

United States
Environmental Protection
Agency

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

EPA-453/R-94-066-B

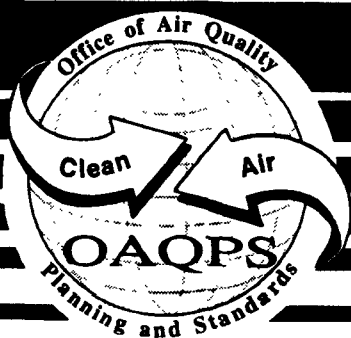
March 1995

Air



STUDY OF
VOLATILE ORGANIC COMPOUND EMISSIONS
FROM
CONSUMER AND COMMERCIAL PRODUCTS

Comprehensive Emissions Inventory



REPORT TO CONGRESS

***VOLATILE ORGANIC COMPOUND EMISSIONS
FROM
CONSUMER AND COMMERCIAL PRODUCTS***

VOLUME 2

COMPREHENSIVE EMISSIONS INVENTORY

**Emission Standards Division
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711**

December 1994

ACKNOWLEDGEMENT

This study was completed with a great degree of cooperation and assistance from the Chemical Specialties Manufacturers Association, the Cosmetic, Toiletry, and Fragrance Association, the Soap and Detergent Association, the National Aerosol Association, the Automotive Chemical Manufacturers Council, and the Adhesive and Sealant Council.

Most of the studies in Section 4 were conducted under the auspices of the EPA's Air and Energy Environmental Research Laboratory.

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1.0 INTRODUCTION	1-1
1.1 The Problem	1-1
1.1.1 Ozone Nonattainment and Small Sources of VOC Emissions	1-1
1.1.2 VOC's or NO _x -- Which Should We Control?	1-1
1.1.3 Relative Photochemical Reactivity	1-2
1.2 Congressional Response: The Clean Air Act of 1990	1-3
1.2.1 Requirements Under §183(e) - Consumer/Commercial Products	1-3
1.2.2 Scope of Consumer/Commercial Products Under §183(e)	1-4
1.2.3 EPA's Study and Report to Congress - Purpose and Structure	1-4
1.3 Inventory of VOC's in Consumer and Commercial Products	1-5
1.3.1 Role of the Consumer and Commercial Products Inventory	1-5
1.3.2 Elements of the Inventory	1-6
1.4 Adjustments to Inventory Data	1-7
1.4.1 Fate of Consumer Product VOC's in Wastewater and Landfills	1-8
1.4.2 Emissions in Nonattainment Areas	1-8
1.5 Summary of Findings	1-9
1.6 References	1-13
2.0 CONSUMER PRODUCTS SURVEY	2-1
2.1 Background	2-1
2.1.1 Previous Efforts and the Need for the Survey	2-1
2.1.2 Development of the Survey Approach and Format	2-3
2.1.3 Features of the Survey	2-5
2.1.4 Other Uses of the Information	2-6

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Page</u>
2.2 Survey Questionnaire and Mailing List	2-6
2.2.1 The Survey Questionnaire	2-7
2.2.2 Electronic Reporting Option	2-8
2.2.3 Development of the Mailing List	2-12
2.3 Handling of Survey Responses	2-13
2.3.1 Response Handling and Safeguarding of Confidential Information	2-14
2.3.2 Data Entry	2-17
2.3.3 Batch Files	2-24
2.3.4 SAS Data Sets	2-27
2.4 Results of the Survey	2-29
2.4.1 Response Rate	2-30
2.4.2 Information Obtained from the Survey	2-31
2.5 References	2-54
3.0 PRODUCTS AFFECTED BY EXISTING OR ONGOING FEDERAL REGULATORY PROGRAMS	3-1
3.1 Introduction	3-1
3.2 Category Descriptions and Sources of VOC Emissions	3-4
3.2.1 Architectural and Industrial Maintenance Coatings	3-4
3.2.2 Automobile Refinishing Products	3-5
3.2.3 Aerospace Coatings	3-6
3.2.4 Wood Furniture Coatings	3-6
3.2.5 Ship and Boat Coatings	3-7
3.2.6 Metal Furniture Coatings	3-7
3.2.7 Flat Wood Paneling Coatings	3-8
3.2.8 Large Appliance Coatings	3-9
3.2.9 Magnet Wire Coatings	3-10
3.2.10 Metal Can Coatings	3-11
3.2.11 Metal Coil Coatings	3-12
3.2.12 Other Metal Product Coatings	3-13
3.2.13 Auto and Light Truck Assembly Coatings	3-14

TABLE OF CONTENTS (Continued)

<u>Section</u>		<u>Page</u>
3.2.14	Paper, Film, and Foil Coatings	3-16
3.2.15	Magnetic Tape Coatings	3-19
3.2.16	Business Machine Plastic Parts Coatings	3-19
3.2.17	Automotive Plastic Parts Coatings	3-20
3.2.18	Flexible Packaging Printing	3-20
3.2.19	Rotogravure Publication Printing	3-21
3.2.20	Lithographic Printing	3-22
3.2.21	Letterpress Printing	3-23
3.2.22	Tire Manufacturing Cements	3-24
3.2.23	Miscellaneous Industrial Adhesives	3-25
3.2.24	Metal Cleaning Solvents	3-26
3.2.25	Industrial Cleanup Solvents	3-27
3.2.26	Petroleum Drycleaning Solvents	3-29
3.2.27	Agricultural Pesticides	3-30
3.2.28	Cutback Asphalt Paving Materials	3-31
3.2.29	Synthetic Fiber Spinning Solvents	3-32
3.2.30	Fabric Coatings	3-34
3.2.30	Fabric Printing	3-35
3.5	References	3-35
4.0	PRODUCTS ADDRESSED BY SPECIAL STUDIES	4-1
4.1	Introduction	4-1
4.2	Construction Materials	4-1
4.2.1	Building Materials and Indoor Air Sources	4-1
4.2.2	Roofing Materials	4-8
4.2.3	Asphalt Concrete Paving Materials	4-14
4.2.4	References	4-15
4.3	Foods, Beverages, and Tobacco	4-17
4.3.1	Alcoholic Beverages	4-17
4.3.2	Deep Fat Frying	4-19
4.3.3	Cigarette, Cigar, and Pipe Tobacco	4-24
4.3.4	References	4-32

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Page</u>
4.4 Small Combustion Sources	4-34
4.4.1 Kerosene Space Heaters	4-34
4.4.2 Camp Stoves and Lanterns	4-39
4.4.3 Fire Starting Materials	4-41
4.4.4 References	4-44
4.5 Miscellaneous Products	4-48
4.5.1 Mold Release Agents	4-48
4.5.2 Products Used in the Manufacture of Fiberglass Boats	4-51
4.5.3 Automotive Repair Parts Washers	4-54
4.5.4 Products Used in the Textile Industry	4-56
4.5.5 References	4-70

LIST OF FIGURES

Figure 2-1	Company Sheet	2-9
Figure 2-2	Page One of the Product Sheet	2-10
Figure 2-3	Page Two of the Product Sheet	2-11
Figure 2-4	Consumer Product Survey Response Handling System	2-15
Figure 2-5	Distribution of Survey Questionnaires	2-30

LIST OF TABLES

Table 1-1	VOC Emissions from Consumer/Commercial Products	1-10
Table 1-2	Sources of VOC Emissions in 1990 (Nationwide)	1-13
Table 2-1	Results of the Consumer Products Survey	2-33
Table 3-1	Emissions from Products Affected by Existing/Ongoing Programs	3-2
Table 4.1-1	Emissions from Products Addressed by Special Studies	4-2
Table 4.2-1	Substantiated Building Material Sources of VOC Emissions	4-5
Table 4.2-2	Emission Factors for Various Building Materials	4-7
Table 4.2-3	Summary of Roofing Area Worked by Roof Type (1989)	4-12
Table 4.2-4	VOC Emissions from Roofing Application	4-14
Table 4.3-1	Volatile Compounds Identified in Alcoholic Beverages	4-19
Table 4.3-2	Major Constituents of Mainstream Smoke	4-28
Table 4.3-3	Estimated Emissions of VOC Constituents of Mainstream Smoke	4-30
Table 4.4-1	Kerosene Heater Characteristics	4-34
Table 4.4-2	Average Kerosene Heater Emission Factors	4-36
Table 4.4-3	Estimated 1990 Emissions from Kerosene Heaters	4-38
Table 4.5-1	Emissions from Mold Release Agents by Industry	4-51
Table 4.5-2	Emissions from Parts Washer Solvents (Garment Screen Printing)	4-66
Table 4.5-3	Platen Adhesive Emissions	4-67
Table 4.5-4	Spot Cleaner Emissions (Garment Screen Printing)	4-69

1.0 INTRODUCTION

1.1 THE PROBLEM

1.1.1 Ozone Nonattainment and Small Sources of VOC Emissions

National air quality monitoring data from 1986 through 1988 indicate that there are approximately 100 geographic areas which failed to attain the national ambient air quality standards (NAAQS) for ozone. Ozone is a major component of smog which poses major health and environmental concerns when present in high concentrations at ground level. It is a photochemical oxidant which is formed in the atmosphere through a series of complex chemical reactions between precursor emissions of volatile organic compounds (VOC's) and oxides of nitrogen (NO_x) in the presence of sunlight.

While most of the large, stationary sources of VOC emissions are covered by existing regulations, an examination of emissions data completed in 1989 by the Office of Technology Assessment (OTA) indicates that individually small, dispersed sources of VOC's (area sources) contribute significantly to the continuing ozone nonattainment problem. According to the OTA report, *Catching Our Breath - Next Steps for Reducing Urban Ozone*¹, one area source of VOC emissions is the use of a wide range of consumer and commercial products.

1.1.2 VOC's or NO_x -- Which Should We Control?

Ground-level (tropospheric) ozone is formed through a series of complex chemical reactions involving VOC's and NO_x in the presence of sunlight. Reductions in the amount of ozone formed can be obtained through reducing the concentrations of VOC and/or NO_x available for reaction. A recent report, *Rethinking the Ozone Problem in Urban and Regional Air Pollution*², published by the National Research Council explains that a key factor in reducing ozone formation is the ratio of VOC to NO_x in the ambient air. When the VOC-to- NO_x ratio is greater than 10:1, VOC reductions have little effect because of the excess concentration of VOC's available for reaction. In such " NO_x -limited" scenarios,

NO_x controls may be much more effective than VOC controls alone in reducing ozone formation. Conversely, in airsheds which are not NO_x-limited, VOC controls can be effective in reducing ozone formation.

Although VOC controls alone may offer little reduction in ozone formation under some conditions, there are many instances in which the VOC-to-NO_x ratio favors VOC controls. The U.S. Environmental Protection Agency (EPA) does not anticipate abandonment of efforts to reduce ozone formation through reduction in VOC emissions, especially in the case of area sources such as consumer and commercial products. However, this new way of thinking could affect future strategies for stationary and mobile sources for which NO_x and VOC controls could be tailored to specific conditions.

1.1.3 Relative Photochemical Reactivity

Relative reactivity can be described as the propensity of a VOC species to react in the presence of NO_x and sunlight to form ozone. This phenomenon has been subject to continuing scientific investigation since well before the mid-1970's when the EPA adopted its present scheme of classifying compounds as reactive or negligibly reactive. Although there has been much discussion over the years among atmospheric scientists, there has been no broad acceptance, within either the scientific or regulatory communities, of any single reactivity scale which could be used to make reliable predictions of the ozone formation potential of specific VOC's. This difficulty arises from the fact that the relative reactivity of a species is affected by VOC-to-NO_x ratios, the presence of other VOC's, and radiation conditions. Each of these factors can vary widely according to the meteorologic and geographic conditions not only in the immediate airshed but several days downwind as well.

1.2 CONGRESSIONAL RESPONSE: THE CLEAN AIR ACT OF 1990

1.2.1 Requirements Under §183(e) -- Consumer and Commercial Products

Although control of one small source of VOC emissions may contribute little to overall ambient air quality, VOC reductions obtained through regulation of multiple small sources could have a beneficial additive effect. Section 183(e) of the Clean Air Act (CAA) as amended in 1990 requires the EPA to conduct a study of emissions of VOC's into the ambient air from consumer and commercial products. The objectives of the study are (1) to determine the potential of consumer and commercial product VOC emissions to contribute to ozone levels which violate the NAAQS for ozone; and (2) to establish criteria for regulating consumer and commercial products or classes or categories of products under the authority of §183(e) of the CAA. In establishing criteria for regulating consumer and commercial products, the EPA must take into consideration (1) the uses, benefits, and commercial demand of consumer and commercial products; (2) any health or safety functions served by the products; (3) those consumer and commercial products that emit highly reactive VOC's into the ambient air; (4) those products that are subject to the most cost-effective controls; and (5) the availability of any alternatives to such consumer and commercial products that are of comparable costs, considering health, safety, and environmental impacts. On completion of the study, the EPA must submit a report to Congress that documents the results of the study.

Upon completion of the report, the EPA must list those categories of products which are determined, based on the study, to account for at least 80 percent of the total VOC emissions, on a reactivity-adjusted basis, from consumer and commercial products in areas which violate the NAAQS for ozone. The EPA must divide the list into 4 groups by priority. Pursuant to this requirement, the EPA will publish the prioritized category list in the *Federal Register* following submittal of the report to Congress. Beginning no later than 2 years following publication of the list, the EPA must regulate one group every two years until all 4 groups are regulated.

1.2.2 Scope of Consumer and Commercial Products under §183(e)

According to the definition in §183(e), "the term 'consumer or commercial product' means any substance, product (including paints, coatings, and solvents), or article (including any container or packaging) held by any person, the use, consumption, storage, disposal, destruction, or decomposition of which may result in the release of volatile organic compounds. The term does not include fuels or fuel additives regulated under section 211, or motor vehicles, non-road vehicles, and non-road engines as defined under section 216."

The EPA has determined that the statutory definition of consumer or commercial product is much broader than just the "traditional" consumer products (e.g., personal care products, household cleaning products, household pesticides, etc.). Instead, consumer and commercial products include virtually all VOC-emitting products used in the home, by businesses, by institutions, and in industrial manufacturing operations. Among these products are a wide range of surface coatings, metal cleaning solvents, graphic arts inks, industrial adhesives, agricultural pesticides, asphalt paving materials, and many other products used in industrial manufacturing processes, many of which have been previously regulated by the EPA and/or by the States.

1.2.3 EPA's Study and Report to Congress -- Purpose and Structure

The primary purpose of the study and report to Congress is to educate the EPA and Congress on consumer and commercial products as contributors to ozone nonattainment and to identify opportunities for reduction of VOC emissions from the use of these products. In addition, some information obtained from the EPA studies was used to establish criteria for regulation of consumer and commercial products and utilized during the process of exercising the criteria to develop the regulatory agenda.

In order to prepare the report, the EPA conducted several individual studies. Some of these studies pertain to specific categories of products for which the EPA has little or no existing information; five "generic" studies focus on topics which do not relate to any particular category of products. The 14 individual studies address the following topics:

(1) inventory of VOC emissions from consumer and commercial products; (2) fate of consumer and commercial product VOC's in landfills; (3) fate of consumer and commercial product VOC's in wastewater; (4) aerosol products and packaging systems; (5) economic incentives to reduce VOC emissions from consumer and commercial products; (6) underarm antiperspirants and deodorants; (7) hair care products; (8) aerosol spray paints; (9) adhesives and sealants; (10) household cleaning products; (11) nonagricultural pesticides (including antimicrobials); (12) automotive aftermarket products; (13) air fresheners; and (14) architectural and industrial maintenance coatings.

The report to Congress is comprised of five volumes which document the results of the generic studies, plus one volume (the executive summary) which contains (1) a summary of findings of the EPA's study of consumer and commercial products; (2) a discussion of relative photochemical reactivity as it applies to §183(e); (3) criteria developed by the EPA for regulating products under §183(e); and (4) summaries of each of the 14 individual studies. The six volumes of the report are:

Volume 1: Executive Summary

Volume 2: Comprehensive Emissions Inventory

Volume 3: Fate of Consumer and Commercial Products in Landfills

Volume 4: Fate of Consumer and Commercial Products in Wastewater

Volume 5: Economic Incentives to Reduce VOC Emissions from Consumer Products

Volume 6: Aerosol Products and Packaging Systems

1.3 INVENTORY OF VOC's IN CONSUMER AND COMMERCIAL PRODUCTS

1.3.1 Role of the Consumer and Commercial Products Inventory

The purpose of the inventory effort was to develop estimates of annual VOC emissions in ozone nonattainment areas for every consumer and commercial product category subject to §183(e). These estimates, along with other information, were used to develop a prioritized list of categories to be regulated as required by §183(e). Seven criteria for

regulating consumer and commercial products have been developed based on the factors listed in §183(e). Three of these criteria (emissions of highly reactive compounds, availability of lower-VOC alternatives, and annual VOC emissions) will be evaluated based on the inventory data. These criteria are presented in Volume 1 of the Report to Congress.

The emission estimates and *per capita* emission factors presented in this report can also be used by State and local agencies in developing emission inventories for specific mixes of products and categories within their jurisdiction.

1.3.2 Elements of the Inventory

Because of the wide variety of products subject to §183(e), emission estimates were developed independently for three major subdivisions of the universe of consumer and commercial products.

1.3.2.1 *Traditional Consumer Products (including institutional uses)*

These are products which most people associate with the term "consumer products." This group includes such products as personal care products, household cleaning products, household pesticides, automotive maintenance and detailing products, and many others. Institutional and commercial uses of these or similar products are also considered within the scope of traditional consumer products. Emission estimates for these categories were obtained through a 1993 census survey of consumer product manufacturers. This segment of the inventory is discussed in detail in Section 2.

1.3.2.2 *Industrial Products Affected by Existing or Ongoing Regulatory Programs*

The statutory definition of "consumer or commercial product" is much broader than just the traditional consumer products and includes virtually all VOC-emitting products used in the home, by businesses, by institutions, and in industrial manufacturing operations. This segment of the consumer and commercial products inventory includes those products which are used industrially and are affected by existing or ongoing regulations developed by the

EPA and/or by the States. These products include a wide range of surface coatings, metal cleaning solvents, adhesives, inks, agricultural pesticides, asphalt paving materials, and a host of others. Estimates of VOC emissions from these products were obtained from background documentation developed for the respective regulations or guidance documents. Emission estimates for previously regulated categories are based on "residual" emissions (i.e., emissions which continue after controls have been applied). Estimates for categories associated with ongoing standards development are 1990 "baseline" emission estimates from those categories (i.e., emissions before any controls have been applied). This segment of the inventory is discussed in detail in Section 3.

1.3.2.3 *Products Addressed by Special Studies*

Many consumer and commercial products fall outside the scope of the consumer products survey and the categories affected by existing or ongoing regulatory programs. This third segment of the inventory is comprised of products which do not fall within the first two segments. It includes such products as foods, beverages, and tobacco; small combustion sources such as kerosene heaters, camp stoves, artificial fireplace logs, and commercial explosives; products used in the roofing and textile industries; and a wide range of miscellaneous products including but not limited to, mold release agents, automotive parts washers, and fiberglass boat manufacturing products. Emission estimates for these products were obtained through special studies conducted by the EPA. These studies were limited to searches of the literature for relevant scientific investigations in which VOC emissions from these products were characterized and quantified. This segment of the inventory is discussed in detail in Section 4.

1.4 ADJUSTMENTS TO INVENTORY DATA

In accordance with §183(e), an effort was undertaken to develop estimates of VOC emissions from consumer and commercial products in ozone nonattainment areas. Because the "raw" data from the consumer products survey and the other sources were primarily for nationwide mass emissions based on the VOC content of the products, the following factors

were considered in an effort to develop realistic estimates which could be used to satisfy the requirements of §183(e).

1.4.1 Fate of Consumer Product VOC's in Wastewater and in Landfills

Historically, inventories of VOC emissions from consumer and commercial products have been based on the assumption that all VOC's contained in these products eventually volatilize, enter the ambient air, and are thus available to react to form ozone. However, the VOC's in some products such as soaps, laundry detergents, household cleaners, mouthwashes, disinfectants, etc. may be combined with water during and/or following use and enter the wastewater stream. In order to ensure that the inventory results reflected actual VOC emissions rather than VOC content, the EPA initiated an investigation to identify information on the fate of consumer product VOC's that enter the wastewater stream. This topic is discussed in detail in Volume 4 of the Report to Congress. Based on this information, and information provided by the major consumer product industry trade associations ^{3,4,5,6}, final emission estimates for several product categories reported in this inventory reflect a "percent VOC content emitted" of somewhat less than 100 percent.

Another area of concern was that it may be possible for a portion of the unused product (and VOC content) to remain in the container packaging following disposal in landfills. A study was undertaken by EPA to determine whether some adjustment of the emission estimates should be made to account for this phenomenon. Based on the study, presented in Volume 3 of the Report to Congress, the EPA determined that, because of the scarcity of information and the variability of landfill operating procedures, it was not possible to adjust the emission estimates to account for fate of the VOC's in landfills. Consequently, for the purpose of this inventory study, the assumption was made that any remaining VOC content in the disposed products is eventually emitted to the air.

1.4.2 Emissions in Nonattainment Areas

Section 183(e) primarily focuses on VOC emissions in ozone nonattainment areas. Because much of the emissions data collected reflects nationwide emissions, some adjustment

was necessary to obtain estimates for nonattainment areas. Since emissions from traditional consumer products are roughly proportional to population, the nationwide estimates from the consumer products survey were scaled down based on the distribution of population in ozone nonattainment areas. In 1990, approximately 148 million of the 248 million persons in the U.S. resided in ozone nonattainment areas (59.7 percent). Based on this distribution, the nationwide emission estimates for traditional consumer products were multiplied by a factor of 0.6 to reflect emissions in nonattainment areas.

For many categories of industrial products, estimates were developed based on actual locations of emission sources. Consequently, nonattainment area emission estimates were developed for those products directly. For any categories for which specific locations of emission sources were unknown, the population scaling method discussed above was employed.

1.5 SUMMARY OF FINDINGS OF THE INVENTORY STUDY

Based on estimates developed for the many categories of products investigated in this study, VOC emissions from the use of consumer and commercial products in ozone nonattainment areas totalled 3,332,145 tons in 1990. Table 1-1 presents a summary of the estimates which were developed during this study. More detail is provided in Sections 2, 3, and 4.

Following Table 1-1 is a discussion of the relative contribution of consumer and commercial products among all sources of man-made VOC emissions nationwide.

TABLE 1-1

**VOC EMISSIONS FROM CONSUMER/COMMERCIAL PRODUCTS
IN OZONE NONATTAINMENT AREAS (1990)**

Product Category		Emissions in Nonattainment Areas (tons/yr)
Traditional Consumer Products		597,209
Personal care products	174,115	
Household products	55,095	
Automotive aftermarket products	106,469	
Adhesives and sealants	45,467	
FIFRA-regulated products	121,464	
Coatings & related (except AIM)	89,405	
Other traditional consumer products	5,194	
Architect & Indust Maint (AIM) Coatings		315,000
Industrial Adhesives		230,092
Tire manufacturing cements	26,400	
Platen adhesives (textile industry)	2,092	
Miscellaneous industrial adhesives	201,600	
Industrial Solvents		290,323
Metal cleaning solvents	36,000	
Industrial cleanup solvents	150,000	
Petroleum drycleaning solvents	54,600	
Synthetic fiber spinning solvents	46,200	
Textile industry equipment cleaning	68	
Textile industry spot cleaners	848	
Automotive repair - parts washers	2,607	

TABLE 1-1 (Continued)**VOC EMISSIONS FROM CONSUMER/COMMERCIAL PRODUCTS
IN OZONE NONATTAINMENT AREAS (1990)**

Product Category		Emissions in Nonattainment Areas (tons/yr)
Industrial Coating Operations		1,713,300
Automobile refinishing products	55,000	
Aerospace paints and coatings	107,500	
Wood furniture coatings	60,000	
Ship and boat coatings	15,100	
Metal furniture coatings	63,000	
Flat wood paneling coatings	20,000	
Large appliance coatings	15,600	
Magnet wire coatings	4,800	
Metal can coatings	45,000	
Metal coil coatings	21,600	
Other metal product coatings	218,400	
Auto and light truck assy coatings	75,000	
Paper, film, and foil coatings	65,000	
Magnetic tape coatings	5,500	
Business machine plastic part coatings	5,500	
Automotive plastic part coatings	16,500	
Flexible packaging printing	150,000	
Rotogravure publication printing	20,000	
Lithographic printing	600,000	
Letterpress printing	28,200	
Fabric coating	21,000	
Fabric printing	25,200	
Mold release agents	75,400	

TABLE 1-1 (Continued)

**VOC EMISSIONS FROM CONSUMER/COMMERCIAL PRODUCTS
IN OZONE NONATTAINMENT AREAS (1990)**

Product Category		Emissions in Nonattainment Areas (tons/yr)
Asphalt Paving and Roofing Materials		147,285
Cutback asphalt paving materials	128,400	
Asphalt concrete paving materials	360	
Roofing - built-up	7,126	
Roofing - elastomeric	9,123	
Roofing - modified bitumen	2,276	
Other Consumer/Commercial Products		38,936
Fiberglass boat manufacturing	12,100	
Alcoholic beverage use	11,600	
Smoking tobacco	37	
Kerosene space heaters	39	
Camp stoves and lanterns	6	
Artificial fireplace logs	154	
Agricultural pesticides	15,000	
ALL §183(e) CATEGORIES		3,332,145

To put the VOC contribution from consumer and commercial products into perspective, a 1990 estimate of all man-made VOC emissions was derived by modifying an existing 1985 estimate.⁷ The old estimate was modified by grouping all of the emission sources which fall within the scope of §183(e) and replacing the sum of their individual 1985 estimates with the new estimate developed in this study. To compare consumer and commercial products with other large sources of man-made VOC emissions, it was necessary

to modify the estimate developed for nonattainment areas to reflect nationwide emissions from consumer and commercial products. Employing the population distribution factor (0.6) discussed in Section 1.4.2, the nonattainment area estimate (3,332,145 tons/yr) for all categories under §183(e) was scaled up to a nationwide estimate of about 5,500,000 tons/yr, or about 26 percent of all man-made VOC emissions. This scaled-up estimate is rough and should be used only for this comparison exercise. The principal source categories and their respective VOC emission estimates are presented in Table 1-2.

TABLE 1-2 SOURCES OF VOC EMISSIONS IN 1990 (NATIONWIDE)

Emission Source Category	Nationwide Emissions (tons/yr)	Share of Total (percent)
Mobile Sources	7,920,000	37.8
Consumer/Commercial Products	5,500,000	26.3
Petroleum Marketing	2,460,000	11.8
Fuel Combustion (Stationary Sources)	2,300,000	11.0
Forest, Agricultural, and Other Burning	990,000	4.7
Petroleum Refineries	820,000	3.9
Organic Chemicals Manufacturing	550,000	2.6
Industrial Manufacturing	400,000	1.9
TOTAL FOR ALL SOURCES	20,940,000	100.0

1.6 REFERENCES

1. U.S. Congress, Office of Technology Assessment, *Catching our Breath: Next Steps for Reducing Urban Ozone*, OTA-O-412, Government Printing Office, Washington, D.C., July 1989.
2. National Research Council, Committee on Tropospheric Ozone Formation and Measurement, *Rethinking the Ozone Problem in Urban and Regional Air Pollution*, Washington, D.C., 1991
3. Letter from D. Fratz, Chemical Specialties Manufacturers Association, to B. Moore, U.S. EPA, Office of Air Quality Planning and Standards, Comments on raw survey data concerning compounds reported, percent VOC emitted, and market share reporting, March 25, 1994.

4. Letter from J. Graf, Cosmetic, Toiletry, and Fragrance Association, to B. Moore, U.S. EPA, Office of Air Quality Planning and Standards, Comments concerning survey - percent VOC emitted and market share reporting, May 6, 1994.
5. Letter from R. Sedlak, Soap and Detergent Association, to B. Moore, U.S. EPA, Office of Air Quality Planning and Standards, Comments on percent VOC emitted and market share reporting, May 16, 1994.
6. Letter from R. Sedlak, Soap and Detergent Association, to B. Moore, U.S. EPA, Office of Air Quality Planning and Standards, Further comments on percent VOC emitted from laundry and dishwashing products, August 8, 1994.
7. U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, *Alternative Control Techniques - Control Techniques for Volatile Organic Compound Emissions from Stationary Sources* (EPA-453/R-92-018), December 1992.

2.0 CONSUMER PRODUCTS SURVEY

2.1 BACKGROUND

One important segment of the inventory of VOC's from consumer and commercial products are the "traditional consumer products" described in Section 1.3.2.1. In order to develop an accurate, reliable emission estimate for this segment, the EPA and the consumer products industry undertook a massive effort to assemble accurate formulation and sales information for over 24,000 individual consumer products. The following sections describe the survey process and the results obtained from that effort.

2.1.1 Previous Efforts and the Need for the Survey

There are four major studies that were previously conducted and are believed to be the best, publicly available, comprehensive inventories of VOC content in consumer and commercial products prior to the current effort. The four studies are listed below:

1. *Photochemically Reactive Organic Compound Emissions from Consumer and Commercial Products*, performed by Science Applications International Corporation (SAIC) for EPA Region II (EPA-902/4-86-001, November 1986)
2. *Compilation and Speciation of National Emissions Factors for Consumer/Commercial Solvent Use*, performed by SAIC for EPA's Office of Air Quality Planning and Standards (EPA-450/2-89-008, April 1989)
3. *Analysis of Regulatory Alternatives for Controlling Volatile Organic Compound (VOC) Emissions from Consumer and Commercial Products in the New York City Metropolitan Area (NYCMA)*, performed by Pacific Environmental Services, Inc. (PES) for the New York State Department of Environmental Control (NYDEC) (January 1990)
4. *Expansion of the New York Study: Evaluation of VOC Emission Reduction Alternatives from Selected Consumer and Commercial Products*, performed by PES for EPA's Air and Energy Engineering Research Laboratory (February 1990)

The first three studies are represented as being VOC emissions inventories, although they are actually inventories of the VOC content of the consumer and

commercial products. The third study identified brands of products sold in the New York City area. The fourth study compared brands sold in four other cities to those reported in the third study. The number of product categories, the geographic coverage, and the species of interest vary from study to study, due to the different objectives for each study.

The formulation data used in the first two studies are dated. Many of the formulations date back to the chlorofluorocarbon (CFC) propellant era or shortly after the CFC propellant ban in 1978. The formulations used in these two studies were also primarily generic formulas. The sales data for these two studies are also somewhat old, dating generally from 1981 to 1985. The PES study uses formulation data gathered directly from manufacturers and distributors and includes individual species. Both the formulation and usage data for the PES study are from 1988. None of the listed studies was able to match brand-specific sales data with specific product formulations. Both the second SAIC and the two PES studies indicate that some data are available, but that such data are inadequate to develop the comprehensive emissions inventory required under §183(e).

Market share data were not used in developing the typical formulations nor in apportioning total sales volume to specific brands in any of the existing inventories. The NYDEC study performed by PES contains a great deal of brand-specific formulation data; however, these data were obtained by a voluntary letter survey of suppliers and distributors of commercial and institutional product brands in the New York area. These brands were rarely the same as the nationally marketed retail consumer brands for which market share information is available. Formulation information for nationally marketed retail consumer products is, therefore, one of the main items missing from previous inventories. Market share and total sales volume data for these products are available from a variety of market research organizations.

A second area of concern is the total sales volume and market share data for products marketed for commercial and institutional use. The NYDEC study's letter survey obtained many formulation and sales data for individual products in this category.

These data were extrapolated through the assumption that the total market volume was five times the volume represented in the survey responses because only a 20 percent response was obtained from the survey. A more defensible extrapolation method must be implemented to represent the total market volume for commercial and institutional use. Available market research data appear to address only the retail consumer market.

Many sources of market share data and sales volume data are available, but the boundaries of the market represented by the data are not always clear. It is also very possible that widely different sales volumes will be reported by different market research firms. This is the third major consideration for assessing the accuracy of inventories of the consumer/commercial products categories.

None of these existing inventories are adequate for regulatory assessment and development purposes. In addition, no adequate speciated inventories exist for any significant consumer product category.

2.1.2 Development of the Survey Approach and Format -- A Cooperative Effort

The following discussion summarizes the events that led to the development of the Consumer and Commercial Products Survey.

2.1.2.1 *Events Prior to the Clean Air Act Amendments of 1990*

In anticipation of the Clean Air Act Amendments, the EPA conducted a symposium in November 1989 on regulatory approaches for reducing VOC emissions from the use of consumer products. The purpose of the symposium was to initiate a dialogue among the EPA, the States, and industry toward working cooperatively in addressing this source of emissions. Approximately 100 companies and trade associations participated in the symposium. State environmental agencies from California, Michigan, New Jersey, New York, North Carolina, Texas, and Virginia were represented as well. The proceedings of that symposium were documented in an EPA report (EPA-450/3-90-008, January 1990).

One of the key issues raised by industry representatives at the symposium was the lack of a reliable, speciated inventory of VOC emissions from traditional consumer products. The industry demanded that the EPA employ a census survey of consumer product manufacturers and distributors to develop such an inventory.

2.1.2.2 *Development of the Survey Questionnaire and Approach*

In November of 1990 the EPA and the Cosmetics, Toiletries, and Fragrances Association (CTFA) met twice with the Chemical Specialties Manufacturers Association (CSMA) at CSMA's headquarters in Washington, D.C. to discuss the plan for developing the inventory. It was suggested that the best approach for a number of consumer product categories would be through a survey of the manufacturers of those products. Information for this consumer products survey would be collected by the EPA via questionnaires distributed under the authority of Section 114 of the CAA. This approach was suggested by the consumer products industry, specifically the CSMA.

Refinements to the survey approach were made over the next two years by the work group consisting of EPA, CSMA, CTFA, the Soap and Detergent Association (SDA), several other associations, and representatives of several companies (L&F Products, Sherwin-Williams, Procter & Gamble, Drackett, Gillette, S.C. Johnson Wax, United Industries, Aeropres Corporation, CCL Custom Manufacturing, Helene Curtis, Inc., and Carter-Wallace, Inc.). This work group met on several occasions to develop a joint protocol for the consumer products inventory effort.

In December 1991, the survey questionnaire developed by the work group was sent to nine test respondents. The responses from this test were analyzed and the results presented at the March 1992 meeting of the work group. Revisions to the questionnaire were made and sent to the work group members for final endorsement.

2.1.2.3 *Approval to Conduct the Survey*

It was recognized early in the planning of the survey that, due to the large number of survey questionnaires necessary, Office of Management and Budget (OMB) approval would be required through the submission of an information collection request (ICR). The CSMA offered to endorse the ICR and state that the industry and EPA reached a consensus that the Section 114 approach is the most suitable vehicle for gathering the required information. The ICR was submitted to OMB in July 1992, and approval was granted by OMB in December 1992.

2.1.3 Features of the Survey

The survey focus was to establish a reasonably accurate inventory of the VOC *content* of consumer and commercial products. This is the first step necessary to determine the VOC *emissions* from these products. Separate studies have been conducted to estimate the fraction of VOC content emitted to the atmosphere for various products.

The product categories included in the survey were selected to ensure the most comprehensive database possible without causing an unreasonable economic burden. The list of product categories (along with the category codes used with each) are given in Appendix A, under Attachment A to the survey form (Enclosure 1).

Listing of individual VOC ingredients (speciation) was necessary to develop the most useful, accurate, and reliable data base of VOC *content* in consumer and commercial products. If speciation were not provided by the manufacturers in the course of the inventory, it would have to be developed or assumed by EPA, and would be challenged as inaccurate. Therefore, the goal of the survey was to create an accurate estimate of total VOC for each product category with small ranges of uncertainty for each species in each category. Speciation data for each category creates greater flexibility, allowing the data to be used in a number of ways:

1. To perform quality assurance checks on the submitted formulation data.

2. To estimate the fraction of the VOC content which escapes to the ambient air using the known fate pathways identified in other EPA studies.
3. To develop hazardous air pollutant and indoor air pollution inventories.

2.1.4 Other Uses of the Information

The primary use of the survey was to provide the basic information (VOC content) that was used to develop VOC emission estimates for consumer and commercial products.

A secondary use of the inventory could be in the preparation of a national hazardous air pollutant (HAP) inventory. The CAA requires the EPA to list major sources of hazardous air pollutants, including urban area sources. Some of the major HAP's in consumer and commercial products include methylene chloride, trichloroethane, toluene, xylene, and methanol. Some additional toxic materials are present in smaller quantities. These include hexane, ethylene glycol, diethanolamine, chlorobenzene, methyl ethyl ketone, and methyl isobutyl ketone. The consumer products portion of the HAP inventory may be particularly useful for indoor air pollution assessments.

A third use of the inventory derived from the survey will be to provide *per capita* emission factors for the States to use in State Implementation Plan (SIP) inventories. Some differences in *per capita* use of specific products by geographic region or season may exist, but identification of these variables is beyond the scope of this study.

2.2 SURVEY QUESTIONNAIRE AND MAILING LIST

Survey packets were mailed to approximately 3,700 respondents from a mailing list developed with the assistance of several trade associations. The survey packets consisted of a cover letter, the survey questionnaire form (Enclosure 1), a computer floppy diskette with a computer program that emulated the questionnaire (Enclosure 2), and supporting documents explaining EPA's regulatory authority and procedures for

protecting confidential business information (Enclosures 3 through 5). Appendix A contains an example of a survey packet without the accompanying computer diskette. Appendix B contains the original mailing list.

2.2.1 The Survey Questionnaire

The purpose of this section is to give an overview of the information requested in the survey questionnaire. The survey questionnaire form and instructions explain the information being requested and should be referred to for greater detail. The survey questionnaire consists of two "sheets", each requesting different information.

The *Company Sheet* requests general information on the company and/or division providing the survey information. The Company Sheet also allows the company to indicate that the information request does not apply to them either because they do not produce any of the products listed as included in one of the survey categories (Attachment A to the Survey Form) or that they are not identified on the product label as the "owner" of the brand name. Figure 2-1 shows the Company Sheet.

The *Product Sheet* consists of a two-page form that requests product-specific information. The information requested includes the Company and Division reporting the information, the product category code taken from a list of categories listed in Attachment A to the survey form, the product or product group name, information on product packaging and sizes, the sales of the product in 1990 (in pounds), the total amount of reportable VOC (RVOC) in the product (percent of product net weight), a list of each RVOC ingredient (defined in Attachment B of the survey form) that comprises at least five percent of the total product weight, the percentages of methylene chloride and 1,1,1-trichloroethane in the product (exempt as VOC but of interest as toxic air pollutants), and which classes of information should be considered confidential business information (CBI). The list of RVOC ingredients is requested in Item 11A on the survey questionnaire. If the responding company did not have this information, they were instructed to provide an alternate contact (company) that could provide that information. This can occur when a company, such as a large chain store, sells it's brand of a product

(*e.g.*, spray paint) that is actually produced and packaged by second firm (*e.g.*, a contract packager). Figure 2-2 shows page 1 and Figure 2-3 shows page 2 of the Product Sheet.

2.2.2 Electronic Reporting Option

The computer version of the survey form consisted of an introductory screen that appeared at the beginning of the program, two data entry screens emulating the two pages of the product sheet, and a closing screen used at termination of a session with the program. Additional functions allowed the person using the software to get context-specific help (help related to the current data being entered), to search the data files for a specific record (information on a specific product), print the data in the data files by either record number or by alphabetical listing by product name, and to create an export disk for submittal of the entered data. The computer files generated by the software were designed to be sent on computer disk instead of on individual paper forms for each product. The Company Sheet, however, should have accompanied each submission, whether on disk or paper. This was done intentionally to avoid problems when the data on the disk is unreadable or when questions arise on data that was entered, that a contact person could be reached. An additional reason was to ensure that a signature from a company employee always accompanied a data submittal.

FIGURE 2-1 COMPANY SHEET

1. Company Name:

Division Name:

2. Person to Contact:

3. Address:

4. Phone:

5. Type of Business (mark with "X" for all that apply):

☐ Manufacturer ☐ Retailer ☐ Distributor ☐ Private Label
Contract Packager ☐ Custom Contract
Packager

6. Indicate Number of Product Sheets Attached: _____

or Zero Product Sheets Are Attached Because:

☐ This company does not manufacture, distribute, or sell any of the reportable products listed in Attachment A.

☐ This company does manufacture, distribute, or sell some of the reportable products listed in Attachment A, but this company is not the party responsible to report because it is not named on the product label.

7. Certification. The company or division officer who is responsible for environmental compliance or government affairs must sign the certification statement below:

"I hereby certify that, to the best of my knowledge and belief, all information entered on this Company Sheet and any attached Product Sheets is complete and accurate."

NAME

SIGNATURE

TITLE

DATE SIGNED

FIGURE 2-2 PAGE ONE OF THE PRODUCT SHEET

Page 1 of 2

1. Company Name : _____
Division Name : _____
2. Product Category Code (see Attachment A): ☐ ☐ ☐ ☐

Description (from Attachment A and/or additional descriptions):

3. Product Form : ☐ Aerosol ☐ Spray Pump ☐ Liquid ☐ Gel ☐ Solid

☐ Other _____
4. Full Product or Product Group Name :

5. If the data on this **Product Sheet** represent more than a single Stock Keeping Unit (SKU), enter the number of SKU's represented (see instructions on grouping products): _____
6. Major Customer Type : ☐ Household ☐ Comm/Inst ☐ Industrial
7. Product Size -by Volume : ☐ 0 to 32 fl.oz. ☐ >32 fl.oz. to 5 gal. ☐ >5
to 55 gal. ☐ >55 gal.
or
-by Weight : ☐ 0 to 1 lb. ☐ 1 to 5 lb. ☐ 5 to 20 lb. ☐ >20 lb.
8. Net Product Weight sold in the U.S. for 1990 (pounds) :
9. Total Reportable VOC (weight % of net products): _____
Do not include methylene chloride or 1,1,1-trichloroethane in this total.
If formulation information is not available to your company, go to item 11B.
10. Total Number of Reportable VOC ingredient compounds : _____

FIGURE 2-3 PAGE TWO OF THE PRODUCT SHEET

Page 2 of 2

- 11A. List the largest reportable VOC ingredient compounds and their weight %'s for all reportable VOC that are 5% or more of the total net product weight. Use the criteria listed in Attachment B to determine if the compound is an RVOC. Please list these compounds in order of highest to lowest weight percent, if possible. **Do not report individual components of ingredients which are fragrance materials.**

Reportable VOC Ingredient Compounds			Weight % in Final Product
	Name	CAS No.	
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.	All Other Reportable VOC		
Total Reportable VOC % (should match item 9)			

Additional information is requested separately for two other compounds: methylene chloride and 1,1,1-trichloroethane. Do not include these compounds in total RVOC.

Methylene chloride	75-09-2	
1,1,1-trichloroethane	71-55-6	

- 11B. Enter name and address of company with formulation information if you do not have the data to complete item 11A. **This requirement does not apply to ingredients which are fragrance materials.**

12. Indicate which items contain Confidential Business Information :

☐ Sales
 ☐ Total RVOC %
 ☐ Ingredients
 ☐ Ingredient Wt. %s

The mailing list for the survey questionnaires was derived from a number of sources, most notably CSMA, CTFA, SDA, the Motor Equipment Manufacturers Association (MEMA), the Adhesives and Sealants Council, and the California Air Resources Board (CARB). There was a degree of overlap between the lists provided by the various sources, and although methods were used to eliminate as many duplications as possible, there were some that remained in the final version of the mailing list. These became apparent only after responses to the survey were returned. There were over 9,000 entries on the mailing list before any deletions of duplicates were performed.

The list provided by CSMA included their membership, as well as the list of companies to whom they occasionally send promotional material (*i.e.*, potential CSMA members and other interested parties). The list provided by CTFA included names listed in two documents that they publish: *CTFA - Who's Who 1992* (their membership directory) and the *Cosmetic Industry ON CALL 1992*, which is put out jointly with the American Academy of Dermatology. The list from the Adhesives and Sealants Council was taken from their membership directory. The membership lists often consisted of sales managers or administrative officers who were not the best contact person for receiving the survey questionnaire. In many cases, addressing survey packets to these individuals resulted in delayed responses and may have reduced the overall response rate (see discussion in Section 2.4). The CTFA "On Call" list gives the technical and/or emergency contact person for companies that produce cosmetics and cosmetic ingredients. The list from CARB was found to be the least reliable, with many companies out-of-business and/or not responding. The lists provided by MEMA and SDA were given after the preliminary list from the other sources was compiled and reviewed by them. They then submitted potential respondents that were not already included on the list.

After all contributions to the survey mailing list were completed, the list was printed in alphabetical order to account for obvious duplications. This reduced the number of listings by one-half. A second reduction was accomplished by doing a search of the data file by substrings (unique parts) of each company's name to look for similarities in other records of the data file. Both of these strategies were tempered by not eliminating possible subsidiaries or divisions of

the parent company in different locations. This conservative approach did lead to some duplication; however, the result was more often justified by the fact that many responses were received from divisions or subsidiaries which were not included on the mailing list.

The final mailing list was comprised of 3,610 potential respondents. After the mailing was completed, a number of additional contacts were added to the mailing list through forwarding of survey packets to companies that had moved or been sold, and to divisions requesting additional forms to be sent to other divisions or subsidiary companies. The final number of "contacts" included in the mailing list data file is 3,802.

2.3 HANDLING OF SURVEY RESPONSES

The data collected from the Consumer and Commercial Products Survey were entered into dBase[®] database files either by the company providing the information or by EPA contractor staff working on the survey project. The SURVEY software, developed using Clipper[®] Version 5.0 and provided on the disk enclosed with the survey questionnaire, was the usual method for this entry into the data files. This software was also used by the EPA contractor staff when the responding company provided their response via paper forms. In some cases, the responding company provided information in a format other than those used in the database files or hard copy forms provided with the survey questionnaires; these were handled on a case-by-case basis. All responses to the survey (either on disk or hard copy) were handled as confidential business information (CBI) using a CBI Plan approved by the document control officer (EPA-DCO) in the Emission Standards Division (ESD) of the Office of Air Quality Planning and Standards (OAQPS), U.S. EPA, Research Triangle Park, North Carolina, and only after a notice of EPA's need for CBI handling was published in the *Federal Register* (FR Vol. 58, No. 137, 38758, July 20, 1993). The CBI plan is presented in Appendix C.

The discussion in this section covers the methods used to handle an individual response to the survey. The discussion includes the following steps in the information flow:

- 1) data entry from a hard copy form,
- 2) creation of batch files containing response data from several responding companies,

- 3) quality assurance (QA) checks performed on the batch data,
- 4) building of an interim SAS[®] data set,
- 5) additional QA checks performed on the SAS[®] data set, and
- 6) migration of this data to the final data set used to create the summary data tables presented in this report.

2.3.1 Response Handling and Safeguarding of Confidential Business Information

There were several procedures used in handling responses to the survey that helped assure protection of CBI as outlined in Appendix C, and for the processing of survey data (Figure 2-4). When an envelope with a potential response was received, it was held in the CBI-approved file cabinet until the Document Control Officer (DCO) could open and log the response into the system designed for that purpose. The paper forms (hard copy) of the survey were placed into a data entry queue while those responses received on diskette were tested for the presence of viruses and to assure that the file structure corresponded with those used in the data entry program. All materials contained within an envelope was placed in a CBI file folder for the responding company and given a CBI log-in number. If additional submissions were received for that company and division they were appended to that same file.

The log-in system was built around the database file used to generate the mailing list. That file was updated to track responses received, survey forms returned as undeliverable, and the processing of the data in the survey response. Upon log-in, CBI cover sheets and a CBI control record were added to the file. Hard copy survey responses were keyed into a separate set of data files for each file folder, with the data diskette kept with that file. Several data entry personnel performed these tasks simultaneously on separate personal computers (PC's). Control of CBI files was maintained by following the standard CBI handling procedures discussed in Appendix C.

All disks with data to be read into SAS[®] were checked for the presence of viruses and for proper file structure. These checks were conducted regardless of whether the data was entered by the project staff or by the respondent company. This data was then read into batch files for

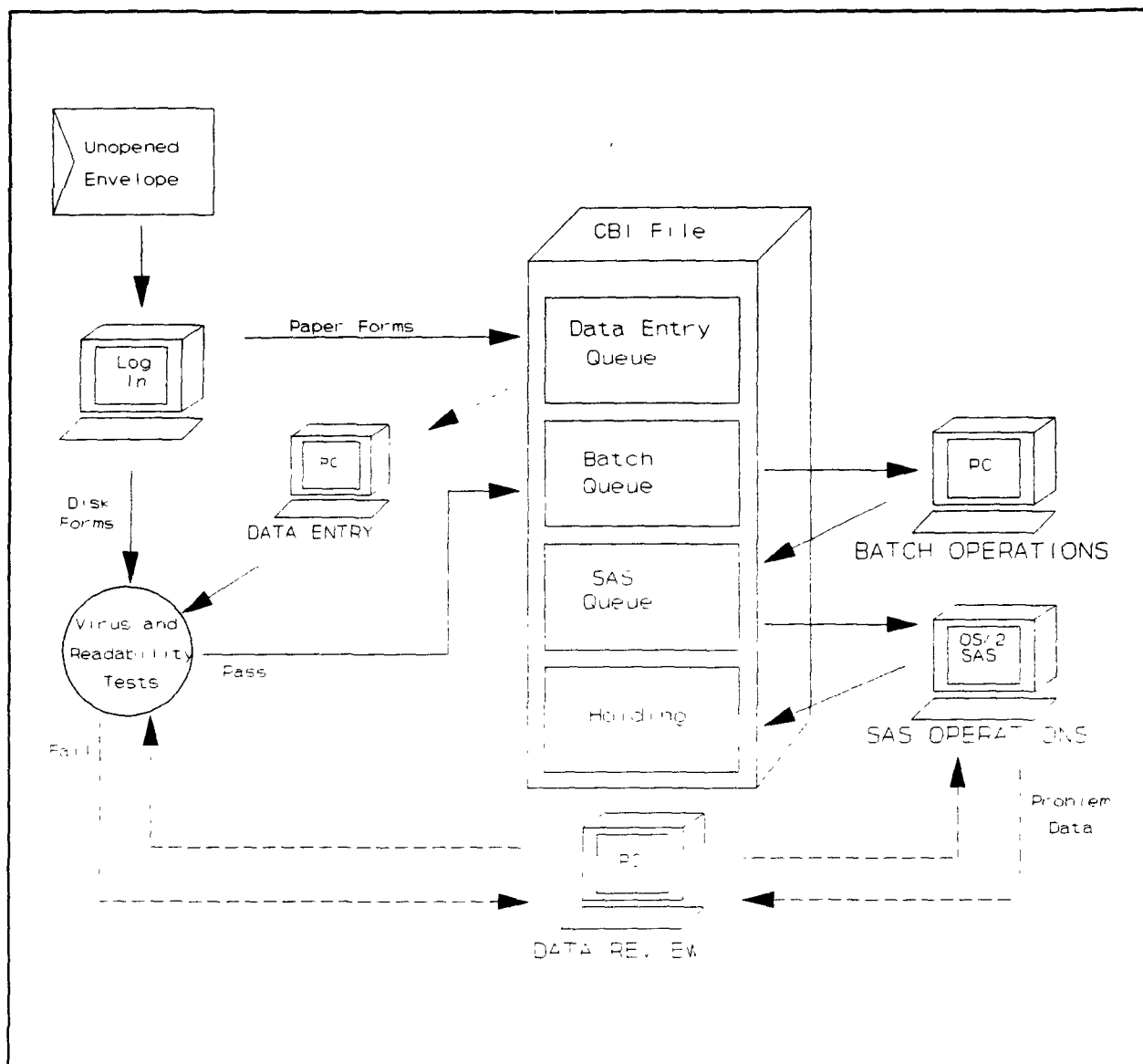


Figure 2-4. Consumer and Commercial Product Survey Response handling system.

more efficient transfer of the data into SAS[®], and more effective quality assurance.

Below is an outline of the responsibilities of the various project staff in handling of the survey responses and the data derived from those responses. A more detailed discussion is presented later.

2.3.1.1 *Document Control Officer (DCO)*

The Document Control Officer was responsible for the envelopes containing survey responses from the time they arrived until they were archived at the end of the project. The DCO opened the envelope with a response and performed the log-in using the software developed for that purpose. These responsibilities included the following:

- 1) Update the file based on the information on the respondent's Company Sheet;
- 2) Enter the Postmark date on the envelope;
- 3) Enter the date the envelope was received;
- 4) Assign a CBI Control Number to the file and either attach that number to the disk or to a blank disk added to the file;
- 5) Set up a file for the response and all materials associated with that response;
- 6) Place the file into the proper queue (Data Entry, Batch, or Holding) in the file cabinet or give to the data review person for determination on anomalous submissions; and }
date a file moves from one queue to the next.

Responses were not processed unless all the above steps could be completed in that same day. The DCO assured that the responses being handled by data entry were secured (filed and locked) daily, and that the CBI Log was updated.

2.3.1.2 *Data Entry*

There were a number of data entry personnel working at any one time. When a file was checked out from the data entry queue, the data entry person was required to sign the control record for that file and leave it with the DCO. After completing the data entry, the file was returned with the data diskette to the DCO for filing in the "batch" queue.

2.3.1.3 *Batch Operator*

The Batch Operator's duties included checking the format and contents of all data on disks to ensure that it met the requirements for entry to the SAS[®] data set. Disks were checked-out

from the DCO with the entire file. If any anomalies on the disk were noted that could not be rectified immediately, the file and disk were returned to the DCO to be stored in the batch queue until the problem could be resolved. After work with a disk was complete, the file and disk were returned to the DCO and filed under "Holding." The diskette containing the batch files was held in the SAS[®] queue.

2.3.1.4 SAS[®] Operator

The responsibilities of the SAS Operator were to maintain the SAS data sets, generate reports, ensure that the information in the data sets passed QA checks, and perform any analyses as directed. There were a number of tasks that this person was required to perform that was dictated by the nature of the responses received. The primary data handling function of this person was the reading of batch files into the SAS[®] data sets.

2.3.1.5 Data Reviewer

The task of data review was conducted by the project manager and a data entry person. Any disks that contained a virus were investigated to determine if an uncontaminated disk or other version of the data could be acquired. Data formats other than those constructed for the project were viewed using various software to determine if it could be read into the data files or in some other way used in the project. Additional review and/or revisions to the data entered into batches was conducted if there were problems identified by the SAS Operator.

2.3.2 Data Entry

As mentioned previously, the data entry step was performed either by the responding company where they provided data via computer diskette, or by the EPA contractor staff when the responding company provided data via hard copy form. In cases where the responding company provided a response by some alternate format (flat ASCII files, other data formats, *etc.*), every attempt was made to enter the data into the proper format. Sometimes, however, the data was unusable and the file was never entered into the final data set. The following

discussion covers the data entry step, including the automated QA checks performed by the data entry program.

The data entry program was included along with the required data files in a self-extracting file on a 360 kilobyte double-sided, double-density 5.25 inch diskette. This format was used so that a responding company with any IBM[®] compatible, personal computer could use the software. A company unable to use that format was requested to call the Survey technical support line for assistance in acquiring another disk. When the INSTALL batch file (included on the Survey diskette) was executed, it created a directory on the computer's hard drive called "SURVEY," extracted all the files needed from the floppy disk, and copied these files onto the hard disk in the SURVEY directory. At that point the software was ready for use.

The software was designed to gather the information from the PRODUCT SHEETS of the survey questionnaire (Appendix A). The information from the COMPANY SHEET was not included as part of the electronic data gathering to ensure that a signed, hard copy form was returned, which gave authentication to the data submittal and a method to contact the respondent if the data on a data disk was unreadable. Appendix D presents the data dictionaries for the data files used by the Survey software.

Each data item asked for in the Survey software is presented below along with a discussion of validity checks performed internally by the software for that item. These validity checks allow only a certain range of possible entries to be allowed. Many data items were mandatory and trying to skip over that item or leave a value at zero would not be allowed by the validity checks.

2.3.2.1 *Company Name and Division Name*

Company Name information was mandatory and the program would not progress to the next data entry item nor to the second page of the data entry screen unless some entry was made for the Company Name. The Division Name was not mandatory but was requested in the event that one company would be providing information for many divisions, either in one submittal or by separate submittals from each division. The information in these two fields, along with the

Product Name and Product Form information, were included in the indexes used with the data files, and in the linkages between the three data files used for storing the survey data (the Product file, the RVOC Ingredient file, and the Alternate Contact file).

The Company Name and Division Name entered in the first record were held in the computer memory and automatically entered when a second record was added to the data files. This process was continuous, whereby the Company Name and Division Name for the third record was automatically entered from the information in the second record. In this way, any change to these fields resulted in the "new" company and division names being read into records subsequently added to the data files.

2.3.2.2 *Product Category Code*

The Category Code was limited to those valid codes listed in Attachment A to the survey questionnaire (Appendix A). The Survey software read this information into an array in the computer memory. Any entries attempted in this field were checked against the array for validity. If the data entry person attempted to enter blanks or an invalid code, the software presented a series of pop-up menus that allowed a correct category name and code to be chosen and entered into Product file. Categories were added to the list based on the information available to estimate the market share of the responding companies, and upon the nature of the responses collected from the survey. A discussion of these revisions to the list of categories is included in Section 4.

2.3.2.3 *Product Form*

There were six valid options for entry as the Product Form: "A" for Aerosols, "P" for Spray Pump, "L" for Liquid, "G" for Gel, "S" for Solid, or "O" for Other. In the software version, this was the entry of the appropriate letter while on the hard copy form check-off boxes were used. If "Other" was chosen, the data entry person was asked to provide a more detailed description of the product form.

2.3.2.4 *Full Product or Product Group Name*

This item was intended to be a unique entry so that no other product could have the same Company Name, Division Name, Product Form, and Product Name. The check for a valid entry involved first reading the information for all of the items listed above in the Product file at start-up into an array in the computer memory; then checking an attempted entry against that array. As new products were entered, the information was added to the array. If the validity check was passed, the Product Name was entered into the Product file. If the name was edited, any records linked to that Product Name in the RVOC Ingredient file or the Alternate Contact file, and in the validity check array were also changed. Blanks were not allowed for the Product Name.

Companies were allowed to group information for a number of products with similar formulations into one product sheet/record. The stipulations for grouping products were that the products all had to be in the same category (have the same four-digit category code), have the same product form, and not differ by more than five percent in total RVOC. This was done to reduce the number of separate product sheets a company would need to submit and thereby reduce the overall burden of reporting.

2.3.2.5 *Stock Keeping Units (SKU's)*

Stock Keeping Units were used as a barometer of how many package sizes and grouped products would be represented by any product sheet. The data entry person was instructed to enter the number of SKU's represented for the product sheet. It was suggested by the trade associations as being a useful and easily identifiable number for responding companies. This information was not mandatory. The default value was one.

2.3.2.6 *Major Customer Type*

The data entry person was instructed to check off all customer types that applied to the listed product or product group. The purpose of the question was to determine if the product or products being used by any one group had differences in formulation that would affect

emissions of VOC's. This information will be useful to EPA in future determinations of effective regulation of individual product categories. The software presented this question as a series of logical (Yes/No) choices; the hard copy form presented check-off boxes. No choices in this set of logical fields were required.

2.3.2.7 *Product Size*

The data entry person had the opportunity to answer yes or no to a set of product size ranges in a manner similar to how Item 6 above was done. There was an additional choice, however, where the data entry person could change from weight ranges to volume ranges by pressing the <Alt> and <F1> keys simultaneously, which changed the value in the Product file. Both sets of ranges were presented as check-off boxes on the hard copy form. No choices for size ranges were required by the software.

2.3.2.8 *Net Product Weight Sold in the U.S. for 1990 (Pounds)*

The net product weight sold in the U.S. for 1990 (Item 8) was a required entry. The data entry person was instructed to enter the total number of pounds of the product sold in the U.S. for the year 1990. The responding companies were given the option to use a fiscal year with the stipulation that the fiscal year cover the major portion of calendar year 1990. In many cases, the responding companies requested using a more recent year because the data were more accessible. This was allowed as long as the responding company documented any divergence from the survey instructions or any adjustments made to the data in a cover letter.

2.3.2.9 *Total Reportable VOC*

The total reportable VOC percent (Item 9) was the first data item requested in the second page of the data entry screens in the Survey software, although on the hard copy form Item 9 and Item 10 were found on the first page. The data entry person was prompted to answer yes or no as to whether they had formulation data for the product before any information was requested for the second data entry screen. If the answer to this logical question was yes, the second data entry screen presented requests for Item 11A; if the answer was no, the screen

requested information for Item 11B. Regardless of the response to this query, Items 9, 10 and 12 were requested; however, requests for Item 11A and 11B information were mutually exclusive.

The responding company was instructed to evaluate the list of ingredients for products containing RVOC, as defined in Attachment B to the survey questionnaire (Appendix A), and enter the total weight percent that those ingredients represented. The instructions for the survey questionnaire requested that individual ingredients be listed in Item 11A for those comprising five percent or greater of the total product weight. This total should have included all RVOC ingredients and not only those that were greater than five percent and required to be listed in Item 11A. A zero entry was allowed in this field.

2.3.2.10 *Total Number of VOC Ingredient Compounds*

The intention of this data item was for the responding company to provide the total number of ingredients they have identified as RVOC, regardless of the percent weight that any individual ingredient may have. The entry in this item should have included all RVOC that comprised the total RVOC entered in Item 9 and not only those to be listed individually in 11A. A zero was allowed if the total RVOC percent entered in Item 9 was zero, and/or no items were previously entered in Item 11A.

2.3.2.11 *List of RVOC Ingredients or Alternate Contact*

Two options were available for the responding company to answer Item 11: the first was to give the list of all RVOC ingredients that comprise five percent or more of the final product weight, and the second was to give an alternate contact company that could provide the RVOC ingredient list. The first option was available as Item 11A and the second as Item 11B on the Survey questionnaire. These options were both shown on the hard copy form but were mutually exclusive in the Survey software. The only exception to this exclusivity were the requests for information on methylene chloride (MeCl) and 1,1,1-trichloroethane (TCA). The request for what information was done as described for Item 9 in Section 2.3.2.9 above.

An array was created in the computer's memory after a response to Item 10 was registered for storing RVOC ingredient information. After the entry of RVOC ingredients was complete, the data was transferred as separate records in the RVOC Ingredient file for individual ingredients. If data was previously entered in the RVOC Ingredient file for the current Company/Division/Product/Form combination, that information was read into the array for editing and replaced afterward. Internal QA checks on the ingredient array included confirming that the number of ingredients listed did not exceed the number entered in Item 10, and that the total RVOC percent in the ingredient list did not exceed the value reported in Item 9. If either of these checks were failed, the data entry person was prompted to either change the entries to the ingredient list, or to Item 9 or Item 10 as appropriate. Another QA check was to determine the average weight percent of the remaining unlisted ingredients (average of "Other"). This check was performed as described in the formula below:

$$\text{Average "Other" RVOC} = \frac{(\text{Item 9 Entry} - \text{Total RVOC Listed})}{(\text{Item 10 Entry} - \text{Number of RVOC Listed})}$$

Until the QA checks were passed, data entry was halted at the RVOC ingredient list. The entries for MeCl and TCA were not included in the RVOC ingredient list, however, the QA checks were failed if values for these items plus those for the RVOC list were greater than 100 percent.

If the information for an alternate contact was being entered, the information was stored in a discrete record in the Alternate Contact file for the Company/Division/Product/Form combination from the Product file. The request for MeCl and TCA information was also included if Item 11B information was being entered.

2.3.2.12 *Claims of Confidentiality*

Confidentiality claims could be made in four logical fields that were synonymous with the check-off boxes in the Survey questionnaire: claiming sales, the total RVOC percent, the ingredient list, and/or the ingredient weight percents as Confidential Business Information. This

information was not required by any validity checks. This information was included at the request of OMB, even though all responses to the survey were to be treated as confidential.

2.3.3 Batch Files

Data for single companies were provided on separate diskettes either by the responding company or through entry of the data from paper forms by the EPA contractor staff. These diskettes were held in CBI files with all other materials sent with the data submissions. The large number of diskettes, some listing only a few products were then combined with the data from several other companies into "batch" files so that QA analysis could be performed more effectively, the data could be read into the SAS[®] data set more efficiently, and the original data files would remain unchanged. The following discussion gives the details of how the batch files were compiled, the procedures for performing QA analysis, the procedures for changing the data failing the QA analysis, and how those changes were documented. The discussion of how the data were transferred to the SAS[®] data sets is presented in Section 2.3.4.

2.3.3.1 *Compilation of Batch Files*

As mentioned above, the data from the three data files for individual companies were combined into similar files that contained data for several companies. There were two additional fields added to these batch files that contained the disk identification number (DISK_ID) and the identification number for the batch (BATCH_ID). Disk numbers were assigned to data diskettes at the time the survey responses were opened and logged into the CBI tracking system used for the project (detailed in the CBI Plan in Appendix C). Batch numbers were assigned sequentially through the software that read individual data diskettes into the batch files. The batch files were named such that the batch number was incorporated into the batch file name. Product file data from the individual data disks was read into the PROnnn.DBF file, where nnn refers to the batch number. In a similar manner, the data from the RVOC Ingredient file and Alternate Contact file were read into the RVOnnn.DBF and PROnnn.DBF files, respectively.

Two checks were performed on the data diskettes, however, before any data was read into batch files. The first data check was for the presence of computer viruses, and the second was

a check for readability and proper file format. Many companies submitted data in a format other than the dBase[®] format provided for use with the Survey software, which would cause problems when attempting to read the file into a batch. If a problem occurred during the generation of a batch and the batch files were unusable, that batch number was abandoned and the diskette that caused the problems was reviewed and revised. Revisions were performed on copies of the original data diskettes that were kept unchanged in the file for that data submission.

Batches were created by reading the data files from individual CBI file folders, all from the same type of disk (either 3.5" or 5.25") onto a disk of the other size. This avoided writing data to the hard drive of the computer running the batch creation software, and the need to then erase that file from the hard drive and/or lock-up the computer. The disks containing the batch files could then be stored along with the other CBI file folders as specified in the CBI plan (Appendix C). The data read into a batch was not ordered in any way other than availability at the time that the batch was being created.

2.3.3.2 *Quality Assurance Checks for Batch Files*

After the data was transferred to batch files, a dBase[®] program (QA_RVOC) was executed that performed some of the QA and validity checks used in the data entry program and wrote exceptions to a series of text files for later review. This program performed six checks on the data in the Product file and the RVOC Ingredient file:

- 1) If the category code was missing in the Product file;
- 2) If there were any duplications for a Company/Division/Product/Form in the Product file;
- 3) If there were no matching records in the RVOC Ingredient file for records found in the Product file;
- 4) If the RVOC percent listed in the Product file matched the total RVOC for all ingredients listed in the RVOC Ingredient file for that Company/Division/Product/Form combination;
- 5) That the pounds sold in 1990 listed in the Product file was greater than 1; and
- 6) If there were records in the RVOC Ingredient file with no match in the Product file.

If problems requiring revisions to the data in the batch files were found, the original batch was not edited directly. A new batch number was assigned by adding 1000 to the original batch number and the files (PROnnn, RVOnnn, and ALTnnn) were copied to a new diskette with the new batch number incorporated into the file name. Therefore, if the original batch number was 54, the original product data for the batch was contained in the PRO54.DBF file; and the batch file that was created for revisions to the data was PRO1054.DBF, with a batch number of 1054. If additional revisions to the data were determined to be necessary, the next cycle of revisions would be found in the 2054 batch file. Whenever a change to a particular record was made, it was documented on a form that was filed with the other documents in the CBI file for that company's data submission, in the log book used to track the creation of batches, and in a data review log book. This redundancy allows the tracking of all changes to the data if ever an audit of data from a particular company or product needs to be performed in the future.

2.3.3.3 *Revisions to Batch files*

Two additional dBase[®] programs were written to correct the most common errors found in the batch files. These programs were executed on the "1000" series of batches because they performed some automated additions, deletions, and revisions to data in the batch files. These programs documented these changes in reports particular to the program being executed.

The first program (DUP_RVOC) marked any duplicated records for deletion in the RVOC ingredient file (RVOnnnn.DBF) for a particular Company/Division/Product/Form combination when the ingredient name was identical for a second record. This type of error seemed to be an artifact of incomplete deletion of records if the data entry person made additions and/or deletions to the list of RVOC ingredients in Item 11A in the SURVEY software. The records marked for deletion were not removed permanently from the data file until after the person performing the data review had checked the data file and verified that deletion was indeed warranted.

The second program (FIX_MISS) was written to add missing RVOC ingredient records to the RVOnnnn.DBF file if none existed for a record found in the PROnnn.DBF file. The first step was to determine the average RVOC percent by dividing the total RVOC percent in the

RVOC field by the number of RVOC ingredients as entered in the PROnnnn.DBF file for the Company/Division/Product/Form combination. If that value was less than five percent, a record in the RVOnnnn.DBF file was created with the appropriate Company/Division/Product/Form data entered, "Other" listed as the ingredient name, 0 as the RVOC Number (Appendix D) and the total RVOC from the Product file entered as the RVOC percent. If the average value was greater than five percent, two records were added for the Company/Division/Product/Form listed in the Product file, one that listed "Other" as the ingredient name with 0 as the RVOC percent, and the second listed as "Unknown" with the total RVOC percent from the Product file entered as the RVOC percent.

Additional revisions to the batch were performed by the person performing the data review as needed and based on the reports generated by the QA_RVOC program. These changes were documented on standardized sheets, one for each disk number, so that these error sheets could be filed with the other original information for the data submission.

2.3.4 SAS[®] Data Sets

There were three steps involved in the development of the SAS[®] data sets used to generate the table presented in Section 2.4. The first step involved the reading of the data in the batch files into a temporary data set and performing rudimentary, automated QA analysis on the data from that batch. The second step involved the appending of the data in the temporary data set into a set of "validation" files upon which additional QA was performed. Data were read into the final master data set after passing all validation checks and were analyzed with the results used to create the table shown in Section 2.4. No revisions to the data were performed on the master data sets. The discussion below gives additional detail on these three steps.

2.3.4.1 *Reading of Batch Files*

The SAS[®] data sets were created from the batch files that were compiled as described in Section 2.3.3 above. As batch files became available, they were read individually into a set of temporary data sets, where a number of QA checks were performed and had to be passed before

the data for the batch were added to a validation file. The QA checks performed on the temporary data sets included those listed below.

1) Uniqueness

- only one product record for a combination of

Company
Division
Product Name
Product Form

- only one RVOC record per product (as defined above) with a unique RVOC number
 - only one alternate contact per product (as defined above)
- 2) Checks of entered CAS registry numbers in the RVOC Ingredient file for validity.
 - 3) Checks that the Product Form entry is valid: either A, P, L, G, S, or O.
 - 4) Checks for a valid Category Code as specified in the Survey.
 - 5) Checks for a valid record in the Product file for each listed RVOC ingredient in the RVOC file.
 - 6) Check for a mandatory RVOC record when the number of RVOC ingredients is greater than zero, the average RVOC percent is greater than five, and there is no Alternate record for the product.
 - 7) Check that the total RVOC percent listed in the RVOC list for a product matches the RVOC percent entered in the Product file.

Whenever a problem with a batch was encountered that did not allow it to be read into the SAS[®] data sets, the batch was revised by the data review person as a "1000" series batch as previously described. After the data from a batch was read into SAS[®], the diskette holding that batch data was filed in holding along with all the original data submission files. All the SAS[®] data sets were stored on a Bernoulli[®] disk drive (a high capacity, removable storage media) that was removed from the computer running SAS[®] for OS/2[®], and placed in a locked CBI file cabinet when not in use.

2.3.4.2 *Validation Data Sets*

There were three validation files used, one for each of the three data files used in the Survey software and batch files: PRVALID for the Product data, RVVALID for the RVOC ingredient data, and ALVALID for the Alternate contact data. The validation files were created to have various QA checks performed upon them. Their contents were compared to those of batch files being read into the temporary data sets previously described. These comparisons ensured that no duplicated data were read into the SAS[®] data sets.

When revisions to the data in a batch file were required after the batch data was read into a validation file, the 1000 series batch file was generated by the data review person, the SAS operator erased the old batch data, and appended the 1000 series batch data to the validation file. If this process were repeated, the second revision to the batch would be in the "2000" series, and that data would replace the 1000 series data in the data sets. Simple editorial changes to data were performed, when feasible, directly on the SAS[®] data sets and documented.

2.3.4.3 *Master Data Sets*

All revisions were conducted on the batch files and validation files. After all QA tests were satisfactorily passed and the data were believed to be valid, the master data sets were created. No revisions or editorial changes were enacted upon the master data sets. The analyses used to create the table shown in Section 2.4 were performed on the master data sets.

2.4 RESULTS OF THE SURVEY

An overview of the response rate to the survey and a summary of the survey responses are discussed in the following section. The total number of questionnaires mailed was 3,610; however, a number of companies had responses from more than one division and some companies forwarded copies to companies that were not on the original mailing list. These additional sources of survey responses brought the total number of questionnaires being tracked to 3,802.

2.4.1

Response Rate

The response rate is illustrated graphically in Figure 2-5. Out of the 3,802 survey questionnaires accounted for in the tracking system, only 1,283 questionnaires (approximately one-third) are included in the No Response category. An additional 352 (9.3 percent) were returned as undeliverable by the U.S. Postal Service. Approximately one-quarter of the survey questionnaires were responded to by the company indicating that they did not manufacture, distribute, or sell any of the products found in one of the product categories (Company Sheet Only). Responses via either product sheets or data diskettes were provided by the remaining companies. Thirty responses (0.8 percent) were obviously inappropriate and could not be used in the survey without lengthy follow-up. The remaining responses were complete with product information. An additional 35 completed responses were provided for a company by a third party (*e.g.*, consulting firm, custom packager, etc.). There were, therefore, 1,173 complete responses (including product formulation data) from companies manufacturing consumer and commercial products.

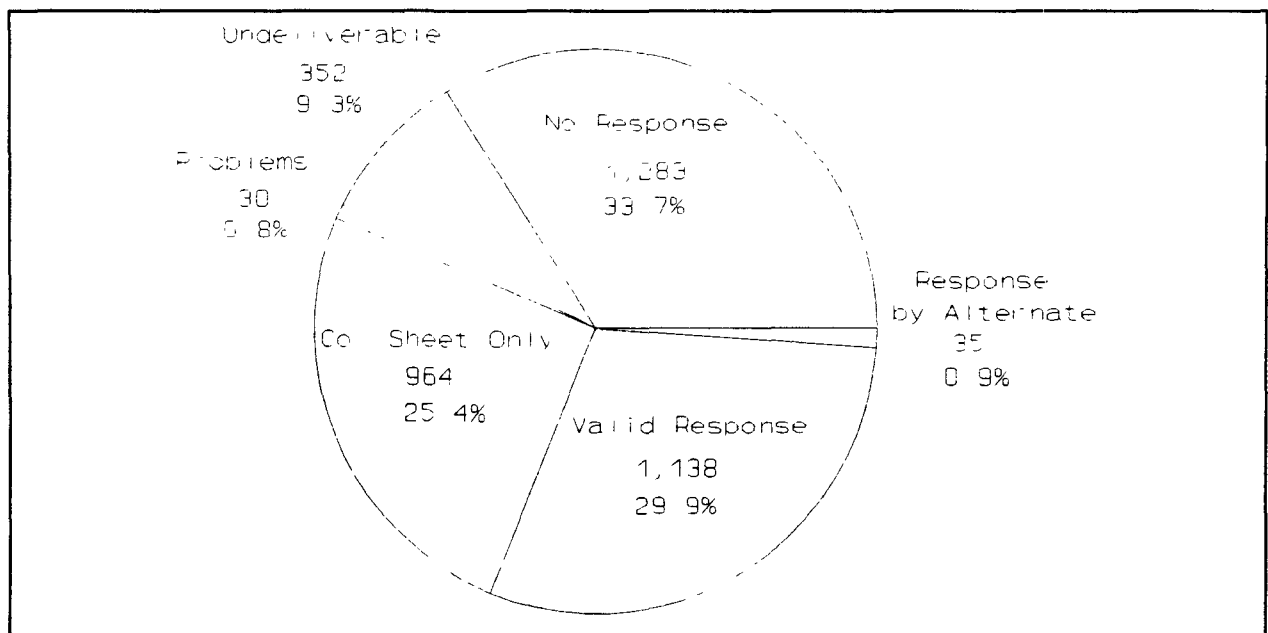


Figure 2-5. Distribution of survey questionnaires

Not all of the 1,173 complete responses, however, could be used in the final analysis. A number of problems were encountered when the information was attempted to be entered into the data entry system from both hard copy product sheets and data diskette submissions. In all cases, attempts were made to contact the company when problems were identified, but these attempts were not always successful. In many cases, information vital to the project was not provided, such as the pounds of product sold in 1990. In a number of other cases, products were inappropriately grouped (*i.e.*, products from more than one category were reported together). These problems and a number of others were not resolved and 96 such responses were not included in the final data set. Therefore, the final data set included 1,077 complete responses.

2.4.2 Information Obtained from the Survey

The compiled survey data are presented in several ways. The following sections describe the outputs of the survey which have been generated to date. Other analyses of the data may be generated by the EPA as the need arises.

2.4.2.1 *Total RVOC Emissions by Individual Product Category*

The primary purpose of the survey was to develop 1990 estimates of VOC emissions from traditional consumer products, including commercial and institutional uses. Table 2-1, the principal output of the survey, presents RVOC emission data for each product category surveyed. Specifically, this table provides information for each category on (1) number of products reported; (2) product sales reported (tons); (3) RVOC content reported (tons); (4) estimated market coverage (*i.e.* what percentage of the market for a particular category was captured by the survey); (5) adjusted product sales (reported sales scaled up based on market coverage); (6) adjusted RVOC content (reported content scaled up based on market coverage); (7) RVOC content emitted (*i.e.*, the percentage of the product's RVOC content which enters the ambient air after fate adjustments); (8) tons of RVOC emitted nationwide; (9) pounds of RVOC emitted per 10,000 persons; and (10) RVOC emissions in ozone nonattainment areas (tons).

Items 1, 2, and 3 were obtained directly from the survey responses. Item 4 (market coverage) was estimated based on information furnished by CSMA, CTFA, and SDA following their reviews of the initial results of the survey and lists of companies responding in each category^{1,2,3}. Adjusted product sales (item 5) and adjusted RVOC content (item 6) were obtained by dividing reported sales and reported RVOC content by the estimated market coverage percentage. The adjustments were made in the following manner:

$$\frac{\textit{Tonnage Reported}}{\textit{Estimated Market Coverage}} = \textit{AdjustedTonnage}$$

Percent RVOC emitted was obtained by multiplying the RVOC content by a fate adjustment factor. The adjustment factor ranged from 1 percent to 100 percent and was based on information supplied by CSMA, CTFA, and SDA^{1,2,3,4,5}. The fate adjustments were made to account for products which enter the wastewater stream and subsequently biodegrade rather than being emitted to the air. A fate adjustment factor of 100 percent means that all the RVOC content of the product is emitted to the air. Conversely, an adjustment factor of 1 means that only 1 percent of the RVOC's are emitted.

Probably the most useful of the items in Table 2-1 are items 9 and 10. Data on emissions in ozone nonattainment areas will be used by the EPA in determining which categories will be targeted for regulation under §183(e). The *per capita* emission factors (in this case, pounds of RVOC emitted per 10,000 persons) will enable the EPA, States, and local environmental agencies to develop emission estimates for specific combinations of products based on population. This is by far the most comprehensive and accurate set of emission factors ever developed for consumer products.

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
PERSONAL CARE PRODUCTS										
Hair Care Products										
1101 Bleaches and lighteners	21	2,936	101	95	3,091	106	10	11	1	7
1102 Brilliantines	4	6	0	95	6	0	100	0	0	0
1103 Conditioners	191	124,273	847	95	130,814	892	5	45	4	27
1104 Conditioning sprays	17	1,328	13	95	1,398	14	100	14	1	8
1105 Curl activators	20	1,160	1	95	1,221	1	100	1	0	1
1106 Curl revitalizers	9	792	170	95	834	179	100	179	14	107
1107 Dyes - Permanent	35	14,880	1,463	95	15,663	1,540	10	154	12	92
1108 Dyes - Semipermanent	12	3,161	34	95	3,327	36	10	4	0	2
1109 Dyes - Temporary	9	6,317	739	95	6,649	778	10	78	6	47
1110 Finishing hair sprays	126	168,742	152,152	94	179,513	161,864	100	161,864	13,054	97,118
1111 Finishing spritzes	17	7,051	6,115	95	7,422	6,437	100	6,437	519	3,862
1112 Grooming creams	16	1,338	4	95	1,408	4	100	4	0	2
1114 Mousses	61	18,498	2,300	95	19,472	2,421	100	2,421	195	1,453
1115 Permanent wave treatments	55	50,287	232	95	52,934	244	10	24	2	14
1116 Pomades	8	1,849	3	95	1,946	3	100	3	0	2
1118 Rinses	7	927	0	95	976	0	5	0	0	0

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
1119 Setting lotions	21	1,290	237	95	1,358	249	100	249	20	149
1120 Shampoos	237	276,639	1,596	95	291,199	1,680	5	84	7	50
1121 Spray shines	12	872	558	95	918	587	100	587	47	352
1122 Straighteners	2	5	0	95	5	0	10	0	0	0
1123 Styling gels	92	12,015	591	95	12,647	622	100	622	50	373
1124 Styling sprays	35	6,006	3,638	95	6,322	3,829	100	3,829	309	2,297
1125 Styling spritzes	27	8,996	7,096	95	9,469	7,469	100	7,469	602	4,481
1126 Thickeners	4	28	0	95	29	0	100	0	0	0
1127 Tonics	11	1,383	367	95	1,456	386	100	386	31	232
1199 Other hair care products	35	2,588	48	95	2,724	51	100	51	4	31
All Hair Care Products	1,084	713,367	178,305		752,801	189,392		184,516	14,880	110,707
Deodorants and Antiperspirants										
1201 Underarm deodorants	128	24,364	8,896	100	24,364	8,896	100	8,896	717	5,338
1202 Underarm antiperspirants	88	37,755	20,752	100	37,755	20,752	100	20,752	1,674	12,451
1203 Foot deodorant sprays	6	176	167	95	185	176	100	176	14	106
1204 Feminine hygiene deodorants	4	66	32	95	69	34	100	34	3	20
1299 Other deod/antiperspirants	5	345	81	95	363	85	100	85	7	51
All Deod/Antiperspirants	231	62,706	29,928		62,736	29,943		29,943	2,415	17,966

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
Fragrance Products										
1301 Colognes	357	10,217	8,461	95	10,755	8,906	100	8,906	718	5,344
1302 Perfumes	139	174	153	95	183	161	100	161	13	97
1303 Toilet waters	105	902	807	95	949	849	100	849	68	509
1304 After shave treatments	181	10,619	5,987	95	11,178	6,302	100	6,302	508	3,781
1305 Body fragrance sprays	37	1,728	1,562	95	1,819	1,644	100	1,644	133	986
1306 Bath oils, beads and capsules	72	9,649	153	95	10,157	161	5	8	1	5
1399 Other fragrance products	98	3,582	741	95	3,771	780	100	780	63	468
All Fragrance Products	989	36,871	17,864		38,812	18,803		18,650	1,504	11,190
Powders										
1401 Baby powders	27	87,535	10	95	92,142	11	100	11	1	7
1402 Body powders	65	3,418	17	95	3,598	18	100	18	1	11
1403 Foot powders	14	4,226	2,497	95	4,448	2,628	100	2,628	212	1,577
1499 Other powder products	60	2,389	847	95	2,515	892	100	892	72	535
All Powder Products	166	97,568	3,371		102,703	3,549		3,549	286	2,130

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
Nail Care Products										
1501 Polishes	42	2,642	1,467	95	2,781	1,544	100	1,544	125	926
1502 Base coats, undercoats	32	552	419	95	581	441	100	441	36	265
1503 Polish removers	45	7,669	5,973	95	8,073	6,287	100	6,287	507	3,772
1504 Nail extenders	5	11	0	95	12	0	100	0	0	0
1505 Cuticle softeners	13	104	0	95	109	0	10	0	0	0
1506 Manicure preparations	11	53	0	95	56	0	100	0	0	0
1599 Other nail care products	46	1,077	823	95	1,134	866	100	866	70	520
All Nail Care Products	194	12,108	8,682		12,746	9,138		9,138	737	5,483
Facial and Body Treatments										
1601 Astringents	110	14,785	5,449	95	15,563	5,736	100	5,736	463	3,442
1602 Creams, scrubs, cleaners	336	23,673	286	95	24,919	301	10	30	2	18
1603 Rouges and blushes	70	1,144	10	95	1,204	11	100	11	1	7
1604 Foundations & fixatives	182	3,973	122	95	4,182	128	100	128	10	77
1605 Lipsticks	194	905	3	95	953	3	100	3	0	2
1606 Moisturizers	356	13,679	90	95	14,399	95	100	95	8	57
1607 Skin lighteners	8	255	17	95	268	18	100	18	1	11

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pet)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
1608 Facial masques	82	1,477	8	95	1,555	8	100	8	1	5
1610 Mascara	65	907	122	95	955	128	100	128	10	77
1611 Eyeliner	34	129	11	95	136	12	100	12	1	7
1612 Eye shadow	44	399	6	95	420	6	100	6	0	4
1613 Eye makeup remover	32	484	0	95	509	0	100	0	0	0
1614 Eyebrow pencil	17	55	0	95	58	0	100	0	0	0
1615 Hand and body lotions	192	55,068	311	95	57,966	327	100	327	26	196
1616 Skin protectants	47	11,710	136	95	12,326	143	100	143	12	86
1617 Depilatories	12	1,488	6	95	1,566	6	10	1	0	1
1618 Self-tanning preparations	20	841	28	95	885	29	100	29	2	17
1619 Suntan oils and lotions	51	1,500	47	95	1,579	49	100	49	4	29
1620 Sunscreens	81	4,126	123	95	4,343	129	100	129	10	77
1699 Other facial/body treatments	111	2,943	235	95	3,098	247	100	247	20	148
All Facial/Body Treatments	2,044	139,541	7,010		146,884	7,376		7,100	573	4,261

Oral Care Products

1701 Mouthwashes	60	123,082	23,932	77	159,847	31,081	5	1,554	125	932
1702 Breath fresheners	10	588	386	95	619	406	5	20	2	12
1703 Toothpastes, etc.	42	85,055	1,083	95	89,532	1,140	5	57	5	34

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
1704 Plaque removal solutions	11	31,279	2,111	95	32,925	2,222	5	111	9	67
1705 Fluoride rinses	10	8,744	562	95	9,204	592	5	30	2	18
1706 Dental care products	19	3,675	33	95	3,868	35	5	2	0	1
1799 Other oral care products	21	1,031	25	95	1,085	26	5	1	0	1
All Oral Care Products	173	253,454	28,132		297,080	35,502		1,775	143	1,065
Health Use Products (External Only)										
1801 Over-the-counter drugs	302	41,205	3,989	95	43,374	4,199	100	4,199	339	2,519
1802 Prescription pharmaceuticals	96	2,397	412	95	2,523	434	100	434	35	260
1899 Other health use products	150	9,960	1,538	95	10,484	1,619	100	1,619	131	971
All Health Use Products	548	53,562	5,939		56,381	6,252		6,252	504	3,750
Miscellaneous Personal Care Products										
1901 Hand cleaners and soaps	497	458,559	13,115	75	611,412	17,487	5	874	70	524
1902 Rubbing alcohol	30	35,230	23,027	95	37,084	24,239	100	24,239	1,955	14,543
1903 Shaving creams, gels, etc.	95	46,550	1,842	97	47,990	1,899	5	95	8	57
1999 Other misc. personal care	167	113,425	3,862	95	119,395	4,065	100	4,065	328	2,439
All Misc Pers Care Prod	789	653,764	41,846		815,881	47,690		29,273	2,361	17,563

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
HOUSEHOLD PRODUCTS										
Hard Surface Cleaners										
2101 General purpose cleaners	1,176	476,656	25,425	90	529,618	28,250	5	1,413	114	848
2102 Glass cleaners	455	206,322	14,688	95	217,181	15,461	100	15,461	1,247	9,277
2103 Oven cleaners	127	27,177	1,734	95	28,607	1,825	100	1,825	147	1,095
2104 Tub, tile, and sink cleaners	226	54,161	2,576	95	57,012	2,712	50	1,356	109	814
2105 Mildew removers	21	18,805	15	100	18,805	15	100	15	1	9
2106 Toilet bowl cleaners	202	55,364	189	100	55,364	189	5	9	1	5
2107 Rust stain removers	34	3,337	1	100	3,337	1	100	1	0	1
2108 Metal cleansers	316	20,303	1,458	100	20,303	1,458	100	1,458	118	875
2109 Soap scouring pads	11	12,233	93	100	12,233	93	100	93	8	56
2199 Other hard surface cleaners	945	226,340	5,874	100	226,340	5,874	5	294	24	176
All Hard Surface Cleaners	3,513	1,100,698	52,053		1,168,800	55,878		21,925	1,768	13,156
Laundry Products										
2201 Detergents	274	2,289,441	41,027	81	2,826,470	50,651	1	507	41	304
2202 Soaps	13	20,535	1	73	28,130	1	1	0	0	0

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
2203 Presoaks	14	3,263	17	73	4,470	23	1	0	0	0
2204 Prewash spot removers	68	63,484	2,527	73	86,964	3,462	25	866	70	520
2205 Bleaches	79	809,638	714	58	1,395,928	1,231	1	12	1	7
2206 Whiteners/brighteners	17	16,229	16	73	22,232	22	1	0	0	0
2207 Bluing	2	161	0	73	221	0	1	0	0	0
2208 Fabric softeners	111	436,397	6,022	75	581,863	8,029	1	80	6	48
2209 Water conditioners	20	39,658	10	73	54,326	14	1	0	0	0
2210 Starches, sizings, etc.	36	92,813	4,404	73	127,141	6,033	100	6,033	487	3,620
2299 Other laundry products	53	22,837	1,284	73	31,284	1,759	1	18	1	11
All Laundry Products	687	3,794,456	56,022		5,159,029	71,225		7,516	606	4,510
Fabric and Carpet Care Products										
2301 Carpet cleaners	314	42,843	1,529	100	42,843	1,529	50	765	62	459
2302 Carpet deodorizers	64	21,458	222	100	21,458	222	100	222	18	133
2303 Upholstery cleaners	30	2,065	197	100	2,065	197	100	197	16	118
2304 Spot removers	192	5,103	984	100	5,103	984	100	984	79	590
2305 Fabric stain repellants	66	4,886	1,042	95	5,143	1,097	100	1,097	88	658
2306 Water repellants	7	205	3	50	410	6	100	6	0	4
2307 Fabric dyes	4	33	0	100	33	0	5	0	0	0

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pet)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
2308 Antistatic sprays	35	106	22	50	212	44	100	44	4	26
2309 Dry cleaning fluids	12	1,690	1,630	100	1,690	1,630	100	1,630	131	978
2399 Other fabric/carpet care	82	2,999	154	100	2,999	154	100	154	12	92
All Fabric/Carpet Care	806	81,388	5,783		81,956	5,863		5,099	411	3,058

Dishwashing Products

2401 Dish detergents (manual)	226	497,400	22,708	78	637,692	29,113	5	1,456	117	874
2402 Dish detergents (machine)	120	303,994	3,370	79	384,803	4,266	2	85	7	51
2403 Rinse aids	71	6,554	88	73	8,978	121	1	1	0	1
2404 Film and spot removers	16	361	1	73	495	1	1	0	0	0
2499 Other dishwashing products	42	1,790	4	73	2,452	5	1	0	0	0
All Dishwashing Products	475	810,099	26,171		1,034,420	33,506		1,542	124	926

Waxes and Polishes

2501 Furniture waxes and polishes	186	30,314	3,406	95	31,909	3,585	100	3,585	289	2,151
2502 Floor waxes and polishes	631	154,969	3,667	95	163,125	3,860	100	3,860	311	2,316
2503 Dusting aids	110	3,627	559	90	4,030	621	100	621	50	373
2599 Other waxes and polishes	74	19,391	501	90	21,546	557	100	557	45	334
All Waxes and Polishes	1,001	208,301	8,133		220,610	8,623		8,623	695	5,174

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
Air Fresheners										
2601 Room air fresheners	376	114,686	25,410	95	120,722	26,747	100	26,747	2,157	16,048
2602 Toilet deodorant blocks	56	7,246	6,648	75	9,661	8,864	50	4,432	357	2,659
2699 Other air fresheners	146	9,824	1,916	90	10,916	2,129	100	2,129	172	1,277
All Air Fresheners	578	131,756	33,974		141,299	37,740		33,308	2,686	19,984
Shoe and Leather Care Products										
2701 Leather treatments	21	287	101	100	287	101	100	101	8	61
2703 Shoe polishes	7	243	43	50	486	86	100	86	7	52
2799 Other leather care products	14	235	85	75	313	113	100	113	9	68
All Shoe & Leather Care	42	765	229		1,086	300		300	24	181
Miscellaneous Household Products										
2801 Lubricants	253	6,500	1,641	50	13,000	3,282	100	3,282	265	1,969
2802 Drain openers	80	18,278	386	100	18,278	386	1	4	0	2
2803 Charcoal lighters	16	86,340	35,653	90	95,933	39,614	10	3,961	319	2,377
2804 Wick lamp fuels	21	7,716	5,963	90	8,573	6,626	10	663	53	398

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
2805 Plant leaf cleaners and waxes	7	53	6	100	53	6	100	6	0	4
2806 Driveway cleaners	17	216	3	90	240	3	100	3	0	2
2899 Other misc. HH products	195	21,299	5,031	90	23,666	5,590	100	5,590	451	3,354
All Misc Household Prod	589	140,402	48,683		159,743	55,507		13,509	1,089	8,106

AUTOMOTIVE AFTERMARKET PRODUCTS

Detailing Products

3101 Waxes, polishes, sealers	271	15,954	3,924	95	16,794	4,131	100	4,131	333	2,479
3102 Vinyl and leather cleaners	43	1,163	157	95	1,224	165	100	165	13	99
3103 Upholstery fabric cleaners	34	2,707	226	95	2,849	238	100	238	19	143
3104 Tire cleaners	66	5,089	383	90	5,654	426	100	426	34	256
3105 Wheel cleaners	41	2,703	142	90	3,003	158	100	158	13	95
3106 Bug and tar removers	44	1,327	858	95	1,397	903	100	903	73	542
3107 Chrome cleaners, polishes	16	528	103	95	556	108	100	108	9	65
3108 Rubber and vinyl protectants	65	2,851	1,101	95	3,001	1,159	100	1,159	93	695
3199 Other detailing products	226	16,846	1,622	90	18,718	1,802	100	1,802	145	1,081
All Auto Detailing Products	806	49,168	8,516		53,196	9,090		9,090	733	5,455

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
Maintenance and Repair Products										
3201 Engine degreasers	175	17,518	10,506	98	17,876	10,720	25	2,680	216	1,608
3202 Carburetor, choke cleaners	140	12,704	11,159	95	13,373	11,746	50	5,873	474	3,524
3203 Brake cleaners	93	15,219	3,772	95	16,020	3,971	100	3,971	320	2,383
3204 Brake anti-squeal compounds	19	281	18	95	296	19	100	19	2	11
3205 Tire sealants and inflators	20	10,956	3,260	100	10,956	3,260	100	3,260	263	1,956
3206 Belt dressings	34	337	54	100	337	54	100	54	4	32
3207 Engine starting fluids	32	4,592	4,099	90	5,102	4,554	50	2,277	184	1,366
3208 Lubricants (exc engine oil)	482	70,325	17,342	100	70,325	17,342	100	17,342	1,399	10,405
3209 Antifreezes	49	217,527	0	90	241,697	0	100	0	0	0
3210 Brake fluids	28	27,033	5,468	90	30,037	6,076	100	6,076	490	3,646
3211 Body repair (exc coatings)	99	11,171	472	90	12,412	524	100	524	42	314
3212 Windshield deicers	46	3,944	2,031	100	3,944	2,031	100	2,031	164	1,219
3213 Windshield washer fluids	84	128,913	48,313	60	214,855	80,522	100	80,522	6,494	48,313
3299 Other repair products	599	58,863	39,356	90	65,403	43,729	100	43,729	3,527	26,237
All Auto Maint/Rep Prod	1,900	579,383	145,850		702,633	184,548		168,358	13,577	101,014

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pet)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
ADHESIVES AND SEALANTS										
Consumer Adhesives										
4101 Household glues and pastes	41	12,312	287	90	13,680	319	100	319	26	191
4102 Arts and crafts adhesives	37	2,780	481	90	3,089	534	100	534	43	320
4103 Carpet and tile adhesives	95	72,345	4,365	90	80,383	4,850	100	4,850	391	2,910
4104 Wallpaper adhesives	6	2,103	3	90	2,337	3	100	3	0	2
4105 Woodworking glues	42	21,745	571	90	24,161	634	100	634	51	380
4106 Pipe cements and primers	29	5,896	5,049	90	6,551	5,610	100	5,610	452	3,366
4107 Thread locking compounds	14	2,493	7	90	2,770	8	100	8	1	5
4108 Automotive adhesives	121	52,060	1,937	90	57,844	2,152	100	2,152	174	1,291
4109 Construction adhesives	166	138,965	28,367	90	154,406	31,519	100	31,519	2,542	18,911
4199 Other adhesives	540	102,249	19,781	90	113,610	21,979	100	21,979	1,773	13,187
All Consumer Adhesives	1,091	412,948	60,848		458,831	67,608		67,608	5,452	40,563
Sealants										
4201 Spackling compounds	19	20,551	9	90	22,834	10	100	10	1	6
4202 Caulking compounds	132	75,689	2,340	90	84,099	2,600	100	2,600	210	1,560

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
4203 Window glazing compounds	33	16,275	237	90	18,083	263	100	263	21	158
4204 Pipe thread sealants	18	1,238	16	90	1,376	18	100	18	1	11
4205 Plumbers putties	1	443	0	90	492	0	100	0	0	0
4206 Painters putties	1	2	0	90	2	0	100	0	0	0
4207 Wood fillers	24	2,395	635	90	2,661	706	100	706	57	424
4208 Insulating and sealing foams	14	5,176	8	90	5,751	9	100	9	1	5
4209 Driveway patch compounds	48	3,108	137	90	3,453	152	100	152	12	91
4210 Cold process roof cements	38	3,633	1,220	90	4,037	1,356	100	1,356	109	814
4299 Other sealants	343	51,459	2,753	90	57,177	3,059	100	3,059	247	1,835
All Sealants	671	179,969	7,355		199,965	8,173		8,173	659	4,904
FIFRA-REGULATED PRODUCTS										
Insecticides										
5101 Lawn and garden insecticides	276	57,946	6,599	75	77,261	8,799	100	8,799	710	5,279
5102 Space insecticides, foggers	167	23,283	3,480	95	24,508	3,663	100	3,663	295	2,198
5103 Flying insect sprays	151	15,920	5,465	95	16,758	5,753	100	5,753	464	3,452
5104 Residual insecticides	256	43,950	16,320	95	46,263	17,179	100	17,179	1,385	10,307
5105 Hornet and wasp sprays	69	4,385	1,206	95	4,616	1,269	100	1,269	102	761
5106 Flea and tick products	117	11,306	2,602	95	11,901	2,739	100	2,739	221	1,643

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
5199 Other insecticides	339	94,480	16,039	90	104,978	17,821	100	17,821	1,437	10,693
All Insecticides	1,375	251,270	51,711		286,285	57,223		57,223	4,615	34,333
Fungicides & Nematicides										
5201 Lawn and garden treatments	62	3,833	381	90	4,259	423	100	423	34	254
5202 Wood preserv. (AIM)	0	0	0	100	0	0	100	0	0	0
5203 Mold and mildew retardants	7	440	23	100	440	23	100	23	2	14
5299 Other fungicides/nematicides	101	64,597	23,312	90	71,774	25,902	100	25,902	2,089	15,541
All Fungicides/Nematicides	170	68,870	23,716		76,473	26,348		26,348	2,125	15,809
Herbicides										
5301 Aquatic herbicides	16	13,814	15	90	15,349	17	5	1	0	1
5302 Swimming pool algicides	42	9,352	183	90	10,391	203	5	10	1	6
5303 Herbicides, defoliants	400	328,636	43,143	100	328,636	43,143	100	43,143	3,479	25,886
5399 Other herbicides	63	86,289	20,164	100	86,289	20,164	100	20,164	1,626	12,098
All Herbicides	521	438,091	63,505		440,665	63,527		63,318	5,106	37,991

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
Antimicrobial Agents										
5401 Sanitizers	161	65,585	1,559	100	65,585	1,559	50	780	63	468
5402 Disinfectants	644	364,103	28,651	99	367,781	28,940	50	14,470	1,167	8,682
5403 Sterilants	20	13,597	2,373	90	15,108	2,637	75	1,978	160	1,187
5499 Other antimicrobial agents	96	8,876	344	100	8,876	344	75	258	21	155
All Antimicrobial Agents	921	452,161	32,927		457,350	33,480		17,486	1,410	10,492
Other FIFRA-Regulated Products										
5501 Insect repellants	69	10,183	7,951	99	10,286	8,031	100	8,031	648	4,819
5502 Cat and dog repellants	20	1,323	168	100	1,323	168	100	168	14	101
5503 Rodent poisons and baits	31	3,148	12	100	3,148	12	100	12	1	7
5599 Misc other FIFRA products	116	43,054	29,853	100	43,054	29,853	100	29,853	2,408	17,912
All Other FIFRA Products	236	57,708	37,984		57,811	38,064		38,064	3,070	22,839
COATINGS AND RELATED PRODUCTS (Except Architectural and Industrial Maintenance Coatings)										
Aerosol Spray Paints										
6101 Nonflat enamels	168	54,694	40,414	100	54,694	40,414	100	40,414	3,259	24,248

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
6102 Flat enamels	67	15,432	8,514	100	15,432	8,514	100	8,514	687	5,108
6103 Nonflat lacquers	85	9,919	8,054	100	9,919	8,054	100	8,054	650	4,832
6104 Flat lacquers	45	2,092	1,651	100	2,092	1,651	100	1,651	133	991
6105 Metallic pigmented coatings	90	6,039	5,065	100	6,039	5,065	100	5,065	408	3,039
6106 Clear coatings	111	4,251	3,643	100	4,251	3,643	100	3,643	294	2,186
6107 Traffic marking coatings	47	5,348	3,323	100	5,348	3,323	100	3,323	268	1,994
6108 Exact match auto paints	29	1,956	1,487	100	1,956	1,487	100	1,487	120	892
6109 Vinyl/fabric coatings	5	255	214	100	255	214	100	214	17	128
6110 Glass coatings	5	681	14	100	681	14	100	14	1	8
6111 Automotive sanding primers	50	3,587	2,840	100	3,587	2,840	100	2,840	229	1,704
6112 Rust-inhibitive primers	107	5,075	3,706	100	5,075	3,706	100	3,706	299	2,224
6113 Spatter finishes	7	1,014	628	100	1,014	628	100	628	51	377
6114 Wood stains	11	1,659	222	100	1,659	222	100	222	18	133
6115 Engine enamels	44	3,619	2,967	100	3,619	2,967	100	2,967	239	1,780
6116 High temperature coatings	38	2,273	1,900	100	2,273	1,900	100	1,900	153	1,140
6199 Other aerosol spray paints	255	13,447	3,702	100	13,447	3,702	100	3,702	299	2,221
All Aerosol Spray Paints	1,164	131,341	88,344		131,341	88,344		88,344	7,125	53,005

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
Coating-Related Products										
6201 Paint thinners (non-auto)	52	14,093	14,061	90	15,659	15,623	100	15,623	1,260	9,374
6202 Paint removers	214	14,335	5,333	90	15,928	5,926	100	5,926	478	3,556
6203 Brush cleaners	14	434	370	90	482	411	100	411	33	247
6204 Packaged solvents	346	41,705	31,115	90	46,339	34,572	100	34,572	2,788	20,743
6299 Other related products	157	22,107	3,721	90	24,563	4,134	100	4,134	333	2,480
All Coating Related Prod	1,083	92,674	54,600		102,971	60,666		60,666	4,892	36,400
MISCELLANEOUS PRODUCTS (Not Otherwise Covered)										
Arts and Crafts Supplies										
7101 Artists paints, thinners	16	1,017	577	90	1,130	641	100	641	52	385
7102 Fixative sprays	6	143	87	90	159	97	100	97	8	58
7103 Specialty cleaning products	43	1,182	643	90	1,313	714	100	714	58	428
7104 Ceramic finishing products	15	393	19	90	437	21	100	21	2	13
7199 Other arts and crafts supplies	36	2,209	526	90	2,454	584	100	584	47	350
All Arts & Crafts Supplies	116	4,944	1,852		5,493	2,057		2,057	166	1,234

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
Non-Pesticidal Veterinary and Pet Products										
7201 Animal drugs (external only)	67	15,399	256	100	15,399	256	100	256	21	154
7202 Animal grooming products	49	1,621	126	100	1,621	126	100	126	10	76
7203 Cat litters	9	191,761	262	60	319,602	437	100	437	35	262
7299 Other vet and pet products	95	5,810	37	100	5,810	37	100	37	3	22
All Pet/Vet Products	220	214,591	681		342,432	856		856	69	514
Pressurized Food Products										
7302 Pan sprays	35	9,408	2,584	95	9,903	2,720	100	2,720	219	1,632
7303 Whipped dessert toppings	9	6,837	107	90	7,597	119	100	119	10	71
7399 Other pressurized products	2	142	0	90	158	0	100	0	0	0
All Pressurized Food Prod	46	16,387	2,691		17,658	2,839		2,839	229	1,703
Office Supplies										
7401 Pens	26	5,931	16	25	23,724	64	100	64	5	38
7402 Ink	7	32	2	25	128	8	100	8	1	5
7403 Permanent markers	17	603	14	25	2,412	56	100	56	5	34

TABLE 2-1 RESULTS OF THE CONSUMER PRODUCTS SURVEY (Continued)

Product Category	Products Reported (Number)	Product Sales Reported (Tons)	RVOC Content Reported (Tons)	Estimated Market Coverage (Percent)	Adjusted Product Sales (Tons)	Adjusted RVOC Content (Tons)	RVOC Content Emitted (Pct)	RVOC Emitted in U.S. (Tons)	Emissions per 10,000 Persons (Pounds)	Emissions Nonattain Areas (Tons)
7404 Dry erasable markers	4	76	0	25	304	0	100	0	0	0
7405 Highlighters	7	478	2	25	1,912	8	100	8	1	5
7406 Correction fluids	1	0	0	25	0	0	100	0	0	0
7408 Inked ribbons	1	307	0	25	1,228	0	100	0	0	0
7499 Other office supplies	13	1,426	692	25	5,704	2,768	100	2,768	223	1,661
All Office Supplies	76	8,853	726		35,412	2,904		2,904	234	1,743
ALL SURVEYED CATEGORIES	24,005	11,249,164	1,133,431		13,621,483	1,262,014		995,352	80,270	597,209

Notes on Results of the Consumer Products Survey

- Reportable volatile organic compounds (RVOC's) are a subset of VOC's (EPA's definition of VOC can be found in 57 FR 3941, February 3, 1992). RVOC's are those VOC's which have a vapor pressure greater than 0.1 mm Hg at 20°C or which, if the vapor pressure is unknown, contain 12 or less carbon atoms. Those VOC's which exist as solids at 20°C and readily sublime are also RVOC's.
- Figures for *Products Reported*, *Product Sales Reported*, and *RVOC Content Reported* were obtained directly from the survey responses.
- Estimated Market Coverage* information was obtained from CSMA, CTFA, and SDA.
- Adjusted Product Sales* and *Adjusted RVOC Content* were obtained by dividing *Product Sales Reported* and *RVOC Content Reported* by *Estimated Market Coverage*.
- Percent RVOC Content Emitted* is based on information submitted by CSMA, CTFA, and SDA. This factor accounts for biodegradation or other fates (other than being emitted to the air) of consumer product RVOC's which enter the wastewater stream.
- RVOC Emitted in U.S.* was obtained by multiplying *Adjusted RVOC Content* by *Percent RVOC Content Emitted* and reflects actual RVOC emissions to the air.
- Emissions per 10,000 Persons* was obtained by dividing *RVOC Emitted in U.S.* by the U.S. population (248 million) and multiplying by 10,000.
- Emissions in Ozone Nonattainment Areas* was obtained by multiplying *RVOC Emitted in U.S.* by 0.60, which is the fraction of U.S. population living in ozone nonattainment areas (148 million / 248 million = 0.5968 ≈ 0.60).

2.4.2.2 *Distribution of Products of Various VOC Contents within Categories*

In order for the EPA to assess the availability of lower-VOC alternatives, histograms were prepared for individual product categories which show the distribution of market share (by tons of product sold) at various levels of VOC content. On these histograms, tons of product sold is plotted against RVOC content levels in 5 percent increments. By examining the histograms, the EPA can identify the distribution of high-VOC and low-VOC products and can use this information to assess the possible emission reductions which could be obtained from a given VOC limit. This information can also enable the EPA to determine (for a given category) to what extent lower-VOC alternatives are accepted by consumers.

In addition to the histograms discussed above, graphs were prepared for each product category which present the cumulative tons of product sold versus the percent of RVOC content. Because of space limitations, these histograms and graphs are not presented in this report but can be used in the regulatory phase.

2.4.2.4 *Formulations of Consumer Products*

Another useful output of the survey is a compilation of formulations for every product reported. Except in the confidential files of survey responses, the formulations are not identified by product brand name or manufacturer. To further protect the confidentiality of the formulation data, the products are presented in descending order of RVOC content within each category. This compilation is quite voluminous; for example, there were over 1,100 individual formulations of aerosol spray paints reported. Consequently, these formulations could not be included in this report, but can be used during the regulatory phase.

2.4.2.4 *RVOC Ingredients of Consumer Products*

Another important output of the survey is information on individual chemical species contained in consumer products. This information will allow the EPA to identify those products

which contain highly reactive compounds and/or compounds which are considered to be hazardous air pollutants.

Although methylene chloride and 1,1,1 trichloroethane are not defined as VOC's by the EPA, these compounds are of interest to the EPA. Therefore, respondents to the survey were required to report the amounts of these compounds used as ingredients in their products. However, these compounds were not counted as RVOC's, and Table 2-1 does not present them as RVOC emissions.

Due to the large volume, information on specific ingredients is not included in this report.

2.5 REFERENCES

1. Letter from D. Fratz, Chemical Specialties Manufacturers Association, to B. Moore, U.S. EPA, Office of Air Quality Planning and Standards, Comments on raw survey data concerning compounds reported, percent VOC emitted, and market share reporting, March 25, 1994.
2. Letter from J. Graf, Cosmetic, Toiletry, and Fragrance Association, to B. Moore, U.S. EPA, Office of Air Quality Planning and Standards, Comments concerning percent VOC emitted and market share reporting, May 6, 1994.
3. Letter from R. Sedlak, Soap and Detergent Association, to B. Moore, U.S. EPA, Office of Air Quality Planning and Standards, Comments on percent VOC emitted and market share reporting, May 16, 1994.
4. Letter from D. Fratz, Chemical Specialties Manufacturers Association, to B. Moore, U.S. EPA, Office of Air Quality Planning and Standards, Further comments concerning compounds reported and percent VOC emitted, June 27, 1994.
5. Letter from R. Sedlak, Soap and Detergent Association, to B. Moore, U.S. EPA, Office of Air Quality Planning and Standards, Further comments on percent VOC emitted from laundry and dishwashing products, August 8, 1994.

3.0 PRODUCTS AFFECTED BY EXISTING OR ONGOING FEDERAL REGULATORY PROGRAMS

3.1 INTRODUCTION

This segment of the consumer and commercial products inventory includes those products which are used industrially and are affected by existing or ongoing regulations developed by the EPA and/or by the States. These products include a wide range of surface coatings, metal cleaning solvents, adhesives, inks, agricultural pesticides, asphalt paving materials, and a host of others. Estimates of VOC emissions from these products were obtained from background documentation developed for the respective regulations or guidance documents. Emission estimates for previously regulated categories are based on "residual" emissions (i.e., emissions which continue after controls have been applied). Estimates for categories associated with ongoing standards development are 1990 "baseline" emission estimates from those categories (i.e, emissions before any controls have been applied).

The purpose of this inventory study was to develop estimates of VOC emissions in ozone nonattainment areas. Accordingly, the estimates presented in this report reflect nonattainment area emissions. For many of the industrial products discussed in this section, estimates were developed based on actual locations of emission sources, and include only those emissions in nonattainment areas. For categories for which specific locations of sources are unknown, the scaling method discussed in Section 1.4.2 was used to apportion emissions based on population distribution.

Table 3-1 presents a summary of VOC emissions in nonattainment areas attributable to industrial products and activities subject to §183(e) for which Federal regulatory programs are existing or under development.

TABLE 3-1

**VOC EMISSIONS IN NONATTAINMENT AREAS
FOR PRODUCTS AFFECTED BY EXISTING OR ONGOING
REGULATORY PROGRAMS**

Category	Nonattainment Emissions (tons/yr)	Year of Estim	Ref	Federal Control Measure
Architect & indust maint coatings	315,000 ^a	1990	1	B ^b
Automobile refinishing products	55,000 ^a	1990	2	A ^b
Aerospace paints and coatings	107,500	1990	3	M ^b
Wood furniture coatings	60,000	1990	4	M ^b
Ship and boat coatings	15,100	1990	5	A, M ^b
Metal furniture coatings	63,000 ^a	1985	6	C, N
Flat wood paneling coatings	20,000 ^a	1985	6	C
Large appliance coatings	15,600 ^a	1985	6	C, N
Magnet wire coatings	4,800 ^a	1985	6	C
Metal can coatings	45,000 ^a	1985	6	C, N
Metal coil coatings	21,600 ^a	1985	6	C, N
Other metal product coatings	218,400 ^a	1985	6	C
Auto and light truck assy coatings	75,000	1990	6	C, N
Paper, film, and foil coatings	65,000	1985	6	C, N
Magnetic tape coatings	5,500	1990	6	C, N
Business mach plastic part coating	5,500	1990	6	C ^b , N
Automotive plastic part coatings	16,500	1990	6	C ^b
Flexible packaging printing	150,000	1990	6	C, N
Rotogravure publication printing	20,000	1990	6	C, N
Lithographic printing	600,000	1990	6	C
Letterpress printing	28,200 ^a	1985	6	
Tire manufacturing cements	26,400 ^a	1985	6	C, N

TABLE 3-1
VOC EMISSIONS IN NONATTAINMENT AREAS
FOR PRODUCTS AFFECTED BY EXISTING OR ONGOING
REGULATORY PROGRAMS
(Continued)

Category	Nonattainment Emissions (tons/yr)	Year of Estim	Ref	Federal Control Measure
Miscellaneous industrial adhesives	201,600 ^a	1985	6	
Metal cleaning solvents	36,000	1990	6	C, N ^b
Industrial cleanup solvents	150,000 ^a	1990	7	A
Petroleum drycleaning solvents	54,600 ^a	1985	6	C, N
Agricultural pesticides	15,000 ^a	1987	8	A
Cutback asphalt paving materials	128,400 ^a	1985	6	C
Synthetic fiber spinning solvents	46,200 ^a	1985	6	N
Fabric coating	21,000 ^a	1985	6	C, N
Fabric printing	25,200 ^a	1985	6	C
TOTAL FOR THIS TABLE	2,611,100			

a Nonattainment area emission estimates were obtained by adjusting nationwide estimates according to the distribution of nationwide population in nonattainment areas in 1990. Estimates for categories without this footnote were developed for nonattainment areas and needed no adjustment.

$$\frac{148 \text{ million (nonattainment areas)}}{248 \text{ million (nationwide)}} = 59.68\% = 60\%$$

b Document or regulation currently being developed

A Alternative Control Techniques Document (ACT)

B Regulation requiring Best Available Controls under §183(e)

C Control Technology Guidelines Document (CTG)

N New Source Performance Standards (NSPS)

M Maximum Achievable Control Technology (MACT) Standard

3.2 CATEGORY DESCRIPTIONS AND SOURCES OF VOC EMISSIONS

3.2.1 Architectural and Industrial Maintenance Coatings ¹

The U.S. architectural and industrial maintenance (AIM) coating industry is composed of roughly 500 manufacturers. AIM coatings are used by do-it-yourself, professional, and industrial painters. AIM coatings include house paints, wood finishes, cement coatings, roof coatings, traffic paints, and industrial maintenance coatings. For purposes of regulation, AIM coatings have been further classified into numerous coating categories. These categories include:

Alkali Resistant Primers
Anti-fouling Coatings
Bituminous Coatings & Mastics
Chalkboard Resurfacers
Concrete Protective Coatings
Extreme High Durability Coatings
Flat Coatings
Flow Coatings
Graphic Arts Coatings
High Temperature Coatings
Industrial Maintenance (I/M) Coatings
Lacquer Stains
Mastic Texture Coatings
Multi-Color Coatings
Nuclear Power Plant Coatings
Pre-Treatment Wash Primers
Quick Dry Coatings
Roof Coatings
Sanding Sealers
Shellacs
Swimming Pool Coatings
Traffic Marking Paints
Waterproofing Sealers

Antenna Coatings
Anti-Graffiti Coatings
Bond Breakers
Concrete Curing Compounds
Dry Fog Coatings
Fire-Retardant/Resistive Coatings
Floor Coatings
Form Release Compounds
Heat Reactive Coatings
Impacted Immersion Coatings
Lacquers
Magnesite Cement Coatings
Metallic Pigmented Coatings
Non-Flat Coatings
Ornamental Metal Lacquers
Primers and Undercoaters
Repair/Maint Thermoplastic Coatings
Rust Preventative Coatings
Sealers
Stains
Thermoplastic Rubber Coatings
Varnishes
Wood Preservatives

3.2.2 Automobile Refinishing Products ²

The steps involved in automobile refinishing include surface preparation, coating application, and spray equipment cleaning. Each of these steps can be a source of VOC emissions. Emissions can be reduced by using waterborne surface preparation products, and by using coatings that are inherently low in VOC, such as urethanes. Emissions could also be reduced by reformulating conventional coatings to lower their VOC content. Improved transfer efficiency reduces VOC emissions by decreasing the amount of coating overspray. Gun cleaning equipment that controls evaporative losses also recirculates solvent for several cleanings to reduce solvent use.

The active ingredient in low-VOC surface preparation products is detergent rather than solvent. Low-VOC surface preparation products reportedly work as well as conventional products, but they must be allowed to remain on the surface longer before being wiped off and they require additional rubbing for thorough removal.

Emissions from coating applications can be reduced by: (1) applying coatings with lower VOC content, (2) using spray equipment that has a higher transfer efficiency so that less coating is waste, and (3) abatement.

Gun cleaning is a source of solvent emissions. Spray equipment can be cleaned manually with little to no control of evaporative emissions or with gun cleaning equipment designed to reduce solvent consumption, evaporation, and worker exposure. Solvent may be emitted from gun cleaning equipment both during actual cleaning operation (active losses) and during standby (passive losses). An estimated 60 percent reduction in VOC emissions is achieved by shops that switch from cleaning guns manually to a gun cleaner.

3.2.3 Aerospace Coatings ³

The most common coatings used are the broad categories of non-specialized primers and topcoats. There are also numerous specialty coatings ranging from temporary protective coatings to radiation effect coatings designed to shield aircraft from radar detection. Coatings are applied to aerospace vehicles and components using several methods of application. The methods most commonly used are spraying, brushing, rolling, flow coating, and dipping. Spray application systems include conventional air spray, airless spray, air-assisted airless, electrostatic, and high volume low pressure spray. Emissions from coating applications occur from the evaporation of the solvents during mixing, application, drying, and overspray.

3.2.4 Wood Furniture Coatings ⁴

Wood furniture coatings are used in the manufacture of furniture. Adhesives are used in assembling furniture components, in laminating veneers, and in installing upholstery. Solvents are used to thin coatings, to remove coatings from furniture that did not meet specifications, and to clean equipment.

Formaldehyde may be emitted from conversion varnishes, a type of coating used to finish kitchen cabinets and some office furniture. Styrene may be emitted from some ultraviolet light cured coatings and polyester coatings.

There are many low-VOC coating alternatives available. These include waterborne topcoats and sealers. Some ultraviolet light cured coatings may be 100 percent solids (no VOC). Some coatings replace some of the VOC with liquid CO₂. More efficient application methods such as high volume, low pressure spray equipment can be used to further reduce emissions.

3.2.5 Ship and Boat Coatings ⁵

Emissions from shipyard operations are primarily VOC emissions that result from painting operations. Emissions of VOC's from painting operations result in three components: (1) organic solvent in the paint "as supplied" by the paint manufacturer, (2) organic solvent in the thinner, which is added to the paint prior to application and becomes part of the paint "as applied", and (3) any additional volatile organic released during the cure. The organic solvents from both components are emitted as the applied paint dries/cures. This organic solvent portion of a paint is composed of a mixture of different solvents that perform either of two equally important functions: (1) reduce viscosity so the paint can be atomized as it leaves the spray gun, or (2) provide essential surface characteristics of the paint once it is applied. Solvents used for atomization typically have low boiling points and flash to a vapor upon leaving the spray gun. These solvents evaporate relatively quickly during initial drying to prevent excessive flow. Solvents responsible for imparting the desired surface characteristics must have higher boiling points and subsequently evaporate more slowly than atomizing solvents to allow sufficient leveling and adhesion. Of the solvents used in marine paints, most are VOC's. The most significant reductions in VOC emissions would result from shipyards transitioning to reformulated coatings.

3.2.6 Metal Furniture Coatings ⁶

Metal furniture coating consists of the application of prime and top coatings to any piece of metal furniture or metal part included in the categories of household furniture, office furniture, public building and related furniture, and partitions and fixtures. Typically, the metal substrate is first cleaned, rinsed in a phosphate bath, and oven-dried to improve coating adhesion. If a prime coat is necessary, the part may be dipped, sprayed, or flow coated and then dried in a curing oven. Subsequent topcoats, or in the event no prime is required, the single topcoat is usually by spray. The freshly coated parts are conveyed to the oven through a flash-off tunnel during which the coating "flows

out" to a uniform thickness and some of the solvent evaporates. The parts are baked in single or multi-pass ovens at 150-230°C.

There are approximately 1400 known domestic metal furniture coating plants, including 445 for household and 253 for office furniture. There are likely several hundred more that custom manufacture, finish, or refinish metal furniture that have not yet been identified.

Specific emission sources on the coating line are the coating application, the flash-off area, and the bake oven. On the average conveyORIZED spray coating line, it is estimates that about 40 percent of the total VOC emissions come from the application station, 30 percent from the flash-off area, and 30 percent from the bake oven. In addition, fugitive emissions also occur during mixing and transfer of coatings.

Control techniques used by this industry include converting to low-solvent coatings, improving transfer efficiency with state-of-the-art application equipment or incineration. Adoption of high-solids or waterborne coatings can reduce VOC emissions from prime-coating operations by 70 and 92 percent, respectively. Conversion to an electrodeposition prime coat can reduce emissions by 94 percent. Emissions from topcoats can be reduced by conversion to waterborne, high-solids, or powder coatings, giving reductions of up to 80 percent, 70 percent, and 99 percent, respectively.

3.2.7 Flat Wood Paneling Coatings ⁶

A typical flat wood coating facility applies stains and varnishes to natural plywood panels used for wall coverings. Other plants print wood grain patterns on particle board panels that were first undercoated with an opaque coating to mask the original surface. Coatings applied to flat wood paneling include fillers, sealers, "groove" coats, primers, stains, basecoats, inks, and topcoats. Most coatings are applied by direct roll coating. Filler is usually applied by reverse roll coating. The offset rotogravure process is used

where the coating and printing operation requires precision printing techniques. Other coating methods include spray techniques, brush coating, and curtain coating. A typical flat wood paneling coating line includes a succession of coating operations. Each individual operation consists of the application of one or more coatings followed by a heated oven to cure the coatings. A typical production line begins with mechanical alterations of the substrate (filling of holes, cutting of grooves, sanding, etc.), followed by the coating operations, and packaging/stacking for shipment. Approximately 60 domestic plants coat flat wood paneling.

Emission of VOC from a flat wood coating occurs primarily at the coating line, although some emissions also occur at paint mixing and storage areas. All solvent that is not recovered can be considered a potential emission.

Control techniques for flat wood panels include add-on controls, materials changes, and process changes. Conversion to waterborne coatings can lower VOC emissions by at least 70 percent. Use of low solvent coatings that cure by ultraviolet light is gaining greater acceptance and, where applicable, effects a near 100 percent reduction of VOC emissions.

3.2.8 Large Appliance Coatings ⁶

Large appliance products include kitchen ranges, ovens, microwave ovens, refrigerators, freezers, washers, dryers, dishwashers, water heaters, and trash compactors. A "large appliance surface-coating line" consists of the coating operations for a single assembly line within an appliance assembly plant. Typically, the metal substrate is first cleaned, rinsed in a phosphate bath, and oven dried to improve coating adhesion. If a prime coat is necessary, the part may be dipped, sprayed, or flow-coated and dried in a curing oven. Subsequently, the topcoat is applied, usually by spray. The fresh coated parts are conveyed through a flash-off tunnel to evaporate solvent and cause

the coating to flow out properly. After coating and flash-off, the parts are baked in single or multipass ovens at 150-230°C.

There are approximately 170 plants in the United States that manufacture large appliances.

A surface coating line has three main sources of emissions. Major emissions occur at the application (spray booth) area, flash-off area, and the curing oven. Fugitive emissions occur during mixing of coatings. Emissions from top-coat application can be reduced by use of waterborne, high-solids, or powder coatings, giving reductions of 80 percent, 70 percent, and 99 percent, respectively, from levels typical of high VOC coatings.

3.2.9 Magnet Wire Coatings ⁶

Magnet wire coating is the process of applying a coating of electrically insulating varnish or enamel to aluminum or copper wire for use in electrical machinery. The uncoated wire is unwound from spools and passed through an annealing furnace to make the wire more pliable and to burn off oil and dirt left from previous operations. The wire passes from the furnace to the coating applicator. At a typical applicator, the wire acquires a thick coating by passage through a coating bath. The wire is then drawn vertically through an orifice or coating die which scrapes off excess coating and leaves a film of the desired thickness. The wire is routed from the coating die into an oven where the coating is dried and cured. A typical oven has two zones. The wire enters the drying zone, held at 200°C, and exits through the curing zone, held at 430°C. A wire may pass repeatedly through the coating applicator and oven to build a multilayered coating. After the final pass through the oven, the wire is rewound on a spool for shipment. There are approximately 30 plants nationwide which coat magnet wire.

The oven exhaust is the most important emission source in the wire coating process. Solvent emissions from the applicator are low due to the dip coating technique. Emission reductions achieved through coating reformulations would require replacement of conventional solvent-borne coatings with either high-solids coatings (greater than 77 percent solids by volume) or waterborne coatings (i.e., 29 volume percent solids, 8 volume percent organic solvent, 63 volume percent water). Use of powder coatings, hot melt coatings, or waterborne emulsions, which contain little or no organic solvent, would eliminate VOC emissions.

3.2.10 Metal Can Coatings ⁶

There are two major types of cans. Coating application methods used by can manufacturers vary with the type of can. The coatings used depend on the type of can and the type of product to be packed in the can. A "three-piece" can is made from a cylindrical body and two end pieces. A large metal sheet is first roll coated with both an exterior and an interior coatings, then cut to size, rolled into a cylinder (body) and sealed at the side seam. A bottom end piece formed from coated metal is then attached to the body. The can interior may then be spray coated before the can is filled with a product and sealed with the top end piece. A "two-piece can body and bottom is drawn and wall ironed from a single shallow cup. After the can is formed, exterior and interior coatings are applied by roll coating and spraying techniques, respectively. The can is then filled with product and the top end piece is attached.

The metal can industry consists of over 400 plants nationwide. In recent years there has been a dramatic shift from three-piece cans to two-piece cans. Almost all beverage cans and many food cans are now two-piece.

Solvent emissions from can coating operations occur from the application area, flash-off area, and the curing/drying oven. Emissions vary with production rate, VOC content of coatings used, and other factors. Substitution of waterborne or high-solids

coatings for conventional coatings can reduce VOC emissions by 60 to 90 percent at many of these operations.

3.2.11 Metal Coil Coatings ⁶

The metal coil coating industry applies coatings to metal sheets or strips that come in rolls or coils. The metal strip is uncoiled at the beginning of the coating line, cleaned, and then pretreated to promote adhesion of the coating to the metal surface. When the coil reaches the coating application station, a coating is applied, usually by rollers, to one or both sides of the metal strip. Some coil coatings are applied by electrodeposition. The strip then passes through an oven to cure the coating and is then water or air quenched. If the line is a "tandem" line, the metal strip passes through a second sequence of coating applicator, oven, and quench station. Finally, the coil is rewound for shipment or further processing. In 1980, there were 109 plants containing an estimated 147 coil coating lines in the United States.

Approximately 90 percent of the total VOC content of the coating evaporates in the curing ovens. Of the remaining 10 percent, about 8 percent evaporates at the applicator station and 2 percent at the quench station. The rate at which VOC emissions occur is determined by the operating parameters of the line, including: (1) the width of the metal strip, (2) the VOC and solids content of the coating, (3) the speed at which the strip is processed, (4) the thickness at which the coating is applied, and (5) whether emission abatement equipment has been installed.

Low solvent and waterborne coatings are also available for many end uses. These coatings may achieve emission reductions of up to 90 percent compared to conventional solvent-borne materials.

3.2.12 Other Metal Product Coatings ⁶

The original equipment manufacturers discussed here have been referred to by a variety of names, including coaters of miscellaneous metal parts. The category includes hundreds of small- and medium-sized industries and their companies which coat metal parts for which more specific regulatory guidance was not published as part of the guideline series (i.e., can, coil, wire, automobile and light-duty truck, metal furniture, and large appliances). Although many products are coated by manufacturers in this category, the coating processes have many features in common. Typically, the metal substrate is first cleaned, rinsed in a phosphate bath, and oven-dried to minimize contamination and maximize coating adhesion. If a prime coat is used, it may be applied by dipping, spraying, or flow-coating. The part is then dried in a curing oven. Subsequent top coats, or if no prime is used, the single topcoat is usually applied by spray. The freshly-coated parts are often conveyed through a flash-off tunnel or room, permitting the coating to flow out to a uniform thickness. Some of the solvent will evaporate during this time. The parts are then baked in single or multi-pass ovens at 150-230°C. Large products with high mass such as large industrial, construction, and transportation equipment are usually coated with materials that will cure by air- or forced air-drying, rather than baking, since the specific heat capacity of the large mass makes raising its temperature high enough to cure a coating in an oven prohibitively expensive.

Organic emissions from coating miscellaneous metal parts and products are emitted from the application, flash-off area, and the bake oven (if used). The bulk of VOC emitted by lines which spray or flow coat, evaporates from the application and flash-off areas. For dip-coating operations, the bulk of the VOC is emitted from the flash-off area and bake oven. Fugitive emissions also occur during mixing and transfer of coatings.

Control techniques available to the industries that coat miscellaneous metal parts and products include converting to low-solvent coatings, improving transfer efficiency

with state-of-the-art application equipment, or incineration. Spray application of waterborne coatings can reduce emissions by 70 to 95 percent; use of higher solids coatings from 50 to 80 percent; and powder coatings, 95 to 98 percent. Use of electrodeposition (EDP) to apply prime coats can reduce emissions up to 94 percent over conventional coatings used for operations. Transfer efficiency is the ratio of the amount of coating solids deposited onto the surface of the coated part to the total amount of coating solids used. Improvements in transfer efficiency will decrease the volume of coating that must be sprayed to cover a specific part. Of course, the less paint used, the lower the total VOC emission rates.

3.2.13 Auto and Light Truck Assembly Coatings ⁶

The automobile and light-duty (less than 8,500 pounds gross vehicle weight) truck assembly industry receives parts from a variety of sources and produces finished vehicles ready for sale to vehicle dealers. The automobile and light-duty truck coating process is a multistep operation performed on an assembly line producing up to 90 units per hour. There were about 65 automobile or light-duty truck assembly plants in the United States in 1984.

Body surfaces to be coated are cleaned with various materials which may include solvents to remove oil and grease. Then a phosphating process prepares the surface for the prime coat. The primer is applied to protect metal surfaces from corrosion and to ensure good adhesion of the topcoat. Primer may be solvent-based or waterborne. Solvent-based primer is applied by a combination of manual and automatic spraying, flow coat or dip processes. Waterborne primer is most common now and is most often applied in an electrodeposition (EDP) bath. The prime coat is oven cured before further coating. When EDP is used to apply primer, the resulting film may be too thin and rough to compensate for all surface defects, so a guide coat (primer-surfacer) is usually applied and oven-cured before the topcoat application. Recent developments in EDP technology produce a thicker dry film which in some cases eliminates the need for the

guide coat. On some vehicles an additional coating called a chip guard or anti-chip primer is applied along the bottom of the doors and fenders. These flexible urethane or plastisol coatings help protect susceptible parts of the coated vehicle from damage by stones or gravel.

The topcoat (color) is then applied by a combination of manual and automatic spraying. The topcoat requires multiple applications to ensure adequate appearance and durability. An oven bake may follow each topcoat application, or the individual coats may be applied wet-on-wet with a final oven back.

The painted body is then taken to a trim operation area where vehicle assembly is completed. Some additional coating may be done in a final off-line repair step if needed to correct paint defects or damage.

Single coating (not clearcoated) lacquer and enamel topcoats have traditionally been used in this industry. Since 1980, the entire domestic auto industry has converted to a composite, two coating, topcoat system which consists of a thin layer of a highly pigmented basecoat followed by a thick layer of clearcoat. These two coating systems are referred to as basecoat/clearcoat. They can provide higher gloss and better chemical resistance than conventional single coating topcoats, especially for metallic colors. Some domestic manufacturers are switching all of their colors to basecoat/clearcoat while others are using basecoat/clearcoat for metallic colors only. The switch to basecoat/clearcoat was prompted by the use of basecoat/clearcoat on virtually all imported metallic colored cars.

Solvent emissions occur in the application and curing stages of the surface coating operations. The application and curing of the prime coat, guide coat, and topcoat accounted for a majority of the VOC emitted from most assembly plants in the past. Conversions to lower VOC content coatings and more efficient application equipment has reduced the contribution of these operations to total plant-wide VOC emissions at many

assembly plants. Final topcoat repair, cleanup, adhesives, sound deadeners, and miscellaneous coating sources account for the remaining emissions. Approximately 70 to 90 percent of the VOC emitted during the application and curing process is emitted from the spray booth and flash-off areas, and 10 to 30 percent from the bake oven.

Use of waterborne EDP coatings is the most common control technique for prime coats. Waterborne guide coats and topcoats have been used in three plants.

The industry and its suppliers have focused primarily on developing higher solids solvent-borne enamels and improving transfer efficiency. Most of the coating development work has been directed toward basecoat/clearcoat coatings. Low solids, high VOC content basecoat/clearcoat materials have been used since the mid-1960's, especially on metallic-colored imported cars. Higher solids basecoat/clearcoat topcoats have been developed to help meet VOC emission regulations and match the appearance of imported vehicles. These coatings are in use at many plants, including two of the plants that used waterborne topcoats. (The third plant that used waterborne topcoats has closed.)

3.2.14 Paper, Film, and Foil Coatings ⁶

Paper is coated for a variety of decorative and functional purposes with a variety of coatings which may be waterborne, organic solvent-borne, or solventless extrusion type materials. A coating operation is defined as the application of a uniform layer across a substrate. This definition of coating also includes saturation processes. In paper-coating operations, the coating mixture is usually applied by means of a reverse roller, a knife, or a rotogravure roller to a web of paper. The major components of a paper-coating line are, in sequence: the unwind roll (from which the paper is fed to the process), the coating applicator, the oven, tension and chill rolls, and the rewind roll. Ovens may be divided into from two to five different temperature zones. The first is usually maintained at about 43°C. The other zones have progressively higher

temperatures up to 200°C to cure the coating after most of the solvent has evaporated. The large volume organic solvents used in paper coating mixtures are toluene, xylene, methyl ethyl ketone, isopropyl alcohol, methanol, acetone, and ethanol. There are approximately 800 plants nationwide where paper-coating operations are employed.

The coating of pressure sensitive tapes and labels (PSTL) is an operation in which a backing material such as paper, cloth, or cellophane is coated one or more times to create a tape or label that sticks on contact. Adhesives and release agents are the two primary types of coatings applied in this industry. Essentially all of the VOC emissions from the PSTL industry come from solvent-based coatings which are used to produce 80 to 85 percent of all PSTL products.

In the solvent-based coating process, a roll of backing material is unrolled, coated, dried, and rolled up. The coating may be applied to the web by knife coater, blade coater, metering rod coater, gravure coater, reverse roll coater, or a dip and squeeze coater. After the coating has been applied, the web moves into a drying oven where the web coating is dried by solvent evaporation and/or cured to a final finish. Direct-fired ovens are the most common type used. Drying ovens are typically multizoned with a separate hot air supply and exhaust for each zone. The temperature increases from zone to zone in the direction in which the web is moving, thus the zone maintained at the highest temperature is the final zone that the web traverses before exiting the oven. A large drying/curing oven may have up to six zones ranging in temperature from 43°C to 204°C.

A tandem coating line is one in which the web undergoes a sequence of coating and drying steps without rewinding between steps. Tandem coating lines are usually employed by plants that manufacture large volumes of the same product.

Over 100 plants with a total of about 300 coating lines produce pressure sensitive tapes and labels in the United States.

The main emission points from paper-coating lines are the coating applicator and the oven. In a typical paper-coating plant, about 70 percent of all emissions are from the coating lines. The other 30 percent are emitted from solvent transfer, storage, and mixing operations. Most of the VOC emitted by the line are from the first zone of the oven.

Use of low-solvent coatings can achieve significant reductions in VOC emissions when substituted for conventional organic solvent-borne coatings. One type, waterborne, can effect an 80 to 99 percent reduction.

Fugitive emissions from solvent transfer, storage, and mixing operations can be reduced through good housekeeping practices, such as maintaining lids on mixing vessels, and good maintenance, such as repairing leaks promptly.

By definition, all PSTL products have an adhesive coating. It is generally the thickest coating applied and the source of 85 to 95 percent of the total emissions from a line. In an uncontrolled facility, essentially all of the solvent used in the coating formulation is emitted to the atmosphere. Of these uncontrolled emissions, 80 to 95 percent are emitted from the drying oven. A small fraction of the coating solvent may remain in the web after drying. The remaining 5 to 20 percent of applied solvent is lost as fugitive emissions by evaporation from a number of small sources such as the applicator system and the coated web upstream of the drying oven. Some fugitive losses also occur from storage and handling of solvent, spills, and mixing tanks, and during cleaning of equipment, such as a gravure roll.

An emission control technique is the use of low-VOC coatings such as waterborne, hot-melt, and radiation cured coatings. Emissions of VOC from such coatings are negligible.

3.2.15 Magnetic Tape Coatings ⁶

Organic solvent, metal-oxide particles, and suitable resins are combined to form the coatings used by magnetic tape coating operations. The coating equipment consists of an unwind roll for the plastic film substrate, a coating applicator, a drying oven, and a windup roll for the coated tape. The coating mixture is supplied to the plastic film substrate by the coating applicator (often via some sort of roll or rotogravure coater). The plastic film is carried through the drying oven where organic solvent evaporates. The plastic substrate with the dried magnetic coating is then rewound at the end of the line. Slitting operations to produce the consumer product are almost always performed later as an off-line operation.

Roughly 10 percent of the solvent used by a plant evaporates from mix and storage tanks. Another 10 percent evaporates from the coating applicator and the flash-off area between the coater and the oven. The remainder evaporates in the drying oven and is exhausted through the oven exhaust stack.

3.2.16 Business Machine Plastic Parts Coatings ⁶

Plastic parts for business machines are coated for several reasons. Exterior coatings are applied to improve appearance, color match, and provide chemical resistance. Metal-filled coatings are applied to interior surfaces to provide electromagnetic interference/radio frequency interference (EMI/RFI) shielding. This limits both escape and intrusion of stray electronic signals, and in many cases is required by Federal Communications Commission (FCC) regulations. Coatings are generally spray applied in this industry, using air-atomized spray equipment. Many of the conventional and lower VOC content coatings used in this industry are two-component urethane coatings.

VOC emissions from plastic parts coating occur in the spray booth flash-off area and back oven. Up to 90 percent of all VOC emissions come off in the spray booth. Substitution of waterborne or high-solids coatings for conventional coatings can reduce VOC emissions from exterior coating and EMI/RFI shielding by 60 to 80 percent.

3.2.17 Automotive Plastic Parts Coating ⁶

These coatings are used to finish interior and exterior plastic parts used in automotive and other transportation equipment. Examples include bumpers, bumper covers, body panels, dashboards, and other interior and exterior parts.

Emissions can be reduced through the use of low-VOC coatings, which appear to be readily available.

3.2.18 Flexible Packaging Printing ⁶

The image areas on the image cylinder of a flexographic press are raised above the nonimage areas. A distinguishing feature is that the image carrier is made of rubber which is attached to the cylinder. A feed cylinder which rotates in an ink fountain delivers ink to a distribution roll, which in turn transfers ink to the image cylinder. following transfer from the image cylinder to substrate, the ink dries by evaporation in a high velocity, low temperature (<120°F) air dryer. Some solvent is absorbed into the web. Typical ink solvents are alcohols, glycols, esters, hydrocarbons, and ethers. An estimates 21,400 flexographic presses were in operation in the United States in 1984.

The major emission points from a flexographic press are the ink fountains, feed cylinder, distribution roll, image cylinder, printed web, and dryer exhaust. The potential amount of VOC emissions is equal to the total amount of solvent consumed by the printing plant if none of the ink reacts to form an organic by-product. This includes the

solvent in the raw inks, solvent in any extenders used, the solvent added at the press, and clean-up solvent.

Emissions from flexographic printing operations can be reduced by improvements in the equipment for containment of the emissions from the print station and installation of an incineration system. Overall, a capture efficiency of 65 to 70 percent and a combustion efficiency of 90 percent (for an overall reduction of 60 percent) appears reasonable. Some flexographic packaging operations can now use waterborne inks. Emission reductions equal to or better than those achieved by incineration can be attained when the solvent portion of the ink consists of 75 volume percent water and 25 volume percent organic solvent (solids to liquid ratio remaining the same). Higher-solids inks with 60 percent solids are becoming available.

3.2.19 Rotogravure Publication Printing ⁶

In the rotogravure printing process, image areas are recessed relative to nonimage areas. The rotating cylinder picks up ink from an ink trough or fountain. Excess ink is scraped from the blank area by a steel doctor blade. The ink is then transferred directly as the roll contacts the web. The web is then dried in a low temperature dryer. Typical ink solvents include alcohols, aliphatic naphthas, aromatic hydrocarbons, esters, glycol ethers, ketones, and nitroparaffins. It is estimated that there were approximately 1,600 rotogravure presses in the United States in 1984.

The major emission points from a rotogravure press are the ink fountains, wet printing cylinders, wet printer web, and drier exhaust. The total amount of organic solvent consumed by the printing plant is the maximum potential VOC emission (if no reaction by-products are formed during the drying operation). This consists of solvent in the raw ink, solvent contained in any extenders used, solvent added at the press, and solvent used for cleanup. New publication rotogravure presses with good capture or containment devices can achieve better than 84 percent overall control. For some

printing operations, equivalent emission reductions may be possible through use of waterborne and/or high ink solids.

3.2.20 Lithographic Printing ⁶

Lithography is a printing process characterized by a planographic image carrier (i.e., the image and nonimage areas are on the same plane) which is mounted on a plate cylinder. The image area is made water repellant while the nonimage area is water receptive. Rotation of the plate cylinder causes the image plate to first contact an aqueous fountain solution which typically contains up to 25 weight percent isopropyl alcohol. This solution wets only the nonimage area of the plate. The image plate then contacts the ink which adhered only to the image area. In offset lithographic printing, the ink is transferred from the image plate to a rubber-covered blanket cylinder. The blanket cylinder then transfers the image to the web. Lithographic heatset inks, containing approximately 40 volume percent solvent, require a heated dryer to solidify the printed ink. Other lithographic inks, containing about 5 volume percent solvent, dry by oxidation or by absorption into the substrate.

There are approximately 400 printing plants in the United States operating over 1000 heatset web offset lithographic printing presses.

Emission points on a web-offset lithographic printing line include the ink fountains and associated inking rollers, the water fountains and associated dampening rollers, the plate and blanket cylinders, the dryer, and the final printed product. Alcohol is emitted from the dampening system and the plate and blanket cylinders at a rate of about 0.5 kilograms per kilogram of ink consumed. Wash-up solvents are a small source of emissions from the inking system and the plate and blanket cylinders. When heat-set inks are printed, the drying oven is the major source of VOC emissions with 40 to 60 percent of the ink solvent evaporating from the oven.

Two approaches for controlling VOC emissions from heat-set web offset lithographic printing presses are (1) material reformulation, and (2) add-on control. Substitution of polyols, such as ethylene glycol, for the alcohol in the aqueous fountain solution can result in a reduction of VOC emissions from fountain solutions. Ink reformulation to reduce the solvent content will reduce VOC emissions from the dryer somewhat.

3.2.21 Letterpress Printing ⁶

Letterpress is the oldest form of moveable type printing, with the image areas raised relative to the blank or nonimage areas. The image carrier may be made of metal or plastic. Viscous ink is applied to the image carrier and transferred directly to paper or other substrate. Letterpress is the dominant printing process for periodical and newspaper publishing. Newspaper ink is composed of petroleum oils and carbon black, but no volatile solvent. The ink "dries" by adsorption into the substrate. Web presses printing on nonporous substrates employ solvent-borne inks which dry by evaporation. Sheet-fed presses employ solventless inks which dry by air oxidation. There are over 10,000 commercial letterpress printing plants in the United States.

The major VOC emission points on web letterpress printing lines are the image carrier and inking mechanism of the press, the dryer, the chill rolls, and the printed product. About 60 percent of the solvent in the ink is lost in the drying process. Use of washup solvents contribute to overall VOC emissions.

Use of the ultraviolet curing inks in place of solvent-borne inks can essentially eliminate emissions. Use of heat reactive inks which contain only 15 percent of the organic solvent content of conventional inks will reduce overall emissions by 80 percent. A similar reduction is achievable with waterborne inks.

3.2.22 Tire Manufacturing Cements ⁶

In 1984, the rubber tire manufacturing industry consisted of approximately 60 plants nationwide. The tire manufacturing process generally consists of four main steps: (1) compounding of raw materials, (2) transforming the raw materials into tire components and preparing the components for assembly, (3) assembling the components (tire building), and (4) molding, curing, and finishing of the assembled components into the final product. Each of these steps is a potential source of VOC emissions.

During compounding, raw crumb rubber is combined with fillers, extenders, accelerators, antioxidants, and pigments. This mixture is then transferred to roll mills which knead the material and form it into sheets.

Tire components are made in several parallel operations. Rubber stock and other raw materials, including wire and fabric, are used to make tire tread, sidewalls, cords, belts, and beads. The major source of VOC emissions during this step is the evaporation of VOC's from solvent-based cements. Tire building is the assembly of the various tire components to form an uncured or "green" tire. The assembly takes place on a collapsible, rotating drum. Organic solvents may be applied to some tire components in this step to further "tackify" (make sticky) the rubber. Green tires are then sprayed on the inside with lubricants and on the outside with mold release agents before molding and curing in automatic presses. Curing usually takes 20 to 60 minutes at a temperature of 100°C to 200°C. The cooled tire is finished with buffing and grinding operations.

Each of the four production steps may include one or more sources of VOC emissions. Organic solvent-based green tire spraying, undertread cementing, sidewall cementing, tire building, tread end cementing, and bead cementing contribute 97 percent of the total VOC's emitted from tire production.

Emission control by either incineration or carbon adsorption is applicable to undertread cementing, sidewall cementing, automatic or manual tread end cementing, bead cementing, and green tire spraying. With an 80 percent efficient capture system, emission reductions of 75 percent can be attained for each of these processes.

In addition to add-on control technology, there are low solvent use techniques which are applicable to several processes. Limiting the amount of solvent used during tread end cementing and bead cementing can effectively reduce emissions from these sources by as much as 85 percent. VOC emissions from water-based green tire sprays are 90 to 100 percent less than emissions from organic solvent-based sprays.

3.2.23 Miscellaneous Industrial Adhesives ⁶

Adhesives are used for joining surfaces in assembly and construction of a large variety of products. Adhesives allow faster assembly speeds, less labor input, and more ability for joining dissimilar materials than other fastening methods. By far the largest use of adhesives is for the manufacture of pressure sensitive tapes and labels. Other large industrial users are automobile manufacturing (including especially attachment of vinyl roofs), packaging laminating, and construction of shoes. Adhesives may be waterborne, organic solvent-borne, or hot-melt. Only organic solvent-borne adhesives have the potential for significant VOC emissions.

Approximately 75 percent or more of all rubber-based adhesives are organic solvent-borne cements. Methods of application commonly used are brush application, spraying, dipping, felt pad application, and roller coating. Solvents used in solvent-borne adhesives include aliphatic and aromatic hydrocarbons, alcohols, and ketones.

The VOC emissions from solvent-based adhesives are a result of the evaporation of the solvents in the adhesive. Emissions arise mainly at the point of application and in many cases are swept from the area with local ventilation systems. Essentially all of the

organic solvent in an adhesive is emitted to the atmosphere as the adhesive dries.

Adhesives vary widely in composition but a typical solvent-borne adhesive might contain 80 weight percent solvent so that approximately 0.8 kg of VOC evaporates for every kg of adhesive used.

The trend in control technology for solvent adhesives is not to control emissions from a solvent-borne adhesive, but rather to replace them with a low solvent type which can perform as well as the solvent-borne adhesive. Various types of low solvent adhesive include waterborne, hot-melt, solventless two-component, and radiation-cured. VOC reductions of 80 to 99 percent can be achieved by such replacement. Hot-melt adhesives are the most widely used of these alternative processes. Use of waterborne adhesives is expected to increase significantly in the future.

3.2.24 Metal Cleaning Solvents ⁶

Solvent metal cleaning (degreasing) uses organic solvents to remove soluble impurities from metal surfaces. Organic solvents include petroleum distillates, chlorinated hydrocarbons, ketones, and alcohols. Industrial uses include solvent metals cleaning include automobiles, electronics, appliances, furniture, jewelry, plumbing, aircraft, refrigeration, business machinery, and fasteners.

Methods of solvent metal cleaning include cold cleaning, open top vapor degreasing, and conveyORIZED degreasing. Cold cleaning uses all types of solvents with the solvent maintained below its boiling point. Open top vapor degreasers use halogenated solvents heated to their boiling points. Both cold cleaners and open top vapor degreasers are batch operations. ConveyORIZED degreasers are loaded continuously and may operate as vapor degreasers or as cold cleaners.

For cold cleaners, emission sources are as follows: (1) bath evaporation, (2) solvent carry-out, (3) agitation, (4) waste solvent evaporation, and (5) spray evaporation.

Emission rates vary widely with the average emission rate estimated to be about 0.3 megagrams (.33 tons) per year per unit.

Unlike cold cleaners, open top vapor degreasers lose a relatively small proportion of their solvent in the waste material and as liquid carry-out. Most of the emissions are vapors that diffuse out of the degreaser into the work place. These fugitive emissions escape to the atmosphere through doors, windows, and exhausts. An average open top degreaser with an open top area of 1.67 m^2 (18 ft^2) has an emission rate of 4.2 kilograms (9.3 pounds) per hour or 9,500 kilograms (21,000 pounds) per year.³

Emission sources for conveyORIZED degreasers include bath evaporation, carry-out emissions, exhaust emissions, and waste solvent emissions. Carry-out emissions are the largest single source. An average emission rate for a conveyORIZED degreaser is about 25 megagrams (28 tons) per year while that for a nonboiling conveyORIZED degreaser is almost 50 megagrams (55 tons) per year.

Controls to reduce emissions from the solvent bath include the following: (1) improved cover, (2) high freeboard, (3) chilled water and refrigerated chillers, (4) carbon adsorption, and (5) safety switches. Carry-out emissions from cold cleaners can be reduced by using drainage racks and by controlling the velocity at which parts are introduced and withdrawn. Carry-out emissions from conveyORIZED degreasers are reduced by using a drying tunnel and rotating baskets.

3.2.25 Industrial Cleanup Solvents⁷

A variety of cleaning solvents are used by industry to remove contaminants such as adhesives, inks, paint, dirt, soil, oil, and grease. Parts, products, tools, machinery, equipment, vessels, floors, walls, and other work areas are cleaned for a variety of reasons including housekeeping, safety, operability, and to avoid product contamination. Solvents are used in enormous volumes and a portion evaporates during use, making

cleaning fluids a major source of emissions of VOC. Data collected by EPA show nationwide usage of VOC solvent from only six industries is about 380,000 megagrams per year (Mg/yr) (410,000 tons per year [tons/yr]). Less comprehensive data from other sources suggest total VOC solvent usage for cleaning by all U. S. industry is more than 1 million tons each year.

On average, 25 percent or more of the solvent that was used for cleaning purposes by the six industries (automotive, electrical equipment, metal furniture, photographic supplies, packaging, and magnetic tape) used for the study was lost by spillage or evaporation. This value varied significantly among industries depending on the type of cleaning performed.

All use of solvent for cleaning can be evaluated on the basis of one of only nine general types: cleaning of spray guns, spray booths, equipment, large manufactured components, small manufactured components, floors, tanks, lines, and parts. Within each group, however, there is considerable variation, including differences in cleaning techniques, soils removed, solvency, and a likely host of others.

Emission reduction techniques can be grouped into two categories - those that reduce evaporation at the source (unit operation) and those that control emissions. Actions that may reduce emissions at the source include switching to a different cleaner, reducing usage rates, and increasing collection of used solvent. Reduced usage and increased collection may be accomplished by changing work practices, modifying equipment (e.g., tools used in cleaning, solvent storage vessels, solvent dispensers), or changing a process. After the release of emissions, the only way to reduce emissions is with containment or capture and use of an add-on air pollution control device.

3.2.26 Petroleum Drycleaning Solvents ⁶

Dry cleaning is a service industry, involved in the cleaning of apparel or renting apparel. Basically, the industry is segregated into three areas based on customers and types of services offered. These areas are: (1) coin-operated, (2) commercial, and (3) industrial. The industry is also subdivided according to the type of solvent used which are: petroleum solvents, perchloroethylene (perc), and trichlorotrifluoroethane (Freon-113®). Freon-113 and perc will not be discussed further since they are considered negligibly reactive. Dry cleaning operations are similar to detergent and water wash operations. There are approximately 6,000 facilities in the United States with petroleum dry cleaning equipment.

VOC's are emitted from dryers, washers, solvent filtration systems, settling tanks, stills, and piping and ductwork associated with the installation and operation of these devices. Because of the large number of variations in the types of equipment and operating practices, in dry cleaning plants there is a large variation in emission rates. For that reason, details on emission factors or typical plant emission rates will not be discussed here. The emission sources in dry cleaning plants can be characterized in two broad groups - vented and fugitive emissions. Solvent is vented from article dryers, solvent stills, and filter and article drying cabinets. The largest source of vented emissions is from article dryers. Fugitive emissions occur from all equipment in dry cleaning facilities, however, these emissions vary greatly since they are dependent on equipment operating and good housekeeping practices. The major fugitive emission sources are solvent or liquid leaks from pipes or ductwork, and wet or not completely dried articles, used-wet filters, and solvent and still waste which are all left in open containers in or outside dry cleaning facilities.

New petroleum article dryers using water cooled condensers have only recently been available and have been demonstrated to achieve emission reductions of approximately 80 percent (or reduced outlet emissions to 3.5 kilograms per 100 kilograms

of articles cleaned). Fugitive emission sources are controlled by improved operating and maintenance practices.

3.2.27 Agricultural Insecticides and Herbicides⁸

Insecticides are used in agriculture to destroy or control populations of harmful insects. Herbicides are chemical weed killers that are used extensively on farms and other areas. Herbicides are grouped using a multiple-classification system based on selectivity, mode of action (contact versus translocation), timing of application, and areas covered. Herbicides are classed as selective when they are used to kill weeds without harming the crop and as nonselective when the purpose is to kill all vegetation. Contact herbicides kill the plant parts to which the chemical is applied, whereas translocated (systematic) herbicides are absorbed by roots or above-ground parts of plants and then circulate within the plant system to distant tissues.

Until the introduction of synthetic organic insecticides in 1940, a variety of materials had been used as insecticides, including extracts of pepper and tobacco, vinegar, turpentine, fish oil, brine, sulfur, hydrogen cyanide gas, and petroleum oils. Since the introduction of synthetic organic insecticides, a variety of compound classes have been used, including organochlorines, organophosphates, organosulfurs, carbamates, formamidines, dinitrophenols, and synthetic pyrethroids. These compound classes have various modes of action including physical toxicants, axonic poisons, central nervous system synaptic poisons, enzyme inhibition, metabolism, and narcotics.

Pesticides may be applied as liquids, dry solids, or gases. Liquid pesticides are applied as a spray of water or oil droplets containing a solution or suspension of active ingredients. Pesticides formulated as dusts or granules are normally applied dry. Pesticides that exist in a gaseous state at ambient temperature and pressure may be applied either as gases or pressurized liquids or as solids that vaporize upon release. This type of pesticide application is known as fumigation.

World usage of pesticides is valued at approximately \$23 billion annually. The United States is the leading user of pesticides, accounting for an estimated 29 percent of the total world volume of pesticide usage (in pounds of active ingredient) in 1989. The U. S. produced approximately 1.3 billion pounds (lb) of the active ingredients used in pesticides, valued at \$7.5 billion retail.

The VOC emission reduction from agricultural pesticide application has been on the solvent content in the formulations of emulsifiable concentrates. In addition to reducing the VOC content in solvent-based liquid pesticides, reasonable control alternatives include reducing the use of organic fumigants and improving efficiency of application methods. In general, these control alternatives can be applied to agricultural pesticides; however, there may not be an alternative formulation for a given emulsifiable concentrate or a pesticide substitute for a fumigant in a certain situation.

Emissions of VOC's from pesticide applications are the result of volatilization of the active ingredient (AI), organic solvents, emulsifiers, and other organic compounds that may be used in the formulation.

3.2.28 Cutback Asphalt Paving Materials ⁶

Liquefied asphalts are generally prepared by cutting back or blending asphalt cement with petroleum distillate or by emulsifying asphalt cement with water and an emulsifying agent. Heated asphalt cement is generally used to make asphalt pavements such as asphalt concrete. Cutback and emulsified asphalt are used in nearly all paving applications. In most applications, cutback and emulsified asphalt are sprayed directly on the road surface; the principle other mode is in cold mix applications normally used for wintertime patching.

Emissions from cutback asphalt occur as the petroleum distillate (diluent) evaporates; the average diluent content in the cutback is 35 percent by volume. The

percentage of diluent to evaporate is dependent on the cure type. The emission factors are: slow cure (SC) - 20 to 30 percent of diluent content, average 25 percent; medium cure (MC) - 60 to 80 percent, average 70 percent; rapid cure (RC) - 70 to 90 percent, average 80 percent. These factors are independent of the percent of diluent in the mix within the normal range of diluent usage for cutback asphalts.

The technology to control hydrocarbon emissions from these paving operations consists of substituting emulsified asphalts in place of cutback asphalts. Emulsified asphalts use water and non-volatile emulsifying agents for liquefaction; virtually no pollutants are emitted during the curing of emulsions. Emulsified asphalts are used widely in the construction and maintenance of pavements ranging from high traffic volume highways and airports to low-volume rural roads and city streets.

3.2.29 Synthetic Fiber Spinning Solvent ⁶

Synthetic fibers are manufactured as continuous filaments (which may then be chopped into staple) of modified cellulose or manmade polymers. They are used to manufacture carpets, apparel, industrial textiles, rope, tires, cigarette filters, and composite materials. There are three broad manufacturing classifications: melt spinning, solvent spinning, and reaction spinning.

In the melt-spinning process, a thermoplastic polymer is heated to above its melting point and is forced (extruded) through a spinneret (a group of orifices). The filament solidifies as it is quenched in a stream of cool air or other medium. Typical polymers suitable for melt spinning are polyesters, nylons, and polyolefins. Melt-spinning accounts for the preponderance of synthetic fiber production in the United States with 2,300,000 Mg (5.0 billion lbs) produced in 1983. There are approximately 130 plants engaged in melt-spinning.

Solvent spinning can be subdivided into two types of processes, wet or dry. Both first require the polymer to be dissolved in a suitable solvent at a ratio of about three parts solvent to one part polymer. In wet spinning, the polymer solution is extruded through a spinneret that is submerged in a liquid that extracts the solvent, thereby precipitating the polymer filament. In dry spinning the polymer solution is extruded into a zone of heated gas that evaporates the solvent leaving the polymer filament behind.

A third process, reaction spinning, is much like wet spinning. A low molecular weight fluid "prepolymer" is extruded into a bath containing a co-reactant which causes formation of the filament by polymerization. This process is minor tonnage-wise and henceforth will be included in the discussion of the wet spinning process.

Typical polymers suitable for solvent spinning are acrylics, modacrylics, acetates, triacetates, rayon, and spandex. Approximately 1,400,000 Mg (3.0 billion lb) of solvent-spun fiber were produced in the U. S. in 1983 at approximately 20 plants.

Once spun, all fibers undergo post-spinning processing. It may involve one or more of the following: washing, stretching, cutting (into staple), crimping, twisting, drying, and finally packaging.

Solvents are not used in melt-spinning; therefore, all VOC emissions are due to unreacted monomer and oils applied to the filaments as they emerge from the spinneret. Emissions may occur in the exhaust from the quenching step or any of the post-spinning processing steps that require steam, hot water, or dry heat. The monomer concentrations are usually quite low. The lubricating oils have rather low vapor pressures and often condense into a visible aerosol.

Melt spinning and the associated post-spinning processes, if controlled at all, are usually served by fabric filters, rotoclones, scrubbers, or electrostatic precipitators. Since the uncontrolled emission rates are small, controls are installed at the plant's discretion.

Removal efficiencies have not been determined by EPA. The textile industry has reported reductions of similar types of emissions by 70 to 95 percent.

3.2.30 Fabric Coating ⁶

Fabric coating involves the application of decorative or protective coatings to a textile substrate. A large segment of this industry is application of rubber coatings to fabrics. More specifically, for purposes of the regulatory program, fabric coating is the uniform application of (1) an elastomeric or thermoplastic polymer solution, or (2) a vinyl plastisol or organisol, across all of one (or both) side of a supporting fabric surface or substrate. The coating imparts to the fabric substrate such properties as elasticity, strength, stability, appearance, and resistance to abrasion, water, chemicals, heat, fire, or oil. Coatings are usually applied by blade, roll coater, reverse roll coater, rotogravure coater, or dip coater.

The basic fabric coating process includes preparation of the coating, the application of the coating to the substrate, and the drying/curing the applied coating. The web substrate is unwound from a continuous roll, passed through a coating applicator and drying/curing oven, and then rewound. There are at least 130 fabric coating plants located throughout the United States.

The major sources of VOC emissions in a fabric coating plant are the mixer and coating storage vessels, the coating applicator, and the drying oven. The relative contribution of these three areas are estimated at 10 to 25 percent, 20 to 30 percent, and 45 to 70 percent, respectively. The potential VOC emissions from a fabric coating plant are equal to the total solvent used at the plant.

Incineration is the most common means for control of coating application and curing emissions on fabric coating lines which use a variety of coating formulations. Coaters which use a single solvent can be most economically controlled by carbon

adsorption. Either of these control devices can reduce the VOC emissions in the gases directed to the device by 95 percent or more. Inert gas condensation systems may be applicable to some fabric coating lines. Such systems are estimated to be about 99 percent efficient in the recovery of solvent which passes through the system.

3.2.31 Fabric Printing ⁶

Fabric printing is application of a decorative design to a fabric by intaglio (etched) roller (another name for rotogravure), rotary screen, or flat screen printing operation. The fabric web passes through the print machine where a print paste is applied to the substrate. After leaving the print machine, the web passes over steam cans or through a drying oven to remove water and organic solvent from the printed product. After the drying process, the fabric is washed and dried again. There are approximately 200 fabric printing plants located throughout the United States.

The most significant source of VOC emissions in a fabric printing plant is the drying process, either the steam cans or the ovens. Other emissions occur as fugitive VOC. These are as evaporation from wastewater streams, open print paste barrels, printing troughs, the printing rollers and screens, "striketrough" onto the backing material, and from the printed fabric before it reaches the drying process. Average emission factors for printing fabric are 142 kg VOC per 1000 kg fabric for roller printing, 23 kg VOC per 1000 kg fabric for rotary screen printing, and 79 kg VOC per 1000 kg fabric for flat screen printing.

3.5 REFERENCES

1. U.S. EPA Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, *Architectural and Industrial Maintenance Coatings*, Draft Report, September 1994.

2. U.S. EPA Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, *Alternative Control Techniques - VOC Emissions from Automobile Refinishing*, (EPA-453/R-94-031), April 1994.
3. Aerospace Paints and Coatings NESHAP - Proposed Rule under 40 CFR Part 63, 59 FR 29216, June 6, 1994.
4. U.S. EPA Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, Wood Furniture Coatings NESHAP - background for proposed rule (under development)
5. U.S. EPA Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, *Alternative Control Techniques - Surface Coating Operations At Shipbuilding and Ship Repair Facilities*, (EPA-453/R-94-032), April 1994.
6. U.S. EPA Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, *Alternative Control Techniques - Control Techniques for Volatile Organic Compound Emissions from Stationary Sources*, (EPA-453/R-92-018), December 1992.
7. U.S. EPA Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, *Alternative Control Techniques - Industrial Cleaning Solvents*, (EPA-453/R-94-015), February 1994.
8. U.S. EPA Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, *Alternative Control Techniques - Control of VOC Emissions from Agricultural Pesticide Application*, (EPA-453/R-92-011), March 1993.

4.0 PRODUCTS ADDRESSED BY SPECIAL STUDIES

4.1 INTRODUCTION

Several categories of products fall outside the scope of categories covered in Sections 2 and 3. These categories were the subjects of special studies carried out to develop 1990 emission estimates based on information in the literature. For those products for which data on emissions was not available, any useful information (such as VOC content and function of the product) was summarized and included here. Specific methodology is discussed for each category included. All emission estimates discussed in the following sections are nationwide estimates. However, the summary estimates presented in Table 4.1-1 and in Section 1.5 have been scaled down based on population in ozone nonattainment areas (see Section 1.4.2).

4.2 CONSTRUCTION MATERIALS

4.2.1 Building Materials and Indoor Air Sources

4.2.1.1 *Description*

Since the mid-1970's, a growing number of complaints have surfaced regarding the indoor environment to which occupants of modern buildings are exposed. Energy efficiency also became increasingly important during this time. Consequently, new buildings were being built with less outside air infiltration, thus confining more indoor air pollutants. Since the early 1980's, much work has been done by the EPA and other groups to identify and measure VOC emission rates from building materials and consumer products in small test chambers and laboratories.¹ The purposes of this section are to describe the latest efforts in determining emission rates from building materials and to try and develop a national VOC emissions estimation for these building materials.

TABLE 4.1-1

**VOC EMISSIONS IN NONATTAINMENT AREAS FOR
PRODUCTS COVERED BY SPECIAL STUDIES**

Category	Nonattain Area Emissions (tons/year)	Year	Ref
CONSTRUCTION MATERIALS			
Particle board	*		9
Plywood	*		9
Wallpaper	*		9
Carpeting	*		9
Roofing - built-up	7,126 ^a	1989	10
Roofing - elastomeric	9,123 ^a	1989	10
Roofing - modified bitumen	2,276 ^a	1989	10
Asphalt concrete paving materials	360 ^a	1991	11
FOODS, BEVERAGES, TOBACCO			
Alcoholic beverages	11,600 ^a	1990	9
Deep-fat frying oils	*	1990	9
Smoking tobacco	37 ^a	1987	9
SMALL COMBUSTION SOURCES			
Kerosene space heaters	39 ^a	1990	9
Camp stoves, lanterns, heaters	6 ^a	1990	9
Artificial fire logs	154 ^a	1990	9
TEXTILE INDUSTRY			
Platen Adhesives	2,092 ^a	1990	12
Equipment cleaning solvents	68 ^a	1990	12
Spot Cleaners - Screen Printers	848 ^a	1990	12

TABLE 4.1-1

**VOC EMISSIONS IN NONATTAINMENT AREAS FOR
PRODUCTS COVERED BY SPECIAL STUDIES
(Continued)**

Category	Nonattain Area Emissions (tons/year)	Year	Ref
Spot Cleaners - Woven Goods	0	1990	12
Spot Cleaners - Knit Goods	0	1990	12
MISCELLANEOUS PRODUCTS			
Mold Release Agents	75,400 ^a	1989	10
Automotive Repair - Parts Washers	2,607 ^a	1987	11
Fiberglass Boat Manufacturing Products	12,100 ^a	1990	13
TOTAL FOR THIS TABLE	123,836		

Key to Table 4-1

- * This category was investigated and is discussed in the text, but an emission estimate could not be developed based on the available information.
- a Nonattainment area emission estimates were obtained by adjusting nationwide estimates according to the distribution of nationwide population in nonattainment areas in 1990. Estimates for categories without this footnote were determined specifically for nonattainment areas and needed no further adjustment.

$$\frac{148 \text{ million (nonattainment areas)}}{248 \text{ million (nationwide)}} = 59.68\% \approx 60\%$$

The building materials source category contains a number of different product lines, each with a variety of manufacturers and manufacturing methods. For the purposes of this report, the term building materials refers to carpet, plywood, particle board, chipboard, fiberboard, treated lumber, gypsum board, laminated plastics, insulation, linoleum, and wallpaper. Each of these materials has been found to have the potential of emitting various types of VOC's during their expected lifetime. These materials are present in many kinds of structures including apartments, automobiles, commercial buildings, hospitals, mobile homes, nursing homes, office buildings, residences, and schools.² The use or consumption of new building materials is highly dependent upon the current economic situation. Higher economic growth generally leads toward business expansion, house building, automobile sales, etc., which cause an increase in building material consumption.

The available information on the qualitative analysis of speciated VOC emissions from various building materials is presented in Table 4.2-1. This table includes sources for which some current substantiated data on speciated VOC's are available. Substantiated sources are those for which either quantitative or qualitative emissions data have been obtained. The information presented in Table 4.2-1 should be used with some caution because the composition of materials and products changes over time as manufacturers alter their manufacturing processes and products.²

4.2.1.2 *Estimating VOC Emissions from Building Materials*

Previous studies of building materials have shown emissions to be very dependent upon test variables such as air exchange rate, temperature, humidity, product loading (area of product/volume of test chamber), and age of material.^{1,3,4} To date, much research has been conducted to determine the concentrations of speciated VOC's in the ambient air surrounding building materials. This research has been performed in chamber tests, laboratory experiments, and on-site tests of various types of buildings. However, only a limited number of these studies have developed emission rates for these materials. Several short term tests (*i.e.*, days and weeks) have specified emission rates calculated as an average for the duration of the experiment. However, based on the current available literature, no

TABLE 4.2-1. SUBSTANTIATED BUILDING MATERIAL SOURCES OF VOCs^a

VOC	Chemical Formula	Substantiated Sources
Formaldehyde	CH ₂ O	carpeting, particle board, plywood, paneling, fiberboard, chipboard, gypsum board, ceiling panels, urea foam insulation, linoleum
Ethanol	C ₂ H ₆ O	fiberboard
Acetone ³	C ₃ H ₆ O	particle board
Methyl acetate ¹	C ₃ H ₆ O ₂	plywood
Isopropanol	C ₃ H ₈ O	particle board
2-Butanone (MEK)	C ₄ H ₈ O	fiberboard, particle board
Benzene	C ₆ H ₆	particle board
Ethylacetate	C ₄ H ₈ O ₂	linoleum floor covering
n-Butanol	C ₄ H ₁₀ O	linoleum
n-Hexane	C ₆ H ₁₄	chipboard, gypsum board, insulation foam
2-Methylpentane	C ₆ H ₁₄	chipboard, gypsum board, insulation foam, wallpaper
Benzaldehyde	C ₇ H ₆ O	fiberboard, particle board
Toluene	C ₇ H ₈	chipboard, wallpaper, vinyl coated wallpaper, linoleum floor covering
Heptane	C ₇ H ₁₆	particle board
Styrene	C ₈ H ₈	fiberboard, insulation foam
Xylenes	C ₈ H ₁₀	wallpaper
Ethylbenzene	C ₈ H ₁₀	chipboard, fiberboard, insulation foam
Nonane	C ₉ H ₂₀	chipboard, wallpaper
1,2,4-Trimethylbenzene	C ₉ H ₁₂	chipboard, linoleum floor covering, vinyl coated wallpaper
n-Propylbenzene	C ₉ H ₁₂	chipboard, insulation foam
Isopropylbenzene	C ₉ H ₁₂	insulation foam
Limonene	C ₁₀ H ₁₆	chipboard
α-Pinene	C ₁₀ H ₁₆	fiberboard, gypsum board, chipboard
Decane	C ₁₀ H ₂₂	chipboard, fiberboard, wallpaper
Undecane	C ₁₁ H ₂₄	gypsum board, chipboard, wallpaper
4-Phenylcyclohexene	C ₁₂ H ₁₄	latex backing on carpets

^a From reference 2 except where noted.

long term tests (*i.e.*, one year) have been conducted to determine an annual average speciated VOC emission rate from any one specific type of building material. Therefore, no annualized total or speciated VOC emission estimates from building materials can be developed at this time.

Some emission rates have been developed for formaldehyde from wood products^{3,4,5} and 4-phenylcyclohexene from carpeting⁶ and are presented in Table 4.2-2. No information is presented for chipboard, gypsum board, laminated plastics, insulation, linoleum, or wallpaper. Only one source had information for chipboard and gypsum board, and no test parameters or conditions were given.⁴ Also, no information was available for laminated plastics, although one contact is currently conducting tests on the material.⁷

Table 4.2-2 shows that measured formaldehyde emission rates for particle board vary across two orders of magnitude based on information from three separate references. The second and third table entries for particle board illustrate the significance of time variation (age of material) on emissions (*i.e.*, emissions decrease with time as a building material ages and loses VOC content). Plywood emissions exhibit similar characteristics; two separate studies indicate a very wide range of formaldehyde emission rates.

Table 4.2-2 also illustrates the variability of the magnitude of carpet emissions. One reference cited the range (from separate studies) of measured formaldehyde emissions from carpeting to be between zero and $2.7 \mu\text{g}/\text{m}^2\text{h}$ (micrograms per square meter per hour).⁵ Another reference indicated that 4-phenylcyclohexene emissions from latex-backed carpets may drop by nearly 50 percent in a period of one week.⁴ Emissions of 4-phenylcyclohexene have been found to be the cause of the "new carpet" smell.

Separate studies have also shown that indoor ventilation rates can have a significant impact on the both the concentration of VOC in a building and the amount of VOC emitted from a particular building material.^{4,8} Specifically, one study of carpet revealed that, as the rate of air changes per hour (ACH) increased (outside air), the concentration of VOC's dropped. However, the actual emission rate of VOC from carpet may increase due to the

TABLE 4.2-2. EMISSION FACTORS FOR VARIOUS BUILDING MATERIALS

Source	Emission Factor ($\mu\text{g}/\text{m}^2\text{h}$)	Condition	Compound(s)	Reference
Particle board	200	2 yrs old	total vapor-phase organic compounds	4
Particle board	2,000	new	formaldehyde	4
Particle board	140	low density - aged 8 months	formaldehyde	3
Particle board	83 - 1,040 ^a	NA ^b	formaldehyde	5
Plywood	5 - 720 ^c	after 24 hours	formaldehyde	1
Hardwood plywood	62.5 - 1,420 ^a	NA	formaldehyde	5
Softwood plywood	1 - 11 ^a	NA	formaldehyde	5
Wallpaper	0.1	NA	total vapor-phase organic compounds	4
Carpeting	0 - 2.7 ^a	NA	formaldehyde	5
Latex-backed carpet	150	1 week old	4-phenylcyclohexene	4
Latex-backed carpet	80	2 weeks old	4-phenylcyclohexene	4

^a The range of emission factors presented is based on the reference author's own summary of various studies.

^b NA denotes information not available.

^c Four different brands of plywood were tested in this study; the results show the range of emission factors found.

increased movement of air particles around the carpet fibers.⁸

Based on these findings, there does not appear to be enough consistent emission rate data available to warrant a reliable annual emissions estimation from building materials. Although current testing is under way to obtain more reliable data, it would not be feasible at this time to develop emissions estimations for the building material products described in this report.⁴ However, when these data become available, estimations of emissions for these product categories can be made with some degree of reliability.

4.2.2 Roofing Materials⁹

4.2.2.1 *Description*

A modern roof design normally includes a structure to carry loads, insulation to control heat flow, a barrier to control air and vapor flow, and vapor retarders to prevent water retention. Several different types of roofs have been developed to accomplish these objectives. The main types of roofs used today are sloped roofing materials (e.g., asphalt shingles, wood shakes and shingles, slate roofs, thatched roofs, etc.), built-up roofing (BUR), elastomeric (primarily ethylene-propylene-diene monomer, or EPDM), thermoplastic, modified bitumen (MBR), and liquid-applied roofing.

The total amount of commercial/industrial roofing performed in 1989 was approximately 3.3 billion square feet, with 1.3 billion square feet as BUR, 1 billion square feet as EPDM, and 0.7 billion square feet as MBR. These three roofing types make up over 90 percent of the commercial roofing market. This report focuses on the processes and emissions from BUR, EPDM, and MBR. Sloped roofing materials, which are used primarily in residential situations, are considered to be a very minor source of emissions. Thermoplastic and liquid-applied roofing applications are not included here due to their relatively minor share of the total roofing market.

4.2.2.2 *Built-Up Roofing*

In 1970, BUR was 90 percent of the roofing market; in 1989 it was less than 40 percent. In the BUR application process, several layers of felts, insulations, and other materials are applied using hot asphalt, asphalt emulsions, or asphalt mastics. Coal tar may be used in place of asphalt.

BUR processes vary by manufacturer specifications, however, three major types of BUR processes have been identified. These processes are differentiated by the type of adhesive used to bond the roofing materials to the roof. The three most common types of adhesives are hot asphalt, asphalt emulsions, and asphalt mastics. A typical BUR reroofing job begins with surface preparation of the roof by removing the old roof and surfacing material (e.g., gravel). After the surface is prepared, an asphalt primer is applied if the deck is constructed of concrete. Next, a base ply or insulation layer is applied using hot asphalt or cold process asphalt. Several layers of felts are then attached to the roof with an intermediary layer of asphalt between each layer. A cap sheet layer is then applied, followed by a flood coating of asphalt to seal the roof. Flashing, vents, and other areas of the roof receive a layering of flashing cement to provide extra sealing capabilities in these areas. Solvent cleaners are used to remove asphaltic materials from tools and may also be used by workers to clean their hands. Emissions points for BUR are the application of roofing materials using asphaltic compounds, flashing cements, asphalt primers, and cleaning operations.

4.2.2.3 *Elastomeric Roofing*

Elastomeric roofing consists of natural and synthetic rubbers and rubberlike materials. The most common elastomeric roofing material is ethylene-propylene-diene monomer (EPDM). Three methods have been identified for the application of EPDM roofing systems: loose-laid and ballasted, comprising 70 percent of the total; fully-adhered, comprising 20 percent of the total; and mechanically-fastened, comprising 10 percent of the industry. A typical fully-adhered EPDM roofing process involves removing the old roofing system, surfacing materials, and debris, leaving a clean substrate. EPDM sheets are laid side-by-side

with a three inch overlap and are bonded to the roof using bonding cement. The seams are cleaned and primed in preparation for taping. Tape is applied to each seam leaving a waterproof surface. General cleaning operations are carried out daily to remove roofing materials from skin, tools, clothing, etc. Emissions result from the use of primers, cements, and cleaners.

4.2.2.4 *Modified Bitumen Roofing*

The MBR process is very similar to the BUR category. Modified bitumen sheets are constructed using asphaltic materials like BUR felts and plies, but are augmented by adding thermoplastic materials like styrene-butadiene-styrene (SBS) or atactic polypropylene (APP). These plasticizers lend greater elongation and roof movement tolerance. The modified bitumen sheets are typically built-up in the factory. Fewer layers of modified bitumen sheets are applied in a typical roofing job than in a BUR job since the MBR sheets are already built up.

Modified bitumen can be applied in several ways, including hot asphalt, propane torch-activated adhesive and self-adhering sheets; squeegee-applied cold adhesives; and spray-applied cold adhesives. The most common means of attaching MBR are hot asphalt, torch activation, and self-adhering sheets, representing 99 percent of the market. The hot asphalt-applied MBR process is similar to the BUR process. The old roofing material or surfacing material is removed, or the roofing surface is cleared, leaving a clean substrate. An asphalt primer is applied to concrete decks. The MBR plies are applied using hot asphalt. Only a few MBR plies are required where the BUR process requires several plies. Flashing cement is used around vents and other exposures. General cleaning operations are performed on an intermittent basis. The squeegee-applied and spray-applied MBR systems are similar in the application process, but much higher in emissions.

4.2.2.5 *Other Roofing Types*

Several other types of roofing are used in the roofing industry: asphalt shingles, metal, thermoplastics, foam, and others. These roofing processes are not considered in this report due to their limited usage in the roofing industry or their low VOC emissions potential. These alternate roofing types and some possible emissions points are described below.

Asphalt shingles are composed of asphalt, minerals, binders, and fillers. Some heat-activated adhesives are used which bond the shingles to the roof after they are mechanically attached. Emissions from these adhesives are not expected to be significant.

Metal roofs are typically applied using mechanical fasteners. Sealants and caulks may be used for waterproofing attachment areas. Also, rust inhibitors and metal preparation solvent may be used to protect the metal from corrosion. Emissions points include the sealants, caulks, rust inhibitors, metal solvents, and general cleanup operations.

Thermoplastics such as hypalon roofing materials are similar to EPDM in their application processes. Thermoplastics are applied in sheets and may be bonded by heat or solvent welding. Emissions points include the solvent used for welding, cleaners for thermoplastic surface preparation, and general clean up operations. No significant emissions are expected from heat welding.

Polyurethane foams and other types of foam roofing materials have found a small niche in the roofing industry. The foam is applied in liquid form to the roof. The liquid foam expands and hardens to form a waterproof layer. The blowing agent used to spray the liquid foam onto the roof may be a significant source of emissions for this category. Emissions may also be associated with the protective paints and coatings and cleaning solvents used.

4.2.2.6 Development of VOC Emission Estimates

Emissions were estimated for the three major roofing types (BUR, EPDM, and MBR) based on total square feet worked for each roofing type, material usage per square foot of roof by roofing type, and VOC content of the materials used. Assumptions were required where no data were readily available. Table 4.2-3 provides estimates of total area worked annually in million square feet by roofing category.

TABLE 4.2-3 SUMMARY OF ROOFING AREA WORKED BY ROOF TYPE (1989)

ROOFING TYPE	AREA WORKED (million square feet)	
Built-Up Roofing		1,300
Hot Asphalt	1,235	
Asphalt Emulsion	32.5	
Asphalt Mastic	32.5	
EPDM		1,000
Fully-Adhered	200	
Loose-Laid	700	
Mechanically Fastened	100	
Modified Bitumen		700
Hot Asphalt/Torch/Self-Adhering	630	
Squeegee Applied Adhesive	35	
Spray Applied Adhesive	35	
TOTAL		3,000

Within BUR, emissions were estimated for three processes: hot asphalt, asphalt emulsions, and asphalt mastics. Approximately 1.3 billion square feet of BUR was applied in 1989. According to a roofing manufacturer representative, 95 percent or more of BUR was applied using hot asphalt and five percent or less used asphalt emulsion or asphalt mastic. It is assumed that the remaining five percent is divided equally between asphalt emulsion and asphalt mastic.

The total square footage of elastomeric roofing in 1989 was 1 billion square feet. Elastomeric roofs are dominated by EPDM and may be applied by three different processes. The elastomer may be loose-laid and ballasted, fully-adhered, or mechanically fastened. Loose-laid EPDM is applied 70 percent of the time, fully-adhered represents 20 percent of the total, and mechanically fastened represents 10 percent of the total. Only loose-laid and fully-adhered EPDM systems were evaluated in this study. Fully-adhered elastomeric roofs are most commonly applied using bonding cement which consists of solvent and rubber compound. Composition and usage rates for EPDM roofing were taken from a roofing manufacturer's specifications.

The total amount of MBR applied in 1989 was 700 million square feet. Hot asphalt, torch-activated adhesive, and self-adhesive sheets make up 90 percent of the MBR market. It is assumed that the squeegee-applied and spray-applied cold adhesives make up five percent each of the MBR market.

4.2.2.7 *Summary of Emission Estimates from Roofing Application*

Total nationwide VOC emissions are 30,874 tons for application of roofing materials. The total square footage for roofing work in 1989 was 3 billion. The resulting average emission factor is 0.021 pounds VOC per square foot. A summary of the roofing processes, emissions, and emission factors is given in Table 4.2-4.

TABLE 4.2-4 VOC EMISSIONS FROM ROOFING APPLICATION

Roofing Category	Application Process	Total VOC Emissions (tons/yr)	Area Worked Annually (10 ⁶ ft ²)	Emission Factor (lbs/ft ²)
BUR	Hot Asphalt	6094	1235	0.01
	Emulsion	860	32.5	0.05
	Asphalt Mastic	4922	32.5	0.30
EPDM	Fully-Adhered	10678	200	0.11
	Loose-Laid	4527	700	0.01
	Mech Fastened	0	100	0
MBR	Hot asphalt	3186	630	0.01
	Squeegee	207	35	0.12
	Spray	400	35	0.23
TOTAL		30,874	3,000	0.021 ^a

^a Weighted average of emission factors and total square footage.

4.2.3 Asphalt Concrete Paving Materials ¹⁰

4.2.3.1 *Description*

Generally, paved roads are constructed of either bituminous asphalt concrete or portland cement concrete. Asphalt concrete is blended at a facility that may be located several hours from the job site. The hot asphalt concrete mixture (hot mix) is blended and maintained at approximately 300°F until being laid and compacted. The major constituent of asphalt

concrete is aggregate, a mixture of sand and gravel. Asphalt, a derivative of the bottom cut in the distillation of crude oil, serves as the binder for the aggregate. A variation is formulated by dissolving asphalt with kerosene and naphtha (i.e. cutback asphalt). Emissions from cutback asphalt paving materials are presented in Section 3 of this report. Therefore, the following discussion is limited to asphalt concrete.

An estimated 460 to 500 million tons of hot mix was prepared in 1991. This estimate does not include cutback asphalt. Approximately 5 percent of the hot mix is asphalt. Asphalt concrete contains low concentrations of VOC's when properly prepared. A common test to determine the suitability of asphalt concrete is the "loss on heating" test. When heated, if more than 0.5 percent volatilizes, the material is rejected. In practice, asphalt concrete typically contains about 0.0025 percent VOC.

4.2.3.2 *VOC Emissions from Asphalt Concrete*

Based on 500 million tons of asphalt concrete used annually, the usage of asphalt cement in this material (5%) is estimated to be 25 million tons nationwide. At a typical VOC content of 0.0025 percent, the asphalt cement contains approximately 600 tons of VOC. It is assumed that all the VOC's contained in the concrete are emitted.

In the asphalt paving industry, regular equipment cleaning currently is performed using high pressure water sprays rather than solvents, although this has not always been the practice. However, many construction crews coat the truck and hopper beds with diesel fuel to prevent sticking. The asphalt concrete absorbs any excess liquid, which ultimately evaporates. Diesel fuel is also used to clean shovels and rakes. There is insufficient data to develop an estimate of these additional emissions.

4.2.4 References for Section 4.2

1. van der Wal, Jan F., Steenlage, Ronald, and Hoogeveen, Ank W. "Measurement of Organic Compound Emissions from Consumer Products in a Walk-in Test Chamber" in the *Proceedings of the 5th International Conference on Indoor Air Quality and Climate. Volume 3*. Ottawa, Canada. July 29-August 3, 1990.

2. Samfield, Max M. *Indoor Air Quality Data Base for Organic Compounds*. EPA-600-R-92-025. U.S. Environmental Protection Agency, Air and Energy Engineering Research Laboratory, Research Triangle Park, N.C. February 1992.
3. Mason, Mark A. and Tichenor, Bruce A. "Organic Emissions from Consumer Products and Building Materials to the Indoor Environment" in the *Journal of the Air Pollution Control Association*. 38: 264-268, 1988.
4. Tucker, W. Gene. "Emissions of Air Pollutants from Indoor Materials: An Emerging Design Consideration" Paper presented at the 5th Canadian Building and Construction Congress. Montreal, Canada. November 27-29, 1988.
5. Godish, Thad, *Indoor Air Pollution Control* Lewis Publishers, Chelsea, MI 1989.
6. Singhvi, R., Burchette, S., Turpin, R., and Lin, Y. "4-Phenylcyclohexene from Carpets and Indoor Air Quality" in the *Proceedings of the 5th International Conference on Indoor Air Quality and Climate*. Volume 4. Ottawa, Canada. July 29-August 3, 1990.
7. Teleconference between J. Todd of Scientific Consulting Group in Rockville, MD, and L. Loe of TRC Environmental Corporation in Chapel Hill, N.C. August 28, 1992. Discussed current emissions tests.
8. U.S. Environmental Protection Agency. *Carpet Policy Dialogue - Compendium Report September 27, 1991*. EPA/560/2-91-002. Office of Toxic Substances, Washington, D.C. September 1991.
9. U.S. EPA Air and Energy Engineering Research Laboratory, Research Triangle Park, North Carolina, *Source Characterizations and Emission Estimates for Mold Release Agents and Roofing Applications*, September 1993.
10. U.S. EPA Air and Energy Engineering Research Laboratory, Research Triangle Park, North Carolina, *Evaluation of Volatile Organic Emissions Data for Nonprocess Solvent Use in 15 Commercial and Industrial Business Categories*, (EPA-600/R-94-019), February 1994.
11. U.S. EPA Air and Energy Engineering Research Laboratory, Research Triangle Park, North Carolina, *Nonprocess Solvent Use in the Textile Industry*, August 1993.
12. U.S. EPA Air and Energy Engineering Research Laboratory, Research Triangle Park, North Carolina, *Project Summary - Assessment of VOC Emissions from Fiberglass Boat Manufacturing*, (EPA-600/S2-90/019), June 1990.

4.3 FOODS, BEVERAGES, TOBACCO

4.3.1 Alcoholic Beverages

4.3.1.1 *Description*

Alcoholic beverages include wine, beer, and distilled spirits (*e.g.*, whiskey, rum, brandy, gin and vodka). During 1990, consumption of domestic beer in the United States was estimated to be 192.6 million barrels (5.97 billion gallons (22.6 billion liters)).¹ In 1990, the consumption of domestic wine including wine cooler beverages, was estimated at 509.1 million gallons (1,926 million liters).² In 1990, the consumption of all distilled spirits was estimated to be 542.4 million gallons (2,053 million liters). Grain alcohol, a distilled spirit, represented 90 percent of the total distilled spirits consumed.³

It is important for the alcoholic beverage industry to impart desirable characteristics to these beverages making them acceptable to the consumer. The most important characteristic of the alcoholic beverages is the flavoring. Various flavoring and aroma compounds are added to alcoholic beverages to formulate their typical taste and odor. These additions may include many different volatile and nonvolatile organic compounds, which can be divided into several groups according to their chemical nature. Fusel alcohols, fatty acids, and esters form the quantitatively and qualitatively largest groups in the volatile aroma fraction of alcoholic beverages. Carbonyl compounds and phenols, which are relatively smaller in quantity, are used in flavoring alcoholic beverages.⁴

4.3.1.2 *Methods for Estimating VOC Emissions from Consumption of Alcoholic Beverages*

Literature searches were conducted for information on emissions from the use of alcoholic beverages. Available information on the VOC components in alcoholic beverages was identified and reviewed. Trade associations thought to be knowledgeable on the subject of alcoholic beverages were identified through the *1993 National Trade and Professional Associations of the United States*.⁵ The Beer Institute, Wine Institute, and the Distilled

Spirits Council were contacted to identify and obtain any useful information on emissions from the use of alcoholic beverages. The only information available from the professional associations was estimates on beverage consumption.^{1,2,3}

The literature search revealed several studies which were performed to determine the types of compounds and the characteristics they offer to various alcoholic beverages. All of the analytical studies identified were performed on distilled beverages, such as whisky, rum and scotch; none were identified for beer and wine. Table 4.3-1 presents some of the volatile components which were identified through these analyses of distilled spirits. The compounds present in Table 4.3-1 were found to be the most abundant in the spirits.⁴ However, none of the brief reports which summarized the test analyses of distilled spirits defined the particular spirit analyzed.

Although numerous VOC compounds have been identified in distilled beverages, information on the VOC concentration and/or emissions from the consumption and/or disposal of the product(s) was not available. Emission factors presented in the *Compilation of Air Pollutant Emission Factors (AP-42)* document are specific to alcoholic beverage production processes and do not address emissions on the consumption or disposal of alcoholic beverages.⁶

Although accurate estimates of VOC emissions from the consumption of alcoholic beverages were not available, the EPA made a rough estimate based on annual consumption and the following assumptions:

- (1) Alcohol contents (by volume) for beer, wine, and distilled spirits are 6%, 12%, and 40%, respectively.
- (2) Approximately 5% of the alcohol content is emitted.

This procedure resulted in an estimate of nationwide VOC emissions from alcoholic beverages of 19,300 tons per year, or approximately 156 pounds per 1000 persons.

TABLE 4.3-1. VOLATILE COMPOUNDS IDENTIFIED IN ALCOHOLIC BEVERAGES

Compound Group	Volatile Compound
Fusel Alcohols	3-methyl-1-butanol
	2-methyl-1-butanol
	1-propanol
	2-methyl-1-butanol
Fatty Acid Esters	ethyl acetate
	ethyl 9-hexadecenoate
Phenols	phenol
	o-cresol
	m-cresol
	p-cresol

4.3.2 Deep Fat Frying

4.3.2.1 *Description*

Deep fat frying involves the cooking of foods in hot oils or greases. Potatoes are the most commonly fried food; other foods include doughnuts, fritters, croquettes and breaded and batter-dipped fish and meat. The foods are cooked in externally heated cooking oil vats at temperatures ranging from 325° to 400°F.⁷ Volatile organics, particulate matter, and entrained fat particles are emitted during the frying process.

Volatile organic compound (VOC) emissions derive from cooking oils, vegetable oils, and animal fats which are steam distilled during the frying process. Most foods contain approximately 30 to 75 percent moisture before cooking, which causes fats and oils to be

steam distilled from the cooking vat. Cooking oils are usually compounded within reasonably narrow boiling ranges and, when fresh, very little of the oil is steam distilled. Most emissions therefore result from either the food product or from the use of old, "spent" cooking oil. In general, fish and meat products, which contain higher percentages of fats and oils, produce greater VOC emissions than do vegetable products. In addition, excessive overheating may cause smoke problems. Smoke has been shown to consist of finely divided particles of fat and oil distilled from either the product or the cooking oil.⁷

Deep fat fryers are used in restaurants and fast food facilities (commercial deep fat fryers), and in the kitchens of private homes (residential deep fat fryers). Most private kitchens have a hood filter installed over the stove, which may trap some of the particulate matter or suspended oils and fats emitted during frying. However, self-contained deep fat fryers may or may not be used under the hood. Any emissions which are not vented to the atmosphere may be an indoor air pollutant concern.⁸

Residential deep fat fryers operate mainly during the dinner hours, between 5:00 and 8:00 PM. Although there are many restaurants which operate deep fat fryers only during the dinner hours of 5:00 or 6:00 to 8:00 PM, peak operating hours for a typical restaurant or fast food facility are from 11:00 AM to 2:00 PM, and again from 5:00 to 9:00 PM, seven days per week.⁹ Emissions from deep fat fryers are likely to be highest during these times. It is unlikely that this source will show much temporal or regional variation. It is likely, however, that the extent of deep fat fryer operation will correlate with population variability. As a result, trends in deep fat fryer emissions are expected to follow trends in population growth or diminishment.

4.3.2.2 *Method for Estimating VOC Emissions from the Deep Fat Frying Category*

Emissions of total organic gases (TOG) from the operation of deep fat fryers at restaurants and fast food facilities have been estimated for the South Coast Air Basin (SCAB) and the Southeast Desert Air Basin (SEDAB) of Los Angeles and Riverside counties.⁹ Total organic gases are defined by the California Air Resources Board (CARB) as all gases

consisting of substances that contain carbon, except carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate. More closely related to the definition of VOC is a group of compounds known as reactive organic gases (ROG). The major difference between the CARB definition of ROG and the EPA definition of VOC is that the CARB considers the compound ethane to be reactive. Reactive organic gases can be determined from TOG by applying an ROG fraction, calculated based on an assigned profile code for specific SIC/SCC combinations. The profile code for deep fat fryers is 600, corresponding to a "species unknown" profile in which it is assumed that 25 percent of the total organic gases consist of methane (additional compounds included in the "species unknown" profile include cyclopentane, ethane, ethylene, isobutane, isomers of hexane, isomers of nonane, isomers of pentane, n-butane, n-heptane, n-hexane, n-pentane, propane, toluene, and 2,2,4-trimethylpentane). Thus, emissions of ROG from this source category are equal to 75 percent of the TOG emissions.

Emissions estimates for deep fat fryers are based on an emission factor which has been developed using total fried food production as the activity factor. The emission factor, 1.25 lb TOG per 1000 lb of product fried (or 0.94 lb ROG per 1000 lb), is based on available source tests. The source tests were primarily limited to commercial fryers that fry potatoes, which are considered most representative of the deep fried foods. Although a typical deep fat fryer may fry a variety of foods, the majority are potatoes.⁹

The emission factor for deep fat fryers was developed as follows:⁹

The amount of material processed by each fryer:

Batch size = 3 pounds/batch

Batch time = 4 minutes/batch

Process weight

= 3 pounds/batch x 1 batch/4 minutes x 60 minutes/hr

= 45 pounds/hour

A typical fryer operates in essentially two modes:

Peak hours (11:00 AM to 2:00 PM, 5:00 to 7:00 PM) during which it is estimated that the fryers operate at 75 percent capacity.

$$7 \text{ hours} \times 45 \text{ lb/hr} \times 0.75 = 236.25 \text{ lb}$$

Off hours (2:00 to 5:00 PM and 9:00 to 10:00 PM) during which it is estimated that the fryers operate at 35 percent capacity.

$$4 \text{ hours} \times 45 \text{ lb/hr} \times 0.35 = 63.0 \text{ lb}$$

Total daily production

$$236.25 + 63.0 = 299.25 \text{ lbs (use 300 lb/day as a maximum)}$$

Total yearly production

$$300 \text{ lb/day} \times 360 \text{ days/year} = 108,000 \text{ lb/year}$$

Reactive Organic Gases emitted

$$\begin{aligned} 108,000 \text{ lb/yr} \times 1.25 \text{ lb TOG/1000 lb production} &= \\ 135 \text{ lbs TOG/year per fryer} \times 0.75 \text{ (ROG/TOG)} &= \\ 101.25 \text{ lbs ROG/year per fryer.} \end{aligned}$$

Emissions in the South Coast Air Basin and the Southeast Desert Basin were estimated using the above developed emission factor together with activity data for total number of deep fat fryers operating in the respective areas. The total number of deep fat fryers was obtained on a county-wide basis from estimates made by a representative of the Southern California Gas Company. The total number of fryers was apportioned to each basin of the county according to relative population data.

Based on methods presented in the SCAQMD report (reference 9), total emissions from commercial deep fat fryers operated on a country-wide basis can be estimated using current U.S. population data together with the published TOG emission factor (lb/year per fryer). A

more accurate estimate can be obtained with current data on the total number of deep fat fryers operating commercially in the U.S.. This information may be found through investigations into trade association data, county business patterns, census bureau information, or perhaps, as with the SCAQMD study, from estimates made by local gas companies.

The accuracy of emissions estimates made using either of these techniques is dependent on the accuracy of the emission factor, developed from source tests which were primarily limited to commercial deep fat fryers frying potatoes. Emissions from facilities frying food of a higher fat content such as meat or fish are expected to be higher. More testing is necessary to develop emission factors for other food products which have higher percentages of fats and oils. In lieu of such testing, however, the SCAQMD emission factor may be a reasonable approximation for commercial deep fat frying, given the assumption that potatoes are the most frequently fried product. The additional assumption that commercial fryers operate at 75 and 35 percent capacity during peak and off hours, respectively, should be investigated to ensure that these estimates are realistic. These assumptions can be investigated through telephone or personal interviews with a range of restaurant and fast food facility personnel.

Application of the above method for commercial deep fat fryers to estimate emissions from residential, or home-kitchen fryers, is difficult. As with commercial fryers, emissions from frying meat and fish are expected to exceed the estimated rate of 1.25 lb TOG per 1000 lb fried food. The assumption that potatoes are the most frequently fried food may not be a reasonable assumption for residential cooking, where meats and/or fish may be the more frequently fried products. In addition, the SCAQMD emission factor has been developed from controlled frying processes. More variations in cooking temperature, cooking time and moisture content are likely in residentially fried foods. These variables are identified in *AP-40* as important factors affecting the amount of emissions expected from deep-fat frying.⁷

In addition to obtaining an appropriate emission factor for VOC emissions from residential deep fat fryers, a major obstruction to estimating emissions from residential fryers

is the development of an activity factor. Quantitative information on the number of residential fryers (number of households which own a deep fat fryer) and the extent of their operation (daily/weekly/monthly), as well as the typical mass of food fried per use, can be used to develop the necessary activity factor, in units of pounds of food fried per year. Information on the number of deep fat fryers in use may be estimated using sales data or production data from deep fat fryer producers. However, this approach will not give an accurate estimate of the extent of fryer use. Such information was beyond the scope of this study. Consequently, it was not possible to develop an estimate of VOC emissions from deep fat frying oils.

4.3.3 Cigarette, Cigar, and Pipe Tobacco Smoking

4.3.3.1 *Description*

Combustion of cigarettes and the use of other tobacco products such as cigars and pipes produces VOC's which are released into indoor and outdoor air. Cigar and pipe smoking are believed to represent only a small fraction of total tobacco smoked, so cigarette smoking will be the focus of this section.

By 1936, 120 combustion products were identified in tobacco smoke. Currently, the estimated number of known compounds in tobacco smoke has increased to over 4,000.¹⁰ The physical composition, constituents, and shape of cigarettes have changed significantly in the 30 years since the Surgeon General's Report on Smoking and Health first called attention to the nature and composition of tobacco smoke. Processed uncontaminated dry tobacco contains primarily carbohydrates and proteins. Other major constituents include alkaloids (0.5 to 5 percent), terpenes (0.1 to 3 percent), polyphenols (0.5 to 4.5 percent), phytosterols (0.1 to 2.5 percent), carboxylic acids (0.1 to 7 percent), alkanes (0.1- to 0.4 percent), and alkali nitrates (0.01 to 0.7 percent).¹⁰ Trace elements include aromatic hydrocarbons, aldehydes, ketones, amines, nitriles, N- and O-heterocyclic compounds, pesticides, and metallic compounds.

The physicochemical changes in cigarettes over time, particularly changes in tobacco composition, have brought about changes in the chemical characteristics of tobacco smoke. Cellulosic acetate, which is commonly used for filter tips, can reduce emissions of some phenols and N-nitrosamines from cigarette smoke. Perforated filter tips can remove some CO and HCN, while charcoal filters may decrease emission of aldehydes and HCN. Another change has been a trend towards generally lower levels of pesticide residues.

Researchers generally distinguish between mainstream smoke (MS), sidestream smoke (SS), and environmental tobacco smoke (ETS). Mainstream smoke is drawn from the unlit end of the cigarette, while sidestream smoke is emitted from smoldering cigarettes between puffs. This means that the temperature of combustion for MS is higher (800-900°C) than for SS (~600°C).¹¹ ETS consists of SS and exhaled MS, although for practical purposes, ETS can be considered equal to SS. One study estimates that 85 percent of the smoke actually in a room where people are smoking is SS.¹² Mainstream smoke and SS differ in the amounts of tobacco burned, the temperature at which combustion occurs, and in that the tobacco and filter may absorb some constituents of MS. ETS differs from MS and SS in that MS and SS may undergo chemical and physical changes when they cool and react in air.¹² Indoor temperature and humidity also influence the evaporation rate of VOC's from cigarette smoke.¹¹

Mainstream smoke is further divided into a vapor phase and a particulate phase. The vapor phase tends to contain more free radicals and highly reactive oxygen and carbon compounds, while the particulate phase consists of relatively stable radicals. Table 4.3-2 lists the major compounds of MS identified in laboratory analyses and estimates of their fractional concentrations per cigarette. [The Department of Health and Human Services (DHHS) notes that these laboratory studies do not fully reflect actual emissions from cigarette smokers, since smokers of low-nicotine cigarettes tend to compensate for the lower nicotine levels by drawing smoke more intensely and inhaling more deeply.¹⁰]

4.3.3.2 *Method for Estimating VOC Emissions from Cigarette Smoking*

Generally, in calculating emissions, an emission factor (for example, in grams of pollutant per cigarette) is multiplied by an activity rate (number of cigarettes smoked annually). In effect, the numbers listed in Table 4.3-2 are rough estimates of emission factors for the volatile components of mainstream smoke. A leading researcher of environmental tobacco smoke or ETS indicates that there are currently few good estimates of volatile emissions from sidestream smoke, although these numbers may be available within 2 years.¹³ MS and SS contain the same types of compounds, although the quantities of the constituents may differ.

In order to estimate emissions, some basic assumptions are required. First, it is assumed that complete combustion (smoking) of each cigarette occurs. Also, as much as 50 percent of the VOC may adsorb to interior surfaces in homes or offices.¹³ Underestimation of VOC emissions may occur because MS is considered to constitute only 10 to 15 percent of the combustion products of cigarettes, with SS making up the rest, so using emission factors for MS only will seriously underestimate the magnitude of VOC emissions from this source.¹² Because emission factors for SS are not yet available, only an estimate of the order of magnitude of emissions from this source is possible using the method described here.

4.3.3.3 *Estimated Emissions From Cigarette Smoking*

Using the fractional constituent factors given in Table 4.3-2, Table 4.3-3 lists estimated 1987 emissions by VOC species for cigarette smoking. These values were derived from the following equation:

$$\begin{aligned} \text{emission factor} \times \text{activity level} \times \text{conversion factors} &= \text{emissions estimate} \\ \text{ug/cigarette} \times \text{cigarettes/yr} \times \text{pounds/ug} &= \text{emissions estimate} \end{aligned}$$

The emission factor used are the values listed in Table 4.3-2. Where a range of values was given, the mean was used in the calculation. The activity level is the 1987 consumption of

cigarettes in the United States, 575 billion cigarettes.¹⁴ Again, because of the lack of availability of sidestream smoke emission factors and other uncertainties, these numbers represent order of magnitude estimates only.

**TABLE 4.3-2. MAJOR CONSTITUENTS OF MAINSTREAM SMOKE FROM
UNFILTERED CIGARETTES**

<u>Constituents(a)</u>	<u>Concentration/cigarette</u>	
Volatile alkanes (20)	1	mg(b)
Volatile alkenes (16)	0.4–0.5	mg
Isoprene	0.2–0.4	mg
Butadiene	25–40	ug
Acetylene	20–35	ug
Benzene	12–50	ug
Toluene	20–60	ug
Styrene	10	ug
Other volatile aromatic hydrocarbons (29)	15–30	ug
Formic acid	200–600	ug
Acetic acid	300–1700	ug
Propionic acid	100–300	ug
Methyl formate	20–30	ug
Other volatile acids (6)	5–10	ug(b)
Formaldehyde	20–100	ug
Acetaldehyde	400–1400	ug
Acrolein	60–140	ug
Other volatile aldehydes	80–140	ug
Acetone	100–650	ug
Other volatile ketones (3)	500–100	ug
Methanol	80–180	ug
Other volatile alcohols (7)	10–30	ug(b)
Acetonitrile	100–150	ug
Other volatile nitriles (10)	50–80	ug(b)
Furan	20–40	ug
Other volatile furans (4)	45–125	ug(b)
Pyridine	20–200	ug
Picolines (3)	15–80	ug
3-Vinylpyridine	10–30	ug
Other volatile pyridines (25)	20–50	ug(b)
Pyrrole	0.1–10	ug
Pyrrolidine	10–18	ug
N-Methylpyrrolidine	2–3	ug
Volatile pyrazines (18)	3–8	ug
Methylamine	4–10	ug

(continued)

**TABLE 4.3-2. MAJOR CONSTITUENTS OF MAINSTREAM SMOKE FROM
UNFILTERED CIGARETTES (continued)**

<u>Constituents(a)</u>	<u>Concentration/cigarette</u>	
Nicotine		
Other aliphatic amines (32)	3-10	ug
Nicotine	1000-3000	ug
Nornicotine	50-150	ug
Anatabine	5-15	ug
Anabasine	5-12	ug
Bipyridyls (4)	10-30	ug
Naphthalene	2-4	ug
Other naphthalenes (23)	3-6	ug
Phenol	80-160	ug
Other phenols (45)	60-180	ug
Catechol	200-400	ug
Other catechols (4)	15-30	ug
Scopoletin	15-30	ug
Cyclotenes (10)	40-70	ug
Solanesol	600-1000	ug
Neophytadienes	200-350	ug
Limonene	30-60	ug
Linolenic acid	150-250	ug
Lactic acid	60-80	ug
Indole	10-15	ug
Skatole	12-16	ug
Quinolines (7)	2-4	ug
Benzofurans (4)	200-300	ug
Stigmasterol	40-70	ug
Sitosterol	30-40	ug
Campsesterol	20-30	ug
Cholesterol	10-20	ug
Tobacco-specific N-nitrosamines (4)	0.34-2.7	ug
Glycerol	120	ug

(a)Numbers in parentheses represent individual compounds identified in a given group.

(b)Estimate.

**TABLE 4.3-3. ESTIMATED 1987 EMISSIONS OF VOC CONSTITUENTS OF
MAINSTREAM SMOKE**

<u>Constituents</u>	<u>Estimated emissions (lbs/yr)</u>
Volatile alkanes (20)	12,650
Volatile alkenes (16)	5,693
Isoprene	3,795
Butadiene	405
Acetylene	354
Benzene	392
Toluene	506
Styrene	127
Other volatile aromatic hydrocarbons (29)	291
Formic acid	5,060
Acetic acid	12,650
Propionic acid	2,530
Methyl formate	316
Other volatile acids (6)	101
Formaldehyde	759
Acetaldehyde	11,385
Acrolein	1,265
Other volatile aldehydes	1,392
Acetone	4,744
Other volatile ketones (3)	949
Methanol	1,645
Other volatile alcohols (7)	253
Acetonitrile	1,581
Other volatile nitriles (10)	822
Furan	380
Other volatile furans (4)	1,075
Pyridine	1,392
Picolines (3)	607
3-Vinylpyridine	253
Other volatile pyridines (25)	443
Pyrrole	63
Pyrrolidine	190
N-Methylpyrrolidine	32
Volatile pyrazines (18)	76
Methylamine	89

(continued)

**TABLE 4.3-3. ESTIMATED 1987 EMISSIONS OF VOC CONSTITUENTS OF
MAINSTREAM SMOKE (continued)**

<u>Constituents</u>	<u>Estimated emissions (lbs/yr)</u>
Other aliphatic amines (32)	76
Nicotine	25,300
Nornicotine	1,265
Anabasine	114
Bipyridyls (4)	253
Naphthalene	38
Other naphthalenes (23)	63
Phenol	1,518
Other phenols (45)	1,518
Catechol	3,795
Other catechols (4)	291
Scopoletin	291
Cyclotenes (10)	696
Solanesol	10,120
Neophytadienes	3,479
Limonene	569
Linolenic acid	2,530
Lactic acid	886
Indole	164
Skatole	177
Quinolines (7)	38
Benzofurans (4)	3,163
Stigmasterol	696
Sitosterol	443
Campsesterol	316
Cholesterol	190
Tobacco-specific N-nitrosamines (4)	19
Glycerol	1,518
TOTAL VOC EMISSIONS	121,136

4.3.4 References for Section 4.3

1. Teleconference between Phillip Katz of the Beer Institute and Scott Lowe of TRC Environmental Corporation. Discussed beer consumption and emissions information. April 14, 1993.
2. Teleconference between Wade Stevens of the Wine Institute and Scott Lowe of TRC Environmental Corporation. Discussed wine consumption and emissions information. April 14, 1993.
3. Teleconference between David Byrd of the Distilled Spirits Council of the United States and Scott Lowe of TRC Environmental Corporation. Discussed distilled spirits consumption and emissions information. April 15, 1993.
4. Leftonen, Matti and P. Jounela-Eriksson. "Volatile and Non-Volatile Compounds in the Flavor of Alcoholic Beverages," *Flavour of Distilled Beverages, Origin and Development*. Ellis Horwood Series. New York, N.Y. 1983.
5. *1993 National Trade and Professional Associations of the United States, 28th Edition*. Columbia Books Inc. Washington, D.C. 1993.
6. U.S. Environmental Protection Agency. *Compilation of Air Pollutant Emission Factors*, (AP-42). Office of Air Quality Planning and Standards. Research Triangle Park, N.C. October 1986.
7. U.S. Environmental Protection Agency. *Air Pollution Engineering Manual, Second Edition*. AP-40. Research Triangle Park, NC. May 1973.
8. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC *Identification and Characterization of Missing or Unaccounted for Area Source Categories. Final Report*. September 1991.
9. Eugster, H.R., and W.J Dennison. *Area Source Emissions for C/Y 1989 from Deep Fat Frying in the SCAQMD Air Basin*. C.E.S. No. 66811. South Coast Air Quality Management District Engineering Division Report. October 1990.
10. Surgeon General, *Reducing the Health Consequences of Smoking: 25 Years of Progress*, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, Rockville, MD, 1989.
11. Guerin, M.R., R.A. Jenkins, and B.A. Tomkins, *The Chemistry of Environmental Tobacco Smoke: Composition and Measurement*, Center for Indoor Air Research, Lewis Publishers, Ann Arbor, 1992.
12. Special Projects Office of the Health Program, Office of Technology Assessment, *Passive Smoking in the Workplace: Selected Issues*, May 1986.

13. Teleconference between Joan Daisey, Indoor Environment Division, Lawrence Berkeley Laboratories and Wienke Tax, TRC Environmental Corporation. August 20, 1992. Discussed estimates of emissions from mainstream and sidestream cigarette smoke.
14. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, *Smoking Tobacco and Health: A Fact Book*, DHHS Publication No. (CDC) 87-8397, revised 10/89.

4.4 SMALL COMBUSTION SOURCES

4.4.1 Kerosene Space Heaters

4.4.1.1 *Description*

Kerosene heaters are typically used as a supplemental heat source in areas in which: 1) residential central heating systems are not installed, 2) inadequate heat is available and/or 3) temperatures are extremely cold. Kerosene heaters usually supplement other heating sources such as electric, fuel oil and gas furnaces. Portable kerosene heaters are limited to supplemental heating because the kerosene tank on each heater is too small to provide continuous heating without constant refilling. Table 4.4-1 lists two of the most popular kerosene heater sizes and some of the features.¹

TABLE 4.4-1. KEROSENE HEATER CHARACTERISTICS

Size	Output (Btu/hr)	Tank Size (gal)	Fuel Consumption Rate (gal/hr)
Small	9,000	0.98	0.075
Large	23,000	1.6	0.17

In the past 18 years, there has been a dramatic increase in kerosene heater usage, possibly caused by the increased operating expense for central heating systems. In 1974, there were only 3,400 portable heaters sold in the United States. By 1979, the market had increased to sales of four million heaters annually.¹ Current estimates place today's annual sales for kerosene heaters between 400,000 and 1,000,000 units, with approximately 4.2 million heaters currently in use in the United States.^{1,2,3,4} Overall, 17 million heaters have been sold in the United States.² Kerosene heater usage is most common in the northern regions of the United States and least common in the southwest regions of the United States.

Kerosene heaters can be divided into three main categories: (1) convective (white flame), (2) radiant (blue flame) and (3) hybrid (two-stage). The most popular type of portable

kerosene heater among consumers is the convective heater. These three types of heaters are described here.

- 1) The convective (white flame) heater operates at relatively high combustion temperatures. It uses a relatively simple unobstructed wick.
- 2) The radiant (blue flame) heater operates at lower temperatures than does the convective heater. It uses a cylindrical wick. Flames extend up from the wick into a perforated metal baffle, consisting of two concentric cylinders inside a glass plenum. After the warm up period the metal baffle glows red hot, causing a portion of heat to be output as radiative heat.
- 3) The hybrid (two-stage) heater is similar to the radiant heater, except a second chamber is located above the radiant element where more combustion air is introduced. In this region the flame temperature is allowed to rise, the color becomes white, and secondary combustion of unburned hydrocarbons with an increase in carbon monoxide production occurs before the combustion product leaves the burner. This type of heater incorporates features from both radiant and convective heaters; thus it is appropriately named "hybrid."

Although kerosene heaters are a logical choice for supplementing a central heating source, their lack of exhaust ventilation has prompted a considerable amount of research on the effects of emissions from kerosene heaters on indoor air quality. These studies have quantified emissions rates and provide the basis for a general methodology to estimate emissions from portable kerosene heaters.

4.4.1.2 *Methods for Estimating VOC Emissions from Kerosene Heaters*

The major VOC pollutant from portable, unvented kerosene heaters is the unburnt combustible formaldehyde (HCHO). Significant quantities of formaldehyde are produced and emitted to an indoor atmosphere under the conditions which portable heaters are normally operated. The average emission factors of the currently known VOC species, formaldehyde, are given in Table 4.4-2.^{5,6,7,8,9,10} A four-hour operating cycle was assumed as a basis for developing the emission factors. The cycle was based on engineering judgment and discussions with industry representatives. The cycle contains two operating modes, a warm-

up mode and a steady-state mode. The emission factors in Table 4.4-2 are a combination of warm-up and steady-state data. The emission factors are based on reported data from six independent experiments, and were obtained through interpolation of experimental heater burns at 60, 90 and 720 minutes. The four-hour operating cycle assumed ten minutes of operation in the warm-up mode and the remaining 230 minutes in the steady-state mode. Once the emission factors were estimated, an overall rate was calculated using the following equation:

$$AEF = \frac{(10 \times WU) + (230 \times SS)}{240} \quad (1)$$

where:

- AEF = average emission factor
- WU = warm up rate
- SS = steady-state rate
- 10 = time (minutes) for the warm up stage
- 230 = time (minutes) for the steady-state stage
- 240 = time (minutes) for the total cycle

TABLE 4.4-2. AVERAGE KEROSENE HEATER EMISSION FACTORS (LBS/1,000 GAL)

Heater Type	HCHO
Convective	0.381
Radiant	0.133
Hybrid	0.011

Organic emissions from kerosene fuel evaporation during the fueling and refueling of the kerosene heater tank are composed primarily of C-8 to C-15 alkenes. Other vapor-phase organics present include the C-13 alkenes which are probably the products of incomplete combustion.⁴ Further research is needed to assess the exact VOC species present during evaporation and incomplete combustion of kerosene fuel.

Kerosene emissions are highly variable and are a function of kerosene content and operating practices. Generally, two types of kerosene fuels are used in the heaters. The first and more common fuel (K-1) is a low sulfur content fuel (*i.e.* 0.04 percent maximum). K-2,

the second fuel type, has a higher sulfur content than K-1 (*i.e.* 0.3 percent maximum). K-2 fuel was used more often in early portable kerosene heaters, but is now most often used as the main heating fuel in homes with kerosene furnaces. The higher grade low-sulfur fuel (K-1) is used in modern kerosene heaters to reduce sulfur dioxide production. Kerosene heaters should be operated at a wick setting that is recommended by the manufacturer as being most efficient. Operating the heater at lower wick heights reduces the amount of fuel consumption, but causes more pollutant emissions.

The proposed methodology for estimating formaldehyde emissions from kerosene heaters is based on estimating the emissions during the burn cycle of the three types of kerosene heaters. The methodology requires the following input data:

- Emission rates for kerosene heaters (which are estimated above)
- Typical kerosene consumption and kerosene heater data for the national level

Kerosene heater activity is based on the number of households using kerosene as a supplemental fuel reported in *Census of Housing* and the assumption that these households each operate one kerosene heater. If the *Census of Housing* is not available the identical information maybe obtained from the Department of Energy's *Housing Characteristics* document.

The fuel consumption rate (gallons per year) is calculated, as shown below, by averaging the consumption rates from Table 4.4-1 to obtain an average fuel consumption rate for kerosene heaters. The average rate is then multiplied by the assumed burn cycle (four hours per day) and then by the average winter usage (90 days per year).

$$Consumption = \frac{(0.17 + 0.075)}{2} \frac{gal}{hr} \times \frac{4 hr}{day} \times \frac{90 days}{yr} = \frac{44.1 gal}{yr} \quad (2)$$

The following equation is used for estimating emissions from kerosene heaters:

$$Emissions_{i,study,yr2} = EF_i \times heaters_{study,yr2} \times consumption \quad (4)$$

where:

i	=	the pollutant being studied (HCHO)
study	=	the study area (national level)
yr2	=	the study year (1990)
Emissions _i	=	emissions of pollutant i (HCHO)
EF _i	=	emission factor for pollutant i (lbs of pollutant per gallon of kerosene)
heaters	=	number of households using kerosene as a supplementary fuel (from the <i>Census of Housing or Housing Characteristics</i>)
consumption	=	44.1 gallons per year assumed as kerosene consumption per household using kerosene as a supplementary fuel

4.4.1.3 Estimated Emissions from Kerosene Heaters

The total United States emission estimates for HCHO for 1990 are presented in Table 4.4-3. Emissions have been estimated for the three types of kerosene heaters which are manufactured. The emissions presented in Table 4.4-3 are based on kerosene consumption, the heating cycle and the number of days the heater is used in the year.

TABLE 4.4-3. ESTIMATED 1990 EMISSIONS FROM KEROSENE HEATERS IN THE UNITED STATES

ACTIVITY	PRODUCT	VOC SPECIES	ESTIMATED 1990 U.S. EMISSIONS (POUNDS)
Heating	Convective Heater	Formaldehyde	70,569
	Radiant Heater	Formaldehyde	24,634
	Hybrid Heater	Formaldehyde	2,037
TOTAL		Formaldehyde	97,240

4.4.2 Camp Stoves, Camp Lanterns, and Outdoor Portable Heaters

4.4.2.1 *Description*

Camp stoves, camp lanterns and portable heaters are used in the U.S. for various outdoor activities including backpacking and camping, or work in open areas. Two primary kinds of camp stoves sold in the U.S. are backpack type single burner stoves and family type two or three burner stoves. These stoves are designed to burn Coleman® fuel (C_7H_{16}), regular unleaded gasoline, kerosene, or propane gas. Other fuels used less frequently include aviation gas, starter fluid (ethyl ether), butane and isobutane. Many camping supply stores sell propane and butanes as liquefied gases in pressurized containers.^{11,12}

Camping lanterns used include single or dual mantle lanterns which burn propane gas, Coleman® fuel, unleaded gasoline or kerosene. Portable heaters, used for outdoor heating jobs, include the standard single-head or double-head bulk mount types which are usually designed to operate on propane gas.¹¹

One of the primary manufacturers of camping products is The Coleman Company, Inc.¹² Most of their products are designed to burn on Coleman® fuel. It is estimated that about 5 to 6 million gallons (18.9 to 22.7 million liters) of Coleman® fuel is sold each year.¹³ No information was located on actual numbers of camping stoves, lanterns or heaters used in the U.S.^{14,15,16}, however, a spokesman from Coleman estimated that approximately 40 million Coleman® stoves (that burn Coleman® fuel) and 2 million Coleman® stoves (that burn unleaded gasoline) are currently used in the U.S.¹³ Other smaller-scale manufacturers of camping products include MSR, Primus, and Optimus.¹² Primus and Optimus were not contacted for this brief study. MSR was contacted for information on fuel combustion efficiencies from their products. They were unable to provide any additional information.

4.4.2.2 *Method for Estimating VOC Emissions from Camp Stove, Camp Lantern and Outdoor Portable Heater Fuels*

The methodology that could be used to determine total annual VOC emissions from the use of fuels in camping/outdoor equipment is as follows:¹⁷

- Determine the U.S. sales volumes for fuels in camping/outdoor recreational activities by fuel type and product type - (Vol)
- Conduct laboratory testing to determine emission factors for VOC's from fugitive emissions and incomplete combustion by fuel type and product type - (EF)
- Multiply emission factor by the sales by fuel type and product type to calculate total annual VOC emissions using the following equation

$$\text{Total annual VOC emissions} = (\text{Vol}) * (\text{EF})$$

A spokesman from the Coleman® company estimated that average emission concentrations from total unburnt carbon in Coleman® lanterns are less than 10 to 15 ppm (as carbon) and less than 10 to 60 ppm (as carbon) from Coleman® stoves. This information is based specifically on the use of Coleman® fuel although it was stated, that emission concentrations from the use of other fuels in Coleman® stoves and lanterns would be approximately the same.¹⁶ Based on this information and the test parameter given the total annual emissions were calculated for the use of Coleman® fuel in Coleman® camp stoves and lanterns. However, it should be noted that these emissions concentrations do not take into account fugitive emissions that would occur during storage, transport, and use of the fuel. These fugitive losses would probably account for a greater proportion of VOC emissions than VOC emissions from incomplete combustion, and would vary greatly depending on consumer use practices such as fuel transfer methods and open containers. Furthermore, Coleman® fuel is used in camping products manufactured by other companies whose products might differ in their combustion efficiencies. A spokesman from MSR indicated that some of their products using Coleman® fuel burn with a 55% combustion efficiency.¹⁸ Also note that the concentrations mentioned by Coleman® are based on total unburnt carbon emissions which

may exclude common gaseous products of organic combustion but could include carbon from products not considered VOC's that may be present in fuel formulations.

Given the limited time and the difficulty in obtaining all the relevant information, it was not possible to accurately calculate the total annual VOC emissions from this product category during this study.

4.4.2.3 *Estimated Emissions from Camp Stoves, Lanterns, and Outdoor Portable Heaters*

Based on the information provided by Coleman® from the use of Coleman® stoves and lanterns, a first approximate estimate of total VOC emissions per year was calculated to be less than 10 tons of unburnt Coleman® fuel. Emissions calculation data are not provided due to the lack of more accurate emissions concentrations which should include the fugitive emissions sources mentioned earlier. Accurate emissions estimates from this source category can only be calculated if more accurate emissions data are obtained.

4.4.3 Fire Starting Materials

4.4.3.1 *Description*

Fire starting materials are products used to aid or initiate the combustion process of various consumer products. Fire starting materials include solid and gel starters, and alternative combustion materials such as self-starting charcoal and artificial fire logs.¹⁹ These products may be used for household fireplaces and for outdoor cooking purposes as in grills and camp stoves.²⁰ These materials may be used throughout the year. However it is not likely to expect as much camping or outdoor activities in the winter than in the summer.

Several trade associations and manufacturers were contacted in an attempt to better categorize the various types of fire starting materials that are currently manufactured in the U.S.. None of these sources were able to immediately provide a comprehensive list of the different products sold in the U.S. marketed as "fire starting materials".^{21,22,23,24}

Solid starters usually consist of wood shavings held together with paraffin wax.^{19,23} The actual percentages by volume/weight of these components could not be found at this time although the material was found to be similar to manufactured fire logs.²⁵ The Department of Ecology, State of Washington stated that products of combustion due to the burning of one type of solid starter (Lightening Bug Nuggets) are not found to be any more polluting than the burning of artificial fire logs. Gel starters are usually alcohol-based products.¹⁹ Alco Brite® manufactures a gelled alcohol fuel called Cook 'n' Heat Fuel® which contains 1000 ppm ethanol (75 percent) and 200 ppm (3 percent) methanol. Other similar gel products include the Snap-On-Stove® and Alco Brite® Fire Starter.²⁶ It was not possible during the time period of this study to find out whether Alco Brite has performed any emissions testing of its products. Another manufacturer makes a product known as Mautz Fire Ribbons which consists of a standard petroleum-based solvent, usually p-naphtha, mixed with clay. This product consists of 95 percent solvent and is often used to start fires in bar-b-que grills and torches.²² No other product types or consumption data from solid or gel starters were located during the time period of this study.

Artificial household fire logs are made by compressing sawdust and petroleum wax.^{19,27} Canadian Firelog Ltd. makes a product that contains cedar sawdust (38 percent), paraffin wax (61 percent), calcium carbonate (0.75 percent) and copper sulfate (0.5 percent).^{19,28} One source indicated that the product composition of fire logs does not vary drastically from manufacturer to manufacturer.²⁹ A representative from Duraflame Firelogs estimated that approximately 40 to 60 percent of households in the U.S. use artificial fire logs and of these 15 percent are regular users and up to 30 percent are occasional users. He projected that between 10 to 12 million log cases, each weighing 30 to 36 pounds are sold each year in the U.S.²⁷

4.4.3.2 Method for Estimating VOC Emissions from Fire Starting Materials

Numerous sources were researched to find emissions information for this category.^{19,21,22,23,27} These included the EPA and local university libraries, and several Professional and Trade Associations. One such source was able to provide emissions testing

data for the burning of artificial fire logs.²⁸ No emissions information was available for other fire starting materials.

In 1987 the Canadian Firelog Ltd. had research conducted to test atmospheric emissions from the burning of their product. The test was conducted by measuring stack emissions from a wood burning stove. This testing measured emissions for various products of combustion including polynuclear aromatic hydrocarbons (PAHs). The results of the study indicated that the total PAHs were at minimal concentrations of no greater than 0.02 mg/m³.²⁸ Using the information from this study it is possible to estimate emissions from similar products manufactured in the U.S. The assumption made here is that the composition of artificial fire logs does not greatly vary from manufacturer to manufacturer and therefore emissions will be similar.

Calculation for Total PAH Emissions from Artificial Household Fire Logs²⁸

Test Parameters

Flow rate: 95 acfm

Test Time: 11:50 to 12:20; 0.5 hrs (average)

Mass of fire log used in the study: 5 pounds

Consumption Data

Number of cases of fire logs sold in the U.S. annually: 10 to 12 million; 11 million (average)

Mass of each case: 30 to 36 pounds; 33 pounds (average)

Calculation

PAH emissions from test:

$$< = [(0.02 \text{ mg/m}^3) * (95 \text{ ft}^3/\text{min}) * (0.5 \text{ hrs}) * (60 \text{ min/hr}) * (0.3048 \text{ m/ft})^3]$$

$$< = 1.6 \text{ mg PAH/5 pounds firelog}$$

PAH emissions in the US from artificial firelog combustion:

$$< = (1.6 \text{ mg PAH/5 lbs firelog}) * (11 \times 10^6 \text{ cases/yr}) * (33 \text{ lbs/case})$$

$$< = 1.16 \times 10^8 \text{ mg/yr}$$

$$< = \underline{256 \text{ lbs/yr}}$$

4.4.3.3 *Estimated Emissions from Fire Starting Materials*

From these calculations, it is estimated that the total PAH emissions from the combustion of artificial fire logs does not exceed 256 tons/yr. It should be noted that this information does not include fugitive emissions that might result from product shelf life. Furthermore, it is likely that this emissions test may result in an underestimation of total VOC releases since the measured PAH emissions may not comprise all the VOC's that might be present in the stack emissions.

Due to their composition, it is expected that fugitive emissions and emissions from combustion could result from the alcohol-or solvent based component of solid and gel starters. However, until emissions and consumption data are available from the use of these products, total VOC emissions cannot be accomplished.

4.4.4 References for Section 4.4

1. Telecon. Lowe, Scott, Alliance Technologies Corporation, with Mindi Farber, Energy Information Administration. Kerosene heater sales and other general information. September 5, 1991.
2. Telecon. Lowe, Scott, Alliance Technologies Corporation, with Dr. Harold Smith of the National Kerosene Heater Association. Kerosene space heater statistics. July 13, 1991.
3. *Housing Characteristics*, DOE/EIA-0314(90), U.S. Department of Energy, Energy Information Administration, Washington, DC. Triennial Publication.
4. White, J. *Summary of U.S. EPA Sponsored Large Chamber Characterizations of Emissions from Unvented Kerosene Space Heaters*, EPA/600/D-90/100, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1990.

5. Apte, M.G. and G.W. Traynor. *Comparison of Pollutant Emission Rates from Unvented Kerosene and Gas Space Heaters*, NTIS DE86-015133, Lawrence Berkeley Laboratory, Berkeley, CA, May 1986.
6. Dudney, C.C., A.R. Haythorne, K.P. Monar, M.A. Cohen, and J.D. Spengler. *Impact of Kerosene Heater Usage on Indoor SO₂ Exposures in 50 east Tennessee Homes*, NTIS DE88-016813, Oak Ridge National Laboratory, Health and Safety Research Division, Oak Ridge, TN, July 1988.
7. Jackson, M.D., S.A. Rasor, R.K. Clayton, and E.E. Stephenson, Jr. *Particulate and Organic Emissions from Unvented Kerosene Heaters, test House Study*, EPA-600/D-88/226, U.S. Environmental Protection Agency, Research Triangle Park, NC, October 1988.
8. Lionel, T., R.J. Martin, and N.J. Brown. *A Comparative Study of Combustion in Unvented Space Heating Devices*, NTIS DE85-000673, Lawrence Berkeley Laboratory, Berkeley, CA, October 1984.
9. Traynor, G.W., M.G. Apte, H.A. Sokol, and J.C. Chuang. *Comparison of Measurement Techniques for Quantifying Selected Organic Emissions from Kerosene Heaters*, EPA-600/D-86/142, U.S. Environmental Protection Agency, Research Triangle Park, NC, February 1990.
10. Traynor, G.W., M.G. Apte, H.A. Sokol, J.C. Chuang and J.L. Mumford. *Selected Organic Pollutant Emissions from Unvented Kerosene Heaters*, EPA-600/D-86/142, U.S. Environmental Protection Agency, Research Triangle Park, NC, July 1986.
11. *Coleman Product Information Guide (1993 edition)*. The Coleman Company®, Inc. Wichita, Kansas 67202.
12. Teleconference between Randy Lowe, Recreational Equipment Inc., and Sheila Thomas, TRC Environmental Corporation. Discussed camping equipment and fuels. April 13, 1993.
13. Teleconference between Randy May, The Coleman Company® and Sheila Thomas, TRC Environmental Corporation. Discussed camping equipment and fuels. April 13, 1993.
14. Teleconference between Mike Walsh, Sierra Club, and Sheila Thomas, TRC Environmental Corporation. Discussed camping equipment and fuels. April 13, 1993.
15. Teleconference between Sanjay Mishra, Green Peace, and Sheila Thomas, TRC Environmental Corporation. Discussed camping equipment and fuels. April 13, 1993.

16. Teleconference between Ruth Lister, American Camping Association, and Sheila Thomas, TRC Environmental Corporation. Discussed camping equipment and fuels. April 13, 1993.
17. U.S. Environmental Protection Agency. *Identification and Characterization of Missing or Unaccounted For Area Source Categories*. EPA-600-R-92-006. Air and Energy Engineering Research Laboratory, Research Triangle Park, N.C. 1992.
18. Teleconference between Dan Vorhees, MSR and Sheila Thomas, TRC Environmental Corporation, with . Discussed camping equipment and fuels. April 13, 1993.
19. U.S. Environmental Protection Agency. *Estimation of Emissions from Charcoal Lighter Fluid and Review of Alternatives (Final Report)*. EPA/600/2-90/003. Air and Energy Engineering Research Laboratory, Research Triangle Park, N.C. January 1990.
20. Teleconference between Randy Lowe, Recreational Equipment Inc. (REI) and Sheila Thomas, TRC Environmental Corporation. Discussed camping equipment and fuels. April 13, 1993.
21. Teleconference between Caroline Desseji, Hearth Products Association and Sheila Thomas, TRC Environmental Corporation. Discussed product types and emissions from fire starting materials. April 19, 1993.
22. Teleconference between Doug Mall, Mautz Paint Co. and Sheila Thomas, TRC Environmental Corporation. Discussed product types and emissions from fire starting materials. April 20, 1993.
23. Teleconference between Steve Marshall, Lightening Starters Inc.® and Sheila Thomas, TRC Environmental Corporation. Discussed product types and emissions from fire starting materials. April 19, 1993.
24. Teleconference between Linda Hansen, Hearth and Home Magazine and Sheila Thomas, TRC Environmental Corporation. Discussed product types and emissions from fire starting materials. April 23, 1993.
25. Letter from Michael Landon, State of Washington, Department of Ecology to Marshall Thompson, Lightening Starters, Inc.® Evaluation of Lightening Bug Fire Starters. Letter dated June 17, 1992.
26. Alco Brite®. Dealer Catalog 1993 Products. Hildale, Utah.
27. Teleconference between Chris Caron, Duraflame Fire Logs and Sheila Thomas, TRC Environmental Corporation. Discussed product types and emissions from fire starting materials. April 23, 1993.

28. Canadian Firelog Ltd. Emissions Testing Report. Richmond, British Columbia. December 8, 1987.
29. Teleconference between Dave Eckert, Canadian Firelog Ltd. and Sheila Thomas, TRC Environmental Corporation. Discussed product types and emissions from fire starting materials. April 20, 1993.

4.5 MISCELLANEOUS PRODUCTS

4.5.1 Mold Release Agents¹

4.5.1.1 *Description*

A mold release agent (MRA) can be generically described as any substance used to control or eliminate the adhesion of a material to itself or to another material. The MRA prevents the molded product from sticking to the mold so that the product can easily be removed in one piece. Factors such as penetration, chemical reaction and compatibility, low surface tension, surface configuration, and differences in polarity between the two materials influence adhesion between materials.¹ MRA's may also be known as adherents, anti-blocking agents, external or surface lubricants, parting agents, and slip aids. The MRA consists of the active ingredient (the ingredient that actually causes the adhesion) and a carrier or additive that is used to apply the MRA. The active ingredient is most often inert, that is, it contains no VOC. The carriers and additives often contain VOC, although non-VOC carriers and additives may be used. Major industrial applications for MRA's include casting, molding, forming, and materials transfer operations in a wide variety of industries, including plastic (or polymer) processing, rubber, metal processing, glass, food processing, textiles, printing, and others.

The category is divided into two major types of agents: topical coatings and semi-permanents. Topical coatings, which currently dominate the MRA market, are further divided into external MRA's and internal MRA's. External MRA's operate much in the same manner as oil, lard, and nonstick sprays operate on cookware. Abherents can be applied to a surface by standard coating methods such as spraying, brushing, dusting, dipping, electrostatic powder coating, and plasma arc coating. The product (e.g., resin, metal, rubber, glass, etc.) is injected, laid, rolled, sprayed, etc., in the mold where the product is cured. The part is then released from the mold and the MRA is reapplied to the mold.

Internal MRA's, typically metallic stearates, are agents that are added to the resin itself.¹ While there is no consensus as to how such agents work, one hypothesis is that the MRA migrates to the surface of the resin, that is, to the part/mold interface, during the interval between the injection and the ejection. The agent then acts as an external release agent, essentially lubricating the boundary. A number of factors influence the performance of internal MRA's, including solubility in the resin, rate of migration, lubricity, melting point of the additive, and extent of electrostatic inhibition.^{2,3}

Semipermanents, or multiple release products, are a relatively new concept in release agents. Semipermanents allow a large number of processing cycles to occur before re-application of the MRA is needed. They are usually water- or solvent-based with the latter predominantly used in heat-cured systems. They can be used to coat the mold or can be applied to become an integral part of the mold. Advantages include low buildup, promotion of excellent part surface and finish, minimal transfer to the part, high release efficiencies, low or non-toxicity of some products and high temperature stability (up to 375°C).¹

4.5.1.2 *Mold Release Agents as Sources of VOC Emissions*

Emissions from MRA use can occur at several points in the application process and depend primarily on the mode of application. With external MRA's, VOC emissions will occur from the application of sprays and liquids. Emissions points are the applicator, the mold and the product. With internal MRA's, emissions may occur from the surface of the mold and the surface of the product. However, most internal mold release agents are not mixed with additives and carriers, and therefore, there would be no VOC emissions. Emissions points for application and use of semipermanents are similar to those of external MRA's. However, since these MRA's are not applied as frequently as externals, their relative emissions (assuming the same VOC content as a comparable external MRA) will be lower.

Another source of emissions from the MRA application process involves clean up activities. Mold surfaces are cleaned at regular intervals to increase the efficiency of the

MRA. Many of the products used in clean up are solvents with high VOC contents (e.g., mineral spirits, trichloroethylene).

4.5.1.3 *VOC Emission Estimates*

Total VOC emissions from MRA's were estimated by calculating emissions for aerosol MRA's and liquid MRA's. This resulted in an estimate of 125,592 tons of VOC per year for all MRA's. Using industry-specific data on amount of active ingredient consumed, assumptions on application method, and the total emissions estimate for MRA's, industry-specific emissions estimates were developed. Three major assumptions were used in this process:

- Assume that the relationship of additives and carriers for the industry to total additives and carriers is the same as the relationship of active ingredients for the industry to total active ingredients. For example, polyurethanes consume 23.6 percent of total active ingredient. Therefore, polyurethanes consume 23.6 percent of total additives and carriers.
- Based on the first assumption, assume that the proportion of additives and carriers in an industry to the total additives and carriers is the same as VOC emissions for the industry to total VOC emissions. For example, MRA active ingredient consumption by polyurethanes is 23.6 percent of total MRA active ingredient and, therefore, VOC emissions for polyurethanes are 23.6 percent of total additive and carrier consumption. Thus, assume polyurethanes carries 23.6 percent of the total VOC emissions.
- Since no information is available on the application/delivery mode by industry, assume that the overall distribution (47.5 percent sprays, 33.9 percent liquids, and 18.6 percent dusts) applies to each industry.

Using these three assumptions, MRA VOC emissions for specific industry segments were calculated and are presented in Table 4.5-1.

TABLE 4.5-1 EMISSIONS FROM MOLD RELEASE AGENTS BY INDUSTRY

INDUSTRY	VOC EMISSIONS (tons)
Polyurethanes	29,624
Polyesters	15,440
Epoxies	3,891
Other Thermosets	4,895
Polyvinyl chloride	6,904
Polystyrene	6,653
Other Thermoplastics	5,272
Rubber Processing	20,586
Metal Processing	15,440
Glass Industry	9,540
Other Non-Polymers	7,155
TOTAL	125,529

4.5.2 Products Used in the Manufacture of Fiberglass Boats ²

4.5.2.1 *Description*

The fiberglass boat manufacturing and repair industry consists of about 1,800 facilities. These facilities employ about 47,000 people and are located in 34 of the 48 continental United States. About 88 percent of these establishments are small operations, employing less than 50 people. States that have a large number of boat manufacturing facilities include California, Florida, Illinois, Indiana, Michigan, North Carolina, South Carolina, Tennessee, Texas, and Washington.

The most common fiberglass boat production method is open contact molding. This method consists of laying up plies of fiberglass reinforcement impregnated with resin on an

open male (convex) or female (concave) mold. For manufacturing boats, a female mold is generally preferred since it yields a smooth outer surface which is more desirable for hulls and decks. The layers are built up to the desired thickness and allowed to cure.

The initial layer of resin is formed without any reinforcing material by spraying gel coat (unsaturated polyester resin, catalyst, and pigments) into the empty mold to a precise thickness. After allowing the gel coat to cure fully, laminates of resin and fiberglass are applied by machine lay-up, hand lay-up, or spray lay-up. Machine lay-up involves the simultaneous mechanical application of fiberglass reinforcement material and is generally reserved for large hull boats; e.g., sailboats with deep keels. In hand lay-up, resin is brushed or sprayed on the tacky surface of the gel coat, the fiberglass reinforcement material is placed into the mold, then the laminate is completely wet out with resin and rolled by hand to remove air pockets and other imperfections. The spray lay-up method uses a chopper gun which simultaneously deposits chopped strand fiberglass and catalyzed resin on the mold, after which rollers are used, as in hand lay-up, to remove entrapped air.

Two alternative closed molding methods which have been experimented with in the fiberglass boat manufacturing industry are bag molding and resin transfer molding (RTM). Bag molding uses a bag or flexible membrane to apply vacuum or pressure during the molding operation. Vacuum bag molding applies pressure against the laminate by drawing a vacuum under a cellophane, vinyl, or nylon bag which covers the laminate. Pressure bag holding forces the bag against the laminate using compressed air or steam. In the RTM process, fiberglass reinforcement consisting of continuous or chopped strand glass fiber mats is placed between halves of a mold. After the mold is closed, catalyzed resin is injected into the mold and allowed to cure. The mold is then opened and the finished part removed. The major technical difficulty in using this process for boat manufacturing is that resin void spaces may occur, rendering the part unusable. Also, highly skilled labor is required for RTM to be successful.

4.5.2.2 VOC Emissions from Fiberglass Boat Manufacturing

VOC emissions from fiberglass boat manufacturing consist mainly of acetone and styrene. There are four areas in the fiberglass boat production process where VOC may be emitted to the atmosphere: resin storage, production, assembly, and waste disposal. The major emissions sources are exhausts from gel coat spray booths, room exhausts from the lamination area, and evaporation of acetone or other solvents during cleanup. Emission factors for resin application in open contact molding range from 5 to 13 lb styrene per 100 lb of styrene used. Emissions from gel coat application and curing are 26 to 35 lb per lb of styrene monomer used. Cleaning solvent emissions, primarily acetone, can account for 36 percent of the total VOC emissions and are about equal to 56 percent of the styrene emissions. Total VOC emissions per plant are estimated to range from 2 to 140 tons per year. Total nationwide VOC emissions are estimated to be 20,150 tons per year.

4.5.2.3 Emission Controls

The two general types of VOC emission control techniques available are process changes and add-on controls. The process change offering the greatest potential for VOC emission reductions at low cost is the substitution of lower VOC-containing materials. These include vapor-suppressed resins, low styrene resins, water-based emulsions for cleanup, and dibasic ester compounds for cleanup.

Vapor-suppressed resins contain additives which reduce VOC emissions during resin curing. The most common vapor suppression additive is paraffin, which migrates to the surface of the resin layer and reduces the volatilization of free styrene during resin curing. Styrene emissions reductions ranging from 20 to 35 percent can be achieved on a per plant basis. Vapor-suppressed resins are not currently being used universally in the fiberglass boat manufacturing industry due to problems in secondary bonding which reduce product strength.

The emission reduction from low styrene resins is less than that of vapor-suppressed resins; however, low styrene resins are currently available and being used in the industry.

Styrene emissions can be reduced by about 14 percent using a 35 percent styrene by weight resin. Conventional resins contain 40 to 50 percent styrene by weight. A number of boat plants have reduced the styrene content in their resins to 38 to 40 percent styrene with satisfactory results. Very few boat manufacturers have been able to reduce styrene content below 35 percent without sacrificing some of the structural integrity of the boat.

Water-based emulsions can be used to replace about 50 percent of the solvent used for cleanup. These emulsion cleaners would be expected to reduce clean-up emission by about 50 percent. The cleaners are successfully being used commercially in boat plants for resin cleanup and their use has been required as a permit restriction to reduce VOC emissions from fiberglass boat plants in some recent best available control technology (BACT) decisions. These emulsions, however, appear to be inadequate for gel coat or cured resins cleanup.

Alternative cleaning compounds containing dibasic esters (DBE's) are currently being tested at a number of fiberglass boat plants. These cleaning solutions show great potential to replace acetone completely for resin and gel coat cleanup. Due to the much lower vapor pressure of DBE's, these substitutes can provide dramatic VOC emission reductions. Based on preliminary tests, an estimated reduction of VOC emissions from cleanup activities of 75 percent can be achieved if DBE's are used in place of acetone. The DBE cleaner is currently two to three times more expensive than acetone; however, it lasts longer because it evaporates at a slower rate and it can be recycled.

4.5.3 Automotive Repair Parts Washers ³

A large variety of services may be offered by an automotive repair facility. In addition to engine maintenance, these facilities may repair and service brakes, transmissions, and cooling, air conditioning, and electrical systems. Parts cleaning is common to most facilities and often involves the use of a parts washer.

These washers, which may be maintained and serviced by the facility itself or by an outside company, usually consist of a sink which covers a drum containing solvent and a pump with a filtered intake. The pump circulates solvent from the drum to the sink through a flexible hose. A brush, sometimes mounted to the nozzle of the hose, is used to aid cleaning. Many newer models have a lid that closes to reduce solvent loss through evaporation. Some older parts washers consist of a grate over an open reservoir of solvent. Self-contained systems for immersing parts in solvent for several hours are widely used.

The solvents used in parts washers can vary, but most are based on petroleum distillates. One commonly used solvent contains 85 percent petroleum distillates. Carburetors are usually cleaned by immersion in cleaners that may contain other solvents. One such solvent system used for carburetors is 2-butoxy-1-ethanol and n-methyl-pyrrolidine. Other solvents may include methylene chloride.

Emissions can be attributed to evaporation from the sink and solvent loss through splattering, spillage, or incomplete drainage of cleaned parts. For older washers, evaporation occurs even when the cleaner is not in use. In newer models, the solvent is returned to the drum, and the sink is equipped with a cover to reduce emissions when the cleaner is not in use. Typical parts washers have a storage capacity of 20 gallons. The washers are usually serviced every 30 days, when the dirty solvent is collected and clean solvent installed in the machine.

Estimates of VOC emissions from these cleaners were made based on the assumption that 10 percent (2 gallons) of the solvent is lost during the typical service interval of 1 month. The annual losses are estimated to be 157 pounds per machine. In 1990, there were approximately 55,000 repair facilities nationwide. Assuming one machine per shop, nationwide emissions were estimated to be 4317 tons per year.

4.5.4 Products used in the Textile Industry ⁴

4.5.4.1 *Description*

The textile industry includes facilities involved in the following activities:

- fiber preparation followed by manufacturing of yarn and thread;
- manufacturing of woven fabrics, knit fabrics, carpets, and rugs from yarn;
- dyeing and finishing of fiber, yarn, fabric, knit, and woven apparel;
- manufacturing of apparel and other articles from yarn; and
- manufacturing of nonwoven fabrics and other miscellaneous textiles.

Both man-made and natural fibers are processed. Examples of the latter group include cotton, wool, silk, flax, and jute while the former include such fibers as rayon, polyester, acetate, and nylon. Blends of these fibers may also be processed.

4.5.4.2 *Yarn Production*

Yarn production begins with the blending of fiber from several bales. Dirt and impurities are mechanically removed. Carding aligns the fibers into a thin web and further separates impurities. The thin web is gathered into a rope-like strand called a sliver. To produce yarn from sliver, one of two methods of spinning is employed: ring or open-end spinning. In ring spinning, several strands of sliver are combined and drawn, or drafted, into a longer and thinner form that is about one-eighth of its original diameter, which is called roving. The roving is drafted to a smaller diameter and fed through a ring that rotates about and wraps the yarn around a bobbin. The yarn from several bobbins is combined onto a larger cone in a process called winding.

In open-end spinning, individual fibers are removed from the sliver and reassembled with twist to form yarn. Open-end spinning utilizes the action of water, air, or mechanical rotors.

During yarn production, yarn is often wound from one type of tube or cone to another. For example, after ring spinning, yarn is wound from spinning bobbins to cones or dye tubes, depending on how the yarn is subsequently processed. Yarn that is to be shipped to other facilities may also be wound onto bulk cones. Some package dyeing facilities purchase yarn on bulk cones and wind it onto dye tubes. After package dyeing, yarn is wound from dye tubes to cones. Winding machines that wind yarn onto dye tubes for subsequent package dyeing are called tube winders; those that wind yarn onto cones for knitting or weaving are called cone winders.

4.5.4.3 *Fabric Production*

In general, fabrics may be classified as woven, nonwoven, or knit. The following discussion describes the production process for each type of fabric.

Woven fabric is produced when yarns are interlaced at right angles. Warp yarns are the yarns oriented along the length of the woven fabric while fill yarns are those that run perpendicular to the warp yarns. Warp yarn is prepared in a process called warping by placing cones of yarns on creels and winding them onto warp beams. During warping, the yarns may be coated with size to protect them from the stresses of weaving. A yarn conditioning fluid may also be applied to the yarn as it is wound onto a beam. Prior to weaving, a warp beam is loaded on the front of the loom and the yarn is pulled through heddles, which are metal strips that control each individual yarn. The heddles are connected to a harness which controls groups of yarn. When a harness is raised, an opening is created in which fill yarns are inserted. The order of raising and the number raised is varied to produce patterns on the fabric. Different types of woven fabrics include the plain, twill, satin, dobby, and Jacquard.

Looms may be described by what method is used to insert the fill yarn. Shuttle looms send a carrier with a small bobbin of yarn across the warp. Shuttleless weaving machines use a projectile, a rapier, or a jet of air or water to carry the end of the fill yarn across the warp.

Knit fabrics are produced by the interlooping of yarn. These fabrics may be designated as warp or weft knits. Weft knits are characterized by yarn that runs perpendicular to the length of the fabric. Circular and flat-bed machines are used to manufacture these fabrics. The former type of machine utilizes needles that are arranged in a circle to produce a tubular fabric. In this way, goods, such as hosiery, T-shirts, and turtlenecks, may be produced without vertical seams. Flat-bed knitting machines employ needles that are arranged parallel to each other to produce small items, such as knitted hats and scarves. Because this type of machine does not operate at high speeds, long lengths of knitted fabrics are usually produced on circular knitting machines.

Warp knits are produced by interlooping yarn in the lengthwise direction of the fabric to produce a flat good with straight edges. Specific types of warp knits include tricot, raschel, Milanese, and simplex. Warp knitting machines produce fabric at a greater speed than weft knitting machines.

Nonwoven fabrics are produced by using thermal, mechanical, or chemical means to bond or entangle the fibers or filaments that are laid in a random orientation. Nonwovens may be incorporated into disposable or durable goods, such as household wipes, diapers, protective clothing, road underlays, apparel interfacing, and carpet.

4.5.4.4 *Fabric Preparation*

Greige goods refer to unfinished fabrics from the loom or knitting machines. They may be sold as is or further processed for apparel or household use. The additional processes include fabric preparation, dyeing or printing, and finishing.

The fabric is prepared to promote a clean, uniform substrate for subsequent dyeing, printing, and finishing. The preparation of cotton fabric may begin with singeing, a process that removes lint, surface dirt, and loose fiber. This is accomplished by brushing the fabric and then passing it by a natural gas flame. Desizing uses a sulfuric acid, or enzyme, depending on the size that was applied, to remove sizing that was added to facilitate the

weaving process. The fabric may be scoured in a hot, alkaline solution to remove waxes, oils, and any sizing compounds that may be present in the fabric. A chlorine- or peroxide-based bleach may be used to obtain a uniform-white appearance. Mercerization, treatment of the goods in a caustic soda solution while under tension, is used to increase the luster and strength of the fabric while improving the dyeability.

Synthetic fabric proceeds through a similar sequence, although, in most cases, it requires less preparation than cotton. Wool fabric is prepared by carbonizing, a step that uses sulfuric or hydrochloric acid to reduce to carbon the vegetable matter that adheres to the fibers. The fabric is bleached and singed. Additional chemical and mechanical techniques, such as decating and fulling, may be used to develop the appearance and hand, or feel, of the fabric.

4.5.4.5 *Fabric Dyeing*

Dyeing is the process of adding color to fiber, yarn, and fabric. The dyes may be natural or synthetic and are classified by their chemical makeup. Acid dyes are suited for the dyeing of wool, silk, polyamides, and some acrylic and polyester fibers. Azoic dyes are used on natural and man-made cellulosic fibers, nylon, polyester, and silk. Basic dyes will dye acrylic and some nylon and polyester fibers. Direct dyes are used to dye cellulosic fibers while disperse dyes are applied to synthetic fibers. Reactive dyes are used on cellulosic, wool, silk, and nylon fibers. Sulfur and vat dyes are used on cellulose. Pigments are insoluble colorants added to the fiber-spinning solution in synthetics manufacturing or attached to the surface of a textile with resin binders.

There are several methods for dyeing that can occur at most any step of the textile production process. For example, fiber dyeing and solution dyeing occur prior to yarn spinning. Yarn dyeing, which occurs after the spinning process, can be performed in a variety of ways. Package dyeing involves the dyeing of yarn that has been wound onto perforated spools. The spools are placed on perforated pipes in a package-dyeing machine where dye solution is pumped through the packages. In skein dyeing, loops of yarn are

placed on rods and immersed in a dye solution. Beam dyeing, similar to package dyeing, may be performed to obtain dyed warp yarn for weaving.

Piece dyeing is the batchwise dyeing of fabric, woven or knitted. Beam dyeing is characterized by the pumping of dye through fabric that is wound onto beams. Fabric is sewn into a continuous loop and dyed in rope form in beck and jet dyeing. Becks mechanically pull the fabric through a heated dyebath. Jets use the hydraulic pressure of the dyebath to move the fabric through the machine. Jig dyeing transfers the fabric from a supply beam, through a dyebath, onto a take-up beam, and vice versa.

Garment dyeing is the dyeing of textile products that have already been sewn. They are often dyed in machines that resemble large washing machines. Continuous dyeing is conducted on a range where the fabric or yarn is passed through a series of dye and chemical baths, heat or steam for dye fixation, and hot water washes.

4.5.4.6 *Fabric Printing*

The printing process involves the transfer of color patterns to the surface of the fabric. Dyes and pigments are applied by roller, screen, and transfer printing.

Typically, pigments are used in roller printing. The pigments may be dispersed in water or solvent. Print pastes may be formulated with or without solvents. Some solvent-based print pastes, which contain up to 70 percent Varsol 18, are prepared as emulsions.

Roller printing uses chrome-plated, copper rolls that are engraved or etched with a pattern. The cylinders are positioned around a central impression roller. The unprinted fabric contacts a back greige which is carried by the print belt. Print paste is transferred from a trough to the cylinder by means of a rotating, cylindrical, furnishing brush. A doctor blade removes excess print paste from the cylinder before it contacts the fabric. After the last print cylinder, the cloth is lifted from the back greige and is heated on steam cans or in an oven to

fix the color. Excess print paste is washed from the fabric on a continuous range before it is forwarded to the finishing ranges. The back greige is used only once before being washed. The print belt is brushed and washed as it returns to the front of the machine.

In screen printing, a squeegee is used to force ink or dye through a porous screen mesh. An image is formed because the stencil, which is added to the screen, blocks out certain areas on the mesh.

Screen printing of textiles may be performed with either flat-bed or rotary screen presses. Garment screen printers use flat-bed presses to print on garments and fabric pieces. These presses may be either manually or automatically operated. On manual presses, each printing step including the use of the squeegee is hand operated. On automatic presses, the garments are manually loaded and unloaded on the press, but the garment moves automatically from color-station to color-station. Also automatic in operation are the squeegee and flood bar, which redistributes the ink on the screen after the squeegee has been used. Six- and eight-color manual presses are commonly used; automatic presses with up to 12 color-stations were observed during the site visits.

Most garment screen printers use plastisol inks. These inks contain no volatiles since they consist of two components, polyvinyl chloride (PVC) resins and a plasticizer, that fuse together when the ink is exposed to heat. A relatively small number of garment screen printers use water-based inks. These inks cure through evaporation and may contain some solvent component.

Rotary screen presses use metal cylindrical screens to print on rolls of fabric. Each screen on a press rotates as fabric moves on a belt that travels under it. Ink that is continuously pumped inside the screen is forced through the stencil by a stationary squeegee-like blade that is inside of each screen. During the site visits, rotary screen presses with as many as 14 color-stations were observed.

Typically, the print pastes used in rotary screen printing are water-based systems. One printer stated that varsol-containing print pastes for pigments are no longer used. The pigments and dyes are similar to, if not the same as, those used for dyeing.

Prior to the first production run on the rotary screen printing machines, samples are often prepared on a strike-off table. These prints enable the facility to check the screens for pattern registration and the print-paste formulations for the proper shade. A strike-off table consists of a stationary belt onto which several yards of fabric are adhered. A screen is mounted in a carrier, print paste is placed inside the screen, and the screen is rolled down the length of the fabric. The process is repeated for each additional screen.

A variety of methods may be used to produce stencils. The photostencil method may be used with both flat-bed and rotary screens. In the case of flat-bed screens, it is the dominant process for stencil making. Photostencils are produced by coating the screen with a light-sensitive emulsion. After the emulsion dries, a film positive is placed on it and the emulsion is exposed to light. The light hardens the exposed areas of the emulsion; the rest is washed away with water. Equipment is available that prints a digitally-stored image directly onto the emulsion of flat-bed screens using an opaque, water-based ink. The screen can then be exposed to light without the use of a film positive. Knife-cut stencils are only used on flat-bed presses. These stencils are produced by cutting away areas on a piece of water- or lacquer-soluble film and adhering the film directly to the screen. The type of film that is used depends on whether a water- or solvent-based ink is used. Some stencils on rotary screens are produced using a laser. In this system, the screen is coated with an emulsion and after the emulsion dries, a laser is used to etch a pattern in it.

There are two major types of transfer printing which involve the transfer of color from a paper surface to the fabric. In vapor-phase transfer printing, dyes are printed onto paper which is placed on the fabric surface. Heat causes the dye to vaporize and condense onto the fabric. The pattern is fixed with heat and pressure. Melt transfer printing is performed in a similar way, except that heat is used to transfer dye and a thermoplastic binder to the textile.

4.5.4.7 *Fabric Finishing*

Chemical finishes are applied to fabric to impart certain characteristics. For example, permanent-press, soil-release, soil-resistant, and stain-resistant finishes may be applied to make caring of the fabric easier. To provide comfort and safety, absorbent, antistatic, flame-retardant, chemical-resistant, and water-repellent finishes may be applied. The feel of fabric may be improved with softeners. These finishes are applied by padding a solution or resin onto the fabric, drying it on a tenter frame to specific dimensions, and curing it in an oven.

Other finishes are applied by physical means. Calendering is a process where fabric is passed over heated rolls, imparting a slick and shiny surface. Other mechanical finishing processes that can alter the texture of the fabric include napping, sueding, brushing, and shearing.

4.5.4.8 *VOC Emissions from Products Used in the Textile Industry*

Estimates of VOC emissions can be made for certain solvent-containing products that are used in the textile industry. In this section, estimates are calculated for emissions from:

- parts washer solvents used by garment screen printers;
- platen adhesives; and
- spot cleaners.

Garment screen printers primarily use parts washer solvents to clean ink from press parts. Most garment screen printers also use platen adhesives. Spot cleaners may be used in any textile facility that produces a finished product (e.g., thread, yarn, fabric, garments, etc.).

In some instances, it is difficult or impossible to estimate emissions from a specific product. For example, estimates of emissions from winder cleaners are complicated by the

fact that facilities may use products that contain very different amounts of solvent. Estimates of emissions from cot adhesives pose a similar problem since some facilities use fiber-, metal-, or plastic-lined cots that do not require adhesive. The same difficulty is encountered when attempting to determine emissions from the screen cleaners used in garment screen printing facilities. Some facilities use products containing 100 percent petroleum distillates while others use water-based products containing d-limonene. Similarly, the screen reclaimers that are used may or may not contain solvent. Although data were collected during the site visits on each of these specific products, this information may not represent the true distribution of their use within the industry and, therefore, cannot be extrapolated on a national basis for emission estimates.

Parts Washer Solvent

Two factors may affect the emission of solvent from parts washers: evaporation from the sink and evaporation from depleted solvent that is splattered or carried out of the washer on wet parts. In general, newer models of parts washers are designed so that the solvent returns by gravity to the reservoir, where it is less likely to evaporate. Therefore, for the purposes of this estimate, emissions due to evaporation from the sink will be ignored. In some instances, these emissions may be significant (e.g., at a facility where an older parts washer with an open reservoir is used). Exact measurements of solvent depletion through carryout are not available. Therefore, an assumption that 10 percent of the solvent is lost during the interval of usage was used for this calculation.

The emission estimates are also based on usage data collected from site visits to three garment screen printing facilities. The amount of parts washer solvent used by a printer will depend not only on the number of press pieces cleaned but also, to some extent, on the number of garments printed. Therefore, an estimate of the amount of parts cleaning solvent used per garment was calculated and used to determine emissions.

Results from these estimation methods are shown in Table 4.5-2. Emissions from facilities that print 100 dozen or fewer garments each day are ignored since it is assumed that facilities this small will not operate a parts washing machine.

EMISSIONS FROM PARTS WASHER SOLVENTS (GARMENT SCREEN PRINTING)

TABLE 4.5-2

Garments Printed Daily (dozen)		Garments Printed Yearly per Facility	% of Garment Printing Facilities	Number of Facilities	Total Number of Garments Printed Yearly	Estimated Yearly VOC Emissions from Parts Washer Solvents	
Range	Average					pounds	tons
10 to 50	30.0	90,000	67.5	7,094	696,000,357	0	0.0
51 to 100	75.5	226,500	12.6	1,324	326,965,501	0	0.0
101 to 200	150.5	451,500	7.8	820	403,473,985	41,227	20.6
201 to 300	250.5	751,500	2.0	210	172,195,644	17,595	8.8
301 to 500	400.5	1,201,500	2.6	273	357,898,850	36,570	18.3
501 +	501.0	1,503,000	7.4	778	1,274,247,765	130,204	65.1
				TOTAL	3,230,782,102	225,596	112.8

Platen Adhesives

The emissions estimates for platen adhesives, shown in Table 4.5-3, were determined from two sources of data: platen adhesive usage data collected from the SPAI survey and the total number of garment screen printing facilities, determined from the SPAI 1990 Industry Profile Results. The outcome of the estimate shows that 4,935.9 tons of platen adhesives are used by garment screen printers each year. Water-based platen adhesives account for 2.6 percent, or 126.6 tons, of the usage. Yearly VOC emissions are 3,486.4 tons, of which 37.6 percent is from VOC propellants. Non-VOC organic chemicals emissions are 797.1 tons; 1,1,1-TCA and MeCl_2 account for 44.0 and 56.0 percent, respectively, of this amount.

**TABLE 4.5-3
PLATEN ADHESIVE EMISSIONS**

	Average per Facility, lbs	Estimated Yearly Amounts	
		Pounds	Tons
Total Usage	939.4 (16,467.2 fl. oz.)	9,871,797.8	4,935.9
Usage of Water-based Products	24.1	253,161.4	126.6
Total Organic Emissions	815.2	8,566,963.7	4,283.5
• VOC Emissions	663.5	6,972,764.2	3,486.4
-- VOC Propellants	249.7	2,624,221.3	1,312.1
• NonVOC Emissions	151.7	1,594,199.5	797.1
-- 1,1,1-TCA	66.8	702,086.6	351.0
-- MeCl_2	84.9	892,112.9	446.1

TABLE 4.5-2

EMISSIONS FROM PARTS WASHER SOLVENTS (GARMENT SCREEN PRINTING)

Garments Printed Daily (dozen)		Garments Printed Yearly per Facility	% of Garment Printing Facilities	Number of Facilities	Total Number of Garments Printed Yearly	Estimated Yearly VOC Emissions from Parts Washer Solvents	
Range	Average					pounds	tons
10 to 50	30.0	90,000	67.5	7,094	696,000,357	0	0.0
51 to 100	75.5	226,500	12.6	1,324	326,965,501	0	0.0
101 to 200	150.5	451,500	7.8	820	403,473,985	41,227	20.6
201 to 300	250.5	751,500	2.0	210	172,195,644	17,595	8.8
301 to 500	400.5	1,201,500	2.6	273	357,898,850	36,570	18.3
501 +	501.0	1,503,000	7.4	778	1,274,247,765	130,204	65.1
				TOTAL	3,230,782,102	225,596	112.8

Platen Adhesives

The emissions estimates for platen adhesives, shown in Table 4.5-3, were determined from two sources of data: platen adhesive usage data collected from the SPAI survey and the total number of garment screen printing facilities, determined from the SPAI 1990 Industry Profile Results. The outcome of the estimate shows that 4,935.9 tons of platen adhesives are used by garment screen printers each year. Water-based platen adhesives account for 2.6 percent, or 126.6 tons, of the usage. Yearly VOC emissions are 3,486.4 tons, of which 37.6 percent is from VOC propellants. Non-VOC organic chemicals emissions are 797.1 tons; 1,1,1-TCA and MeCl_2 account for 44.0 and 56.0 percent, respectively, of this amount.

TABLE 4.5-3
PLATEN ADHESIVE EMISSIONS

	Average per Facility, lbs	Estimated Yearly Amounts	
		Pounds	Tons
Total Usage	939.4 (16,467.2 fl. oz.)	9,871,797.8	4,935.9
Usage of Water-based Products	24.1	253,161.4	126.6
Total Organic Emissions	815.2	8,566,963.7	4,283.5
● VOC Emissions	663.5	6,972,764.2	3,486.4
-- VOC Propellants	249.7	2,624,221.3	1,312.1
● NonVOC Emissions	151.7	1,594,199.5	797.1
-- 1,1,1-TCA	66.8	702,086.6	351.0
-- MeCl_2	84.9	892,112.9	446.1

Spot Cleaners

Only emissions from garment screen printers and finishers of woven or knit goods were determined in this section. Estimates of emissions for spot cleaners used by garment screen printers are presented in Table 4.5-4. Garment screen printers use 3,256.3 tons of VOC-based spot cleaners each year. Finishers of woven and knit goods use spot cleaners which contain no VOC's but which contain 1,1,1 trichloroethane. Therefore, no VOC emissions can be attributed to the use of spot cleaners in these two segments of the industry.

TABLE 4.5-4

SPOT CLEANER EMISSIONS (GARMENT SCREEN PRINTERS)

Garments Printed Daily (dozen)		Garments Printed Yearly per Facility	% of Garment Printing Facilities	Number of Facilities	Total Number of Garments Printed Yearly	Estimated Yearly Organic Emissions from Spot Cleaners	
Range	Average					pounds	tons
10 to 50	30.0	90,000	67.5	7,094	696,000,357	1,402,991	502.9
51 to 100	75.5	226,500	12.6	1,324	326,965,501	659,094	329.5
101 to 200	150.5	451,500	7.8	820	403,473,985	813,319	406.7
201 to 300	250.5	751,500	2.0	210	172,195,644	347,110	173.6
301 to 500	400.5	1,201,500	2.6	273	357,898,850	721,449	360.7
501 +	501.0	1,503,000	7.4	778	1,274,247,765	2,568,616	1,284.3
TOTAL						6,512,579	3,256.3

4.5.5 References for Section 4.5

1. U.S. EPA Air and Energy Engineering Research Laboratory, Research Triangle Park, North Carolina, *Source Characterizations and Emission Estimates for Mold Release Agents and Roofing Applications*, September 1993.
2. U.S. EPA Air and Energy Engineering Research Laboratory, Research Triangle Park, North Carolina, *Project Summary - Assessment of VOC Emissions from Fiberglass Boat Manufacturing*, (EPA-600/S2-90/019), June 1990.
3. U.S. EPA Air and Energy Engineering Research Laboratory, Research Triangle Park, North Carolina, *Evaluation of Volatile Organic Emissions Data for Nonprocess Solvent Use in 15 Commercial and Industrial Business Categories*, (EPA-600/R-94-019), February 1994.
4. U.S. EPA Air and Energy Engineering Research Laboratory, Research Triangle Park, North Carolina, *Nonprocess Solvent Use in the Textile Industry*, August 1993.