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Architectural Coatings - Background for Proposed Standards

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1.0 INTRODUCTION

National air quality monitoring data from 1989 through 1991 indicate that there are approximately 170 geographic areas that failed to attain the National Ambient Air Quality Standards (NAAQS) for ozone, with approximately 19 percent being classified as being serious or severe, and 22 percent being classified as being moderate or submarginal.[1] Ozone is a photochemical oxidant that is formed in the atmosphere through a series of chemical reactions between precursor emissions of volatile organic compounds (VOC) and oxides of nitrogen (NO_x) in the presence of sunlight.

Although most large, stationary sources of VOC emissions are covered by existing regulations, an examination of emissions data completed in 1989 by the Congressional Office of Technology Assessment (OTA) indicates that individual small, dispersed sources of VOC (area sources) contribute significantly to the continuing ozone nonattainment problem. According to the OTA report, "Catching Our Breath: Next Steps for Reducing Urban Ozone," one area source of VOC emissions is the use of a wide range of consumer and commercial products.[2] These products include architectural coatings.

Section 183(e) of the 1990 Amendments to the Clean Air Act requires the EPA to conduct a study of emissions of VOC into the ambient air from consumer and commercial products. The study and report to Congress, which was completed in March 1995, examined the potential of VOC emissions from consumer and commercial products to contribute to ozone nonattainment and prioritized groupings of products for regulation. Under Section 183(e), the EPA is required to regulate one group of products every two years, with the first group regulated no later than two years after publishing the list. The EPA published the consumer product category list and schedule for regulation in the Federal Register on March 23, 1995. Accordingly, the EPA is required to regulate the first group of products, which includes architectural coatings, no later than March 1997. Justification for placement of architectural coatings in the first grouping is based on several factors including the magnitude of VOC emissions and the cost-effectiveness of control.

Almost all architectural coatings contain VOC. The volume of coating used and VOC content are the primary factors that affect the total amount of VOC emitted by this product category. The VOC emitted from architectural coatings includes VOC that are part of a coating's original formulation, VOC that are added during thinning, and VOC released as reaction byproducts while the coating dries and hardens. The total national amount of VOC emitted from architectural coatings was estimated to be 530,000 tons per year (at maximum thinning).[3]

1.1 REFERENCES

1. Code of Federal Regulations. Designation of Areas for Air Quality Planning Purposes, 40 CFR Part 81. Office of the Federal Register, Washington, DC.

2. U.S. Congress, Office of Technology Assessment. Catching Our Breath: Next Steps for Reducing Urban Ozone. U.S. Government Printing Office. Washington, DC. Publication No. OTA-0-412. July 1989. p. 16.

3. Memorandum from Harrison, R., Radian Corporation, to Ducey, E., U.S. Environmental Protection Agency, Emission Standards Division. Determination of Architectural and Industrial Maintenance Coatings Baseline Sales and VOC Emissions. November 14, 1995.

2.0 PRODUCT CATEGORY DESCRIPTION

The purpose of this chapter is to define and describe architectural coatings and to describe the volatile organic compound (VOC) emissions associated with their use. These coatings are applied in the field to stationary structures and their appurtenances, portable buildings, pavements, or curbs. Architectural coatings contain VOC, typically as solvents, which are released to the air while the coating dries and hardens. Coatings that are used in a shop setting in manufacturing, repair, or line applications are not included in the definition of an architectural coating. Some applications in a shop setting are covered under a control techniques guideline (CTG) document for the control of emissions from the coating of miscellaneous metal parts in ozone nonattainment areas.[1]

2.1 FUNCTION AND PURPOSE

Architectural coatings protect the substrates on which they are applied from corrosion, abrasion, decay, ultraviolet light damage, and/or the penetration of water and/or chemicals. Some architectural coatings may also increase the aesthetic value of a structure by changing the color or texture of its surface. These coatings may also be important in constructing a structure as well as protecting or enhancing the appearance of the finished structure. Examples of the latter are concrete form-release compounds, which prevent concrete from sticking to forms, and concrete-curing compounds, which allow concrete to cure properly. Another function of architectural coatings is to promote and/or maintain public safety, such as making structures more fire retardant and marking traffic patterns.

In general, without the protection afforded by architectural coatings, stationary structures would be more susceptible to deterioration (e.g., mechanical wear and/or corrosion) and would require more frequent repair and replacement, which would increase the cost of maintaining such structures. In addition to the economic impact, increased maintenance would increase the consumption of resources to repair and replace these structures. The actual dollar value of these benefits is not easily quantified, although the cost of coating a structure is usually only a small fraction of the overall cost of the structure. The value of some benefits, such as aesthetic benefits of decorative coatings, is highly subjective.

2.2 COATING COMPOSITION AND FORMULATION

The essential components of most coating formulations include the resin (or binder), the solvent, and the pigments. Clear coatings, such as varnishes, normally do not contain pigments. Other components that are typically included for performance purposes or to improve the coating manufacturing or application process include antisettling agents, antiskinning agents, defoamers and antifoamers, dispersing and emulsifying agents, driers, preservatives and fungicides, ultraviolet light absorbers, catalysts, coalescing agents, and surfactants. Various combinations of these components will produce a wide range of coatings for many different applications.[2]

Solvents impart fluid characteristics to resins by creating a solution, emulsion, or dispersion, and usually evaporate during the application, drying, or curing of the coating. Organic solvents include aliphatic and aromatic hydrocarbons, alcohols, ethers, esters, and ketones, some of which are often used in combination. Chlorinated hydrocarbons and nitroparaffins are less commonly used as solvents.[3] The most important criteria for selecting an organic solvent are its odor, toxicity, and solvency; that is, a solvent's ability to make the resin soluble and its evaporation rate.[3-4] The solvent component of a coating is usually the largest source of VOC, although with some resin systems, the reaction byproducts of curing may account for 30 to 50 percent of the VOC.[5]

Water is a polar solvent that cannot dissolve most resins used in coatings. However, water can be used in emulsion and dispersion coatings as a diluent, such as in latex and emulsion coatings.[6-8] Some resins can be chemically modified to become water-soluble or water-reducible, thereby allowing water to be used as a replacement for a portion of the organic solvent needed to create the proper solution viscosity.[9] Acrylic and alkyd resins are examples of resins that can be modified for use in water-soluble coatings.[10]

Coatings may be considered to be solventborne, waterborne, or 100 percent solids, depending on whether an organic solvent, water, or a reactive diluent is used as the principal flow controller. The U.S. Environmental Protection Agency (EPA) defines solventborne coatings as "coatings which contain only organic solvents. If water is present, it is only in trace quantities."[11] A waterborne coating is "a coating which contains more than 5 weight-percent water in its volatile fraction."[12] From a practical viewpoint, solventborne coatings are those with resins dissolved in an organic solvent (or blend of solvents). Conversely, waterborne coatings are those with the resin system suspended in water as liquid emulsions or solid dispersions.

2.3 PRODUCT TYPES AND USES

Coatings can be classified in many ways and the terms used generally describe some aspect of their composition or function. The majority of the State regulations in effect for VOC content of architectural coatings categorize coatings partially according to their intended function or end use and partially by composition. These coating categories are generally well recognized and understood by many coating manufacturers and users. These coating types include flats, nonflats, and specialty coatings, which include industrial maintenance (IM) coatings. Descriptions of flat, nonflat, and a general description of specialty coatings are provided below.

2.3.1 Flat Coatings

Flat coatings are defined as coatings that register a gloss of less than 15 on an 85-degree meter, or less than 5 on a 60-degree meter, as measured by American Society for Testing and Materials (ASTM) Method D-523-89 Standard Test Method for Specular Gloss.

Flat coatings used on interior walls and trim are primarily waterborne vinyl acetate and acrylic latexes.[13] Vinyl latexes are less expensive than acrylics and have good color retention and grease and oil resistance. Acrylics have excellent color retention and better durability, and are more water-resistant than vinyl acetate latexes.[9,14] Acrylic latexes modified with alkyds have been developed as an improvement on acrylic latexes for exterior housepaints.[15]

2.3.2 Nonflat Coatings

Nonflat coatings are those that register a gloss of 15 or greater on an 85-degree meter, or 5 or greater on a 60-degree meter, as measured by ASTM Method D-523-89, Standard Test Method for Specular Gloss. Like flats, nonflat coatings are used for both interior and exterior wall and trim paint.

Nonflat coatings have a range of glosses that are described with such terms as high-gloss, semigloss, or eggshell finish. The gloss level corresponding to each of these terms may vary from manufacturer to manufacturer. Nonflats are similar in composition to flat coatings in that the most popular formulations are waterborne vinyl acetate and acrylic latexes.

Flat coatings and nonflat coatings together make up what are often referred to as trade sales paints. These are shelf goods intended for use by the do-it-yourself and professional painter for painting both interior and exterior walls and trim with a brush or roller.[13,15-17] Trade sales paints may also be formulated for spray application.[16]

2.3.3 Specialty Coatings

Specialty coatings are distinct from flat and nonflat coatings because they are intended for more specialized applications than coating interior and exterior walls and trim. Most individual specialty coating categories represent only a small percentage of total architectural coating use, but collectively account for approximately 42 percent of architectural coating use and, more importantly, represent about 70 percent of architectural coating VOC emissions.[18]

Specialty architectural coatings are formulated to meet the needs of specific applications. As a result, the demand for some of these coatings may be limited and they may be produced by only a few manufacturers. However, many of these coatings have a relatively high solvent content. As a result, they collectively account for VOC emissions that are disproportionate to the total volume used. There are many categories of these specialty coatings.

2.4 COATING SELECTION AND USE

The proper selection and use of coatings are the primary factors in determining whether a structure (e.g., bridges) will be protected effectively by the coating. The following paragraphs describe the factors that are typically considered in architectural coating selection.

The factors that are considered in the selection of a coating depend on the knowledge and requirements of the person selecting and applying the coating. Important factors in consumer selection of a coating are price, availability, and name recognition (reputation). Decorative and protective qualities of the coating are also significant considerations; a coating should provide the desired results and perform under the conditions specified by the user. The relative importance of these criteria will differ from consumer to consumer.

Coatings must also be compatible with preexisting coatings over which they will be applied. In coating systems requiring a primer and a topcoat, the resins and solvents in the topcoat must be compatible with those in the primer to prevent premature coating deterioration. Some coatings, therefore, are selected as a coating system.

Although most architectural coating use is by painting contractors, public works departments, or institutional or industrial facility owners, about 40 percent of architectural coatings are applied by do-it-yourself painters or homeowners.[19] Homeowners want a house paint that has the decorative qualities they desire (e.g., color and gloss) and that is easy to apply and durable. Homeowners may rely on past experience, advertising, cost, brand recognition, color selection, and information from the retailer in selecting a coating. Specific performance information supplied by the manufacturer is usually limited to product sales literature and a statement on the container about coverage.

For interior use, waterborne latex paints are most commonly applied to walls, and both latex and oil-based alkyds are used for interior woodwork and trim. Waterborne latex paints have the advantages of being fast drying, easy to apply and clean up, and have minimal solvent odor.[16] Alkyds, however, may brush on smoother and typically offer good adhesion and stain resistance, but may be slower drying and harder to clean up. Important factors in selecting an interior paint are hiding power, resistance to fading and stains, ability to withstand scrubbing, and resistance to blocking (which is required for windows, doors, shelves, or other cases in which coated surfaces contact each other or other objects). Blocking refers to the tendency for some waterborne latex coatings to soften and become sticky even after they have dried.[20-22]

For exterior applications to homes, alkyds have some advantages over latexes, although they are more prone to yellowing when they are "shielded from the bleaching effect of direct sunlight (e.g., under eaves or a porch roof)." Although latexes are easier to apply and clean up, alkyds may have better adhesion, do not exhibit blocking, and provide a smoother finish with more initial gloss. Latexes, however, offer better protection against mildew and may maintain their original color better over time when exposed to the weather. Other factors considered when selecting an exterior house paint are resistance to chalking and dirt.[23]

Commercial painting contractors who work on small-scale projects, such as residential homes, usually choose a coating based on the customer's specifications for color and finish. However, because of the level of competition in bidding among contractors, coating cost is one of the few variables that the contractor can control to develop a competitive bid.[24]

Painting contractors also provide services to State departments of transportation (DOT) that use IM coatings to protect bridges and traffic marking coatings to mark pavements. In most States, the DOT does its own performance testing of coatings and establishes selection criteria based on these tests. Durability is one of the most important factors in selecting a coating for DOT work.[25] Other factors that affect the selection of traffic marking materials include: VOC emissions, visibility, pavement type, traffic density, position of the line or marking, climatic conditions, drying or setting time, safety of material, application procedure, amount to be applied, initial cost, annual cost, and equipment availability.[26]

In IM coating applications, long-term coating performance is usually the greatest concern in coating selection. These coatings are intended to protect equipment and other structures against severe environments that may include immersion in water, wastewater, or chemicals, exposure to corrosive solutions or fumes, exposure to high temperatures, exposure to heavy abrasion, or exterior exposure of metal substrates. Furthermore, coating application may be costly and difficult, as with a bridge or water tower. In many cases, the facility owner relies on the painting contractor or the coating manufacturer for guidance. Unfortunately, there is no manufacturers' consensus on standard performance testing and what constitutes "acceptable results." Some large contractors have addressed this problem by developing their own criteria for selecting a coating based on the manufacturers' test data.[27]

Several different types of coatings are used for IM applications, depending on the demands of the particular application. The most commonly used coatings include those based on chlorinated rubber, vinyl chloride, alkyd, bituminous, epoxy, or polyurethane resin systems.

Chlorinated rubber coatings are one of several coating types used for protecting steel and concrete in IM applications. They are fast drying, show good adhesion between coats, are very durable compared to conventional coatings, and are very resistant to moisture, acids, bases, and many solvents. Their disadvantages are that they are difficult to apply with a brush and can be degraded by animal fats, oils, and some solvents. In addition, they also contain residual carbon tetrachloride, a carcinogen.[28]

Vinyl coatings are used to protect steel and concrete under very corrosive conditions and are resistant to chemicals, moisture, and weather. However, they typically have a low solids content and, consequently, produce a relatively thin film with each coat.[29]

Bituminous coatings are used for the protection of buried or submerged steelwork or as roof coatings when mixed with aluminum pigments.[29]

Alkyd coatings are used in IM situations where exposure conditions are relatively mild and a decorative finish is desired.[29]

Epoxy coatings are used as both primers and finish coats for steel and concrete where chemical, solvent, and abrasion resistance is required. Epoxy coatings tend to chalk when exposed to sunlight. Solventless epoxy coatings can be applied to submerged steel and can be used for lining storage tanks and other confined spaces.[30]

Polyurethane coatings can be formulated with varying amounts of flexibility and hardness for a variety of IM applications. They are weather- and abrasion-resistant as well as being resistant to chemicals and solvents. Flexible polyurethane coatings can be formulated to accommodate the dimension changes of exterior woodwork.[31]

2.5 STATE REGULATIONS

Currently, no Federal EPA regulations limit VOC content or VOC emissions from architectural coatings. In 1990, five States--Arizona, California, New Jersey, New York, and Texas--had architectural coating regulations that limit VOC content. Since 1990, a few States have developed their own architectural coating regulations, but many are relying on a national rule to provide needed VOC emission reductions.

The VOC limits in Arizona only apply to Maricopa County (where Phoenix is located), and the New York limits apply only to the New York City metropolitan area. The California Air Resources Board (CARB) established a model rule for use by the air pollution control and air quality management districts in developing their rules. Of the 43 California districts, 25 had adopted architectural coating rules as of 1989. The New Jersey limits apply statewide. The Texas limits apply to 16 counties. All State rules, except those of Texas, apply to coating categories that are defined primarily by the coating use and function. The Texas limits are based on coating resin types, as well as coating function.

The Arizona, CARB model rule, New Jersey, New York, and Texas regulatory limits are summarized in table 2-1.

2.6 BASELINE VOC EMISSIONS AND SALES

During the development of the Architectural Coatings proposed rule, 1990 was used as the baseline year for architectural coating sales and VOC emissions. The 1990 sales and VOC content data were obtained using, a 1992 survey (that

TABLE 2-1. STATE VOC LIMITS (GRAMS VOC/LITER COATING, LESS WATER)[a]

Coating Categories	AZ[b] (7/13/91)[c]	CA-CARB[d] (9/1/92)[c]	NJ[e] (8/8/90)[c]	NY[f] (7/1/89)[c]	TX[g] (1/1/91)[c]
All other architectural coatings			250		
Bond breakers		350	600	600	
Concrete-curing compounds	350	350	350	350	
Dry fog coatings: All		400	400	400	
Flat	420				
Nonflat	400				
Enamel undercoaters	350				
Flat architectural coatings			250		
Fire-retardant coatings:					
Clear		650	850 (all others)	850 (all others)	
Pigmented		350	500 (opaque)	500 (opaque)	
Form-release compounds		250			
General primers, sealers & undercoaters	350	350	350	350	
Graphic arts (sign) coatings		500	450	450	
IM High-temperature coatings		550	650	650	
IM Antigraffiti coatings		340			
IM coatings	420	340	450	450	
Lacquers	680	680	680	680	
Magnesite cement coatings		600			
Mastic texture coatings		300	200	200	
Metallic pigmented coatings		500	500	500	
Multicolored coatings		420	600	600	
Nonflat architectural coatings			380		
Opaque stains	350	350	350	350	
Pretreatment wash primers		780			
Quick-dry enamels	400				
Quick-dry primers, sealers & undercoaters			500	500	
Roof coatings	300	300	300	300	
Sanding sealers		550			
Semitransparent stains	350	350	550	550	
Shellacs:					
Clear		730	730	730	
Pigmented		550	550	550	
Specialty flat products	400				
Specialty primers, sealers & undercoaters	350				
Swimming pool coatings		650	600	600	
Swimming pool repair & maintenance coatings		340			

TABLE 2-1. STATE VOC LIMITS
(GRAMS VOC/LITER COATING, LESS WATER)[a] (CONTINUED)

Coating Categories	AZ[b] (7/13/91)[c]	CA-CARB[d] (9/1/92)[c]	NJ[e] (8/8/90)[c]	NY[f] (7/1/89)[c]	TX[g] (1/1/91)[c]
Tile-like glaze coating				550	
Traffic coatings	250	250	250	250	
Varnishes	350	350	450	450	
Waterproofing mastic coating	300		300	300	
Waterproofing sealers	400	400	600	600	
Wood preservatives: All	350		550	550	
Opaque		350			
Semitransparent and clear		350			
Below ground		600			
Nonflat & flat latex paints					260
Interior alkyd paints					420
Exterior alkyd paints					480
Epoxy paints					540
Exterior stains					720
Interior stains					840
Urethane coatings					540
Alkyd varnishes					540
Nitrocellulose-based lacquers					670

[a]Blanks indicate that no definition and/or limit exists for that category.

[b]Arizona Regulation III-Control of Air Contaminants, Rule 335-Architectural Coatings, Section 300-Standards. Applies only to Maricopa County.

[c]Effective date.

[d]Air Resources Board (ARB)-California Air Pollution Control Officers Association (CAPCOA) Suggested Control Measure for Architectural Coatings; a model rule that applies to the whole State.

[e]New Jersey Administrative Code Title 7, Chapter 27, Subchapter 23-Volatile Organic Substances in Consumer Products, Section 7:27-23.3 Architectural Coatings. Applies to the whole State.

[f]New York Title 6, Chapter III-Air Resources, Part 205, Section 205.4, Prohibitions and Requirements. Applies only to the New York City metropolitan area.

[g]Texas resin categories listed at the end of the table. Texas Air Control Board, Regulation V (31 TAC Chapter 115)-Control of Air Pollution from Volatile Organic Compounds, Section 115.191. Applies to the following counties: Dallas, Tarrant, Brazoria, Galveston, Harris, Jefferson, Orange, El Paso, Chambers, Collin, Denton, Fort Bend, Hardin, Liberty, Montgomery, and Waller.

collected 1990 data) sponsored by the National Paints and Coatings Association (NPCA), Bureau of the Census Current Industrial Reports, and the SRI International U.S. Paint Industry Database.[18,32-33] The NPCA survey included 116 coating manufacturers that manufactured coatings in a total of 38 coating categories. This survey represents the most recent and comprehensive source of VOC content and sales information from this industry. The 1990 emissions baseline data includes the impacts of the State rules described in section 2.5 since the baseline was established from a national survey that included data from sales within these States.

Section 2.6.1 of this chapter briefly describes the VOC emission mechanisms. Sections 2.6.2 and 2.6.3 of this chapter describe how the national architectural coatings baseline sales and emissions, respectively, were developed from the NPCA survey database. Section 2.6.4 discusses the VOC emissions from the specialty categories.

2.6.1 VOC Emission Mechanisms

Volatile organic compound emission estimates for architectural coatings include the VOC in the coating, any solvent added as thinner by the user, and any VOC emitted as reaction byproducts. These VOC are emitted as the coating is applied and dries or hardens, either through solvent evaporation or chemical reaction.

The amount of solvent or thinner added to a coating to bring it to the proper consistency for application will directly affect the VOC emissions. Despite guidance from manufacturers, the amount of thinner added often depends on the preference of the user. Some coatings may be applied with no additional thinning and most waterborne coatings may be thinned with water, which does not affect VOC emissions.

Some manufacturers have argued that VOC regulations may not be effective due to over-thinning of lower VOC coatings in the field. A study conducted in California on architectural coating thinning practices found that 2 percent of all architectural coatings observed had been thinned in excess of the local air pollution control district VOC limits.[34] As a result of this thinning, 6 percent of architectural specialty coatings exceeded the VOC limits. A coating was considered to exceed the VOC limit if the VOC content exceeded the specified limit by more than 10 percent, to allow for laboratory error in the analysis of field collected samples. In this study, 121 coatings were observed at 85 different sites and 49 coatings were sampled and analyzed for VOC content.[34]

2.6.2 National Baseline Sales

The 1990 national architectural coating baseline sales were determined to be 654,822,000 gallons using the following approach:

1. The 1991 Current Industrial Reports, produced by the Bureau of Census, provides 1990 national sales estimates for architectural coatings. The definition of "architectural coatings" used in the Bureau of Census Report is more narrow than the "architectural coatings" definition in the proposed rule. Specifically, the Bureau of Census definition excludes industrial maintenance coatings, traffic marking coatings, and some special-purpose coatings. Therefore, in order to include all architectural coating sales, as defined in the regulation, sales data from the following categories were included from the Bureau of Census Report:

    - "Architectural coatings;"
    - "Industrial new construction and maintenance paints;"
    - "Traffic marking paints;" and
    - "Special-purpose coatings not specified by kind."

    The 1990 **national** sales for these categories are 645,365,000 gallons. Note that this estimate does not include sales of wood preservatives, which cannot be desegregated from "other miscellaneous allied paint products."

2. The 1990 NPCA **survey** population baseline sales are reported to be 489,738,102 gallons in the NPCA Survey.[18]

3. During regulatory negotiations, the architectural coating industry and representatives from State Departments of Transportation indicated that the volume of traffic coatings reported in the survey

was only about half of what was actually sold in 1990.[35-36] Consequently, traffic paint sales (and emissions) were doubled to give a revised survey population estimate of 502,125,461 gallons (489,738,102 gallons + 12,387,359 gallons = 502,125,461 gallons).

4. Sales of wood preservatives, 7,251,644 gallons, were subtracted from the revised survey estimate of 502,125,461 gallons, to give a survey baseline sales estimate, excluding wood preservatives, of 494,873,817 gallons (502,125,461 gallons - 7,251,644 gallons = 494,873,817 gallons).

5. The survey baseline sales estimate, excluding wood preservatives, of 494,873,817 gallons includes sales of the same categories included in the national sales estimate of 645,365,000 gallons, which also excludes wood preservative sales. This survey estimate represents 76.6812 percent of the national sales estimate (494,873,817 gallons/645,365,000 gallons = 0.766812 gallons).

6. The 1990 survey estimate of 502,125,461 gallons, including sales of wood preservatives, is assumed to represent 76.6812 percent of total national sales, including wood preservatives. The estimate for total national sales becomes 654,822,000 gallons (502,125,461 gallons/0.766812 = 654,822,000 gallons). Table 2-2 shows the national sales per category.

2.6.3 National Baseline Emissions

National VOC emissions from architectural coatings were estimated to be 530,000 tons using the following procedure.

1. The VOC emissions **at maximum thinning** from the survey population are 785,232,553 pounds, or 392,616 tons, prior to adjusting for underreported traffic paints emissions.

2. After doubling the estimate for traffic paints emissions, the revised survey estimate is 413,452 tons (785,232,553 pounds + 41,671,510 pounds = 826,904,063 pounds or 413,452 tons). Note that this estimate includes emissions of acetone, which was added to the VOC exemptions list on June 16, 1995. The emissions are adjusted for the acetone redesignation in step 4.

3. The survey estimate of VOC emissions is assumed to represent 77 percent of national VOC emissions,

TABLE 2-2. 1990 NATIONAL SALES, INDUSTRY AVERAGE VOC CONTENT AT MAXIMUM THINNING AND TOTAL VOC EMISSIONS AT MAXIMUM THINNING FOR ARCHITECTURAL COATINGS[18]

Coating Category	Total Volume Sold (thousand gallons)[a]	Average VOC Content at Maximum Thinning (lb/gal)	National VOC at Maximum Thinning (tons/yr)[a]
Anti-Graffiti Coatings			
Solventborne	9	4.89	21
Waterborne	6	2.43	7
Appurtenances[b]			
Solventborne	69	3.49	120
Waterborne	2	0.95	1
Below Ground Wood Preservatives			
Solventborne	175	4.55	398
Waterborne	N/A	N/A	N/A
Bituminous Coatings			
Solventborne	1,822	2.68	2,442
Waterborne	25,414	0.03	335
Bond Breakers			
Solventborne	N/A	N/A	N/A
Waterborne	N/A	N/A	N/A
Concrete Curing Compounds			
Solventborne	369	6.27	1,156
Waterborne	64	0.82	26
Dry Fog Coatings			
Solventborne	3,411	3.13	5,331
Waterborne	1,450	1.29	938
Fire-Retardant/Resistive Coatings			
Solventborne and Other/Exempt	38	N/A	1
Waterborne	48	0.27	6
Flats			
Solventborne	4,821	2.81	6,770
Waterborne	211,925	0.48	49,370
Unknown	61	3.60	110
Form Release Compounds			
Solventborne	352	5.06	890
Waterborne	2	N/A	N/A
Graphic Arts Coatings			
Solventborne	322	3.46	556
Waterborne	21	0.35	4

TABLE 2-2. 1990 NATIONAL SALES, INDUSTRY AVERAGE VOC CONTENT AT MAXIMUM THINNING AND TOTAL VOC EMISSIONS AT MAXIMUM THINNING FOR ARCHITECTURAL COATINGS[18] (CONTINUED)

Coating Category	Total Volume Sold (thousand gallons)[a]	Average VOC Content at Maximum Thinning (lb/gal)	National VOC at Maximum Thinning (tons/yr)[a]
High Temperature Coatings			
Solventborne	166	4.89	406
Waterborne	N/A	N/A	N/A
Unknown	0	N/A	1
IM Coatings			
Solventborne[c]	34,420	3.59	59,909
Waterborne	3,950	0.94	1,957
Unknown	13	3.63	26
Other/Exempt	83	0.58	24
Lacquers			
Solventborne	5,815	6.14	17,840
Waterborne	163	2.50	203
Magnesite Cement Coatings	12	N/A	30
Solventborne	N/A	N/A	N/A
Waterborne	N/A	N/A	N/A
Mastic Texture Coatings			
Solventborne	512	2.33	595
Waterborne	1,708	1.19	1,015
Metallic Pigmented Coatings			
Solventborne	7,577	3.85	14,576
Waterborne/Unknown and Other/Exempt	60	2.92	105
Multi-colored Coatings			
Solventborne	555	2.68	745
Waterborne	1	1.00	1
Nonflats			
Solventborne	34,924	3.40	60,840
Waterborne	126,779	0.62	40,876
Unknown	56	2.84	80
Opaque Stains			
Solventborne	8,401	3.60	15,137
Waterborne	7,463	0.48	1,796
Unknown	387	3.17	614
Opaque Wood Preservatives			
Solventborne	814	3.72	1,528
Waterborne	210	0.32	52

TABLE 2-2. 1990 NATIONAL SALES, INDUSTRY AVERAGE VOC CONTENT AT MAXIMUM THINNING AND TOTAL VOC EMISSIONS AT MAXIMUM THINNING FOR ARCHITECTURAL COATINGS[18] (CONTINUED)

Coating Category	Total Volume Sold (thousand gallons)[a]	Average VOC Content at Maximum Thinning (lb/gal)	National VOC at Maximum Thinning (tons/yr)[a]
Pretreatment Wash Primers			
Solventborne	224	6.01	672
Waterborne/Other	7	2.53	8
Primers			
Solventborne	14,216	3.12	22,756
Waterborne	23,510	0.42	4,924
Unknown	113	3.20	181
Other/Exempt	9	0.04	0
Quick-Dry Enamels			
Solventborne	2,201	4.03	4,441
Waterborne	N/A	N/A	N/A
Quick-Dry Primers, Sealers, and Undercoaters			
Solventborne	4,666	3.70	8,630
Waterborne	24	0.26	3
Roof Coatings			
Solventborne	26,938	2.24	30,213
Waterborne	3,904	0.24	461
Sanding Sealers			
Solventborne	944	4.59	2,167
Waterborne	20	1.60	16
Sealers			
Solventborne	2,535	5.31	6,734
Waterborne	2,762	0.34	476
Other/Exempt	0	3.50	0
Semitransparent Stains			
Solventborne	15,930	4.40	35,007
Waterborne	2,148	0.71	765
Unknown	203	4.47	454
Semitransparent & Clear Wood Preservatives			
Solventborne	7,144	4.67	15,837
Waterborne	1,102	0.37	205
Other/Exempt	12	5.51	33
Shellacs			
Solventborne	1,356	4.51	3,061
Waterborne	N/A	N/A	N/A

TABLE 2-2. 1990 NATIONAL SALES, INDUSTRY AVERAGE VOC CONTENT AT MAXIMUM THINNING AND TOTAL VOC EMISSIONS AT MAXIMUM THINNING FOR ARCHITECTURAL COATINGS[18] (CONTINUED)

Coating Category	Total Volume Sold (thousand gallons)[a]	Average VOC Content at Maximum Thinning (lb/gal)	National VOC at Maximum Thinning (tons/yr)[a]
Swimming Pool Coatings			
Solventborne	224	4.77	543
Waterborne	2	2.39	1
Traffic Marking Coatings			
Solventborne[c]	29,246	3.64	50,726
Waterborne	3,052	0.72	1,094
Unknown	13	1.16	24
Undercoaters			
Solventborne	1,197	3.20	1,918
Waterborne	1,248	0.37	218
Varnishes			
Solventborne	8,855	4.17	18,452
Waterborne	166	0.97	80
Unknown	1	3.74	2
Waterproofing (Treatment) Sealers - Clear			
Solventborne	12,115	5.49	33,276
Waterborne	766	1.67	641
Other/Exempt	3	N/A	6
Waterproofing (Treatment) Sealers - Opaque			
Solventborne	3,452	2.03	3,501
Waterborne/Unknown	68	0.58	19
TOTAL	654,822	--	534,382

[a]1990 baseline data from the 1992 NPCA survey was (reference 18) scaled to a national population using the Current Industrial Reports produced by the Bureau of Census (reference 32).

[b]Some manufacturers incorrectly listed coatings under the definition of "Appurtenance," which is not a coating category. These coatings were left under this definition for the VOC emission inventory, since they could not be reclassified.

[c]Excludes acetone emissions.

N/A = Not available or not applicable.

based on the calculation of national baseline sales. National VOC emissions are estimated to be 539,183 tons (413,452 tons/0.77 = 539,183 tons), prior to adjusting for the exclusion of acetone.

4. After excluding the national acetone emissions reported in the SRI database (i.e., 2,300 tons for industrial maintenance and 2,500 tons for traffic paints), the revised national VOC emission estimate is 530,000 tons (539,183 tons - 2,300 tons - 2,500 tons = 534,383 tons or 530,000 tons, rounded to thousands of tons).[33] For each coating category, table 2-2 shows the VOC content per gallon at maximum thinning and the national VOC emissions at maximum thinning.

The EPA estimates that the total 1990 national emissions of VOC from architectural coatings is 530,000 tons. By comparison, national emissions of VOC from all anthropogenic sources, including transportation, stationary source fuel combustion, industrial processes, solid waste disposal, and miscellaneous sources, were estimated by the EPA to be 20.4 million tons/yr in 1989.[37] Architectural coatings, therefore, represent about 2.6 percent of all VOC emissions in the United States.

2.6.4 <u>VOC Emissions from Specialty Coating Categories</u>

Some architectural coating categories are greater VOC emission sources than others because of their VOC contents and/or the volume of use. Estimates of the relative contributions of different coating categories to VOC emissions are available from the 1992 NPCA survey. Some of the specialty categories have relatively high VOC contents. As a result, VOC emissions from specialty categories (including IM coatings) represent 70 percent of VOC emissions from architectural coatings, even though they represent only about 45 percent of architectural coating sales. The relative contributions to VOC emissions from the different specialty categories based on the 1992 NPCA survey are presented in table 2-3. The IM coating category is the largest VOC emissions contributor, contributing approximately 15 percent of the emissions from specialty categories.

TABLE 2-3. RELATIVE CONTRIBUTION OF INDIVIDUAL SPECIALTY CATEGORIES TO VOC EMISSIONS FROM ARCHITECTURAL SPECIALTY COATINGS[18]

Anti-graffiti Coatings	0.01%
Appurtenances	0.03%
Below Ground Wood Preservatives	0.11%
Bituminous Coatings	0.74%
Bond Breakers	N/A[a]
Concrete Curing Compounds	0.31%
Dry Fog Coatings	1.67%
Fire-retardant/Resistive Coatings	<0.01%
Form Release Compounds	0.24%
Graphics Arts Coatings (Sign Paints)	0.15%
High Temperature Coatings	0.11%
Industrial Maintenance Coatings	16.45%
Lacquers	4.80%
Magnesite Cement Coatings	0.01%
Mastic Texture Coatings	0.43%
Metallic Pigmented Coatings	3.90%
Multi-colored Coatings	0.2%
Opaque Stains	4.66%
Opaque Wood Preservatives	0.42%
Pretreatment Wash Primers	0.18%
Primers	7.4%
Quick-dry Enamels	1.18%
Quick-dry Primers, Sealers, and Undercoaters	2.29%
Roof Coatings	8.15%
Sanding Sealers	0.58%
Sealers	1.92%
Semitransparent Stains	9.63%
Semitransparent and Clear Wood Preservatives	4.27%
Shellacs	0.81%
Swimming Pool Coatings	0.14%
Traffic Marking Coatings	13.78%
Undercoaters	0.57%
Varnishes	4.92%
Waterproofing (Treatment) Sealers - Clear	9.01%
Waterproofing (Treatment) Sealers - Opaque	0.94%
Total	100 %

[a] N/A = not available.

2.7 REFERENCES

1. U.S. Environmental Protection Agency. Control of Volatile Organic Emissions from Existing Stationary Sources - Volume VI: Surface Coating of Miscellaneous Metal Parts and Products. Research Triangle Park, NC. Publication No. EPA-450/2-78-015. June 1978.

2. Brandau, A. Introduction to Coatings Technology, Federation Series on Coatings Technology. Federation of Societies for Coatings Technology. Blue Bell, PA. October 1990. pp. 12-14.

3. Reference 2, p. 11.

4. Ellis, W. H. Solvents, Federation Series on Coatings Technology. Federation of Societies for Coatings Technology. Philadelphia, PA. 1986. p. 7.

5. U.S. Environmental Protection Agency. Procedures for Certifying Quantity of Volatile Organic Compounds Emitted by Paint, Ink, and Other Coatings. Research Triangle Park, NC. Publication No. EPA-450/3-84-019. December 1984. pp. iii-iv.

6. Morgans, W. M. Outlines of Paint Technology, Third Edition. New York, Halsted Press. 1990. p. 344.

7. Reference 2, p. 25.

8. Wicks, Z. W., Jr. Film Formation, Federation Series on Coatings Technology. Federation of Societies for Coating Technology. Blue Bell, PA. June 1986. p. 12.

9. Reference 6, p. 349.

10. Martens, C. R. Waterborne Coatings: Emulsion and Water-Soluble Paints. New York, Van Nostrand Reinhold Company. 1981. pp. 58-73.

11. U.S. Environmental Protection Agency. Glossary for Air Pollution Control of Industrial Coating Operations, Second Edition. Research Triangle Park, NC. Publication No. EPA-450/3-83-013R. December 1983. p. 19.

12. Reference 11, p. 23.

13. Reference 2, p. 34.

14. Reference 10, p. 192.

15. Reference 2, p. 35.

16. Reference 10, p. 191.

17. Reference 11, p. 21.

18. Industry Insights. Architectural and Industrial Maintenance Surface Coatings VOC Emissions Inventory Survey. Prepared for the National Paint and Coatings Association in Cooperation with the AIM Reg-Neg Industry Caucus. February 6, 1995.

19. SRI International. U.S. Paint Industry Database. Prepared for National Paint and Coatings Association. Menlo Park, CA. 1990. p. 50.

20. Interior Latex Paints. Consumer Reports. 53(9):568-573. September 1988.

21. Interior Semigloss Paints. Consumer Reports. 54(5):317-321. May 1989.

22. Interior Latex Paints. Consumer Reports. 56(5):335-337. May 1991.

23. Paints for Finishing Touches. Consumer Reports. 55(9):619-623. September 1990.

24. Oldham, C., Radian Corporation, telecommunication with Fitch, J., May Company. March 22, 1991. Conversation about coating selection by painting contractors.

25. Oldham, C., Radian Corporation, telecommunication with Medford, B., North Carolina Department of Transportation. March 12, 1991. Conversation about specifications and testing program of NCDOT.

26. U.S. Environmental Protection Agency. Reduction of Volatile Organic Compound Emissions from the Application of Traffic Markings. Research Triangle Park, NC. Publication No. EPA-450/3-88-007. August 1988. p. 8.

27. Oldham, C., Radian Corporation, telecommunication with Moore, P., Ammon Painting Company. March 12, 1991. Conversation about coating selection by painting contractors.

28. Reference 6, pp. 371-372.

29. Reference 6, pp. 377-378.

30. Reference 6, pp. 379-383.

31. Reference 6, p. 384.

32. Gromos, D. J. Current Industrial Reports: Paint and Allied Products 1990. Bureau of Census, U.S. Department of Commerce. Washington, DC. Publication No. MA28F(90)-1. October 1991. 8 pp.

33. SRI International. U.S. Paint Industry Database. Prepared for, and provided to the U.S. EPA by, National Paint and Coatings Association. Menlo Park, CA. 1992. p. A-18.

34. Giorgi, S., and J. J. Morgester. Field Investigation on Thinning Practices During the Application of Architectural Coatings in Selected Districts in California. California Air Resources Board. Sacramento, CA. Publication No. 91-CD-TP-2. December 1991. 12 pp.

35. Meeting Summary - AIM Coatings Regulation Negotiations Committee Meeting, June 8-9, 1993. Docket Number A-92-18, Docket Item II-E-48, pg. 18.

36. Meeting Summary - AIM Coatings Regulatory Negotiations Committee Meeting, February 3-4, 1994. Docket Number A-92-18, Docket Item II-E-68, pg. 14.

37. U.S. Environmental Protection Agency. National Air Pollutant Emission Estimates 1940-1989. Research Triangle Park, NC. Publication No. EPA-450/4-91-004. March 1991. 74 pp.

3.0 INDUSTRY PROFILE

The purpose of this section is to describe the history, development, and structure of the architectural coatings industry, along with current economic trends and trends in the types of products that are sold.

3.1 INDUSTRY HISTORY AND DEVELOPMENT

The first U.S. paint patent was issued in 1865 for a composition of zinc oxide, potassium hydroxide, resin, milk, and linseed oil.[1] More recent developments in coating technology in the 1940's were ready-to-use waterborne emulsion paints for architectural applications. Acrylic and vinyl acetate latex paints were first developed in Germany during and after World War II and introduced into the United States in the 1950's. The development of the hand roller at about the same time promoted the use of waterborne coatings by homeowners.[2] The earliest latexes were flat coatings and were used only for interiors, but exterior and semigloss latexes were introduced in 1957 and 1968, respectively.[3]

Industrial maintenance (IM) coatings have also developed significantly in the last half century. Polyurethane resins were developed in 1939, epoxy resins in 1947, and both are now commonly used in industrial maintenance (IM) coatings.[3] In the early 1950's, water-soluble and water-dispersible alkyds were introduced for industrial applications.[4] Powder coatings based on polymer resin technology were developed in 1953, but were first used in manufacturing settings, and only recently have been used as IM coatings.[3,5-6]

3.2 INDUSTRY STRUCTURE

The coatings industry, as represented in figure 3-1, produces three types of coating products: architectural coatings, special purpose coatings (including IM and traffic marking coatings), and product finishes. Paint and coating manufacturers purchase raw materials (resins, solvents, pigments, and additives) and process them into coating products that are sold to end users and applicators.[7]

Although traffic marking coatings and IM coatings are considered by the U.S. Environmental Protection Agency (EPA) to be categories of architectural coatings, many references present data for them as either a separate category of specialty or special purpose coatings. This distinction will be maintained in this section to present more detail on the structure of the architectural coatings industry.

Product finishes, marine coatings, and automotive refinishing coatings will not be considered further in this document. Product finishes were addressed in regulatory programs developed in the 1970's and 1980's. Marine coatings and automotive refinishing coatings are the subject of other consumer and commercial product regulations under the Clean Air Act, as amended in 1990 (Act).

The following subsections describe the structure of the U.S. architectural coatings industry in terms of raw material consumption, manufacturers, and distributors and retail markets.

3.2.1 Raw Material Consumption

The raw materials that are consumed by the architectural coatings industry are resins or binders (representing 28.4 percent of total raw materials used by weight), pigments (51 percent), solvents or carriers (18.7 percent), and additives (1.9 percent). In 1991, a total of 4,396 million pounds of resins, pigments, solvents, and additives were used as raw materials in architectural coatings.[8] About 75 percent of these raw materials are derived from fossil fuels, with

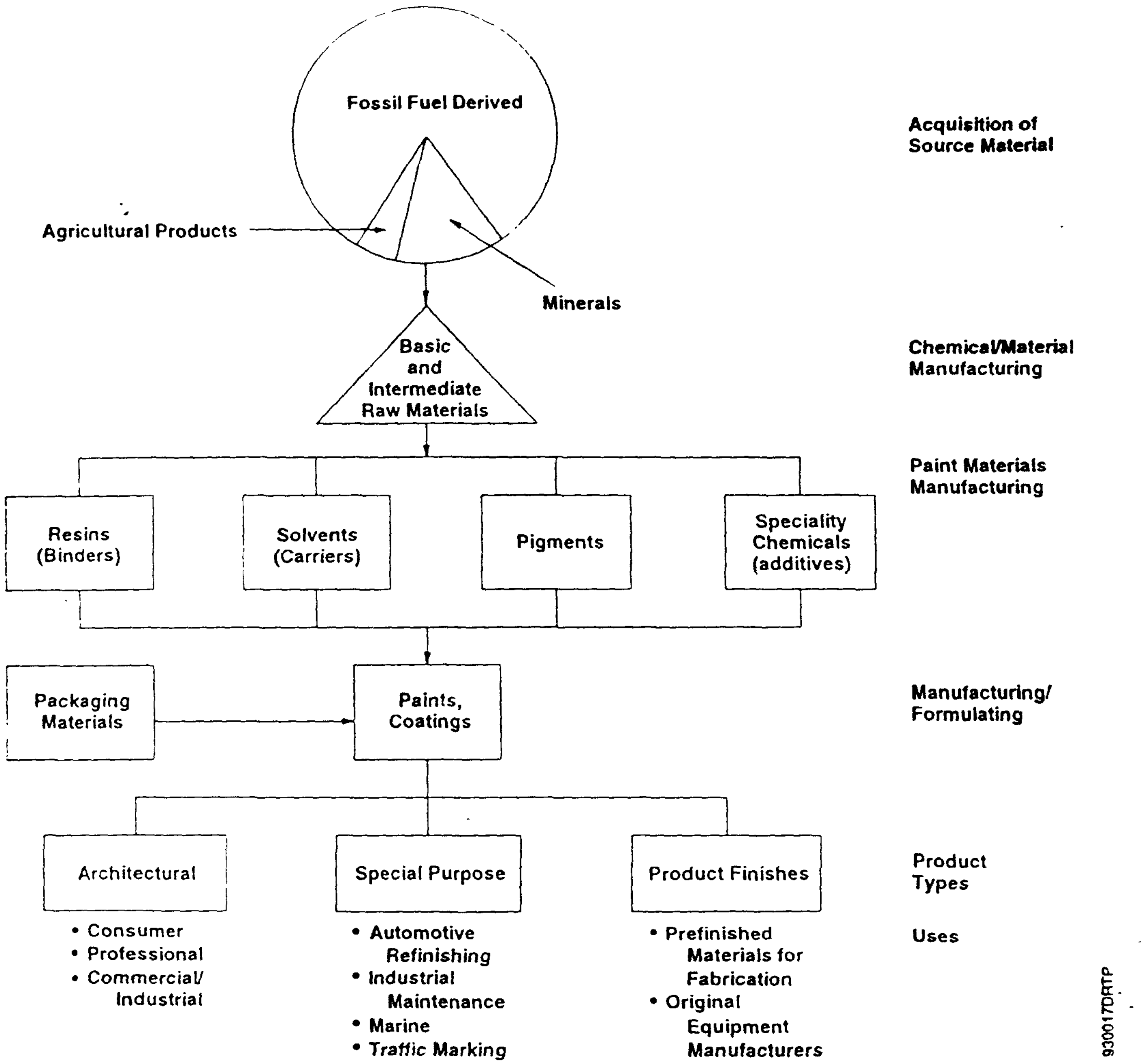

Figure 3-1. Coating industry structure.

the remainder being derived from both mineral and agricultural product materials.[9]

In 1991, the architectural coatings industry consumed approximately 1,250 million pounds of resins. The bulk were alkyd, acrylic, and vinyl resins used in architectural coatings. The consumption of resins by coating and resin type for 1991 is presented in table 3-1.[10-11]

Types of pigments used in architectural coatings include colors, fillers and extenders, and corrosion inhibitors. Titanium dioxide is the most commonly used pigment due to its hiding power. Clays, talcs, silicas, and calcium carbonate are the most commonly used fillers and extenders. Zinc dust and zinc oxide are the pigments most commonly used as corrosion inhibitors. Pigment consumption for architectural coatings in 1991 is summarized in table 3-2.[10,12]

Total solvent consumption for architectural coatings in 1991 was 821.5 million pounds or 410,750 tons. Over one-half of the solvents used in 1991 were aliphatic hydrocarbons. The solvent consumption by coating and solvent type for 1991 is presented in table 3-3.[10,13] As indicated in the table, 6 of the 19 solvents listed are hazardous air pollutants (HAP's) subject to the provisions of section 112 of the CAA.

Additives represent only a small percentage of the raw materials used in the manufacture of architectural coatings. The bulk of additives are used in architectural coatings, with only small amounts used in IM coatings and traffic markings. Thickeners, surfactants and dispersing agents, and antifoaming agents are the most commonly used coating additives. The consumption of additives in 1991 by coating type and additive is presented in table 3-4.[10,14]

3.2.2 Architectural Coatings Manufacturers

Architectural, IM, and traffic coatings accounted for 52 percent of the volume of all paint and allied products shipped in 1990 and 46 percent of their value. In 1990, 1,219 million gallons (Mgal) of all paints and allied products

TABLE 3-1. 1991 RESIN CONSUMPTION BY COATING AND RESIN TYPE (MILLIONS OF POUNDS)[11]

Resin Type	Coating Type: Architectural	Coating Type: Industrial Maintenance	Coating Type: Traffic
Alkyd	246	6	75.5
Acrylic	262	9.9	10.7
Vinyl	355	14	-
Epoxy	-	41.9	-
Urethane	40	23.7	-
Phenolic	8	1.6	-
Styrene Butadiene	15	-	-
Polyester	-	-	0.6
Chlorinated Rubber	-	2.0	1.0
Natural (e.g., shellac, gums)	6	-	-
Linseed Oil	70	-	-
Other	17	17.2	26.5
Totals[a]	1,019	116.3	114.3

[a]Total architectural coatings resin use (including IM and traffic marking coatings) in 1991 was 1,249.6 million pounds.

TABLE 3-2. 1991 PIGMENT CONSUMPTION BY COATING AND PIGMENT TYPE (MILLIONS OF POUNDS)[12]

	Coating Type		
Pigment Type	Architectural	Industrial Maintenance	Traffic
Colors	510	52.4	281.9
Fillers and Extenders	1,119	19	209.9
Corrosion Inhibitors and Others	19	29.2	-
Totals[a]	1,648	100.6	491.8

[a]Total architectural coatings pigment use (including IM and traffic marking coatings) in 1991 was 2,240.4 million pounds.

TABLE 3-3. 1991 SOLVENT CONSUMPTION BY COATING AND SOLVENT TYPE (MILLIONS OF POUNDS)[13]

Solvent Type	Coating Type: Architectural	Industrial Maintenance	Traffic
Aliphatic Hydrocarbons	420	3.3	25.8
Toluene[a]	-	24.2	58.7
Xylenes[a]	2	31.0	0.9
Other Aromatics	-	9.4	14.7
Butyl Alcohol	-	-	-
Ethyl Alcohol	-	-	-
Isopropyl Alcohol	-	-	-
Other Alcohols	3	3.1	-
Acetone	-	4.7	4.9
Methyl Ethyl Ketone[a]	-	2.0	7.4
Methyl Isobutyl Ketone[a]	-	8.5	-
Ethyl Acetate(s)	-	6.1	-
Butyl Acetates	-	19.3	-
Propyl Acetates	-	4.4	-
Other Ketones and Esters	32	6.1	-
Ethylene Glycol[a]	69	-	-
Propylene Glycol	28	-	-
Glycol Ethers[a] & Ether Esters	12	5.5	-
Chlorinated Solvents	-	2.0	11.5
Miscellaneous	2	--	-
Totals[b]	568	129.6	123.9

[a]HAP's subject to the provisions of section 112 of the Act, as amended in 1990.

[b]Total architectural coatings solvent use (including IM and traffic marking coatings) in 1991 was 821.5 million pounds.

TABLE 3-4. 1991 CONSUMPTION OF PAINT ADDITIVES BY COATING AND ADDITIVE TYPE (MILLIONS OF POUNDS)[14]

	Coating Type		
Additive	Architectural	Industrial Maintenance	Traffic
Surfactants and Dispersing Agents	27.0	-	-
Driers	0.0	0.11	0.16
Thickeners	33.0	-	-
Preservatives and Mildewcides	6.0	-	-
Antiskinning Agents	2.0	0.08	0.30
Antifoaming Agents	16.0	-	-
Totals[a]	84.0	0.19	0.46

[a]Total AIM coatings additives use (including IM and traffic marking coatings) in 1991 was 84.65 million pounds.

with a value of approximately $12.4 billion were shipped from U.S. manufacturers.[15]

In this section, information is presented on the number and size of the manufacturers of architectural coatings, first for manufacturers of architectural coatings, then for manufacturers of IM coatings (sometimes referred to as "industrial new construction and maintenance coatings" and "high performance maintenance coatings") and traffic marking coatings (sometimes called just "traffic coatings").

3.2.2.1 Architectural Coating Manufacturers. In 1987, there were 285 companies that each had total shipments of architectural coatings* of $100,000 or more in value.[16] A second source reports that 527 companies produced architectural coatings in 1989.[9] The difference in these two estimates is probably due to the fact that the second reference includes those companies that produced less than $100,000 worth of architectural coatings, as well as special-purpose coatings and product finishes. For comparison, the 1987 Census of Manufactures identified 1,123 companies operating 1,426 establishments that manufactured all types of paints and allied products.[16]

The bulk of architectural coatings are produced by 20 large companies. In 1989, the top 20 companies accounted for 59.6 percent ($2,808 million) of the value of total architectural coating shipments.[9] These top 20 companies and the value of their U.S. shipments are provided in table 3-5.[17]

The U.S. production of architectural coatings is geographically dispersed. In 1987, the top six States for the production of architectural coatings, based on the value of shipments, were (in decreasing order) California, Illinois, Texas, Maryland, Georgia, and Ohio. These six States

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*The Bureau of the Census defines architectural coatings as "Coatings for on-site application to interior or exterior surfaces of residential, commercial, institutional or industrial buildings. These are protective and decorative finishes applied at ambient temperatures for ordinary use and exposure."

TABLE 3-5. MAJOR U.S. PRODUCERS OF ARCHITECTURAL COATINGS[17]

Rank	Company	Value of Shipments[a] ($Million)
1	Sherwin-Williams[b]	$475
2	Benjamin Moore	350
3	Glidden (ICI)[c]	300
4	PPG[d]	235
5	DeSoto	173
6	Valspar	165
7	Grow Group	143
8	United Coatings	100
9	Williams Holdings	100
10	Courtaulds (Porter)	95
11	Kelly-Moore	90
12	M.A. Bruder	82
13	Dunn-Edwards	70
14	Duron	70
15	Pratt & Lambert	70
16	Standard T	65
17	Vogel	65
18	Sinclair	60
19	O'Brien	52
20	Jones-Blair	48
	Other	1,906
	Total	$4,714

[a]U.S. shipments only of paints manufactured by that producer (may include transfers to company stores).

[b]Acquired DeSoto in 1990.

[c]Includes purchase of Roach Paint Co.

[d]Acquired Olympic/Lucite in 1989.

represented 56.6 percent of the total value of U.S. architectural coating shipments.[16]

3.2.2.2 IM and Traffic Coatings Manufacturers. Data for manufacturers of IM coatings and traffic marking coatings are compiled by the Bureau of the Census separately from their data for architectural coatings manufacturers. However, they are compiled in a category described as "special-purpose coatings," which also includes marine coatings, auto refinishing coatings, and aerosol coating concentrates. Some of the data for IM and traffic marking coatings from the Bureau of the Census are not separated from the overall statistics for special-purpose coatings.

Industrial maintenance coatings and traffic coatings accounted for about 44 percent of the volume and 32 percent of the value of special-purpose coatings in 1990.[13] In 1987, there were 245 companies that had total shipments of special-purpose coatings of $100,000 or more in value.[16] The major U.S. producers of special-purpose coatings whose principal products also include IM coatings and traffic coatings are listed in table 3-6. The companies listed in table 3-6 represented 41 percent of the total value of special-purpose coating shipments in 1989.[18] The value of IM and traffic coating shipments is not known for these companies.

Like architectural coatings, the production of special-purpose coatings is geographically dispersed; therefore, the same is probably true for IM coatings and traffic coatings. In 1987, the top six States for production of special-purpose coatings based on the value of shipments were (in decreasing order) Ohio, Missouri, New Jersey, California, Texas, and Illinois. These States represented 55 percent of the total value of special purpose coating shipments in 1987.[16]

3.2.3 Distributors and Retail Markets

Architectural and IM coatings are sold to painting contractors and commercial and IM users through company stores, independent dealers, mass retailers, and through chains of home improvement centers. Do-it-yourself consumers

TABLE 3-6. MAJOR U.S. PRODUCERS OF IM COATINGS AND TRAFFIC COATINGS[18]

Company	Value of Shipments in 1989 ($Million)[a]	Principal Products[b]
Sherwin-Williams	360	Auto refinishing, maintenance
RPM[c]	150	Protective
Courtlands	115	Maintenance, marine
Rust-Oleum	65	Protective
Glidden	55	Maintenance
Ameron	53	Protective
Grow	45	Maintenance, marine
Tnemec	30	Protective
Sigma	25	Maintenance, marine
ConLux	20	Maintenance
Morton International	20	Traffic
Valspar	20	Maintenance
Centerline	17	Traffic

[a]Value of shipments include sales of the product categories listed to the right.

[b]Auto refinishing and marine coatings are included because the Rauch Guide did not separate these categories by value of shipments. Protective coatings are equivalent to industrial protective coatings. Maintenance coatings are equivalent to high-performance architectural coatings. Protective coatings have higher performance requirements than maintenance coatings.

[c]Includes Kop Coat acquired in 1990.

and homeowners purchase architectural coatings through many of the same sellers as other coating users, but generally do not purchase IM coatings. Summary statistics for architectural coating distributors and retail markets are presented in table 3-7 and described in more detail below.[16,19-20]

The National Paint and Coatings Association (NPCA) estimates that there were about 42,000 retail outlets for architectural coatings in 1992. Of these, 3,750 are stores operated by paint companies, 4,700 are independent retailers that purchase paint from a wholesaler, 14,700 are lumber and other building material dealers, 14,900 are hardware stores, and 4,000 are mass merchandisers.[21]

The Bureau of the Census estimates that 29,900 firms were engaged in the application of architectural and IM coatings in 1987. The value of this activity in 1987 was $7.9 billion, of which $6.3 billion was for building construction and $976 million was for nonbuilding construction. Construction work "not specified by kind" accounted for $686 million in value.[20] Building construction includes residential, commercial, and institutional buildings that most likely represent architectural coating applications. Nonbuilding construction includes bridges and elevated highways, utility plants, and heavy industrial facilities that probably represent IM coating applications.

3.2.3.1 Architectural Coatings. According to the 1990 U.S. Census of Paint and Allied Product Manufactures, 558 Mgal of architectural coatings at a value of $4,862 million were shipped in 1990.[13] Interior waterborne coatings are the largest segment of the architectural market representing 47 percent of the volume and 41 percent of the value of coatings shipped. These are followed by exterior waterborne coatings (26 percent of the volume, 24 percent of the value), exterior solventborne (14 percent of the volume, 18 percent of the value), and interior solventborne (10 percent of the volume, 13 percent of the value). The remainder of

TABLE 3-7. SUMMARY OF AIM COATING DISTRIBUTORS AND RETAIL MARKETS

Category	Number or Volume	Value ($Million)
AIM Coating Retailers[19]	42,000	(Not Available)
AIM Coating Applicators (1987)[20]	29,900	7,953
Architectural Coating Shipments (1990)[16]	558 Mgal	4,862
Industrial Maintenance Shipments (1990)[16]	58.9 Mgal	723
Traffic Marking Shipments (1990)[16]	22.2 Mgal	122
All Paint and Allied Products (1990)[16]	1,219 Mgal	12,368

architectural coatings (3.1 percent of both the volume and the value) are lacquers and coatings "not specified by kind."[13]

A study sponsored by the NPCA estimated that about 60 percent of architectural coatings were used for residential structures and the remainder on commercial, institutional, or light-industrial structures. About two-thirds of the paint applied to residential structures is done by homeowners and the rest by contractors.[22]

3.2.3.2 IM Coatings. Industrial maintenance coatings accounted for 59 Mgal of coating shipments in 1990 at a value of $723 million. Exterior coatings represented 62 percent of the total volume of IM coatings shipped and 68 percent of the value.[13]

About 30 percent of IM coatings are used on new construction, about 75 percent are applied to iron or steel, and about 67 percent are applied using spray techniques. Nonfactory structures account for 30 percent of the use of these coatings and include utilities, bridges, highways, railroads, sewer and water plants, and other processing plants.[23]

Some grades of IM coatings are intended for very high performance and are similar to original equipment manufacturer (OEM) finishes. Others are intended for lower performance and are more similar to architectural coatings. Industrial maintenance coatings are generally solventborne and include alkyd, vinyl, epoxy, and urethane formulations. Polyurethane and epoxy systems are the dominant and fastest-growing systems.[23]

3.2.3.3 Traffic Marking Coatings. Traffic marking coatings accounted for 22.2 Mgal of shipments in 1990, valued at about $122 million.[13] These coatings are used for marking pavement on roads, parking lots, runways, and roadside posts.[23] They must be durable and visible under all surface and weather conditions. Fast-drying products are highly desirable to minimize application costs and traffic delays since the travel lane being marked must be closed to traffic.

In 1990, solventborne alkyd and alkyd-chlorinated rubber resins accounted for most of the volume used. Waterborne acrylic coatings accounted for about 10 percent of the volume used. The remainder were two-component epoxies, polyester-based coatings, and hot-extruded thermoplastic coatings.[24]

About 65 percent of total consumption of traffic marking paints is by State highway departments, about 25 percent are sold to city and county road authorities, and the rest are used in parking lots and garages.[24] Traffic coatings are usually sold by competitive bid to government agencies and are applied by contractors or government employees.[23] Some States, however, manufacture their own traffic marking coatings.

3.3 CURRENT INDUSTRY TRENDS

3.3.1 Architectural Coating Sales

The consumption of architectural coatings is closely tied to national economic trends. Between 1981 and 1991, the volume of architectural coatings shipped by manufacturers increased at the average rate of about 1 percent per year. In this period, the volume of architectural coatings sold significantly dropped during the recessionary years of the early 1980's. In 1991, there was a 5 percent drop because of economic slowdown.[25] This drop in volume sales reflected a sharp drop in residential construction and, more importantly, a sharp drop in sales of existing houses. This drop was offset slightly by an increase in the do-it-yourself market for architectural coatings and an overall increase in architectural coating sales from 1983 to 1991.[26]

Sales of architectural coatings recovered in the period from 1983 to 1987 and remained level from 1987 to 1989, with greater than a 5 percent drop in 1991, as shown in table 3-8.[13,27-28] Data from the Bureau of the Census indicate an increase in the shipment of architectural coatings from 1989 to 1990.[13] Shipments of architectural coatings are forecast to be 565 Mgal in 1995.[9] The reason for the

TABLE 3-8. 1979 to 1991 CONSUMPTION OF COATINGS (MILLIONS OF GALLONS)

	Coating Type			
	Architectural			
Year	SRI[27]	Census[13,28]	Industrial Maintenance[27]	Highway and Traffic Markings[27]
1979	459	--	28.5	44
1980	432	--	29.5	42
1981	415	--	30.5	41
1982	391	--	27.5	40
1983	431	--	25.0	40
1984	455	457.3	27.5	41
1985	465	477.9	28.0	41
1986	480	498.1	28.0	42
1987	493	527.0	29.0	42
1988	495	535.9	31.0	42
1989	493	537.5	32.0	42
1990	498	557.7	32.0	42
1991	470	--	32.0	41

increasing difference between the SRI and Bureau of the Census estimates shown in table 3-8 is not known.

3.3.2 Industrial Maintenance and Traffic Coating Sales

The trend in shipments of IM coatings since 1979 is similar to that of architectural coatings, even though this category was formerly thought to be "recession proof."[29] Consumption of IM coatings increased throughout the 1980's except for a decline in 1982 and 1983. Industrial maintenance coating consumption tends to lag behind economic recoveries, and the recovery in IM coatings follows that for architectural coatings by 1 or 2 years.[9]

Traffic coating consumption has remained relatively stable since 1979 (table 3-8). However, usage has declined since 1989 due to higher prices, government budget constraints, and the use of more durable coatings.[9]

3.3.3 Coating Technology Trends

The development of lower-volatile organic compound (VOC) technology through the use of higher-solids and waterborne coatings has been a general trend in the coating industry, including architectural and IM coatings. In the 1970's, coatings were generally of two types: waterborne latexes and low-solids solventborne coatings. Lower-VOC coating technology now includes higher-solids coatings, water-soluble coatings, and solventless (powder or 100 percent solids liquid) coatings, in addition to waterborne latex coatings.[30] These lower-VOC technologies are discussed in more detail in chapter 4.0, Emission Control Techniques.

The forces driving this technological trend are a desire by consumers for waterborne coatings and, more recently, the regulation of VOC emissions by States to meet the National Ambient Air Quality Standard for ozone.[31] These State regulations were outlined earlier in chapter 2.0, Product Category Description. Concerns about the supply of petroleum-derived solvents was a factor encouraging lower-VOC technology in the 1970's and early 1980's, but has not been a factor since the mid-1980's.[31]

The overall trend towards lower-VOC coatings is reflected in the consumption of solvents compared to that of resins as raw materials since 1979. During the recession of the early 1980's, resin consumption did not drop as far as that of solvents and recovered more quickly following the recession. Solvent use dropped 19 percent from 1979 to 1982 and in 1989 had recovered to only 95 percent of the 1979 consumption rate, and then experienced a 7 percent drop from 1989 to 1991.[32,33] In contrast, resin use dropped only 15 percent and by 1989 had increased to 8 percent above the 1979 consumption rate, with only a 5 percent drop from 1989 to 1991.[34,35]

The fraction of resin used in higher-solids and waterborne coatings, such as epoxies and acrylics, has grown faster than the fraction used in solventborne coatings, such as alkyds and vinyls. This is reflected in an overall decline in solvent consumption, particularly in the use of aliphatic hydrocarbons, the solvent type most often used in conventional solventborne coatings. This decline in use of aliphatic hydrocarbons is also due to their low solvency power and their replacement by stronger solvents to produce higher-solids coatings. Aliphatic hydrocarbons represented 20 percent of total paint solvent consumption in 1991, compared to 30 percent in 1973.[29]

In 1991, about 76 percent of architectural coatings were waterborne. Interior architectural coatings were about 76 percent waterborne and exterior architectural coatings were about 68 percent waterborne. The percentages that are waterborne have leveled off since the late 1970's. However, the trend toward increased use of waterborne coatings is expected to resume as a result of increased State and Federal regulations to lower VOC emissions.[27]

Table 3-9 summarizes the percentages of several types of architectural coatings that are waterborne and solventborne for 1973, 1981, and 1991.[10,36] There has been a trend towards waterborne architectural coatings for interior and exterior flats, interior semiglosses, and exterior stains, as well as interior and exterior coatings listed as "other" in table 3-9. However, interior and exterior varnishes, interior glosses, and exterior enamels remain almost entirely solventborne.[9]

In 1989, 85 percent of IM coatings and 85 percent of traffic coatings were conventional solventborne coatings. High-solids coatings (solventborne coatings with at least 60 percent solids by weight) were 10 percent of IM coatings. Only 5 percent of IM coatings and 15 percent of traffic coatings were waterborne.[37]

3.3.4 Trends in Alternatives to Coatings

Wallpaper and vinyl wall coverings are alternatives to interior architectural coatings. Their market share of sales by paint, glass, and wallpaper stores has increased from about 10 percent in 1967 to 18 percent in 1987, while the share of paint has dropped from 54 percent to 42 percent. The vinyl siding market, which represents an alternative to the use of exterior coatings, is also growing and represented 32 percent of the market for coverings of exterior residential surfaces in 1991.[38] These trends are probably due to changes in consumers' preferences and a desire for lower-maintenance coverings, rather than a response to VOC regulations.

TABLE 3-9. USE PERCENTAGES FOR WATERBORNE AND SOLVENTBORNE ARCHITECTURAL COATINGS, BY COATING TYPE[36]

Architectural Coating Type	1973		1981		1991	
	Waterborne	Solventborne	Waterborne	Solventborne	Waterborne	Solventborne
Interior (overall)	70	30	78	22	83	17
Flat[a]	90	10	93	7	97	3
Semigloss	45	55	70	30	72	28
Gloss	0	100	5	95	5-10	90-95
Varnish	0	100	3	97	3	97
Other[b]	22	78	42	57	55	45
Exterior (overall)	55	45	62	38	68	32
Flat	72	28	81	19	88	12
Enamel	20	80	25	75	27	73
Stains	5	95	32	68	45	55
Varnish	0	100	0	100	<1	99
Other[c]	29	71	30	70	50	50

[a]Includes sheen, satin, and low luster.

[b]Includes undercoats, primers, sealers, and stains

[c]Includes undercoats, primers, and sealers.

3.4 REFERENCES

1. Martens, C. R. Waterborne Coatings: Emulsion and Water-Soluble Paints. New York, van Nostrand Reinhold Company. 1981. p. 2.

2. Reference 1, p. 3.

3. Brandau, A. Introduction to Coatings Technology, Federation Series on Coatings Technology. Federation of Societies for Coatings Technology. Blue Bell, PA. October 1990. p. 8.

4. Reference 1, p. 4.

5. Glass, T. and J. Depoy. New Resins and Equipment Make Field-Applied Powder Coatings a Reality. Journal of Protective Coatings and Linings. 8(7):33-36. July 1991.

6. Glass, T. and J. Depoy. Protective Thermoplastic Powder Coatings: Specifically Designed Adhesive Polymers. In: Maintaining Structures With Coatings. Proceedings of SSPC 91, Long Beach. Pittsburgh, Steel Structures Painting Council. November 10-15, 1991. pp. 267-279.

7. SRI International. U.S. Paint Industry Database. Prepared for, and provided to the U.S. Environmental Protection Agency by, National Paint and Coatings Association. Menlo Park, CA. 1992. p. 2.

8. Reference 7, pp. A-9 - A-10.

9. Rauch Associates, Inc. The Rauch Guide to the U.S. Paint Industry. Bridgewater, NJ. 1991.

10. Reference 7, p. A-18.

11. Reference 7, pp. A-7 - A-8.

12. Reference 7, pp. A-11 - A-12.

13. Reference 7, pp. A-15 - A-16.

14. Reference 7, p. A-18.

15. Gromos, D. J. Current Industrial Reports: Paint and Allied Products 1990. Bureau of the Census, U.S. Department of Commerce. Washington, DC. Publication No. MA28F(90)-1. October 1991. 8 pp.

16. Bureau of the Census, U.S. Department of Commerce. 1987 Census of Manufactures - Paints and Allied Products, Industry 2851. Washington, DC. Publication No. MC87-1-28E. January 1990. 11 pp.

17. Reference 9, p. 64.

18. Reference 9, p. 85.

19. Information provided to the U.S. Environmental Protection Agency by the National Paints and Coatings Association at the Regulatory Negotiation Meeting, March 19 and 20, 1992. Washington, DC.

20. Bureau of the Census, U.S. Department of Commerce. 1987 Census of Construction Industries - Painting and Paper Hanging Special Trade Contractors, Industry 1721. Washington, DC. Publication No. CC87-I-11. January 1990. 36 pp.

21. Information provided to U.S. Environmental Protection Agency at Regulatory Negotiation Committee Meeting. April 15-16, 1992. Raleigh, NC.

22. SRI International. U.S. Paint Industry Database. Prepared for and provided to the U.S. Environmental Protection Agency by, National Paint and Coatings Association. Menlo Park, CA. 1990. p. 50.

23. Reference 9, p. 86.

24. Reference 7, p. 79.

25. Reference 7, p. 47.

26. Reference 7, p. 49.

27. Reference 7, p. 44.

28. Shelton, N. A. Current Industrial Reports: Paint and Allied Products 1989. Bureau of the Census, U.S. Department of Commerce. Washington, DC. Publication No. MA28F(89)-1. October 1990. 8 pp.

29. Reference 22, p. v.

30. Reference 7, pp. 31-32.

31. Reference 22, pp. 32-35.

32. Reference 22, p. 143.

33. Reference 7, p. 143.

34. Reference 22, p. 85.

35. Reference 7, p. 85.

36. Reference 7, p. 46.

37. Reference 22, p. 37.

38. Reference 7, pp. 50-51.

4.0 EMISSION CONTROL TECHNIQUES

Reformulation to higher-solids and waterborne coatings is the means by which volatile organic compound (VOC) content of coatings is reduced. The extent to which either of these is technologically and economically feasible will vary among coating categories.

Advantages of waterborne products or formulations, in addition to reduced VOC emissions, are related to the health hazards associated with the solvents used in architectural coatings. These solvents may be harmful if inhaled and are usually flammable. The use of waterborne coatings may reduce the potential for fires and solvent exposure of workers during application, and therefore improve industrial hygiene and safety for applicators and consumers.[1] Easier cleanup, faster drying time, and the reduced odor of waterborne coatings are also major reasons they are preferred over solventborne coatings in residential applications.[2]

Despite these advantages, some industry representatives claim that some lower-VOC coatings are inferior to conventional higher-VOC coatings. In particular, the argument has been made that lower-VOC coatings, especially high-solids alkyds, may be more viscous and tend to produce a thicker coat when applied directly from the can, therefore increasing the amount of coating consumed and the VOC emissions per unit of area covered. It has also been argued that lower-VOC coatings may encourage more thinning, which will negate any reduction in VOC content. Further arguments include the position that some lower-VOC coatings may also require more priming and more topcoats, because of poor adhesion and hiding ability, respectively. Industry representatives have also argued that lower-VOC coatings dry more slowly, are more susceptible to damage and defects during drying, and are less durable. Consequently, opponents of coating VOC restrictions maintain that lower-VOC coatings will require more touchups and repair work, and more frequent recoating. Finally, industry representatives have argued that lower-VOC coatings will require solvents that may be more reactive in the formation of stratospheric ozone.[3] However, advances in lower-VOC technology have led to the development of some waterborne and high-solids coatings that have performance equal to or improved over that of higher-VOC coatings.[4-7] Architectural coatings are offered in varying degrees of quality at both high- and low-VOC levels.

A lower-VOC coating may require a different resin system. When comparing different coating systems for a specific application, the resins involved may be evaluated with respect to the following:

- Chemical resistance;
- Scuff/mark resistance;
- Abrasion resistance;
- Corrosion resistance;
- Flexibility;
- Color retention and gloss level;
- Hardness;
- Drying time; and
- Temperature stability.

For example, where an epoxy may provide superior corrosion resistance for a metal substrate than would an alkyd, the alkyd may have better resistance to ultraviolet radiation. The alkyd would likely exhibit greater color retention upon exterior exposure but the epoxy may tend to chalk and its color fade when exposed to sunlight. The performance characteristics required of a resin may vary widely from application to application and a tradeoff among these is often required.

Lowering the VOC content may involve substituting a higher-solids, lower-VOC epoxy coating for a lower-solids, higher-VOC alkyd coating to use in the same application. Alternatively, a lower-VOC product may be available that uses the same resin but has a different chemistry that requires a lower solvent content.

4.1 LOWER-VOC COATING TECHNOLOGIES

Lower-VOC coating technology alternatives for architectural coating applications can be divided into three categories:

- Waterborne coatings;
- Higher-solids coatings; and
- Powder coatings (limited applications).

The following sections discuss these technologies and how they differ from conventional coatings.

4.1.1 Waterborne Coatings

Waterborne architectural coating technologies are primarily emulsions (also known as latexes). These are two-phase systems in which very fine droplets of resin (the dispersed phase) are suspended or dispersed in water (the continuous phase) in which the resin is insoluble.[8] Emulsions form films by evaporation of the water, which brings the resin droplets closer together until they coalesce to form a continuous film.[9-10]

Vinyl acetate and acrylic emulsions are commonly used in architectural coatings. Coatings based on vinyl acetate emulsions are used by professional and do-it-yourself painters, primarily on interior walls and ceilings. Their advantages include relatively low levels of organic volatiles, ease of application with brushes or rollers, short drying times (recoating is usually possible in a few hours), and cleanup can be done with water.[10]

Coatings based on acrylic emulsions are used in many of the same applications as vinyl acetate-based coatings for interior walls and ceilings. In addition, they are more durable than vinyl acetate-based coatings and may be used as wood primers and exterior finishes. Acrylic latex coatings using harder polymers may be used as floor coatings and as primers for new galvanized iron.[11]

Waterborne coatings may be brushed, rolled, and sprayed with conventional equipment and are frequently used for flat and nonflat house coatings. However, because of the drying and adhesion requirements of some specialty coatings, waterborne systems are not well suited to some specialty end uses. Examples include dry fog coatings where high relative humidity at the application site may limit water evaporation and increase drying time, and concrete coatings where alkalies may leach into the film and disrupt the resin system.[12]

4.1.2 Higher-Solids Coatings

Higher-solids coatings require less solvent to induce flow and form thicker films than conventional coatings of the same type. Examples of high-solids coatings include some types of epoxies and polyurethanes.[13] Some two-component resin systems contain no solvent and are 100-percent solids. The U.S. Environmental Protection Agency (EPA) defines "higher-solids" coatings as generally having greater than 60-percent solids by volume, but recognizes that the term is relative to the typical solids content for a particular coating category.[14]

Thicker films are only desirable in some coating categories. Waterproofing sealers and stains, for example, have very low solids by design because their purpose is to seal or color the surface being coated without creating a film that hides the texture of the surface. Other coatings, such as mastic texture coatings, are intended to be applied as thick films, so they are formulated to have relatively high solids contents. Most coatings with solids higher than 60 percent (including two-component, 100-percent solids epoxy and polyurethane coatings) are associated with industrial maintenance (IM) coating applications, such as bridge coatings and corrosion protection for storage tanks.[5,15-16]

Current high-solids technology focuses on using lower-molecular-weight resins of low viscosity. In 100-percent-solids systems such as epoxy and polyurethane coatings, which have been used on storage tanks and bridges, the resins are nonvolatile liquids that react with each other and harden without solvent evaporation.[15-16] Producing higher-solids coatings to meet specific performance criteria often requires extensive hybridization and modification of traditional resin systems. Some of the hybrid resin systems and conventional two-component systems, such as polyurethane, can be modified to use lower-molecular-weight resins and can be applied with liquid hardeners.[15-16]

Like conventional coatings, most higher-solids coatings can be applied by brush, roller, or spray. The principal application method for 100-percent-solids coatings is by spray because most of these coatings are two-component epoxy or polyurethane systems that require component mixing during application.[15-16] The polyurethanes may have an advantage over epoxies because they can be applied at colder temperatures and, even though initial coating cost is higher, may be less expensive over the life of the coating because of greater durability depending on the exposure situation.[15]

4.1.3 Powder Coatings

Powder coatings are a near-zero-VOC coating technology, initially developed and used in metal product manufacturing industries, that has now been adapted for other coating applications. In manufacturing settings, powder coatings are generally applied by two separate techniques:

- Immersion of a heated substrate into a fluidized bed of powder; or

- Electrostatic deposition of the powder to a substrate that has been preheated or is subsequently heated.

Heating of the powder system or substrate, or both, is required to liquefy, induce flow, and initiate chemical reactions within the coating to assure proper film formation. Because of these constraints, powder coating technology was formerly considered to be limited to the coating of fabricated metal products. However, technological advances in powder coatings and thermal spray equipment have enabled their use in several IM coating applications including the coating of bridges and other steel structures. Powder coatings with field applications are grouped into two systems: polymer resin systems and metallizing systems. Powder coating systems as a group have demonstrated good performance relative to more conventional IM coatings in accelerated performance tests.[5] The current uses of these powder coating systems in various IM applications are described below.

4.1.3.1 Polymer Resin Systems. Thermoplastic polymers, such as polyethylene and polypropylene, were among the first powder coatings to be developed. They also have the simplest application mechanism, which involves melting the solid polymer, spraying the hot liquid onto a heated metal substrate, and resolidification of the polymer as a thin film. However, these coatings have shown marginal abrasion resistance because of poor film adhesion that can cause the coating to fail completely if the film is punctured.[17] Efforts to improve performance have resulted in the development of modified polymers that have demonstrated greater ability to withstand physical and corrosive attack than traditional polymers and even some conventional epoxy coatings.[6-7]

Currently, polymer resin powder coatings are not cost effective in most applications for steel structures compared to more conventional coatings, such as two-part catalyzed epoxies. However, in some architectural coating situations powder coatings are a better alternative. Specifically, these include areas of high abrasion, such as highway light poles subject to blowing sand and road salt, or where a specific chemical resistance is needed, such as chemical storage tank linings. In addition, because both the coating and substrate are heated, application can be done in almost all weather conditions, even extreme cold. One of the primary limitations of these coatings is that they are not very resistant to temperatures above 165 ^{o}F.[6-7]

4.1.3.2 Metallizing Systems. Metallizing coatings are applied to structural steel or other metal objects by melting and spraying a metal. The most common metals applied are zinc and aluminum, either separately or as an alloy.[18] Metallizing systems are primarily used for high-performance and industrial corrosion protection, such as structural steel or tank linings. They have also been used in a few cases to apply zinc coatings to steel-reinforced concrete to protect the reinforcing rods from corrosion.[19-20]

Specialized equipment is required to apply metallizing systems. The metal coatings are applied using a gun that melts a metal wire or powder and then uses compressed air to spray the molten metal on the substrate to be coated. The heat source to melt the wire or powder inside the gun is a flame using an acetylene and oxygen mixture or an electric arc.[18]

Metallizing coatings can only be applied to bare steel or concrete that has been abrasive blasted. Because the metal coating adheres to the substrate by mechanical adhesion, the prepared surface must have the appropriate surface roughness or profile.[18]

Regardless of whether applying polymer resin or metallizing coating systems, the cost of thermal spray equipment for field use is approximately two to three times the cost of conventional coating equipment. This cost is mitigated in some circumstances because powder coating lifespan is often two or three times longer than that of conventional coatings when the coating must withstand severe abrasion or corrosion.[6-7,21]

4.2 PRODUCT REFORMULATION

4.2.1 Resins

Next to the solvent, resins have the most significant effect on VOC content. The need for solvent can be reduced by reducing resin viscosity, which can be done by lowering the molecular weight of the resin. However, with conventional resin types this can impair the performance of the coating.[22]

One alternative is to use a two-component resin system, such as with an epoxy or urethane system, in which two low-molecular-weight components are combined just prior to, or during, application. These two components react during curing to form larger molecules through cross-linking. These types of systems may have good hardness and chemical resistance, but, because of the tightly cross-linked structure, they may lack flexibility and impact and abrasion resistance.[22] Epoxy and polyurethane resins are used in many IM coatings where hardness and chemical resistance are needed, but this technology is poorly suited for consumer use because of limited pot-life (i.e., storage life) and increased complexity.[15-16]

A second alternative is to use natural-drying oil resins, such as linseed oil, that are 100-percent solids and do not require solvents. However, these resins are not suitable for interior applications because they are prone to yellowing, mildewing, and dry slowly.[23]

4.2.2 Pigments

Altering the pigment content of a coating is generally not an effective means of lowering its VOC content. Adding pigment, particularly if the pigment particles absorb the resin, tends to increase the coating viscosity and may make application more difficult.[22] In addition, many coating properties are closely tied to the pigment volume concentration.

Low-density hollow glass or plastic microspheres, or materials that have been treated to have low rates of resin absorption, can be added to a coating to build solids volume without significantly affecting viscosity. These are more effective in reducing VOC content than the addition of conventional pigments.[22]

4.2.3 Plasticizers

Plasticizers are low-viscosity liquids with little volatility. They can be used as fillers to increase the "solids" volume while reducing the viscosity of the wet paint. Plasticizers are commonly used in thermoplastic coating systems, but these systems are high enough in VOC that small volumes of additional plasticizers will not significantly lower the VOC content.[22]

Plasticizers have also been used in thermosetting systems such as epoxies and alkyds, but the plasticizer may reduce the density of cross-linking and therefore impair coating performance, such as reducing solvent resistance. However, some plasticizers have been used successfully in epoxy systems with no loss of film performance.[22]

4.2.4 Reactive Diluents

Reactive diluents are low-molecular-weight, low-viscosity substances in which the resin is miscible or soluble. They are similar to plasticizers in that they can be used to increase the nonvolatile solids content, but are different in that they react with and become part of the resin system. Alone, reactive diluents have some volatility, but this is rapidly lost when they are mixed with and become part of the resin. One disadvantage is that they may reduce the density of cross-linking in the dried film and therefore reduce coating performance. Another disadvantage is that they can be toxic compounds.[22]

4.2.5 Thixotropes and Dispersants

Thixotropes and dispersants are added to control sagging of coatings and the settling of pigment particles in wet coating films, respectively. However, thixotropes and dispersants that introduce any real viscosity are counterproductive to reducing VOC content because additional solvent is needed to reduce viscosity for application. Thixotropes need to be carefully matched to the resin or solvent in the coating. Some thixotropes and dispersants are solventborne and therefore cannot be added without increasing coating VOC content. Solid thixotropes and nonvolatile dispersants can be added as part of the nonvolatile portion of the coating, but only in limited quantities before they begin to affect other coating properties.[22]

4.3 EXAMPLES OF TYPES OF CATEGORY-SPECIFIC PRODUCT REFORMULATION LIMITATIONS

Although significant advancements have been made in the development of lower-VOC coatings, problems have been identified for some categories by some manufacturers. Some of these problems may have been or are likely to be solved as coating technology continues to develop. Examples of these types of problems were identified through two sources. The first source was manufacturers' comments to the California Air Resources Board (CARB) proposal for a model architectural coatings rule in 1989.[24] The second source was the results of a 1991 EPA survey of nine large architectural and IM coating manufacturers.[25] This survey was conducted to collect information on VOC content and the availability of lower-VOC coatings. Listed below are examples of reformulation problems were identified.

4.3.1 Magnesite Cement Coatings

Magnesite cement decking requires a coating that resists alkali attack from the concrete substrate. It has been argued that only high-VOC, lacquer-based coatings function in this application. According to the one manufacturer of this coating type, it cannot be economically reformulated.[26]

4.3.2 Dry Fog Coatings

Lowering the VOC content of a dry fog coating may affect its ability to dry quickly, which is the foremost performance requirement.[25]

4.3.3 Fire-retardant Coatings

These coatings must comply with building codes and fire safety codes. Reformulation, therefore, must take into account a strict specification for performance. There is some question in the fire safety industry whether the American Society for Testing and Materials (ASTM) test method for fire retardance accurately predicts performance under actual fire conditions. The ASTM committee for paints formed a task group to review and develop test methods for fire-retardant coatings.[27]

4.3.4 IM Coatings

Industrial maintenance coatings designed for high-temperature (greater than 400 $^{\circ}F$) resistance may require a higher VOC content than other types of IM coatings.[28]

4.3.5 Lacquers, Shellacs, and Varnishes

Comments have suggested that reformulation of these coatings may adversely affect performance characteristics such as drying time and film hardness.[25]

4.3.6 Metallic Pigmented Coatings

Reformulating for low-VOC content may impair the high-temperature performance of metallic heat-resistant coatings.[25]

4.3.7 Pretreatment Wash Primers

According to comments received on the CARB Model Rule, low-VOC wash primers do not function adequately under "normal conditions," but more specific information was not supplied. A possible overlap with marine coating regulations must be considered for this category because an identical coating is used as a marine coating. For example, the Bay Area Air Quality Management District's marine coatings and architectural coatings rules both include this category and have set the same VOC content limit.[29]

4.3.8 Stains

Some manufacturers of stains indicated that lowering VOC contents in some masonry stains would impair adhesion and flow characteristics and affect hard film formation at low temperatures.[25] Commenters on the CARB model rule have stated that semitransparent wood stains require a higher-VOC content than opaque stains and the performance of stains that comply with the CARB model rule is much poorer than higher-VOC stains.[30]

4.3.9 Swimming Pool Coatings

Lower-VOC epoxy pool coatings cannot be applied over existing chlorinated rubber pool coatings and require complete removal of the chlorinated rubber. Epoxy coatings are not as easily applied by homeowners as chlorinated rubber coatings, which have higher VOC levels, because they require more extensive surface preparation and must be applied more quickly.[31]

4.3.10 Waterproofing Sealers

According to some industry representatives, multipurpose waterproofing sealers at 400 grams per liter (g/L) do not meet minimum performance criteria for clear waterproofing sealers (that is, 60 percent water repellency for wood and 1 percent or less water absorption for brick). Thus, product performance does not meet industry standards. In addition, it has been stated that most of the 400-g/L products change the appearance of the surface because they are high-solids products that leave an oily residue or cause darkening of some of the surfaces to which multipurpose products are applied.[32]

4.3.11 Wood Preservatives

Several categories of wood preservatives are subject to Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) requirements, which increases the time between developing and marketing a new coating and may delay the availability of some reformulated coatings. In addition, the reported reformulation problems with wood preservatives are analogous to those associated with stains, particularly in maintaining the translucence of semitransparent wood preservatives.[25,30]

4.4 REFERENCES

1. Katchen, M. A. Solvent Syndrome. In: Maintaining Structures With Coatings, Proceedings of SSPC 91, Long Beach. Pittsburgh, Steel Structures Painting Council. November 10-15, 1991. pp. 63-67.

2. Martens, C. R. Waterborne Coatings: Emulsion and Water-Soluble Paints. New York, Van Nostrand Reinhold Company. 1981. p. 7.

3. Wendoll, R. The Seven Deadly Sins. Dunn-Edwards Corp. Los Angeles, CA. Presented to the AIM Coatings Regulatory Negotiation Committee. Washington, DC. September 17, 1992.

4. HEEU: A Non-VOC Modifier to Improve Gloss Properties of Waterborne Coatings. Modern Paint and Coatings. 81(9): 28-32. September 1991.

5. Kogler, R., and J. Peart. Environmentally Acceptable Materials for Corrosion Protection of Steel Bridges. In: Maintaining Structures With Coatings, Proceedings of SSPC 91, Long Beach. Pittsburgh, Steel Structures Painting Council. November 10-15, 1991. pp. 113-124.

6. Glass, T., and J. Depoy. New Resins and Equipment Make Field-Applied Powder Coatings a Reality. Journal of Protective Coatings and Linings. 8(7):33-36. July 1991.

7. Glass, T., and J. Depoy. Protective Thermoplastic Powder Coatings: Specifically Designed Adhesive Polymers. In: Maintaining Structures With Coatings, Proceedings of SSPC 91, Long Beach. Pittsburgh, Steel Structures Painting Council. November 10-15, 1991. pp. 267-279.

8. Brandau, A. Introduction to Coatings Technology, Federation Series on Coatings Technology. Federation of Societies for Coatings Technology. Blue Bell, PA. October 1990. 46 pp. p. 25.

9. Prane, J. A. Introduction to Polymers and Resins, Federation Series on Coating Technology. Federation of Societies for Coatings Technology. Philadelphia, PA. July 1986. p. 25.

10. Morgans, W. M. Outlines of Paint Technology, Third Edition. New York, Halsted Press. 1990. p. 339.

11. Reference 10, p. 349.

12. Venturini, P. D., R. A. Friesen, D. S. Simeroth, and D. Donohoue. ARB-CAPCOA Suggested Control Measure for Architectural Coatings: Technical Support Document. State of California Air Resources Board Stationary Source Division. Sacramento, CA. July 1989. pp. 34-65.

13. Reference 10, p. 5.

14. U.S. Environmental Protection Agency. Glossary for Air Pollution Control of Industrial Coating Operations, Second Edition. Research Triangle Park, NC. Publication No. EPA-450/3-83-013R. December 1983. p. 9.

15. Kennedy, H. 100% Solids Polyurethanes, The Next Generation of Water Tank Linings. In: Maintaining Structures With Coatings, Proceedings of SSPC 91, Long Beach. Pittsburgh, Steel Structures Painting Council. November 10-15, 1991. pp. 15-21.

16. Johnson, S. D. Spray Applied 100% Solids Epoxy Coatings. In: Maintaining Structures With Coatings, Proceedings of SSPC 91, Long Beach. Pittsburgh, Steel Structures Painting Council. November 10-15, 1991. pp. 107-112.

17. Reference 2, p. 47.

18. Smith, L. M. SSPC Applicator Training Bulletin: Thermal Spraying: An Introduction. Journal of Protective Coatings and Linings. 8(1):58-59. January 1991.

19. News from the Field: Oregon DOT Uses Zinc Metallizing with Cathodic Protection on Concrete Bridges. Journal of Protective Coatings and Linings. 9(8):69-73. August 1992.

20. Waldorf, J. News from the Field: Metallizing Protects Reinforced Concrete Jetty. Journal of Protective Coatings and Linings. 10(1):75-78. January 1993.

21. Gajcak, W. J., J. Buck, and F. Debellis. Problem Solving Forum: Is the use of thermal-sprayed metal (zinc or zinc/aluminum) in water tanks worth the extra cost over traditional epoxy or vinyl linings? Journal of Protective Coatings and Linings. 8(3):13-17. March 1991.

22. Hare, C. H. Anatomy of Paint: Formulating for Low VOC. Journal of Protective Coatings and Linings. 8(9):73-78. September 1991.

23. Minchew, C. Paint Technology and Performance. Benjamin Moore & Co., Newark, NJ. Presented to the AIM Coatings Regulatory Negotiation Committee. Washington, DC. September 17, 1992.

24. Reference 12, pp. 34-65.

25. Memorandum from Buchanan, S. K., and C. Sarsony, Radian Corporation, to Ducey, E., U.S. Environmental Protection Agency/CPB. May 19, 1992. Analysis of the six screening survey responses and select data from the three performance survey responses.

26. Reference 12, pp. 45-46.

27. Reference 12, pp. 40-41.

28. Reference 12, pp. 42-45.

29. Reference 12, p. 52.

30. Reference 12, pp. 50-52.

31. Reference 12, pp. 63-64.

32. Memorandum from Borman, Earle K., Jr. and D. Forestiere, L&F Products, to Ehrmann, J., and Stinson, B., Keystone. July 21, 1994. Re: July 14, 1994 AIM Coatings Rule Framework and Memorandum of Understanding (MOU). Docket No. A-92-18, Docket Item II-D-188.

5.0 VOC AND HAP EMISSION REDUCTIONS

This section discusses volatile organic compound (VOC) emission reductions, and hazardous air pollutant impacts of implementing VOC controls.

5.1 VOC EMISSIONS REDUCTION ESTIMATE

Quantifying the national VOC emission reductions from VOC reduction strategies requires national baseline VOC emissions. As discussed in chapter 2, baseline architectural coating VOC emissions were calculated by extrapolating from a VOC inventory survey conducted by the National Paint and Coatings Association (NPCA) in 1992. The survey data are summarized in a document that was produced for NPCA by Industry Insights and is available in the architectural coatings docket (A-92-18, item II-I-8).[1] In addition to the survey, supplemental sources were used to determine the baseline sales needed to calculate the VOC emissions. These other data sources are discussed in chapter 2 of this document.

As discussed in the chapter 2, 1990 total national sales were estimated to be 655,000,000 gallons. Total national VOC emissions at maximum thinning were estimated to be 530,000 tons.[2] Based on an estimated 20 percent VOC emissions reduction over the 1990 baseline, total national VOC emissions are expected to be reduced by 106,000 tons annually.[3] Section 5.1.1 discusses the survey data. Section 5.1.2 provides a detailed explanation of one of the key assumptions underlying the emission reduction calculation. Section 5.1.3 presents the calculation procedure and the emission reduction for each category. Section 5.1.4 summarizes the emission reduction assumptions.

5.1.1 Base Survey Data

The NPCA survey was sent to a total of 173 coating manufacturers; of these, approximately 116 responded that they manufactured architectural coatings. The survey included approximately 40 small manufacturers (annual net sales of architectural coatings under $10 million) and 76 large manufacturers. The U.S. Environmental Protection Agency (EPA) estimates that there were approximately 350 small manufacturers and 150 large manufacturers of architectural coatings in the United States in 1990. Therefore, the survey under-represents small manufacturers. A comparison of the small manufacturers' sales to the large manufacturers' sales indicated that the small manufacturers tend to produce higher-VOC coatings, and more coatings classified in specialty coating categories. Because these higher-VOC coatings are underestimated, emissions reductions estimates calculated from the survey data may be underestimated.

During regulatory negotiations, the architectural coating industry indicated that the volume of traffic coatings reported in the survey was only about half of what was actually sold in 1990. Therefore, the traffic coating sales reported in the survey were doubled to increase the accuracy of the baseline emission estimate and subsequent emission reduction calculations.

The survey included data on coating VOC content, hazardous air pollutant (HAP) content, sales, and manufacturer profile information (e.g., manufacturer annual net sales in dollars). The following data were collected on a per-coating-product basis:

- Coating category;
- Coating type (i.e., solventborne or waterborne);

- VOC content of the coating in pounds of VOC per gallon of coating, less water;
- VOC content of the coating at maximum thinning in pounds of VOC per gallon of coating, less water;
- Percentage of the coating volume that is solids; and
- Sales of the coating in gallons.

The reported data were summarized by sorting first by coating category, then by solventborne versus waterborne, and finally by VOC content range. In all, coatings were reported in 39 coating categories. In order to make comparisons to existing State rules and to provide a reasonable degree of resolution, the data were summarized in 50 grams per liter (g/L) VOC content ranges. The following 15 VOC content ranges, in grams of VOC per liter of coating, were established:

0 to 50	051 to 100
101 to 150	151 to 200
201 to 250	251 to 300
301 to 350	351 to 400
401 to 450	451 to 500
501 to 550	551 to 600
601 to 650	651 to 700
	701 and above

Since the manufacturers considered much of the sales and VOC data collected by the survey to be confidential, the raw data were maintained in confidence by Industry Insights. The industry agreed that the data could be summarized in the format described above, provided that there were at least three products reported in each VOC content range. To maintain confidentiality of survey responses, if less than three products were reported in a VOC content range, the data for that range were not shown in the survey data summary tables. However, the data for these ranges were included in the totals.

The survey data were then used to calculate the actual VOC emissions in pounds. This was calculated by multiplying the average VOC content (in pounds per gallon) of the coatings in a given VOC range by the sales (in gallons) for the coatings in that range.

5.1.2 Assumptions for the Emission Reduction Calculation

In order to calculate the VOC emissions that would result from any given set of VOC levels, it is necessary to make assumptions concerning the sales volume of coatings after the VOC levels take effect. These assumptions directly affect the amount of emission reduction that is calculated. The two different approaches that were considered for estimating the sales volume of coatings after regulation are discussed below. These approaches were the "constant gallons" approach and the "constant solids" approach.

Using the constant gallons approach, it is assumed that the total volume (gallons) of coatings sold after regulation remains the same as the volume sold before regulation. From a coating coverage standpoint, this approach assumes that coatings sold after the rule takes effect provide the same area of coverage per gallon as those sold before. Alternatively, using the constant solids approach, it is assumed that the total amount of solids (in pounds) after the regulation takes effect remains the same as it was before regulation. In other words, even though the solids content of individual coatings may change, the aggregate amount of solids for all coatings in a particular category remains constant. Since the solids content of individual cans of coatings are expected to change after regulation, the coverage per gallon will change. An increase in solids content generally increases the amount of coverage per can. This causes a decrease in sales (gallons), since less cans are required to cover the same surface area.

For any given set of potential VOC content requirements, the constant solids approach to calculating VOC reductions will yield a greater emission reduction estimate than the constant gallons approach. This is because under the constant solids approach, both the VOC content of the coatings and the volume of sales of the coatings are assumed to decrease. Under the constant gallons approach, the VOC content of the coatings decrease, but the sales volume is assumed to remain at preregulation levels.

After discussions with the industry, the EPA has concluded that the constant solids approach more accurately portrays what is expected to occur as a result of implementing a national architectural coatings VOC rule. However, this approach may tend to overestimate VOC emission reductions since the relationship between coating solids and coverage achieved in the field may not be as direct a relationship as that theoretically assumed in the emission reduction calculation. For most coating categories, the solids content of the coating correlates to coverage (i.e., the more solids in a coating, the greater the coverage). Total solids applied within a category can therefore be expected to remain relatively constant assuming that the total surface area needing coverage remains essentially constant. Since solids per gallon (or ratio of solids to solvent per gallon) would tend to increase after regulation, overall sales would be expected to decrease. However, an exception to this scenario was made for coatings that have a low-solids content and do not form a film on the surface of the substrate, including clear and semitransparent stains, low-solids stains, and clear waterproofing sealers and treatments. Since these coatings penetrate into the surface and are not film building, the solids content is not directly correlated with the coverage of the coating. Therefore, when estimating emission reductions from these particular categories, the constant gallons approach was used.

5.1.3 Procedure to Calculate Emission Reductions

As described in the previous section, the EPA concluded that the best approach for calculating emission reductions was to assume that solids remain constant (with the exception of the low-solids coatings). In addition, it was assumed that sales of coatings above the regulatory VOC content level will be replaced with sales of coatings at or just below the VOC content level. To calculate the emission reductions that would result from the EPA's proposed VOC levels using this constant solids at the regulatory level approach, the following procedure was used:

I. Determination of emission reduction based on survey population.

STEP 1. The total solids content (gallons) in each VOC range was calculated by multiplying the percent volume solids by the volume of sales in gallons.

STEP 2. The total solids in those ranges above the VOC regulatory level were added to determine the total solids above the VOC level.

STEP 3. The average pounds of VOC per gallon of solids was calculated for each VOC range by dividing the total pounds of VOC in a range by the total gallons of solids in that range.

STEP 4. The total solids above the VOC level were added to the solids at the VOC level range to determine the total amount of solids at the VOC level after regulation.

STEP 5. The new total solids at the VOC level (calculated in step 4) were multiplied by the average pounds of VOC per gallon at the VOC level range (calculated in step 3) to yield the new pounds of VOC at the VOC level.

STEP 6. The emissions from the category after regulation were determined by adding the new pounds of VOC at the VOC level (calculated in step 5) to the total amount of VOC at average content in the ranges below the VOC level.

STEP 7. The emission reduction based on average VOC content was calculated by subtracting the new category emissions (calculated in step 6) from the baseline category emissions.

STEP 8. The procedure in steps 1 through 7 was followed for both solventborne and waterborne coatings, which were included in the database separately. The results were totalled to obtain the total emissions, at average VOC content, for each category.

STEP 9. The emissions reduction fraction was calculated for each category by dividing the emission reduction for each category by the total actual survey baseline emissions from all categories at average VOC content (398,285 tons).

STEP 10. The emissions reduction fraction for each category (calculation step 9) is assumed to equal the emissions reduction fraction at maximum VOC content for the national population.

II. Determination of national emission reduction.

The emission reduction fraction for each category was multiplied by the total estimated VOC emissions at maximum thinning from architectural coatings, 530,000 tons, to obtain the national emission reduction at maximum thinning for each category. The emission reductions for all categories were totaled to obtain a national emission reduction estimate of 106,000 tons.

Table 5-1 shows the VOC levels in the proposed rule and the associated emission reduction at maximum thinning in tons per year that is achieved from each category. In 1997, the overall emission reduction estimated from the table of standards in the proposed rule is 106,000 tons. The largest emission reduction comes from traffic markings, which accounts for 25 percent of the overall annual emission reduction.

5.1.4 Summary of VOC Emission Reduction Assumptions

As mentioned in the sections above, several bias factors were identified during the analysis of the survey and the calculation of the emission reductions that had an impact on the calculated emission reduction value. Some of these factors tend to decrease the calculated emission reduction while others tend to increase the calculated emission reduction.

In table 5-2, each bias factor is listed along with a qualitative description of its impact on the overall emission reduction. Based on this analysis, the EPA has concluded that the calculated emission reduction provides a reasonable estimate of the emission reductions that will result from the EPA's proposed Architectural Coatings Rule.

TABLE 5-1. VOLATILE ORGANIC COMPOUND CONTENT LEVELS AND NATIONAL EMISSION REDUCTIONS FOR ARCHITECTURAL COATINGS AT MAXIMUM THINNING

Coating Category	VOC Standard[a]	% Emission Reduction for Category	% of Total Emission Reduction	Emission Reduction (tons/yr)[b]
Antenna Coatings	530	ND	ND	ND
Anti-fouling Coatings	400	ND	ND	ND
Anti-graffiti Coatings	600	0	0	0
Bituminous Coatings and Mastics	500	0	0	0
Bond Breakers	600	0	0	0
Chalkboard Resurfacers	450	ND	ND	ND
Concrete Curing Compounds	350	54	0.60	636
Concrete Protective Coatings	400	ND	ND	ND
Dry Fog Coatings	400	8	0.45	477
Extreme High Durability Coatings	800	ND	0	ND
Fire-retardant/Resistive Coatings				0
Clear	850	ND	ND	ND
Opaque	450	ND	ND	ND
Flat Coatings				
Exterior	250	23	4.88	5,194
Interior	250	5	1.64	1,749
Floor Coatings	400	ND	ND	ND
Flow Coatings	650	ND	ND	ND
Form Release Compounds	450	0	0	0
Graphic Arts Coatings (Sign Paints)	500	0	0	0
Heat Reactive Coatings	420	ND	ND	ND
High Temperature Coatings	650	0	0	0

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TABLE 5-1. VOLATILE ORGANIC COMPOUND CONTENT LEVELS AND NATIONAL EMISSION REDUCTIONS FOR ARCHITECTURAL COATINGS AT MAXIMUM THINNING (CONTINUED)

Coating Category	VOC Standard[a]	% Emission Reduction for Category	% of Total Emission Reduction	Emission Reduction (tons/yr)[b]
Impacted Immersion Coatings	780	ND	ND	ND
Industrial Maintenance Coatings	450	10	5.21	5,552
Lacquers (including Lacquer Sanding Sealers)	680	7	1.19	1,272
Magnesite Cement Coatings	600	0	0	0
Mastic Texture Coatings	300	3	0.05	52
Metallic Pigmented Coatings	500	2	0.25	265
Multi-colored Coatings	580	0	0	0
Nonferrous Ornamental Metal Lacquers and Surface Protectants	870	ND	ND	ND
Nonflat Coatings:				
Exterior	380	16	5.87	6,254
Interior	380	13	7.91	8,427
Nuclear Coatings	420	ND	ND	ND
Pretreatment Wash Primers	780	0	0	0
Primers and Undercoaters	350	20	5.52	5,883
Quick-dry Coatings:				
Enamels	450	11	0.45	477
Primers, Sealers, and Undercoaters	450	9	0.75	795
Repair and Maintenance Thermoplastic Coatings	650	ND	ND	ND
Roof Coatings	250	23	6.57	6,996
Rust Preventative Coatings	400	ND	ND	ND

TABLE 5-1. VOLATILE ORGANIC COMPOUND CONTENT LEVELS AND NATIONAL EMISSION REDUCTIONS FOR ARCHITECTURAL COATINGS AT MAXIMUM THINNING (CONTINUED)

Coating Category	VOC Standard[a]	% Emission Reduction for Category	% of Total Emission Reduction	Emission Reduction (tons/yr)[b]
Sanding Sealers (other than Lacquer Sanding Sealers)	550	2	0.05	52
Sealers (including Interior Clear Wood Sealers)	400	71	4.83	5,141
Shellacs:				
Clear	650	ND	ND	ND
Opaque	550	ND	ND	ND
Stains:				
Opaque	350	37	6.67	7,102
Clear and Semitransparent	550	44	14.78	15,741
Low Solids (Constant gallons)	120	90	0.65	689
Swimming Pool Coatings	600	0	0	0
Thermoplastic Rubber Coatings and Mastics	550	ND	ND	ND
Traffic Marking Paints	150	49	24.83	26,444
Varnishes	450	17	2.89	3,074
Waterproofing Sealers and Treatments:				
Clear	600	12	3.73	3,975
Opaque	400	5	0.15	159
Wood Preservatives:				
Below Ground	550	26	0.10	106
Clear and Semitransparent	550	ND	ND	ND
Opaque	350	ND	ND	ND
Low Solids	120[c]	ND	ND	ND

TABLE 5-1. VOLATILE ORGANIC COMPOUND CONTENT LEVELS AND NATIONAL EMISSION REDUCTIONS FOR ARCHITECTURAL COATINGS AT MAXIMUM THINNING (CONTINUED)

Coating Category	VOC Standard[a]	% Emission Reduction for Category	% of Total Emission Reduction	Emission Reduction (tons/yr)[b]
Total Emissions Reduction (tons/yr)	-		100	106,514
Percent Emission Reduction	-			20%

[a]Unless otherwise specified, units are in grams of VOC per liter of coating, less water, exempt compounds, and colorant added to tint bases, at the maximum thinning recommended by the manufacturer.

[b]Emission reduction prior to adjustments for rule effectiveness. All emission reductions represent reductions over the 1990 baseline.

[c]Units are grams of VOC per liter of coating, including water and exempt compounds, thinned to the maximum thinning recommended by the manufacturer.

TABLE 5-2. MAJOR BIAS FACTORS AND ASSUMPTIONS INFLUENCING THE CALCULATED EMISSION REDUCTION

Bias Factor	Explanation of Bias
The survey sample included only a small sample of small manufacturers.	Downward Bias: Based on the survey, it was determined that coatings produced by small manufacturers tend to have greater VOC contents (more VOC emissions and the potential for more VOC reductions) than coatings produced by large manufacturers.
Reformulated coatings are assumed to be at the VOC content level in the rule.	Downward Bias: It is likely that some coatings that were above the VOC content levels in the rule will be replaced by coatings that are significantly below the VOC content levels in the rule rather than the assumed "at the limit" approach.
The emission reductions were based on VOC content at maximum thinning.	Upward Bias: Estimating the baseline VOC with maximum thinning increases the baseline emissions and total emission reduction estimates by about 3 percent over the baseline without maximum thinning.
The "constant solids" approach was used to estimate the sales volume of coatings after the rule takes effect.	Upward Bias: The "constant solids" approach was used because the EPA concluded that it provided the best representation of how coating sales would be affected by the regulation. The "constant solids" approach yields a higher emission reduction estimate than the constant gallons approach. The emission reduction likely falls between these two estimates.
Extrapolation of survey data to obtain national emissions estimates	Unknown Bias: An across the board extrapolation of survey data assumed the missing data from manufacturers was equally distributed among categories (with the exception of traffic markings which was adjusted prior to the extrapolation to account for a known under representation).

Note that this emissions reduction estimate does not account for emission reductions from reduced usage of cleanup and thinning solvents that would occur from a switch to lower-VOC waterborne coatings. An estimate from The California Air Resources Board (CARB) is that thinning and cleanup for solventborne coatings requires 1 pint of solvent per gallon of coating applied.[4] However, the actual rate of solvent use for cleanup will vary with the size of the job and the type of coating application equipment used, the coating type, and the individual practices of the applicator. A study done by the New York State Department of Environmental Conservation assumes half a pint of cleanup solvent is used for every gallon of solventborne coating. This is based on the CARB estimate of one pint of cleanup and thinning solvent used for every gallon of solventborne coating and responses to New Jersey and New York's paint and coatings industry survey regarding the volume of organic solvent recommended for thinning prior to application.[5]

5.2 HAZARDOUS AIR POLLUTANT EMISSIONS

Manufacturers faced with VOC content limits for architectural coatings could elect to use solvents "exempt" from regulation as a VOC (e.g., acetone), or may shift from the use of aliphatics (alcohols) to aromatic hydrocarbons (e.g., toluene, xylenes) that have a higher solvency power.[6] Both toluene and xylene are HAP's listed under the Act, as amended in 1990. These potential shifts, if indeed they occur, could increase HAP emissions and worker exposure to toxic compounds compared to baseline emissions. However, HAP content versus VOC content data obtained through the NPCA survey does not indicate that lower-VOC coatings contain more HAP's than higher-VOC coatings.[1] Often, the opposite occurs because many HAP constituents in AIM coatings are also VOC. Furthermore, there is no evidence, based on the NPCA survey data, indicating that lower-VOC coatings have increased aromatic hydrocarbons. Because of both worker exposure and HAP emissions considerations, it is unlikely that manufacturers would shift toward the use of more toxic solvents in their effort to reduce the VOC content of their coatings.

5.3 REFERENCES

1. Industry Insights. Architectural and Industrial Maintenance Surface Coatings VOC Emissions Inventory Survey. Prepared for the National Paint and Coatings Association in Cooperation with the AIM Reg-Neg Industry Caucus. February 6, 1995.

2. Memorandum from Harrison, R., Radian Corporation, to Ducey, E., U.S. Environmental Protection Agency/CPB. November 14, 1995. Determination of Architectural and Industrial Maintenance Coatings Baseline Sales and VOC Emissions.

3. Memorandum from Sarsony, C., and Harrison, R., Radian Corporation, to Ducey., E., U.S. Environmental Protection Agency/CPB. February 22, 1996. Emission Reductions Expected to Result from the Proposed Architectural Coatings VOC Rule.

4. California Air Resources Board. Results of the 1988 Architectural Coatings Sales Survey. California Air Resources Board, Stationary Source Division, Sacramento, CA. May 1991. 23 pp. DRAFT.

5. New York State Department of Environmental Conservation. New York and New Jersey Architectural Surface Coating Study -- Phase I Report. Division of Air Resources, Albany, NY. March 1987. p.8.

6. Venturini, P.D., R.A. Friesen, D.S. Simeroth, and D. Donohove. ARB-CAPCOA Suggested Control Measure for Architectural Coatings: Technical Support Document. State of California Air Resources Board Stationary Source Division. Sacramento, CA. July 1989. p.21.