VOC (VOC content above the limit) product in California as long as they also sell enough of a reformulated low-VOC product (VOC content below the limit) to offset the excess VOC emissions. We will be evaluating ways to provide more flexibility and allow more companies to participate in the program while still maintaining the emission reductions achieved if the company complied with the limits in the regulations.

Proposed
REGULATION FOR REDUCING THE OZONE FORMED FROM ~~VOLATILE ORGANIC COMPOUND EMISSIONS FROM~~ AEROSOL COATING PRODUCT~~S~~ EMISSIONS

[Note: The proposed amendments for this rulemaking action are shown in ~~strikeout~~ to indicate proposed deletions and underline to indicate proposed additions.]

Amend Title 17, California Code of Regulations, Article 3, Aerosol Coating Products, Sections 94521-94524 and 94526, to read as follows:

SUBCHAPTER 8.5 CONSUMER PRODUCTS

Article 3. Aerosol Coating Products

94520. Applicability.

This article shall apply to any person who sells, supplies, offers for sale, applies, or manufactures aerosol coating products for use in the state of California, except as provided in section 94523.

NOTE: Authority cited: Section 39600, 39601, and 41712, Health and Safety Code. Reference: Sections 39002, 39600, 40000, and 41712, Health and Safety Code.

94521. Definitions.

(a) For the purposes of this article, the following definitions apply:

(1) “Adhesive” means a product used to bond one surface to another.

(2) “Aerosol Coating Product” means a pressurized coating product containing pigments or resins that dispenses product ingredients by means of a propellant, and is packaged in a disposable can for hand-held application, or for use in specialized equipment for ground traffic/marking applications.

(3) “Anti-Static Spray” means a product used to prevent or inhibit the accumulation of static electricity.

(4) “Art Fixative or Sealant” means a clear coating, including art varnish, workable art fixative, and ceramic coating, which is designed and labeled exclusively for application to paintings, pencil, chalk, or pastel drawings, ceramic art pieces, or other closely related art uses, in order to provide a final protective coating or to fix preliminary stages of artwork while providing a workable surface for subsequent revisions.

(5) “ASTM” means the American Society for Testing and Materials.

(6) “Auto Body Primer” means an automotive primer or primer surfacer coating designed and labeled exclusively to be applied to a vehicle body substrate for the purposes of corrosion resistance and building a repair area to a condition in which, after drying, it can be sanded to a smooth surface.

(7) “Automotive Bumper and Trim Product” means a product, including adhesion promoters and chip sealants, designed and labeled exclusively to repair and refinish automotive bumpers and plastic trim parts.

(8) “Automotive Underbody Coating” means a flexible coating which contains asphalt or rubber and is designed and labeled exclusively for use on the underbody of motor vehicles to resist rust, abrasion and vibration, and to deaden sound.

(9) “Aviation Propeller Coating” means a coating designed and labeled exclusively to provide abrasion resistance and corrosion protection for aircraft propellers.

(10) “Aviation or Marine Primer” means a coating designed and labeled exclusively to meet federal specification TT-P-1757.

(11) “Base Reactive Organic Gas Mixture” (Base ROG Mixture) means the mixture of reactive organic gases utilized in deriving the MIR scale.

(~~11~~12) “Belt Dressing” means a product applied on auto fan belts, water pump belting, power transmission belting, and industrial and farm machinery belting to prevent slipping, and to extend belt life.

(~~12~~13) “Cleaner” means a product designed and labeled primarily to remove soil or other contaminants from surfaces.

(~~13~~14) “Clear Coating” means a coating which is colorless, containing resins but no pigments except flatting agents, and is designed and labeled to form a transparent or translucent solid film.

(~~14~~15) “Coating Solids” means the nonvolatile portion of an aerosol coating product, consisting of the film forming ingredients, including pigments and resins.

(~~15~~16) “Commercial Application” means the use of aerosol coating products in the production of goods, or the providing of services for profit, including touch-up and repair.

(~~16~~17) “Corrosion Resistant Brass, Bronze, or Copper Coating” means a clear coating designed and labeled exclusively to prevent tarnish and corrosion of uncoated brass, bronze, or copper metal surfaces.

(~~17~~18) "Distributor" means any person to whom an aerosol coating product is sold or supplied for the purposes of resale or distribution in commerce, except that manufacturers, retailers, and consumers are not distributors.

(~~18~~19) "Dye" means a product containing no resins which is used to color a surface or object without building a film.

(~~19~~20) "Electrical Coating" means a coating designed and labeled exclusively as such, which is used exclusively to coat electrical components such as wire windings on electric motors to provide insulation and protection from corrosion.

(~~20~~21) "Enamel" means a coating which cures by chemical cross-linking of its base resin and is not resoluble in its original solvent.

(~~21~~22) "Engine Paint" means a coating designed and labeled exclusively to coat engines and their components.

(~~22~~23) "Exact Match Finish, Engine Paint" means a coating which meets all of the following criteria: (A) the product is designed and labeled exclusively to exactly match the color of an original, factory-applied engine paint; (B) the product is labeled with the manufacturer's name for which they were formulated; and (C) the product is labeled with one of the following: (1.) the original equipment manufacturer's (O.E.M.) color code number; (2.) the color name; or (3.) other designation identifying the specific O.E.M. color to the purchaser.

(~~23~~24) "Exact Match Finish, Automotive" means a topcoat which meets all of the following criteria: (A) the product is designed and labeled exclusively to exactly match the color of an original, factory-applied automotive coating during the touch-up of automobile finishes; (B) the product is labeled with the manufacturer's name for which they were formulated; and (C) the product is labeled with one of the following: (1.) the original equipment manufacturer's (O.E.M.) color code number; (2.) the color name; or (3.) other designation identifying the specific O.E.M. color to the purchaser. Not withstanding the foregoing, automotive clear coatings designed and labeled exclusively for use over automotive exact match finishes to replicate the original factory applied finish shall be considered to be automotive exact match finishes.

(~~24~~25) "Exact Match Finish, Industrial" means a coating which meets all of the following criteria: (A) the product is designed and labeled exclusively to exactly match the color of an original, factory-applied industrial coating during the touch-up of manufactured products; (B) the product is labeled with the manufacturer's name for which they were formulated; and (C) the product is labeled with one of the following: (1.) the original equipment manufacturer's (O.E.M.) color code number; (2.) the color name; or (3.) other designation identifying the specific O.E.M. color to the purchaser.

(~~25~~26) “Executive Officer” means the Executive Officer of the Air Resources Board, or her or his delegate.

(~~26~~27) “Flat Paint Products” means a coating which, when fully dry, registers specular gloss less than or equal to 15 on an 85^{o} gloss meter, or less than or equal to 5 on a 60^{o} gloss meter, or which is labeled as a flat coating.

(~~27~~28) “Flatting Agent” means a compound added to a coating to reduce the gloss of the coating without adding color to the coating.

(~~28~~29) “Floral Spray” means a coating designed and labeled exclusively for use on fresh flowers, dried flowers, or other items in a floral arrangement for the purposes of coloring, preserving or protecting their appearance.

(~~29~~30) “Fluorescent Coating” means a coating labeled as such, which converts absorbed incident light energy into emitted light of a different hue.

(~~30~~31) “Glass Coating” means a coating designed and labeled exclusively for use on glass or other transparent material to create a soft, translucent light effect, or to create a tinted or darkened color while retaining transparency.

(~~31~~32) “Ground Traffic/Marking Coating” means a coating designed and labeled exclusively to be applied to dirt, gravel, grass, concrete, asphalt, warehouse floors, or parking lots. Such coatings must be in a container equipped with a valve and sprayhead designed to direct the spray toward the surface when the can is held in an inverted vertical position.

(~~32~~33) “High Temperature Coating” means a coating, excluding engine paint, which is designed and labeled exclusively for use on substrates which will, in normal use, be subjected to temperatures in excess of 400^{o}F.

(~~33~~34) “Hobby/Model/Craft Coating” means a coating which is designed and labeled exclusively for hobby applications and is sold in aerosol containers of 6 ounces by weight or less.

(35) “Ingredient” means a component of an aerosol coating product.

(~~34~~36) “Ink” means a fluid or viscous substance used in the printing industry to produce letters, symbols or illustrations, but not to coat an entire surface.

(~~35~~37) “Lacquer” means a thermoplastic film-forming material dissolved in organic solvent, which dries primarily by solvent evaporation, and is resoluble in its original solvent.

(~~36~~38) “Layout Fluid” (or toolmaker's ink) means a coating designed and labeled exclusively to be sprayed on metal, glass or plastic, to provide a glare-free surface on which to scribe designs, patterns or engineering guide lines prior to shaping the piece.

(~~37~~39) "Leather preservative or cleaner" means a leather treatment material applied exclusively to clean or preserve leather.

(~~38~~40) "Lubricant" means a substance such as oil, petroleum distillates, grease, graphite, silicone, lithium, etc. that is used to reduce friction, heat, or wear when applied between surfaces.

(~~39~~41) "Manufacturer" means any person who imports, manufactures, assembles, produces, packages, repackages, or relabels a consumer product.

(~~40~~42) "Marine Spar Varnish" means a coating designed and labeled exclusively to provide a protective sealant for marine wood products.

(~~41~~43) "Maskant" means a coating applied directly to a component to protect surface areas when chemical milling, anodizing, aging, bonding, plating, etching, or performing other chemical operations on the surface of the component.

(44) "Maximum Incremental Reactivity" (MIR) means the maximum change in weight of ozone formed by adding a compound to the "Base ROG Mixture" per weight of compound added, expressed to hundredths of a gram (g O_3/g ROC). MIR values for individual compounds and hydrocarbon solvents are specified in sections 94700 and 94701, Title 17, California Code of Regulations.

(~~42~~45) "Metallic Coating" means a topcoat which contains at least 0.5 percent by weight elemental metallic pigment in the formulation, including propellant, and is labeled as "metallic", or with the name of a specific metallic finish such as "gold", "silver", or "bronze."

(~~43~~46) "Mold Release" means a coating applied to molds to prevent products from sticking to the surfaces of the mold.

(~~44~~47) "Multi-Component Kit" means an aerosol spray paint system which requires the application of more than one component (e.g. foundation coat and top coat), where both components are sold together in one package.

(~~45~~48) "Nonflat Paint Product" means a coating which, when fully dry, registers a specular gloss greater than 15 on an 85^o gloss meter or greater than five on a 60^o gloss meter.

(49) "Ozone" means a colorless gas with a pungent odor, having the molecular form O_3.

(~~46~~50) "Percent VOC By Weight" means the ratio of the weight of VOC to the total weight of the product contents expressed as follows:

$$\text{Percent VOC By Weight} = (W_{\mathbf{VOC}} / W_{\mathbf{total}}) \times 100$$

Where:

(A) for products containing no water and no volatile compounds exempt from the definition of VOC: $W_{\mathbf{voc}}$ = the weight of volatile compounds;

(B) for products containing water or exempt compounds: W_{voc} = the weight of volatile compounds, less water, and less compounds exempt from the VOC definition in this section 94521; and

(C) W_{total} = the total weight of the product contents.

(~~47~~51) "Photograph Coating" means a coating designed and labeled exclusively to be applied to finished photographs to allow corrective retouching, protection of the image, changes in gloss level, or to cover fingerprints.

(~~48~~52) "Pleasure Craft" means privately owned vessels used for noncommercial purposes.

(~~49~~53) "Pleasure Craft Finish Primer/Surfacer/Undercoater" means a coating designed and labeled exclusively to be applied prior to the application of a pleasure craft topcoat for the purpose of corrosion resistance and adhesion of the topcoat, and which promotes a uniform surface by filling in surface imperfections.

(~~50~~54) "Pleasure Craft Topcoat" means a coating designed and labeled exclusively to be applied to a pleasure craft as a final coat above the waterline and below the waterline when stored out of water. This category does not include clear coatings.

(~~51~~55) "Primer" means a coating labeled as such, which is designed to be applied to a surface to provide a bond between that surface and subsequent coats.

(56) "Product-Weighted MIR" (PWMIR) means the sum of all weighted-MIR for all ingredients in a product subject to this article. The PWMIR is the total product reactivity expressed to hundredths of a gram of ozone formed per gram of product (excluding container and packaging) and calculated according to the following equations:

(a) Weighted MIR (Wtd-MIR) ingredient = MIR x Weight fraction ingredient,

and,

(b) Product Weighted MIR = $(\text{Wtd-MIR})_1 + (\text{Wtd-MIR})_2 + \ldots + (\text{Wtd- MIR})_n$

where,

MIR = ingredient MIR, as specified in section 94522(h);

Wtd-MIR = MIR of each ingredient in a product multiplied by the weight fraction of that ingredient, as shown in (a);

1,2,3,...,n = each ingredient in the product up to the total n ingredients in the product.

(~~52~~57) "Propellant" means a liquefied or compressed gas that is used in whole or in part, such as a cosolvent, to expel a liquid or any other material from the same self-pressurized container or from a separate container.

(58) "Reactivity Limit" means the maximum "product-weighted MIR" allowed in an aerosol coating product that is subject to the limits specified in section 94522(a)(3) for a specific category, expressed as g O_3/g product.

(59) "Reactive Organic Compound (ROC)" means any compound that has the potential, once emitted, to contribute to ozone formation in the troposphere.

(~~53~~60) "Responsible Party" means the company, firm, or establishment which is listed on the product's label. If the label lists two companies, firms or establishments, the responsible party is the party which the product was "manufactured for" or "distributed by", as noted on the label.

(~~54~~61) "Retailer" means any person who sells, supplies, or offers aerosol coating products for sale directly to consumers.

(~~55~~62) "Retail Outlet" means any establishment where consumer products are sold, supplied, or offered for sale, directly to consumers.

(~~56~~63) "Rust Converter" means a product designed and labeled exclusively to convert rust to an inert material and which contains a minimum acid content of 0.5 percent by weight, and a maximum coating solids content of 0.5 percent by weight.

(~~57~~64) "Shellac Sealer" means a clear or pigmented coating formulated solely with the resinous secretion of the lac beetle (*Laccifer lacca*), thinned with alcohol, and formulated to dry by evaporation without a chemical reaction.

(~~58~~65) "Slip-Resistant Coating" means a coating designed and labeled exclusively as such, which is formulated with synthetic grit and used as a safety coating.

(~~59~~66) "Spatter Coating/Multicolor Coating" means a coating labeled exclusively as such wherein spots, globules, or spatters of contrasting colors appear on or within the surface of a contrasting or similar background.

(~~60~~67) "Stain" means a coating which is designed and labeled to change the color of a surface but not conceal the surface.

(68) “Upper-Limit Kinetic Reactivity” (ULKR) means the maximum percentage of the emitted ROC which has reacted. For this article, the ULKR is one hundred percent and is used to calculate the ULMIR.

(69) “Upper-Limit Mechanistic Reactivity” (ULMR) means the maximum gram(s) of ozone formed per gram of reactive organic compound (ROC) reacting. The ULMR is used to calculate the ULMIR.

(70) “Upper-Limit MIR” (ULMIR) means the upper-limit kinetic reactivity (ULKR) multiplied by the upper-limit mechanistic reactivity (ULMR), as calculated using the following equation:

ULMIR = Upper Limit KR x Upper Limit MR.

The units for ULMIR are g O_3/g ROC.

(~~61~~71) “Vinyl/Fabric/Leather/Polycarbonate Coating” means a coating designed and labeled exclusively to coat vinyl, fabric, leather, or polycarbonate substrates.

(~~62~~72) “Volatile Organic Compound (VOC)” means any compound containing at least one atom of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, and excluding the following:

(A) methane,
methylene chloride (dichloromethane),
1,1,1-trichloroethane (methyl chloroform),
trichlorofluoromethane (CFC-11),
dichlorodifluoromethane (CFC-12),
1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113),
1,2-dichloro-1,1,2,2-tetrafluoroethane (CFC-114),
chloropentafluoroethane (CFC-115),
chlorodifluoromethane (HCFC-22),
1,1,1-trifluoro-2,2-dichloroethane (HCFC-123),
1,1-dichloro-1-fluoroethane (HCFC-141b),
1-chloro-1,1-difluoroethane (HCFC-142b),
2-chloro-1,1,1,2-tetrafluoroethane (HCFC-124),
trifluoromethane (HFC-23),
1,1,2,2-tetrafluoroethane (HFC-134),
1,1,1,2-tetrafluoroethane (HFC-134a),
pentafluoroethane (HFC-125),
1,1,1-trifluoroethane (HFC-143a),
1,1-difluoroethane (HFC-152a),
cyclic, branched, or linear completely methylated siloxanes,
the following classes of perfluorocarbons:
1. cyclic, branched, or linear, completely fluorinated alkanes;

2. cyclic, branched, or linear, completely fluorinated ethers with no unsaturations;
3. cyclic, branched, or linear, completely fluorinated tertiary amines with no unsaturations; and
4. sulfur-containing perfluorocarbons with no unsaturations and with the sulfur bonds to carbon and fluorine, and

(B) the following low-reactive organic compounds which have been exempted by the U.S. EPA:

acetone,
ethane,
methyl acetate,
parachlorobenzotrifluoride (1-chloro-4-trifluoromethyl benzene),
perchloroethylene (tetrachloroethylene).

(~~63~~73) “Webbing/Veiling Coating” means a coating designed and labeled exclusively to provide a stranded to spider webbed appearance when applied.

(74) “Weight Fraction” means the weight of an ingredient divided by the total net weight of the product, expressed to thousandths of a gram of ingredient per gram of product (excluding container and packaging). The weight fraction is calculated according to the following equation:

$$\text{Weight Fraction} = \frac{\text{Weight of the ingredient}}{\text{Total product net weight (excluding container and packaging)}}.$$

(~~64~~75) “Weld-Through Primer” means a coating designed and labeled exclusively to provide a bridging or conducting effect for corrosion protection following welding.

(~~65~~76) “Wood Stain” means a coating which is formulated to change the color of a wood surface but not conceal the surface.

(~~66~~77) “Wood Touch-Up/Repair/Restoration” means a coating designed and labeled exclusively to provide an exact color or sheen match on finished wood products.

(~~67~~78) “Working Day” means any day between Monday through Friday, inclusive, except for days that are federal holidays.

NOTE: Authority cited: Section 39600, 39601, and 41712, Health and Safety Code. Reference: Sections 39002, 39600, 40000, and 41712, Health and Safety Code.

94522. ~~Standards~~ Limits and Requirements for Aerosol Coating Products.

(a)(1) Compliance with Limits. Aerosol coating products manufactured beginning June 1, 2002, for the general coating categories and beginning January 1, 2003, for the specialty coating categories shall comply with the reactivity requirements specified in 94522(a)(3). Aerosol coating products manufactured before the effective dates of the reactivity limits specified in section 94522(a)(3) shall comply with the VOC requirements specified in section 94522(a)(2), except for products that are labeled by the manufacturer with the applicable reactivity limit, as provided in section 94524(b)(1)(B). If an aerosol coating product is so labeled, then the product shall comply with the reactivity requirements specified in section 94522(a)(3), regardless of the date on which the product was manufactured.

(a)(~~1~~2) VOC Limits for Aerosol Coating Products. Except as provided in sections 94522(a)(1), 94523 (Exemptions), 94525 (Variances), 94540 through 94555 (Alternative Control Plan), and 94567(a)(1) (Hairspray Credit Program), Title 17, California Code of Regulations, no person shall sell, supply, offer for sale, apply, or manufacture for use in California, any aerosol coating product which, at the time of sale, use, or manufacture, contains volatile organic compounds in excess of the limits specified in the following Table of Standards after the specified effective dates.

Table of Standards

Percent Volatile Organic Compounds by Weight[1]

Aerosol Coating Category	1/8/96	~~1/1/2002~~
General Coatings		
Clear Coatings	67.0	~~50.0~~
Flat Paint Products	60.0	~~40.0~~
Fluorescent Coatings	75.0	~~60.0~~
Metallic Coatings	80.0	~~65.0~~
Nonflat Paint Products	65.0	~~45.0~~
Primers	60.0	~~40.0~~
Specialty Coatings		
Art Fixatives or Sealants	95.0	~~60.0~~
Auto Body Primers	80.0	~~45.0~~
Automotive Bumper and Trim Products	95.0	~~75.0~~
Aviation or Marine Primers	80.0	~~70.0~~
Aviation Propeller Coatings	84.0	~~70.0~~
Corrosion Resistant Brass, Bronze, or Copper Coatings	92.0	~~70.0~~
Exact Match Finishes:		
Engine Enamel	80.0	~~50.0~~
Automotive	88.0	~~50.0~~
Industrial	88.0	~~70.0~~
Floral Sprays	95.0	~~70.0~~
Glass Coatings	95.0	~~65.0~~
Ground Traffic/Marking Coatings	66.0	~~45.0~~
High Temperature Coatings	80.0	~~60.0~~
Hobby/Model/Craft Coatings:		
Enamel	80.0	~~70.0~~
Lacquer	88.0	~~70.0~~
Clear or Metallic	95.0	~~80.0~~

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[1] As specified in section 94522(c), for aerosol coating products containing methylene chloride, the VOC standards specified in this subsection (a)(2) shall apply to the combined percent VOC and methylene chloride by weight.

Table of Standards

Percent Volatile Organic Compounds by Weight[1]

Aerosol Coating Category	1/8/96	~~1/1/2002~~
Specialty Coatings (Cont'd)		
Marine Spar Varnishes	85.0	~~60.0~~
Photograph Coatings	95.0	~~70.0~~
Pleasure Craft Finish Primers, Surfacers or Undercoaters	75.0	~~55.0~~
Pleasure Craft Topcoats	80.0	~~55.0~~
Shellac Sealers:		
Clear	88.0	~~70.0~~
Pigmented	75.0	~~60.0~~
Slip-Resistant Coatings	80.0	~~60.0~~
Spatter/Multicolor Coatings	80.0	~~55.0~~
Vinyl/Fabric/Leather/Polycarbonate Coatings	95.0	~~70.0~~
Webbing/Veil Coatings	90.0	~~80.0~~
Weld-Through Primers	75.0	~~50.0~~
Wood Stains	95.0	~~75.0~~
Wood Touch-Up, Repair or Restoration Coatings	95.0	~~90.0~~

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[1] As specified in section 94522(c), for aerosol coating products containing methylene chloride, the VOC standards specified in this subsection (a)(2) shall apply to the combined percent VOC and methylene chloride by weight.

(a)(3) Reactivity Limits for Aerosol Coating Products.

(A) Except as provided in sections 94522(a)(1), 94523 (Exemptions) and 94525 (Variances), Title 17, California Code of Regulations, no person shall sell, supply, offer for sale, apply, or manufacture for use in California, any aerosol coating product which, at the time of sale, use, or manufacture, contains reactive organic compounds that have a PWMIR in excess of the limits specified in the following Table of Limits after the specified effective date.

Table of Limits

Product-Weighted MIR in Grams Ozone per Gram Product
(g O_3 / g product)

Aerosol Coating Category

General Coatings	06/01/2002
Clear Coatings	1.54
Flat Paint Products	1.21
Fluorescent Coatings	1.77
Metallic Coatings	1.93
Nonflat Paint Products	1.40
Primers	1.11

Specialty Coatings	01/01/2003
Art Fixatives or Sealants	1.80
Auto Body Primers	1.57
Automotive Bumper and Trim Products	1.75
Aviation or Marine Primers	1.98
Aviation Propeller Coatings	2.47
Corrosion Resistant Brass, Bronze, or Copper Coatings	1.78
Exact Match Finishes:	
Engine Enamel	1.72
Automotive	1.77
Industrial	2.07
Floral Sprays	1.68
Glass Coatings	1.42
Ground Traffic/Marking Coatings	1.18
High Temperature Coatings	1.83
Hobby/Model/Craft Coatings:	
Enamel	1.47
Lacquer	2.70
Clear or Metallic	1.60
Marine Spar Varnishes	0.87
Photograph Coatings	0.99
Pleasure Craft Finish Primers, Surfacers or Undercoaters	1.05

Table of Limits

Product-Weighted MIR in Grams Ozone per Gram Product
(g O_3 / g product)

Aerosol Coating Category

Specialty Coatings (Cont'd)	**01/01/2003**
Pleasure Craft Topcoats	0.59
Shellac Sealers:	
Clear	0.98
Pigmented	0.94
Slip-Resistant Coatings	2.41
Spatter/Multicolor Coatings	1.07
Vinyl/Fabric/Leather/Polycarbonate Coatings	1.54
Webbing/Veil Coatings	0.83
Weld-Through Primers	0.98
Wood Stains	1.38
Wood Touch-Up, Repair or Restoration Coatings	1.49

(a)(~~2~~4) ~~i~~If an aerosol coating product is subject to both a general coating limit and a specialty coating limit, as listed in section 94522(a)(~~1~~2) or (a)(3), and the product meets all the criteria of the applicable specialty coating category as defined in section 94521, then the specialty coating limit shall apply instead of the general coating limit.

(a)(~~3~~5) Notwithstanding the provisions of sections 94522(a)(~~2~~4) or 94524(a), high-temperature coatings that contain at least 0.5 percent by weight of an elemental metallic pigment in the formulation, including propellant, shall be subject to the ~~VOC~~ limit specified for metallic coatings.

(a)(6) The Alternative Control Plan Regulation (sections 94540-94555) may not be used for aerosol coating products subject to the reactivity limits specified in section 94522(a)(3).

(b) **Sell-Through of Products Subject to the VOC Limits Specified in Section 94522(a)(2).**

Notwithstanding the provisions of section 94522(a)(1) and (a)(3), an aerosol coating product manufactured prior to each of the effective dates specified for that product ~~in the Table of Standards~~ in section 94522(a)(3) may be sold, supplied, offered for sale, or applied for up to three years after each of the specified effective dates, provided that the product complies with the limit specified in section 94522(a)(2). This subsection (b) does not apply to any product which~~:(1) is subject to the provisions of Bay Area Air Quality Management District Rule 8-49 and is sold, supplied, offered for sale, or applied within~~

~~the Bay Area Air Quality Management District; or (2)~~ does not display on the product container or package the date on which the product was manufactured, or a code indicating such date.

(c) **Products Containing Methylene Chloride**.

(1) Requirements for Products Subject to the VOC Limits Specified in Section 94522(a)(2).

For any aerosol coating product containing methylene chloride, the VOC standards specified in section 94522(a)(2) shall apply to the combined percent by weight of both volatile organic compounds, and methylene chloride, calculated as follows:

(Percent by weight VOC + Percent by weight methylene chloride) must be less than or equal to the applicable VOC standard

(2) Requirements for Products Subject to the Reactivity Limits Specified in Section 94522(a)(3).

(A) For any aerosol coating product subject to the reactivity limits specified in section 94522(a)(3), no person shall sell, supply, offer for sale, apply, or manufacture for use in California any aerosol coating product which contains methylene chloride. The requirements of this subsection 94522(c)(2) shall not apply to (A) any existing product formulation containing methylene chloride that complies with the Limits specified in section 94522(a)(3) and was sold in California during calendar year 1997, or (B) any product formulation containing methylene chloride that was sold in California during calendar year 1997 that is reformulated to meet the Limits specified in section 94522(a)(3), as long as the content of methylene chloride in the reformulated product does not increase.

(B) The requirements of section 94522(c)(2) shall not apply to any aerosol coating product containing methylene chloride that is present as an impurity in a combined amount equal to or less than 0.01% by weight of the product.

(d) **Products Containing Perchloroethylene or Ozone Depleting Substances**.

(1) Requirements for Products Subject to the VOC Limits Specified in Section 94522(a)(2).

~~After the effective date of this article, f~~For any aerosol coating product ~~for which standards are specfied under~~ subject to the VOC limits specified in section 94522(a)(2), no person shall sell, supply, offer for sale, apply, or manufacture for use in California any aerosol coating product which contains perchloroethylene, or an ozone depleting substance identified by the United States Environmental Protection Agency in the Code of Federal Regulations, 40 CFR Part 82, Subpart A, under Appendices A and B, July 1, 1998. The requirements of this section 94522(d)(1) shall not apply to (A) any existing product formulation that complies with the Table of Standards and was sold in California during calendar year 1992, or (B) any product formulation that was sold in California during calendar year 1992 that is reformulated to meet the Table of Standards, as long as the content of perchloroethylene, or ozone depleting substances, as identified in this section 94522(d), in the reformulated product does not increase.

(2) Requirements for Products Subject to the Reactivity Limits Specified in Section 94522(a)(3).

For any aerosol coating product subject to the reactivity limits specified in section 94522(a)(3), no person shall sell, supply, offer for sale, apply, or manufacture for use in California any aerosol coating product which contains perchloroethylene, or an ozone depleting substance identified by the United States Environmental Protection Agency in the Code of Federal Regulations, 40 CFR Part 82, Subpart A, under Appendices A and B, July 1, 1998. The requirements of this section 94522(d)(2) shall not apply to (A) any existing product formulation containing perchloroethylene or an ozone depleting substance that complies with the Table of Limits and was sold in California during calendar year 1997, or (B) any product formulation containing perchloroethylene that was sold in California during calendar year 1997 that is reformulated to meet the Table of Limits, as long as the content of perchloroethylene, or ozone depleting substances, as identified in this section 94522(d)(2), in the reformulated product does not increase.

(~~2~~3) The requirements of section 94522(d)(1) and (d)(2) shall not apply to any aerosol coating product containing perchloroethylene, or an ozone depleting substance as identified in section 94522(d)(1) or (d)(2), that are present as impurities in a combined amount equal to or less than 0.01% by weight of the product.

(e) **Multicomponent Kits.**

(1) Requirements for Products Subject to the VOC Limits Specified in Section 94522(a)(2).

No person shall sell, supply, offer for sale, apply, or manufacture for use in California any multi-component kit, as defined in section 94521, in which the total weight of VOC and methylene chloride contained in the multi-component kit $(\text{Total VOC + MC})_{\text{actual}}$ is greater than the total weight of VOC and methylene chloride that would be allowed in the multi-component kit if each component product in the kit had separately met the applicable VOC standards $(\text{Total VOC+ MC})_{\text{standard}}$ as calculated below:

$$(\text{Total VOC + MC})_{\text{actual}} = (\text{VOC}_1 \text{ x } W_1) + (\text{MC}_1 \text{ x } W_1) + (\text{VOC}_2 \text{ x } W_2) +$$

$$(MC_2 \text{ x } W_2) + (VOC_n \text{ x } W_n) + (MC_n \text{ x } W_n)$$

$$(\text{Total VOC} + \text{MC})_{\text{standard}} = (STD_1 \text{ x } W_1) + (STD_2 \text{ x } W_2) + (STD_n \text{ x } W_n)$$

Where:
VOC = the percent by weight VOC of the component product
MC = the percent by weight methylene chloride of the component product
STD = the VOC standard specified in section 94522(a) which applies to the component product.
W = the weight of the product contents (excluding container)
Subscript 1 denotes the first component product in the kit
Subscript 2 denotes the second component product in the kit
Subscript n denotes any additional component product

(2) Requirements for Products Subject to the Reactivity Limits Specified in Section 94522(a)(3).

No person shall sell, supply, offer for sale, apply, or manufacture for use in California any multi-component kit, as defined in section 94521, in which the Kit PWMIR is greater than the Total Reactivity Limit. The Total Reactivity Limit represents the limit that would be allowed in the multi-component kit if each component product in the kit had separately met the applicable Reactivity Limit. The Kit PWMIR and Total Reactivity Limit are calculated as in equations (1), (2) and (3) below:

(1) $\text{Kit PWMIR} = (PWMIR_{(1)} \text{ x } W_1) + (PWMIR_{(2)} \text{ x } W_2) + \ldots + (PWMIR_{(n)} \text{ x } W_n)$

(2) $\text{Total Reactivity Limit} = (RL_1 \text{ x } W_1) + (RL_2 \text{ x } W_2) + \ldots + (RL_n \text{ x } W_n)$

(3) $\text{Kit PWMIR} \leq \text{Total Reactivity Limit}$

Where:

W = the weight of the product contents (excluding container)
RL = the Reactivity Limit specified in section 94522(a)(3)
Subscript 1 denotes the first component product in the kit
Subscript 2 denotes the second component product in the kit
Subscript n denotes any additional component product

(f) **Products Assembled by Adding Bulk Paint to Aerosol Containers of Propellant**. No person shall sell, supply, offer for sale, apply, or manufacture for use in the state of California any aerosol coating product assembled by adding bulk paint to aerosol containers of propellant, unless such products comply with the VOC standards specified in section 94522(a)(2), or with the reactivity limits specified in section 94522(a)(3) for products subject to those limits.

(g) **Requirements for Lacquer Aerosol Coating Products Subject to the VOC Limits Specified in Section 94522(a)(2).**

(1) Notwithstanding the provisions of Section 94522(a)(2), lacquer aerosol coating products may be sold, supplied, offered for sale, applied, or manufactured for use in California with a combined VOC and methylene chloride content of up to 80 percent by weight until January 1, 1998.

(2) On or after January 1, 1998, all lacquer aerosol coating products sold, supplied, offered for sale, applied, or manufactured for use in California shall comply with the provisions of section 94522(a)(2), except that lacquer aerosol coating products manufactured prior to January 1, 1998 may be sold, supplied, offered for sale, or applied until January 1, 2001, as long as the product displays on the product container or package the date on which the product was manufactured or a code indicating such date.

(3) This subsection (~~h~~g) does not apply to: (A) any lacquer coating product not clearly labeled as such, or (B) any lacquer coating product which is sold, supplied, offered for sale, applied, or manufactured for use in the Bay Area Air Quality Management District (BAAQMD) and is subject to BAAQMD Rule 8-49, or (C) any lacquer coating product that meets the definition of "clear coating" specified in section 94521.

(h) **Assignment of Maximum Incremental Reactivity (MIR) Values.**

(1) In order to calculate the PWMIR of aerosol coating products as specified in section 94521(a)(56), the MIR values of product ingredients are assigned as follows:

(A) Any ingredient which does not contain carbon is assigned a MIR value of 0.0.

(B) Any aerosol coating solid, including but not limited to resins, pigments, fillers, plasticizers, and extenders is assigned a MIR value of 0.0.

(C) For any ROC not covered under (1)(A) and (1)(B) of this subsection (h), each ROC is assigned the MIR value set forth in Subchapter 8.6, Article 1, sections 94700 and 94701, Title 17, California Code of Regulations.

(D) Only ROCs listed in sections 94700 and 94701, Title 17, California Code of Regulations, can be used to comply with the reactivity limits specified in section 94522(a)(3).

NOTE: Authority cited: Section 39600, 39601, and 41712, Health and Safety Code. Reference: Sections 39002, 39600, 40000, and 41712, Health and Safety Code.

94523. Exemptions.

(a) This article shall not apply to aerosol lubricants, mold releases, automotive underbody coatings, electrical coatings, cleaners, belt dressings, anti-static sprays, layout fluids and removers, adhesives, maskants, rust converters, dyes, inks, and leather preservatives or cleaners.

(b) This article shall not apply to any aerosol coating product manufactured in California for shipment and use outside of California.

(c) The provisions of this article shall not apply to a manufacturer, distributor, or responsible party who sells, supplies, or offers for sale in California an aerosol coating product that does not comply with the ~~VOC standards~~ limits specified in ~~S~~section 94522(a)(2) or (a)(3), as long as the manufacturer, distributor, or responsible party can demonstrate both that the aerosol coating product is intended for shipment and use outside of California, and that the manufacturer, distributor, or responsible party has taken reasonable prudent precautions to assure that the aerosol coating product is not distributed to California. This subsection (c) does not apply to aerosol coating products that are sold, supplied, or offered for sale by any person to retail outlets in California.

(d) The requirements in sections 94522(a)(2) and (a)(3) prohibiting the application of aerosol coating products ~~containing volatile organic compounds in excess of~~ that exceed the limits specified in ~~the Table of Standards~~ sections 94522(a)(2) or (a)(3) shall apply only to commercial application of aerosol coating products.

NOTE: Authority cited: Section 39600, 39601, and 41712, Health and Safety Code. Reference: Sections 39002, 39600, 40000, and 41712, Health and Safety Code.

94524. Administrative Requirements.

(a) **Most Restrictive Limit.**

Except as otherwise provided in section 94522(a)(~~2~~ 4), if anywhere on the container of any aerosol coating product subject to the specified limits in section 94522(a)(2) or (a)(3) ~~listed in the Table of Standards~~, or on any sticker or label affixed thereto, or in any sales or advertising literature, any representation is made that the product may be used as, or is suitable for use as a product for which a lower ~~VOC standard~~ limit is specified, then the lowest applicable ~~VOC standard~~ limit shall apply.

(b) **Labeling Requirements.**

(1) Both the manufacturer and responsible party for each aerosol coating product subject to this article shall ensure that all products ~~subject to section 94522(a)~~

clearly display the following information on each product container which is manufactured 90 days or later after the effective date of this article~~:~~.

(A) Products subject to the VOC limits specified in section 94522(a)(2) shall display:

1. the applicable VOC standard for the product that is specified in section 94522(a)(2), expressed as a percentage by weight unless the product is included in an alternative control plan approved by the Executive Officer, as provided in Article 4. Section 94540-94555, Title 17, California Code of Regulations, and the product exceeds the applicable VOC standard;

2. if the product is included in an alternative control plan approved by the Executive Officer, and the product exceeds the applicable VOC standard specified in section 94522(a)(2), the product shall be labeled with the term "ACP" or "ACP product";

~~(B)~~3. the aerosol coating category as defined in section 94521, or an abbreviation of the coating category; and

~~(C)~~4. the day, month, and year on which the product was manufactured, or a code indicating such date.

(B) Products subject to the reactivity limits specified in section 94522(a)(3) shall display:

1. the applicable reactivity limit for the product that is specified in section 94522(a)(3);

2. the aerosol coating category as defined in section 94521, or an abbreviation of the coating category; and

3. the day, month, and year on which the product was manufactured, or a code indicating such date.

(2) The information required in section 94524(b)(1), shall be displayed on the product container such that it is readily observable without removing or disassembling any portion of the product container or packaging. For the purposes of this subsection, information may be displayed on the bottom of a container as long as it is clearly legible without removing any product packaging.

(3) No person shall remove, alter, conceal, or deface the information required in section 94524(b)(1) prior to final sale of the product.

(4) For any aerosol coating product subject to section 94522(a), if the manufacturer or responsible party uses a code indicating the date of manufacture or an abbreviation of the coating category as defined in section 94521, an explanation of the code or abbreviation must be filed with the Executive Officer prior to the use of the code or abbreviation.

(c) **Reporting Requirements.**

(1) Any responsible party for an aerosol coating product subject to this article which is sold, supplied, or offered for sale in California, must supply the Executive Officer of the Air Resources Board with the following information within 90 days of the effective date of this article: the company name, mail address, contact person, and the telephone number of the contact person.

For responsible parties who do not manufacture their own aerosol coating products, the responsible party shall also supply the information specified in this subsection (c)(1) for those manufacturers which produce products for the responsible party.

The responsible party shall also notify the Executive Officer within 90 days of any change in the information supplied to the Executive Officer pursuant to this subsection (c)(1).

(2) Upon 90 days written notice, each manufacturer or responsible party subject to this article shall submit to the Executive Officer a written report with all of the following information for each product they manufacture under their name or another company's name:

(A) the brand name of the product;
(B) upon request, a copy of the product label;
(C) the owner of the trademark or brand names;
(D) the product category as defined in section 94521;
(E) the annual California sales in pounds per year and the method used to calculate California annual sales;
(F) product formulation data:
  1. for products subject to the VOC limits specified in section 94522(a)(2), the percent by weight VOC, water, solids, propellant, and any compounds exempt from the definition of VOC as specified in section 94521;
  2. for products subject to the reactivity limits specified in section 94522(a)(3), the PWMIR and the weight fraction of all ingredients including: water, solids, each ROC, and any compounds assigned a MIR value of zero as specified in sections 94522(h), 94700, or 94701;
(G) an identification of each product brand name as a “household,” “industrial,” or “both” product; and

(H) any other information necessary to determine the emissions or the product-weighted MIR from aerosol coating products.

The information requested in this section (c)(~~3~~ 2) may be supplied as an average for a group of aerosol coating products within the same coating category when the products do not vary in VOC content by more than two percent (by weight), and the coatings are based on the same resin type, or the products are color variations of the same product (even if the coatings vary by more than 2 percent in VOC content).

(3) Upon written request, the responsible party for aerosol coating products subject to this article shall supply the Executive Officer with a list of all exempt compounds contained in any aerosol coating product within 15 working days.

(d) **Treatment of Confidential Information.**

All information submitted by manufacturers pursuant to section 94524 shall be handled in accordance with the procedures specified in Title 17, California Code of Regulations, sections 91000-91022.

(e) **Special Reporting Requirements for Perchloroethylene-Containing Aerosol Coatings.**

(1) The requirements of this subsection shall apply to all responsible parties for perchloroethylene-containing aerosol coatings sold or offered for sale in California on or after January 1, 1996. For the purposes of this subsection, "perchloroethylene-containing aerosol coating" means any aerosol coating that is required to comply with any ~~VOC standard~~ limit specified in section 94522(a)(2) or (a)(3) and contains 1.0 percent or more by weight (exclusive of the container or packaging) of perchloroethylene (tetrachloroethylene).

(2) Reporting Requirements to Establish Baseline. On or before March 1, 1997, or 60 days after the effective date of this subsection (e) (whichever date occurs later), all responsible parties for perchloroethylene-containing aerosol coatings shall report to the Executive Officer the following information for each product:

(A) the product brand name and a copy of the product label with legible usage instructions;

(B) the product category to which the aerosol coating belongs;

~~(C)~~ ~~the applicable product form(s) (listed separately);~~

(~~D~~C) ~~for each product form listed in (C),~~ the total amount of the aerosol coating sold in California between January 1, 1996 and December 31, 1996, to the nearest pound (exclusive of the container or packaging), and the method used for calculating the California sales;

(~~E~~D) the weight percent, to the nearest 0.10 percent, of perchloroethylene in the aerosol coating;

(3) Annual Reporting Requirements. On or before March 1, 1998, March 1, 1999, March 1, 2000, March 1, 2001, and March 1, 2002, all responsible parties subject to the requirements of this subsection shall provide to the Executive Officer an update which reports, for the previous calendar year, any changes in the annual California sales, perchloroethylene content, or any other information provided pursuant to subsections (e)(2)(A) through (e)(2)(~~E~~D). After March 1, 2002, responsible parties are not required to submit this information unless specifically requested to do so by the Executive Officer.

(4) Upon request, the Executive Officer shall make the information submitted pursuant to this subsection available to publicly-owned treatment works in California, in accordance with the procedures for handling of confidential information specified in Title 17, California Code of Regulations, sections 91000-91022.

(A) On or before July 1, 2002, the Executive Officer shall evaluate the information, along with data on influent and effluent levels of perchloroethylene as reported by publicly-owned treatments works and any other relevant information, to determine if it is likely that publicly-owned treatment works are experiencing increased levels of perchloroethylene, relative to 1996 levels, that can be attributed to aerosol coatings which contain perchloroethylene.

(B) If the Executive Officer determines that it is likely that increased perchloroethylene levels at the publicly-owned treatment works are caused by increased levels of perchloroethylene in aerosol coatings subject to this regulation, then the Executive Officer shall, in conjunction with the publicly-owned treatment works, implement measures which are feasible, appropriate, and necessary for reducing perchloroethylene levels at the publicly-owned treatment works.

NOTE: Authority cited: Section 39600, 39601, 41511, and 41712, Health and Safety Code. Reference: Sections 39002, 39600, 40000, 41511, and 41712, Health and Safety Code.

94525. Variances.

(a) Any person who cannot comply with the requirements set forth in Section 94522, because of extraordinary reasons beyond the person's reasonable control may apply in writing to the Executive Officer for a variance. The variance application shall set forth:

(1) the specific grounds upon which the variance is sought;

(2) the proposed date(s) by which compliance with the provisions of Section 94522 will be achieved, and

(3) a compliance report reasonably detailing the method(s) by which compliance will be achieved.

(b) Upon receipt of a variance application containing the information required in subsection (a), the Executive Officer shall hold a public hearing to determine whether, under what conditions, and to what extent, a variance from the requirements in Section 94522 is necessary and will be permitted. A hearing shall be initiated no later than 75 working days after receipt of a variance application. Notice of the time and place of the hearing shall be sent to the applicant by certified mail not less than 30 days prior to the hearing. Notice of the hearing shall also be submitted for publication in the California Regulatory Notice Register and sent to every person who requests such notice, not less than 30 days prior to the hearing. The notice shall state that the parties may, but need not be, represented by counsel at the hearing. At least 30 days prior to the hearing, the variance application shall be made available to the public for inspection. Information submitted to the Executive Officer by a variance applicant may be claimed as confidential, and such information shall be handled in accordance with the procedures specified in Title 17, California Code of Regulations, Sections 91000-91022. The Executive Officer may consider such confidential information in reaching a decision on a variance application. Interested members of the public shall be allowed a reasonable opportunity to testify at the hearing and their testimony shall be considered.

(c) No variance shall be granted unless all of the following findings are made:

(1) that, because of reasons beyond the reasonable control of the applicant, requiring compliance with Section 94522 would result in extraordinary economic hardship.

(2) that the public interest in mitigating the extraordinary hardship to the applicant by issuing the variance outweighs the public interest in avoiding any increased emissions of air contaminants which would result from issuing the variance.

(3) that the compliance report proposed by the applicant can reasonably be implemented, and will achieve compliance as expeditiously as possible.

(d) Any variance order shall specify a final compliance date by which the requirements of Section 94522 will be achieved. Any variance order shall contain a condition that specifies increments of progress necessary to assure timely compliance, and such other conditions that the Executive Officer, in consideration of the testimony received at the hearing, finds necessary to carry out the purposes of Division 26 of the Health and Safety Code.

(e) A variance shall cease to be effective upon failure of the party to whom the variance was granted to comply with any term or condition of the variance.

(f) Upon the application of any person, the Executive Officer may review, and for good cause, modify or revoke a variance from the requirements of Section 94522 after holding a public hearing in accordance with the provisions of subsection 94525(b).

NOTE: Authority cited: Sections 39600, 39601, and 41712, Health and Safety Code. Reference: Sections 39002, 39600, 40000, and 41712, Health and Safety Code.

94526. Test Methods.

Compliance with the requirements of this article shall be determined by using the following test methods, which are incorporated by reference herein. Alternative test methods which are shown to accurately determine the VOC content, ingredient name and weight percent of each ingredient, exempt compound content, metal content, specular gloss, or acid content may also be used after approval in writing by the Executive Officer:

(a) Testing for Products Subject to the VOC Limits Specified in Section 94522(a)(2).

(1) VOC Content. The VOC content of all aerosol coating products subject to the provisions of this article shall be determined by the procedures set forth in “Air Resources Board Method 310, Determination of Volatile Organic Compounds (VOC) in Consumer Products,” adopted September 25, 1997 and as last amended on [Date of Amendment] ~~November 19, 1998~~.

(2) In sections 3.5 and 3.7 of Air Resources Board (ARB) Method 310, a process is specified for the “Initial Determination of VOC Content” and the “Final Determination of VOC Content”. This process is an integral part of testing procedure set forth in ARB Method 310, and is reproduced below:

Sections 3.5 and 3.7 of Air Resources Board Method 310

3.5 Initial Determination of VOC Content. The Executive Officer will determine the VOC content pursuant to section 3.2 and 3.3. Only those components with concentrations equal to or greater than 0.1 percent by weight will be reported.

3.5.1 Using the appropriate formula specified in section 4.0, the Executive Officer will make an initial determination of whether the product meets the applicable VOC standards specified in ARB regulations. If initial results show that the products does not meet the applicable VOC standards, the Executive Officer may perform additional testing to confirm the initial results.

3.5.2 If the results obtained under section 3.5.1 show that the products does not meet the applicable VOC standards, the Executive Officer will request the product manufacturer or responsible party to supply product formulation data. The manufacturer or responsible party shall supply the requested information. Information submitted to the ARB Executive Officer may be claimed as confidential; such information will be handled in accordance with the confidentiality procedures specified in Title 17, California Code of Regulations, sections 91000 to 91022.

3.5.3 If the information supplied by the manufacturer or responsible party shows that the product does not meet the applicable VOC standards, then the Executive Officer will take appropriate enforcement action.

3.5.4 If the manufacturer or responsible party fails to provide formulation data as specified in section 3.5.2, the initial determination of VOC content under this section 3.5 shall determine if the product is in compliance with the applicable VOC standards. This determination may be used to establish a violation of ARB regulations.

3.7 Final Determination of VOC Content. If a product's compliance status is not satisfactorily resolved under section 3.5 and 3.6, the Executive Officer will conduct further analyses and testing as necessary to verify the formulation data.

3.7 .1 If the accuracy of the supplied formulation data is verified and the product sample is determined to meet the applicable VOC standards, then no enforcement action for violation of the VOC standards will be taken.

3.7.2 If the Executive Officer is unable to verify the accuracy of the supplied formulation data, then the Executive Officer will request the product manufacturer or responsible party to supply information to explain the discrepancy.

3.7.3 If there exists a discrepancy that cannot be resolved between the results of Method 310 and the supplied formulation data, then the results of Method 310 shall take precedence over the supplied formulation data. The results of Method 310 shall then determine if the product is in compliance with the applicable VOC standards, and may be used to establish a violation of ARB regulations.

<u>(b) Testing for Products Subject to the Reactivity Limits Specified in Section 94522(a)(3).</u>

(1) The ingredients and the amount of each ingredient of all aerosol coating products subject to the provisions of this article shall be determined by the procedures set forth in “Air Resources Board Method 310, Determination of Volatile Organic Compounds (VOC) in Consumer Products,” adopted September 25, 1997 and as last amended on [Date of Amendment].

(2) Upon written notification from the Executive Officer, the aerosol coating manufacturer shall have 10 working days to provide to the Executive Officer the following information for products selected for testing:

(A) the product category as defined in section 94521(a);
(B) the PWMIR and the weight fraction of all ingredients including: water, solids, each ROC, and any compounds assigned a MIR value of zero as specified in sections 94522(h), 94700, or 94701;
(C) any other information necessary to determine the PWMIR of the aerosol coating products to be tested.

(3) Final determination of the PWMIR of the aerosol coatings shall be determined using the information obtained from section 94526(b)(1) and (2).

(~~b~~c) Exempt Compounds from Products Subject to the VOC Limits Specified in Section 94522(a)(2). Compounds exempt from the definition of VOC shall be analyzed according to the test methods listed below:

(1) the exempt compound content of ~~all~~ aerosol coating products shall be determined by “Air Resources Board Method 310, Determination of Volatile Organic Compounds (VOC) in Consumer Products,” adopted September 25, 1997 and as last amended on [Amendment Date], which is incorporated herein by reference.

(2) the following classes of compounds will be analyzed as exempt compounds only if manufacturers specify which individual compounds are used in the product formulations and identify the test methods, which prior to such analysis, have been approved by the Executive Officer of the ARB, and can be used to quantify the amounts of each exempt compound: cyclic, branched, or linear, completely fluorinated alkanes; cyclic, branched, or linear, completely fluorinated ethers with no unsaturations; cyclic, branched, or linear, completely fluorinated tertiary amines with no unsaturations; and sulfur-containing perfluorocarbons with no unsaturations and with sulfur bonds only to carbon and fluorine.

(~~c~~d) Metal Content. The metal content of metallic aerosol coating products shall be determined by South Coast Air Quality Management District (SCAQMD) Test Method 318-95 “Determination of Weight Percent Elemental Metal in Coatings by X-ray Diffraction” July 1996, which is incorporated herein by reference.

(~~d~~e) Specular Gloss. Specular gloss of flat and nonflat coatings shall be determined by ASTM Method D-523-89, March 31, 1989, which is incorporated herein by reference.

(~~e~~f) Acid Content. The acid content of rust converters shall be determined by ASTM Method D-1613-91, “Standard Test Method for Acidity in Volatile Solvents and Chemical Intermediates Used in Paint, Varnish. Lacquer, and Related Products, May 15, 1991, which is incorporated herein by reference.

(~~f~~g) Lacquers. Lacquer aerosol coating products shall be identified according to the procedures specified in ASTM Method D-5043-90, “Standard Test Methods for Field Identification of Coatings,” April 27, 1990, which is incorporated herein by reference.

NOTE: Authority cited: Sections 39600, 39601, 39607, 41511, and 41712, Health and Safety Code. Reference: Sections 39002, 39600, 39607, 40000, 41511, and 41712, Health and Safety Code.

94527. Severability.

Each part of this article shall be deemed severable, and in the event that any part of this article is held to be invalid, the remainder of this article shall continue in full force and effect.

NOTE: Authority cited: Sections 39600, 39601, and 41712, Health and Safety Code. Reference: Sections 39002, 39600, 40000, and 41712, Health and Safety Code.

94528. Federal Enforceability.

For purposes of federal enforceability of this article, the United States Environmental Protection Agency is not subject to approval determinations made by the Executive Officer under sections 94525 and 94526. Within 180 days of a request from a person who has been granted a variance under Section 94525, a variance meeting the requirements of the Clean Air Act shall be submitted by the Executive Officer to the Environmental Protection Agency for inclusion in the applicable implementation plan approved or promulgated by the Environmental Protection Agency pursuant to Section 110 of the Clean Air Act, 42 U.S.C., Section 7410.

NOTE: Authority cited: Section 39600, 39601, 39602, and 41712, Health and Safety Code. Reference: Sections 39002, 39600, 39602, 40000, and 41712, Health and Safety Code.

Proposed
TABLES OF MAXIMUM INCREMENTAL REACTIVITY (MIR) VALUES

Add new Title 17, California Code of Regulations, Article 1, Tables of Maximum Incremental Reactivity (MIR) Values, section 94700-94701, to read as follows:

SUBCHAPTER 8.6 MAXIMUM INCREMENTAL REACTIVITY

Article 1. Tables of Maximum Incremental Reactivity (MIR) Values

94700. MIR Values for Compounds.

Organic Compound	MIR Value	Effective Date
1,1,1-Trichloroethane	0.00	*
1,1,2-Trichloroethane	0.06	*
1,1,3-Trimethyl Cyclohexane	1.37	*
1,1-Dichloroethane	0.10	*
1,2,3-Trimethyl Benzene	11.26	*
1,2,4-Trimethylbenzene	7.18	*
1,2-Butanediol	2.21	*
1,2-Dibromoethane	0.05	*
1,2-Dichloroethane	0.10	*
1,2-Dihydroxy Hexane	2.75	*
1,2-Dimethyl Cyclohexene	6.77	*
1,2-Epoxybutane (Ethyl Oxirane)	1.02	*
1,3,5-Triethyl Cyclohexane	1.06	*
1,3,5-Trimethylbenzene	11.22	*
1,3,5-Tripropyl Cyclohexane	0.90	*
1,3-Butadiene	13.58	*
1,3-Diethyl-5-Methyl Cyclohexane	1.11	*
1,3-Diethyl-5-Pentyl Cyclohexane	0.99	*
1,3-Diethyl-Cyclohexane	1.34	*
1,3-Dimethyl Cyclohexane	1.72	*
1,3-Dimethyl Cyclopentane	2.15	*
1,3-Dipropyl-5-Butyl Cyclohexane	0.77	*
1,3-Dipropyl-5-Ethyl Cyclohexane	0.94	*
1,4-Diethyl-Cyclohexane	1.49	*
1-Butanol (N-Butyl Alcohol)	3.34	*
1-Butene	10.29	*
1-Decene	2.28	*
1-Dodecene	1.72	*
1-Ethyl-2-Propyl Cyclohexane	0.95	*
1-Ethyl-4-Methyl Cyclohexane	1.62	*

Organic Compound	**MIR Value**	**Effective Date**
1-Heptanol	2.21	*
1-Heptene	4.56	*
1-Hexanol	2.74	*
1-Hexene	6.17	*
1-Hydroxy-2,2,4-Trimethylpentyl-3-Isobutyrate	0.92	*
1-Methyl Cyclohexene	7.81	*
1-Methyl Cyclopentene	13.95	*
1-Methyl Naphthalene	4.61	*
1-Methyl-2-Hexyl-Cyclohexane	0.70	*
1-Methyl-2-Octyl Cyclohexane	0.60	*
1-Methyl-3-Isopropyl Cyclohexane	1.26	*
1-Methyl-4-Heptyl Cyclohexane	0.58	*
1-Methyl-4-Nonyl Cyclohexane	0.55	*
1-Methyl-4-Pentyl Cyclohexane	0.81	*
1-Nonene	2.76	*
1-Octanol	2.01	*
1-Octene	3.45	*
1-Pentadecene	1.30	*
1-Pentene	7.79	*
1-Tetradecene	1.48	*
1-Tridecene	1.55	*
1-Undecene	1.95	*
2-(2-Butoxyethoxy)-Ethanol	2.70	*
2-(2-Ethoxyethoxy) Ethanol	3.19	*
2-(Chloro-Methyl)-3-Chloro-Propene	1.13	*
2,2,3,3-Tetramethyl Butane	0.44	*
2,2,3-Trimethyl Butane	1.32	*
2,2,4-Trimethyl Pentane (Isooctane)	1.44	*
2,2,5-Trimethyl Hexane	1.33	*
2,2-Dimethoxypropane	11.52	*
2,2-Dimethyl Butane	1.33	*
2,2-Dimethyl Hexane	1.13	*
2,2-Dimethyl Pentane	1.22	*
2,2-Dimethylpropanal (Pivaldehyde)	5.40	*
2,3,3-Trimethyl-1-Butene	4.62	*
2,3,4-Trimethyl Pentane	1.23	*
2,3,5-Trimethyl Hexane	1.33	*
2,3-Dimethyl Butane	1.14	*
2,3-Dimethyl Hexane	1.34	*
2,3-Dimethyl Naphthalene	5.54	*
2,3-Dimethyl Pentane	1.55	*
2,3-Dimethyl-1-Butene	4.77	*
2,3-Dimethyl-2-Butene	13.32	*
2,3-Dimethyl-2-Hexene	10.41	*

Organic Compound	MIR Value	Effective Date
2,4,4-Trimethyl-2-Pentene	5.85	*
2,4-Dimethyl Heptane	1.48	*
2,4-Dimethyl Hexane	1.80	*
2,4-Dimethyl Octane	1.09	*
2,4-Dimethyl Pentane	1.65	*
2,5-Dimethyl Hexane	1.68	*
2,6-Diethyl Octane	1.09	*
2,6-Dimethyl Nonane	0.95	*
2,6-Dimethyl Octane	1.27	*
2-Butanol (S-Butyl Alcohol)	1.60	*
2-Butyl Tetrahydrofuran	2.53	*
2-Butyne	16.33	*
2-Decanone	1.06	*
2-Ethoxyethanol	3.78	*
2-Ethoxyethyl Acetate	1.90	*
2-Ethyl-1-Butene	5.04	*
2-Ethyl-1-Hexanol (Ethyl Hexyl Alcohol)	2.20	*
2-Ethyl-Hexyl Acetate	0.79	*
2-Heptenes	6.96	*
2-Hexanol	2.46	*
2-Hexenes	8.44	*
2-Methoxy Ethyl Acetate	1.18	*
2-Methoxy Ethyl Acetate	1.18	*
2-Methoxy-1-Propanol	3.01	*
2-Methoxy-1-Propyl Acetate	1.12	*
2-Methyl Heptane	1.20	*
2-Methyl Hexane	1.37	*
2-Methyl Naphthalene	4.61	*
2-Methyl Nonane	0.86	*
2-Methyl Octane	0.96	*
2-Methyl Pentane (Isohexane)	1.80	*
2-Methyl-1-Butene	6.51	*
2-Methyl-1-Pentene	5.18	*
2-Methyl-2,4-Pentanediol	1.04	*
2-Methyl-2-Butene	14.45	*
2-Methyl-2-Butene-3-ol (1,2-Dimethylpropyl-1-en-1-ol)	4.10	*
2-Methyl-2-Pentene	12.28	*
2-Methyl-3-Hexanone	1.79	*
2-Methylpropanal	5.87	*
2-Nonanone	1.30	*
2-Octanol	2.16	*
2-Octanone	1.66	*
2-Pentanol	1.74	*
2-Pentanone (Methyl Propyl Ketone)	3.07	*

Organic Compound	**MIR Value**	**Effective Date**
2-Pentenes	10.23	*
2-Tert-Butoxy-1-Propanol	1.81	*
3,3-Diethyl Pentane	1.35	*
3,3-Dimethyl Pentane	1.32	*
3,3-Dimethyl-1-Butene	6.06	*
3,4-Diethyl Hexane	1.20	*
3,4-Diethyl-2-Hexene	3.95	*
3,5-Diethyl Heptane	1.21	*
3,5-Dimethyl Heptane	1.63	*
3,6-Dimethyl Decane	0.88	*
3,6-Dimethyl Undecane	0.82	*
3,7-Diethyl Nonane	1.08	*
3,7-Dimethyl Dodecane	0.74	*
3,7-Dimethyl Tridecane	0.64	*
3,8-Diethyl Decane	0.68	*
3,9-Diethyl Undecane	0.62	*
3-Carene	3.21	*
3-Ethoxy-1-Propanol	4.24	*
3-Hydroxy-2,2,4-Trimethylpentyl-1-Isobutyrate	0.88	*
3-Hydroxy-2,2,4-Trimethylpentyl-1-Isobutyrate Isomers	0.89	*
3-Methoxy-1-Butanol	0.97	*
3-Methoxy-3-Methyl-Butanol	1.74	*
3-Methyl Decane	0.77	*
3-Methyl Dodecane	0.64	*
3-Methyl Heptane	1.35	*
3-Methyl Hexane	1.86	*
3-Methyl Nonane	0.89	*
3-Methyl Pentadecane	0.50	*
3-Methyl Pentane	2.07	*
3-Methyl Tetradecane	0.53	*
3-Methyl Tridecane	0.57	*
3-Methyl Undecane	0.70	*
3-Methyl-1-Butene	6.99	*
3-Methyl-1-Pentene	6.22	*
3-Methyl-2-Isopropyl-1-Butene	3.29	*
3-Methylbutanal (Isovaleraldehyde)	5.52	*
3-Nonenes	5.31	*
3-Octanol	2.57	*
3-Octenes	6.13	*
3-Pentanol	1.73	*
3-Pentanone	1.45	*
4,8-Dimethyl Tetradecane	0.58	*
4-Ethyl Heptane	1.44	*
4-Methyl Cyclohexene	4.48	*

Organic Compound	MIR Value	Effective Date
4-Methyl Decane	0.80	*
4-Methyl Heptane	1.48	*
4-Methyl Nonane	0.99	*
4-Methyl Octane	1.08	*
4-Methyl-1-Pentene	6.26	*
4-Octanol	3.07	*
4-Propyl Heptane	1.24	*
5-Methyl Dodecane	0.64	*
5-Methyl Undecane	0.72	*
6-Methyl Tetradecane	0.57	*
6-Methyl Tridecane	0.62	*
7-Methyl Pentadecane	0.51	*
Acetaldehyde	6.84	*
Acetate, 2,3,5,6,8-Pentamethyl Nonyl	0.74	*
Acetate, 2,3,5,7-Tetramethyl Octyl	0.74	*
Acetate, 2,3,5-Trimethyl Hexyl	0.86	*
Acetate, 2,3-Dimethyl Butyl	0.84	*
Acetate, 2,3-Dimethyl Heptyl	0.84	*
Acetate, 2,4,6,8-Tetramethyl Nonyl	0.63	*
Acetate, 2,4-Dimethyl Heptyl	0.88	*
Acetate, 2,4-Dimethyl Hexyl	0.93	*
Acetate, 2,4-Dimethyl Pentyl	0.98	*
Acetate, 2,5-Dimethyl Heptyl	0.86	*
Acetate, 2-Methyl Hexyl	0.89	*
Acetate, 2-Methyl Octyl	0.63	*
Acetate, 2-Methyl Pentyl	1.11	*
Acetate, 3,4-Dimethyl Hexyl	1.16	*
Acetate, 3,5,7,9-Tetramethyl Decyl	0.58	*
Acetate, 3,5,7-Trimethyl Nonyl	0.76	*
Acetate, 3,5,7-Trimethyl Octyl	0.83	*
Acetate, 3,5-Dimethyl Heptyl	1.01	*
Acetate, 3,5-Dimethyl Hexyl	1.09	*
Acetate, 3,6,8-Trimethyl Nonyl	0.72	*
Acetate, 3,6-Dimethyl Heptyl	0.87	*
Acetate, 3,6-Dimethyl Octyl	0.88	*
Acetate, 3-Ethyl Heptyl	0.71	*
Acetate, 3-Ethyl Hexyl	1.03	*
Acetate, 3-Ethyl Pentyl	1.24	*
Acetate, 3-Ethyl-6,7-Dimethyl Nonyl	0.76	*
Acetate, 3-Ethyl-6-Methyl Octyl	0.80	*
Acetate, 3-Isopropyl Heptyl	0.71	*
Acetate, 3-Methyl Heptyl	0.76	*
Acetate, 3-Methyl Hexyl	1.01	*
Acetate, 3-Methyl Pentyl	1.31	*

Organic Compound	**MIR Value**	**Effective Date**
Acetate, 4,5-Dimethyl Heptyl	0.96	*
Acetate, 4,5-Dimethyl Hexyl	0.86	*
Acetate, 4,6-Dimethyl Heptyl	0.83	*
Acetate, 4,6-Dimethyl Octyl	0.85	*
Acetate, 4,7,9-Trimethyl Decyl	0.55	*
Acetate, 4,7-Dimethyl Nonyl	0.64	*
Acetate, 4-Methyl Heptyl	0.72	*
Acetate, 4-Methyl Hexyl	0.91	*
Acetate, 4-Methyl Octyl	0.68	*
Acetate, 4-Methyl Pentyl	0.92	*
Acetate, 5-Ethyl-3,6,8-Trimethyl Nonyl	0.77	*
Acetate, 5-Methyl Heptyl	0.73	*
Acetate, 5-Methyl Hexyl	0.79	*
Acetate, 5-Methyl Octyl	0.67	*
Acetic Acid	0.71	*
Acetone	0.43	*
Acetylene	1.25	*
Acrolein	7.60	*
Acrylic Acid	11.66	*
Alkyl Phenols	2.34	*
Alpha-Methyltetrahydrofuran	4.62	*
a-Methyl Styrene	1.72	*
Amyl Acetate	0.96	*
a-Pinene	4.29	*
Base ROG Mixture	3.71	*
Benzaldehyde	0.00	*
Benzene	0.81	*
Benzotrifluoride	0.26	*
Biacetyl	20.73	*
b-Pinene	3.28	*
Branched C10 Alkanes	1.09	*
Branched C11 Alkanes	0.87	*
Branched C12 Alkanes	0.80	*
Branched C13 Alkanes	0.73	*
Branched C14 Alkanes	0.67	*
Branched C15 Alkanes	0.60	*
Branched C16 Alkanes	0.54	*
Branched C17 Alkanes	0.51	*
Branched C18 Alkanes	0.48	*
Branched C5 Alkanes	1.68	*
Branched C6 Alkanes	1.53	*
Branched C7 Alkanes	1.63	*
Branched C8 Alkanes	1.57	*
Branched C9 Alkanes	1.25	*

Organic Compound	**MIR Value**	**Effective Date**
Butanal	6.74	*
Butyl Cyclohexane	1.07	*
Butyl Methacrylate	9.09	*
Butyl Propionate	0.89	*
Butylbenzene (Isomers)	5.48	*
C10 3-Alkenes	4.50	*
C10 Alkenes	3.39	*
C10 Bicycloalkanes	1.29	*
C10 Cyclic Ketones	1.02	*
C10 Cyclic Or Di-Olefins	4.56	*
C10 Cycloalkanes	1.27	*
C10 Disubstituted Benzenes	5.92	*
C10 Internal Alkenes	4.50	*
C10 Ketones	1.06	*
C10 Monosubstituted Benzenes	1.97	*
C10 Styrenes	1.53	*
C10 Terminal Alkenes	2.28	*
C10 Tetrasubstituted Benzenes	8.86	*
C10 Trisubstituted Benzenes	8.86	*
C11 3-Alkenes	4.23	*
C11 Alkenes	3.09	*
C11 Bicycloalkanes	1.01	*
C11 Cyclic Or Di-Olefins	4.29	*
C11 Cycloalkanes	0.99	*
C11 Disubstituted Benzenes	5.35	*
C11 Internal Alkenes	4.23	*
C11 Monosubstituted Benzenes	1.78	*
C11 Pentasubstituted Benzenes	8.03	*
C11 Terminal Alkenes	1.95	*
C11 Tetralin Or Indane	2.56	*
C11 Tetrasubstituted Benzenes	8.03	*
C11 Trisubstituted Benzenes	8.03	*
C12 2-Alkenes	3.75	*
C12 3-Alkenes	3.75	*
C12 Alkenes	2.73	*
C12 Bicycloalkanes	0.88	*
C12 Cyclic Or Di-Olefins	3.79	*
C12 Cycloalkanes	0.87	*
C12 Disubstituted Benzenes	4.90	*
C12 Disubstituted Naphthalenes	5.54	*
C12 Hexasubstituted Benzenes	7.33	*
C12 Internal Alkenes	3.75	*
C12 Monosubstituted Benzenes	1.63	*
C12 Monosubstituted Naphthalenes	4.20	*

Organic Compound	**MIR Value**	**Effective Date**
C12 Pentasubstituted Benzenes	7.33	*
C12 Terminal Alkenes	1.72	*
C12 Tetrasubstituted Benzenes	7.33	*
C12 Trisubstituted Benzenes	7.33	*
C13 3-Alkenes	3.38	*
C13 Alkenes	2.46	*
C13 Bicycloalkanes	0.79	*
C13 Cyclic Or Di-Olefins	3.42	*
C13 Cycloalkanes	0.78	*
C13 Disubstituted Benzenes	4.50	*
C13 Disubstituted Naphthalenes	5.08	*
C13 Internal Alkenes	3.38	*
C13 Monosubstituted Benzenes	1.50	*
C13 Monosubstituted Naphthalenes	3.86	*
C13 Terminal Alkenes	1.55	*
C13 Trisubstituted Benzenes	6.75	*
C13 Trisubstituted Naphthalenes	5.08	*
C14 3-Alkenes	3.08	*
C14 Alkenes	2.28	*
C14 Bicycloalkanes	0.71	*
C14 Cyclic Or Di-Olefins	3.11	*
C14 Cycloalkanes	0.71	*
C14 Internal Alkenes	3.08	*
C14 Terminal Alkenes	1.48	*
C15 3-Alkenes	2.82	*
C15 Alkenes	2.06	*
C15 Bicycloalkanes	0.69	*
C15 Cyclic Or Di-Olefins	2.85	*
C15 Cycloalkanes	0.68	*
C15 Internal Alkenes	2.82	*
C15 Terminal Alkenes	1.30	*
C16 Cycloalkanes	0.61	*
C4 Aldehydes	6.74	*
C4 Alkenes	11.93	*
C4 Internal Alkenes	13.57	*
C4 Terminal Alkenes	10.29	*
C5 Aldehydes	5.76	*
C5 Alkenes	9.01	*
C5 Cyclic Ketones	1.43	*
C5 Internal Alkenes	10.23	*
C5 Ketones	3.07	*
C5 Terminal Alkenes	7.79	*
C6 Aldehydes	4.98	*
C6 Alkenes	6.88	*

Organic Compound	MIR Value	Effective Date
C6 Cyclic Ketones	1.61	*
C6 Cyclic Or Di-Olefins	8.65	*
C6 Cycloalkanes	1.46	*
C6 Internal Alkenes	8.44	*
C6 Ketones	3.55	*
C6 Terminal Alkenes	6.17	*
C7 Aldehydes	4.23	*
C7 Alkenes	5.76	*
C7 Cyclic Ketones	1.41	*
C7 Cyclic Or Di-Olefins	7.49	*
C7 Cycloalkanes	1.99	*
C7 Internal Alkenes	6.96	*
C7 Ketones	2.80	*
C7 Terminal Alkenes	4.56	*
C8 Aldehydes	3.65	*
C8 Alkenes	4.68	*
C8 Cyclic Ketones	1.25	*
C8 Cyclic Or Di-Olefins	6.01	*
C8 Cycloalkanes	1.75	*
C8 Disubstituted Benzenes	5.16	*
C8 Internal Alkenes	5.90	*
C8 Ketones	1.66	*
C8 Terminal Alkenes	3.45	*
C9 Alkenes	4.03	*
C9 Bicycloalkanes	1.57	*
C9 Cyclic Ketones	1.13	*
C9 Cyclic Or Di-Olefins	5.40	*
C9 Cycloalkanes	1.55	*
C9 Disubstituted Benzenes	6.61	*
C9 Internal Alkenes	5.31	*
C9 Ketones	1.30	*
C9 Monosub. Benzenes	2.20	*
C9 Styrenes	1.72	*
C9 Terminal Alkenes	2.76	*
C9 Trisub. Benzenes	9.90	*
Carbon Monoxide	0.06	*
Chloroform	0.03	*
Cis-2-Butene	13.22	*
Cis-2-Hexene	8.44	*
Cis-2-Pentene	10.24	*
Cis-3-Heptene	6.96	*
Cis-3-Hexene	8.22	*
Cis-3-Methyl-2-Hexene	13.38	*
Cis-4-Octene	5.94	*

Organic Compound	**MIR Value**	**Effective Date**
Cis-5-Decene	4.89	*
Cresol, Meta-	2.34	*
Cresol, Ortho-	2.34	*
Cresol, Para-	2.34	*
Crotonaldehyde	10.07	*
Cumene (Isopropylbenzene)	2.32	*
Cumene Hydroperoxide (1-Methyl-1-Phenylethylhydroperoxide)	12.61	*
Cyclobutane	1.05	*
Cyclobutanone	0.68	*
Cycloheptane	2.26	*
Cyclohexane	1.46	*
Cyclohexanol	2.25	*
Cyclohexanone	1.61	*
Cyclohexene	5.45	*
Cyclooctane	1.73	*
Cyclopentadiene	7.61	*
Cyclopentane	2.69	*
Cyclopentanol	1.96	*
Cyclopentanone	1.43	*
Cyclopentene	7.38	*
Cyclopropane	0.10	*
Decyl Cyclohexane	0.50	*
Dexpanthenol (Pantothenylol)	9.35	*
Di N-Propyl Ether	3.24	*
Diacetone Alcohol (4-Hydroxy-4-Methyl-2-Pentanone)	0.68	*
Dichlorobenzene, Para-	0.20	*
Diethanolamine	4.05	*
Diethyl Ether	4.01	*
Diethylene Glycol	3.55	*
Diethylene Glycol Methyl Ether (2-(2-Methoxyethoxy)-Ethanol)	2.90	*
Diethylenetriamine**	13.03	*
Di-Isobutyl Ether	1.29	*
Di-Isobutyl Ketone (2,6-Dimethyl-4-Heptanone)	2.94	*
Diisopropyl Carbonate	1.04	*
Di-Isopropyl Ketone	1.63	*
Dimethoxymethane	1.04	*
Dimethyl Adipate	1.95	*
Dimethyl Amine	9.37	*
Dimethyl Carbonate	0.06	*
Dimethyl Ether	0.93	*
Dimethyl Glutarate	0.49	*
Dimethyl Naphthalenes	5.54	*
Dimethyl Succinate	0.25	*
Dimethylaminoethanol	4.76	*

Organic Compound	**MIR Value**	**Effective Date**
Dimethylaminoethanol	4.76	*
Di-N-Butyl Ether	3.17	*
Di-N-Pentyl Ether	2.64	*
Dipropylene Glycol	2.48	*
Dipropylene Glycol Methyl Ether	2.21	*
EEP Solvent (Ethyl 3-Ethoxy Propionate)	3.61	*
Ester, Substituted C7	0.92	*
Ester, Substituted C9	0.89	*
Ethane	0.31	*
Ethanol	1.69	*
Ethanolamine	5.97	*
Ethene	9.08	*
Ethyl Acetate	0.64	*
Ethyl Acetylene	6.20	*
Ethyl Acrylate	8.78	*
Ethyl Amine	7.80	*
Ethyl Benzene	2.79	*
Ethyl Bromide	0.11	*
Ethyl Butyrate	1.25	*
Ethyl Chloride	0.25	*
Ethyl Cyclopentane	2.27	*
Ethyl Formate	0.52	*
Ethyl Isopropyl Ether	3.86	*
Ethyl Lactate	2.71	*
Ethyl N-Butyl Ether	3.86	*
Ethyl Propionate	0.79	*
Ethyl T-Butyl Ether	2.11	*
Ethylbenzene (Isomers)	5.16	*
Ethylcyclohexane	1.75	*
Ethylene Glycol	3.36	*
Ethylene Glycol 2-Ethylhexyl Ether [2-(2-Ethylhexyloxy) Ethanol]	8.26	*
Ethylene Glycol Diacetate	0.72	*
Ethylene Glycol Monobutyl Ether (2-Butoxyethanol)	2.90	*
Ethylene Glycol Monobutyl Ether Acetate (2-Butoxyethyl Acetate)	1.67	*
Ethylene Glycol Monomethyl Ether (2-Methoxyethanol)	2.98	*
Ethylene Glycol Monopropyl Ether (2-Propoxyethanol)	3.52	*
Ethylene Oxide	0.05	*
Formaldehyde	8.97	*
Formic Acid	0.08	*
Furan	16.54	*
Glutaraldehyde	4.79	*
Glycerol (1,2,3-Propanetriol)	3.27	*
Glycolic Acid (Hydroxyacetic Acid)	12.62	*
Glyoxal	14.22	*

Organic Compound	**MIR Value**	**Effective Date**
Heptanal	4.23	*
Heptyl Acetate	0.73	*
Heptyl Cyclohexane	0.66	*
Hexanal	4.98	*
Hexane	1.45	*
Hexyl Acetate	0.87	*
Hexyl Cyclohexane	0.75	*
Hexylbenzene (Isomers)	4.53	*
HFC-134a (1,1,1,2-Tetrafluoroethane)	0.00	*
HFC-152a (1,1-Difluoroethane)	0.00	*
Hydroxy Acetone	3.08	*
Hydroxy Methacrolein	6.61	*
Hydroxyethylethylene Urea	14.75	*
Indane	3.17	*
Isoamyl Isobutyrate	0.89	*
Isobutane	1.35	*
Isobutanol (Isobutyl Alcohol)	2.24	*
Isobutyl Acetate	0.67	*
Isobutyl Isobutyrate	0.64	*
Isobutyl Methacrylate	8.99	*
Isobutylene (2-Methylpropene)	6.35	*
Isodecyl Alcohol	1.18	*
Isopentane	1.68	*
Isoprene	10.69	*
Isopropanol (2-Propanol)	0.71	*
Isopropyl Acetate	1.24	*
Isopropyl Cyclopropane	1.52	*
Limonene (Dipentene)	3.99	*
Limonene, d- (Orange Terpene)	3.99	*
Methacrolein	6.23	*
Methacrylic Acid	22.30	*
Methane	0.01	*
Methanol	0.71	*
Methoxy Acetone	2.14	*
Methyl Acetate	0.07	*
Methyl Acetylene	6.45	*
Methyl Acrylate	12.24	*
Methyl Amyl Ketone (2-Heptanone)	2.80	*
Methyl Bromide	0.02	*
Methyl Butyrate	1.18	*
Methyl Chloride	0.03	*
Methyl Cyclohexane	1.99	*
Methyl Cyclopentane	2.42	*
Methyl Ethyl Ketone (2-Butanone)	1.49	*

Organic Compound	MIR Value	Effective Date
Methyl Ethyl Ketoxime (Ethyl Methyl Ketone Oxime)**	15.43	*
Methyl Formate	0.07	*
Methyl Glyoxal	16.21	*
Methyl Isobutyl Ketone (4-Methyl-2-Pentanone)	4.31	*
Methyl Isobutyrate	0.70	*
Methyl Isopropyl Carbonate	0.69	*
Methyl Lactate	2.75	*
Methyl Methacrylate	15.84	*
Methyl Naphthalenes	4.61	*
Methyl N-Butyl Ether	3.66	*
Methyl N-Butyl Ketone (2-Hexanone)	3.55	*
Methyl Pivalate (2,2-Dimethyl Propanoic Acid Methyl Ester)	0.41	*
Methyl Propionate	0.71	*
Methyl Pyrrolidone (1-Methyl-2-Pyrrolidone)	2.56	*
Methyl T-Amyl Ether	2.14	*
Methyl T-Butyl Ether	0.78	*
Methyl T-Butyl Ketone	0.78	*
Methylene Chloride (Dichloromethane)	0.07	*
Methylene Diphenylene Diisocyanate	0.79	*
Methylvinyl Ketone	8.73	*
Monochlorobenzene	0.36	*
Monoisopropanol Amine (1-Amino-2-Propanol)	19.17	*
Morpholine**	15.43	*
Naphthalene	3.26	*
N-Butane	1.33	*
N-Butoxy-2-Propanol	2.70	*
N-Butyl Acetate	0.89	*
N-Butyl Benzene	1.97	*
N-Butyl Bromide	0.60	*
N-Butyl Butyrate	1.12	*
N-Butyl Formate	0.95	*
N-C16	0.52	*
N-C17	0.49	*
N-C18	0.47	*
N-C19	0.44	*
N-C20	0.42	*
N-C21	0.40	*
N-C22	0.38	*
N-Decane	0.83	*
N-Dodecane	0.66	*
Neopentane	0.69	*
N-Heptane	1.28	*
N-Heptyl Acetate	0.73	*
N-Hexyl Acetate	0.87	*

Organic Compound	MIR Value	Effective Date
Nitrobenzene	0.07	*
Nitroethane	12.79	*
Nitromethane	7.86	*
N-Methyl Acetamide	19.70	*
N-Nonane	0.95	*
N-Nonyl Acetate	0.58	*
N-Octane	1.11	*
N-Octyl Acetate	0.64	*
Nonyl Cyclohexane	0.54	*
N-Pentadecane	0.56	*
N-Pentanol (Amyl Alcohol)	3.35	*
N-Propanol (N-Propyl Alcohol)	2.74	*
N-Propyl Benzene	2.20	*
N-Propyl Bromide	0.35	*
N-Propyl Butyrate	1.17	*
N-Propyl Formate	0.93	*
N-Propyl Propionate	0.93	*
N-Tetradecane	0.58	*
N-Tridecane	0.62	*
N-Undecane	0.74	*
Octanal	3.65	*
Octyl Cyclohexane	0.60	*
Oxo-Hexyl Acetate	1.03	*
Oxo-Heptyl Acetate	0.97	*
Oxo-Octyl Acetate	0.96	*
Oxo-Nonyl Acetate	0.85	*
Oxo-Decyl Acetate	0.83	*
Oxo-Dodecyl Acetate	0.72	*
Oxo-Tridecyl Acetate	0.67	*
PCBTF (P-Trifluoromethyl-Cl-Benzene)	0.11	*
Pentanal (Valeraldehyde)	5.76	*
Pentane	1.54	*
Pentyl Cyclohexane	0.91	*
Pentylbenzene (Isomers)	4.96	*
Peracetic Acid (Peroxyacetic Acid)	12.62	*
Perchloroethylene	0.04	*
Phenol	1.82	*
Pine Oil	4.29	*
Propane	0.56	*
Propionaldehyde	7.89	*
Propionic Acid	1.16	*
Propyl Acetate	0.87	*
Propyl Cyclohexane	1.47	*
Propyl Cyclopentane	1.91	*

Organic Compound	MIR Value	Effective Date
Propylbenzene (Isomers)	6.12	*
Propylene (Propene)	11.58	*
Propylene Carbonate	0.25	*
Propylene Carbonate (4-Methyl-1,3-Dioxolan-2-One)	0.25	*
Propylene Glycol	2.75	*
Propylene Glycol Monoethyl Ether (1-Ethoxy-2-Propanol)	3.25	*
Propylene Glycol Monomethyl Ether (1-Methoxy-2-Propanol)	2.62	*
Propylene Glycol Monomethyl Ether Acetate (1-Methoxy-2-Propanol Acetate)	1.71	*
Propylene Glycol Monopropyl Ether (1-Propoxy-2-Propanol)	2.86	*
Propylene Glycol T-Butyl Ether (1-Tert-Butoxy-2-Propanol)	1.71	*
Propylene Oxide	0.32	*
Sabinene	3.67	*
S-Butyl Acetate	1.43	*
S-Butyl Benzene	1.97	*
Styrene	1.95	*
Terpene	3.79	*
Tert-Butyl Acetate	0.22	*
Tert-Butyl Alcohol	0.45	*
Tetrahydrofuran	4.95	*
Tetrahydropyran	3.81	*
Tetralin	2.83	*
Tolualdehyde	0.00	*
Toluene	3.97	*
Toluene Diisocyanate	0.00	*
Toluene Isocyanate, Para-	0.93	*
Trans 2,2-Dimethyl 3-Hexene	5.97	*
Trans 2,5-Dimethyl 3-Hexene	5.44	*
Trans 3-Methyl-2-Hexene	14.17	*
Trans 4,4-Dimethyl-2-Pentene	6.99	*
Trans 4-Methyl-2-Hexene	7.88	*
Trans-1,2-Dichloroethene	0.81	*
Trans-2-Butene	13.91	*
Trans-2-Heptene	7.33	*
Trans-2-Hexene	8.44	*
Trans-2-Pentene	10.23	*
Trans-3-Heptene	6.96	*
Trans-3-Hexene	8.16	*
Trans-3-Octene	6.13	*
Trans-4-Decene	4.50	*
Trans-4-Nonene	5.23	*
Trans-4-Octene	5.90	*
Trans-5-Dodecene	3.74	*
Trans-5-Pentadecene	2.82	*
Trans-5-Tetradecene	3.08	*

Organic Compound	MIR Value	Effective Date
Trans-5-Tridecene	3.38	*
Trans-5-Undecene	4.23	*
Trichloroethylene	0.60	*
Triethanolamine	2.76	*
Triethyl Amine**	16.60	*
Trimethyl Amine	7.06	*
Trimethylene Oxide	5.22	*
Tripropylene Glycol Monomethyl Ether	1.90	*
Vinyl Acetate	3.26	*
Vinyl Chloride	2.92	*
Xylene, Meta-	10.61	*
Xylene, Ortho-	7.49	*
Xylene, Para-	4.25	*

*30 Days after the Regulation is approved by the Office of Administrative Law.
**ULMIR

94701. MIR Values for Hydrocarbon Solvents.

(a) Aliphatic Hydrocarbon Solvents

Bin	Average Boiling Point*** (degrees F)	Criteria	MIR Value	Effective Date
1	80-205	Alkanes (< 2% Aromatics)	2.08	*
2	80-205	N- & Iso-Alkanes (≥ 90% and < 2% Aromatics)	1.59	*
3	80-205	Cyclo-Alkanes (≥ 90% and < 2% Aromatics)	2.52	*
4	80-205	Alkanes (2 to < 8% Aromatics)	2.24	*
5	80-205	Alkanes (8 to 22% Aromatics)	2.56	*
6	>205-340	Alkanes (< 2% Aromatics)	1.41	*
7	>205-340	N- & Iso-Alkanes (≥ 90% and < 2% Aromatics)	1.17	*
8	>205-340	Cyclo-Alkanes (≥ 90% and < 2% Aromatics)	1.65	*
9	>205-340	Alkanes (2 to < 8% Aromatics)	1.62	*
10	>205-340	Alkanes (8 to 22% Aromatics)	2.03	*
11	>340-460	Alkanes (< 2% Aromatics)	0.91	*
12	>340-460	N- & Iso-Alkanes (≥ 90% and < 2% Aromatics)	0.81	*
13	>340-460	Cyclo-Alkanes (≥ 90% and < 2% Aromatics)	1.01	*
14	>340-460	Alkanes (2 to < 8% Aromatics)	1.21	*
15	>340-460	Alkanes (8 to 22% Aromatics)	1.82	*
16	>460-580	Alkanes (< 2% Aromatics)	0.57	*
17	>460-580	N- & Iso-Alkanes (≥ 90% and < 2% Aromatics)	0.51	*
18	>460-580	Cyclo-Alkanes (≥ 90% and < 2% Aromatics)	0.63	*
19	>460-580	Alkanes (2 to < 8% Aromatics)	0.88	*
20	>460-580	Alkanes (8 to 22% Aromatics)	1.49	*

*30 Days after the Regulation is approved by the Office of Administrative Law.
***Average Boiling Point = (Initial Boiling Point + Dry Point) / 2

(b) Aromatic Hydrocarbon Solvents

Bin	Boiling Range (degrees F)	Criteria	MIR Value	Effective Date
21	280-290	Aromatic Content (100%)	7.37	*
22	320-350	Aromatic Content (100%)	7.51	*
23	355-420	Aromatic Content (100%)	8.07	*
24	450-535	Aromatic Content (100%)	5.00	*

*30 Days after the Regulation is approved by the Office of Administrative Law.

California Environmental Protection Agency

Air Resources Board

METHOD 310

DETERMINATION OF VOLATILE ORGANIC COMPOUNDS (VOC) IN CONSUMER PRODUCTS AND REACTIVE ORGANIC COMPOUNDS IN AEROSOL COATING PRODUCTS

(Including Appendices A and B)

Adopted: September 25, 1997
Amended: September 3, 1999
Amended: [Date of Adoption]

DISCLAIMER: Mention of any trade name or commercial product in Method 310 does not constitute endorsement or recommendation of this product by the Air Resources Board.

NOTE: The regulatory amendments adopted in this rulemaking are shown in ***bold underline*** *to indicate additions to the version of Method 310 as last amended on September 3, 1999.*

METHOD 310

DETERMINATION OF VOLATILE ORGANIC COMPOUNDS (VOC) IN CONSUMER PRODUCTS <u>AND REACTIVE ORGANIC COMPOUNDS IN AEROSOL COATING PRODUCTS</u>

1 APPLICABILITY

1.1 This method (Method 310) applies to the determination of the percent by weight of<u>**:**</u>

(1) volatile organic compounds (VOC) in consumer products, antiperspirant and deodorant products, and aerosol coatings products as those terms are defined in Title 17, California Code of Regulations (CCR), Division 3, Chapter 1, Subchapter 8.5 (Consumer Products), commencing with section 94500, and

(2) low vapor pressure-volatile organic compounds (LVP-VOC) as that term is defined in section 94508(a)(78)<u>**, and**</u>

<u>**(3) the reactive organic compounds (ROC) contained in aerosol coating products, as that term is defined in Title 17, CCR, section 94521**</u>.

1.2 Method 310 determines the total volatile material in a product and the presence of any compounds prohibited by ARB regulations (“prohibited compounds”). Components of the product that do not meet the definition of a VOC or are exempted by ARB regulations for a specific product category (“exempt compounds”) are subtracted from the total volatile material to determine the final VOC content for the product. <u>**Method 310 is also used to determine the percent by weight of the ROCs contained in aerosol coating products, for the purpose of determining compliance with the Regulation for Reducing the Ozone Formed from Aerosol Coating Product Emissions, Title 17, CCR, sections 94520 to 94528 (the “Aerosol Coatings Regulation”).**</u>

1.3 Method 310 does not apply to the determination of the composition or concentration of fragrance components in products.

1.4 The term “Executive Officer” as used in this document means the Executive Officer of the Air Resources Board or his or her authorized representative.

2 TEST METHODS

Method 310 incorporates by reference the following American Society for Testing and Materials (ASTM), National Institute for Occupational Safety and Health

(NIOSH), and United States Environmental Protection Agency (US EPA) analytical test methods:

2.1 ASTM D 2369-97: Standard Test Method for Volatile Content of Coatings (July 10, 1997).

2.2 ASTM D 1426-93: Standard Test Methods for Ammonia Nitrogen in Water (September 15, 1993).

2.3 ASTM D 4017-96a: Standard Test Method for Water in Paints and Paint Materials by the Karl Fisher Titration Method (July 10, 1996).

2.4 ASTM D 3792-91: Standard Test Method for Water Content of Water-Reducible Paints by Direct Injection Into a Gas Chromatograph (May 15, 1991).

2.5 ASTM D 859-94: Standard Test Method for Silica in Water (determination of polymethylsiloxanes after digestion) (May 15, 1994).

2.6 ASTM D 3074-94: Standard Test Methods for Pressure in Metal Aerosol Containers (November 15, 1994) with the modifications found in Appendix A to this Method 310.

2.7 ASTM D 3063-94: Standard Test Methods for Pressure in Glass Aerosol Bottles (November 15, 1994) with the modifications found in Appendix A to this Method 310.

2.8 ASTM D 3064-89: Standard Terminology Relating to Aerosol Products (November 24, 1989).

2.9 NIOSH: Method 1400 Alcohols I (analysis of acetone and ethanol by gas chromatography). NIOSH Manual of Analytical Methods, Volume 1 (February 1984).

2.10 Gas Chromatography/Mass Spectrometry for Volatile Organics (analysis of exempt and prohibited compounds in the product by headspace/gas chromatography/mass spectrometry).

2.10.1 US EPA Method 8240B, September 1994, Revision 2, Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS), Test Methods for Evaluating Solid Waste, Volume 1 B, Chapter 4, Section 4.3.2: Laboratory Manual Physical/Chemical Methods, SW-846, September 1994.

2.10.2 US EPA Method 8260B, December 1996, Revision 2, Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS), Test Methods for Evaluating Solid Waste, Volume 1 B, Chapter 4, Section 4.3.2: Laboratory Manual Physical/Chemical Methods, SW-846, December 1996.

2.11 US EPA Reference Method 24, Determination of Volatile Matter Content, Water Content, Density, Volume Solids, and Weight Solids of Surface Coatings: 40 Code of Federal Regulations (CFR) Part 60, Appendix A, as it existed on July 1, 1994.

2.12 US EPA Reference Method 24A, Determination of Volatile Matter Content and Density of Printing Inks and Related Coatings: 40 CFR Part 60, Appendix A, as it existed on July 1, 1994.

2.13 US EPA Reference Method 18, Measurement of Gaseous Organic Compound Emissions by Gas Chromatography: 40 CFR Part 60, Appendix A, as it existed on July 1, 1994.

2.14 US EPA Method 300.7, March, 1986. Dissolved Sodium, Ammonium, Potassium, and Calcium in Wet Deposition by Chemically Suppressed Ion Chromatography.

2.15 ASTM D 86-96: Standard Test Methods for Distillation of Petroleum Products (April 10, 1996).

2.16 ASTM D 850-93: Standard Test Methods for Distillation of Industrial Aromatic Hydrocarbons and Related Materials (April 15, 1993).

2.17 ASTM D 1078-97: Standard Test Methods for Distillation Range of Volatile Liquids (July 10, 1997).

2.18 ASTM D 2879-97: Standard Test Method for Vapor-Pressure-Temperature Relationship and Initial Decomposition Temperature of Liquids by Isoteniscope (April 10, 1997) with the modifications found in Appendix B to this Method 310.

2.19 ASTM D 2887-97: Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography (April 10, 1997).

2.20 ASTM E 1719-97: Standard Test Method for Vapor Pressure of Liquids by Ebulliometry (March 10, 1997).

3 CONSUMER PRODUCTS TESTING PROCEDURE

3.1 The testing begins when the Executive Officer selects a product for analysis by Method 310. The Executive Officer will maintain sample chain of custody throughout the selection and analytical process.

3.2 Initial Testing of Aerosol Products

If the sample is an aerosol product, the aerosol propellant is separated from the liquid portion of the product by using ASTM D 3074-94 (as modified in Appendix A for metal aerosol container) or ASTM D 3063-94 (as modified in Appendix A for glass aerosol container). The propellant portion is analyzed for exempt or prohibited compounds by using US EPA Reference Method 18. The remaining liquid portion of the product is then analyzed as specified in section 3.3.

3.3 Initial Testing of Non-Aerosol Products and the Liquid Portion of Aerosol Products

The liquid, solid, or gel product sample is analyzed to determine the total volatile material present in the sample and to determine the presence of any exempt or prohibited compounds. This analysis is conducted by performing the following tests:[1]

3.3.1 Gravimetric analysis of samples to determine the weight percent of total volatile material, using US EPA Reference Methods 24/24A, ASTM D 2369-97.

3.3.2 Determination of sample water content. For determination of water content either ASTM D 4017-96a, or ASTM D 3792-91 may be used, or results from both procedures may be averaged and that value reported.

3.3.3 Determination of ammonium content using ASTM D 1426-93 or US EPA Method 300.7.

3.3.4 Determination of ketones and alcohol content using NIOSH Method 1400.

3.3.5 Analysis of exempt and prohibited compounds, if present (US EPA Reference Method 18, US EPA Method 8240B, US EPA Method 8260B, ASTM D 859-94, NIOSH Method 1400).

3.3.6 If LVP-VOC status is claimed or the analysis indicates the presence of an LVP-VOC component and the percent VOC is not in compliance, the Executive Officer will request formulation data as specified in Section 3.5.2.

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[1] Alternate test methods may be used, as provided in section 7.0

3.4 Prohibited Compounds

If the sample is found to contain compounds prohibited by ARB regulations (i.e., ozone-depleting compounds) at concentrations equal to or exceeding 0.1 percent by weight, the Executive Officer will reanalyze the sample for confirmation.

3.5 Initial Determination of VOC Content

The Executive Officer will determine the VOC content pursuant to sections 3.2 and 3.3. Only those components with concentrations equal to or greater than 0.1 percent by weight will be reported.

3.5.1 Using the appropriate formula specified in section 4.0, the Executive Officer will make an initial determination of whether the product meets the applicable VOC standards specified in ARB regulations. If initial results show that the product does not meet the applicable VOC standards, the Executive Officer may perform additional testing to confirm the initial results.

3.5.2 If the results obtained under section 3.5.1 show that the product does not meet the applicable VOC standards**,** the Executive Officer will request the product manufacturer or responsible party to supply product formulation data. The manufacturer or responsible party shall supply the requested information. Information submitted to the ARB Executive Officer may be claimed as confidential; such information will be handled in accordance with the confidentiality procedures specified in Title 17, California Code of Regulations, sections 91000 to 91022.

3.5.3 If the information supplied by the manufacturer or responsible party shows that the product does not meet the applicable VOC standards, then the Executive Officer will take appropriate enforcement action.

3.5.4 If the manufacturer or responsible party fails to provide formulation data as specified in section 3.5.2, the initial determination of VOC content under this section 3.5 shall determine if the product is in compliance with the applicable VOC standards. This determination may be used to establish a violation of ARB regulations.

3.6 Determination of the LVP-VOC status of compounds and mixtures. This section does not apply to antiperspirants and deodorants or aerosol coatings products because there is no LVP-VOC exemption for these products.

3.6.1 Formulation data. If the vapor pressure is unknown, the following ASTM methods may be used to determine the LVP-VOC status of compounds and mixtures: ASTM D 86-96 (April 10, 1996), ASTM D 850-93 (April 15, 1993), ASTM D 1078-97 (July 10, 1997), ASTM D 2879-97 (April 10, 1997), as modified in Appendix B to this Method 310, ASTM D 2887-97 (April 10, 1997) and ASTM E 1719-97 (March 10, 1997).

3.6.2 LVP-VOC status of "compounds" or "mixtures." The Executive Officer will test a sample of the LVP-VOC used in the product formulation to determine the boiling point for a compound or for a mixture. If the boiling point exceeds 216^{o} C, the compound or mixture is an LVP-VOC. If the boiling point is less than 216^{o} C, then the weight percent of the mixture which boils above 216^{o} C is an LVP-VOC. The Executive Officer will use the nearest 5 percent distillation cut that is greater than 216^{o} C as determined under 3.6.1 to determine the percentage of the mixture qualifying as an LVP-VOC.

3.6.3 Reference method for identification of LVP-VOC compounds and mixtures. If a product does not qualify as an LVP-VOC under 3.6.2, the Executive Officer will test a sample of the compound or mixture used in a products formulation utilizing one or both of the following: ASTM D 2879-97, as modified in Appendix B to this Method 310, and ASTM E 1719-97, to determine if the compound or mixture meets the requirements of Title 17, CCR, section 94508(a)(78)(A).

3.7 Final Determination of VOC Content

If a product's compliance status is not satisfactorily resolved under sections 3.5 and 3.6, the Executive Officer will conduct further analyses and testing as necessary to verify the formulation data.

3.7.1 If the accuracy of the supplied formulation data is verified and the product sample is determined to meet the applicable VOC standards, then no enforcement action for violation of the VOC standards will be taken.

3.7.2 If the Executive Officer is unable to verify the accuracy of the supplied formulation data, then the Executive Officer will request the product manufacturer or responsible party to supply information to explain the discrepancy.

3.7.3 If there exists a discrepancy that cannot be resolved between the results of Method 310 and the supplied formulation data, then the results of Method 310 shall take precedence over the supplied formulation data. The results of Method 310 shall then determine if the product is in compliance with the applicable VOC standards, and may be used to establish a violation of ARB regulations.

4 CALCULATION OF VOC CONTENT

This section specifies the procedure for calculating and determining the final VOC content of a product, which is reported as a single percent by weight of VOC.

4.1 Aerosol Products

For aerosol products, the percent VOC content shall be calculated using the following equation:

$$\text{PERCENT VOC} = \frac{\text{WL}\ (\text{TV} - \text{A} - \text{H} - \text{EL}) + \text{WP} - \text{EP}}{\text{WL} + \text{WP}} \times 100\%$$

Where[2]:

WL = weight (gm) of liquid product excluding container and packaging

TV = weight fraction of non-propellant total volatile material (US EPA Reference Methods 24/24A, ASTM D 2369-97)

A = weight fraction of ammonia (as NH_4) in liquid (ASTM D 1426-93) or US EPA Method 300.7

H = weight fraction of water in liquid (ASTM D 3792-91 or ASTM D 4017-96a)

EL = weight fraction of exempt compounds in liquid (US EPA Method 8240B, US EPA Method 8260B, US EPA Reference Method 18, ASTM D 859-94, NIOSH Method 1400, ASTM D 86-96, ASTM D 850-93, ASTM D 1078-97, ASTM D 2879-97, as modified in Appendix B to this Method 310, ASTM D 2887-97, ASTM E 1719-97. LVP-VOCs are exempted in accordance with section 94508(a)(78).

WP = weight (gm) of propellant (ASTM D 3074-94 [as modified and include ASTM D 3064-89] or ASTM D 3063-94 [as modified and include ASTM D 3064-89])

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[2] Alternate test methods, as provided in 6.0, or appropriate approved methods from section 2.0 may be used.

EP = weight (gm) of exempt compounds in propellant (US EPA Reference Method 18)

4.2 Non-Aerosol Products

For non-aerosol products, the percent VOC content shall be calculated using the following equation:

$$\text{PERCENT VOC} = (TV - A - H - EL) \times 100\%$$

5 TESTING TO DETERMINE REACTIVE ORGANIC COMPOUNDS IN AEROSOL COATING PRODUCTS

This section specifies the procedure for determining the percent by weight of the reactive organic compounds contained in aerosol coating products, for the purpose of determining compliance with the Aerosol Coatings Regulation.

5.1 The testing begins when the Executive Officer selects a product for analysis. The Executive Officer will maintain sample chain of custody throughout the selection and analytical process. When a product is selected for testing, the Executive Officer will request the product manufacturer or responsible party to supply the product formulation data specified in Title 17, CCR, section 94526(b)(2). The manufacturer or responsible party shall supply the requested information within 10 working days. Information submitted to the Executive Officer may be claimed as confidential; such information will be handled in accordance with the confidentiality procedures specified in sections 91000 to 91022, Title 17, CCR.

5.2 Initial Testing of the Propellant Portion of Aerosol Coating Products

The aerosol propellant is separated from the non-propellant portion of the product by using ASTM D 3074-94 (as modified in Appendix A for metal aerosol container) or ASTM D 3063-94 (as modified in Appendix A for glass aerosol container). The propellant portion is analyzed for reactive organic compounds and other compounds by using US EPA Reference Method 18. The remaining non-propellant portion of the product is then analyzed as specified in section 5.3.

5.3 Initial Testing of the Non-Propellant Portion of Aerosol Coating Products

The non-propellant portion of the product sample is analyzed to determine the reactive organic compounds in the sample, including the presence of any prohibited compounds. This analysis is conducted by performing the following tests:[3]

5.3.1 Gravimetric analysis of samples to determine the weight percent of total volatile material, using US EPA Reference Methods 24/24A, ASTM D 2369-97.

5.3.2 Determination of sample water content. For determination of water content either ASTM D 4017-96a, or ASTM D 3792-91 may be used, or results from both procedures may be averaged and that value reported.

5.3.3 Determination of ammonium content using ASTM D 1426-93 or US EPA Method 300.7.

5.3.4 Determination of ketones and alcohol content using NIOSH Method 1400.

5.3.5 Analysis of reactive organic compounds and, if present, prohibited compounds (US EPA Reference Method 18, US EPA Method 8240B, US EPA Method 8260B, ASTM D 859-94, NIOSH Method 1400).

5.4 Prohibited Compounds

If the sample is found to contain compounds prohibited by the Aerosol Coatings Regulation (e.g., ozone-depleting compounds) at concentrations equal to or exceeding 0.1 percent by weight, the Executive Officer will reanalyze the sample for confirmation.

5.5 Initial Determination and Verification of Reactive Organic Compound Content

The Executive Officer will determine the reactive organic compound content by verifying formulation data pursuant to sections 5.2 and 5.3. Only those components with concentrations equal to or greater than 0.1 percent by weight will be reported.

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[3] Alternate test methods may be used, as provided in section 7.0

5.5.1 **Based on manufacturers formulation data and the analysis conducted under section 5, the Executive Officer will make an initial determination of whether the product meets the applicable requirements specified in the Aerosol Coatings Regulation. If initial results show that the product does not meet the applicable requirements, the Executive Officer may perform additional testing to confirm the initial results.**

5.6 Final Determination of Reactive Organic Compound Content

If a product's status is not satisfactorily resolved under section 5.1 - 5.5, the Executive Officer may conduct additional analyses and testing as necessary to verify the formulation data.

5.6.1 **If the Executive Officer is unable to verify the accuracy of the supplied formulation data, then the Executive Officer will request the product manufacturer or responsible party to supply additional information to explain the discrepancy.**

5.6.2 **If the additional information supplied by the manufacturer or responsible party shows that the product does not meet the applicable requirements, then the Executive Officer will take appropriate enforcement action.**

5.63 **If the manufacturer or responsible party fails to provide additional information as specified in section 5.6.1, the initial determination of reactive organic compound content under section 5.1 – 5.5 shall determine if the product is in compliance with the applicable reactive organic compound limits. This determination may be used to establish a violation of the Aerosol Coatings Regulation.**

5.6.4 **If there exists a discrepancy that cannot be resolved between the results of Method 310 and the formulation data or additional information supplied by the manufacturer or responsible party, then the results of Method 310 shall take precedence over the supplied formulation data or additional information. The results of Method 310 shall then determine if the product is in compliance with the applicable requirements, and may be used to establish a violation of the Aerosol Coatings Regulation.**

6 METHOD PRECISION AND ACCURACY

6.1 The precision of Method 310 **for determining VOC content** was evaluated using seven representative products with known volatile organic compound (VOC) contents ranging from 6.2 to 81.2 percent VOC by weight. Each sample was divided into six portions, and each portion was separately analyzed to determine the VOC content. Based on the results of this analysis, the 95 percent confidence interval for Method 310 is 3.0 percent by weight (Wt/Wt%).

<u>6.2</u> **<u>For determining the percent by weight of the individual ingredients in aerosol coating products, the precision and accuracy of the determination for each ingredient is governed by the precision and accuracy of the test method used to ascertain the percent by weight of each ingredient.</u>**

<u>7</u> ALTERNATE TEST METHODS

Alternative test methods which are shown to accurately determine the concentration of VOCs or constituent components in antiperspirant/deodorants, consumer products, or aerosol coating products (or their emissions) may be used upon written approval of the Executive Officer.

Method 310 - Appendix A

PROPELLANT COLLECTION PROCEDURES

1 APPLICATION

The procedure applies to modify ASTM D 3074-94 and D 3063-94 to allow collection of the propellant for analysis and density measurement for metal aerosol containers and glass aerosol containers, respectively. These modified procedures also retain the aerosol standard terminology listed in ASTM D 3064-89. The aerosol product container is pierced and the propellant is bled into an evacuated manifold. After the manifold reaches atmospheric pressure, approximately 1 liter of the propellant is collected in a clean, evacuated Tedlar bag. For density measurement the propellant is collected into an evacuated 250 mL glass dilution bulb that has been weighed to the nearest 0.1 mg. After filling, the dilution bulb is re-weighed to determine the density of the propellant. Alternately, density may be determined using a Density/Specific Gravity Meter. The Tedlar bag with the propellant aliquot is taken to the laboratory for analysis.

2 LIMITATIONS

Nitrogen analysis: Nitrogen may be used as a component of the propellant system. Ambient air is 78 percent nitrogen and may be present as a contaminate in the system prior to sample collection. This is eliminated by completely evacuating the propellant collection system and sweeping out any connecting lines to the Tedlar bag with product before starting sample collection. This procedure will eliminate or reduce nitrogen contamination to less than 0.1% by weight of the sample and the analysis of the propellant gas will be unaffected.

3 APPARATUS AND MATERIALS

3.1 Propellant Collection System[1]: See Figure 1. The system was built from 1/4" stainless steel and Teflon tubing. The vacuum pump is of bellows diaphragm design.

3.2 Tedlar Bags, 1 liter, equipped with slip valve and septum

3.3 Density Measurement

3.3.1 250 mL gas dilution bulb, or

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[1] The metal piercing adapter is available from Mid-West Screw Products, Inc., 3523 North Kenton Ave., Chicago, IL 60641. Interim Part Number: 8013A-3/4 Longer SS. The gasket is available from Alltech Associate 2051 Waukegan road, Deerfield, IL 60015, part number 80-16. The glass aerosol adapter is available from Modern Machine Ship, Inc. P.O. Box 826, 123 N. Hazel Street, Danville, IL 61832.

3.3.2 Density/Specific gravity meter meeting the following minimum specifications:

3.3.2(a) Measurement Method: Natural Oscillation Type

3.3.2(b) Range: 0 - 3 g/cm^3

3.3.2(c) Measurement Temperature Range: 4 ^oC ~ 70 ^oC.

3.3.2(d) Temperature Accuracy: +/- 0.02 ^oC (10 ^oC ~ 30 ^oC) and +/-0.05 ^oC (4 ^oC ~70 ^oC).

3.3.2(e) Temperature Control Accuracy: +/- 0.01 ^oC.

3.3.2(f) Measurement Time: 1- 4 minutes.

3.4 Gas tight syringe, 100 µl

3.5 Balance, capable of accurately weighing to 0.1 mg

3.6 Can Piercing Platform. See Figure 2 (metal cans) and Figure 3 (glass containers).

3.7 Platform Shaker, equivalent to Thermolyne M49125

4 PROCEDURE

4.1 Propellant Collection for Metal Aerosol Containers

4.1.1 Turn on vacuum pump, close valves and evacuate the system (see Figure 1).

4.1.2 Remove the valve actuator on the aerosol can and weigh can to the nearest 0.01 g. Invert the can into cork holding ring on the piercing apparatus, center and snug against the gasket. (Figure 2)

4.1.3 Connect Tedlar bag to output 2, evacuate bag and seal. Connect 250 mL glass dilution bulb to output 1, evacuate bulb and seal.

4.1.4 Slowly raise the hydraulic jack until the can is pierced. Record the pressure of the can.

4.1.5 Vent the can until the pressure is at about 25 psi. Collect the propellant in the Tedlar bag.

4.1.6 After the propellant is collected, close and remove the Tedlar bag and vent the remainder of the propellant.

4.1.7 Weigh the evacuated 250 mL bulb to the nearest 0.1 mg. Use gloves while handling the bulb. Connect the bulb to the Tedlar bag and open to fill the bulb. Close the valves and re-weigh the dilution bulb, record the weight gain and calculate the propellant density in gm/l.

4.1.8 After the flow ceases from the can, it is removed from the assembly and allowed to vent overnight. The can may be placed on a platform shaker to vent the remainder of the propellant.

4.1.9 Reweigh can to the nearest 0.01 gm and record weight loss (total gms propellant). The can may now be opened for analysis of the liquid product.

4.2 Propellant Collection for Glass Aerosol Containers

4.2.1 Turn on vacuum pump, close valves and evacuate the system (see Figure 1).

4.2.2 Connect Tedlar bag to output 2, evacuate bag and seal. Connect 250 mL glass dilution bulb to output 1, evacuate bulb and seal.

4.2.3 The gauge assembly is prepressurized in order to minimize product expulsion and system contamination.

4.2.4 Remove actuator from valve of the aerosol glass container, and weigh container to the nearest 0.01 gm.

4.2.5 With container in an inverted position place the valve onto the tapered adaptor. Bring the top plate down to the flat of the container and tighten the nuts. A cork ring may be required to stabilize the container.

4.2.6 Record pressure of container and vent until the pressure is approximately one-half of recorded pressure. Collect propellant sample into the Tedlar bag.

4.2.7 After the propellant is collected, close and remove the Tedlar bag and vent the remainder of the propellant.

4.2.8 Weigh the evacuated 250 mL bulb to the nearest 0.1 mg. Use gloves while handling the bulb. Connect the bulb to the Tedlar bag and open to fill the bulb. Close the valves and re-weigh the dilution bulb, record the weight gain and calculate the propellant density in gm/l.

4.2.9 Continue to vent container on the platform assembly overnight.

4.2.10 Remove container from platform and loosen valve assembly, do not remove valve assembly at this time.

4.2.11 Place container on a platform shaker to vent the remainder of the propellant.

4.2.12 Reweigh container and valve assembly to the nearest 0.01 gm and record weight loss (total gms propellant). The container may now be opened for analysis of the liquid product.

FIGURE 1

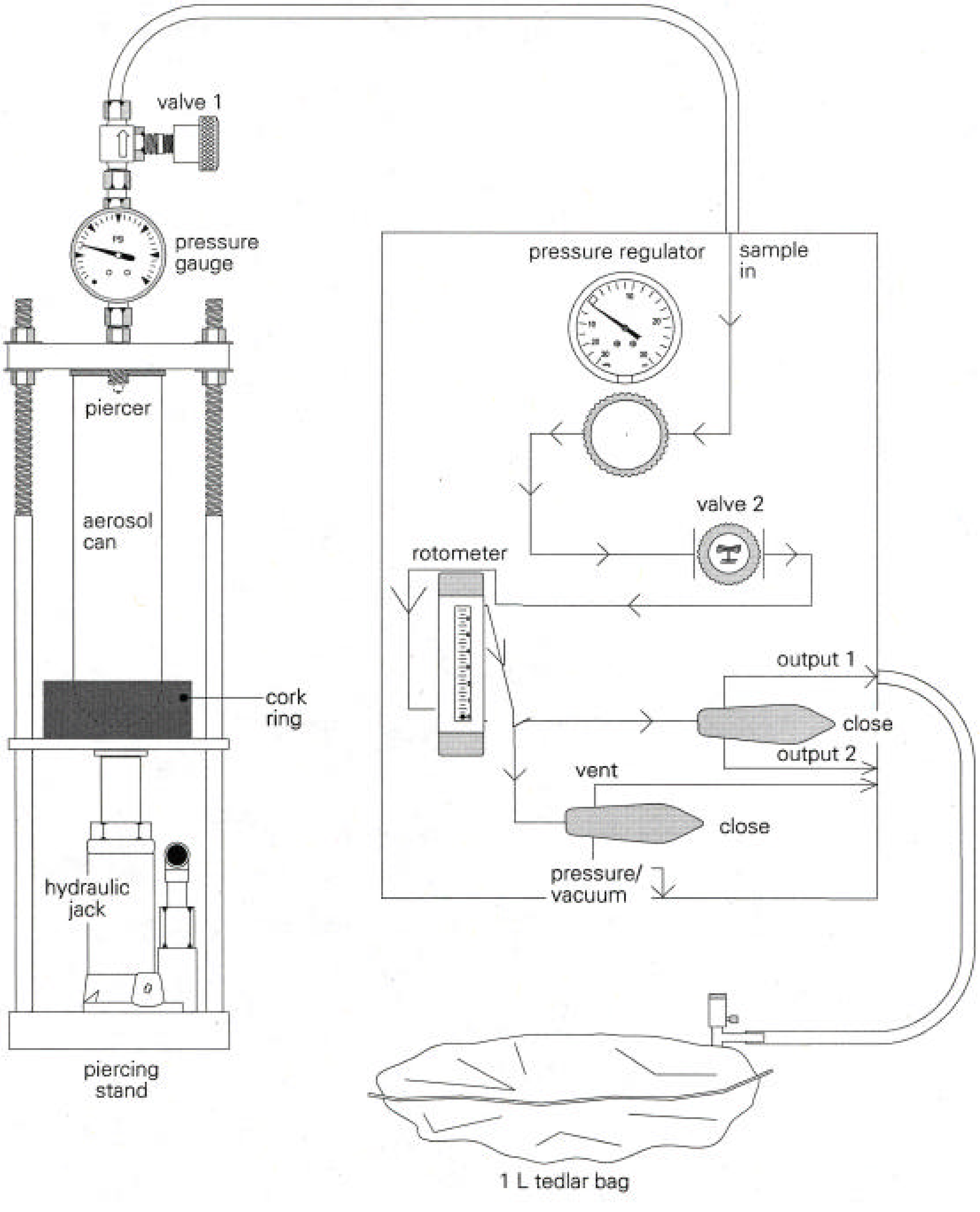
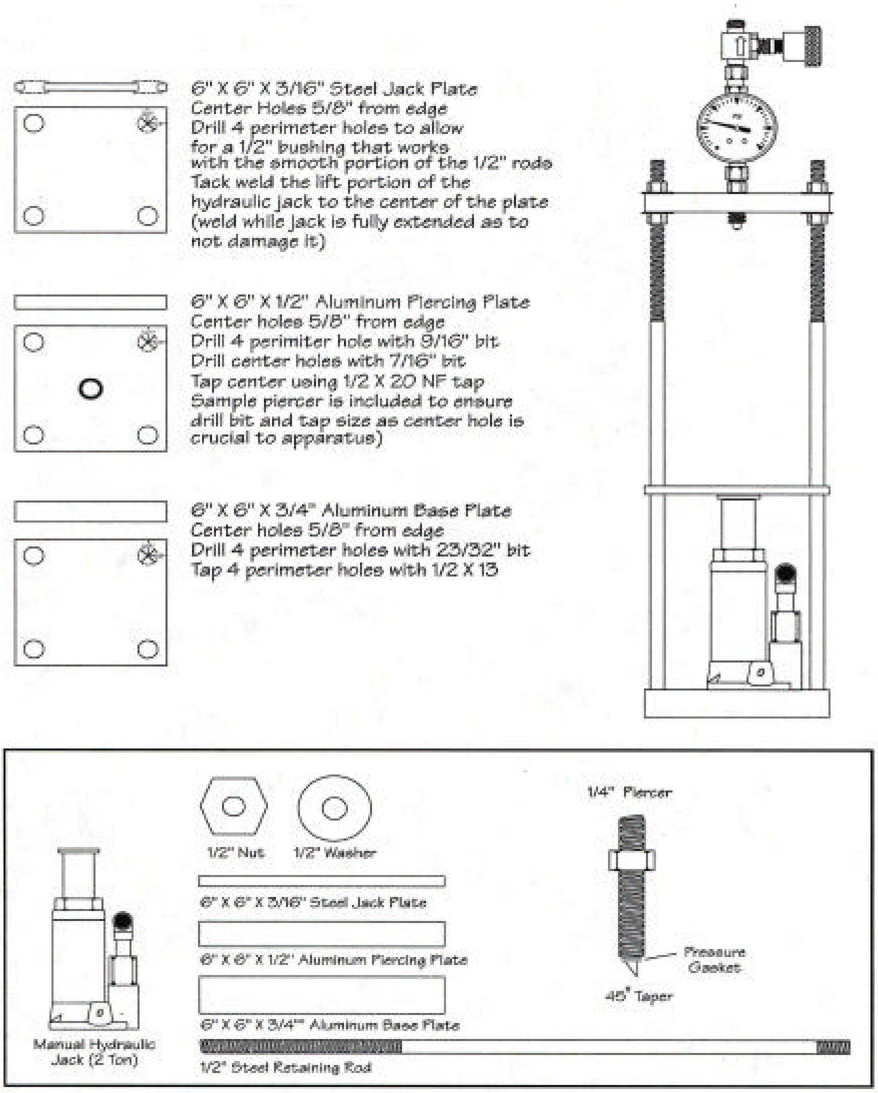

valve 1
pressure gauge
piercer
aerosol can
cork ring
hydraulic jack
piercing stand
pressure regulator
sample in
valve 2
rotometer
output 1
close
output 2
vent
close
pressure/ vacuum
1 L tedlar bag

FIGURE 2

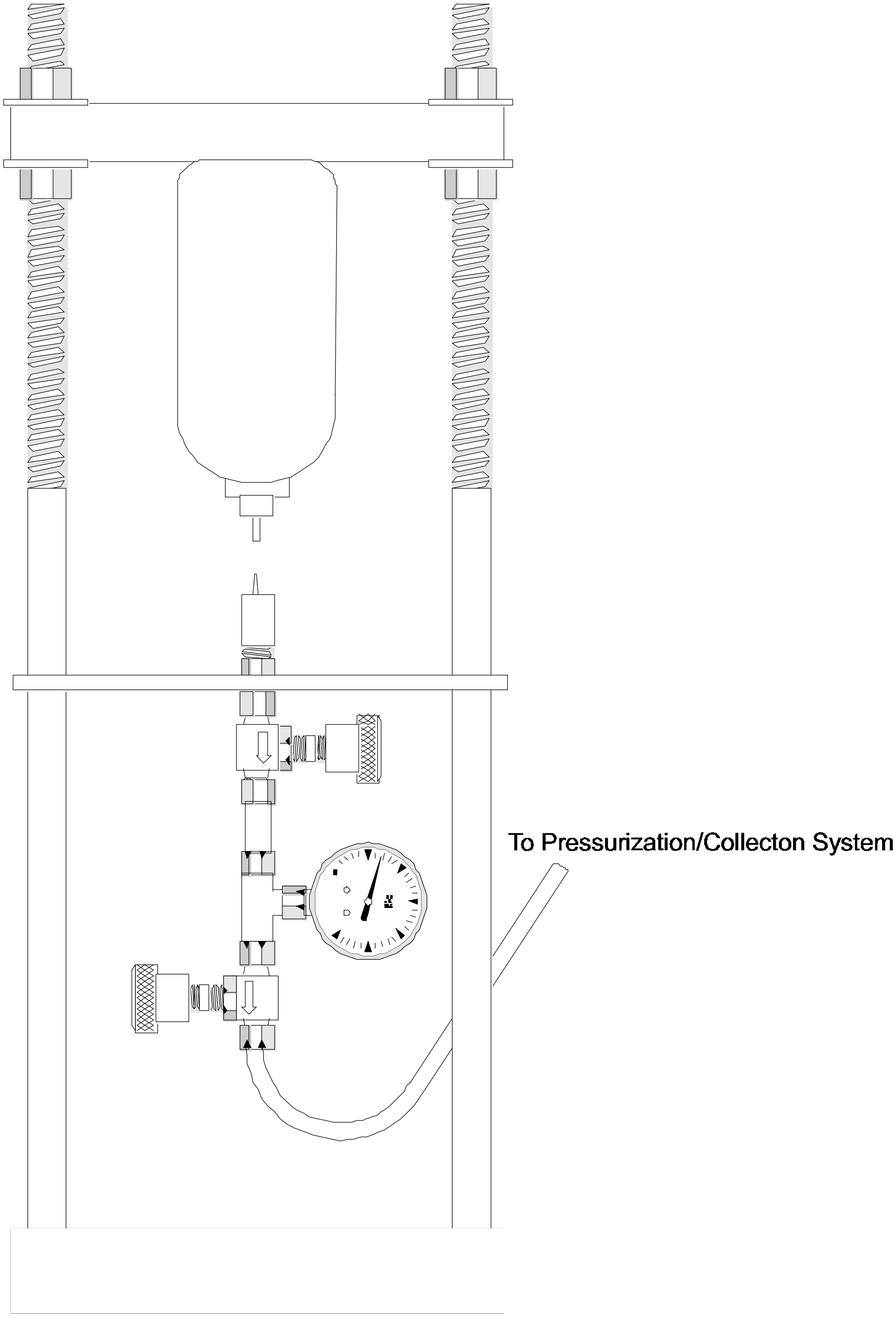


6" X 6" X 3/16" Steel Jack Plate
Center Holes 5/8" from edge
Drill 4 perimeter holes to allow
for a 1/2" bushing that works
with the smooth portion of the 1/2" rods
Tack weld the lift portion of the
hydraulic jack to the center of the plate
(weld while jack is fully extended as to
not damage it)

6" X 6" X 1/2" Aluminum Piercing Plate
Center holes 5/8" from edge
Drill 4 perimiter hole with 9/16" bit
Drill center holes with 7/16" bit
Tap center using 1/2 X 20 NF tap
Sample piercer is included to ensure
drill bit and tap size as center hole is
crucial to apparatus)

6" X 6" X 3/4" Aluminum Base Plate
Center holes 5/8" from edge
Drill 4 perimeter holes with 23/32" bit
Tap 4 perimeter holes with 1/2 X 13

FIGURE 3



Method 310 - Appendix B

MODIFICATIONS to ASTM D-2879-97 (April 10, 1997)

This procedure modifies ASTM D-2879-97 (April 10, 1997) as follows:

1. Modifications to the isoteniscope apparatus include:
   a. capacitance manometers and digital readout
   b. manifold system made of stainless steel and modified in design
   c. Ultra-torr fittings and Ultra-torr flex-lines
   d. ballast on the vacuum side of the isoteniscope manifold as depicted in ASTM D 2879-97 schematics, has been removed.
   e. stainless steel liquid nitrogen trap (Cold Trap)
   f. stainless steel high vacuum valves
   g. recirculating cooling system (required for extremely low pressure work only)
   h. diffusion pump (required for extremely low pressure work only)
   i. hot ion cathode vacuum gauges (required for extremely low pressure work only)

2. A purge and degassing procedure consisting of lower pressures and a liquid nitrogen bath replaces the step of lightly boiling the sample as outlined in ASTM D 2879-97.

3. Purge and Degassing Cycle

   a. With the U-tube connected, the system is evacuated to approximately 1.0 mm Hg. This readily removes most of the higher volatility gases from the sample.

   b. The stainless steel, liquid nitrogen cold trap is filled. The manifold is now brought to approximately 300 mm Hg with the purified nitrogen, regulated through the needle valve.

   c. The isoteniscope tube is carefully placed into a Dewar of liquid nitrogen. The ½ atmosphere pressure of nitrogen prevents the sample from splashing while being frozen. After the sample freezes, the system is evacuated to 0.05 mm Hg.

   d. The U-tube is removed from the Dewar, secured and allowed to warm to room temperature. The U-tube bulb head should be angled so the dissolved gases will be readily evacuated as the frozen sample starts to melt. When gases build up, it may be necessary to tilt the U-tube to release the gases.

   e. Repeat the freeze and degas process once, reducing pressure each time to less than 0.05 mm Hg. After the sample has returned to room temperature, close valve #3. There should be minimal dissolved gases left once the frozen sample starts to melt. Tilt the tube to release any gas pockets (if necessary). Do not push nitrogen into the evacuated space between the sample in the arm and the sample in the reservoir. At this point, if the sample is properly degassed, a “natural break” should form in the sample. This creates a vapor space as the liquid level in the bulb leg of the manometer falls to a quasi-equilibrium position, usually with the fluid level higher in the long manometer leg. If there is no pendulum effect, and the liquid level in the long leg of the manometer is significantly higher than the level in the short leg (> 2 mm), degassing is probably incomplete, and the degassing procedure should be repeated.

4. Data Evaluation

The regression based on the plot of Log P vs. 1/T as outlined in ASTM D 2879-97 has been removed and replaced with a nonlinear regression to generate the coefficients for an Antoine equation. The data analysis procedure assumes that the measured pressure is the sum of the compound’s vapor pressure and a residual fixed gas pressure. The vapor pressure’s dependence on absolute temperature is represented by an Antoine expression, and the fixed gas as pressure is directly proportional to absolute temperature as outlined in ASTM 2879. This leads to the model equations:

$$P_{model} = P_{vapor} + P_{fixed\ gas}$$

$$P_{model} = B0*10^{(B1/(T+B2))} + B3*T$$

where T is the absolute temperature (K) and B0, B1, B2 and B3 are coefficients to be determined via a nonlinear regression which minimizes the sum of squares $(P_{meas}-P_{model})^2$ for all experimental data points. The vapor pressure at 20^o C is then calculated as:

$$P_{vapor}(293.15\text{ K}) = B0*10^{(B1/(293.15+B2))}$$

With a set of pressure vs temperature measurements, the nonlinear regression can be performed using a statistical software packages. The following constraints are imposed to obtain meaningful Antoine equation coefficients for low vapor pressure samples:

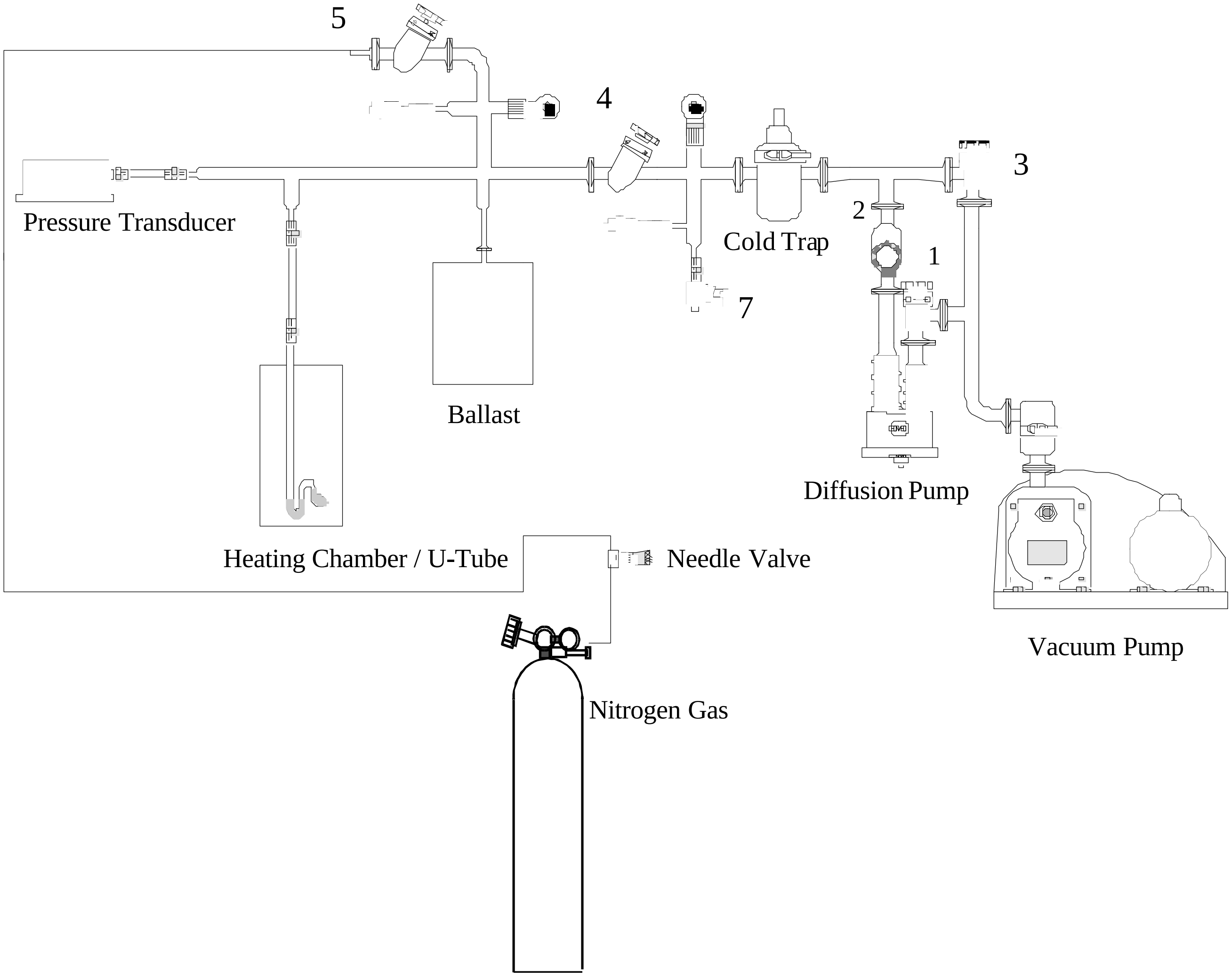
a. Pressures shall be measured at temperatures ranging from room temperature to about 180^o C. Narrower ranges will not provide sufficient information to determine the Antoine curvature, i.e., B2 coefficient. Wider ranges can lead to experimental difficulties maintaining the vapor space in the isoteniscope. A minimum of 12 points is necessary to provide ample degrees of freedom for the calculations.

b. Initial pressures at room temperature shall be less than 1 mm Hg. Higher values are indicative of significant levels of dissolved fixed gases. These will vaporize during the course of the experiment as temperature is increased and invalidate the model's assumption for the fixed gas contribution.

c. $-235 \leq B2 \leq 0$. Positive values of B2 imply that the heat of vaporization of the substance increases with increasing temperature. Thermodynamic data for many compounds suggests this is unrealistic. Large negative values can lead to unrealistically low vapor pressure values coupled with excessive fixed gas contributions. The -235(K) bound is chosen to be consistent with literature values of B2 for many pure compounds. For hydrocarbons in the LVP-VOC range, $B2 \geq -100$ provides reasonable agreement between measured and literature vapor pressures.

d. The fixed gas coefficient, B3, should normally be ≥ 0.

Isoteniscope Vapor Pressure Measurement Apparatus



METHODS FOR ESTIMATING MAXIMIUM INCREMENTAL REACTIVITY (MIR) OF HYDROCARBON SOLVENTS AND THEIR CLASSIFICATION

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ABSTRACT

Hydrocarbon solvents (HCS) are complex mixtures of alkanes, branched alkanes, cycloalkanes, and aromatics that are used in manufacturing a variety of household and commercial products such as aerosol coatings. These solvents contain volatile organic compounds (VOCs) which can react photochemically in the atmosphere to contribute to ground-level ozone formation. To determine the air-quality impact of HCS, a quantitative assessment of their ozone formation potential (i.e. reactivity) is needed. At present, except for a few HCS, no experimental data are available for determining their maximum impact on urban ozone formation (i.e. maximum incremental reactivity or MIR). Although a computational method exists for determining the MIR value, the detailed chemical speciation data needed for such a calculation may not be available for all HCS. In this work, we have developed an empirical estimation method for calculating the MIRs of HCS. This method assumes that the overall reactivity of a HCS can be separated into the contribution from its chemical constituent classes such as *n*-alkanes, branched-alkanes, cycloalkanes, and substituted aromatics. A boiling point-MIR relationship was developed for each chemical class, and composition weighted *n*-alkane-branched alkane-cycloalkane-aromatics surrogate mixtures were used to calculate the reactivity of HCS with different boiling ranges. During its development, this estimation technique was tested against the hydrocarbon solvent data provided by the Chemical Manufacturing Association (CMA), and over 90 percent of the calculated and experimental MIR values of hydrocarbon solvents differed by no more than a factor of 1.15. This result suggests that the technique developed can be used for calculating the MIR values of HCS with no experimental data available. This estimation method was then used to develop a HCS classification scheme for the reactivity-based VOC regulation for aerosol coatings.

INTRODUCTION

Hydrocarbon solvents (HCS) are complex mixtures of alkanes, branched alkanes, cycloalkanes, and aromatics that are used in manufacturing a variety of household and commercial products such as aerosol coatings (Shell, 1996). These solvents contain volatile organic compounds (VOCs) which can react photochemically in the atmosphere to contribute to ground-level ozone formation. To determine the air-quality impact of HCS, a quantitative assessment of their ozone formation potential (i.e. reactivity) is needed. However, because of their complex composition, and the significant amount of time needed for conducting laboratory investigations of the ozone formation potential of these chemicals, the reactivities of only a few HCS have been studied (see, for example, Carter *et al.*, 1996, Carter, 2000).

In addition to making an experimental determination, the reactivity of a complex mixture can be evaluated using the compositional data and ozone formation potential of the ingredients (see, for example, Chang and Rudy, 1990). Ozone formation potentials are available for only about 600 compounds (Carter, 2000). However, it is not feasible to perform compositional analyses for all mixtures because of the diversity of HCS. Although hydrocarbon solvent compositions vary according to their manufacturing processes (see, for example, CMA, 1997), their production is based primarily on fractionation distillation, an industrial process for separating chemicals using their difference in boiling points, and hence, chemical structure. In this work, we have developed an empirical approach for estimating the reactivity of HCS using the boiling point-chemical structure relationship and the maximum incremental reactivity (MIR) scale developed by Dr. W.P.L. Carter at the University of California, Riverside (Carter, 2000). A HCS reactivity classification scheme (i.e. grouping of HCS of similar reactivities into “bins”) based on the method developed is proposed.

FORMULATION OF THE ESTIMATION METHOD

The proposed estimation method for hydrocarbon solvent reactivity assumes that the overall MIR can be estimated by summing the reactivity contribution from individual chemical classes. For hydrocarbon solvent mixtures composed of *n*-alkanes, branched alkanes, cycloalkanes, and mono-, di-, poly-substituted benzenes, the total MIR of a solvent mixture is then given by:

Mixture MIR = Sum of % Wt MIR of all straight-chain alkanes
+ Sum of % Wt MIR of all branched alkanes
+ Sum of % Wt MIR of all cycloalkanes
+ Sum of % Wt MIR of all mono-substituted benzenes
+ Sum of % Wt MIR of all di-substituted benzenes
+ Sum of % Wt MIR of all poly-substituted benzenes

where % Wt = percent composition weighted. For a given carbon number, the MIR values are relatively insensitive to the position of the substituent groups (see, for example, Carter, 2000). In addition, MIR values of C_{n-1}, C_n, and C_{n+1} homologs are similar (Carter, 2000), and hydrocarbon solvent mixtures have rather narrow carbon number distributions (see for example, Carter et al., 1997). Hence, the composition weighted (% Wt.) MIR of all compounds can be approximated by, for example, for branched (Br) alkanes:

Sum of % Wt MIR of all branched alkanes
= MIR of a Br-alkane
x total Wt % of Br-alkanes in the Mixture

Thus, the MIR of a complex HCS mixture can be calculated by using a simple n-alkane-branched-alkane-cycloalkane-aromatics mixture (i.e. surrogate mixture).

Mixture MIR = MIR of a straight-chain alkane x Total Wt % alkanes
+ MIR of a branched alkane x Total Wt % branched alkanes
+ MIR of a cycloalkane x Total Wt % cycloalkanes
+ (MIRs of a mono-, di-, poly-substituted benzenes) x Total Wt % aromatics

The mid-boiling range of HCS was used as a guide for selecting a surrogate *n*-alkane, branched alkane, cycloalkane, and mono-, di-, poly-substituted aromatics (see below). Hydrocarbon solvent data provided by the Hydrocarbon Solvent Panel of the Chemical Manufacturing Association (CMA) on the mixtures' boiling ranges, carbon number distribution by weight percent, weight percentage composition of chemical classes, and MIR values were used to validate the method developed.

Surrogate Mixture Development

The method for surrogate mixture development utilizes the fact that boiling points of alkanes (normal, branched and cyclic) and aromatics increase with increasing numbers of carbon atoms (Morrison and Boyd, 1987). Figure 1 shows the plot of average carbon numbers for HSC and estimated values based on a series of carbon number-boiling point curves of C_5 or C_7 - C_{15} model *n*-alkanes, branched alkanes, and cycloalkanes (Table 1). The average carbon number of a HCS is calculated using the detailed carbon number distribution (% of mixture) data provided by CMA. Surrogate species used for constructing the carbon number-boiling curves are listed in Table 1. The boiling points of surrogates are either obtained from the literature (CRC, 1996) or estimated by using the method of Kinney (Lyman et al., 1990). Using the average boiling point of HCS as an index, an *n*-alkane, a branched-alkane, and a cycloalkane are selected from standard carbon number-boiling point curves. The average boiling point is defined as the sum of initial boiling point (IBP) plus dry point (DP) divided by two. The average carbon number of a surrogate mixture is then calculated by summing the composition weighted carbon number contributed from these species. A sample calculation is presented in Appendix 1. As can be seen in Figure 1, a good correlation ($r^2 = 0.96$) was observed between the calculated HCS average carbon numbers based on reported data and the

Table 1. Summary of Surrogate Alkane and Cycloalkane Species and Their Boiling Points.

Surrogate Species Carbon Number (CN)	Compound Used to Derive Correlation	Boiling Point (BP)[a]
Normal ALKANES		
N-C7	n-Heptane	208.4
N-C8	n-Octane	258.8
N-C9	n-Nonane	303.8
N-C10	n-Decane	345.2
N-C11	n-Undecane	384.8
N-C12	n-Dodecane	421.2
N-C13	n-Tridecane	453.2
N-C14	n-Tetradecane	487.4
N-C15	n-Pentadecane	518.0
Branched ALKANES		
BR-C5	Branched C5 Alkanes	86.0
BR-C6	Branched C6 Alkanes	140.9
BR-C7	Branched C7 Alkanes	186.8
BR-C8	Branched C8 Alkanes	236.3
BR-C9	Branched C9 Alkanes	278.0
BR-C10	Branched C10 Alkanes	322.7
BR-C11	Branched C11 Alkanes	324.7
BR-C12	Branched C12 Alkanes	366.8
BR-C13	Branched C 13 Alkanes	439.7
BR-C14	Branched C14 Alkanes	473.9
BR-C15	Branched C15 Alkanes	505.4
Cyclo ALKANES		
CYC-C7	C7 Cycloalkanes	213.8
CYC-C8	C8 Cycloalkanes	269.6
CYC-C9	C9 Cycloalkanes	312.7
CYC-C10	C10 Cycloalkanes	344.8
CYC-C11	C11 Cycloalkanes	379.5
CYC-C12	C12 Cycloalkanes	417.1
CYC-C13	C13 Cycloalkanes	474.8
CYC-C14	C14 Cycloalkanes	481.5
CYC-C15	C15 Cycloalkanes	510.7

[a] Unit = degree F; calculated value using the chemical species specified by Carter (2000); individual boiling point of each chemical was obtained from CRC (1996) or calculated using method described by Kinney (Lyman et al. 1990).

estimated values using the surrogate approach. This result suggests that a *n*-alkane-branched-alkane-cycloalkane surrogate mixture selected by using the average boiling point of a HCS can be reliably used to determine the major ingredients' carbon number in a complex HCS. A similar approach can be applied to aromatic-containing HCS for surrogate mixture development.

Calculating the Maximum Incremental Reactivity (MIR) of the Surrogate Mixtures.

Relationships Between MIR and Boiling Point of Alkanes and Aromatics

As described above, the reported mid-boiling range of a HCS can be used for selecting a *n*-alkane-branched-alkane-cycloalkane surrogate mixture. The surrogate mixture is then used to develop a method for estimating hydrocarbon solvent reactivity. Figure 2 shows the plot of MIR values of $C_5 – C_{15}$ *n*-alkane, branched-alkane, and cycloalkane surrogates versus their corresponding boiling points. The MIR values used are obtained from the latest compilation by Carter (2000). The data for cycloalkanes can be described by a nonlinear regression equation :

$$\text{CYCLO-MIR} = \alpha + \beta(\text{BP}) + \delta(\text{BP})^2$$

where α, β, and δ are regression coefficients with the values of 3.97, -0.0107, 8.14×10^{-6}, respectively, and BP is the boiling point of the surrogate. For *n*-alkanes and branched alkanes, the MIR-boiling point relationships are described by a nonlinear regression equation to reflect their similarity in reactivity [$\text{MIR} = 1.99 - 0.0034(\text{BP}) + 1.01 \times 10^{-6} (\text{BP})^2$]. Using these equations, reactivity calculations for HCS can be modeled by a hypothetical n-alkane-branched-alkane species and a cycloalkane. For determining the reactivity contribution of substituted aromatics in a solvent, ozone formation potentials of mono-, di-, and poly-substituted benzenes were calculated based on the data supplied by CMA. Using this information, together with the solvent's average boiling point, the MIR-boiling point relationships of each group of substituted benzenes were established. These relationships are:

Mono-substituted benzenes (BEN1) : MIR (BEN1) = - 0.014 (BP) + 6.94
Di-substituted benzenes (BEN2) : MIR (BEN2) = - 0.008 (BP) + 8.45
Poly-substituted benzenes (BEN3) : MIR (BEN3) = 0.013 (BP) + 4.15

MIR of Surrogate Mixtures

At a given boiling point, the MIR values of a cycloalkane (MIR_{cyc}) and a hypothetical (combined) normal- and branched-alkane (MIR_{com}) surrogate species can be determined using the MIR-Boiling Point (BP) relationship established above. The MIR of an aliphatic surrogate mixture is equal to the sum of the composition-weighted MIR of each surrogate [i.e. MIR = MIR_{cyc} x (% Wt. Cycloalkane) + MIR_{com} x (% Wt. n-alkanes +

% Wt of branched-alkanes)] (see Appendix 1: sample calculation). For representing the reactivity contribution of aromatics in a surrogate mixture, a separated estimate for a mono-, a di-, and a poly-substituted benzene was performed. This was accomplished by using the MIR-BP relationship established (see above) and the estimated fractional contribution of each substituted benzene. The fractional distribution of mono-, di-, and poly-substituted benzenes in a HCS is estimated by using a simplified form of Lorentzian distribution function, *f(x)*, and the solvent boiling range data supplied by CMA.

$$f(x) = \frac{1}{1 + (x - m)^2}$$

where m is the location of the peak boiling point. The estimated fractional distribution of total mono-, di-, and poly-substituted benzenes in a HCS is presented in Figure 3.

Figure 4 shows a plot of MIR values calculated with the method described above (i.e. surrogate mixture approach) versus the reported MIR of hydrocarbon solvent mixtures by CMA and experimental values for mineral spirits (Carter, 2000). The solid line represents perfect agreement, and the dashed lines represent disagreement by a factor of 1.15. Only 8 of 83 calculated and reported (or experimental) hydrocarbon solvent mixtures MIR values differ by more than a factor of 1.15. However, none exceed the error limits if a multiplication factor of 1.5 was used. In addition, the good fits of the calculated to experimental data for mineral spirits is gratifying. In conclusion, this estimation technique allows the reactivity of complex hydrocarbon solvent mixtures, with no experimental data available, to be reliably calculated.

Hydrocarbon Solvent Classification (“Bin” Assignment)

As described above, HCS are complex mixtures of organic compounds. For this reason, in developing a way to group HCS of similar reactivity, it is important to ensure that the MIR value assigned for the group reliably reflects the reactivity of a particular HCS mixture within the group. Using the surrogate mixture procedure developed, calculations were performed to determine the effects of hydrocarbon composition (i.e. relative percentages of *n*-alkanes, branched alkanes, cycloalkanes, and aromatics) and carbon number (as a function of boiling point) on a mixture’s MIR value.

Our computational results indicate that, up to a certain temperature range, changing the mixture composition from 20 to 80 percent of total n-alkanes and branched alkanes (with the rest of the mixture being cycloalkanes) has only a minor effect on the mixture MIR value, and the coefficient of variation ranges from 8-13 percent across the temperature range studied (80 – 580 degree F). For hydrocarbon solvent mixtures containing mainly (i.e. ≥ 90 %) n-alkanes and branched alkanes or cycloalkanes, our computational results indicate that the HCS MIR value is similar to that of the major ingredient. This is consistent with the observation that a cycloalkane has a slightly higher reactivity than the *n*-alkane or branched alkane with the same number of carbons. In addition, substituted aromatic content of < 2 percent has little effect on the group MIR value of HCS. To evaluate the effect of a mixture's carbon number (i.e. chemical species composition) on HCS reactivity, calculations were performed over the average boiling points from 80 – 580 ^{o}F. This temperature range is consistent with the existing HCS data. At a particular average boiling range interval, for example, 80 to 205 ^{o}F, an increase in a mixture's carbon numbers has only a slight effect on the calculated reactivity (coefficient of variation ≤ 15 %). Therefore, using a surrogate mixture MIR's coefficients of variation of 15 percent as a grouping criterion, we have developed four HCS reactivity groups over the average boiling range of 80 – 580 ^{o}F.

Table 2 lists the four major hydrocarbon solvent groups. Within each group, five different sub-groups (or classes) are defined according to their dominant ingredients. For HCS composed of alkanes and less than 2 % aromatics, three classes are proposed: Class A (< 90 % *n*-alkanes + branched alkanes or cycloalkanes), Class B (≥ 90 % *n*-alkanes + branched alkanes), and Class C (≥ 90 % cycloalkanes (see above). For mixtures containing ≥ 2 % aromatics, 2 classes are proposed i.e. Class D with aromatic content greater than or equal to 2 percent but less than 8 percent and Class E with 8 and up to 22 percent of aromatics. The aromatics content chosen is based on the classification scheme used in American Society of Testing and Materials method (ASTM, 1995). The categorization criteria such as mid-boiling point, percent total alkanes, cycloalkanes, and aromatics are consistent with the typical solvent sales specification data.

Figure 5 shows the comparison between the assigned MIR value for *n*-alkane-branched-alkane-cycloalkane only mixture (i.e. Bin 2; average boiling point : 80 to 205 ^{o}F) to the reported HCS MIR values. The solid line represents perfect agreement, and the dashed lines represent disagreement by a factor of 1.15. As can be seen in Figure 5, these values are well within the specified uncertainty. Similar results are also obtained from the other aliphatic hydrocarbon solvent bins. For aromatic-containing hydrocarbon solvent bins (for example, bin number 15), a good agreement between the assigned and reported are also observed (Figure 6). In most cases (~70 percent), the assigned MIR is approximately ± 15 percent of the reported values, and only a few (~ 7 percent) have a discrepancy between the assigned and reported values greater than 30 percent.

CONCLUSIONS

A technique for the calculation of MIR values of HCS mixtures based on the average boiling point of the mixture and relative proportions of *n*-alkane, branched alkane, cycloalkane, and total aromatics has been developed and tested against the available database. Over 90 percent of the hydrocarbon solvent mixtures with calculated and reported MIR values disagree by a factor of 1.15 or less. Because this approach is developed without being dependent on hydrocarbon solvent compositional data, it is expected that MIR values can be calculated with similar accuracy levels for new hydrocarbon solvents which have ≤ 22 percent aromatic content. However, if the solvent mixture is made by blending HCS with distinctly different boiling points (other than using conventional distillation procedures), the calculated MIR may be erroneous because the basic assumptions used in deriving this estimation method may no longer be

Table 2. Hydrocarbon Solvent Classification (Bins) and Group MIR Values

Average BP (oF)	CLASS	CRITERIA	MIR (g O3/ g Organics)	BIN NO.
80-205	A	ALKANES (< 2% AROMATICS)	2.08	1
	B	N- & ISO-ALKANES (≥ 90% & < 2% AROMATICS)	1.59	2
	C	CYCLO-ALKANES (≥ 90% & < 2% AROMATICS)	2.52	3
	D	ALKANES (2 to < 8% AROMATICS)	2.24	4
	E	ALKANES (8 to 22% AROMATICS)	2.56	5
> 205-340	A	ALKANES (< 2% AROMATICS)	1.41	6
	B	N- & ISO-ALKANES (≥ 90% & < 2% AROMATICS)	1.17	7
	C	CYCLO-ALKANES (≥ 90% & < 2% AROMATICS)	1.65	8
	D	ALKANES (2 to < 8% AROMATICS)	1.62	9
	E	ALKANES (8 to 22% AROMATICS)	2.03	10
> 340-460	A	ALKANES (< 2% AROMATICS)	0.91	11
	B	N- & ISO-ALKANES (≥ 90% & < 2% AROMATICS)	0.81	12
	C	CYCLO-ALKANES (≥ 90% & < 2% AROMATICS)	1.01	13
	D	ALKANES (2 to < 8% AROMATICS)	1.21	14
	E	ALKANES (8 to 22% AROMATICS)	1.82	15
> 460-580	A	ALKANES (< 2% AROMATICS)	0.57	16
	B	N- & ISO-ALKANES (≥ 90% & < 2% AROMATICS)	0.51	17
	C	CYCLO-ALKANES (≥ 90% & < 2% AROMATICS)	0.63	18
	D	ALKANES (2 to < 8% AROMATICS)	0.88	19
	E	ALKANES (8 to 22% AROMATICS)	1.49	20

Average Boiling Point = [Initial boiling point (IBP) + Dry Point (DP)]/2 valid, and caution should be used. In addition, the present method has neither used oxygenated compounds for its derivation nor been tested against any oxygenated HCS data for its tolerance. Hence, this method should not be used for calculating oxygenated HCS MIR values.

As discussed previously, the proposed grouping methodology (i.e. hydrocarbon solvent binning approach) is a simplification of this estimation method for calculating hydrocarbon solvent MIR values. It is expected that the grouping method is inherently less reliable for determining MIR values of HCS. Based on the recommended uncertainty of MIR values (Stockwell, 1999), the accuracy of this method may not be improved by narrowing the group interval. Thus, additional research is needed to provide kinetic and mechanistic information for improving MIR values and to obtain information on new solvent classes, especially those with chemical ingredients other than only alkanes and aromatics.

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FIGURE CAPTIONS

Figure 1. Comparison between the hydrocarbon solvent mixture average carbon numbers and the estimated values.

Figure 2. Plot of maximum incremental reactivity values versus boiling points of cycloalkanes (Δ), branched alkanes ( ), and n-alkanes (O).

Figure 3. Plot of fractional distribution of mono-, di-, and poly-substituted benzenes versus average solvent boiling points.

Figure 4. Comparison of the calculated and reported MIR values for 54 aliphatic (O) and 29 aromatic-containing (Δ) hydrocarbon solvent mixtures. Experimental mineral spirits data are represented as a square ( ). (Solid line denotes perfect agreement; dashed lines denote disagreement by a factor of 1.15)

Figure 5. Comparison of the group assigned MIR value and reported values for 16 hydrocarbon solvents in Bin 2 classification. (Solid line denotes the assigned group MIR value of 1.59; dashed lines denote disagreement by a factor of 1.15).

Figure 6. Comparison of the group assigned MIR values and reported values for 5 aromatic-containing hydrocarbon solvents in Bin 15 classification. (Solid line denotes the assigned group MIR value of 1.82; dashed lines denote disagreement by a factor of 1.15).

Appendix 1: Sample Calculations

Sample Data:
Hypothetical Aliphatic Hydrocarbon Solvent A
Boiling Range : 300 – 415 ^{o}F (average boiling point: 357.5 ^{o}F)
Average molecular weight = 168

Carbon Number	Carbon Number Fractionation (wt %)	n-Alkane	Branched-Alkane (wt %)	Cycloalkane
10	1.2	0	0	0
11	29.6	11.7	2.4	12.6
12	53.5	13.6	13.3	31.3
13	15.3	0.5	7.0	7.7
14	0.4	0	0	0
Total	100.0	25.8	22.7	51.5

Using the carbon number fractionation information, the average carbon number of solvent A is calculated as follows:

Average carbon number of the mixture:

$$\sum_{n=10}^{N}\left\{\left(\frac{\text{mol. wt. of solvent x wt \% of } C_n}{\text{mol. wt. of } C_n}\right)\text{x Carbon Number of } C_n\right\}$$

$= 11.9$

where n = 10,11,…14.

(A) Carbon Number Estimation

Average carbon number estimation based on wt % of n-alkanes, branched alkane, and cycloalkane:

Carbon number (CN) of a mixture can be calculated by the model species-boiling relationships of
n-alkane : CN = (BP + 85.1)/41.5
branched alkane : CN = (BP + 102.7)/40.8
cycloalkanes : CN = (BP + 28.7)/37.0

Combine with the mid-boiling range (BP) of solvent A, the calculated carbon number of n-alkane, branched alkane, and cycloalkane is 11, 12, and 11, respectively.

Estimated carbon number
= calculated CN of *n*-alkane x wt % of total *n*-alkane
+ calculated CN of branched alkane x wt % of total branched alkanes
+ calculated CN of cycloalkane x wt % of total cycloalkanes
= 11 x (25.8/100) + 12 x (22.7/100) + 11 x (51.5/100)
= 11.3

(B) Hydrocarbon Solvent MIR Estimation

Using the equations of :

$$\text{CYCLO-MIR} = 3.97 - 0.0107(\text{BP}) + 8.14 \times 10^{-6} (\text{BP})^2$$

$$\text{ALK-Br-ALK MIR} = 1.99 - 0.0034 (\text{BP}) + 1.01 \times 10^{-6} (\text{BP})^2$$

The estimated MIR of hydrocarbon solvent A

= CYCLO-MIR x Total Wt % of cycloalkanes
+ ALK-Br-ALK MIR x Total Wt % of alkanes and branched alkanes

= 1.18 x (25.8 + 22.7)/100 + 0.90 x (51.5/100)

= 1.04

Note: These calculations are used for illustrative purpose only; actual data were processed by Excel spreadsheet program. Slight difference may be due to roundoff error.

Example of Calculating the Product Weighted MIR of an Aerosol Coating Product

Ingredient	Weight Percent	Weight Fraction	MIR (g ozone/g VOC)	Weighted MIR
Acetone	20	0.200	0.43	0.086
Toluene	20	0.200	3.97	0.794
Propane	10	0.100	0.56	0.056
Xylenes	20	0.200	7.37	1.474
Butane	10	0.100	1.33	0.133
Solids	20	0.200	0.00	0.000

Product Weighted MIR = 2.543 g O_3/g product

For illustrative purposes:

Calculation of Upper-Limit MIR for Methyl Ethyl Ketoxime:

Number of Carbons: 4
Molecular Weight of Methyl Ethyl Ketoxime: 87.121 g / mole
Molecular Weight of Ozone: 47.998 g / mole

Upper-Limit Kinetic Reactivity (ULKR)= 1
Upper-Limit Mechanistic Reactivity (ULMR)
= minimum of {7 x Number of Carbons, or 35}

ULKR = 1
ULMR = minimum of {28, 35} = 28

Upper-Limit MIR = ULKR x ULMR x Conversion Factor (into gram basis)
= 1 x 28 x (47.998 / 87.121)
= 15.43 g ozone formed per g methyl ethyl ketoxime

For illustrative purposes:

Calculation of Upper-Limit MIR for Morpholine:

Number of Carbons: 4
Molecular Weight of Morpholine:
87.121 g / mole
Molecular Weight of Ozone: 47.998 g / mole

Upper-Limit Kinetic Reactivity (ULKR)= 1
Upper-Limit Mechanistic Reactivity (ULMR)
= minimum of {7 x Number of Carbons, or 35}

ULKR = 1
ULMR = minimum of {28, 35} = 28

Upper-Limit MIR = ULKR x ULMR x Conversion Factor (into gram basis)
= 1 x 28 x (47.998 / 87.121)
= 15.43 g ozone formed per g morpholine

For illustrative purposes:

Calculation of Upper-Limit MIR for Diethylenetriamine:

Number of Carbons: 4
Molecular Weight of Diethylenetriamine: 103.167 g / mole
Molecular Weight of Ozone: 47.998 g / mole

Upper-Limit Kinetic Reactivity (ULKR)= 1
Upper-Limit Mechanistic Reactivity (ULMR)
= minimum of {7 x Number of Carbons, or 35}

ULKR = 1
ULMR = minimum of {28, 35} = 28

Upper-Limit MIR = ULKR x ULMR x Conversion Factor (into gram basis)
= 1 x 28 x (47.998 / 103.167)
= 13.03 g ozone formed per g diethylenetriamine

For illustrative purposes:

Calculation of Upper-Limit MIR for Triethylamine:

Number of Carbons: 6
Molecular Weight of Triethylamine: 101.191 g / mole
Molecular Weight of Ozone: 47.998 g / mole

Upper-Limit Kinetic Reactivity (ULKR)= 1
Upper-Limit Mechanistic Reactivity (ULMR)
= minimum of {7 x Number of Carbons, or 35}

ULKR = 1
ULMR = minimum of {42, 35} = 35

Upper-Limit MIR = ULKR x ULMR x Conversion Factor (into gram basis)
= 1 x 35 x (47.998 / 101.191)
= 16.60 g ozone formed per g triethylamine

Appendix G: Analysis of the Potential Impacts of Increased Use of Methylene Chloride

Exposure Analysis: Long-Term Exposure in the Workplace

To determine the long-term exposure in the workplace (i.e., during a full workday) to methylene chloride, we used the following 8-hour time-weighted average (TWA) predictive model. This model was used in a study on perchloroethylene emissions from the use of chemical brake cleaners in automotive repair facilities (ARB, 1996). We determined the use of this model was appropriate for aerosol coating products that contain methylene chloride because the model is designed to estimate exposure to a compound from an aerosol product and is not defined to one specific compound.

The predictive model consists of the following:

$$C_s = \frac{(24.45 \times 10^{-3}\ \text{m}^3/\text{mol})(A)(B)(10^6)}{(M)(V)(1 + D)}$$

where,

C_s = Predicted room concentration of Methylene chloride, ppm
A = Methylene chloride content per can, grams/can
B = Number of cans used per work period
M = Molecular weight of methylene chloride, 84.94
V = Shop volume, m^3
D = Shop volume changes/work period
$= \frac{(F)(60\ \text{min/hr})(8\ \text{hr/work period})}{H}$
F = Air turnover rate, 1.5 ft^3/min-ft^2 (the Building Officials and Code Administrators (BOCA) standard air flow in an automotive repair facility)
H = Repair shop ceiling height, ft (15.6 ft.)

To run the model, we used the input parameters shown in Table-1. The parameters were chosen to represent "worst-case" scenarios for two different products in two different conditions. In a 13 ounce can of aerosol coating product we assumed the content of methylene chloride per can to be 92 to 184 grams. We also assumed that the number of cans used would be one to two per work period. The shop volumes chosen were based on data gathered for the perchloroethylene needs assessment for automotive consumer products (ARB, 1997b). "Real-life" conditions likely would consist of larger work areas with greater air turnover rates, use of products with lower methylene chloride content, and lower usage of the aerosol coating product.

TABLE-1.

Predictive Model Input Parameters for Emissions of Methylene Chloride from Aerosol Coating Products

Parameter	Description	Range of Values	Source	Comments
A	grams of methylene chloride/13 oz. Can	92 - 184	ARB, 1998	Methylene Chloride Range = 25% - 50%
B	no. cans/work period	1 - 2	ARB, 1998	Assumed a worst-case scenario for the number of cans used per work period
V	shop volume, m^3	896 - 4733	ARB, 1997	Assumed height = 15.6 ft. (4.76 meters)
D	Shop air turnover, hr	12 - 46	Norton, 1993	Typical D at height = 15.6 ft. Assumed Low D = 25% of typical

Table -2 shows the predictive model results using the input parameters in Table-1. These results indicate that an individual using the particular aerosol coating product under assumed worst-case conditions would be exposed to TWA room concentrations of 0.1 to 9.1 ppm. The "worst-case" condition that generated the highest concentration of methylene chloride consisted of a shop volume of 896 m^3 and usage of two cans per 8-hour work period of an aerosol coating product containing 50 percent methylene chloride. These results, when compared to the State and Federal OSHA permissible exposure limit (PEL), are at least 3-fold below the standard and at the most, 15-fold below. However, PELs have been used to derive chemical exposure guidelines for a worker's exposure and are not designed or recommended for protection of the general public. They do not address the potential adverse health effects to the sensitive population (e.g., children, elderly, population with respiratory diseases, etc.). Therefore, we used the following analysis to estimate what the maximum, or "worst-case," ambient exposure would be to determine what the health impact would be to the sensitive population.

TABLE-2.

Predicted Time-Weighted Average Methylene Chloride Concentrations Under Varying Shop Volumes, Methylene Chloride Contents, and Aerosol Coating Products

	Predicted TWA Range Over 8-hour Work Period* (ppm)		Comparison to State and Federal Permissible Exposure Levels (PELs)
	Methylene chloride content, grams (13 oz. can)		
	Automotive Bumper and Trim Product	Clear Coating Product	Federal and State PEL (25 ppm)*
Shop Volume	184 grams (50%)	92 grams (25%)	
896 m^3	1.2 - 9.1 ppm	0.6 - 4.6 ppm	3-fold below
1874 m^3	0.6 - 4.4 ppm	0.3 - 2.2 ppm	6-fold below
4733 m^3	0.2 - 1.7 ppm	0.1 - 0.9 ppm	15-fold below

* OSHA, 1998; CCR, 1997.

Exposure Analysis -Health Risk Assessment for Ambient Exposure

To evaluate the impact from methylene chloride emissions from aerosol coating use on surrounding areas, we conducted a health risk assessment of a hypothetical ”typical” work area. A health risk assessment consists of the evaluation of possible adverse health effects to the community surrounding a facility that emits potentially toxic substances. Potential adverse health effects may include acute noncancer effects, chronic noncancer effects, and cancer effects. To conduct the risk assessment, we used the Office of Environmental Health Hazard Assessment, Air Toxics Hot Spots Program Risk Assessment Guidelines (OEHHA, 1999a,b; 2000).

Potential Noncancer Health Effects. Adverse acute effects may result from short-term exposure to a pollutant. Acute exposure to high concentrations of methylene chloride can cause irritation to the eyes, respiratory tract, and skin. Chronic noncancer health effects are those that may result from long-term exposure to relatively low pollutant concentrations. Long-term exposure to low concentrations of methylene chloride can lead to effects on the central nervous system, gastrointestinal system, and liver (OEHHA, 2000). Noncancer reference exposure levels (RELs) have been developed from animal or human studies for a number of substances. Table-3 shows the noncancer RELs for methylene chloride. These RELs generally include a margin of safety to protect the most sensitive individuals. Potential acute effects can be evaluated by comparing a one-hour maximum ground level concentration with the REL in Table-4. Chronic noncancer effects are also evaluated by comparing an estimated annual average ground level concentration of methylene chloride with the chronic REL in Table-3.

The one-hour maximum and annual average concentrations needed for this analysis are derived from an appropriate air quality dispersion analysis performed on the source emitting methylene chloride.

TABLE-3
Noncancer Reference Exposure Levels (RELs) for Methylene Chloride

Noncancer Effect	Reference Exposure Levels	
	(*u*g/m^3)	**(parts per million)**
Acute	14,000	4
Chronic	400	0.12

Note: Acute and chronic RELs are from OEHHA, 1999a; 2000.

The potential for acute and chronic health effects from exposure to a toxic substance can also be evaluated using the hazard index approach. An acute hazard index is calculated by dividing the estimated maximum one-hour exposure level by the acute REL. The chronic hazard index is also calculated by dividing the estimated annual average concentration by the chronic REL. Hazard indices of one or less are not considered to be indicative of public health impacts from noncancer toxicity of the evaluated substance. If the total chronic hazard index exceeds 0.5, in its guidelines OEHHA recommends that the effects from background concentrations of criteria pollutants be added to the source’s or facility’s total chronic hazard index. The criteria pollutants recommended for inclusion in such cases are ozone, nitrogen dioxide, sulfur dioxide, sulfates, and hydrogen sulfide (OEHHA, 1999a; 2000).

Potential Cancer Effects. For this analysis, we will express the potential additional effect of cancer from exposure to methylene chloride emissions from use of an aerosol coating product as a maximum individual risk. The maximum individual risk is the probability (expressed as chances in a million) that an individual will develop cancer, under a worst case scenario of being exposed continuously for 70 years to the maximum ground level concentration of a pollutant. The risk is calculated as the product of the maximum annual average concentration of the pollutant and the unit risk factor specified for the pollutant.

Methodology for Estimating the Potential Health Impacts. The methodology used to estimate the potential health impacts from emissions of methylene chloride from aerosol coating use was to model the airborne methylene chloride emissions for a hypothetical "typical" source. This modeling gives estimated ground level concentrations at varying distances. The input parameters as listed in Table-4 are the parameters the SCREEN3 model (SCREEN3 Modeling Results for Methylene Chloride is included with this Appendix) uses to estimate the downwind, ground-level, maximum 1-hour concentrations for designated distances from the center of the volume source.

TABLE-4.
Input Parameters Used in SCREEN3 Modeling (v. 96043)

Methylene Chloride Emission Rate (acute) [grams/second]	0.013
Methylene Chloride Emission Rate (annualized) [grams/second]	0.01
Receptor Height [meters][1]	0
Source Release Height [meters][2]	2.38
Initial Lateral Dimension of Volume [meters][3]	3.19
Initial Vertical Dimension of Volume [meters][4]	2.21
Meteorology Option	Full
Land Type [Urban or Rural]	Urban
Receptor Distance (from center of source) [meters]	20
Operating Schedule [hrs/yr]	2808

1. Selected by convention as ground-level receptor.
2. One-half of building height (15.6 ft., 4.76 meters).
3. Exterior building width (45 ft., 13.7 meters) divided by factor 4.3 per SCREEN3 User's Guide.
4. Exterior building height (15.6 ft., 4.76 meters) divided by factor 2.15 per SCREEN3 User's Guide.

The methylene chloride emission rates for acute exposure are based on the assumption of a worst-case scenario of a facility using 13 ounce cans of an aerosol coating product containing a

50 percent methylene chloride content by weight and using 520 cans per year (10 cans per week).

The methylene chloride usage in terms of grams per year is given by Equation 1.

(1) (13 oz of product per can)(520 cans/year)(28.35 grams/oz)(50% methylene chloride)
= 95,823 grams/year

With the methylene chloride usage calculated, the acute and annualized emission rates in terms of grams per second are calculated using Equations 2 and 3, respectively.

(2) Emission Rate = (95,823 grams/year)(year/520 cans)(0.25 cans/hr)(1 hr/3600 secs)
= 0.013 grams/sec

(3) Emission Rate (Annualized) = (95,823 grams/year)(year/2808)(1 hr/3600 secs)
= 0.01 grams/sec

Using the input parameters for a worst-case scenario, the estimated acute maximum 1-hour concentration at 20 meters from the center of the facility is 169.1 *u*g/m^3 and the estimated annualized (chronic) 1-hour concentration is 130.1 *u*g/m^3. It should be noted that the SCREEN3 model must be run twice; once using the acute emission rate and once using the annualized emission rate. A summary of the output from the SCREEN3 model is shown in Appendix H SCREEN3 Modeling Results for Methylene Chloride. For more information on the SCREEN3 model, please refer to the SCREEN3 model user's guide (U.S. EPA, 1995).

Since potential cancer risks and noncancer chronic health impacts require an assessment of the annual average concentration of methylene chloride, the U.S. EPA conversion factor of 0.08 (U.S. EPA, 1992) is used to estimate the maximum annual average concentration from the annualized maximum-hour concentration. In addition the maximum annual average concentration is discounted by the operating schedule for the hours the facility does not emit. The maximum annual average concentration is calculated by using Equation 4.

(4) Maximum Annual Average Concentration
= [Max. 1-hr Conc.(annualized)][Operating Schedule (hrs/yr)][1 yr/8760 hrs][0.08]
= [130.1 *u*g/m^3][2808 hrs/yr][1 yr/8760 hrs][0.08]
= 3.33 *u*g/m^3

Calculation of Potential Cancer Risk and Noncancer Acute and Chronic Hazard Indices. To determine the potential cancer risk and the noncancer acute and chronic hazard indices, we compared the modeling output with the unit risk factor (cancer) and the RELs (noncancer). The risk assessments are conducted using the Office of Environmental Health Hazard Assessment, Air Toxics Hot Spots Program Risk Assessment Guidelines (OEHHA, 1999a,b; 2000). For this scenario, we calculated the potential cancer and noncancer health impacts at a near source location of 20 meters from the center of the volume source. When compared to the acute and chronic RELs in Table VIII-4 (14,000 and 400 *u*g/m^3, respectively), the modeling results indicate it is unlikely for significant acute or chronic noncancer effects to result from the emissions of methylene chloride in this example as assumed in this analysis. In addition this finding is also supported by the calculated acute and chronic hazard indices, which are all below 1.0 and 0.5. The modeling results in Table VIII-4, as discussed above, are also assessed for the potential cancer risk posed by the scenario. The resulting potential 70-year maximum individual risk per million is 3.3. This is calculated by multiplying the unit risk value for methylene chloride (1X10^{-6}) by the maximum annual average concentration.

Summary of Potential Health Effects

The results of the analysis, as shown in Table VIII-6, shows that a worst-case scenario for an aerosol coating product containing 50 percent methylene chloride does not pose a significant risk for acute and chronic noncancer effects. However, the risk assessment analysis shows that there is a potential to increase the cancer risk if there is an increased use of an aerosol coating product containing methylene chloride, or if there is an increase in the content of methylene chloride in the aerosol coating product. Therefore, because of the potential for an increased cancer risk and because methylene chloride is already listed as a toxic air contaminant (TAC), in the proposed amendments to the Aerosol Coatings Regulation we are proposing a provision to restrict the amount of methylene chloride that can be used in an aerosol coating product. This provision is further explained in Chapter X, section E, of this Technical Support Document.

TABLE-5.
Results of SCREEN3 Modeling (Maximum Exposed Individual (MEI) at 20 meters)

Health Criteria	Worst-Case Scenario
Methylene Chloride Emission Rate (lb/day)	0.81
Max. 1-hour Concentration (*u*g/m^3)	169.1
Max. Annual Average Concentration (*u*g/m^3)	3.33
Individual Cancer Risk (per million)	3.33
Acute Hazard Index	0.012
Chronic Hazard Index	0.33

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