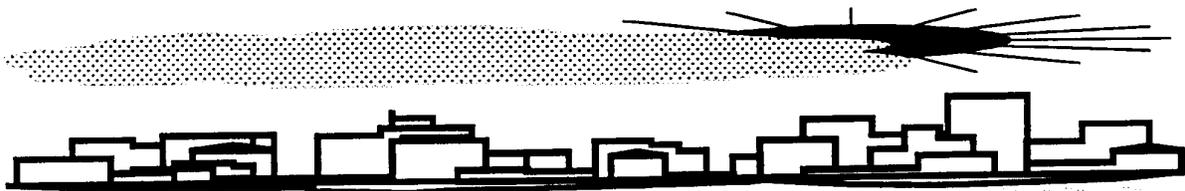




# LOCATING AND ESTIMATING AIR EMISSIONS FROM SOURCES OF XYLENE



L & E

EPA-454/R-93-048

LOCATING AND ESTIMATING AIR EMISSIONS  
FROM SOURCES OF XYLENE

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

March 1994

This report has been reviewed by the Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, and has been approved for publication. Any mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use.

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## EXECUTIVE SUMMARY

Emissions of xylene and its isomers into the atmosphere are of special significance because of the Clean Air Act Amendments of 1990. These amendments mandate that emissions of xylene be subject to standards that allow for the maximum degree of reduction of emissions and that, by 1995, a list of source categories be established that accounts for no less than 90 percent of xylene emissions. This document is designed to assist groups interested in inventorying air emissions of xylene by providing a compilation of available information on sources and emissions of these substances.

Xylene is an aromatic hydrocarbon that occurs naturally in petroleum and coal tar and is a constituent of smoke from most combustion sources. In the U.S., xylene is produced primarily using catalytic reforming of petroleum (approximately 95%). There were 20 production facilities for mixed xylenes in the U.S. in 1989. During the same year, the total annual capacity for xylene manufacturing in the U.S., the Virgin Islands, and Puerto Rico was 5,648 million kilograms (12,452 million pounds).

Xylenes is used as a solvent in the manufacturing of chemicals, agricultural sprays, adhesives and coatings, as an ingredient in aviation fuel and gasoline, and as a feedstock in manufacturing various polymers, phthalic anhydride, isophthalic acid, terephthalic acid and dimethyl terephthalate.

At the time of publication of this document, estimates of nationwide emissions of xylene were not available. Updates to this document will attempt to incorporate any nationwide emission estimates subsequently developed.

SECTION 1.0  
PURPOSE OF DOCUMENT

The Environmental Protection Agency (EPA) and State and local air pollution control agencies are becoming increasingly aware of the presence of substances in the ambient air that may be toxic at certain concentrations. This awareness, in turn, has led to attempts to identify source/receptor relationships for these substances and to develop control programs to regulate emissions. Unfortunately, very little information is available on the ambient air concentrations of these substances or on the sources that may be discharging them to the atmosphere.

To assist groups interested in inventorying air emissions of various potentially toxic substances, EPA is preparing a series of documents such as this that compiles available information on sources and emissions of these substances. Prior documents in the series are listed below:

<u>Substance</u>	<u>EPA Publication Number</u>
Acrylonitrile	EPA-450/4-84-007a
Carbon Tetrachloride	EPA-450/4-84-007b
Chloroform	EPA-450/4-84-007c
Ethylene Dichloride	EPA-450/4-84-007d
Formaldehyde (Revised)	EPA-450/2-91-012
Nickel	EPA-450/4-84-007f
Chromium	EPA-450/4-84-007g
Manganese	EPA-450/4-84-007h
Phosgene	EPA-450/4-84-007i
Epichlorohydrin	EPA-450/4-84-007j
Vinylidene Chloride	EPA-450/4-84-007k
Ethylene Oxide	EPA-450/4-84-007l
Chlorobenzenes	EPA-450/4-84-007m
Polychlorinated Biphenyls (PCBs)	EPA-450/4-84-007n
Polycyclic Organic Matter (POM)	EPA-450/4-84-007p
Benzene	EPA-450/4-84-007q
Organic Liquid Storage Tanks	EPA-450/4-88-004
Coal and Oil Combustion Sources	EPA-450/2-89-001
Municipal Waste Combustors	EPA-450/2-89-006

<u>Substance</u>	<u>EPA Publication Number</u>
Perchloroethylene and Trichlorethylene	EPA-450/2-90-013
1,3-Butadiene	EPA-450/2-89-021
Chromium (supplement)	EPA-450/2-89-002
Sewage Sludge	EPA-450/2-90-009
Styrene	EPA-450/4-91-029
Methylene Chloride	EPA-454/R-93-006

This document deals specifically with xylene and its isomers. Its intended audience includes Federal, State, and local air pollution personnel and others who are interested in locating potential emitters of xylene, and making gross estimates of air emissions therefrom.

Because of the limited amounts of data available on some potential sources of xylene emissions, and since the configurations of many sources will not be the same as those described here, this document is best used as a primer to inform air pollution personnel about (1) the types of sources that may emit xylene, (2) process variations and release points that may be expected within these sources, and (3) available emissions information indicating the potential for xylene to be released into the air from each operation.

The reader is strongly cautioned against using the emissions information contained in this document to try to develop an exact assessment of emissions from any particular facility. Because insufficient data are available to develop statistical estimates of the accuracy of these emission factors, no estimate can be made of the error that could result when these factors are used to calculate emissions from any given facility. It is possible, in some extreme cases, that order-of-magnitude differences could result between actual and calculated emissions, depending on differences in source configurations, control equipment, and operating practices. Thus, in situations where an accurate assessment of xylene emissions is necessary, source-specific information should be obtained to confirm the existence of particular emitting operations, the types and effectiveness of control measures, and the impact of operating practices. A source test and/or material balance should be considered as the best means to determine air emissions directly from an operation.

In addition to the information presented in this document, another potential source of emissions data for xylene is the Toxic Chemical Release Inventory (TRI) database required by Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA 313).<sup>1</sup> SARA 313 requires owners and operators of certain facilities that manufacture, import, process or otherwise use certain toxic chemicals to report annually their releases of these chemicals to any environmental media. As part of SARA 313, EPA provides public access to the annual emissions data. The TRI data include general facility information, chemical information, and emissions data. Air emissions data are reported as total facility release estimates, broken out into fugitive and point components. No individual process or stack data are provided to EPA. The TRI requires the use of available stack monitoring or measurement of emissions to comply with SARA 313. If monitoring data are unavailable, emissions are to be quantified based on best estimates of releases to the environment.

The reader is cautioned that the TRI will not likely provide facility, emissions, and chemical release data sufficient for conducting detailed exposure modeling and risk assessment. In many cases, the TRI data are based on annual estimates of emissions (i.e., on emission factors, material balances, engineering judgement). Although the TRI database was consulted during the development of this report, it should be referred to as an additional information source to locate potential emitters of xylene, and to make preliminary estimates of air emissions from these facilities. To obtain an exact assessment of air emissions from processes at a specific facility, source tests or detailed material balance calculations should be conducted, and detailed plant site information should be compiled.

Each L&E document, as standard procedure, is sent to government, industry, and environmental groups wherever EPA is aware of expertise. These groups are given the opportunity to review the document, comment, and provide additional data where applicable. Where necessary, the documents are then revised to incorporate these comments. Although these documents have undergone extensive review, there may still be shortcomings. Comments subsequent to publication are welcome and will be addressed based on available time and resources. In addition, any information is welcome on process descriptions, operating parameters,

control measures, and emissions information that would enable EPA to improve the contents of this document. Comments and information may be sent to the following address:

Chief, Emission Factor and Methodologies Section  
Emission Inventory Branch (MD-14)  
U.S. Environmental Protection Agency  
Research Triangle Park, NC 27711

1.1 REFERENCE FOR SECTION 1.0

1. Toxic Chemical Release Reporting: Community Right-To-Know. Federal Register 52(107): 21152-21208. June 4, 1987.

## SECTION 2.0 OVERVIEW OF DOCUMENT CONTENTS

The purpose of this document is to assist Federal, State and local air pollution agencies and others who are interested in locating potential air emitters of xylene and its isomers and making gross estimates of air emissions therefrom. Because of the limited background data available, the information summarized in this document does not and should not be assumed to represent the source configuration or emissions associated with any particular facility.

This section provides an overview of the contents of this document. It briefly outlines the nature, extent, and format of the material presented in the remaining sections of this report.

Section 3.0 of this document briefly summarizes the physical and chemical characteristics of xylene and provides an overview of its production and use. This background section may be useful to someone who needs to develop a general perspective on the nature of this substance and how it is manufactured and consumed.

Section 4.0 of this document focuses on major production source categories that may discharge air emissions containing xylene and its isomers. Individual companies and locations are included that produce or use xylene. Section 5.0 discusses the uses of xylene as feedstocks and major solvent uses, particularly paint manufacturing and surface coating operations. Section 6.0 addresses emissions as a result of releases from gasoline use. Section 7.0 describes emissions sources from the manufacture of products other than xylene, or as a by-product of another process (*e.g.*, coal combustion). Example process descriptions and flow diagrams are provided in addition to available emission factor estimates for each major industrial source category described in Sections 4.0, 5.0, 6.0 and 7.0.

Section 8.0 of this document summarizes available procedures for source sampling and analysis of xylene. The summaries provide an overview of applicable sampling and analytical

procedures, citing references for those interested in conducting source tests. Although a NIOSH procedure is provided, no EPA endorsement of this method is given or implied.

Appendix A identifies potential source categories of xylene emissions by Standard Industrial Classification (SIC) codes and associated descriptions. The readers interested in cross referencing SICs with Source Classification Codes (SCCs) and associated descriptions, should consult the *Crosswalk/Air Toxic Emission Factor Database Management System*, Version 1.2 (October 1991) and/or the *VOC/PM Speciation Database Management System*, Version 1.4 (October 1991).<sup>1,2</sup> Appendix B presents paint and ink manufacturing facilities and printing facilities with sales greater than \$1,000,000. Appendix C contains a listing of some of the surface coating source categories in which xylene is used. Appendix D summarizes, in table format, all the emission factors listed in this document.

Each emission factor listed in this document includes an emission factor grade based on the criteria for data quality and emission factor ratings required in the compendium for *AP-42*.<sup>3</sup> These criteria for rating test data are presented below. The data used to develop emission factors are rated as follows:

- A - Tests performed by a sound methodology and reported in enough detail for adequate validation. These tests are not necessarily EPA reference test methods, although such reference methods are certainly to be used as a guide.
- B - Tests that are performed by a generally sound methodology but lack enough detail for adequate validation.
- C - Tests that are based on a nonvalidated or draft methodology or that lack a significant amount of background data.
- D - Tests that are based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

Because of the almost impossible task of assigning a meaningful confidence limit to industry-specific variables (*i.e.*, sample size vs. sample population, industry and facility

variability, method of measurement), the use of a statistical confidence interval for an emission factor is not practical. Therefore, some subjective quality rating is necessary. The following emission factor quality ratings are applied to the emission factor tables.

A - Excellent. The emission factor was developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category\* is specific enough to minimize variability within the source category population.

B - Above average. The emission factor was developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. As in the A rating, the source category is specific enough to minimize variability within the source category population.

C - Average. The emission factor was developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. As in the A rating, the source category is specific enough to minimize variability within the source category population.

D - Below average. The emission factor was developed only from A- and B-rated test data from a small number of facilities and there may be reason to suspect that these facilities do not represent a random sample of the industry. There may also be evidence of variability within the source category population. Limitations on the use of the emission factors are footnoted for each emission factor table.

E - Poor. The emission factor was developed from C- and D-rated test data, and there may be reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are always footnoted.

U - Unrated or Unratable.<sup>4</sup> The emission factor was developed from suspect data with no supporting documentation to accurately apply an A through E rating. A "U" rating may be applied in the following circumstances:

- a gross mass balance estimation
- QA/QC deficiencies found with C- and D-rated test data
- gross engineering judgement
- technology transfer

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\*Source category: A category in the emission factor table for which an emission factor has been calculated; generally a single process.

This document does not contain any discussion of health or other environmental effects of xylene. It does include a discussion of ambient air monitoring techniques; however, these ambient air monitoring methods may require modifications for stack sampling and may affect data quality.

## 2.1 REFERENCES FOR SECTION 2.0

1. U.S. Environmental Protection Agency. *Crosswalk/Air Toxic Emission Factor Database Management System, Version 1.2*. Office of Air Quality Planning and Standards. Research Triangle Park, NC. October 1991.
2. U.S. Environmental Protection Agency. *Volatile Organic Compound (VOC)/Particulate Matter (PM) Speciation Database Management System, Version 1.4*. Office of Air Quality Planning and Standards, Research Triangle Park, NC. October 1991.
3. U.S. Environmental Protection Agency. *Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections*. Emission Inventory Branch, Office of Air and Radiation, Office of Air Quality Planning and Standards. Research Triangle Park, NC. March 1992.
4. Group discussion meeting on applying "U" rating to emission factors. Anne Pope, EIB; Robin Baker Jones, Midwest Research Institute; Garry Brooks, Radian Corporation; and Theresa Moody, TRC Environmental Corporation.

SECTION 3.0  
BACKGROUND

3.1 NATURE OF POLLUTANT

Xylene is an aromatic hydrocarbon that occurs naturally in petroleum and coal tar and is a constituent of smoke from most combustion sources. Most xylene that is commercially available is synthetically derived from petroleum and to a lesser extent from coal. Three xylene isomers exist: ortho-xylene, meta-xylene, and para-xylene, abbreviated o-, m-, and p-xylene, respectively. Mixed xylenes are a mixture of the three isomers and a small amount of ethylbenzene.<sup>1</sup>

Xylene's molecular formula is  $C_8H_{10}$ , also known as  $C_6H_4(CH_3)_2$ . Molecular structures of the three xylene isomers are represented as follows:<sup>1</sup>

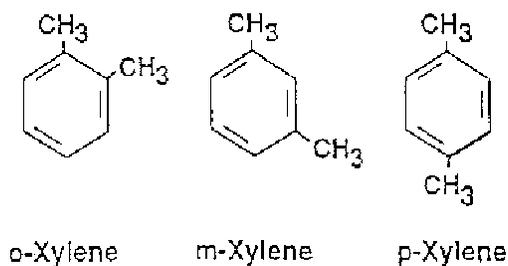


Table 3-1 summarizes the chemical identification information, and Table 3-2 presents some chemical and physical properties for mixed xylenes and each isomer. This colorless liquid has a sweet odor and is volatile, flammable, and explosive in air. Xylene is not soluble in water, but is soluble in alcohol and many organic liquids.

**TABLE 3-1.  
CHEMICAL IDENTITY OF MIXED XYLENE AND XYLENE ISOMERS**

Chemical name	Mixed Xylene	o-Xylene	m-Xylene	p-Xylene
Synonyms	dimethylbenzene xylol methyl toluene	1,2-dimethylbenzene 1,2-xylene o-dimethylbenzene o-methyltoluene o-xylol ortho-xylene	1,3-dimethylbenzene 1,3-xylene m-dimethylbenzene m-methyltoluene m-xylol meta-xylene	1,4-dimethylbenzene 1,4-xylene p-dimethylbenzene p-methyltoluene p-xylol para-xylene
Trade names	Violet 3	NA <sup>a</sup>	NA	Scintillar
Molecular formula	C <sub>6</sub> H <sub>4</sub> (CH <sub>3</sub> ) <sub>2</sub>	C <sub>6</sub> H <sub>4</sub> (CH <sub>3</sub> ) <sub>2</sub>	C <sub>6</sub> H <sub>4</sub> (CH <sub>3</sub> ) <sub>2</sub>	C <sub>6</sub> H <sub>4</sub> (CH <sub>3</sub> ) <sub>2</sub>
Identification Numbers: <sup>b</sup>				
CAS Registry	1330-20-7	95-47-6	108-38-3	106-42-3
NIOSH/RTECS	ZE 2100000	ZE 2450000	ZE 2275000	ZE 2625000
EPA Hazardous Waste	U239	U239; Xylene	U239; Xylene	U239; Xylene
OHM/TADS	NA	F003; Xylene	F003; Xylene	F003; Xylene
DOT/UN/NA/IMCO Shipping	UN 1307; Xylene (xylol)	7216952	7216953	7216951
	IMCO 3.2	UN 1307; o-Xylene; o-Xylol	UN 1307; m-Xylene; m-Xylol	UN 1307; p-Xylene; p-Xylol
	IMCO 3.3	IMCO 3.2 Xylenes	IMCO 3.2 Xylenes	IMCO 3.2 Xylenes
HSDB	4500	IMCO 3.3 Xylenes	IMCO 3.3 Xylenes	IMCO 3.3 Xylenes
NCI	C55232	134	135	136
STCC	49 093 50; Xylene	NA	NA	NA
		49 093 50; Xylene	49 093 50; Xylenes	49 093 51; Xylene (p-xylene)

<sup>a</sup>NA = not available.

<sup>b</sup>CAS (Chemical Abstract Services); NIOSH (National Institute of Occupational Safety and Health); RTECS (Registry of Toxic Effects of Chemical Substances); EPA (Environmental Protection Agency); OHM/TADS (Oil and Hazardous Materials/Technical Assistance Data System); DOT/UN/NA/IMCO (Department of Transportation/United Nations/North America/International Maritime Dangerous Goods Code); HSDB (Hazardous Substances Data Bank); NCI (National Cancer Institute); STCC (Standard Transport Commodity Code).

Source: Reference 1.

**TABLE 3-2.**  
**PHYSICAL AND CHEMICAL PROPERTIES OF MIXED XYLENE AND XYLENE ISOMERS**

	Mixed Xylene	o-Xylene	m-Xylene	p-Xylene
Molecular weight (g)	106.16	106.16	106.16	106.16
Melting point	No data	-25 C	-47.4 to -48 C	13 to 14 C
Boiling point	137 to 144 C	144 C	138 to 139 C	137 to 138 C
Density (g/mL)	at 20 C: 0.860	at 20 C: 0.8801	at 15 C: 0.8684 at 20 C: 0.8642	at 20 C: 0.86104 to 0.864
Physical state	Liquid	Liquid	Liquid	Liquid at low temperatures: solid (plates or prisms)
Color	Colorless	Colorless	Colorless	Colorless
Odor	Sweet	Sweet	Sweet	Sweet
Odor threshold (ppm): Air Water	0.0045-0.1 0.17	0.08-0.17 1.8	3.7 1.1	0.47 0.53
Solubility: Water  Organic solvents	Practically insoluble at 25 C: 0.013 g/100 l (130 ppm)  Miscible with absolute alcohol, ether, and other organic liquids	Insoluble at 0 C: 142 mg/l (142 ppm) at 20 C: 175 mg/l (175 ppm) at 25 C: 175 mg/l (175 ppm) to 213 mg/l (213 ppm) Miscible with alcohol, ether	Insoluble at 20 C: 160 mg/l at 25 C: 160 mg/l (160 ppm) to 173 mg/l (173 ppm) Miscible with alcohol, ether, and many other organic solvents	Insoluble at 25 C: 162.4 mg/l (ppm) to 198 mg/l (ppm) Miscible in alcohol, ether, and other organic solvents
Partition coefficients: Log P octanol/water  Log K <sub>oc</sub>	3.12 to 3.33  NA <sup>a</sup>	2.77 to 3.18 (estimated)  at 25 C: 47.7 to 68.1 at 110 C: 82.2 to 117	3.09 to 3.28 (estimated)  166	3.08 (measured) 3.09 to 3.28 (estimated) 260
Vapor pressure	at 7.5 C: 2.50 mm Hg at 20 C: 6.16 mm Hg at 21 C: 6.72 mm Hg	at 20 C: 5.0 mm Hg at 25 C: 6.8 mm Hg at 30 C: 9.0 mm Hg	at 20 C: 6 mm Hg at 28.3 C: 10 mm Hg at 30 C: 11 mm Hg	at 20 C: 6.5 mm Hg to 9 mm Hg at 25 C: 8.82 mm Hg to 8.84 mm Hg at 30 C: 12 mm Hg at 27.3 C: 10 mm Hg
Henry's law constant	NA	at 25 C: $5.19 \times 10^{-3}$ atm-m <sup>3</sup> /mol	at 25 C: $7.19 \times 10^{-3}$ atm-m <sup>3</sup> /mol	at 25 C: $7.60 \times 10^{-3}$ atm-m <sup>3</sup> /mol
Flash Point C (F)	37.8 (100) TOC <sup>b</sup>	17 (62.6) CC <sup>c</sup>	25 (77) CC <sup>c</sup>	25 (77) CC <sup>c</sup>
Conversion factors	1 mg/m <sup>3</sup> = 0.23 ppm 1 ppm = 4.41 mg/m <sup>3</sup>	1 mg/m <sup>3</sup> = 0.23 ppm 1 ppm = 4.41 mg/m <sup>3</sup>	1 mg/m <sup>3</sup> = 0.23 ppm 1 ppm = 4.41 mg/m <sup>3</sup>	1 mg/m <sup>3</sup> = 0.23 ppm 1 ppm = 4.41 mg/m <sup>3</sup>

<sup>a</sup>NA = not available.

<sup>b</sup>TOC = tag open cup.

<sup>c</sup>CC = closed cup.

Source: References 1,2.

Atmospheric releases of xylenes are primarily as fugitive emissions from industrial sources (*e.g.*, petroleum refineries, chemical plants); as emissions in automotive exhausts; and as a result of volatilization from their use as a solvent. Due to the high volatility of xylenes, most environmental releases partition to the atmosphere.<sup>3</sup> Xylenes are moderately mobile in soil, where they may be adsorbed. Xylenes may leach into groundwater, where they can persist for several years. Xylenes are rapidly transformed by photooxidation in the troposphere, and can participate in the formation of ground-level ozone. Xylenes are stable to hydrolysis and oxidation in the aquatic environment.<sup>1</sup>

### 3.2 OVERVIEW OF PRODUCTION AND USE

The total annual capacity for xylene manufacturing in the United States, the Virgin Islands, and Puerto Rico was 5,648 million kilograms (12,452 million pounds) in 1989.<sup>4</sup> Processes/feedstocks used to manufacture xylenes include petroleum reformat (95.4 percent), toluene disproportionation (0.4 percent), pyrolysis gasoline (four percent), and coke oven light oil (0.2 percent). Reformat is the favored feedstock for xylene recovery because it contains larger quantities of *o*-xylene and *p*-xylene than are found in pyrolysis gasoline.<sup>5,6</sup> Mixed xylenes produced from petroleum reformat contain approximately 20 percent *o*-xylene, 44 percent *m*-xylene, 20 percent *p*-xylene, 15 percent ethylbenzene, and 1 percent other hydrocarbons. By comparison, mixed xylenes produced from coal tar generally consist of 10 to 15 percent *o*-xylene, 45 to 70 percent *m*-xylene, 23 percent *p*-xylene, and 6 to 10 percent ethylbenzene.<sup>1</sup> There were 20 production facilities for mixed xylenes in the United States in 1989.<sup>4</sup>

High purity mixed xylenes are used as a solvent in chemical manufacture, agricultural sprays, adhesives, paints, and coatings (5.2 percent). Xylene is also an ingredient in aviation fuel and gasoline (39.3 percent), and is used as a feedstock material in the chemical, plastic, and synthetic fiber industries (55.5 percent). Isomers of xylene are used in manufacturing various polymers. As feedstocks, *o*-xylene is used in making phthalic anhydride (PA); *m*-xylene for isophthalic acid; and *p*-xylene for terephthalic acid (TPA) and dimethyl terephthalate (DMT).<sup>5,6</sup>

Figure 3-1 is a chemical use tree for xylene showing the production sources and distribution of mixed xylenes into products and/or separation of isomers. Ortho-xylene is used almost exclusively in making phthalic anhydride, which is an aromatic acid anhydride commercially available as white, free-flowing flakes or colorless molten material having an acrid odor. Phthalic anhydride is used mainly in the manufacture of plasticizers, unsaturated polyester resins, and alkyd resins. In addition, m-xylene is used in the manufacture of isophthalic acid, which is used to make specialized resins. Finally, p-xylene is used exclusively for making dimethyl terephthalate and terephthalic acid (DMT/TPA) which are raw materials used in the manufacture of polyethylene terephthalate (PET) used in polyester fibers, molded plastics, films, and blown beverage bottles.<sup>5,6</sup>

Production Feedstock	Product	Use	Percent
Petroleum Reformate (95.4%)	Mixed Xylenes	o-Xylene - Phthalic Anhydride	7.7
Pyrolysis Gasoline (4.0%)		p-Xylene - DMT/TPA	45.8
Coke Oven Light Oil (0.2%)		m-Xylene - Isophthalic Acid	2.0
Toluene Disproportionation (0.4%)		Solvent Uses	5.2
		Gasoline Blending and Other Uses	39.3

Figure 3-1. Chemical use tree for xylenes.<sup>4</sup>

### 3.3 REFERENCES FOR SECTION 3.0

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2. Sax, N. Irving and Richard J. Lewis, Sr. *Dangerous Properties of Industrial Materials*. Van Nostrand Reinhold, New York, NY. 1989.
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4. SRI International. *Chemical Economic Handbook Petrochemicals/Primary*, 450.0000 to 499.9999. Menlo Park, CA. April 1990.
5. *Chemical Products Synopsis for o-Xylene*. Mannsville Chemical Products Corporation. Asbury Park, NJ. June 1992.
6. *Chemical Products Synopsis for p-Xylene*. Mannsville Chemical Products Corporation. Asbury Park, NJ. May 1992.

## SECTION 4.0 EMISSIONS FROM XYLENE PRODUCTION

This section on xylene production provides separate discussions on the production of mixed xylenes and the three isomers (m-, o-, and p-xylene). The discussion of the mixed xylenes is presented first because each isomer is isolated from a mixed xylene feed, and an understanding of mixed xylene production is basic to describing the production of the isomers. Process flow diagrams are provided as appropriate, with specific streams or vents shown in the figures labeled to correspond with the discussion in the text. Emission factors for the production processes are presented where available and associated control technologies are described. If a particular facility is being referenced, the reader should contact the specific facility to verify the nature of the processes used, production volume, and controls that are in place before applying any of the emission factors presented in this document.

Twenty companies are known to produce xylenes in the United States, with a total production capacity of greater than 5.6 billion kilograms (12.4 billion pounds) of mixed xylenes for use by the chemical industry. The largest known producers are Amoco (Texas City, TX and Whiting, IN), Exxon (Baytown, TX), Amerada Hess (St. Croix, VI), and Phillips (Guayama, PR). It is estimated that their combined production capacities account for about 51 percent of the total production for the United States. About 95 percent of mixed xylenes is produced through catalytic reforming, and about 75 percent of mixed xylenes production is consumed by the producers for isolation of isomers. Table 4-1 presents production facilities in the United States, plant locations, and production capacities for mixed xylenes. A number of facilities listed in Table 4-1 have suspended operations or have changed processes as noted by footnotes and/or comments in the table. Such facilities are included here to provide historical information, and because some facilities may become operational again in the future.<sup>1</sup>

**TABLE 4-1.  
U.S. PRODUCERS OF MIXED XYLENES (continued)**

Company and Plant Location	Annual Production Capacity, 1989		Feedstock	On-Site Disposition of Mixed Xylenes
	Millions of Kilograms	(Millions of Pounds)		
Amerada Hess Corporation Hess Oil Virgin Island Corp., subsidiary St. Croix, VI	484	(1,067)	Catalytic reformate	Some mixed xylenes are supplied to St. Croix Petrochemical Corporation for p-xylene separation.
American Petrofina Inc. Fina Oil and Chemical Co., subsidiary Port Arthur, TX	147 131	(324) (289)	Catalytic reformate Toluene disproportionation	_____
Amoco Oil Co. Texas City, TX	640	(1,411)	Catalytic reformate	Used for m- and p-xylene separation.
Whiting, IN	634	(1,398)	Catalytic reformate	All output is pipelined to Amocoat Decatur, Alabama for p-xylene separation.
Aristech Chemical Corp., Clairton, PA	6	(13)	Coke-oven light oil	Plant idle since August 1986.
Arochem International Inc. Penuelas, PR	212 196*	(467) (432)	Catalytic reformate Catalytic reformate	No captive use. No captive use. On standby.
Ashland Chemical Co. Petrochemicals Division Catlettsburg, KY	75 7	(165) (15)	Catalytic reformate Coke-oven light oil	No captive use. Goes to solvents by exchange.
BP Chemicals America, Inc. Alliance, LA	212	(467)	Catalytic reformate	No captive use. Sold to the merchant market.
Chevron Chemical Co. Aromatics and Derivatives Division Pascagoula, MS	248	(547)	Catalytic reformate	Captively consumed for p-xylene separation.
The Coastal Corp. <sup>b</sup> Coastal Refining and Marketing, Inc., subsidiary Corpus Christi, TX	150 76 <sup>c</sup>	(331) (168)	Catalytic reformate Toluene disproportionation	No captive use. _____

(continued)

**TABLE 4-1.  
U.S. PRODUCERS OF MIXED XYLENES (continued)**

Company and Plant Location	Annual Production Capacity, 1989		Feedstock	On-Site Disposition of Mixed Xylenes
	Millions of Kilograms	(Millions of Pounds)		
Exxon Chemical Co. Exxon Chemical Americas Baytown, TX	690	(1,521)	Catalytic reformate	About 90 percent of mixed xylenes is transferred to Exxon Chemical Americas at Baytown for o- and p-xylene separation.
Kerr-McGee Refining Corp. Southwestern Refining Co., Inc. Corpus Christi, TX	98	(216)	Catalytic reformate	No captive use.
Koch Refining Co. Corpus Christi, TX	310	(683)	Catalytic reformate	All output is captively consumed in o- and p-xylene separation.
Lyondell Petrochemical Co. Houston, TX	272 49	(600) (108)	Catalytic reformate Toluene disproportionation	All output can be consumed for isomer separation.
Marathon Oil Co. Texas City, TX	36	(79)	Catalytic reformate	No captive use.
Mobil Chemical Co. Petrochemicals Division Chalmette, LA	165	(364)	Catalytic reformate	Output is captively consumed in o- and p-xylene separation.
Phillips Petroleum Co. Chemicals Division Sweeny, TX	105	(231)	Catalytic reformate	Some output transferred to Phillips Paraxylene at Guayama for p-xylene separation.
Phillips Puerto Rico Core Inc., subsidiary Guayama, PR	320	(705)	Catalytic reformate	About 20 percent is captively consumed for o-xylene separation; an additional 65 percent is transferred to Phillips Paraxylene at Guayama for p-xylene separation.

(continued)

**TABLE 4-1.  
U.S. PRODUCERS OF MIXED XYLENES (continued)**

Company and Plant Location	Annual Production Capacity, 1989		Feedstock	On-Site Disposition of Mixed Xylenes
	Millions of Kilograms	(Millions of Pounds)		
Salomon Inc. Phibro Energy Inc. Hill Petroleum Hill Chemical Co. Houston, TX	56	(123)	Catalytic reformat	No captive use.
Shell Chemical Co. Deer Park, TX	196 20	(432) (44)	Catalytic reformat Pyrolysis gasoline	No captive use. _____
Sun Refining and Marketing Co. Marcus Hook, PA	36 49	(79) (108)	Catalytic reformat Toluene disproportionation	No captive use. _____
Toledo, OH	171	(377)	Catalytic reformat	No captive use.
Unocal Corporation Oil and Gas Division Beaumont, TX <sup>d</sup>	98	(216)	Catalytic reformat	No captive use. All to solvents.
Chicago, IL	33	(73)	Catalytic reformat	_____
<b>Total</b>	<b>5,650</b>	<b>(12,456)</b>		

<sup>a</sup>Arochem International had one process unit on standby. This capacity is not included in the total.

<sup>b</sup>The Coastal Corp. was scheduled to start a sulfalene unit in Corpus Christi, TX in March 1990 with an expected annual capacity of 150 million kilograms.

<sup>c</sup>The Coastal Corp. capacity shown as toluene disproportionation has not been operated since 1983. This capacity is not included in the total.

<sup>d</sup>The entire operation at this plant was scheduled for shutdown in the first quarter of 1990.

Source: Reference 1.

## 4.1 MIXED XYLENES PRODUCTION

Most of the xylene produced annually is derived from petroleum fractions. However, the concentration of light aromatics [*e.g.*, benzene, toluene, and xylene (BTX)] in petroleum rarely exceeds one percent. Through processing, petroleum, specifically crude oil, can be converted to BTX streams. Several petroleum fractions are used in aromatic conversion processing. The fraction most important to the xylene production process is "straight-run light naphtha" which includes all of the crude oil components heavier than pentanes and up to a final boiling point between 105°C and 170°C (221° to 338°F).<sup>2</sup> It is from this stream that the majority of xylene is produced by catalytic reforming via hydrotreating. A second refinery stream, also used as a feedstock in xylene production, is the naphtha that results from the pyrolysis or "steam cracking" (*e.g.*, hydrocracking) of heavier distillate fractions. Although the primary goal of cracking naphtha is to manufacture ethylene and propylene, secondary reactions also produce considerable amounts of "pyrolysis gasoline" rich in aromatics. Additional xylene production methods include separation from coal tars and disproportionation or transalkylation of toluene.<sup>2,3</sup>

### 4.1.1 Hydrotreating

Hydrotreating, schematically illustrated in Figure 4-1, is the process by which the quality of liquid hydrocarbon streams is improved by subjecting them to mild or severe conditions of hydrogen pressure in the presence of a catalyst. Both pyrolysis gasolines and straight-run light naphthas (*e.g.*, catalytic reformer feeds) undergo hydrotreating prior to subsequent processing and xylene recovery. The liquid petroleum feed is preheated (Step 1), heated in a furnace (Step 2), and combined with recycled hydrogen gas. The combined feed is passed through a reactor containing a catalyst bed where the hydrogenation reaction takes place (Step 3).<sup>4</sup> Upon leaving the reactor, the stream is cooled and moved to a separator vessel where recycle or net hydrogen is removed (Step 4). The liquid then moves to a stabilizer or stripper which removes hydrogen, hydrogen sulfide, ammonia, water, organic compounds of arsenic and palladium, and light hydrocarbons dissolved in the separator liquid (Step 5). The stripped, hydrotreated fraction is

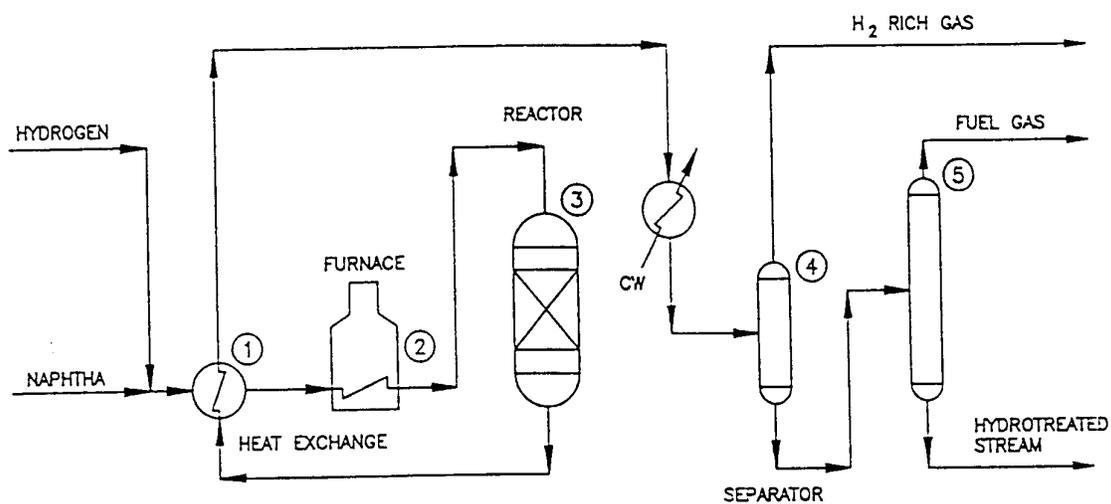


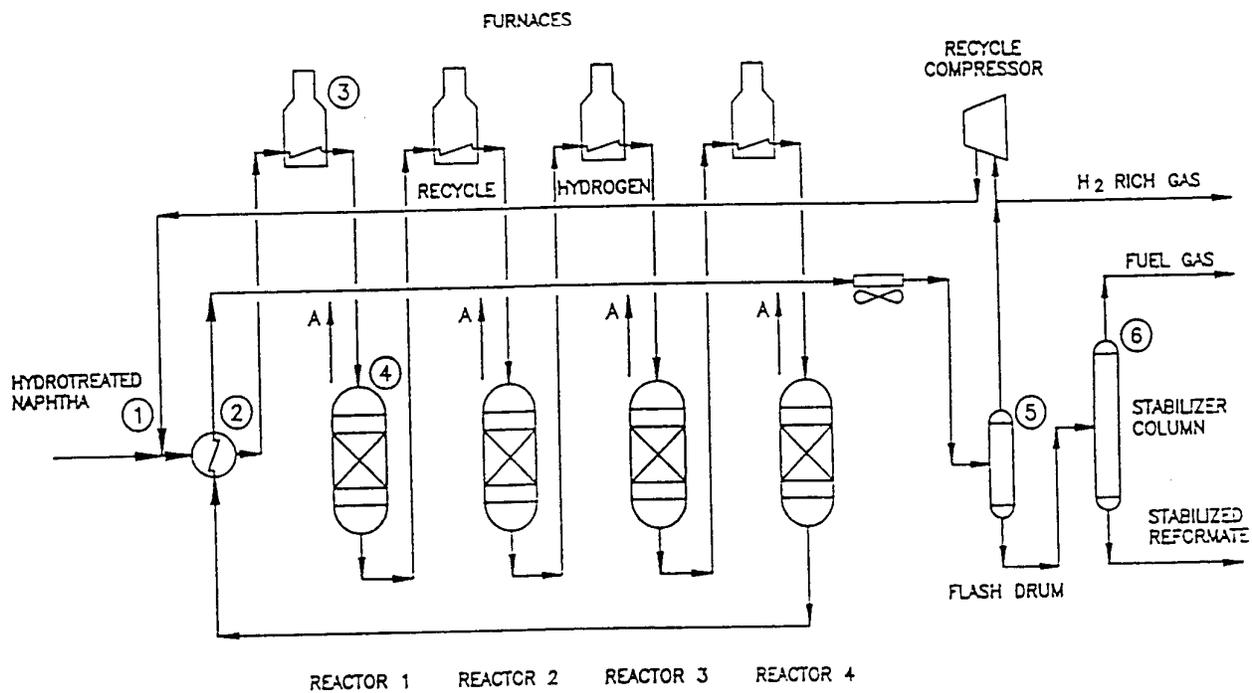
Figure 4-1. Process flow diagram for hydrotreating<sup>2</sup>

(Reprinted with permission from Hancock, E.G., ed., *Toluene, the Xylenes and their Industrial Derivatives*. Elsevier Scientific Publishing Company. New York, New York. 1982.)

then routed to the next processing step, either catalytic reforming (for naphthas) or secondary hydrogenation (for pyrolysis gasoline).<sup>5</sup>

#### 4.1.2 Catalytic Reforming

Catalytic reformat is the major source of xylene, accounting for approximately 95 percent of the xylene production capacity feedstocks.<sup>1,3</sup> Catalytic reforming involves the catalytic dehydrogenation of straight-run light naphtha in the presence of hydrogen (which reduces coke formation) to yield a mixture of aromatic hydrocarbons (*e.g.*, benzene, toluene, and the xylenes).<sup>2,3</sup> The catalytic reforming process is illustrated in Figure 4-2, and the reactions involved in this process are presented below.<sup>2</sup>



↑ DENOTES POTENTIAL LOCATION OF EMISSIONS  
 ↑<sup>A</sup> FUGITIVE EMISSIONS

Figure 4-2. Typical reforming unit<sup>2</sup>

(Reprinted with permission from Hancock, E.G., ed., *Toluene, the Xylenes and their Industrial Derivatives*. Elsevier Scientific Publishing Company. New York, New York. 1982.)

Prior to reforming, the light naphtha is hydrotreated to remove compounds that would act as catalyst poisons in the reforming step.<sup>2,4</sup> The hydrotreated naphtha is fed to the reformer unit containing the following components:<sup>2,5</sup>

- Reactors which contain fixed bed catalysts
- Heaters to bring the naphtha and recycle gas to reaction temperature and to supply heats of reaction
- A product cooling system and a gas-liquid separator
- A hydrogen-gas recycle system
- A stabilizer to separate light hydrocarbons dissolved in the receiver liquid

The naphtha is combined with recycled hydrogen (Step 1), preheated (Step 2), heated to the reaction temperature in a fired heater (Step 3), and then transferred to a series of catalyst-containing reactors (Step 4).<sup>2</sup> Because the reaction is endothermic, a series of three or four reactors with inter-stage reheat furnaces may be necessary to achieve the required conversion. The reactors normally contain increasing amounts of catalyst in each stage.<sup>2,4</sup>

The effluent from the last reactor is cooled and transferred to a receiving unit (*e.g.*, the flash drum) where the hydrogen is separated from the liquid reformat (Step 5). The hydrogen gases are compressed and recycled to the reactors while the reformat is moved to a stabilizer fractionator (Step 6). The fractionator removes C<sub>4</sub> and lighter hydrocarbons to produce a stabilized reformat. The stabilized reformat is used as a feedstock in the xylene recovery process (described in Section 4.2).<sup>2,5</sup>

Most of the facilities that produce xylene by catalytic reforming have proprietary processes. Table 4-2 lists the process licensor and the process name. The primary differences between these processes involve solving reforming process problems such as catalyst regeneration. The processes also differ in the methods used to extract aromatics depending on the type and purity of the product desired.<sup>2</sup>

**TABLE 4-2.**  
**CATALYTIC REFORMING PROCESSES**

Licensor	Name of Process
Chevron Research Co.	Rheniforming
Engelhard Industries	Magnaforming
Exxon Research Engineering	Powerforming
Houdry Division, Air Products	Houdriforming
Institut Francais du Petrole	Aromizing Catalytic Reforming
Standard Oil Co. (Indiana)	Ultraforming
UOP Process Division	Platforming

Source: Reference 2.

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#### 4.1.3 Secondary Hydrogenation (for Pyrolysis Gasoline)

Pyrolysis gasoline, a by-product of ethylene and propylene manufacture, accounts for four percent of domestic xylene production capacity feedstock materials.<sup>1,3</sup> Because pyrolysis gasoline contains reactive compounds (*e.g.*, diolefins and styrenes) which will polymerize if subjected to reactor conditions severe enough to saturate olefins and remove sulfur compounds, it must undergo an initial hydrogenation step described in Section 4.1.1 to reduce the reactives to olefins prior to storage or further processing. The resulting product can be used as a high octane gasoline blending component or treated further for aromatic (*e.g.*, benzene, toluene, and xylenes) extraction.<sup>2</sup>

Following initial hydrogenation, the pyrolysis gasoline normally undergoes second stage hydrogenation in which olefins are saturated, organic sulfur forms hydrogen sulfide, combined nitrogen is converted to ammonia, and oxygenated compounds are reduced to hydrocarbons and

water. After these parallel reactions have been completed, the gases and liquid are separated. The liquid is then stripped of gaseous impurities, such as hydrogen sulfide, and remaining light hydrocarbons before being transferred to xylene recovery units.<sup>2,5</sup>

Most of the world's facilities that produce xylene from pyrolysis gasoline have proprietary hydrotreating processes. The primary differences between these processes involve operating parameters such as temperature, pressure, catalyst composition, and reactor geometry. Table 4-3 lists the process licensor and the process name.<sup>2</sup>

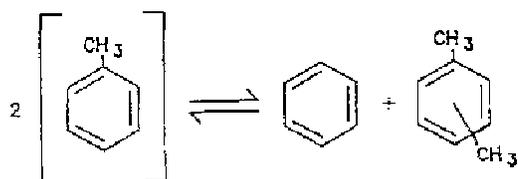
**TABLE 4-3.  
PYROLYSIS GASOLINE HYDROGENATION PROCESSES**

<b>Licensor</b>	<b>Name of Process</b>
British Petroleum (BP)	BP Selective Hydrogenation Process
C-E Lummus	DPG Hydrotreating
Engelhard Industries	HPN Process
Houdry Division, Air Products	HPG Process
Institut Francais du Petrole	IFP Selective Hydrogenation Process
Lurgi GmbH/Bayer AG	Bayer Selective Diolefin Hydrogenation Lurgi Olefin Hydrogenation and Desulphurisation
UOP Process Division	LT Unibon Process

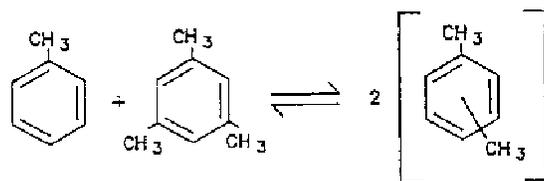
Source: Reference 2.

#### 4.1.4 Xylene Production from Toluene Disproportionation or Transalkylation

Less than one percent of recovered xylenes is obtained from toluene disproportionation or transalkylation processes. In the disproportionation process, toluene is converted to equivalent volumes of benzene and xylenes, as shown in the equation that follows:<sup>2</sup>



In transalkylation, the reactions are as follows:<sup>2</sup>



Many of the facilities that perform one of these processes can change mode to operate using the other process.<sup>2</sup> In the United States, only three companies are known to convert toluene to mixed xylenes by these processes: Fina Oil and Chemical, Lyondell Petrochemical, and Sun Refining. A total annual xylene capacity of 216 million kilograms (476 million pounds) is reported from toluene disproportionation/transalkylation processes.<sup>1</sup>

The toluene disproportionation/transalkylation method of producing xylenes is expensive when compared to the reforming process; however, it has two advantages. One is that no ethylbenzene is formed in the xylenes stream, so isomer isolation is less difficult. Second, no net hydrogen is consumed. An estimated 176 million kilograms (387 million pounds) of xylenes were produced by this method in 1988.<sup>1</sup> The supply of xylenes from this source is estimated to reach about 244 million kilograms (538 million pounds) per year by 1993.<sup>1</sup>

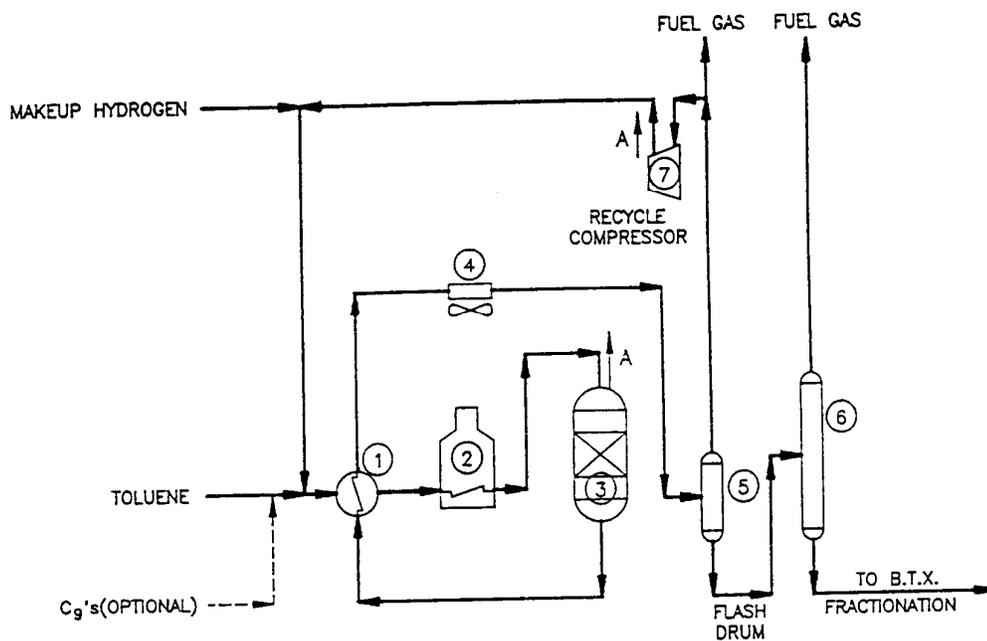
An example of a disproportionation/transalkylation process is illustrated in Figure 4-3 (the Toray/UOP Tatoray Process). The use of a hydrogen atmosphere in this process, in addition to the type of catalyst employed, allows several months of operation before catalyst regeneration is required. A hydrogen recycle compressor (Step 7) is required and can be a potential location of fugitive emissions. The gas from this compressor is combined with make-up hydrogen, toluene feed, and, optionally, C<sub>9</sub> feed. The mixture is vaporized and superheated by heat exchange counter current to the reactor effluent (Step 1) and then by a fired heater (Step 2). The aromatics react to yield a near-equilibrium mixture when passing through the catalyst bed (Step 3). The mixture then passes back through the feed-effluent exchanger (Step 1) and through supplementary cooling and condensing (Step 4) to a flash drum (Step 5). Here, the vapor phase is split into a fuel gas purge and recycle hydrogen (Step 7), and the liquid phase is transferred to a stabilizer column (Step 6) for the removal of residual light ends (low molecular weight organics). The stabilized liquid is then returned to BTX fractionation for further processing.<sup>2</sup>

#### 4.1.5 Coal-Derived Mixed Xylenes

Less than one percent of the production of mixed xylenes is coal derived. When coal is carbonized in coke ovens, for every ton of coal, about 2 to 3 gallons of a crude light oil is produced that contains 3 to 6 percent mixed xylenes by volume. The light oil may be captured and sold to petroleum refiners that use it as a supplementary source of aromatics, or processed by the coke-oven operators/tar distillers, or burned as fuel. The mixed xylenes present in light oil from coke ovens are not usually reclaimed, and the amount of mixed xylenes that can be obtained from the light oil is minimal. Light oil is expected to continue to be a minor source of xylenes.<sup>1</sup> Figure 4-4 illustrates the typical process for mixed xylene production from coal-derived light oil.

## 4.2 ISOMERIZATION AND SEPARATION OF XYLENE ISOMERS

The demand for mixed xylenes is low in comparison to the demand for pure isomers, especially p-xylene. Separation of organic compounds from refinery processes typically utilizes



↑ = POTENTIAL EMISSION POINT  
 A ↑ = FUGITIVE EMISSIONS

Figure 4-3. Toray/UOP Tatoray (disproportionation/transalkylation) process.<sup>2</sup>

(Reprinted with permission from Hancock, E.G., ed., *Toluene, the Xylenes and their Industrial Derivatives*. Elsevier Scientific Publishing Company. New York, New York. 1982.)

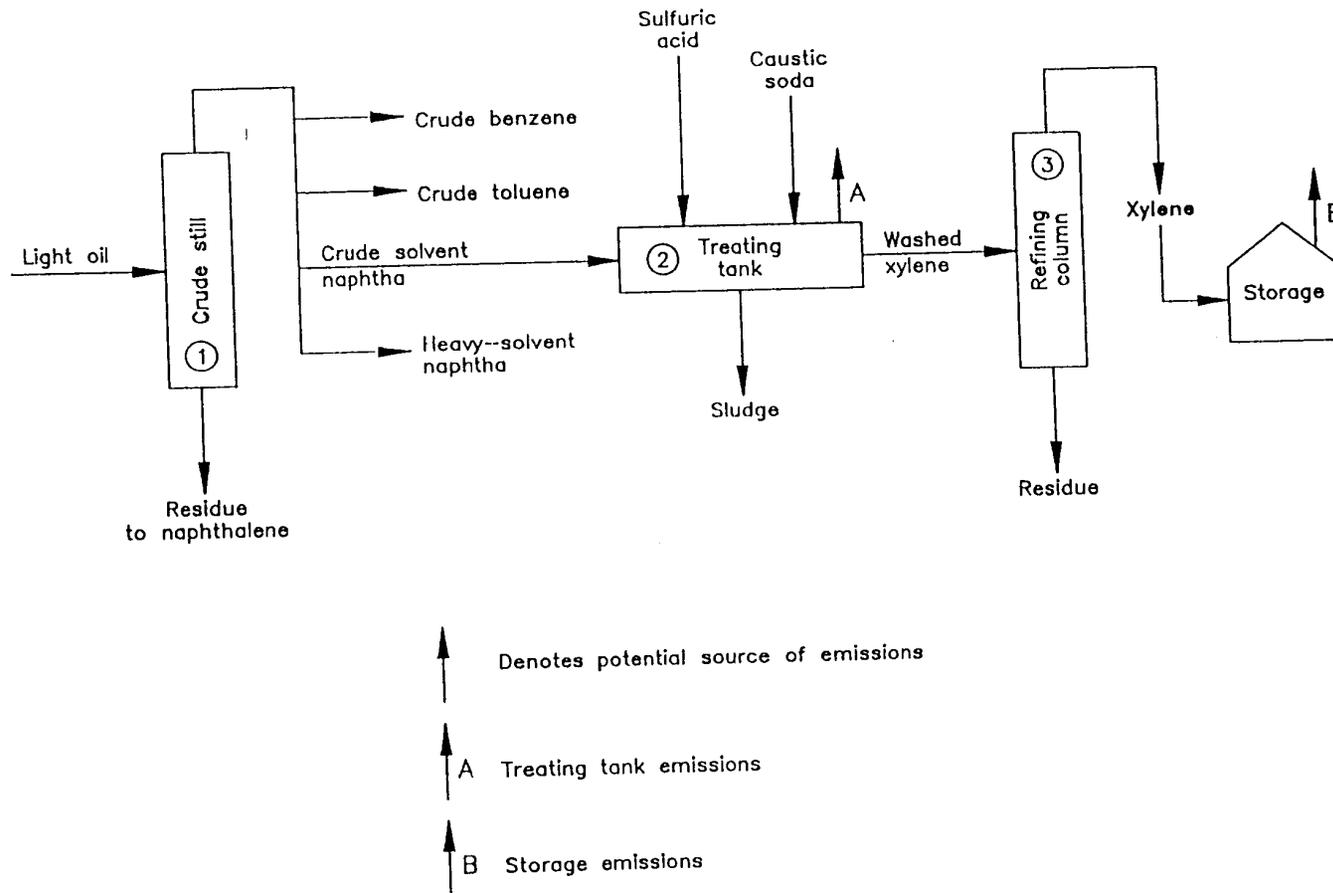


Figure 4-4. Mixed xylene production from coal-derived light oil.<sup>4</sup>

(Reprinted with permission from Lowenheim, F.A., and Moran, M.K., *Faith, Keyes, and Clark's Industrial Chemicals*, Fourth Edition, 1975.)

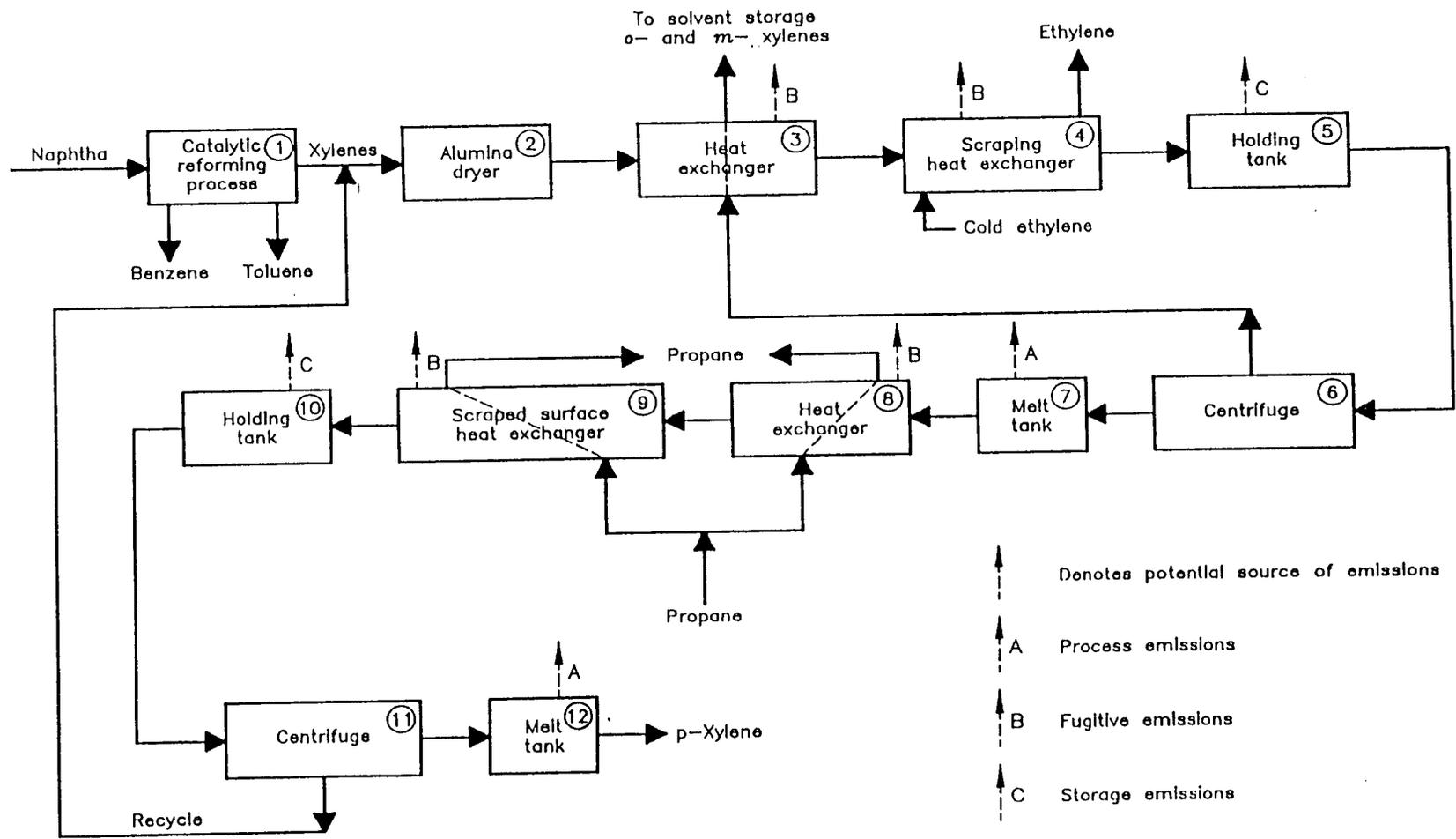
fractional distillation which is based on differences in the boiling points of the compounds. However, isolation of individual isomers through conventional distillation is difficult for xylene isomers because of the closeness of their boiling points, as shown in Table 4-4.<sup>2</sup> Differences in freezing points, however, can be used to separate isomers.<sup>2</sup> A typical crystallization process for the separation of isomers using differences in freezing points is shown in Figure 4-5.

There are also differences in adsorptive properties that can be used to isolate individual xylene isomers. In adsorption, the pore structure of the solid-phase adsorbent will preferentially retain the product isomer of interest. A subsequent treatment with a desorbent liquid (usually another organic such as toluene) will dissociate the product from the adsorbent. Separation of the product isomer of xylene can then be accomplished using simple fractional distillation. The example of an adsorption process shown in Figure 4-6 is a continuous extraction system that utilizes a moving bed flowing counter to the liquid phase.<sup>2</sup> Alterations in the choice of adsorbent will extract different isomers.

**TABLE 4-4.**  
**PHYSICAL CHARACTERISTICS OF XYLENE ISOMERS**  
**AFFECTING SEPARATION PROCESSES**

Compound	Freezing Point °C (°F)	Boiling Point °C (°F)	Catalytic Reformate Isomer Content (%)	
			Range	Typical
o-xylene	-25.2 (-13.4)	144.4 (291.9)	19-26	23
m-xylene	-47.9 (-54.2)	139.1 (282.4)	35-40	40
p-xylene	13.3 (55.9)	138.4 (281.1)	16-20	17
ethylbenzene	-95.0 (-139.0)	136.2 (277.2)	17-21	20

Source: Reference 2.



Denotes potential source of emissions

A Process emissions

B Fugitive emissions

C Storage emissions

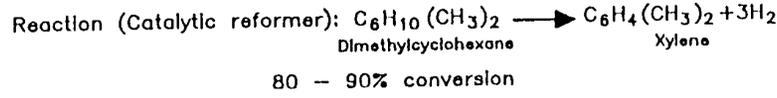
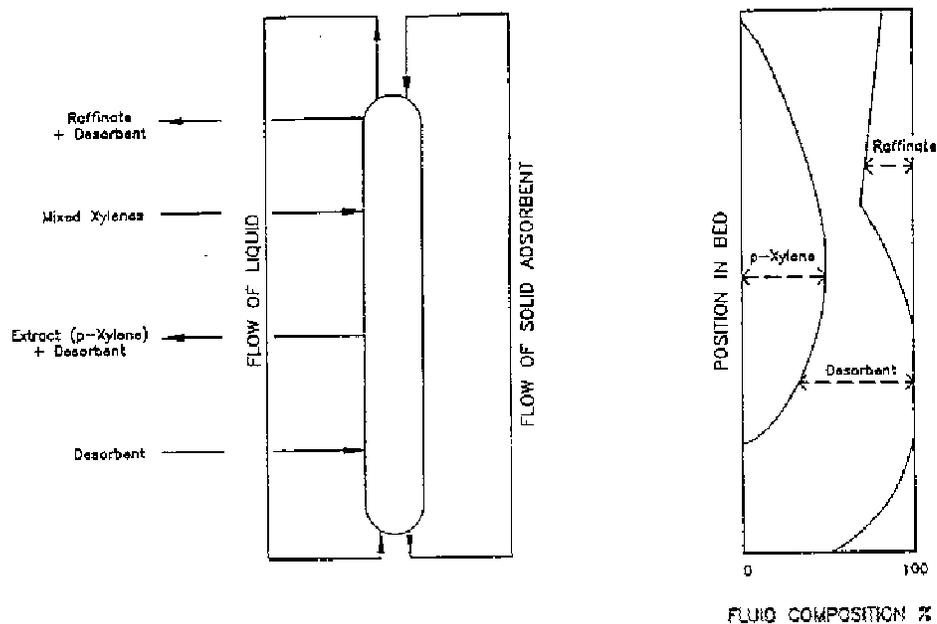


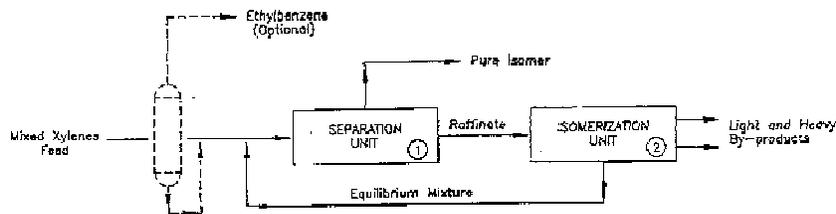
Figure 4-5. Mixed xylenes separation by the crystallization process.<sup>4</sup>



**Figure 4-6.** Moving bed adsorption system for separation of xylene isomers.<sup>2</sup>

(Reprinted with permission from Hancock, E.G., ed., *Toluene, the Xylenes and thier Industrial Derivatives*. Elsevier Scientific Publishing Company. New York, New York. 1982.)

The typical mix of xylene isomers from a catalytic reformat stream consists of the following: m-xylene (40 percent), o-xylene (24 percent), p-xylene (19 percent), and ethylbenzene (17 percent).<sup>2</sup> However, the demand for individual isomers does not match the proportions found in mixed xylenes, with p-xylene in highest demand, followed by o- and m-xylene. In order to meet the demand for pure isomers, additional processing of mixed xylenes is required. Isomerization of m-xylene to o- and p-xylene and subsequent separation are commonplace.<sup>1</sup> A simple separation/isomerization loop is shown in Figure 4-7. The separation unit (Step 1) can utilize either differences in freezing points (crystallization) or adsorptive properties to separate the isomers, as previously discussed. The isomerization unit (Step 2) usually involves a proprietary process using one of three basic designs: those using a noble metal catalyst in a hydrogen atmosphere; those using a non-noble metal catalyst without hydrogen; or a liquid-phase process which uses transalkylation reactions (Section 4.1.4).<sup>3</sup>



**Figure 4-7.** Simple separation - isomerization loop.<sup>2</sup>

(Reprinted with permission from Hancock, E.G., ed., *Toluene, the Xylenes and their Industrial Derivatives*. Elsevier Scientific Publishing Company. New York, New York. 1982.)

#### 4.2.1 Para-xylene Production

Para-xylene is the isomer of mixed xylenes in highest demand. It is used to make terephthalic acid (TPA) and dimethyl terephthalate (DMT), intermediates in the manufacture of polyethylene terephthalate (PET) fibers, molded plastics, and films.

##### Isomerization --

Isomerization of xylene isomers requires an acidic catalyst, whereas isomerization of ethylbenzene additionally requires a hydrogenation catalyst, usually platinum. Removal of ethylbenzene increases the efficiency of p-xylene separation and the isomerization of the remaining C<sub>9</sub> aromatics. Ortho-xylene is often produced along with p-xylene in the isomerization process and is recovered separately. Therefore, prior to p-xylene isomerization or recovery, o-xylene and ethylbenzene are usually isolated. Recovery of p-xylene is then performed via crystallization or adsorption, and the remaining liquor or raffinate is isomerized to convert m-

xylene to o- and p-xylene. The isomerization unit feed is sometimes mixed with hydrogen (depending on the process), heated to the reaction temperature, and passed over the catalyst. Vapor-phase and high-temperature isomerization processes are commonly used in the United States.<sup>1</sup> The octafining process uses a combination of silica-alumina and platinized alumina catalysts to isomerize xylenes, however, most U.S. companies use the zeolite-based isomerization processes introduced in the 1970s. It is claimed that these processes can isomerize xylenes, selectively disproportionate the remaining ethylbenzene, and improve the overall p-xylene yield.<sup>1</sup>

#### Separation --

A high-purity p-xylene stream (99 - 99.5 percent by weight) can be isolated by using a two-stage, low-temperature crystallization process. The first crystallization, the coldest stage, yields a slurry of crude p-xylene and a filtrate containing other isomers. Melting of the resulting slurry with a subsequent higher temperature recrystallization yields high-purity p-xylene. Common crystallization processes have been developed by Chevron, Amoco, ARCO, Phillips, Shell, Esso, Krupp, and Maruzen.<sup>1</sup>

Isolation of p-xylene by adsorption results in higher yields (90 - 95 percent per pass through the process) than can be obtained by a single step crystallization process (60 - 70 percent). In the Parex process (licensed by UOP, Inc.) and the Aromax process (licensed by Toray Industries, Inc.), p-xylene is continuously and selectively retained on a zeolite adsorbent in the liquid phase. Zeolite permits entry of the main feed components into the pore structure and selectively adsorbs p-xylene. These continuous processes operate with a fixed bed, which appears to move in the direction opposite to the liquid streams. The process shown in Figure 4-6 is representative of a moving bed adsorption system. The p-xylene retained on the adsorbent is removed by a desorbent such as toluene or p-diethylbenzene; with p-xylene separated from the desorbent hydrocarbon by distillation. The typical p-xylene product from this process is around 99.5 percent pure and contains about 0.3 percent ethylbenzene, 0.17 percent m-xylene, and 0.1 percent o-xylene.<sup>1</sup>

Production Capacity and Demand --

The U.S. p-xylene annual consumption grew an average of about 4 percent per year from 1986 to 1991. However, average growth in production was only 1.5 percent per year reflecting decreases in exports. Table 4-5 shows both the historical and projected production capacity, actual production, imports, exports, and demand for p-xylene. Demand grew an average of about 10 percent per year from 1985 to 1988. The increased use of PET soft drink bottles and other containers, polyester apparel (PET fiber production), and the popularity of video tapes (PET films) have all contributed to an increase in PET demand and thereby demand for p-xylene. Overall, the United States p-xylene demand is expected to increase in the range of 2 to 4 percent per year in the near future.<sup>5</sup>

**TABLE 4-5.  
ESTIMATED DOMESTIC U.S. SUPPLY AND  
DEMAND OF P-XYLENE**

Millions of Kilograms (Millions of Pounds)								
	1980	1985	1987	1988	1989	1990	1991	1992
Production Capacity	2,495 (5,500)	2,495 (5,500)	2,515 (5,545)	2,717 (5,990)	2,801 (6,175)	2,835 (6,250)	2,971 (6,550)	2,815 (6,205)
Production	1,922 (4,237)	2,167 (4,778)	2,338 (5,155)	2,541 (5,601)	2,424 (5,344)	2,359 (5,200)	2,864 (5,432)	NA
Imports	23 (50)	67 (147)	115 (253)	101 (222)	120 (265)	86 (189)	87 (191)	NA
Exports	379 (835)	510 (1,125)	368 (811)	393 (866)	311 (686)	299 (659)	289 (637)	NA
Demand	1,566 (3,452)	1,724 (3,800)	2,985 (4,597)	2,248 (4,957)	2,233 (4,923)	2,145 (4,730)	2,464 (5,432)	2,524 (5,565)

NA = No data available.

Source: Reference 4.

Currently, U.S. p-xylene production capacity greatly exceeds demand. Some older, less efficient plants may be closed as the gap between U.S. production and demand increases, export markets decline, and prices weaken. St. Croix Petrochemicals ceased operation in 1991 with 295 million kilograms (650 million pounds) of capacity. St. Croix Petrochemical is jointly owned by Amerada Hess and Cape Industries and obtained feedstock from the adjacent Amerada Hess refinery. Kemtec Petrochemical, which started up in 1989, closed a 181 million kilograms (400 million pounds) unit in Canada in 1991 due to financial difficulties. However, newer efficient facilities are adding capacity. Exxon added 68 million kilograms (150 million pounds) of capacity at Baytown, TX in 1991. Koch added 68 million kilograms (150 million pounds) of capacity at Corpus Christi in 1991 and will expand to 385 million kilograms (850 million pounds) per year in 1992, and ultimately to 454 million kilograms (1,000 million pounds). Lyondell Petrochemicals expanded to 197 million kilograms (435 million pounds) in 1990. Although total world demand for p-xylene is expected to steadily increase, near term global production capacity additions are expected to substantially exceed the growth rate of consumption, resulting in a continually oversupplied market. Table 4-6 lists U.S. p-xylene producers and 1992 capacities.<sup>7,8</sup>

#### 4.2.2 Ortho-xylene Production

Ortho-xylene is used predominately in the manufacture of phthalic anhydride. Additional minor uses of o-xylene are in the manufacture of bactericides, soybean herbicides, and lube oil additives. Ortho-xylene is commercially available as a mixture of at least 95 percent o-xylene, and 5 percent m-xylene and p-xylene. All o-xylene producers also recover p-xylene; however, not all p-xylene producers recover o-xylene.<sup>9</sup>

Separation --

Ortho-xylene is first separated from other C<sub>8</sub> compounds in a distillation column (xylene splitter using the distillation stages). The first distillation recovers m- and p-xylene and ethylbenzene leaving a mixture of o-xylene, C<sub>9</sub>, and higher aromatics. The mixture remaining is redistilled to recover separate components. The higher aromatics are used as solvents or as

**TABLE 4-6.**  
**DOMESTIC U.S. P-XYLENE PRODUCERS AND 1992**  
**PRODUCTION CAPACITIES**

Producer	Location	1992 Production Capacity Millions of Kilograms (Millions of Pounds)
Amoco Chemicals	Decatur, AL	506 (1,115)
Amoco Chemicals	Texas City, TX	685 (1,510)
Chevron Chemical	Pascagoula, MS	238 (525)
DuPont	Chocolate Bayou, TX	27 <sup>a</sup> (60)
Exxon	Baytown, TX	454 (1,000)
Koch Refining Co.	Corpus Christi, TX	397 (875)
Lyondell	Houston, TX	197 (435)
Mobil Chemical	Chalmatte, LA	77 (170)
Phillips 66	Las Mareas, PR	261 (600)

<sup>a</sup>Listed in Reference 7 (1991) but not in Reference 8 (1992).

Source: References 7 and 8.

blending components for gasoline. The purity of the o-xylene production is 97.5 percent, containing about 1 percent C<sub>9</sub> and heavier products and 1.5 percent other xylenes.<sup>1</sup>

#### Production Capacity and Demand --

Table 4-7 presents historical and projected figures for o-xylene capacity, production, imports, exports, and demand.<sup>1,6,9</sup> Worldwide overcapacity still exists. In 1988, imports met almost 25 percent of U.S. demand. Ortho-xylene is shipped to the United States from Eastern and Western Europe, as well as South America. Table 4-8 lists domestic U.S. o-xylene producers and their corresponding 1992 capacities. An additional 91 million kilograms (200 million pounds) of production capacity is available through the AroChem International facility at

**TABLE 4-7.  
ESTIMATED DOMESTIC U.S. SUPPLY AND DEMAND OF  
O-XYLENE**

Millions of Kilograms (Millions of Pounds)									
	1980	1985	1986	1987	1988	1989	1990	1991	1992
Production Capacity	619 (1365)	438 (965)	438 (965)	438 (965)	438 (965)	438 (965)	438 (965)	NA	445 (980)
Actual Production	451 (995)	306 (675)	357 (788)	430 (947)	440 (971)	436 (963)	428 (943)	424 (935)	NA
Imports	NA	49 (109)	88 (195)	57 (126)	124 (273)	24 (53)	5 (12)	8 (18)	NA
Exports	217 (478)	34 (75)	49 (107)	58 (127)	55 (121)	24 (54)	33 (73)	38 (84)	NA
Demand	235 (517)	322 (709)	397 (876)	429 (946)	509 (1,123)	445 (982)	400 (882)	394 (869)	433 (955)

NA No data available.

Source: References 1, 6 and 9.

**TABLE 4-8.  
DOMESTIC U.S. O-XYLENE PRODUCERS AND 1992  
PRODUCTION CAPACITIES**

Producer	Location	1992 Capacity Millions of Kilograms (Millions of Pounds)
AroChem International	Penuelas, PR	91 (200)
Exxon Chemical	Baytown, TX	127 (280)
Koch	Corpus Christi, TX	79 (174)
Lyondell Petrochemicals	Houston, TX	109 (240)
Mobil Chemical	Chalmette, LA <sup>a</sup>	70 (155)
Phillips 66	Guayama, PR	59 (130)

<sup>a</sup>Formerly owned by Tenneco, Inc. until 1988.

Source: References 6 and 9.

Penuelas, PR. The Shell facility at Deer Park, TX, with a 54 million kilogram (120 million pound) production capacity is closed indefinitely.<sup>6</sup>

The growth of the o-xylene market between 1982 and 1991 averaged 1.7 percent per year and is expected to be at two percent through 1992. Ortho-xylene facilities are expected to continue operating at 90 percent of capacity. However, additional foreign production capacity may reduce short-term o-xylene demand by five percent. Long-term, the market for o-xylene will be limited by demand from producers of phthalic anhydride, whose facilities are operating at close to capacity.<sup>6</sup>

#### 4.2.3 Meta-xylene Production

The production of m-xylene relies on separation of the isomer from a mixed xylenes feed. First, a mixture of m- and p-xylene is obtained after removal of o-xylene and ethylbenzene via fractionation. Para-xylene is then partially removed via crystallization or adsorption. High purity m-xylene is then obtained by one of the following methods: crystallization using carbon tetrachloride; through a process in which a nickel thiocyanate/gamma-picoline Werner complex encapsulates p-xylene; or by formation of a complex of m-xylene with hydrofluoric acid (HF), and boron trifluoride (BF<sub>3</sub>). The HF/BF<sub>3</sub>/m-xylene complex process, developed by Mitsubishi Gas Chemical, is currently the most common commercial process.<sup>3</sup>

Amoco Chemical Company is the only known U.S. company isolating m-xylene and using it for the manufacture of isophthalic acid at their Texas City, TX facility. As of January 1989, Amoco had a production capacity of 110 million kilograms (243 million pounds).<sup>2</sup> Historical production, export, import, and demand information for m-xylene was not available at the time of report preparation.

#### 4.2.4 Ethylbenzene Production

Although ethylbenzene is not a xylene isomer, it is discussed here because it is a major component of mixed xylenes and its separation is integral to production of the individual isomers of xylene. Ethylbenzene recovery by super fractionation of C<sub>8</sub> aromatics (requiring three 200 foot distillation columns in series) is more difficult than o-xylene fractionation because of the closeness of its boiling point to that of p-xylene. Removal of ethylbenzene increases the efficiency of the p-xylene separation processes and the isomerization of the remaining C<sub>8</sub> aromatics. Product purity of ethylbenzene is 99.6 percent; the remainder is toluene, paraffins, and some m- and p-xylene. This method of producing ethylbenzene is energy intensive compared with the production of ethylbenzene via alkylation of benzene and ethylene. While about 99 percent of ethylbenzene is consumed in styrene production, a small amount is used in solvent applications, sometimes replacing xylene.<sup>1</sup>

#### 4.3 EMISSIONS

Most air emissions associated with xylene production from petroleum fractions arise from loading operations, storage, and equipment leaks. Process vents also contribute to air emissions. Xylene emissions from other sources, such as waste treatment and disposal facilities are discussed in Section 7.0. Emissions from the production of mixed xylenes and individual isomers are discussed separately in this subsection.

Emissions from the production of mixed xylenes are dependent on the refinery configuration, the mix of products being manufactured, and the nature of the crude oil feedstock.<sup>3</sup> Verifying the production process and other operational parameters at a particular facility is highly recommended before determining emissions.

#### 4.3.1 Process Emissions

Emission factors for the production of mixed xylenes, xylene isomers, and ethylbenzene are presented in Table 4-9. Process-related emission factors for mixed xylene production were only identified for the treating tank in the production from coal-derived light oil (Step 2 in Figure 4-4) and for the ethylene cracking unit in pyrolysis gasoline production. The emission factors for the production of xylene isomers and ethylbenzene are general, overall production process emission factors. As mentioned previously, because the production of ethylbenzene is so highly associated with mixed xylene production, the process description and xylene emission factors for ethylbenzene production are presented here.

**TABLE 4-9.  
PRODUCTION PROCESS EMISSION FACTORS FOR  
MIXED XYLENES AND XYLENE ISOMERS**

Production Process	Emission Source	Emission Factor kg/Mg (lbs/ton) Product		Emission Factor Grade
Coal-Derived Mixed Xylene	Treating Tank	0.50	(1.0)	U <sup>a</sup>
Mixed Xylene from Pyrolysis Gasoline	Ethylene Cracking Unit	0.07	(0.14) <sup>b</sup>	D
p-Xylene Production	Overall	1.14	(2.27) <sup>c</sup>	D
o-Xylene Production	Overall	2.09	(4.16) <sup>c</sup>	D
m-Xylene Production	Overall	1.58	(3.14)	U <sup>a</sup>
Ethylbenzene Production	Overall	0.1 <sup>d</sup>	(0.2) <sup>d</sup>	U <sup>e</sup>

<sup>a</sup>Based on engineering judgement by Hydrosience, Inc.

<sup>b</sup>Based on site visit data.

<sup>c</sup>Based on inventory compiled by the Texas Air Control Board.

<sup>d</sup>Emission factor given in kg/Mg (lbs/ton) used.

<sup>e</sup>Based on engineering estimates by the Texas Air Control Board.

Source: Reference 10.

#### 4.3.2 Storage Emissions

Possible sources of xylene emissions include storage tank losses and handling losses that occur during product loading into drums, tank trucks, tank cars, barges, or ships. Storage tank losses include working losses that occur while filling the tank, and breathing losses due to expansion from temperature changes. The calculations to determine emissions from storage tanks are complex and require a knowledge of a number of factors which are plant specific. Equations for storage tank emissions are given in the U.S. Environmental Protection Agency's report titled *Estimating Air Toxics Emissions from Organic Liquid Storage Tanks* (EPA-450/4-88-004).<sup>11</sup> In the absence of specific data on the storage tank, generic emission factors were identified in the literature and are shown in Table 4-10 for mixed xylene, xylene isomer, and ethylbenzene production. The emission factors shown were based on various source test data, inventory data, and/or engineering judgement. Thus, there are some differences in emission factors for storage emissions when such differences would normally not be expected.

#### 4.3.3 Equipment Leak Emissions (Fugitive Emissions)

Emission factors for fugitive emissions are presented in Table 4-11. However, these emission factors should be used cautiously and are only recommended for obtaining gross emission estimates. They do not take into account the actual number of various leaking and nonleaking components within a facility, but are only a general estimate based on a hypothetical plant. The discussion below presents a more credible approach to determining fugitive emissions.

Emissions occur from process equipment components whenever the liquid or gas streams leak from the equipment. Equipment leaks can occur from the following components: pump seals, process valves, compressor seals and safety relief valves, flanges, open-ended lines, and sampling connections. Emission estimates can be calculated in the five ways described in the EPA publication *Protocols for Generating Unit-Specific Emission Estimates for VOC and VHAP* (EPA-450/3-88-010).<sup>12</sup> The methods differ in complexity; however, greater complexity usually yields more accurate emission estimates.

**TABLE 4-10.**  
**STORAGE EMISSION FACTORS FOR**  
**MIXED XYLENES AND XYLENE ISOMERS**

Production Process	Product/Feedstock Stored	Emission Factor		Emission Factor Grade
		kg/Mg (lbs/ton)	Product Stored	
Toluene Disproportionation	Mixed Xylenes	0.10	(0.20)	U <sup>a</sup>
Coal-Derived Mixed Xylene	Mixed Xylenes	0.60	(1.2)	U <sup>a</sup>
Catalytic Reforming	Mixed Xylenes	0.06	(0.12) <sup>b</sup>	D
Pyrolysis Gasoline	Mixed Xylenes	0.30	(0.60) <sup>c</sup>	D
p-Xylene Production	p-Xylene	0.19	(0.38) <sup>b</sup>	D
o-Xylene Production	o-Xylene	0.08	(0.16) <sup>b</sup>	D
m-Xylene Production	m-Xylene	0.12	(0.24)	U <sup>a</sup>
Ethylbenzene Production	Mixed Xylenes	0.05 <sup>d</sup>	(0.1) <sup>d</sup>	U <sup>e</sup>

<sup>a</sup>Based on engineering judgement by Hydroscience, Inc.

<sup>b</sup>Based on inventory compiled by the Texas Air Control Board.

<sup>c</sup>Based on site visit data.

<sup>d</sup>Emission factor given in kg/Mg (lbs/ton) used.

<sup>e</sup>Based on engineering estimates by the Texas Air Control Board.

Source: Reference 10.

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The simplest method requires that the number of each component type be known. For each component, the xylene content of the stream and the time the component is in service are needed. This information is then multiplied by the EPA's average emission factors for the Synthetic Organic Chemical Manufacturing Industries (SOCMI) shown in Table 4-12.<sup>12</sup> This method is an improvement on using the factors shown in Table 4-11. However, this method should only be used if no other data are available, as it may result in an overestimation of actual

equipment leak emissions. For each component, estimated emissions are calculated in the following way:<sup>12</sup>

$$\left[ \begin{array}{c} \text{No. of} \\ \text{equipment} \\ \text{components} \end{array} \right] \times \left[ \begin{array}{c} \text{Weight \%} \\ \text{xylyene} \\ \text{in the stream} \end{array} \right] \times \left[ \begin{array}{c} \text{Component-} \\ \text{specific} \\ \text{emission factor} \end{array} \right] \times \left[ \begin{array}{c} \text{No. hrs/yr in} \\ \text{xylyene service} \end{array} \right]$$

**TABLE 4-11.**  
**FUGITIVE EMISSION FACTORS FOR**  
**MIXED XYLENES AND XYLENE ISOMERS**

Production Process	Emission Factor kg/Mg (lbs/ton) Product		Emission Factor Grade
Mixed Xylenes from Toluene Disproportionation	0.05	(0.10) <sup>a</sup>	E
Coal-Derived Mixed Xylene	0.15	(0.30) <sup>a</sup>	E
Mixed Xylenes from Catalytic Reforming	0.03	(0.06) <sup>b</sup>	D
Mixed Xylene from Pyrolysis Gasoline	0.03	(0.06) <sup>c</sup>	D
p-Xylene Production	0.24	(0.48) <sup>b</sup>	D
o-Xylene Production	0.38	(0.76) <sup>b</sup>	D
m-Xylene Production	0.30	(0.6) <sup>a</sup>	E
Ethylbenzene Production	0.05 <sup>d</sup>	(0.1) <sup>d,e</sup>	E

<sup>a</sup>Based on engineering judgement by Hydrosience, Inc.

<sup>b</sup>Based on inventory compiled by the Texas Air Control Board.

<sup>c</sup>Based on site visit data.

<sup>d</sup>Emission factor given in kg/Mg (lbs/ton) used.

<sup>e</sup>Based on estimates by the Texas Air Control Board.

Source: Reference 10.

**TABLE 4-12.**  
**AVERAGE EMISSION FACTORS FOR FUGITIVE**  
**EQUIPMENT LEAK EMISSIONS**

Equipment	Service	Emission Factor (kg/hr/source)	Emission Factor (lb/hr/source)	Data Quality Rating <sup>a</sup>
Valves	Gas	0.0056	0.0123	U
	Light Liquid	0.0071	0.0156	
	Heavy Liquid	0.00023	0.00051	
Pump Seals	Light Liquid	0.0494	0.109	U
	Heavy Liquid	0.0214	0.0471	
Compressor Seals	Gas/Vapor	0.228	0.502	U
Pressure Relief Seals	Gas/Vapor	0.104	0.229	U
Flanges	All	0.00083	0.0018	U
Open-Ended Lines	All	0.0017	0.0037	U
Sampling Connections	All	0.0150	0.0033	U

<sup>a</sup>Based on engineering judgement.  
Source: Reference 12.

To obtain more accurate equipment leak emission estimates, one of the more complex estimation methods should be used. These methods require that some level of emission measurement for the facility's equipment components be collected. These are described briefly, and the reader is referred to the *Protocols* document for the calculation details.<sup>12</sup>

The first method, the leak/no leak approach, is based on a determination of the number of leaking and non-leaking components. These values are then multiplied by two different sets of EPA-derived emission factors as presented in the *Protocols* document.<sup>12</sup> The second method groups screening results into three ranges: 0-1,000 ppmv; 1,001-10,000 ppmv; and greater than 10,000 ppmv. The number of each component falling in a particular range is multiplied by the component-specific emission factor for that range. These emission factors have also been

developed by EPA. Another procedure uses screening data in correlation equations derived from earlier work by EPA. An additional method calls for the facility to develop its own correlation equations, but this method requires more rigorous testing, bagging and analyzing of equipment leaks to determine mass emission rates.

#### 4.3.4 Emission Controls

Controls on process emissions are usually vented to fuel gases or recycled into other processes. Storage emissions are usually controlled by using floating roof tanks to reduce emissions from standing and working losses. Submerged filling reduces emissions during loading of the product into drums, tanks, and barges.

Although no specific information on controls of fugitive emissions used by the industry was identified, equipment components in xylene service will have some controls in place. Generally, control of fugitive emissions will require the use of sealless or double mechanical seal pumps, an inspection and maintenance program, as well as replacement of leaking valves and fittings. Typical controls for equipment leaks are listed in Table 4-13. Some leakless equipment is available such as leakless valves and sealless pumps.<sup>13</sup>

**TABLE 4-13.  
CONTROL TECHNIQUES AND EFFICIENCIES APPLICABLE TO  
EQUIPMENT LEAK EMISSIONS**

<b>Equipment component (Emission source)</b>	<b>Control technique</b>	<b>Percent reduction<sup>a</sup></b>
Pump Seals:		
Packed and Mechanical	Seal area enclosure vented to a combustion device	100
	Monthly LDAR <sup>b</sup>	61
	Quarterly LDAR	32
	Semiannual LDAR	0
	Annual LDAR	0
Double Mechanical <sup>c</sup>	N/A <sup>d</sup>	-----
Compressors	Vent degassing reservoir to combustion device	100
Flanges	None available	0
Valves:		
Gas	Monthly LDAR	73
	Quarterly LDAR	64
	Semiannual LDAR	50
	Annual LDAR	24
Liquid	Monthly LDAR	59
	Quarterly LDAR	44
	Semiannual LDAR	22
	Annual LDAR	0
Pressure Relief Devices		
Gas	Monthly LDAR	50
	Quarterly LDAR	44
	Rupture Disk	100
Sample Connections	Closed-purge sampling	100
Open-ended Lines	Caps on open ends	100

<sup>a</sup>If a negative reduction for a control technique was indicated, zero was used.

<sup>b</sup>LDAR = Leak detection and repair.

<sup>c</sup>Assumes the seal barrier fluid is maintained at a pressure above the pump stuffing box pressure and the system is equipped with a sensor that detects failure of the seal and/or barrier fluid system.

<sup>d</sup>N/A - Not applicable. There are no VOC emissions from this component.

Source: Reference 11.

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11. U.S. Environmental Protection Agency. *Estimating Air Toxics Emissions from Organic Liquid Storage Tanks*. EPA-450/4-88-004. Office of Air Quality Planning and Standards, Research Triangle Park, NC. October 1988.
12. U.S. Environmental Protection Agency, *Protocols for Generating Unit-Specific Emission Estimates for Equipment Leaks of VOC and VHAP*, EPA-450/3-88-010. Office of Air Quality Planning and Standards. Research Triangle Park, NC. 1988.
13. U.S. Environmental Protection Agency, *Fugitive Emission Sources of Organic Compounds--Additional Information on Emissions, Emission Reductions, and Costs*. EPA-450/3-82-010. Research Triangle Park, NC. April 1982.

## SECTION 5.0 EMISSIONS FROM MAJOR USES OF XYLENE

Xylene is used as a solvent and/or feedstock in the manufacture of many products. This section discusses the emissions of xylene from processes that use xylene as a feedstock in the manufacture of another product or as a solvent. Emissions of xylene as a residual component of a product containing xylene are discussed separately in Section 6.0. Emissions of xylene from coal combustion, hazardous and solid waste incineration, and wastewater treatment processes are discussed in Section 7.0.

### 5.1 PHTHALIC ANHYDRIDE PRODUCTION

Phthalic anhydride (PA),  $C_8H_4O_3$ , is produced by the oxidation of o-xylene, naphthalene, or mixtures of both feedstocks, in the presence of catalysts. Ortho-xylene is the dominant feedstock used in PA production. In 1990, there were four known active producers of phthalic anhydride in the United States using o-xylene as a feedstock.<sup>1</sup> Table 5-1 lists U.S. phthalic anhydride producers and 1990 capacities.

Phthalic anhydride is commercially available as white, free-flowing flakes or colorless molten material, the latter of which comprises 90 percent of the PA shipped. PA is used in the manufacture of a variety of products including plasticizers, unsaturated polyester resins, alkyd resins, polyols, phthalocyanine pigments, dyes, perfumes, pharmaceuticals and chemical intermediates. The largest end use of phthalate plasticizers is in compounding flexible polyvinyl chloride.<sup>1</sup> Other end uses for phthalate plasticizers include some nitrocellulose lacquers and some adhesives.<sup>2</sup> The unsaturated polyester resins are used to produce a number of fabricated fiberglass-reinforced plastics including construction materials, boats and molded automobile body panels.<sup>1</sup>

**TABLE 5-1.  
PHTHALIC ANHYDRIDE PRODUCERS USING  
O-XYLENE AS A FEEDSTOCK**

Producer	Location	1990 Capacity <sup>a</sup> Millions of Kilograms (Millions of Pounds)	
Aristech (Mitsubishi)	Pasadena, TX	95.3	(210)
Exxon Chemical	Baton Rouge, LA	113.4	(250)
Stepan Chemical	Millsdale, IL	77.1	(170)
Sterling Chemical Company	Texas City, TX	79.4	(175)
Total Capacity		365.2	(805)

<sup>a</sup>Excludes the 79.4 million kilograms per year produced at the BASF plant in South Kearney, NJ, which closed in October of 1990.

Source: Reference 1.

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PA is also used extensively in the manufacture of paint resins. Alkyd resins use for protective coatings has decreased in the paint vehicle market. However, alkyd resins still comprise a significant portion of the resin used in the United States. Small miscellaneous applications for PA include halogenated anhydrides used as fire retardants, polyester polyols for urethanes, dialkyl phthalate, and phenolphthalein.<sup>1</sup> Table 5-2 presents the 1990 estimate of the end use pattern of PA.

In 1988, the total phthalic anhydride production in the United States was approximately 476 million kilograms (1,049 million pounds) per year. At a conversion rate of 0.93 kg of o-xylene per kilogram of phthalic anhydride produced, approximately 443 million kilograms (977 million pounds) of o-xylene were used in 1988 for production of phthalic anhydride. Table 5-2 estimates are based on the unit capacities in Table 5-1. The 1988 use of o-xylene for production of phthalic anhydride is higher than the capacity listed in Table 5-1 because the 1988

**TABLE 5-2.**  
**PHTHALIC ANHYDRIDE END USE PATTERN - 1990**  
**ESTIMATE**

Derivative	Percent	Approximate o-Xylene use	
		Millions of Kilograms	(Millions of Pounds)
Phthalate Plasticizers	53	180	(397)
Unsaturated Polyesters	24	82	(180)
Alkyd Resins	16	54	(120)
Miscellaneous	7	24	(52)

Source: Reference 1.

---

production figures include BASF's South Kearney, NJ, phthalic anhydride plant, which closed in October 1990 and had a capacity of 79.4 million kilograms per year. The 1990 projected use of o-xylene for phthalic anhydride production is estimated to be 340 million kilograms (749 million pounds). In addition to the closing of the BASF plant, U.S. demand for PA has leveled off in 1988-1989. Demand and production are not expected to increase until the economy improves.<sup>1</sup>

#### 5.1.1 Process Description

Figure 5-1 shows the process flow diagram for phthalic anhydride production using o-xylene as the basic feedstock. Filtered air is preheated, compressed, mixed with vaporized o-xylene and fed into the fixed-bed tubular reactors (Step 1). The reactors contain vanadium pentoxide as the catalyst and are operated at 340°C to 385°C (644° to 725°F). In order to maintain catalyst activity, small amounts of sulfur dioxide are added to the reactor feed. Exothermic heat is removed by a molten salt bath circulated around the reactor tubes and

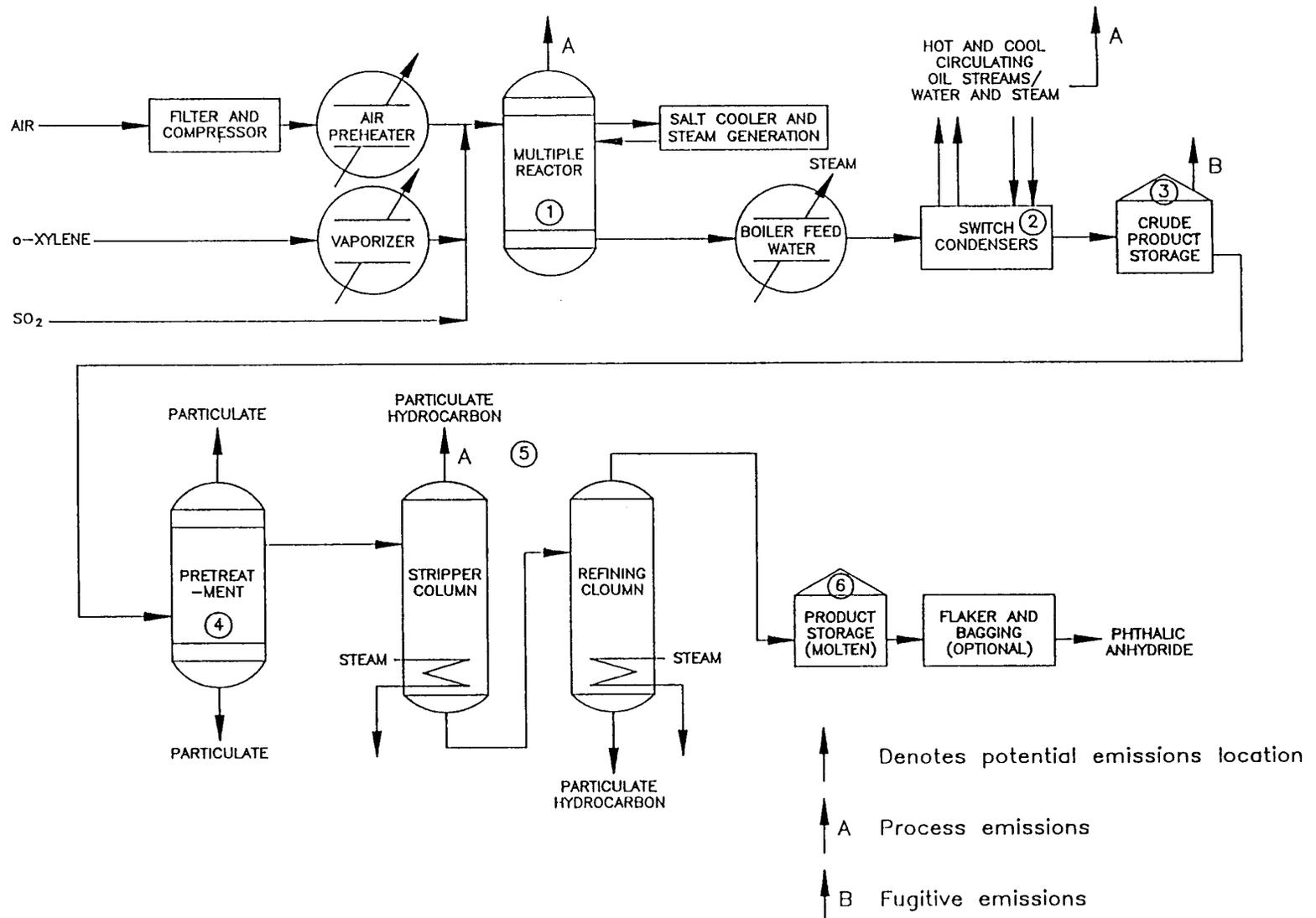
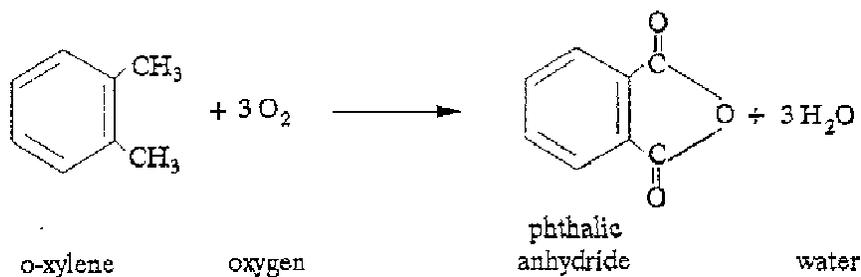


Figure 5-1. Flow diagram for phthalic anhydride production using o-xylene as basic feedstock.<sup>3</sup>

produce PA (Step 4). The liquid then flows to the vacuum distillation column where the remaining water and impurities are removed (Step 5). In the final step, the pure product is pumped to molten storage (Step 6). The chemical reaction for air oxidation of o-xylene is as follows:<sup>3</sup>



### 5.1.2 Emissions<sup>3</sup>

The major source of xylene emissions from the PA production process is the reactor and condenser effluent labeled as A in Figure 5-1. This combined effluent is vented from the condenser unit.

Pretreatment and distillation emissions (particulates and hydrocarbons including xylene) are usually processed through the water scrubber and/or incinerator used for the main process stream (reactor and condenser), or through the scrubbers alone. Small amounts of gaseous emissions occur from product storage in the liquid phase. These gas streams can either be sent to the main process vent gas control devices or first processed through sublimation boxes or devices used to recover escaped PA.

The most efficient system of control (96 percent) is the combined usage of a water scrubber and thermal incinerator. A thermal incinerator alone is approximately 95 percent efficient in the combustion of organic pollutants for o-xylene-based production. Table 5-3 gives xylene emission factors for process, fugitive, and storage tank emissions from the production of phthalic anhydride. Several emission factors are available for estimation of storage emissions of xylene. Two of the factors listed in Table 5-3 were based on test data for controlled and uncontrolled storage tank emissions. The third emission factor for storage emissions was based on engineering estimates and is therefore less reliable. The discussion in Section 4.3.3 on fugitive emissions should be referred to for more detail.

**TABLE 5-3.  
MIXED XYLENE AND ORTHO-XYLENE EMISSION FACTORS  
FOR PHTHALIC ANHYDRIDE PRODUCTION**

Emission Source	Emission Factor g/kg PA produced (lb/lb PA produced)	Emission Factor Grade <sup>a</sup>
Storage tanks	0.002 (2.0 x E-6) <sup>b</sup>	D
Storage tanks	0.20 (2.0 x E-4) <sup>c</sup>	D
Storage tanks	0.02 (2.0 x E-5)	U <sup>d</sup>
Fugitive	0.04 (4.0 x E-5)	U <sup>d</sup>
Process	0.14 (1.4 x E-4)	U <sup>d</sup>

<sup>a</sup>Based on AP-42 criteria selection described in Section 2.0 of this document.

<sup>b</sup>Based on test data, controlled.

<sup>c</sup>Based on test data, uncontrolled.

<sup>d</sup>Based on engineering estimates for o-xylene emissions.

Source: Reference 4.

## 5.2 TEREPHTHALIC ACID PRODUCTION

Terephthalic acid (TPA) is an aromatic acid produced from p-xylene. TPA is a reactive compound and undergoes reactions characteristic of aromatic dicarboxylic acids. TPA production is the major end-use of p-xylene. Approximately 0.71 pounds of p-xylene are required to produce 1 pound of TPA. TPA is produced as either the free acid or further processed to form the intermediate dimethyl terephthalate (DMT). Approximately 0.61 pounds of p-xylene are required to produce 1 pound of DMT. For the purpose of simplifying this discussion, all capacity and production will be expressed in terms of TPA. Any production or capacity discussed here in terms of DMT can be converted to TPA by dividing the figure for DMT by 1.16.<sup>5</sup>

In 1988, the United States' production of TPA/DMT reached a high of 3,606 millions of kilograms per year (7,950 millions of pounds per year). The corresponding p-xylene consumed as a feedstock for TPA/DMT production was 2,249 millions of kilograms (4,959 millions of pounds). Terephthalic acid production has declined since 1988 (thus reducing p-xylene demand) due to a decline in the export demand for TPA/DMT and the slower domestic economy. The export demand for TPA/DMT is expected to continue to decline for the next several years because new plants are being built outside the United States. If the U.S. demand for TPA/DMT does not increase to offset the reduced export demand, the use of p-xylene in producing TPA/DMT will decline further. Despite the decreasing demand for TPA, Amoco expanded domestic production in 1990, as reflected in Table 5-4. Any further expansions are expected to be modest due to the anticipated decline in export demand.<sup>5</sup> Table 5-4 lists known U.S. terephthalic acid producers and 1992 capacities.

TPA/DMT is used primarily in the polyester fibers industry. The consumption of TPA/DMT in polyester fiber production is approximately 60-65 percent of the total TPA/DMT production. TPA/DMT is also used in the production of polyethylene terephthalate resins, which are a raw material for polyethylene terephthalate (PET) plastic bottle molding, and plastic tape and film production. An 8 to 10 percent annual increase is expected in the demand for PA in PET bottle resins, but the demand for domestic polyester fiber is expected to decline due to the

**TABLE 5-4.**  
**TEREPHTHALIC ACID PRODUCERS USING P-XYLENE AS A**  
**FEEDSTOCK - 1992 PRODUCTION CAPACITIES**

Producer	Location	Product	1992 Capacity as TPA <sup>a</sup>	
			Millions of Kilograms	(Millions of Pounds)
Amoco Chemicals	Decatur, AL	TPA only	998	(2200)
Amoco Chemicals	Charleston (Cooper River), SC	TPA only	544	(1200)
Cape Industries (Hercofina)	Wilmington, NC	DMT from TPA <sup>b</sup>	612	(1350)
DuPont	Cape Fear, NC	DMT from TPA <sup>b</sup>	544	(1200)
DuPont	Old Hickory, TN	DMT from TPA <sup>b</sup>	227	(500)
Eastman	Columbia, SC	DMT from TPA <sup>b</sup>	408	(900)
Eastman	Kingsport, TN	DMT from TPA <sup>b</sup>	204	(450)
Total			3,537	(7,800)

<sup>a</sup>Based on announced capacities and trade estimates.

<sup>b</sup>USITC production statistics were reported as DMT; to reach a common reporting base the DMT capacity was divided by 1.16.

Source: Reference 5.

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reduced level of domestic textile production.<sup>5</sup> The p-xylene demand for production of TPA/DMT will follow the demand for TPA/DMT. Annual worldwide DMT and TPA use is expected to increase by 1.1 percent and 7.2 percent each year, respectively.<sup>6</sup> Table 5-5 lists the 1991 estimate of the end use pattern of TPA.<sup>5</sup>

**TABLE 5-5.  
TEREPHTHALIC ACID END USE PATTERN -  
1991 ESTIMATE**

Derivative	Percent	Approximate p-Xylene use	
		Millions of Kilograms	(Millions of Pounds)
Polyester Fibers	61	1,532	(3,378)
PET Bottles and Plastics	22	552	(1,218)
PET Tape and Films	13	327	(720)
Miscellaneous (includes engineering resins)	4	101	(222)

Source: Reference 5.

### 5.2.1 Process Description

There are a variety of processes for producing both TPA and DMT. Different processes are used to produce technical and polymer grades of TPA and DMT. This discussion will concentrate on the polymer grade production methods used in the United States. Polymer grade TPA/DMT is required for a majority of the derivatives manufactured from TPA/DMT.

The Hercules/Dynamit Nobel Process, shown in Figure 5-2, is the most common method for producing DMT. The p-xylene is oxidized by air to p-toluic acid, which is subsequently esterified to methyl p-toluate. A second oxidation and subsequent esterification yields DMT. The p-xylene, air and catalyst are fed continuously to the reactor, which is maintained at 140°C - 170°C (284°F - 338°F) and 400 kPa - 700 kPa (58 psi - 102 psi) (Step 1). Condensed p-xylene is recycled back to the oxidation reactor. The exhaust from the oxidation reactor is fed to the esterification reactor which operates at 200°C - 250°C (392°F - 482°F) and sufficient

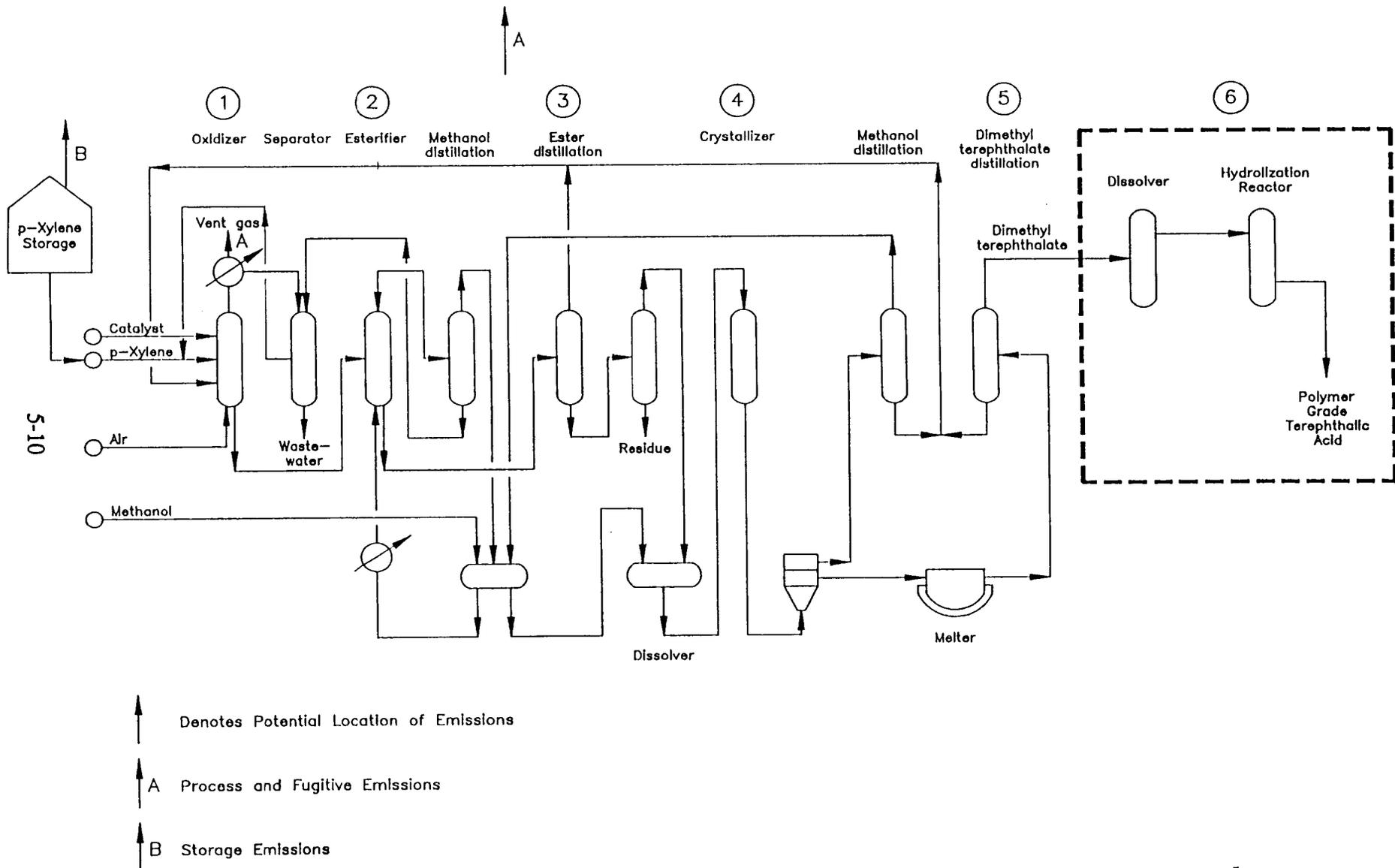


Figure 5-2. Production of polymer grade dimethyl terephthalate by the Dynamit Noble process.<sup>7</sup>

(Reprinted with permission from John Wiley & Sons, Inc., *Kirk-Othmer Encyclopedia of Chemical Technology*, 3rd Ed, 1982.)

pressure to maintain a liquid phase (Step 2). Methanol is added in the esterification reactor. The products from the esterification reactor are separated by distillation and the methyl p-toluate is recycled to the oxidation reactor (Step 3). The crude dimethyl terephthalate is purified through crystallization (Step 4) and distillation (Step 5). The product may be used as polymer grade DMT or can be hydrolyzed to produce polymer grade TPA. Hercofina produces TPA by hydrolyzing DMT at 180°C - 250°C (356°F - 482°F) in an aqueous solution with a neutral salt such as potassium chloride (Step 6). The hydrolyzation may also be accomplished without the neutral salt at 260°C (500°F).<sup>4,7</sup>

Amoco produces polymer grade TPA based on the liquid phase oxidation of p-xylene in the presence of a catalyst to produce crude terephthalic acid (C-TPA). A process diagram is shown in Figure 5-3. Acetic acid and p-xylene are fed to a reactor with a cobalt acetate catalyst (Step 1). The reactor is fed with compressed air to supply oxygen for the reaction. Reactor pressure and temperature are maintained at 1,500 kPa - 3,000 kPa (220 psi - 435 psi) and 175°C - 230°C (347°F - 446°F) respectively. Products from the reactor are pumped to a centrifuge to separate the C-TPA (Step 2). The C-TPA produced is purified using the Amoco purification process. This process consists of processing an aqueous slurry of the C-TPA through a dissolver which operates at greater than or equal to 250°C (482°F) (Step 3). The solution from the dissolver is pumped to a hydrogenation reactor which contains a noble metal catalyst (Step 4). Hydrogen is fed to the reactor and impurities, such as 4-formylbenzoic acid, are converted to soluble compounds which remain in the mother liquor during the recrystallization process for the polymer grade TPA (Step 5).<sup>4,7</sup>

### 5.2.2 Emissions<sup>3</sup>

The atmospheric emissions from the production of C-TPA are difficult to characterize due to the variety of processes involved. Emissions vary extensively, both qualitatively and quantitatively.

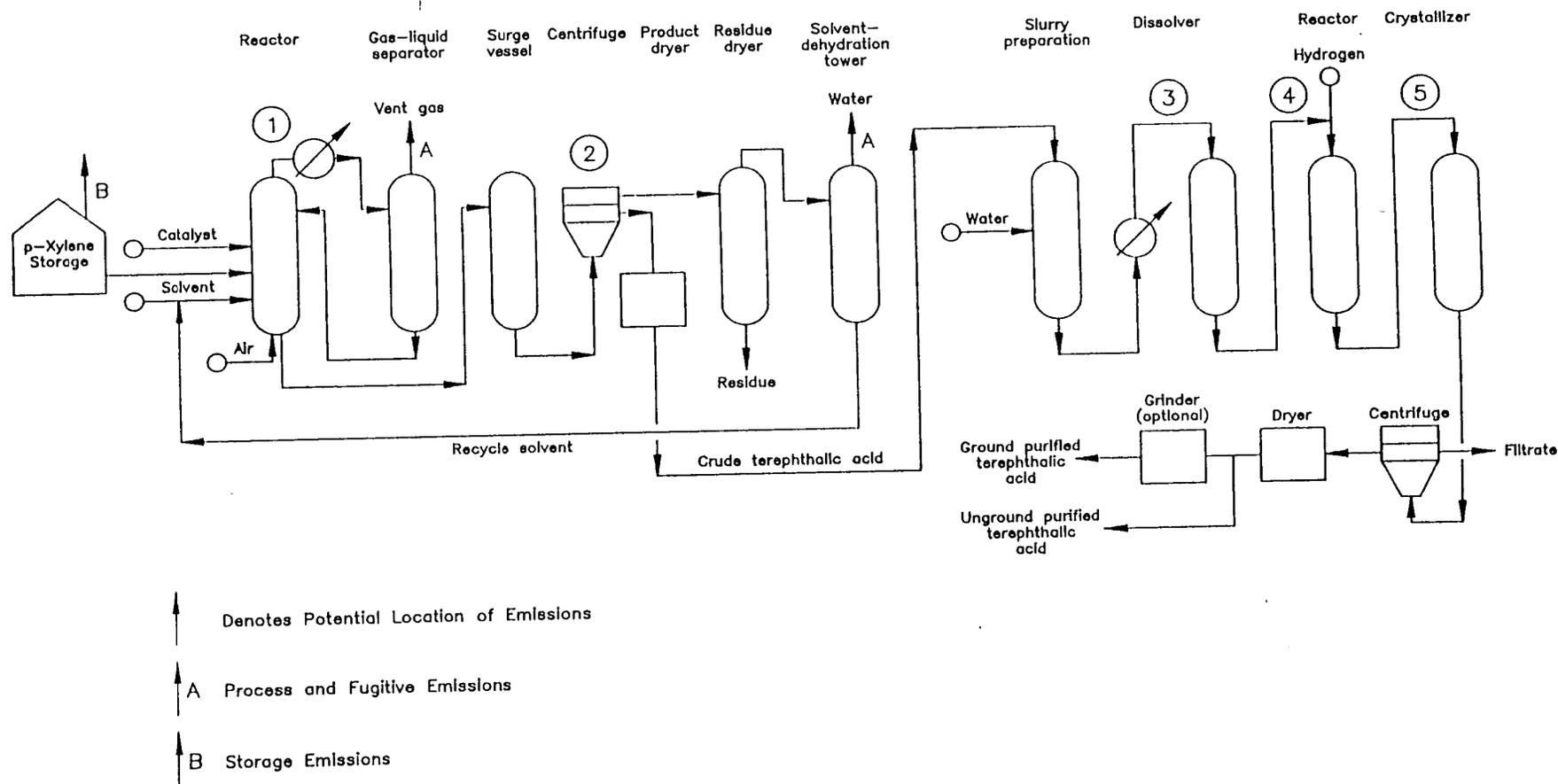


Figure 5-3. Production of polymer grade terephthalic acid by catalytic liquid-phase air oxidation of p-xylene.<sup>7</sup>

(Reprinted with permission from John Wiley & Sons, Inc., *Kirk-Othmer Encyclopedia of Chemical Technology*, 3rd Ed, 1982.)

The reactor gas from vent A in Step 1 (shown in Figure 5-3) usually contains nitrogen (from air oxidation), unreacted oxygen, unreacted p-xylene, acetic acid (reaction solvent), carbon monoxide and methyl acetate from oxidation of p-xylene, and water. The quantity of VOC emitted from this vent can vary with absorber pressure and the temperature of exiting vent gases.

During crystallization of terephthalic acid and separation of crystallized solids from the solvent (by centrifugation or filtering), noncondensable gases carrying VOC are emitted. These vented gases and the C-TPA dryer vent gas are combined and released to the atmosphere from the vent in Step 2 (shown in Figure 5-3). Different methods used in this process can affect the amount of noncondensable gases and accompanying VOC emitted from this vent. Gases released from the residue still (shown in Figure 5-3) flow to the solvent dehydration tower where small amounts of xylene may be emitted with the water removed.

Carbon adsorption control technology for a VOC gas stream similar to the reactor vent gas and product transfer vent gas has been demonstrated. A thermal oxidizer which provides reduction of both carbon monoxide (CO) and VOC is an alternative to the carbon adsorption system. Emission sources and factors for both the C-TPA and TPA processes are given in Table 5-6. Section 4.3.3 should be referred to for a more detailed discussion of fugitive emissions.

### 5.3 MALEIC ANHYDRIDE PRODUCTION

Essentially all maleic anhydride (MA) is manufactured by the catalytic vapor-phase oxidation of hydrocarbons, with only minor amounts recovered as a by-product of phthalic anhydride production. Since 1988, maleic anhydride has been manufactured in the United States from n-butane. Although xylene is not used as a feedstock in MA production, it is commonly used as a processing aid. A fraction of the MA vapors which are exhausted from the reactor are condensed to produce a crude MA liquor. The balance of the vapors are then scrubbed with water or an organic solvent such as o-xylene. The MA is recovered from an aqueous scrubber liquor through a dehydrator with the addition of xylene to form a water-xylene azeotrope.

**TABLE 5-6.**  
**MIXED XYLENES EMISSION FACTORS FOR TEREPHTHALIC**  
**ACID AND CRUDE TEREPHTHALIC ACID PRODUCTION**

Industrial Process	Emission Source	Emission Factor	Emission Factor Grade <sup>a</sup>
Terephthalic acid production	Storage	0.11 g xylene/kg (0.00011 lb xylene/lb) xylene used <sup>b</sup>	D
Terephthalic acid production	Fugitive	0.07 g xylene/kg (0.00007 lb xylene/lb) xylene used <sup>b</sup>	D
Terephthalic acid production	Process - general	2.54 g xylene/kg (0.00254 lb xylene/lb) xylene used <sup>b</sup>	D
Crude terephthalic acid production by air oxidation process	p-Xylene storage tank vents	0.11 g xylene/kg (0.00011 lb xylene/lb) crude terephthalic acid produced <sup>c</sup>	D
Crude terephthalic acid production by air oxidation process	Reactor vent (uncontrolled) <sup>d</sup>	6 g xylene/kg (0.006 lb xylene/lb) crude terephthalic acid produced	D
Crude terephthalic acid production by air oxidation process	Reactor vent (controlled) <sup>e</sup>	0.18 g xylene/kg (0.00018 lb xylene/lb) crude terephthalic acid produced	D

<sup>a</sup>Based on AP-42 criteria selection described in Section 2.0 of this document.

<sup>b</sup>Based on site visit data.

<sup>c</sup>Uncontrolled, filling emissions only, hypothetical plant operating 8760 h/yr with 230 Gg/yr capacity.

<sup>d</sup>Uncontrolled, based on hypothetical plant operating 8760 h/yr with 230 Gg/yr capacity.

<sup>e</sup>Carbon adsorption control (97 percent emission reduction), hypothetical plant operating 8760 hr/yr with 230 Gg/yr capacity.

Source: Reference 4.

Distillation is used to recover MA from an organic solvent scrubber liquor.<sup>8</sup> Table 5-7 lists the major U.S. maleic anhydride producers and their locations.

**TABLE 5-7.  
MALEIC ANHYDRIDE PRODUCERS USING O-XYLENE  
AS A PROCESSING AID**

Producer	Location
Amoco	Joliet, IL
Aristech	Neville Island, PA
Ashland Chemical	Neal, WV
Mobay Synthetics Corporation	Houston, TX
Monsanto	Pensacola, FL

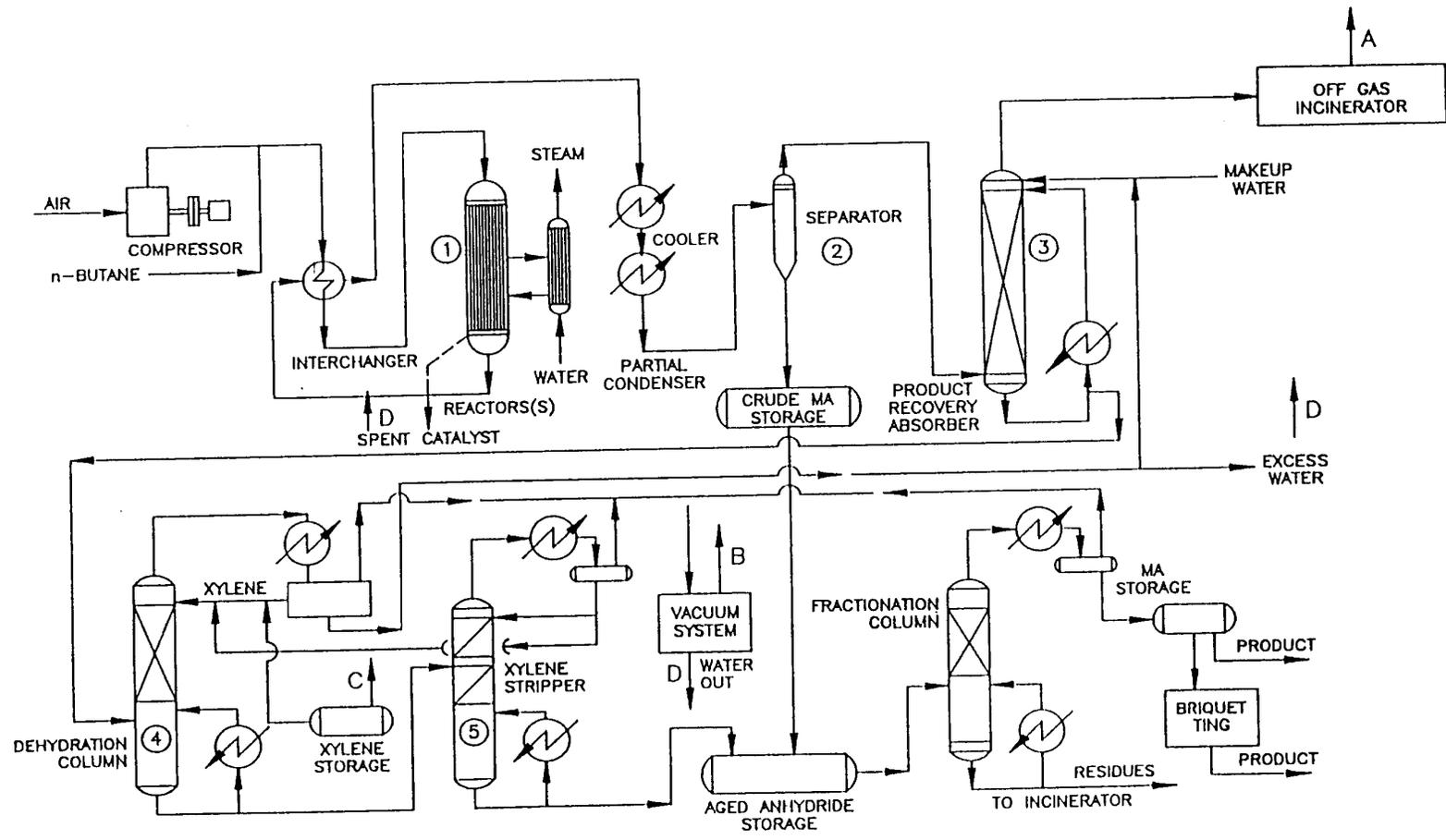
Source: Reference 9.

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Based on available information, the consumption of o-xylene as a processing aid for MA is a maximum of 3 million kilograms (6.6 million pounds) assuming that all o-xylene not used in phthalic anhydride production is used for the production of MA. Because much of the o-xylene used is recycled in the process, the quantity of o-xylene used in the production of MA is not drastically affected by production increases.

### 5.3.1 Process Description<sup>3,7</sup>

Maleic anhydride is produced from n-butane in a reactor by oxidation. Figure 5-4 illustrates the process. The n-butane and compressed air are fed to the reactor, which is commonly filled with a phosphorus-vanadium-oxygen catalyst (Step 1). Products from this vapor phase reaction are exhausted to a condenser where a fraction of the MA is recovered as a molten liquid (Step 2). Liquid MA is pumped to further processing and storage. The MA and water vapors not condensed are scrubbed in the product recovery absorber (Step 3). The liquid used to absorb the product may be o-xylene or water. MA product recovered through absorption with o-xylene is separated by distillation. MA product recovered using water is sent to a dehydrator



- ↑ A PRODUCT RECOVERY ABSORBER VENT
- ↑ B VACUUM SYSTEM VENT
- ↑ C STORAGE AND HANDLING EMISSIONS
- ↑ D SECONDARY EMISSION POTENTIAL

Figure 5-4. Maleic anhydride process.<sup>3</sup>

where o-xylene is added and the water and o-xylene are removed through an azeotropic distillation process (Step 4). The o-xylene is subsequently purified and reused in the process (Step 5). The product MA is then sent to storage.

### 5.3.2 Emissions

Fugitive emissions of xylene, n-butane, MA, and maleic acid arise from the storage and handling of n-butane, xylene, and MA. Xylene emissions from processes used to manufacture maleic anhydride may occur from the scrubber, the dehydrator, o-xylene distillation or o-xylene storage tanks.<sup>3</sup> Figure 5-4 indicates these potential emission points as letters "A" through "D". Xylene emission sources and factors are shown in Table 5-8. Section 4.3.3 should be referred to for a more detailed discussion of fugitive emissions.

**TABLE 5-8.  
MIXED XYLENES EMISSION FACTORS FOR MALEIC  
ANHYDRIDE PRODUCTION**

Emission Source	Emission Factor	Emission Factor Grade <sup>a</sup>
Process Emissions	11.6 g xylene/kg product) (0.0116 lb xylene/lb product)	E
Storage Emissions	0.075 g xylene/kg product (0.000075 lb xylene/lb product)	E
Fugitive Emissions	0.4 g xylene/kg product (0.0004 lb xylene/lb product)	E

<sup>a</sup>Based on AP-42 criteria selection described in Section 2.0 of this document.

Source: Reference 4.

## 5.4 PAINT AND INK MANUFACTURING

Paints are made by blending pigments, solvents, resins (or binders), oils (for some inks), and other additives. The fluid component of the paint or ink, made of binders (oils and/or resins) and solvents, is called the vehicle. Vehicles transfer the pigment/binder mixture to the substrate surface in a thin, uniform film and play no role in film formation. When a paint is deposited on a substrate, the vehicle solvent(s) should evaporate completely. Xylene is only one of the vehicle solvents used by paint manufacturers.<sup>10</sup> Paints and coatings account for about 65-70 percent of mixed xylenes consumption as solvents. Like toluene, the use of xylene in paints and coatings has been increasing since 1987, largely due to increasing consumption in short-oil and medium-oil-length alkyds. The manufacturing processes for both paints and inks are very similar, therefore this section will concentrate on paint production.

The long-term use of xylene in the coating industry is expected to gradually decrease. Table 5-9 lists estimates of the quantity of xylene used as solvents. Table 5-10 shows estimated consumption of xylene derivatives in paints and coatings in 1988.<sup>11</sup> Figure 5-5 illustrates xylene use in the paint and coatings industry. Total use of xylene and xylene derivatives (*e.g.*, DMT, PA, Isophthalic Acid) in paint production accounts for 10 percent of the total annual xylene consumption in the United States.

### 5.4.1 Process Description

Paint and ink facilities use similar manufacturing processes to produce their respective products in batch scale production fashion. Most plants purchase raw materials (*e.g.*, pigments, solvents, resins, and other additives) and then formulate, or blend, a finished product. Normally, no chemical reactions take place during the process. Batch process production of paint and ink involves four major steps:<sup>10</sup>

- Preassembly and premix
- Pigment grinding/milling

**TABLE 5-9.**  
**ESTIMATED QUANTITIES OF XYLENE USED AS SOLVENTS**  
**IN PAINTS AND COATINGS**

Year	Total Solvent Sales				Use in Paints and Coatings			
	Millions of Kilograms (Millions of Pounds)		Millions of Liters (Millions of Gallons)		Millions of Kilograms (Millions of Pounds)		Millions of Liters (Millions of Gallons)	
1979	361	(795)	416	(110)	234	(515)	269	(71)
1980	327	(720)	379	(100)	214	(470)	246	(65)
1981	320	(705)	371	(98)	211	(465)	242	(64)
1982	295	(650)	341	(90)	186	(410)	216	(57)
1983	305	(670)	352	(93)	200	(440)	231	(61)
1984	309	(680)	356	(94)	207	(455)	238	(63)
1985	295	(650)	341	(90)	211	(465)	242	(64)
1986	295	(650)	341	(90)	211	(465)	242	(64)
1987	300	(660)	344	(91)	211	(465)	242	(64)
1988	308	(680)	356	(94)	216	(475)	246	(65)
1989	318	(700)	363	(96)	218	(480)	250	(66)

Source: Reference 11.

**TABLE 5-10.**  
**ESTIMATED CONSUMPTION OF XYLENE DERIVATIVES IN**  
**PAINTS AND COATINGS, 1988**

Derivative	Derivative Production from Xylene Millions of Kilograms (Millions of Pounds)		Xylenes Consumption Millions of Kilograms (Millions of Pounds)		Derivative Consumption in Paints and Coatings Millions of Kilograms (Millions of Pounds)		Xylene Equivalents for Paints and Coatings Millions of Kilograms (Millions of Pounds)	
Solvent	-		308	(680) (mixed)	216	(475)	216	(475)
Dimethyl terephthalate/ terephthalic acid (in DMT equivalents)	3,682	(8,100)	2,249	(4,947) (p-)	6.4	(14)	3.6	(8)
Phthalic anhydride	422	(928)	409	(900) (o-)	84	(185)	77	(170)
Isophthalic acid	67	(148)	48	(105) (m-)	18	(40)	13	(28)
Total xylenes			3,015	(6,632)			310	(681)

Source: Reference 11.

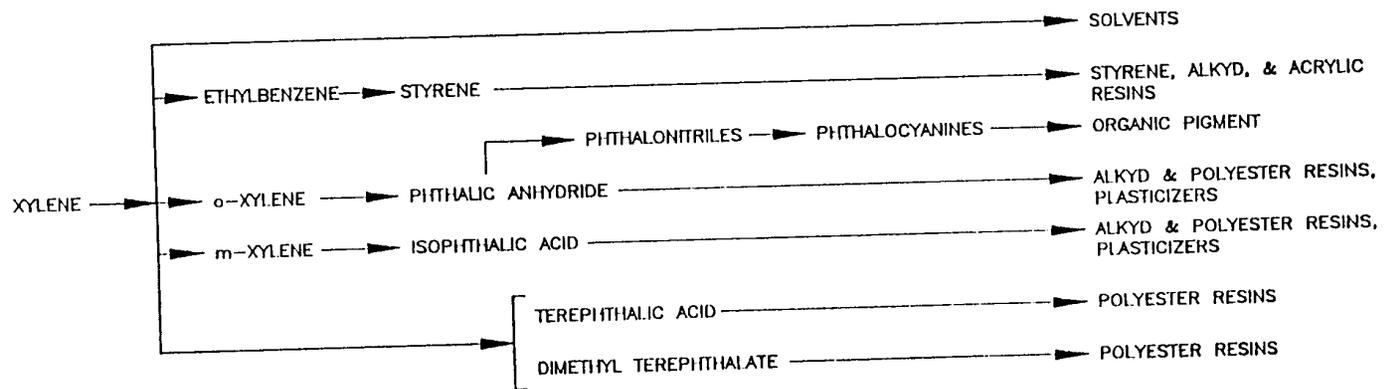


Figure 5-5. Use of xylene isomers and derivatives in the paints and coatings industry.<sup>11</sup>

- Product finishing/blending
- Product filling/packaging

Some large scale paint manufacturing facilities produce resins on-site as part of their paint manufacturing processes. The resins are often produced in reactors at atmospheric pressure with process temperatures between 70°C to 120°C (158°F to 248°F). Xylene, or solvents containing xylene, are used to dissolve the reactants and promote heat transfer for the reaction. The resin products are then tinted and thinned to finished product specifications.<sup>10</sup>

The manufacturing process is summarized in Figure 5-6.<sup>10</sup> The first step in the manufacturing process is preassembly and premix. In this step, the liquid raw materials (*e.g.*, resins, solvents, oils, alcohols, and/or water) are "assembled" and mixed in containers to form a viscous material to which pigments are added. The premix stage results in the formation of an intermediate product which is referred to as the base or mill base. With further processing, this base with high pigment concentration may become any one of a variety of specific end products.<sup>10</sup>

The incorporation of the pigment into the paint or ink vehicle to yield a fine particle dispersion is referred to as pigment grinding or milling. The goal of pigment grinding is to achieve fine, uniformly-ground, smooth, round pigment particles which are permanently separated from other pigment particles. The degree to which this is realized determines the coating effectiveness and permanency of the paint or ink. Some of the more commonly used types of dispersion (milling) equipment are roller mills, ball and pebble mills, attritors, sand mills, bead and shot mills, high-speed stone and colloid mills, high-speed disk dispersers, impingement mills, and horizontal media mills.<sup>10</sup>

Final product specifications are achieved in the product finishing step, which consists of three intermediate stages: thinning, tinting and blending. Material letdown, or thinning, is the process by which a completed mill base dispersion is let down or reduced with solvent and/or binder to give a coating which is designed to provide a durable, serviceable film that is easily

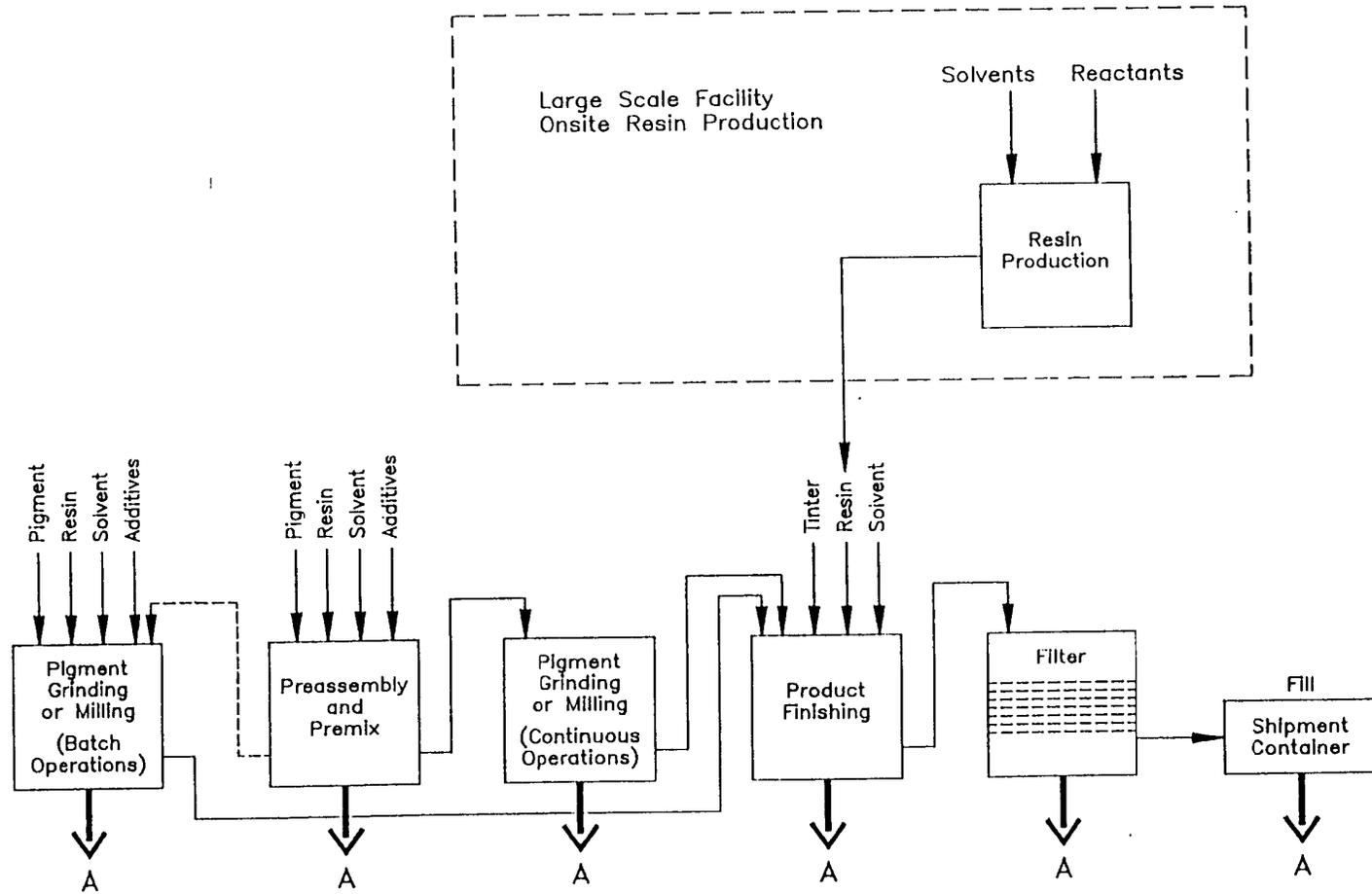


Figure 5-6. Paint manufacturing process.<sup>10</sup>

applied to the substrate. Tinting is the process of adjusting the color of completed mill base dispersions. Various combinations of pigments, solvents, resins, and pastes are added to the material to meet the color requirements. Blending is the process of incorporating the additions into the material in order to meet the desired product specifications.<sup>10</sup>

#### 5.4.2 Emissions

The primary factors affecting the emission of xylene during paint manufacture are the types of solvents and resins used in the manufacturing process, the temperature at which these compounds are mixed, the degree of coverage (if any) on the manufacturing equipment, and the methods and materials used during cleanup operations.<sup>10</sup>

Xylene is released from several types of equipment and handling operations throughout the paint and ink manufacturing processes and during cleanup operations. During the preassembly and premix stage, emissions may come from equipment such as mix tanks or drums while resins are being thinned and materials are being added. Xylene emissions also occur during the pigment grinding step when materials are added to the dispersion equipment. The emissions that occur during the product finishing step are mainly a result of material additions during the thinning and tinting stages. Xylene emissions from product filling operations occur during material transfer and free-fall into the receiving container. Another emission source is product filtering. As product flows through a filtering device, it is often exposed to the air, resulting in releases of the incorporated xylene. Fugitive emissions also result from flanges, valves, and pumps used to transfer material from equipment for one manufacturing stage to equipment for the next stage.<sup>10</sup>

Emissions occurring during the manufacturing stages may be reduced by using equipment and process modifications such as tank lids or closed-system milling equipment. In addition to emissions from process operations, xylene is also released from a variety of cleaning operations following the manufacture of solvent based products. In many facilities, manufacturing equipment is cleaned manually (with solvents, brushes, and /or rags) on the production floor on

an as-needed basis. The standard method of cleaning grinding equipment involves emptying the mill of product and then adding solvent to the vessel to capture remaining product residue. Emissions occur during cleaning solvent addition and removal as well as during the cleaning process. Emissions from cleaning equipment may be reduced by using rubber wipers, high-pressure spray heads, or automatic tub washers.<sup>10</sup>

There is little emission factor information available for the manufacture of paints. Figures range from process solvent losses of one to two percent under well controlled conditions to much higher percentages. The process solvent losses vary significantly from facility to facility and therefore those emissions should be evaluated on a case-by-case basis. Many paint manufacturing facilities calculate total plant VOC emissions based on raw material consumption and final products produced rather than calculating emissions from processes or equipment by an alternative method. Total emissions, therefore, reflect solvent losses during manufacturing, cleaning operations, storage and packaging.<sup>10</sup>

## 5.5 REFERENCES FOR SECTION 5.0

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## SECTION 6.0

### EMISSIONS FROM THE USE OF XYLENE-CONTAINING MATERIALS

As discussed in Section 3.0, xylene is present in many materials, including paints and coatings, inks, adhesives, resins, pharmaceuticals, gasoline and other formulated products. This section examines residual emissions from the use of xylene-containing materials. Xylene may be emitted when xylene-containing products such as paint, ink and gasoline release small amounts over time. Such releases are described in this section as residual emissions.

The production descriptions and emissions data presented in this section represent the most common and relevant processes and products. Because of xylene's widespread use, all processes cannot be included in this document.

#### 6.1 SURFACE COATING OPERATIONS

Surface coating operations involve the application of paint, varnish, lacquer or primer for decorative, functional, or protective purposes. In 1989, 318 million kilograms (700 million pounds) of xylene were consumed in paints and coatings.<sup>1</sup> Appendix C contains a listing of some of the surface coating source categories in which xylene is used. Appendix C also indicates associated SICs, potential xylene emission points, and emissions reduction opportunities. References are provided for additional information.

The general application methods for surface coating operations are discussed in this section. Because surface coating is a very broad category, detailed process descriptions and process flow diagrams for each category are not included in this document; however, the reader is encouraged to review the references mentioned at the end of this section and in Appendix C.

### 6.1.1 Process Description

Industrial surface coating operations use several different methods to apply coatings to substrates. Some of the more commonly used techniques include spraying, dipping, rolling, flow coating, knife coating, and brushing. In addition to the application of coatings to substrates, many surface coating operations also include surface preparation steps (*e.g.*, cleaning and degreasing), and drying and curing stages. Spraying operations are normally performed in a spray booth using one of the following spray application methods: air atomization; airless atomization; air-assisted airless; high-volume, low-pressure (HVLP); and electrostatic methods. Dip coating involves briefly immersing the substrate in a tank containing a bath of paint. The object is slowly removed from the tank allowing excess paint to drain back into the tank. Roller coating is used to apply coatings and inks to flat surfaces. A typical roller coating machine contains three or more power driven rollers, one of which is partially immersed in the coating material. The paint is transferred to a second, parallel roller by direct contact. The sheet to be coated is run between the second and third rollers, and is coated by transfer of paint from the second roller. Flow coating is used on articles which cannot be dipped due to their buoyancy, such as fuel oil tanks, gas cylinders, or pressure bottles. In this operation, the coating material is fed through overhead nozzles, distributing the paint in a steady stream over the article to be coated. Excess paint is allowed to drain from the coated object and is then recycled. Knife coating is used primarily to coat paper or fabric webs. The adjustable blade or "knife" distributes a liquid coating evenly over a moving surface.

### 6.1.2 Emissions

Figure 6-1 is a generic schematic flow diagram of a surface coating operation. Process operations, auxiliary facilities, and emission points are illustrated. Note that this is a generic figure and may differ significantly from any specific surface coating operation. The operations shown include degreasing, surface coating, and drying and curing.<sup>2,3</sup> Auxiliary facilities include degreasing solvent storage, and surface coating storage and blending. Industrial categories, specific operations and emission points resulting in expected xylene emissions from surface coating operations are presented in Appendices A and C.

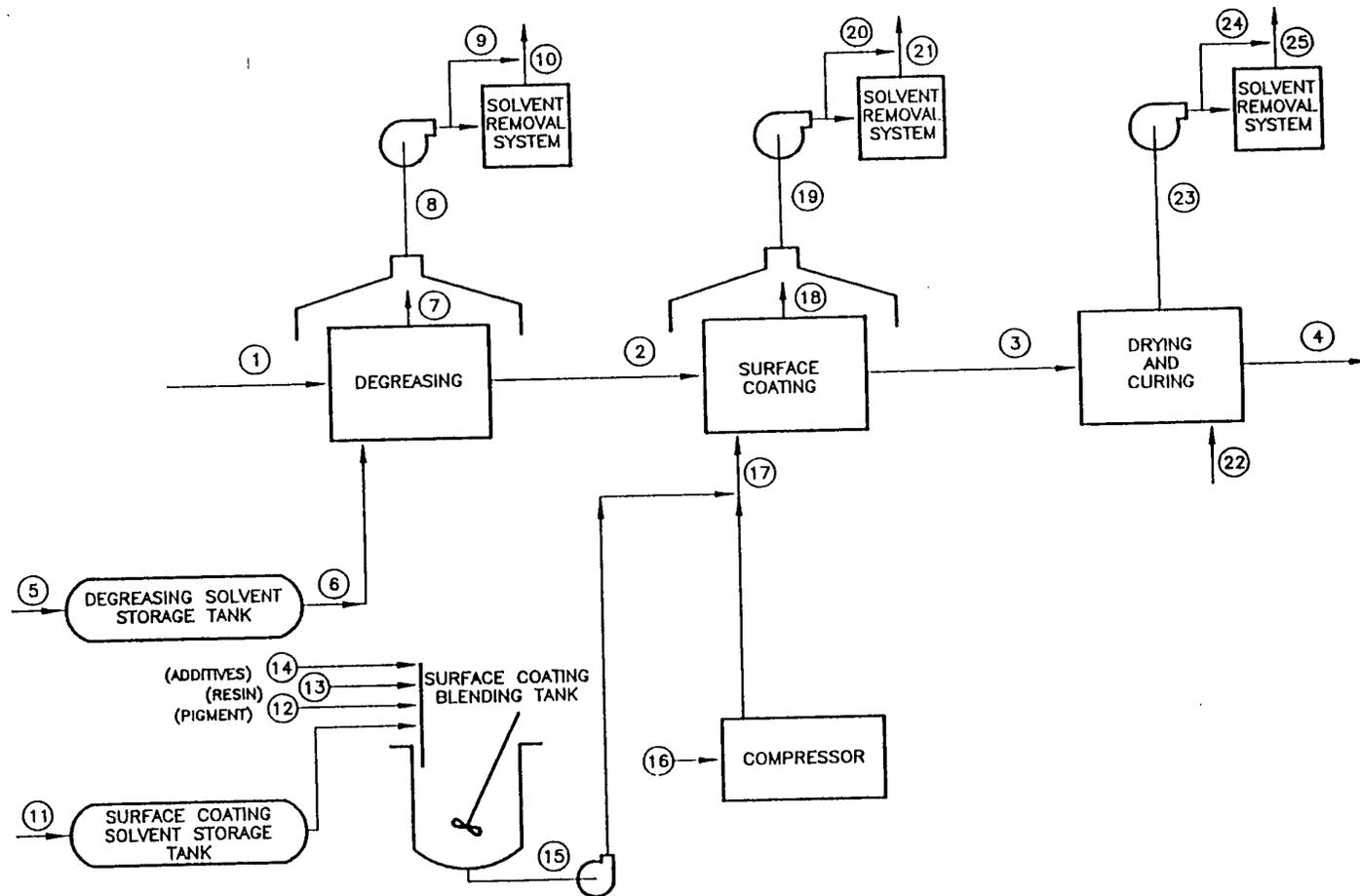


Figure 6-1. Flow diagram of a surface coating operation?

Streams 1, 2, 3, and 4 depict the flow of products through the plant. Stream 1 represents the input of uncoated products to the surface coating system. Stream 2 represents the flow of degreased or scoured products to the surface coating operation. The type of surface coating operation used will depend upon the product-type coated, coating requirements, and the method of application. Stream 3 represents the product flow to the drying and curing operation. Stream 4 represents the flow of coated finished products from the surface coating section of a manufacturing plant.

Streams 5 through 10 represent the flow of degreasing solvent through the surface coating section of a manufacturing plant. Streams 5 and 6 depict the flow of solvent into the plant and to the degreasing unit. Streams 7 and 8 represent the flow of solvent vapors from the degreasing unit through the fume handling system. Uncontrolled and controlled emissions are represented by streams 9 and 10, respectively.

Streams 11 through 21 represent the flow of surface coating raw materials through the plant. Streams 11, 12, 13, and 14 represent the flow of solvent, pigment, resin, and additives to the surface coating blending tank. Stream 15 is the flow of coating to the surface coating unit. For those operations that use spray painting, stream 16 is the flow of compressed air. Streams 18 and 19 represent the flow of solvent and resin from the surface coating unit through the fume handling equipment. Uncontrolled and controlled emissions are depicted by streams 20 and 21. Potential release sources are identified in Appendix C.

In Figure 6-1, streams 22 through 25 represent the flow of gases (*e.g.*, fuel, steam or electrically heated air) to the drying and curing operation. Drying and curing operations occur in flash-off areas and curing ovens. Flash-off areas are the places between application areas, or between an application area and an oven, in which solvent is allowed to volatilize from the coated piece. Ovens are used between some coating steps to cure the coating prior to the next step in the finishing sequence. Streams 24 and 25 represent uncontrolled and controlled emissions. No emission factor data were found in the literature.

Facilities with surface coating operations may purchase and apply ready-to-use coatings, or they may dilute their purchased coatings to decrease the coating viscosity and improve performance and ease of application. Xylene is used in solvent-based coating formulations either as part of the coating vehicle or as a thinner. If a coating formulation is to be diluted in-house, several factors (*e.g.*, temperature, humidity, and type of coating) can determine the required dilution ratio. Consequently, the amount of xylene used may vary.<sup>2,4-6</sup> Emissions from the mixing and blending of surface coatings are discussed in Section 5.4.2.

Xylene may also be used in clean-up operations. Clean-up solvent is used to clean application equipment, piping, spray booths, coating storage and distribution equipment, and to strip cured coatings from wood parts or machinery.<sup>1</sup>

One method of reducing xylene emissions from surface coating operations is to modify the surface coating formulation. Conventional coatings normally contain at least 70 percent by volume solvent (either one solvent or a mixture of solvents) to permit easy handling and application. Minimizing or eliminating the use of these solvents in surface coating formulations is the most effective way to reduce VOC emissions. Alternatives to these conventional coatings include water-based coatings, high-solids coatings, powder coatings, and radiation curable coatings.<sup>2</sup>

Large surface coating facilities may use add-on control devices to capture and control solvent emissions. Some commonly used capture devices include covers, vents, hoods, and partial or total enclosures. Adsorbers, condensers and incinerators, which can achieve control efficiencies of 95 to 98 percent, are the most common control devices used in surface coating operations.<sup>2,4,5</sup>

## 6.2 PRINTING AND PUBLISHING

The printing and publishing industry encompasses publishing, commercial printing, and trade services.<sup>7</sup> The trade services group includes typesetting, photoengraving, electrotyping and stereotyping, and platemaking services. The trade services group is not examined in this

document because data on solvent use and emissions from these services are not available. Ink consumption in these groups has been apportioned to the four printing processes according to the type of ink consumed (*e.g.*, gravure ink consumption assigned to gravure printing). Process descriptions, however, will only be provided for the commercial printing processes. Attention is given to the gravure and flexographic processes as end uses of xylene. Xylene emissions from off-set lithography processes have not been measured and are thought to be minimal. The reader is encouraged to explore xylene consumption and emissions in all facilities reporting under the SIC code 27 as solvent use is an inherent aspect of the operations in printing and publishing facilities.

The publishing and printing groups are concentrated in four states: California, New York, Pennsylvania, and Illinois. The majority of establishments are small facilities that employ between 1 and 20 people.<sup>7,8</sup> Appendix B, Table B-3 lists the companies in the printing and publishing SIC codes grossing \$1,000,000 or greater in annual sales.<sup>9</sup>

### 6.2.1 Process Description

The production of a printed product consists of five steps. First, the artwork and/or copy (text) is developed. Next, a printing plate is made. The plate is then tested in the press adjustment step. The actual printing of the product is the fourth step in the printing process, and the main source of xylene emissions. The final step is cutting and finishing<sup>10</sup>

Printing ink composition will vary among printing methods and among jobs using the same printing press and method. Printing inks can generally be described as heat-set or non-heatset. Heatset inks require the application of heat to drive off the ink solvent and set the ink to the substrate. Non-heatset inks dry by oxidation or adsorption to the substrate and do not require heat. Other, less common, ink types include radiation and thermally cured inks. All evaporative inks consist of three basic components: pigments, binders, and solvents.<sup>2</sup> Printing processes using heatset inks that dry through evaporation of the solvent are the major concern for VOC (including xylene) emissions. Only the gravure and flexography printing processes are

described here due to the fact that specific emissions of xylene were not identified from the other printing methods.

#### Gravure Printing Process Description--

The configuration of the image surface makes the gravure process unique. The printing cylinder is etched or engraved, creating tiny cells which comprise the image surface. The depth of each cell may vary and regulates the quantity of ink received by the substrate. The average rotogravure press has eight printing units, each printing one color. The paper position, speed, and tension through the printing unit is regulated by a series of rollers. A substrate dryer, equipped with heated air jets to evaporate the solvent from the substrate and set the ink, is located at the top of each printing unit. The dryer air is exhausted from the unit by a recirculation fan. The fan directs a portion of the solvent laden air to a control device, such as a carbon adsorption system. The remaining portion of the air flow is recirculated over a steam heating coil and back through the dryer.<sup>11</sup>

Each printing unit has a self-contained inking system. The ink system consists of an ink fountain, a circulation pump, and a mix tank. Solvent, and occasionally extenders or varnishes, are added to the ink concentrate in the mix tank. Additional ink, solvent, varnishes, and extenders are automatically added to the mix tank. The additions are monitored by level and viscosity control devices.<sup>11</sup>

A low viscosity ink is required for the gravure printing process. Raw ink concentrate generally contains 50 percent solvent by volume. A xylene-toluene-lactol spirit mixture (naphtha) is commonly used as a solvent in printing inks. Lactol Spirit is a petroleum solvent component of naphtha used in the mixture to hasten evaporation. Xylene is known to produce a higher quality product than naphtha and dissolves the ink resins well, however, xylene is more expensive than naphtha. The ink concentrate is diluted at press side with additional solvent at a volume ratio of approximately 1:1. Since solvent is also added automatically to the inking system to replace evaporative losses, the resultant ink mixture may contain as much as 80 percent solvent by volume and 20 percent by volume ink and varnish solids.<sup>11</sup>

## Flexographic Printing Process Description--

Flexographic printing is used to print flexible packaging, milk cartons, gift wraps, folding cartons, paperboard, paper cups and plates, labels, tapes, and envelopes. The majority of flexographic printing is done with a web-fed substrate.<sup>2</sup>

Solvent-based flexographic inks typically consist of alcohols, glycols, esters, hydrocarbons, and ethers. These inks may contain as much as 75 percent solvent by volume. Water-based and steam-set inks are also used in flexographic printing. Water-based inks contain approximately 25 percent by volume solvents.<sup>12</sup> About 15 percent of all flexographic inks used are water-based.<sup>13</sup> Steam-set inks use glycol solvents but do not contribute significantly to air emissions because the glycols are essentially water-soluble, have low volatilities, and are stable on the presses.<sup>14,15</sup>

### 6.2.2 Emissions

#### Gravure Printing Emission Points--

Emissions from the rotogravure press occur from the ink fountain, the press, the dryer, and the chill rolls.<sup>2</sup> The dryer vent is the most typical point of control. The other emission sources are considered fugitive. Emissions are influenced by press and job variables, solvent concentration in the ink, and solvent added as make-up during printing. Approximately 2.5 to 7 percent of the solvents used are retained in the printed product. The remaining solvents are reclaimed for reuse, recycled, and sold back to suppliers, or lost as fugitive emissions.<sup>11,16,17</sup> Typical ink formulations contain approximately 50 to 85 percent solvents by volume. Water based inks, used in packaging and product printing, contain approximately 5 to 30 percent solvents by volume and account for 30 to 40 percent of all inks used. Water-based inks account for approximately 15 percent of all inks used in all gravure printing processes.<sup>13,18</sup>

Although specific emission estimates of xylene are not available, ink and solvent consumption numbers have been published and are reported below. Additionally, VOC emission factors and rates are available. A local survey may provide the needed information on the percentage of xylene used relative to total solvent consumption. Xylene emissions may then be

estimated by multiplying the percentage of xylene by the ink consumption rate and solvent content of the ink.

The Gravure Association of America (GAA) conducted a survey of their membership which reported solvent purchased, reused, and recovered in the various segments of the industry during 1987.<sup>19</sup> Table 6-1 presents a summary of these statistics for publication, folding cartons, flexible packaging, and product gravure printing. The GAA membership reported a total of 18,630 thousand metric tons (41.4 million pounds) of virgin solvent purchased; 110,800 thousand metric tons (246.2 million pounds) of solvent recovered; and 80,685 thousand metric tons (179.3 million pounds) of solvent reused. More solvent is recovered than bought due to solvent recovery from ink formulations. The portion of solvent that is recovered but not reused is sold back to the manufacturers, lost as fugitive emissions, or destroyed by incineration.<sup>19</sup>

**TABLE 6-1.**  
**GRAVURE ASSOCIATION OF AMERICA INDUSTRY**  
**SURVEY RESULTS**

Millions of Kilograms (Millions of Pounds)										
Reported Results				Projected Gravure Industry Estimates						
Printing Process	Solvents Purchased		Solvents Recovered		Solvents Reused		Solvents Purchased or Reused		Solvents Recovered	
Publication Plants	1	(2.2)	101.3	(222.9)	73.8	(162.3)	182.3	(401)	247.1	(543.6)
Folding Cartons	2.9	(6.4)	0.7	(1.6)	0.7	(1.6)	22.2	(48.8)	4.4	(9.7)
Flexible Packaging	7.2	(15.9)	2.8	(6.2)	1.9	(4.1)	78.4	(172.5)	24.3	(53.4)
Product Gravure	7.7	(16.9)	7.0	(15.5)	5.1	(11.3)	--	--	--	--

Source: Reference 19.

Carbon adsorption and incineration systems have traditionally been employed to control VOC emissions from the gravure printing process. The package printing sector has also achieved significant VOC reduction through the use of water-based printing inks.

Rotogravure package printing plants may use water-based inks. The use of water-based inks may contribute to an overall VOC reduction of 65 to 75 percent, if the solvent content of the inks is maintained below 25 percent by volume.<sup>12</sup>

One recent study has demonstrated that capture and control systems have been successfully applied to gravure printing presses that achieve greater than 90 percent overall VOC control.<sup>20</sup> The average VOC control efficiency at these facilities ranged from 94 to 99.5 percent. The facilities included in the study used total enclosure capture systems and one of the following add-on destruction devices:

- Catalytic Incineration
- Regenerative Incineration
- Thermal Incineration
- Carbon Adsorption

The EPA has developed and published standard criteria for the design and operation of permanent total enclosure (PTE) systems. The PTE criteria have been published in the following sources:

- *Guidelines for Developing a State Protocol for the Measurement of Capture Efficiency.* Environmental Protection Agency. Policy Statement. April 16, 1990.
- *Polymeric Coating of Supporting Substrates - Background Information for Promulgated Standards* (EPA-450/3-85-022b)<sup>21</sup>
- *Magnetic Tape Manufacturing Industry - Background Information for Promulgated Standards* (EPA-450/3-85-029b)<sup>22</sup>

Capture efficiency may be estimated at 100 percent if all the EPA PTE criteria are met.<sup>20</sup>

#### Flexographic Printing Emission Points--

Sources of emissions from flexographic printing operations are similar to the sources encountered from gravure operations. Emission control strategies are also similar. Incineration and carbon adsorption emission control techniques are available for use in the flexographic printing process. However, it is often difficult to install effective hooding and ducting devices on the presses. Therefore, overall control efficiencies are approximately only 60 percent.<sup>12</sup> Alternative emission control techniques include the use of water-based inks and microwave driers.<sup>14</sup>

Recent studies have indicated that flexographic printing presses controlled by catalytic and regenerative incineration may achieve a 95 percent overall VOC reduction efficiency.<sup>13,23</sup> A metal oxide catalyst is used in catalytic incinerators used on flexographic printing presses to avoid poisoning by chlorinated solvents.<sup>23</sup>

### 6.3 GASOLINE AND AUTOMOTIVE EMISSIONS

Aromatic hydrocarbons including xylene are added to gasoline to raise the octane rating, thereby suppressing engine knock, increasing power, and providing smoother running engines. Xylene and other hazardous components may then be emitted in automotive exhaust. One study estimates the global release rate of xylene from automobile exhaust to be in the range of 3 to 8 metric tons (6,600 to 17,600 pounds) per year.<sup>24</sup> Automotive emissions have been related to photochemical smog and ozone formation for many years. Atmospheric models recently became sophisticated enough to accommodate compositional variations.<sup>25</sup>

Two studies involving automotive emissions are briefly described below. One study used 46 vehicles to provide detailed composition of organic emissions under various driving conditions.<sup>25</sup> The other study used a mobile TAGA 6000 EM tandem mass spectrometer system to obtain time resolved data for selected aromatic compounds.<sup>26</sup> Both of these studies present possible protocols to perform tests that would better characterize emissions and eventually estimate emissions of various VOC species, including xylene. However, the information presented in these studies was not sufficiently comprehensive for emission factor development.

Table 6-2 lists the existing factors for xylene as a result of gasoline use, both from evaporative and tailpipe emissions. These emission factors were taken from a previously published EPA document.<sup>27</sup> These factors are based on an activity measure of vehicle miles traveled, which were derived based on engineering estimates and are therefore given a quality rating of "U."

**TABLE 6-2.  
EMISSION FACTORS FROM GASOLINE USE**

Emission Source	Emission Factor Grams/VMT <sup>a</sup> (pounds/VMT)	Quality Rating
Evaporation from automobile fuel tank	$2.57 \times 10^{-3}$ ( $5.66 \times 10^{-6}$ )	U <sup>b</sup>
Automobile exhaust	$1.1 \times 10^{-6}$ ( $2.39 \times 10^{-9}$ )	U <sup>b</sup>

<sup>a</sup>VMT = Vehicle Mile Traveled

<sup>b</sup>Based on engineering judgement.

Source: Reference 27.

#### 6.4 GASOLINE MARKETING

Gasoline storage and distribution activities represent potential sources of xylene emissions. The xylene content of gasoline ranges from less than 1 to almost 10 percent by weight, but typical concentrations are around 5.6 percent by weight. Therefore, total hydrocarbon emissions resulting from storage tanks, material transfer, and vehicle fueling include emissions of xylene. This section describes sources of xylene emissions from gasoline marketing operations. Because the sources of these emissions are so widespread, individual locations are not identified in this section. Instead, emission factors are presented, along with a general discussion of the sources of these emissions.<sup>28</sup>

The transportation and marketing of petroleum liquids involve many distinct operations, each of which represents a potential source of xylene evaporative losses. Crude petroleum products are transported from production operations to a refinery by pipelines, water carriers (e.g., barges and tankers), tank trucks, and rail tank cars. The refined products are conveyed to fuel marketing terminals and petrochemical industries by these same modes. From fuel marketing terminals, the fuels are delivered by tank trucks to service stations, commercial accounts and local bulk storage plants.<sup>29,30</sup>

As shown in Figure 6-2, typical components of gasoline marketing include refinery storage, gasoline terminals, gasoline bulk plants, service stations, and ground transportation. The gasoline terminals and gasoline bulk plants are large facilities for the wholesale marketing of gasoline, kerosene, and fuel oil. They receive these petroleum products from refineries or other terminals, mostly by pipeline, tanker, or barge, and store the products in large tanks. The primary function of marine and pipeline terminals is to distribute products to other terminals. Tank truck loading terminals distribute products by tank trucks to bulk plants, retail outlets or final consumers. Most of these petroleum terminals have daily throughputs of more than 76,000 liters (20,000 gallons) of gasoline.

Service stations receive gasoline by tank truck from terminals or bulk plants or directly from refineries, and usually store the gasoline in underground tanks. Gasoline service stations are establishments primarily selling gasoline and automotive lubricants.

Gasoline is by far the largest volume petroleum product marketed in the United States, with a nationwide consumption of 419 billion liters (111 billion gallons) in 1991.<sup>31</sup> There are presently an estimated 1,700 bulk terminals storing gasoline in the United States.<sup>32</sup> About half of these terminals receive products from refineries by pipeline, and half receive products by ship or barge delivery. Most of the terminals (66 percent) are located along the east coast and in the Midwest. The remainder are dispersed throughout the country, with locations largely determined by population patterns.

The emission factors presented in the following discussions were derived using the following method. Standard published emission factors for transportation and marketing for total VOC emissions were modified to account for the fraction of xylene in the vapors emitted. The fraction of xylene in the vapors was taken from the *Air Emissions Species Manual Volume I: Volatile Organic Compound (VOC) Species Profiles*.<sup>33</sup> A distinction was made between winter and summer blends of gasoline because the xylene fraction varies significantly with the different blends. The winter blend gasoline vapors were reported to be 1.07 percent xylene; summer blend gasoline vapors were reported to be 0.2 percent xylene.

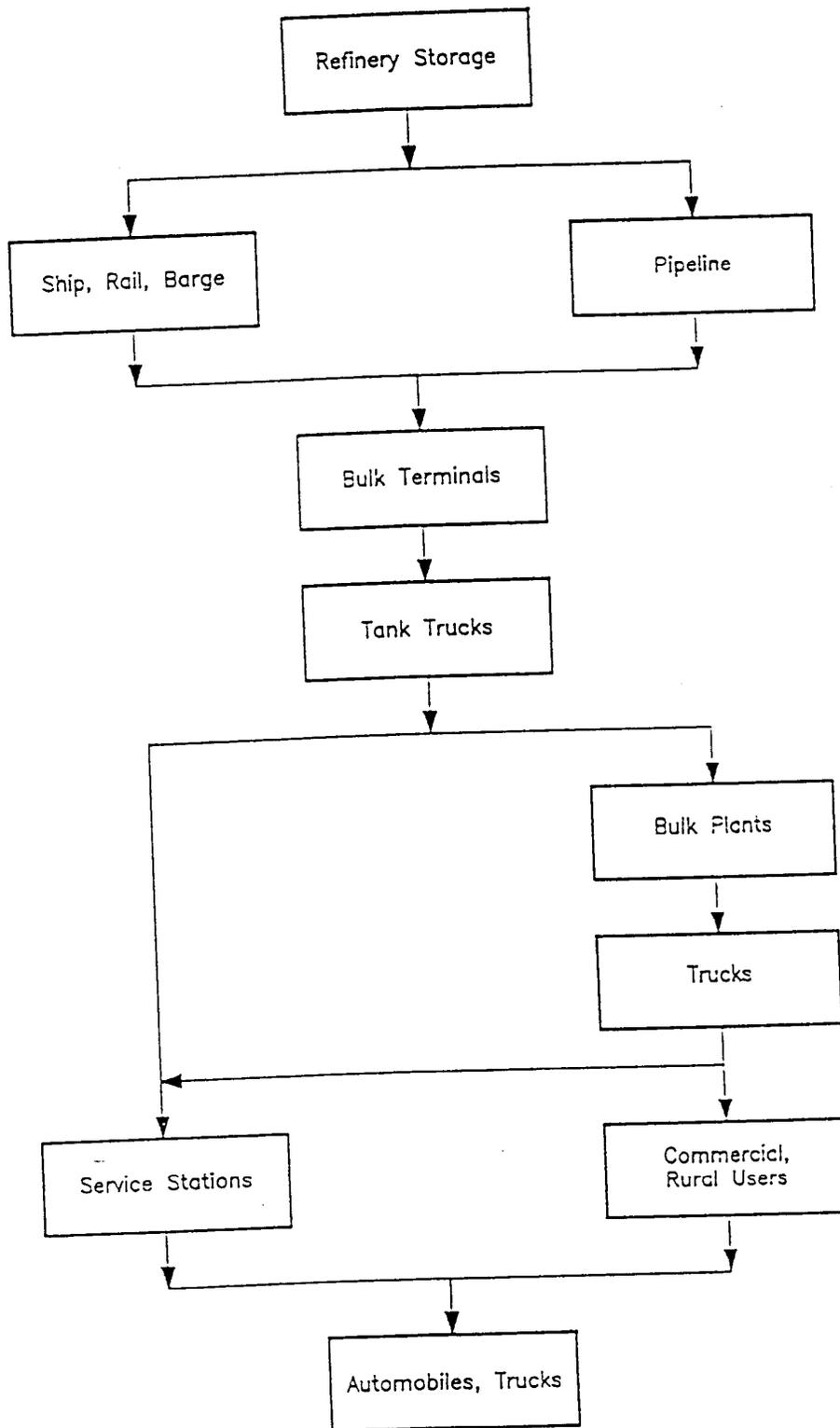


Figure 6-2. The gasoline marketing distribution system in the United States.<sup>28</sup>

#### 6.4.1 Xylene Emissions From Loading Marine Vessels

Volatile organic compounds (VOC) can be emitted from crude oil and refinery products (gasoline, distillate oil, etc.) when loaded and transported by marine tankers and barges. Loading losses are the primary source of evaporative emissions from marine vessel operations.<sup>32</sup> These emissions occur as vapors in "empty" cargo tanks are expelled into the atmosphere as liquid is added to the cargo tank. The vapors may be composed of residual material left in the "empty" cargo tank and/or the material being added to the tank. Therefore, the exact composition of the vapors emitted during the loading process may be difficult to determine if the residual material and the material being loaded are not of similar composition.

Emission factors for volatile organic compounds from marine vessel loading were found in EPA documents.<sup>28</sup> Average xylene/VOC ratios of 0.0107 for winter blend gasolines and 0.002 for summer blend gasolines were also identified in the *Air Emissions Species Manual*. Emission factors for xylene from marine vessel loading were derived from these sources and are given in Table 6-3. Factors are available for crude oil, distillate oil, and other fuels.<sup>32</sup> However, reliable estimates of the xylene content of these fuels were not found. Therefore, it was not possible to provide xylene emission factors for marine vessel loading of fuels other than gasoline. However, based on field experience it was assumed that xylene content of distillate oil and other fuels is very small (<0.1 percent).

#### 6.4.2 Xylene Emissions from Bulk Gasoline Plants, Bulk Gasoline Terminals

Each operation in which gasoline is transferred or stored is a potential source of xylene emissions. At bulk terminals and bulk plants, loading, unloading, and storing gasoline are sources of xylene emissions. The gasoline that is stored in above ground tanks is pumped through loading racks that measure the amount of product. The loading racks consist of pumps, meters, and piping to transfer the gasoline or other liquid petroleum products. Loading of gasoline into tank trucks can be accomplished by one of three methods: splash, top submerged, or bottom loading. In splash loading, gasoline is introduced into the tank truck directly through a compartment located on the top of the truck.<sup>28</sup> Top submerged loading involves inserting a

**TABLE 6-3.  
UNCONTROLLED VOLATILE ORGANIC COMPOUND AND XYLENE EMISSIONS FROM  
LOADING GASOLINE IN MARINE VESSELS**

<b>Emission Source</b>	<b>Volatile Organic Compound Emission Factor (mg/liter Transferred)<sup>a</sup></b>	<b>Winter Blend Mixed Xylenes Emission Factor (mg/liter Transferred)<sup>b</sup></b>	<b>Summer Blend Mixed Xylenes Emission Factor (mg/liter Transferred)<sup>b</sup></b>	<b>Emission Factor Grade</b>
Tanker Ballasting	100	1.07	0.2	E
Transit	320 <sup>c</sup>	3.42	0.64	E
Ship/Ocean Barge: <sup>d</sup>				
Uncleaned; volatile previous cargo	315	3.37	0.63	E
Ballasted; volatile previous cargo	205	2.19	0.41	E
Cleaned; volatile previous cargo	180	1.93	0.36	E
Gas-freed; volatile previous cargo	85	0.91	0.17	E
Any condition; nonvolatile previous cargo	85	0.91	0.17	E
Typical situation; any cargo	215	2.30	0.43	E
Barge:				
Uncleaned; volatile previous cargo	465	4.98	0.93	E
Gas-freed; any cargo	245	2.62	0.49	E
Typical situation; any cargo	410	4.39	0.82	E

<sup>a</sup>Factors are for nonmethane-nonethane VOC emissions.

<sup>b</sup>Based on an average xylene/VOC ratio of 0.0107 and 0.002 for winter and summer blends of gasoline.<sup>33</sup>

<sup>c</sup>Units for this factor are mg/week-liter transported.

<sup>d</sup>Ocean barge is a vessel with compartment depth of 40 feet; barge is a vessel with compartment depth of 10-12 feet.

Source: References 28 and 33.

downspout into the fill pipe so that gasoline is added to the tank truck near the bottom of the tank. Bottom loading is the loading of product into the truck tank from the bottom. Because emissions occur when the product being loaded displaces vapors in the tank being filled, the reduced turbulence of top submerged loading and bottom loading reduce the amount of material (including xylene) that is emitted.<sup>28</sup> A majority of facilities which load gasoline use bottom loading.

#### Emissions from Gasoline Loading and Unloading --

Bulk plants receiving gasoline from transfer trucks use vapor balancing systems, consisting of a pipeline between the vapor spaces in the truck tank and the storage tanks. These systems allow vapor displaced by liquid being introduced in the storage tank to transfer into the truck as gasoline fills the storage tank.<sup>28</sup> Table 6-4 lists emission factors for gasoline vapor and xylene from gasoline loading racks at bulk terminals and bulk plants. The gasoline vapor emission factors were taken from Reference 28. The xylene factors were obtained by multiplying the gasoline vapor factor by the mixed xylene content of the vapor (Winter Blend 0.0107; Summer Blend 0.002).<sup>33</sup>

#### Emissions from Gasoline Storage --

Storage emissions of xylene at bulk terminals and bulk plants depend on the type of storage tank used. A typical bulk terminal may have four or five above ground storage tanks with capacities ranging from 1,500 to 15,000 cubic meters (396,258 to 3,962,581 gallons).<sup>28</sup> Most tanks in gasoline service have an external or internal floating roof to prevent the loss of product through evaporation and working losses. Fixed-roof tanks, still used in some areas to store gasoline, use pressure-vacuum vents to control breathing losses. A breather valve (pressure-vacuum valve), which is commonly installed on many fixed-roof tanks, allows the tank to operate at a slight internal pressure or vacuum. Any fixed roof tanks which are used to store gasoline have some type of vapor recovery/control system to control VOC emissions. When the pressure-vacuum valve is opened, (as during tank filling) the vapors exhausted will be sent to the vapor recovery/control system. Commonly, the vapor control device is a condenser or an adsorber through which the collected vapors can be returned to the storage tanks. Some facilities use an incineration device such as a flare to control these VOC emissions from fixed roof tanks.

**TABLE 6-4.  
XYLENE EMISSION FACTORS FOR GASOLINE LOADING AT BULK  
TERMINALS AND BULK PLANTS**

<b>Loading Method</b>	<b>Gasoline Vapor Emission Factor,<sup>a</sup> mg/liter</b>	<b>Winter Blend Xylene Emission Factor,<sup>b</sup> mg/liter</b>	<b>Summer Blend Xylene Emission Factor,<sup>b</sup> mg/liter</b>	<b>Emission Factor Grade</b>
Splash	1430	15.3	2.9	E
Submerged <sup>c</sup>	590	6.3	1.2	E
Balance Service	980	10.5	2.0	E

<sup>a</sup>Gasoline factors represent emissions of nonmethane-nonethane VOC. Factors are expressed as mg gasoline vapor per liter gasoline transferred.<sup>28</sup>

<sup>b</sup>Based on an average xylene/VOC ratio of 0.0107 and 0.002 for winter and summer blends of gasoline, respectively.<sup>33</sup>

<sup>c</sup>Submerged loading is either top or bottom submerged.

Source: References 28 and 33.

Fixed roof tanks consist of a cylindrical steel shell with a permanently affixed conical or dome-shaped roof. Fixed roof tanks emit vapors to the atmosphere through working and breathing losses. Working losses are primarily caused by displacement of vapor laden air during filling. Breathing losses are caused by expansion and contraction of vapors and evaporation caused by atmospheric temperature and pressure changes.

External floating roof tanks, in contrast, consist of a cylindrical steel shell and a roof which floats on the surface of the stored liquid. Internal floating roof tanks have an additional fixed roof over the floating roof of the tank. Floating roof tanks exhibit smaller vapor losses than fixed roof tanks. The four classes of losses that floating roof tanks experience include withdrawal loss, rim seal loss, deck fitting loss, and deck seam loss. Withdrawal losses are caused by the stored liquid clinging to the side of the tank following the lowering of the roof as liquid is withdrawn. Rim seal loss is caused by leaks at the seal between the roof and the sides of the tank. Deck fitting loss is caused by leaks around support columns and deck fittings within internal floating roof tanks. Deck seam loss is caused by leaks at the seams where panels of a bolted internal floating roof are joined.

Table 6-5 shows emission factors for storage tanks at a typical bulk terminal. Table 6-6 shows the uncontrolled emission factors for xylene from a typical bulk plant. The emission factors were based on EPA factors and the weight fraction of mixed xylenes in the vapor of 0.0107 in winter blend gasoline and 0.002 in summer blend gasoline.<sup>28,33</sup> Bulk plants and terminals use the same two basic methods for loading gasoline into tank trucks.

#### Emissions from Gasoline Tank Trucks --

Gasoline tank trucks have been demonstrated to be major sources of vapor leakage. Some vapors may leak uncontrolled to the atmosphere from dome cover assemblies, pressure-vacuum (P-V) vents, and vapor collection piping and vents. Other sources of vapor leakage on tank trucks that occurs less frequently can be caused by tank shell flaws, liquid and vapor transfer hoses, improperly installed or loosened overfill protection sensors, and vapor couplers. This leakage has been estimated to be as high as 100 percent of the vapors which should have been

**TABLE 6-5.  
XYLENE EMISSION FACTORS FOR STORAGE LOSSES AT A TYPICAL  
GASOLINE BULK TERMINAL<sup>a</sup>**

Storage Method	Winter Blend Xylene Emission Factor Mg/yr/Tank <sup>b</sup>	Summer Blend Xylene Emission Factor Mg/yr/Tank <sup>b</sup>	Emission Factor Grade
Fixed Roof <sup>c</sup>			
Working Loss	0.36	0.067	E
Breathing Loss	0.09	0.017	E
External Floating Roof <sup>d</sup>			
Working Loss	e	e	E
Storage Loss			
- Primary Seal	0.09	0.017	E
- Secondary Metallic Shoe Seal	0.04	0.0067	E

<sup>a</sup>Terminal with 950,000 liters/day (250,000 gallons/day) with four storage tanks for gasoline.

<sup>b</sup>Based on an average xylene/VOC ratio of 0.0107 for winter blends and 0.002 for summer blends of gasoline.

<sup>c</sup>Typical fixed-roof tank based upon capacity of 2,680 m<sup>3</sup> (16,750 bbls.).

<sup>d</sup>Typical floating-roof tank based upon capacity of 5,760 m<sup>3</sup> (36,000 bbls.).

<sup>e</sup>Emission factor =  $(1.68 \times 10^{-7} Q)$  Mg/yr winter blend and  $(3.13 \times 10^{-8} Q)$  Mg/yr summer blend, where Q is the throughput through the tanks in barrels.

Source: References 28 and 33.

**TABLE 6-6.  
UNCONTROLLED GASOLINE VAPOR AND XYLENE EMISSIONS FROM  
A TYPICAL BULK PLANT<sup>a</sup>**

<b>Emission Source</b>	<b>Gasoline Vapor Emission Factor, mg/liter</b>	<b>Winter Blend Xylene Emission Factor,<sup>b</sup> mg/liter</b>	<b>Summer Blend Xylene Emission Factor,<sup>b</sup> mg/liter</b>	<b>Emission Factor Grade<sup>c</sup></b>
Storage Tanks - Fixed Roof:				
Breathing Loss	600	6.4	1.2	E
Filling Loss	1150	12.3	2.3	E
Draining Loss	460	4.9	0.9	E
Gasoline Loading Racks:				
Splash Loading	1430	15.3	2.9	E
Submerged Loading	590	6.3	1.2	E
Submerged Loading (Balance Service)	980	10.5	2.0	E

<sup>a</sup>Typical bulk plant with a gasoline throughput of 19,000 liters/day (5,000 gallons/day).

<sup>b</sup>Based on an average xylene/VOC ratio of 0.0107 and 0.002 for winter and summer blends of gasoline respectively.<sup>33</sup>

<sup>c</sup>Based on AP-42 criteria selection discussed in Section 2.0 of this document.

Source: References 28 and 33.

captured and to average 30 percent. Since terminal controls are usually found in areas where trucks are required to collect vapors after delivery of product to bulk plants or service stations (balance service), the gasoline vapor emission factor associated with uncontrolled truck leakage was assumed to be 30 percent of the balance service truck loading factor (980 mg/liter x 0.30 = 294 mg/liter).<sup>28</sup> Thus, the emission factors for xylene emissions from uncontrolled truck leakage are 3.08 mg/liter for winter blend gasoline and 0.06 mg/liter for summer blend gasoline, based on a mixed xylene/vapor ratio of 0.0107 for winter blend gasoline and 0.002 for summer blend gasoline.<sup>33</sup>

#### 6.4.3 Xylene Emissions from Service Stations

The following discussion on service station operations is divided into two areas: the filling of the underground storage tank (Stage I) and automobile refueling (Stage II). Although terminals and bulk plants also have two distinct operations (tank filling and truck loading), the filling of the underground tank at the service station ends the wholesale gasoline marketing chain. The automobile refueling operations interact directly with the public and control of these operations can be performed by putting control equipment on either the service station or the automobile.

##### Stage I Emissions at Service Stations --

Normally, gasoline is delivered to service stations in large tank trucks from bulk terminals or smaller account trucks from bulk plants. Emissions are generated when hydrocarbon vapors in the underground storage tank are displaced to the atmosphere by the gasoline being loaded into the tank. As with other loading losses, the quantity of the service station tank loading loss depends on several variables, including the quantity of liquid transferred, size and length of the fill pipe, the method of filling, the tank configuration and gasoline temperature, vapor pressure, and composition. A second source of emissions from service station tankage is underground tank breathing. Breathing losses occur daily and are attributed to temperature changes, barometric pressure changes, and gasoline evaporation.

## Stage II Emissions at Service Stations --

In addition to service station tank loading losses, vehicle refueling operations are considered to be a major source of emissions. Vehicle refueling emissions are attributable to vapor displaced from the automobile tank by dispensed gasoline and to gasoline spillage. The major factors affecting the quantity of emissions are gasoline temperature, auto tank temperature, gasoline Reid vapor pressure (RVP), dispensing rates, and level of emission controls employed (*e.g.*, Stage II vapor recovery). Table 6-7 lists the uncontrolled emissions from a typical gasoline service station.<sup>28,33</sup>

### 6.4.4 Control Technology for Gasoline Transfer

At bulk terminals and bulk plants, xylene emissions from gasoline transfer may be controlled by a vapor processing system in conjunction with a vapor collection system.<sup>28</sup> Figure 6-3 shows a vapor balance system at a bulk plant. These systems collect and recover gasoline vapors from empty, returning tank trucks as they are filled with gasoline from storage tanks.

At service stations, vapor balance systems contain the gasoline vapors within the station's underground storage tanks for transfer to empty gasoline tank trucks returning to the bulk terminal or bulk plant. Figure 6-4 shows a diagram of a service station vapor balance system.

### 6.4.5 Control Technology For Gasoline Storage

The control technologies for controlling xylene emissions from gasoline storage involve upgrading the type of storage tank used or adding a vapor control system. For fixed-roof tanks, emissions are most readily controlled by installation of internal floating roofs.<sup>32</sup> An internal floating roof reduces the area of exposed liquid surface on the tank and, therefore, decreases evaporative loss. Installing an internal floating roof in a fixed-roof tank can reduce total emissions by 68.5 to 97.8 percent.<sup>28</sup>

**TABLE 6-7.  
UNCONTROLLED GASOLINE VAPOR AND XYLENE EMISSIONS FROM A  
TYPICAL SERVICE STATION<sup>a</sup>**

Emission Source	Gasoline Vapor Emission Factors mg/liter	Winter Blend Xylene Emission Factors <sup>b</sup> mg/liter	Summer Blend Xylene Emission Factors <sup>b</sup> mg/liter	Emission Factor Grade
<b>Underground Storage Tanks</b>				
Tank Filling Losses				
- Submerged Fill	880	9.4	1.8	E
- Splash Fill	1380	14.8	2.8	E
- Balanced Submerged Filling	40	1.3	0.2	E
Breathing Losses	120	7.6		E
<b>Automobile Refueling</b>				
Displacement Losses				
- Uncontrolled	1320	5.5 <sup>c</sup>	2.6	E
- Controlled	132	0.6 <sup>c</sup>	0.3	E
Spillage	84	0.4 <sup>c</sup>	0.2	E

<sup>a</sup>Typical service station has a gasoline throughput of 190,000 liters/month (50,000 gallons/month).

<sup>b</sup>Based on an average xylene VOC ratio of 0.0107 and 0.002 for winter and summer blends of gasoline.<sup>33</sup>

<sup>c</sup>Based on composite profile developed for the refueling of 4 cars with winter blend gasoline. o-Xylene = 0.15 percent, m-xylene = 0 percent, p-xylene = 0.27 percent.

Source: References 28 and 33.

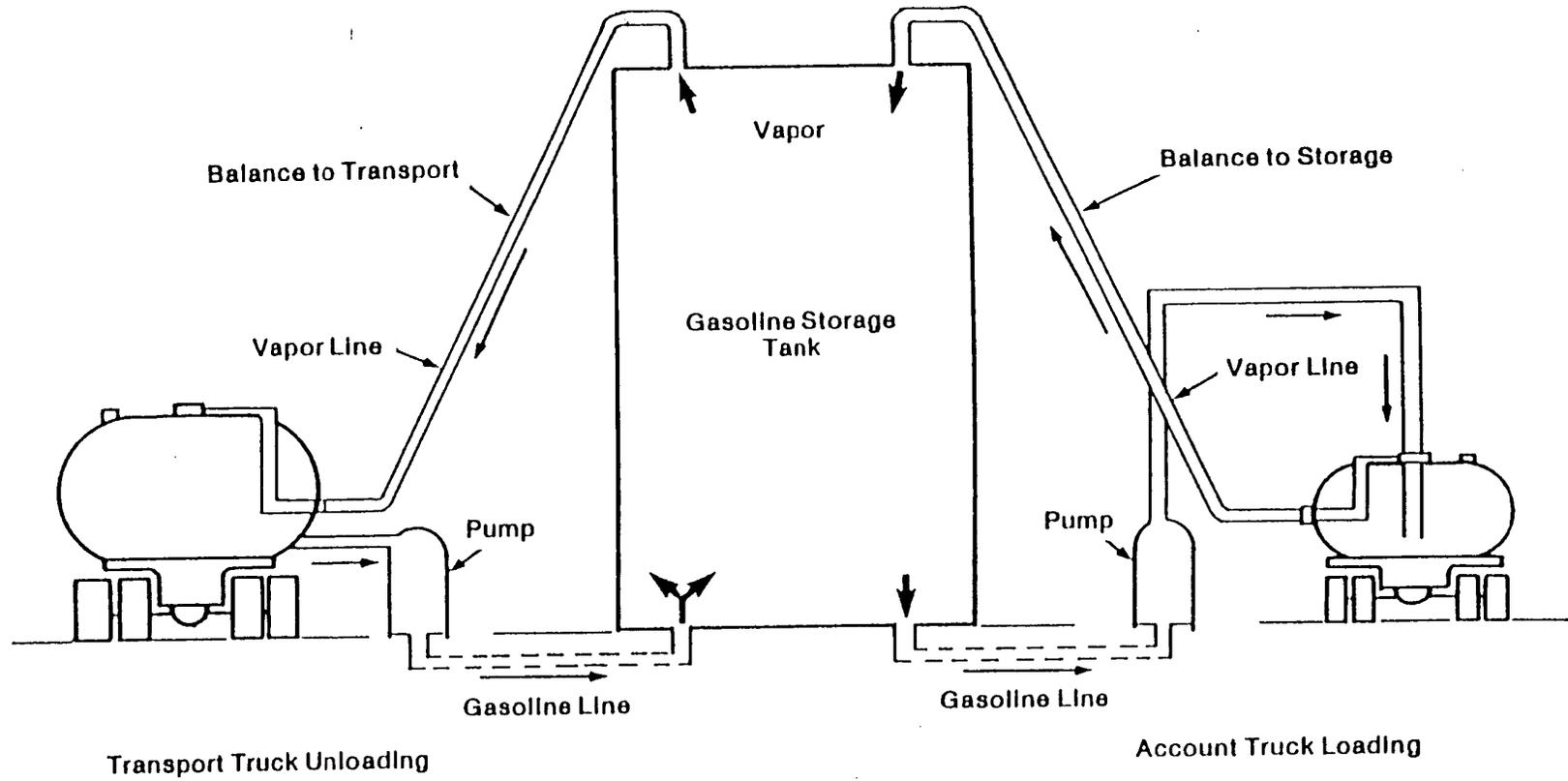


Figure 6-3. Bulk plant vapor balance system.<sup>28</sup>

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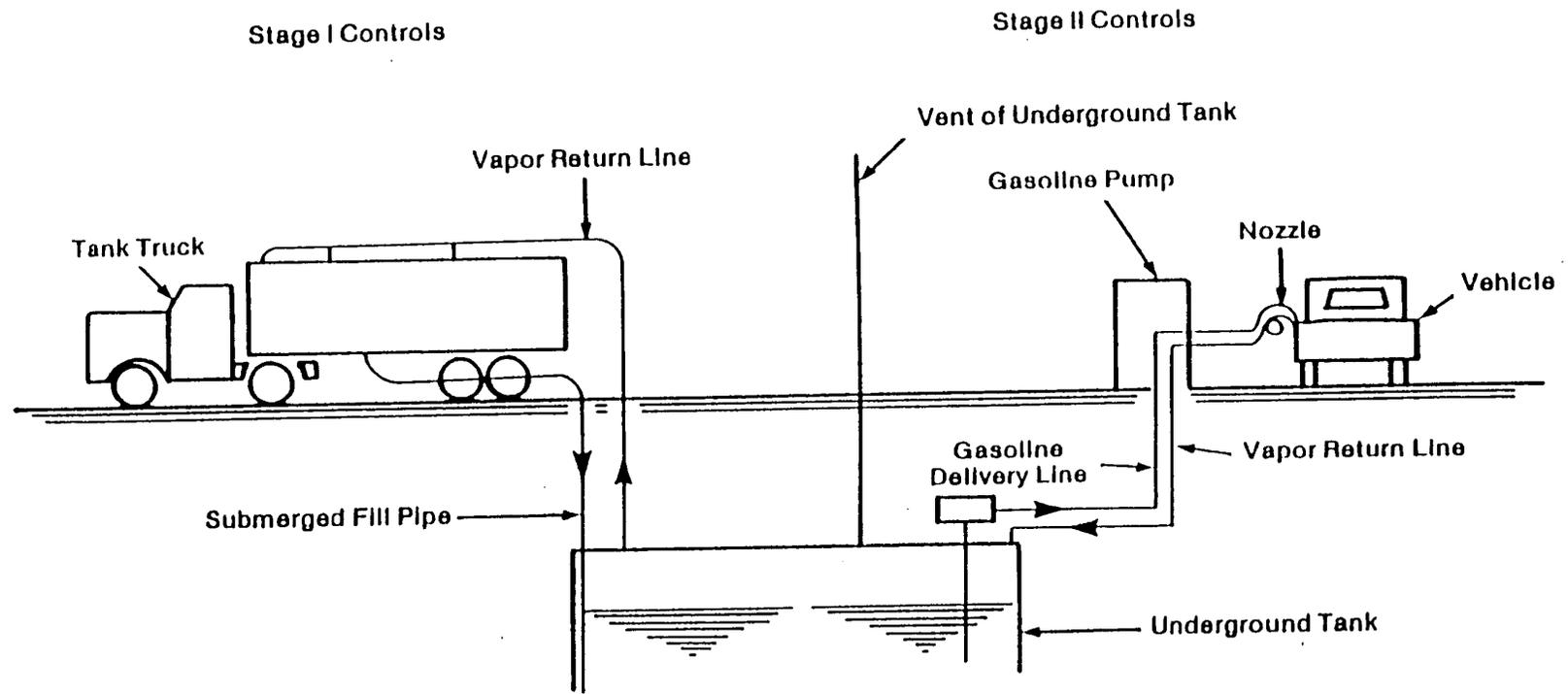


Figure 6-4. Service station vapor balance system.<sup>28</sup>

For external floating-roof tanks, no control measures have been identified for controlling withdrawal losses and emissions.<sup>28</sup> These emissions are functions of the turnover rate of the tank and the characteristics of the tank shell. Rim seal losses in external floating roof tanks depend on the type of seal. Liquid-mounted seals are more effective than vapor-mounted seals in reducing rim seal losses. Metallic shoe seals are more effective than vapor-mounted seals but less effective than liquid mounted seals.<sup>28</sup>

#### 6.4.6 Control Technology For Vehicle Refueling Emissions

Vehicle refueling emissions are attributable to vapor displaced from the automobile tank by dispensed gasoline and to gasoline spillage. The quantity of displaced vapors is dependent on gasoline temperature, vehicle tank size and temperature, fuel level, gasoline RVP, and dispensing rates.<sup>28</sup>

The two basic refueling vapor control alternatives are control systems on service station equipment (Stage II controls), and control systems on vehicles (onboard controls). Onboard controls are basically limited to the carbon canister.

There are currently three types of Stage II systems in limited use in the United States: the vapor balance, the hybrid, and the vacuum assist systems. In the vapor balance system, gasoline vapor in the automobile fuel tank is displaced by the incoming liquid gasoline and is prevented from escaping to the atmosphere at the fillneck/nozzle interface by a flexible rubber "boot." This boot is fitted over the standard nozzle and is attached to a hose similar to the liquid hose. The hose is connected to piping which vents to the underground tank. An exchange is made (vapor for liquid) as the liquid displaces vapor to the underground storage tank. The underground storage tank assists this transaction by drawing in a volume of vapor equal to the volume of liquid removed.<sup>28</sup>

The vacuum assist system differs from the balance system in that a "blower" (a vacuum pump) is used to provide an extra pull at the nozzle/fillneck interface. Assist systems can recover vapors effectively without a tight seal at the nozzle/fillpipe interface because only a close fit is

necessary. A slight vacuum is maintained at the nozzle/fillneck interface allowing air to be drawn into the system and preventing the vapors from escaping. Because of this assist, the interface boot need not be as tight fitting as with balance systems. Further, the vast majority of assist nozzles do not require interlock mechanisms. Assist systems generally have vapor passage valves located in the vapor passage somewhere other than in the nozzles, resulting in a nozzle which is less bulky and cumbersome than nozzles employed by vapor balance systems.<sup>28</sup>

The hybrid system borrows from the concepts of both the balance and vacuum assist systems. It is designed to enhance vapor recovery at the nozzle/fillneck interface by a vacuum, whose low velocity minimizes the level of excess vapor/air returned to the underground storage tank.

With the hybrid system, a small amount of the liquid gasoline (less than 10 percent) pumped from the storage tank is routed (before metering) to a restricting nozzle called an aspirator. As the gasoline passes through this restricting nozzle, a small vacuum is generated. This vacuum is used to draw vapors into the rubber boot at the interface. Because the vacuum is so small, very little excess air, if any, is drawn into the boot, hose and underground storage tank, alleviating the need for a secondary processor, such as an incinerator.<sup>28</sup>

Onboard vapor control systems consist of carbon canisters installed on the vehicle to control refueling emissions. The carbon canister system adsorbs, on activated carbon, the vapors which are displaced from the vehicle fuel tank by the incoming gasoline. Such a system first adsorbs the emissions released during refueling and subsequently purges these vapors from the carbon to the engine carburetor when it is operating. This system is essentially an expansion of the present evaporative emissions control system used in all new cars to minimize breathing losses from the fuel tank and to control carburetor evaporative emissions. However, unlike the present system, a refueling vapor recovery system will require a tight seal at the nozzle/fillneck interface during refueling operations to ensure vapors flow into the carbon canister and are not lost to the atmosphere.<sup>28</sup>

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## SECTION 7.0

### BY-PRODUCT EMISSIONS:

#### PROCESSES UNRELATED TO PRODUCTION OR USE OF XYLENE

Xylene and other pollutants can be emitted to the atmosphere as the result of product manufacturing or from the burning of fossil fuels. Processes that release xylene as by-product emissions are described in this section. These processes include coal combustion, hazardous and solid waste incineration, and wastewater treatment processes.

#### 7.1 COAL COMBUSTION

Two coal combustion studies are briefly described in this section. The first combustion study was performed to collect data on the chemical composition of fugitive aerosol emissions at a pilot-scale gasifier using lignite coal. Sampling was conducted at the Grand Forks Energy Technology Center gasifier, Grand Forks, North Dakota. From the gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS) analyses that were performed, it was determined that xylene was emitted from the gasifier. However, no data were reported and emission factors could not be developed.<sup>1</sup>

Another air monitoring study was performed on a burning coal refuse (gob) pile in Oak Hill, West Virginia. The West Virginia Air Pollution Control Commission requested assistance from EPA to perform a study of the heavy metal and organic chemical emissions from a burning gob pile. Carbon monoxide emissions are expected from these burning gob piles, while emissions of other compounds such as xylene are suspected. Under the direction of EPA, GCA/Technology Division performed a study on the types and quantities of emissions from the gob pile.<sup>2</sup>

The gob pile studied was similar to many of the hundred known to exist in coal mining areas in the country. This coal waste pile was created as the result of a nearby deep mining operation. The emissions have been generated for decades as a result of the spontaneous combustion of low grade, yet combustible coal refuse material.<sup>2</sup>

Red dog, the solid matrix remaining after the combustible fractions are burned out of the coal waste, is a popular fill and highway construction material. The two major results of mining red dog are increased gaseous emissions and an increased fugitive particulate emission rate due to the excavation and loading of the red dog into trucks. The slow natural combustion process presents a difficult situation for effective pollution control. Due to cost and the large amount of material involved, emission control of such a large area source is usually restrictive, although not impossible.<sup>2</sup>

GCA's investigative study was a two-phase approach in order to maximize the quality of results. The first phase was a preliminary assessment, followed by a more comprehensive quantitative emissions program. The preliminary assessment assisted in identifying pollutants present in the gob pile emissions and their approximate concentrations. The second phase of the investigation began with the siting of GCA's Mobile Laboratory and the startup of the analytical instrumentation. In addition, two meteorological monitoring stations were erected and calibrated, one at approximately 10 feet elevation directly at the test area and one slightly downwind at approximately 200 feet elevation above the test area, to measure overall regional wind conditions.<sup>2</sup>

Samples were collected at the centerpoint of each of 24 equal area grids. All samples were collected from within 10-inch diameter ductwork positioned over the sample point to minimize dilution, mixing, and variable wind conditions. After all sample analyses were completed, a calculation was performed to convert measured concentrations (ppm, ppb,  $\mu\text{g}/\text{m}^3$ ) to average emission rates (lb/hr) for each parameter. An extrapolation of the average emission rate from the sampled area to that of the total pile was then performed. Also, due to the large range of values for most parameters, a standard error calculation was used to describe the variability of each compound-specific average rate. Table 7-1 lists the emission rate and the emission factor for xylene resulting from this study.<sup>2</sup>

**TABLE 7-1.  
XYLENE EMISSIONS FROM COMBUSTIBLE COAL REFUSE  
MATERIAL**

Total Emission Rate	Emission Factor	Quality Rating
3.2 ± 1.7 kg/hr (7.1 ± 3.8 lb/hr)	3.1 x 10 <sup>-5</sup> kg/hr/m <sup>3</sup> (1.9 x 10 <sup>-6</sup> lb/hr/ft <sup>3</sup> ) of burning refuse material	D

Source: Reference 2.

In summary, the investigative study resulted in calculated emission rates and emission factors for various parameters. This study concludes that the possibility of downwind exposure to toxic and suspected toxic airborne contaminants from the burning coal refuse pile exists.<sup>2</sup> However, a search of the XATEF and SPECIATE databases did not identify any emission factors for coal combustion.<sup>3,4</sup>

## 7.2 HAZARDOUS AND SOLID WASTE INCINERATION

Most atmospheric emissions of pollutants from the various hazardous and solid waste disposal methods come from incineration. In addition to particulate matter, other pollutants, such as volatile organic compounds (including xylene) and carbon monoxide are frequently emitted as a result of incomplete combustion of the waste due to improper combustor design or poor operating conditions.

Several methods are used to incinerate municipal waste. These include mass burn excess air combustion, starved air or modular combustion, and refuse-derived fuel combustion. Approximately 70 percent of the total municipal solid waste is incinerated in mass burn units. More information on the methods of municipal waste combustion can be found in the document, *Characterization of the Municipal Waste Combustion Industry*.<sup>5</sup> Similarly, hazardous waste can be incinerated by several methods including thermal, catalytic and regenerative incineration. Xylene emission factors for incineration sources were not found.

Open-air burning presents a particularly unique source of atmospheric emissions of pollutants. This method of solid waste incineration allows for exposure to many variables including wind, ambient temperatures, and other environmental parameters such as rain and humidity, degree of compactness of the refuse, and composition and moisture of the refuse. In general, lower temperatures are achieved in open-air burning than in closed combustion. Therefore, this allows for increased emissions of particulate matter, carbon monoxide, and volatile organic compounds (including xylene), with decreased emissions of nitrogen oxides.<sup>6</sup> Other important regulating factors for open-air burning are fuel loading (how much refuse material is burned per unit of land area) and arrangement of the refuse (in rows, piles, or spread out).<sup>4</sup> Although specific xylene emission factors are unavailable for open burning in general, data indicate that emissions of volatile organic compounds from non-agricultural materials are approximately 25 percent methane, 8 percent other saturates, 18 percent olefins, and 49 percent other compounds (oxygenates, acetylene, and aromatics, including xylene). However, emissions have been measured for the open burning of scrap tires.<sup>7</sup> Table 7-2 shows the measured emission rates and the burn rates that are a critical factor in determining emissions. Figure 7-1 shows a scatterplot and the basic statistics of the data in Table 7-2. As shown in Figure 7-1, the relationship of burn rate of tires to the emission rate is nonlinear. Emission factor quality ratings are not presented in Table 7-2 because these are emission rates calculated from one study and emission factors were not developed from this data.

### 7.3 WASTEWATER TREATMENT PROCESSES

Atmospheric emissions of volatile organic compounds such as xylene can occur at any wastewater treatment process where the wastewater comes into contact with the surrounding ambient air. The majority of air emissions from wastewater treatment facilities usually comes from the initial physical processes (*e.g.*, screening, sedimentation, floatation, and filtration) due to both a higher pollutant concentration in the influent and a greater surface area caused by turbulence and mixing. Other sources of emissions include equalization and aeration basins and clarifiers.

**TABLE 7-2.  
XYLENE EMISSION RATES FROM THE OPEN BURNING OF  
SCRAP TIRES**

Burn Rate		Emission Rate	
kilograms/hour	(pounds/hour)	kg xylene/metric ton tires	(lbs xylene/ton tires)
0.50	(1.10)	3.212	(6.438)
0.80	(1.76)	1.962	(3.932)
0.90	(1.98)	1.208	(2.422)
1.27	(2.80)	0.381	(0.764)
1.30	(2.87)	1.063	(2.130)
1.40	(3.09)	1.036	(2.077)
1.50	(3.31)	0.736	(1.475)
1.70	(3.75)	0.454	(0.909)
2.27	(5.00)	0.111	(0.223)
2.30	(5.07)	0.480	(0.962)
3.50	(7.72)	0.294	(0.590)
6.63	(14.62)	0.147	(0.295)

Source: Reference 7.

**Figure 7-1. Emissions from open burning of scrap tires.<sup>7</sup>**

Because of the many factors that may affect emissions of volatile organics, including xylene, from wastewater treatment processes, calculating actual emissions estimates must be performed on a chemical-by-chemical, process-by-process basis. Several models have been developed that estimate emissions from wastewater treatment processes. Brief descriptions of some appropriate models are presented below; however, further information should be consulted in the appropriate reference(s).

The SIMS model (Surface Impoundment Modeling System) developed by the Control Technology Center of the U.S. Environmental Protection Agency is a personal computer-based software program designed to estimate atmospheric emissions from surface impoundments and wastewater collection devices.<sup>8</sup> The Tsvoglou and Neal Reaeration model can be used with the SIMS model to estimate VOC emissions from the devices that comprise the headworks of a POTW (since the SIMS model does not account for emissions from these devices or for adsorption onto solids).<sup>9</sup>

Several inherent problems exist with using these models. First, the VOC concentrations in the wastewater are highly variable among the influent, effluent, and sludge partitions; therefore, a single emission estimate would be highly questionable. Second, the estimates are usually based on constant behavior of relatively pure compounds, so mixing and variable chemical concentrations would render the emission factors less useful. Finally, these estimates are generally on the conservative side, and actual emissions will often tend to be higher than the estimates.

A major process resulting in the emission of wastewater pollutants is the separation of the lighter organic phase from the main body of wastewater and the heavier inorganic solid phase. A top organic layer consisting of many volatile organic and oil-based compounds is formed and exposed to ambient air. Factors affecting volatilization of organic compounds from the top organic layer include characteristics of the wastewater and oil layers, the ambient wind speed, design characteristics of the wastewater treatment operation, the concentration of pollutants in the wastewater, detention time in the treatment system, and partition coefficients of the pollutants.

EPA has published several guidance documents and reports regarding emissions from wastewater treatment systems which are referenced here.<sup>8,9,10</sup>

#### 7.4 REFERENCES FOR SECTION 7.0

1. Joseph R. Stetter, Richard D. Flotard, and Elizabeth Gebert, *Environmental Monitoring and Assessment in International Journal, Characterization of Airborne Particles at a High-BTU Coal-Gasification Pilot Plant*. 1(4). 1982.
2. Seely, Douglas E. and Engle, Ronald J. *Investigative Air Monitoring Study at a Burning Coal Refuse Pile in Oak Hill, West Virginia*. Presented at the 77<sup>th</sup> Annual Meeting of APCA. San Francisco, CA. June 24-29, 1984.
3. U.S. Environmental Protection Agency. *Crosswalk/Air Toxic Emission Factor Database Management System (XATEF)*, Version 1.2. Office of Air Quality Planning and Standards. Research Triangle Park, NC. October 1991.
4. U.S. Environmental Protection Agency. *Volatile Organic Compound (VOC)/Particulate Matter (PM) Speciation Database Management System*, Version 1.4. Office of Air Quality Planning and Standards. Research Triangle Park, NC. October 1991.
5. Radian Corporation. *Characterization of the Municipal Waste Combustion Industry*, Appendix A. Research Triangle Park, NC. October 1986.
6. Gerstle, R.W., and D. A. Kemnitz. "Atmospheric Emissions from Open Burning," *Journal of Air Pollution Control Association*. 12:324-327. May 1967.
7. U.S. Environmental Protection Agency. *Characterization of Emissions from the Simulated Burning of Scrap Tires*, EPA-600/2-89-054. Control Technology Center, Research Triangle Park, NC. October 1989.
8. U.S. Environmental Protection Agency. *Surface Impoundment Modeling System (SIMS) Version 2.0 User's Manual*, EPA-450/4-90-019a. Control Technology Center. Research Triangle Park, NC. 1990.
9. Tsvoglou, E.C., and L.A. Neal. "Tracer Measurement of Reaeration, III. Predicting the Reaeration Capacity of Inland Streams," *Journal of Water Pollution Control Federation* 48(12):2669. 1976.
10. U.S. Environmental Protection Agency. *Guidance Services, Control of Volatile Organic Compound Emissions from Industrial Wastewater, Volume I*, Preliminary Draft. Office of Air Quality Planning and Standards. Research Triangle Park, NC. April 1989.

## SECTION 8.0

### AMBIENT AIR AND STATIONARY SOURCE TEST PROCEDURES

Xylene(s) emissions can be measured from ambient air and stationary sources utilizing the test methods presented below. If applied to stack sampling, the ambient air monitoring methods may require adaptation or modification. To ensure that results will be quantitative, appropriate precautions must be taken to prevent exceeding the capacity of the methodology. Ambient methods which require the use of sorbents are susceptible to sorbent saturation if high concentration levels exist. If this happens, breakthrough will occur, and quantitative analysis will not be possible.

- EPA Method TO-1: Determination of Volatile Organic Compounds in Ambient Air Using Tenax<sup>®</sup> Adsorption and Gas Chromatography/Mass Spectrometry (GC/MS)
- EPA Method TO-3: Determination of Volatile Organic Compounds in Ambient Air Using Cryogenic Preconcentration Techniques and Gas Chromatography with Flame Ionization and Electron Capture Detection
- EPA Method TO-14: Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using SUMMA<sup>®</sup> Passivated Canister Sampling and Gas Chromatography (GC)
- EPA Method 0030: Volatile Organic Sampling Train (VOST) with EPA Method 5040: Analysis of Sorbent Cartridges from VOST
- EPA Reference Method 18: Measurement of Gaseous Organic Compound Emissions by Gas Chromatography
- NIOSH Method 1501: Aromatic Hydrocarbons

## 8.1 EPA METHOD TO-1

Ambient air concentrations of xylene(s) can be measured using EPA Method TO-1 from the *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*.<sup>1</sup> This method is used to collect and determine nonpolar, volatile organics (aromatic hydrocarbons, chlorinated hydrocarbons) that can be captured on Tenax<sup>®</sup> and determined by thermal desorption techniques. The compounds determined by this method have boiling points in the range of 80° to 200°C (180° to 390°F).

Figure 8-1 presents a schematic diagram of the sampling system. Figure 8-2 presents a schematic diagram of a typical Tenax<sup>®</sup> cartridge design. Ambient air is drawn through the cartridge which contains approximately 1 to 2 grams of Tenax.<sup>®</sup> The xylenes are trapped on the Tenax<sup>®</sup> cartridge, which is then capped and sent to the laboratory for analysis utilizing gas chromatograph/mass spectrometry (GC/MS) according to the procedures specified in EPA Method 5040.

The exact run time, flow rate and volume sampled varies from source to source depending on the expected concentrations and the required detection limit. Typically, 10 to 20 L of ambient air are sampled. Analysis should be conducted within 14 days of collection. A capillary having an internal diameter of 0.3mm and a length of 50 meters is recommended. The MS identifies and quantifies the compounds by mass fragmentation or ion characteristic patterns. Compound identification is normally accomplished using a library search routine on the basis of GC retention time and mass spectral characteristics.

## 8.2 EPA METHOD TO-3

Ambient air concentrations of xylene(s) can be measured directly at the source using EPA Method TO-3 from the *Compendium Methods for the Determination of Toxic Organic*

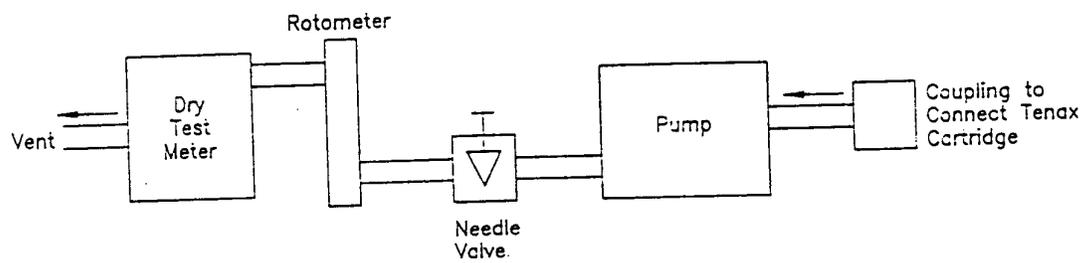
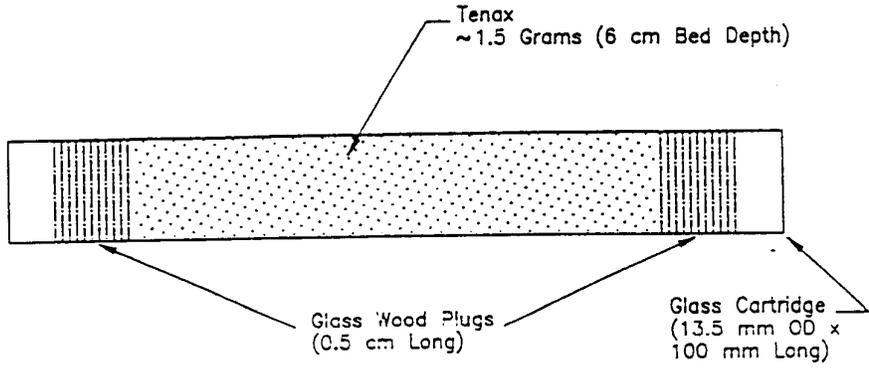
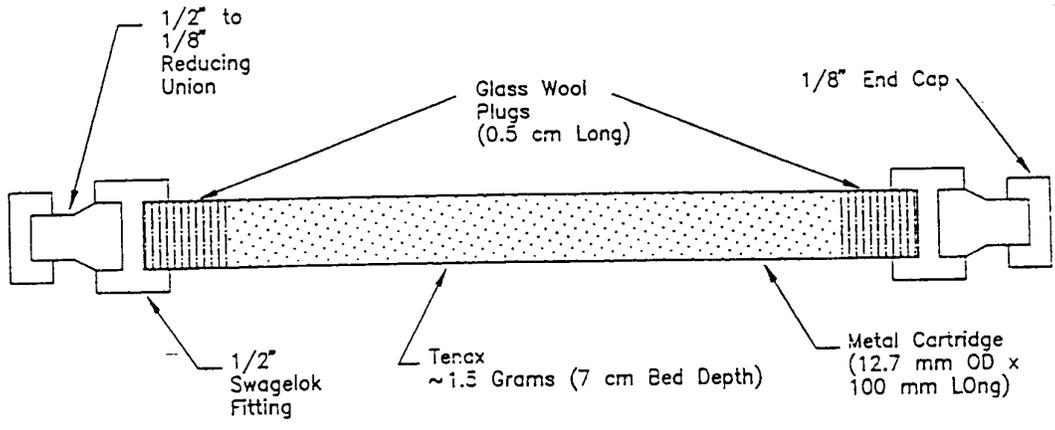


Figure 8-1. Typical sampling system configuration.<sup>1</sup>



(a) Glass Cartridge



(b) Metal Cartridge

Figure 8-2. Tenax cartridge designs.<sup>1</sup>

*Compounds in Ambient Air.*<sup>1</sup> This method is designed for the determination of highly volatile nonpolar organic compounds having boiling points in the range of -10° to 200°C (14° to 390°F). Figure 8-3 presents a schematic of a typical on-line sampling system.

The ambient air sample is collected in the cryogenic trap utilizing a volume-measuring device. The GC oven is then chilled to a subambient temperature. The sample valve is then switched and the sample is carried onto the cooled GC column. Simultaneously, the cryogenic trap is heated to assist in the sample transfer process. The GC column is heated to the desired temperature and the peaks are identified and quantified using a flame ionization detector (FID) or electron capture detector (ECD).

### 8.3 EPA METHOD TO-14

Ambient air concentrations of xylene(s) can also be measured using EPA Method TO-14 from the *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air.*<sup>1</sup> This method is based on collection of a whole air sample in SUMMA<sup>®</sup> passivated stainless steel canisters and is used to determine semivolatile and volatile organic compounds. The compounds are separated by gas chromatography and measured by mass-selective detector or multidetector techniques such as flame ionization detection (FID), electron capture detection (ECD), and photoionization detection (PID). The recommended column for Method TO-14 is an HP OV-1 capillary type with 0.32mm I.D. x 0.88 um cross-linked methyl silicone coating or equivalent. Samples should be analyzed within 14 days of collection.

This method is applicable to specific semivolatiles and VOCs that have been tested and determined to be stable when stored in pressurized and subatmospheric pressure canisters. Xylenes have been successfully measured at the parts per billion by volume (ppbv) level using this method. Figure 8-4 presents a diagram of the canister sampling system.

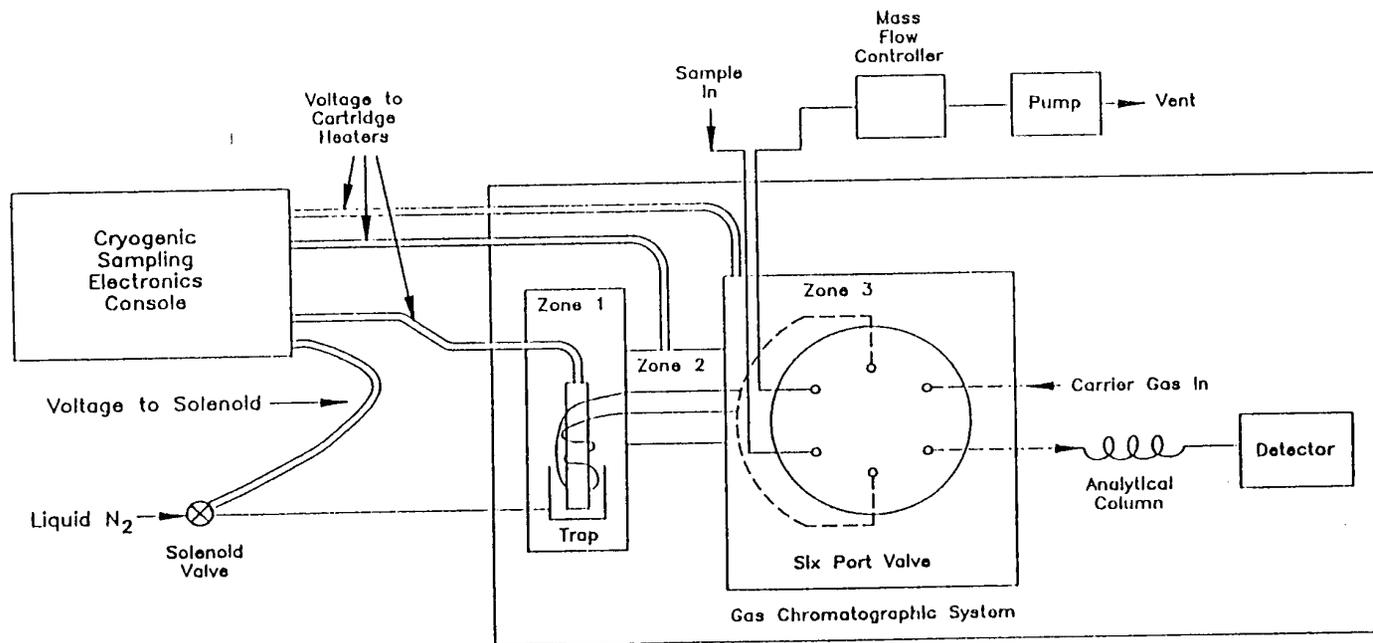


Figure 8-3. Automated sampling and analysis system for cryogenic trapping.<sup>1</sup>

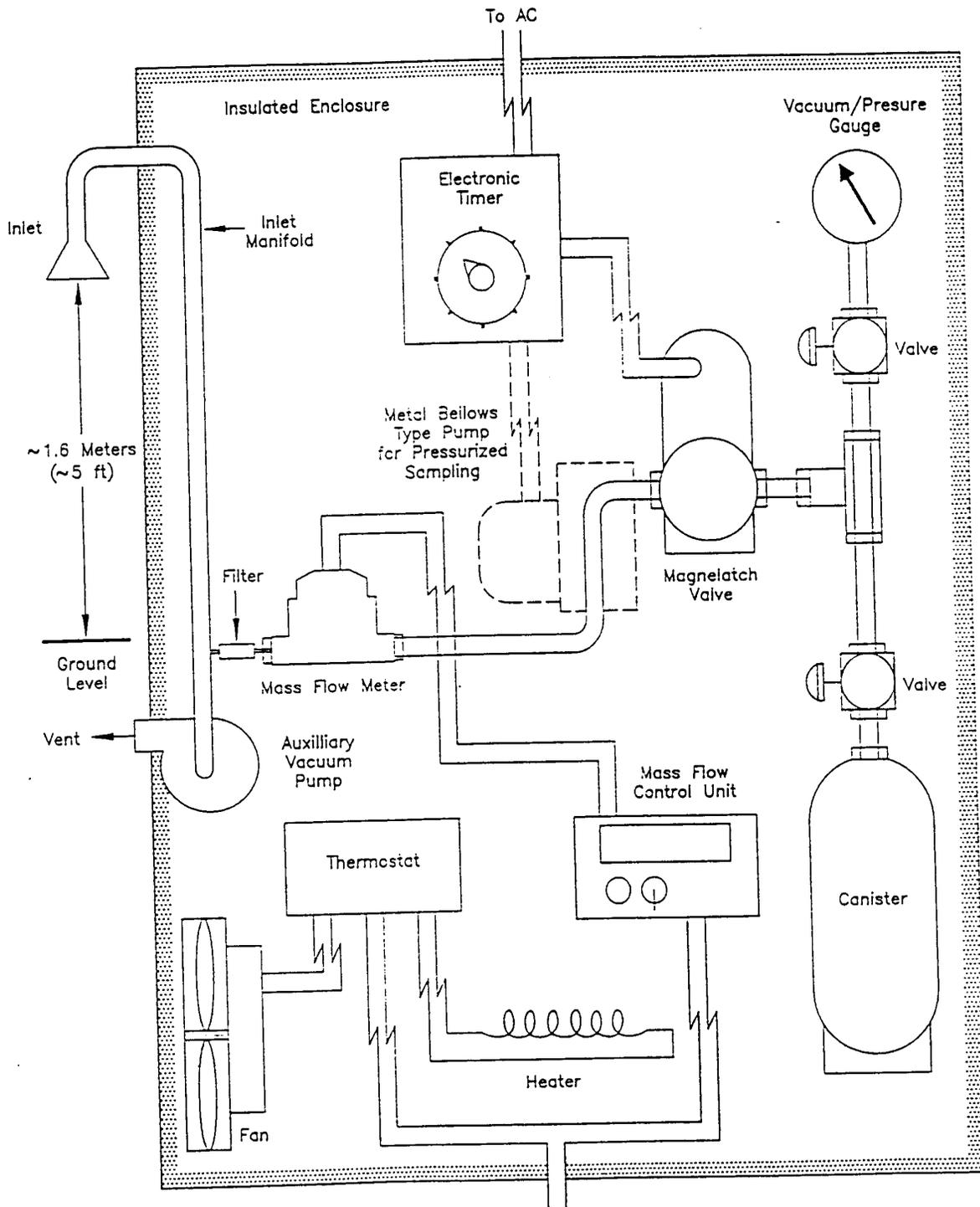


Figure 8-4. Sampler for subatmospheric pressure canister sampling.<sup>1</sup>

#### 8.4 EPA METHOD 0030

The volatile organic sampling train (VOST) is designed for the collection of volatile organic compounds from the stack gas effluents of hazardous waste incinerators.<sup>2</sup> Figure 8-5 presents a schematic of the principle components of the VOST. The VOST method was designed to collect volatile organics with boiling points in the range of 30° to 100°C (86° to 212°F). Many compounds with boiling points above 100°C (212°F) may also be effectively collected using this method. Xylene(s) concentrations have been successfully measured utilizing this methodology; however, quantitative data require validation.

In most cases, 20 L of effluent stack gas are sampled at an approximate flow rate of 1 L/minute, using a glass-lined heated probe and a volatile organic sampling train. The gas stream is cooled to 20°C (68°F) by passage through a water-cooled condenser and the volatile organics are collected on a pair of sorbent resin traps. Liquid condensate is collected in an impinger located between the two resin traps. The first resin trap contains about 1.6 g Tenax<sup>®</sup> and the second trap contains about 1 g each of Tenax<sup>®</sup> and petroleum-based charcoal.

The Tenax<sup>®</sup> cartridges are then thermally desorbed and analyzed by purge-and-trap GC/MS along with the condensate catch as specified in EPA Method 5040.<sup>2</sup> Analysis should be conducted within 14 days of collection.

#### 8.5 EPA METHOD 5040

The contents of the sorbent cartridges (collected using EPA Method 0030) are spiked with an internal standard and thermally desorbed for 10 minutes at 80°C (176°F) with organic-free nitrogen or helium gas (at a flow rate of 40 mL/min); bubbled through 5 mL of organic-free water; and trapped on an analytical adsorbent trap.<sup>2</sup> After the 10 minute desorption, the analytical adsorbent trap is rapidly heated to 180°C (356°F), with the carrier gas flow reversed

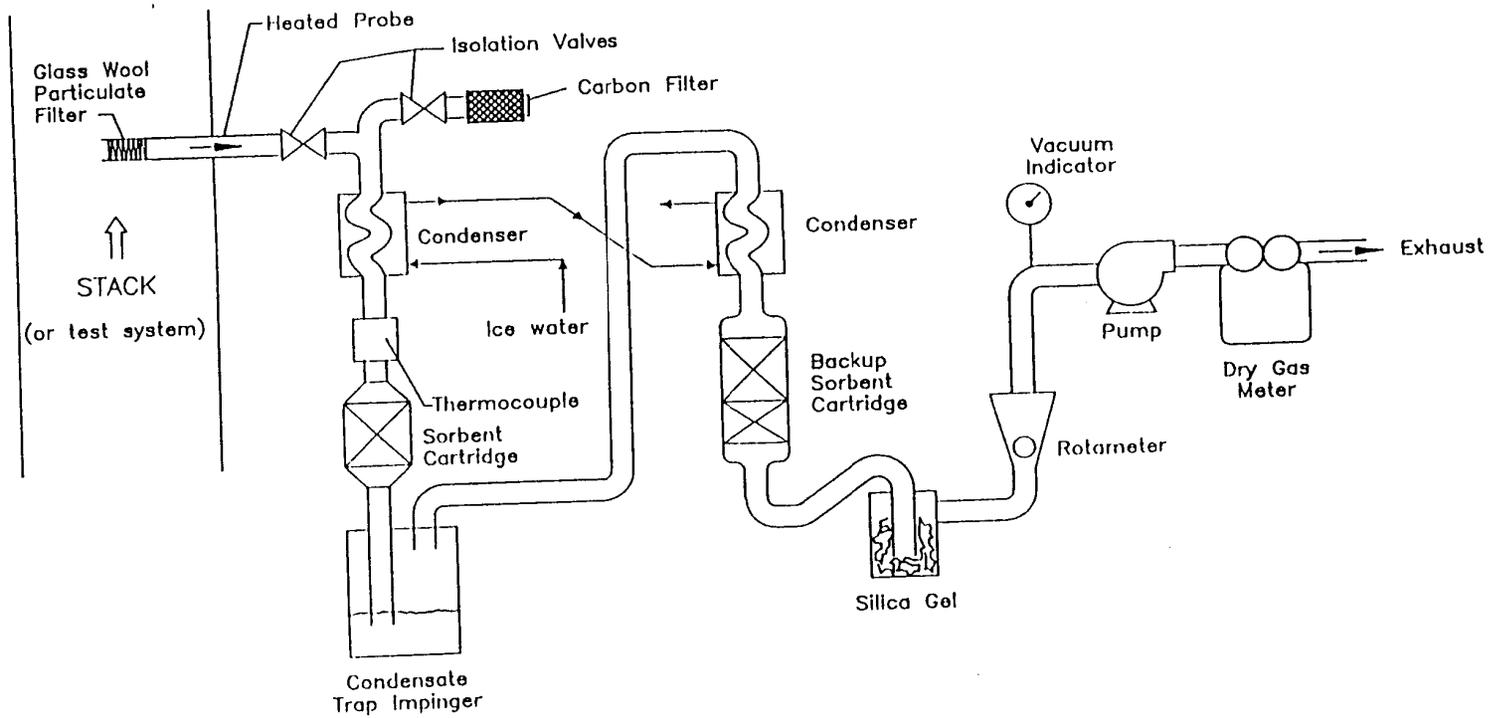


Figure 8-5. Schematic of volatile organic sampling train (VOST).<sup>2</sup>

so that the effluent flow from the analytical trap is directed into the GC/MS. The volatile organics are separated by temperature-programmed gas chromatography and detected by low resolution mass spectrometry. The concentrations of the volatile compounds are calculated using the internal standard technique. EPA Method 5030 and 8420 may be referenced for specific requirements for the thermal desorption unit, purge-and-trap unit, and GC/MS system.

A diagram of the analytical system is presented in Figure 8-6. The Tenax<sup>®</sup> cartridges should be analyzed within 14 days of collection. The desired detection limit of this method is 0.1 ng/L (20 ng per Tenax<sup>®</sup> cartridge).

## 8.6 EPA REFERENCE METHOD 18

EPA Reference Method 18 can be utilized for the sampling and analysis of approximately 90 percent of the total gaseous organics emitted from industrial sources.<sup>3</sup> It does not include techniques to identify and measure trace amounts of organic compounds, such as those found in room air and from fugitive sources. Xylene(s) emissions can be measured from stationary sources using this method. Method 18 can be conducted using either the direct interface method (on-line GC/FID) or by the collection of an integrated Tedlar<sup>®</sup> or Mylar<sup>®</sup> bag sample with subsequent analysis by GC/FID.

The direct interface method draws a sample of the exhaust gas through a heated sample line directly into a heated sample loop and into the GC/FID for analysis. Figure 8-7 presents a schematic of the principle components of the direct interface system.

Utilizing the bag-in-drum technique, presented in Figure 8-8, a sample of the exhaust gas is drawn into a Tedlar<sup>®</sup> or Mylar<sup>®</sup> bag. The bag is placed inside a rigid leakproof container and evacuated. The bag is then connected by a Teflon<sup>®</sup> sample line to a sampling probe located at the center of the stack or exhaust vent. The sample is drawn into the bag by pumping air out of

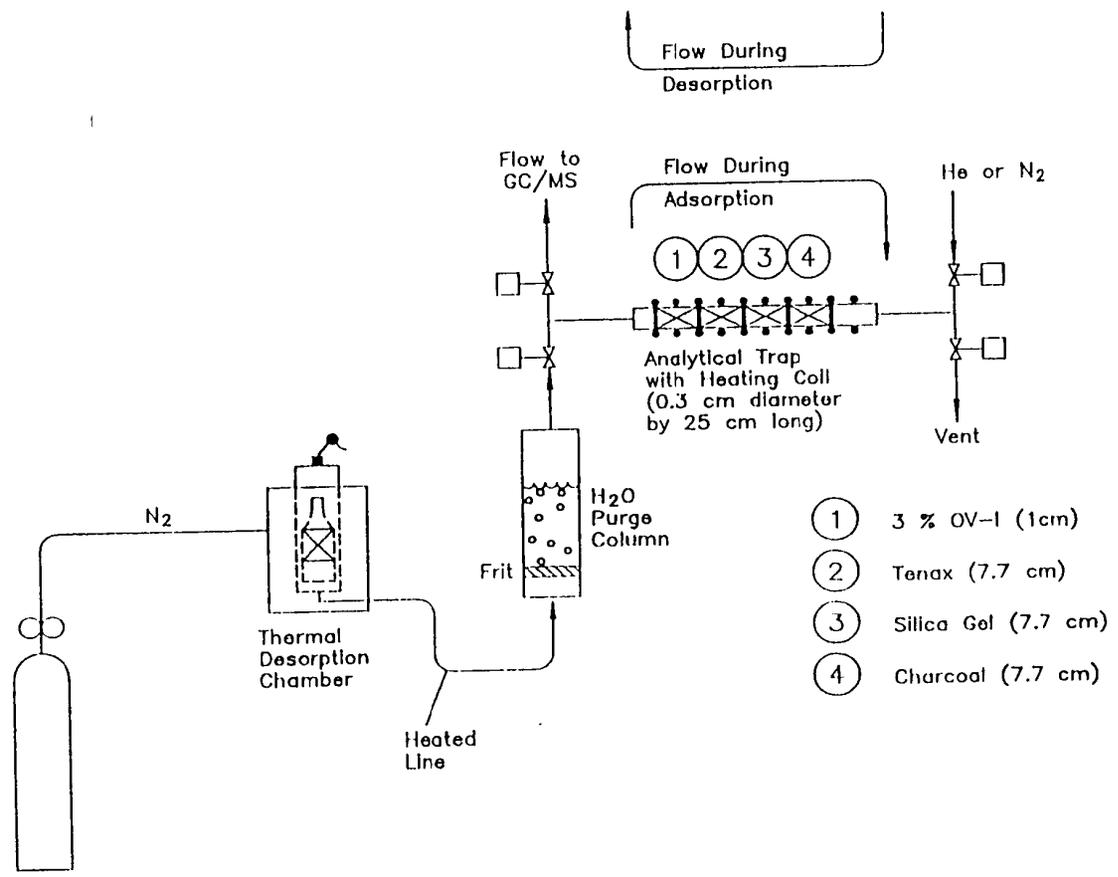


Figure 8-6. Schematic diagram of trap desorption/analysis system.<sup>2</sup>

8-12

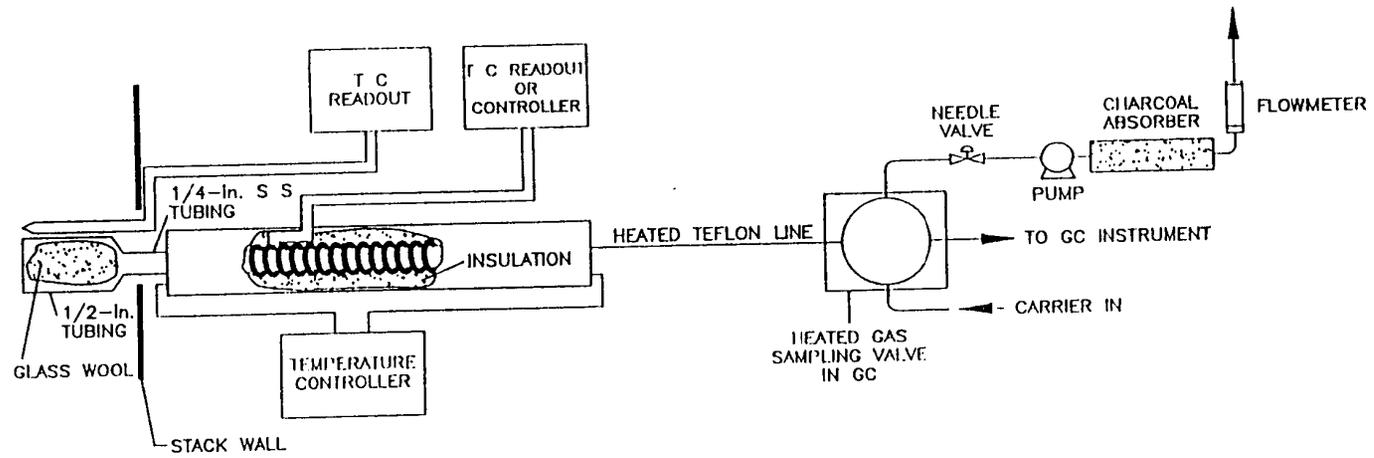


Figure 8-7. Direct interface sampling system.<sup>3</sup>

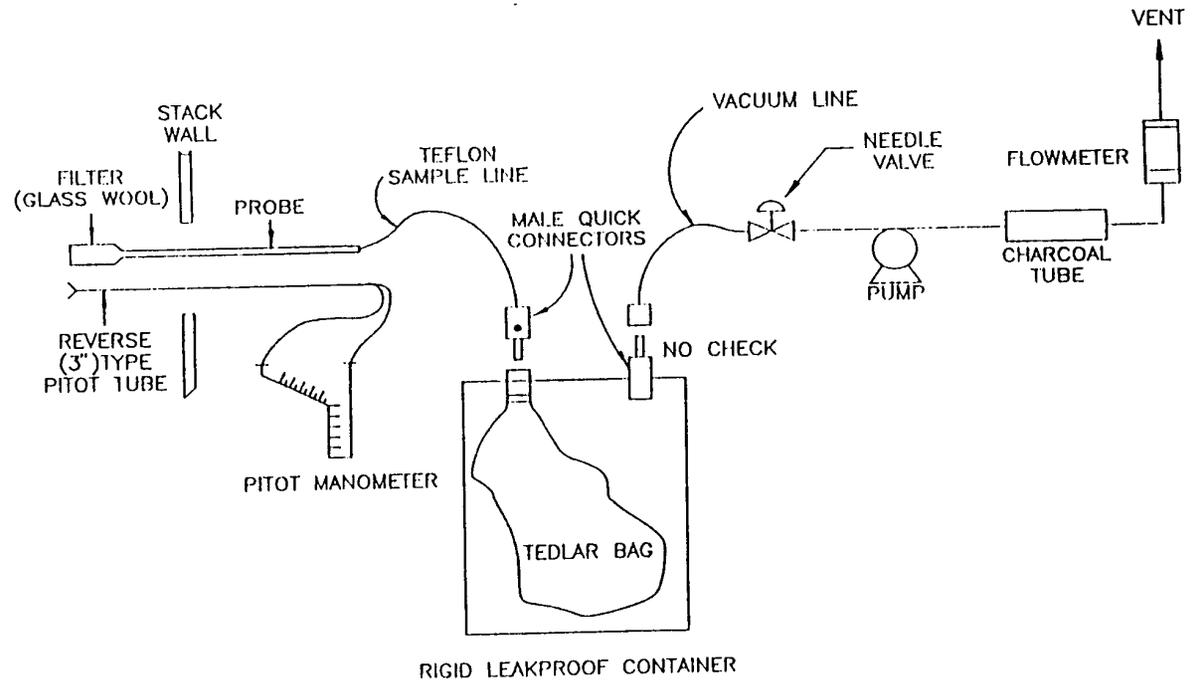


Figure 8-8. Integrated bag sampling train.<sup>3</sup>

the rigid container. The sample is then analyzed by GC/FID. Based on laboratory studies, the recommended time limit for analysis is within 14 days of collection.

## 8.7 NIOSH METHOD 1501

Ambient air and exhaust gas concentrations of xylene(s) can also be measured using NIOSH Method 1501.<sup>4</sup> This method has limited applications and applies to ten specific aromatic hydrocarbons. The levels of detection are much higher than the other procedures discussed.

Ambient air or exhaust gas samples are collected on solid sorbent tubes containing coconut shell charcoal. Ten to 20 L of air are collected, depending on the expected concentrations, using a vacuum pump set at an approximate flow rate of 1 L/minute.

The samples are then capped, sent to the laboratory, desorbed with carbon disulfide and analyzed by GC/FID. The column specified in NIOSH Method 1501 is a 3.0m x 2mm glass or stainless steel with 10 percent OV-275 on 100/120 mesh Chromosorb W-AW or equivalent. Analysis should be conducted within 14 days. Figure 8-9 presents a diagram of the NIOSH Method 1501 sampling system.

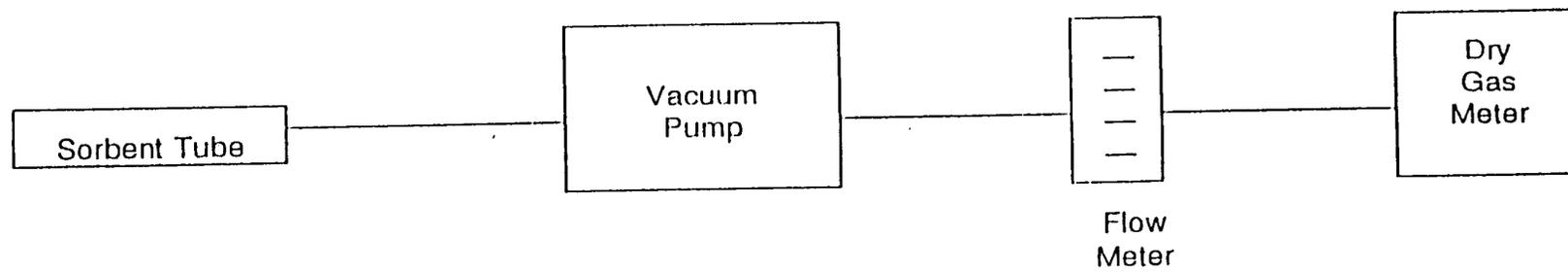


Figure 8-9. Method 1501 sampling system.<sup>4</sup>

## 8.8 REFERENCES FOR SECTION 8.0

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2. U.S. Environmental Protection Agency. *Test Methods for Evaluating Solid Waste*, Third Edition. Report No. SW-846. Office of Solid Waste and Emergency Response, Washington, DC. November 1986.
3. 40 CFR, Part 60, Appendix A, *Method 18: Measurement of Gaseous Organic Compounds by Gas Chromatography*. pp 823 through 852.
4. NIOSH *Manual of Analytical Methods*, Third Edition, Volumes 1 and 2. Cincinnati, OH. February 1984.

APPENDIX A

POTENTIAL SOURCE CATEGORIES OF MIXED XYLENE EMISSIONS

**TABLE A-1.**  
**POTENTIAL SOURCE CATEGORIES OF MIXED XYLENE**  
**EMISSIONS (continued)**

SIC Code	Source Description
1311	Crude Petroleum and Natural Gas
1321	Natural Gas Liquids
1382	Oil and Gas Exploration
1400	Nonmetallic Minerals, Except Fuels
1475	Phosphate Rock
1499	Miscellaneous Nonmetallic Minerals
2044	Rice Milling
2082	Malt Beverages
2221	Broadwoven fabric mills, manmade
2231	Broadwoven fabric mills, wool
2261	Finishing plants, cotton
2262	Finishing plants, manmade
2281	Yarn spinning mills
2426	Hardwood dimension and flooring mills
2431	Millwork
2434	Wood kitchen cabinets
2435	Hardwood veneer and plywood
2491	Wood Preserving
2493	Reconstituted wood products
2512	Upholstered household furniture
2515	Mattresses and bedsprings
2517	Wood TV and radio cabinets
2519	Household furniture, nec
2531	Public building and related furniture

(continued)

**TABLE A-1.**  
**POTENTIAL SOURCE CATEGORIES OF MIXED XYLENE**  
**EMISSIONS (continued)**

<b>SIC Code</b>	<b>Source Description</b>
2541	Wood partitions and fixtures
2591	Drapery hardware and blinds and shades
2599	Furniture and fixtures, nec
2611	Pulp mills
2653	Corrugated and solid fiber boxes
2655	Fiber cans, drums and similar products
2672	Paper coated and laminated, nec
2674	Bags: uncoated paper and multiwall
2721	Periodicals
2732	Book printing
2752	Commercial printing, lithographic
2754	Commercial printing, gravure
2761	Manifold business forms
2782	Blankbooks and looseleaf binders
2789	Bookbinding and related work
2796	Platemaking services
2800	Chemicals and Allied Products
2812	Alkalies and Chlorine
2813	Industrial gases
2816	Inorganic Pigments
2819	Industrial Organic Chemicals, nec
2821	Plastics materials and resins
2822	Synthetic rubber

(continued)

**TABLE A-1.**  
**POTENTIAL SOURCE CATEGORIES OF MIXED XYLENE**  
**EMISSIONS (continued)**

<b>SIC Code</b>	<b>Source Description</b>
2823	Cellulosic manmade fibers
2824	Organic fibers, noncellulosic
2834	Pharmaceutical preparations
2841	Soap and other detergents
2842	Polishes and sanitation goods
2843	Surface active agents
2844	Toilet preparations
2851	Paints and allied products
2861	Gum and Wood Chemicals
2865	Cyclic crudes and intermediates
2869	Industrial Organic Chemicals, nec
2873	Nitrogenous Fertilizers
2874	Phosphatic Fertilizers
2879	Agricultural chemicals, nec
2892	Explosives
2893	Printing Ink
2899	Chemical preparations, nec
2911	Petroleum Refining
3011	Tires and inner tubes
3052	Rubber and plastics hose and belting
3053	Gaskets, packing and sealing devices
3061	Mechanical rubber goods
3080	Misc. Plastics Products, nec

(continued)

**TABLE A-1.  
POTENTIAL SOURCE CATEGORIES OF MIXED XYLENE  
EMISSIONS (continued)**

<b>SIC Code</b>	<b>Source Description</b>
3081	Unsupported plastics film and sheet
3082	Unsupported plastics profile shapes
3086	Plastics foam products
3087	Custom compound purchased resins
3089	Plastics products, nec
3211	Flat glass
3229	Pressed and blown glass, nec
3231	Products of purchased glass
3241	Cement, hydraulic
3251	Brick and Structural Clay Tile
3253	Ceramic wall and floor tile
3255	Clay Refractories
3264	Porcelain electrical supplies
3272	Concrete products, nec
3274	Lime
3275	Gypsum Products
3292	Asbestos products
3295	Minerals, ground or treated
3296	Mineral Wool
3299	Nonmetallic mineral products, nec
3312	Blast furnaces and steel mills
3313	Electrometallurgical products
3315	Steel wire and related products

(continued)

**TABLE A-1.  
POTENTIAL SOURCE CATEGORIES OF MIXED XYLENE  
EMISSIONS (continued)**

<b>SIC Code</b>	<b>Source Description</b>
3317	Steel pipe and tubes
3321	Gray and Ductile Iron Foundries
3325	Steel foundries, nec
3334	Primary Aluminum
3339	Primary Nonferrous Metals, nec
3341	Secondary Nonferrous Metals
3351	Copper rolling and drawing
3353	Aluminum sheet, plate, and foil
3354	Aluminum extruded products
3355	Aluminum rolling and drawing, nec
3363	Aluminum die-castings
3364	Nonferrous die-casting exc. aluminum
3366	Copper foundries
3399	Primary metal products, nec
3411	Metal cans
3412	Metal barrels, drums, and pails
3423	Hand and edge tools, nec
3425	Saw blades and handsaws
3429	Hardware, nec
3431	Metal Sanitary Ware
3433	Heating equipment, except electric
3441	Fabricated structural metal
3443	Fabricated plate work (boiler shops)

(continued)

**TABLE A-1.**  
**POTENTIAL SOURCE CATEGORIES OF MIXED XYLENE**  
**EMISSIONS (continued)**

SIC Code	Source Description
3444	Sheet metalwork
3446	Architectural metal work
3448	Prefabricated metal buildings
3449	Miscellaneous metal work
3451	Screw machine products
3462	Iron and steel forgings
3463	Nonferrous forgings
3465	Automotive stampings
3466	Crowns and closures
3471	Plating and polishing
3482	Small arms ammunition
3483	Ammunition, exc. for small arms, nec
3489	Ordnance and accessories, nec
3491	Industrial valves
3493	Steel springs, except wire
3494	Valves and pipe fittings, nec
3495	Wire springs
3496	Misc. fabricated wire products
3497	Metal foil and leaf
3498	Fabricated pipe and fittings
3511	Turbines and turbine generator sets
3519	Internal combustion engines, nec
3523	Farm machinery and equipment

(continued)

**TABLE A-1.  
POTENTIAL SOURCE CATEGORIES OF MIXED XYLENE  
EMISSIONS (continued)**

<b>SIC Code</b>	<b>Source Description</b>
3524	Lawn and garden equipment
3531	Construction machinery
3532	Mining machinery
3533	Oil and gas field machinery
3534	Elevators and moving stairways
3535	Conveyors and conveying equipment
3536	Hoists, cranes, and monorails
3537	Industrial trucks and tractors
3541	Machine tools, metal cutting types
3542	Machine tools, metal forming types
3545	Machine tool accessories
3546	Power-driven handtools
3548	Welding apparatus
3549	Metalworking machinery, nec
3553	Woodworking machinery
3554	Paper industries machinery
3555	Printing trades machinery
3556	Food products machinery
3559	Special industry machinery, nec
3561	Pumps and pumping equipment
3563	Air and gas compressors
3564	Blowers and fans
3565	Packaging machinery

(continued)

**TABLE A-1.**  
**POTENTIAL SOURCE CATEGORIES OF MIXED XYLENE**  
**EMISSIONS (continued)**

SIC Code	Source Description
3566	Speed changers, drives, and gears
3569	General industrial machinery, nec
3571	Electronic computers
3572	Computer storage devices
3579	Office machines, nec
3581	Automatic vending machines
3582	Commercial laundry equipment
3589	Service industry machinery, nec
3596	Scales and balances, exc. laboratory
3599	Industrial machinery, nec
3613	Switchgear and switchboard apparatus
3624	Carbon and Graphite Products
3625	Relays and industrial controls
3629	Electrical industrial apparatus, nec
3631	Household cooking equipment
3632	Household refrigerators and freezers
3633	Household laundry equipment
3634	Electric housewares and fans
3635	Household vacuum cleaners
3639	Household appliances, nec
3641	Electric lamps
3643	Current-carrying wiring devices
3644	Noncurrent-carrying wiring devices

(continued)

**TABLE A-1.**  
**POTENTIAL SOURCE CATEGORIES OF MIXED XYLENE**  
**EMISSIONS (continued)**

SIC Code	Source Description
3645	Residential lighting fixtures
3646	Commercial lighting fixtures
3647	Vehicular lighting equipment
3648	Lighting equipment, nec
3651	Household audio and video equipment
3661	Telephone and telegraph apparatus
3669	Communications equipment, nec
3672	Printed circuit boards
3675	Electronic capacitors
3676	Electronic resistors
3677	Electronic coils and transformers
3678	Electronic connectors
3679	Electronic components, nec
3691	Storage batteries
3694	Engine electrical equipment
3695	Magnetic and optical recording media
3699	Electrical equipment and supplies, nec
3711	Motor vehicles and car bodies
3715	Truck trailers
3716	Motor homes
3724	Aircraft engines and engine parts
3728	Aircraft parts and equipment, nec
3731	Ship building and repairing

(continued)

**TABLE A-1.**  
**POTENTIAL SOURCE CATEGORIES OF MIXED XYLENE**  
**EMISSIONS (continued)**

SIC Code	Source Description
3732	Boat building and repairing
3743	Railroad equipment
3751	Motorcycles, bicycles, and parts
3761	Guided missiles and space vehicles
3764	Space propulsion units and parts
3769	Space vehicle equipment, nec
3792	Travel trailers and campers
3795	Tanks and tank components
3799	Transportation equipment, nec
3812	Search and navigation equipment
3821	Laboratory apparatus and furniture
3823	Process control instruments
3824	Fluid meters and counting devices
3825	Instruments to measure electricity
3826	Analytical instruments
3827	Optical instruments and lenses
3829	Measuring and controlling devices, nec
3841	Surgical and medical instruments
3842	Surgical appliances and supplies
3861	Photographic equipment and supplies
3873	Watches, clocks, watchcases and parts
3900	Miscellaneous Manufacturing Industries
3914	Silverware and plated ware

(continued)

**TABLE A-1.  
POTENTIAL SOURCE CATEGORIES OF MIXED XYLENE  
EMISSIONS (continued)**

SIC Code	Source Description
3931	Musical instruments
3944	Games, toys, and children's vehicles
3949	Sporting and athletic goods, nec
3951	Pens and mechanical pencils
3952	Lead pencils and art goods
3953	Marking devices
3961	Costume jewelry
3993	Signs and advertising specialties
3995	Burial caskets
3996	Hard surface floor coverings, nec
4111	Local and suburban transit
4226	Special warehousing and storage, nec
4491	Marine Cargo Handling
4499	Water transportation services, nec
4512	Air transportation, scheduled
4581	Airports, flying fields, and services
4741	Rental of railroad cars
4789	Transportation services, nec
4911	Electric Services
4925	Gas production and/or distribution
4939	Combination utilities, nec
4952	Sewerage Systems
4953	Refuse systems

(continued)

**TABLE A-1.**  
**POTENTIAL SOURCE CATEGORIES OF MIXED XYLENE**  
**EMISSIONS (continued)**

SIC Code	Source Description
5021	Furniture
5032	Brick, stone, and related materials
5085	Industrial Supplies
5113	Industrial and personal service paper
5153	Grain and field beans
5169	Chemicals and allied products, nec
5171	Petroleum bulk stations and terminals
5172	Petroleum products, nec
5191	Farm supplies
5198	Paints, varnishes, and supplies
5231	Paint, glass, and wallpaper stores
5541	Gasoline service stations
5712	Furniture stores
6512	Nonresidential building operators
7532	Top and body repair and paint shops
7538	General automotive repair shops
7629	Electrical repair shops, nec
7641	Reupholstery and furniture repair
7694	Armature rewinding shops
7699	Repair services, nec
8211	Elementary and secondary schools
8221	Colleges and universities
8299	Schools and educational services, nec

(continued)

**TABLE A-1.  
POTENTIAL SOURCE CATEGORIES OF MIXED XYLENE  
EMISSIONS (continued)**

SIC Code	Source Description
8331	Job training and related services
9199	General government, nec
9224	Fire Protection
9511	Air, water, and solid waste management
9711	National security
9999	Nonclassifiable establishments

Source:

Toxic Chemical Release Inventory (TRI), 1987-1990. On-line access through the databases. National Library of Medicine, Bethesda, MD.

*Crosswalk/Air Toxic Emission Factor Database Management System User's Manual, Version 1.2.* EPA-450/4-91-028. U.S. Environmental Protection Agency, Research Triangle Park, NC. October 1991.

*Volatile Organic Compound (VOC) Particulate Matter (PM) Speciation Database Management System Documentation and User's Guide, Version 1-32a.* Final Report. EPA Contract No. 68-02-4286, Radian Corporation, Research Triangle Park, NC. September 1990.

APPENDIX B

LISTS OF PAINT, INK, AND PRINTING FACILITIES WITH ANNUAL SALES  
GREATER THAN \$1 MILLION

**TABLE B-1.  
PAINT AND ALLIED PRODUCTS FACILITIES (SIC 2851) WITH  
ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Name	Address	Sales in \$ Millions
Aervoe-Pacific Co. Inc.	PO Box 485, Gardnerville NV 89410	11
AExcel Corp.	7373 Production Dr, Mentor OH 44060	20
Agri-Blend Inc.	PO Box 957, Rowlett TX 75088	1*
Akron Paint & Varnish Inc.	1390 Firestone Parkway, Akron OH 44301	4*
Akzo Coatings Inc. Reliance Universal Inc.	1930 Bishop Ln, Louisville KY 40218	300
Akzo Coatings Inc. Akzo Resins & Vehicles	21625 Oak St, Matteson IL 60443	13
Akzo Coatings Inc.	1600 Watterson Towers, Louisville KY 40218	550*
Allentown Paint Manufacturing Co.	PO Box 597, Allentown PA 18105	4
Also Indus Inc. Morton Paint Co.	Box 6208, Canton OH 44706	3
Ameritone Paint Corp.	PO Box 190, Long Beach CA 90801	40
Ameron Inc. Enmar Finishes Div.	PO Box 9610, Little Rock AR 72219	15
Ameron Inc. Ameron Protective Coatings Div.	201 N Berry St, Brea CA 92621	112
Amsterdam Color Works Inc.	1546 Stillwell Ave, Bronx NY 10461	7
Aspen Paints	1128 SW Spokane St, Seattle WA 98134	4
Atlas Coating Corp.	820 E 140th St, Bronx NY 10454	7*
Automotive Finishes Inc.	6430 Wyoming Ave, Dearborn MI 48126	4
Baker Sealants & Coating	234 Suydam Ave, Jersey City NJ 07304	5
Barrett Varnish Co.	1532 S 50th Ct, Cicero IL 60650	3
Bee Chem Co.	2700 E 170th St, Lansing IL 60438	66
Behr Process Corp.	PO Box 1287, Santa Ana CA 92702	33*
Benjamin Moore & Co.	51 Chestnut Ridge Rd., Montvale NJ 07645	370*
Bennette Paint Manufacturing Co.	PO Box 9088, Hampton VA 23670	5
Best Bros Paint Manufacturing Co.	PO Box 2056, Sinking Spr PA 19608	1
Beverly Manufacturing Co. (Los Angeles)	9118 S Main St, Los Angeles CA 90003	2
Birk Paint Manufacturing Inc.	230 Kearny Ave, Jersey City NJ 07305	2
Blue Ridge Talc Co. Inc.	PO Box 39, Henry VA 24102	9
Brewer Chem Corp.	PO Box 48, Honolulu HI 96810	50
Brod-Dugan Co.	2145 Schuetz Rd, St. Louis MO 63146	15
Bruning Paint Co.	601 S Haven, Baltimore, MD 21224	30
Burkes Paint Co. Inc.	727 S 27th St, Washougal WA 98671	3
Buten Paint & Wallpaper	5000 Ridge Ave, Philadelphia PA 19128	40
Cabot Stains	100 Hale St, Newburyport MA 01950	30
Cal Western Paint Corp.	11748 Slauson Ave, Santa Fe Spr CA 90670	5
Calbar Inc.	2626 N Martha St, Philadelphia PA 19125	4
California Products Corp.	PO Box 569, Cambridge MA 02139	32
Carbit Paint Co.	927 W Blackhawk St, Chicago IL 60622	5

(continued)

**TABLE B-1.**  
**PAINT AND ALLIED PRODUCTS FACILITIES (SIC 2851) WITH**  
**ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Name	Address	Sales in \$ Millions
Carboline Co.	350 Hanley Indus Ct, St. Louis MO 63144	65
Cardinal Color Co.	50-56 1st St, Paterson NJ 07524	7
Cardinal Indus Finish Inc.	1329 Potrero Ave, South El Mon CA 91733	18
Century Chem Co.	5 Lawrence St, Bloomfield NJ 07003	5
Certified Coating Products	2414 S Connor Ave, Los Angeles CA 90040	1
CF Jameson & Co. Inc.	PO Box 197, Bradford MA 01835	1
Charles A Crosbie Labs Inc.	PO Box 3497, Van Nuys CA 91407	1
Chemical Technology Labs Inc.	12150 S Alameda St, Lynwood CA 90262	3
Chemical Coating Corp.	7300 Crider Ave, Pico Rivera CA 90660	3
Ciba-Geigy Corp. Drakenfeld Colors	PO Box 519, Washington PA 15301	28
Clement Coverall Inc.	PO Box 557, Camden NJ 08101	4
CM Athey Paint Co.	1809 Bayard St, Baltimore MD 21230	6
Coatings & Chems Corp.	3067 N Elston Ave, Chicago IL 60618	5
Colonial Refining & Chem Co.	20575 Ctr Ridge Rd, Cleveland OH 44116	3
Columbia Paint Corp.	PO Box 2888, Huntington WV 25728	5
Columbia Paint Co.	PO Box 4569, Spokane WA 99202	17
Colwell Gen Inc.	PO Box 329, Fort Wayne IN 46801	20
Commercial Chem Co. Inc.	PO Box 2126, Santa Ana CA 92707	4
Con-Lux Coatings Inc.	PO Box 847, Edison NJ 08818	25
Cook & Dunn Paint Corp. Pure All Paint Coatings Co.	700 Gotham Ave, Carlstadt NJ 07072	8*
Cook & Dunn Paint Corp.	700 Gotham Parkway, Carlstadt NJ 07072	20
Cook & Dunn Paint Corp. Adelphi Coating	700 Gotham Parkway, Carlstadt NJ 07072	3
Cook Paint & Varnish Co.	PO Box 419389, Kansas City MO 64141	100
Coronado Paint Co. Inc.	PO Box 308, Edgewater FL 32032	28
Cosan Chem Corp.	400 14th St, Carlstadt NJ 07072	10*
Cotter & Co. Gen Paint & Chem Co.	201 Jandus Rd., Cary IL 60013	120
Courtaulds Coatings USA Inc.	PO Box 1439, Louisville, KY 40201	160*
Cowman & Campbell	PO Box 70328, Seattle WA 98107	3
CP Inc.	PO Box 333, Connerville IN 47331	5
Crest Chem Indus Ltd.	PO Box 85, New Lenox IL 60451	1*
Crosby Coatings Inc.	PO Box 1038, Chico CA 95927	6
CWC Indus Inc.	2686 Lisbon Rd, Cleveland OH 44104	5
Dalys Inc.	3525 Stone Way N, Seattle WA 98103	5
Dampney Co. Inc.	85 Paris St, Everett MA 02149	4
Daniel Products Co.	400 Claremont Ave, Jersey City NJ 07304	20
Davis Paint Co.	1311 Iron St, Kansas City MO 64116	13

(continued)

**TABLE B-1.  
PAINT AND ALLIED PRODUCTS FACILITIES (SIC 2851) WITH  
ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Name	Address	Sales in \$ Millions
Davlin Paint Co. Inc.	700 Allston Way, Berkely CA 94702	3*
DC Franche & Co.	1401 W Wabansia Ave, Chicago IL 60622	3
De Boom Paint Co.	645 Texas St, San Francisco CA 94107	5
Dean & Barry Co.	296 Marconi Blvd, Columbus OH 43215	15
Decratrend Paints	251 Mason Way, City of Indu CA 91746	17
Deft Inc.	17451 Von Karman Ave, Irvine CA 92714	15
Del Paint Corp.	3105 E Reno St, Oklahoma City OK 73117	4
Delrac Manufacturers of Bisonite Products Co. Inc.	PO Box 764, Tonawanda NY 14151	3*
DeSoto Inc.	PO Box 5030, Des Plaines IL 60017	408
Devoe & Reynolds Co.	PO Box 7600, Louisville KY 40207	120*
Dexter Corp. Dexter Specialty Coatings Div.	1 E Water St, Waukegan IL 60085	80
Diamond Products Co. Inc.	709 S 3rd Ave, Marshalltown IA 50158	18*
DJ Simpson Co.	PO Box 2265, South San Francisco CA 94080	5
Dover Sales Co. Inc.	PO Box 2479, Berkeley CA 94702	3*
Duncan Enterprises	PO Box 7827, Fresno CA 93747	30
Dunn Edwards Corp.	PO Box 30389, Los Angeles CA 90039	150*
Dupli-Color Products Co.	1601 Nicholas Blvd, Elk Grove Vi IL 60007	50
Duralac Inc.	84 Lister Ave. Newark NJ 07105	4
Duron Inc.	10406 Tucker St, Beltsville MD 20705	150
Dye Specialties Inc.	PO Box 1447, Secaucus NJ 07096	8
Egyptian Lacquer Manufacturing	PO Box 4449, Lafayette IN 47903	10
Ellis & Everard (US Holdings) Inc. Prillaman Chem Corp.	PO Box 4024, Martinsville VA 24112	96*
Elpaco Coatings Corp.	PO Box 447, Elkhart IN 46515	8
Emco Finishing Products Inc.	470 Cresent St, Jamestown NY 14701	2
Empire State Varnish Co.	38 Varick St, Brooklyn NY 11222	5
Environmental Coatings Inc.	6450 Hanna Lake SE, Caledonia MI 49316	5
Epoca Co.	5 Lawrence St, Bloomfield NJ 07003	1
Epoxy Coatings Co.	PO Box 1035, Union City CA 94587	1
Evans Paint Inc.	PO Box 4098, Roanoke VA 24015	4*
Everseal Manufacturing Co. Inc.	475 Broad Ave, Ridgefield NJ 07657	12
Fabrionics Inc.	Route 130 S, Camargo IL 61919	13
Farboil Co.	8200 Fischer Rd, Baltimore MD 21222	11
Farwest Paint Manufacturing Co. Inc.	PO Box 68726, Tukwila WA 98168	3
Federated Paint Manufacturing Co.	1882 S Normal St, Chicago IL 60616	8*
Ferro Corp. Coatings Div.	PO Box 6550, Cleveland OH 44101	73*

(continued)

**TABLE B-1.**  
**PAINT AND ALLIED PRODUCTS FACILITIES (SIC 2851) WITH**  
**ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Name	Address	Sales in \$ Millions
Fiber-Resin Corp.	PO Box 4187, Burbank CA 91503	10
Fine Line Paint Corp.	12234 Los Nietos Rd, Santa Fe Spr CA 90670	5
Finishes Unlimited Inc.	PO Box 69, Sugar Grove IL 60554	3
Finnaren & Haley Inc.	2320 Haverford Rd, Ardmore PA 19003	25*
Flecto Co. Inc.	PO Box 12955, Oakland CA 94608	20
Frank W Dunne Co.	1007 41st St, Oakland CA 94608	7
Frazee Indus Inc.	PO Box 2471, San Diego CA 92112	100
Fredericks-Hansen Paint	PO Box 5638, San Bernardino CA 92408	12
Fuller O'Brien Corp.	450 E Grand Ave, South San Francisco CA 94080	140
Gilbert Spruance Co.	Richmond St & Tioga St, Philadelphia PA 19134	10
Given Paint Manufacturing Co. Inc.	111 N Piedras St, El Paso TX 79905	7*
GJ Nikolas & Co. Inc.	2810 Washington Blvd, Bellwood IL 60104	2
Glidden Co. Eastern Region	PO Box 15049, Reading PA 19612	140
Glidden Co. Southwest Region	PO Box 566, Carrollton TX 75011	59
Glidden Co. Resin Div.	1065 Glidden St NW, Atlanta GA 30318	30
Gloss-Flo Corp.	135 Jackson St, Brooklyn NY 11211	4
Glyptal Inc.	305 Eastern Ave, Chelsea MA 02150	5
Gordon Bartels Co.	2600 Harrison Ave, Rockford IL 61108	7
Graham Paint & Varnish Co.	4800 S Richmond St, Chicago IL 60632	10*
Grow Group Inc. US Paint Div.	831 S 21st St, St. Louis MO 63103	30*
Grow Group Inc. Natl Aerosol Products Co.	2193 E 14th St, Los Angeles CA 90021	5
Grow Group Inc.	200 Park Ave, New York NY 10166	413
Guardsman Products Inc.	3033 Orchard Vista Dr, Grand Rapids MI 49501	190
Guardsman Chems Inc.	13535 Monster Rd, Seattle WA 98178	6
H Behlen & Brother Inc.	Route 30 N Perth Rd, Amsterdam NY 12010	10
Hancock Paint & Varnish	109 Accord Dr, Norwell MA 02061	10
Hanna Chem Coatings Inc.	PO Box 147, Columbus OH 43216	25
Harco Chem Coatings Inc.	208 DuPont St, Brooklyn NY 11222	6
Harrison Paint Corp.	PO Box 8470, Canton OH 44711	20
Hartin Paint & Filler	PO Box 116, Carlstadt NJ 07072	3
Hempel Coatings USA	201 Route 17 N, Rutherford NJ 07070	15
Hentzen Coatings Inc.	6937 W Mill Rd, Milwaukee WI 53218	12
Heresite Protective Coatings Inc.	PO Box 250, Manitowoc WI 54221	15
Hoboken Paint Co. Inc.	40 Indus Rd, Lodi NJ 07644	17
Hoffers Inc.	PO Box 777, Wausau WI 54401	47
Hy-Klas Paints Inc.	1401 S 12th St, Louisville KY 40210	6
Hydrosol Inc.	8407 S 77th Ave, Bridgeview IL 60455	30

(continued)

**TABLE B-1.  
PAINT AND ALLIED PRODUCTS FACILITIES (SIC 2851) WITH  
ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Name	Address	Sales in \$ Millions
ICI Americas Inc. ICI Paints	925 Euclid Ave, Cleveland OH 44115	843
Illinois Bronze Paint Co.	300 E Main St, Lake Zurich IL 60047	25
Indurall Coatings Inc.	PO Box 2371, Birmingham AL 35201	8
Industrial Coatings Intl.	7030 Quad Ave, Baltimore MD 21237	14*
Insilco Corp. Sinclair Paint Co.	6100 S Garfield Ave, Los Angeles CA 90040	100*
International Paint Co. USA Inc.	6001 Antoine, Houston TX 77091	50
International Paint Co. USA Inc. Southwest Div.	PO Box 920762, Houston TX 77292	18
International Coatings Co.	13929 E 166th St, Cerritos CA 90701	5
Irathane Syss Inc.	PO Box 276, Hibbing MN 55746	8*
IVC Indus Coatings Inc.	PO Box 18163, Indianapolis IN 46218	9
J Landau & Co. Inc.	PO Box 135, Carlstadt NJ 07072	4
James B Day & Co.	Day Ln, Carpentersville IL 60110	8
James Bute Co.	PO Box 1819, Houston TX 77251	3*
Jasco Chem Corp.	PO Drawer J, Mountain View CA 94040	7
John L Armitage & Co.	1259 Route 46 E, Parsippany NJ 07054	8*
Johnson Paints Inc.	PO Box 061319, Fort Myers FL 33906	9
Jones Blair Co. Gilman Paint & Wallcovering Div.	PO Box 1257, Chattanooga TN 37401	38
Kalcor Coatings Co.	37721 Stevens, Willoughby OH 44094	6
Kaufman Products Inc.	1326 N Bentalov St, Baltimore MD 21216	1*
Keeler & Long Inc.	PO Box 460, Watertown CT 06795	10
Kelly-Moore Paint Co. Inc. Hurst Div.	301 W Hurst Blvd, Hurst TX 76053	15
Kelly-Moore Paint Co.	987 Commercial St, San Carlos CA 94070	230*
King Fiber Glass Corp. Fiber Resin Supply Div.	366 W Nickerson St, Seattle WA 98119	2
Komac Paint Inc.	1201 Osage St, Denver CO 80204	10
Kop-Coat Co. Inc.	480 Frelinghuysen Ave, Newark NJ 07114	15
Kop-Coat Co. Inc. Pettit Paint Co.	36 Pine St, Rockaway NJ 07866	11
Kurfees Coatings Inc.	201 E Market St, Louisville KY 40202	16
Kwal-Howells Inc.	PO Box 39-R, Denver CO 80239	23
L & H Paint Products Inc.	PO Box 7311, San Francisco CA 94120	4
Lasting Paints Inc.	PO Box 4428, Baltimore MD 21223	6
Lenmar Inc.	150 S Calverton Rd, Baltimore MD 21223	13
Lilly Chem Products Inc.	PO Box 188, Templeton MA 01468	11
Lilly Industrial Coatings Inc.	733 S West St, Indianapolis, IN 46225	212
Lily Co. Inc.	PO Box 2358, High Point NC 27261	30
Linear Dynamics Inc.	400 Lanidex Plz, Parsippany NJ 07054	30

(continued)

**TABLE B-1.**  
**PAINT AND ALLIED PRODUCTS FACILITIES (SIC 2851) WITH**  
**ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Name	Address	Sales in \$ Millions
Lyle Van Patten Co. Inc.	321 W 135th St, Los Angeles CA 90061	3
MA Bruder & Sons Inc.	PO Box 600, Broomall PA 19008	140*
Maas & Waldstein Co.	2121 McCarter Highway, Newark NJ 07104	15
MAB Paints Inc.	630 N 3rd St, Terre Haute IN 47808	32
Magruder Color Co. Inc. Radiant Color Div.	PO Box 4019, Richmond CA 94804	30
Major Paint Co.	4300 W 190th St, Torrance CA 90509	65
Mansfield Paint Co. Inc.	169 W Longview Ave, Mansfield OH 44905	2
Martec Inc.	760 Aloha St, Seattle WA 98109	3
Martin-Senour Co.	101 Prospect Ave, Cleveland OH 44115	44*
Mautz Paint Co.	PO Box 7068, Madison WI 53707	19
McCormick Paint Works Co.	2355 Lewis Ave, Rockville, MD 20851	18*
McWhorter-McCloskey Inc.	5501 E Slauson Ave, Los Angeles CA 90040	5
Mercury Paint Co. Inc.	14300 Schaefer Highway, Detroit MI 48227	18
Mid-States Paint Co.	9315 Watson Indus Park, St. Louis MO 63126	3
Midwest Lacquer Manufacturing Co.	9353 Seymour Ave, Schiller Par IL 60176	5
Midwest Paint Manufacturing Co.	2313 W River Rd N, Minneapolis MN 55411	2
Millmaster Onyx Group Inc. Mantrose-Haeuser Co.	500 Post Rd E, Westport CT 06880	15
Mobile Paint Manufacturing Co.	4775 Hamilton Blvd, Theodore AL 36582	45
Mohawk Finishing Products	Route 30 N, Amsterdam NY 12010	35*
Moline Paint Manufacturing Co.	5400 23rd Ave, Moline IL 61265	17
Moling Paint Manufacturing	5400 23rd Ave, Moline IL 61265	125
Monarch Paint Co.	PO Box 55604, Houston TX 77255	29*
Morton Intl Inc. Norris Paint/TMT	PO Box 2023, Salem OR 97308	5
Muralo Co. Inc.	PO Box 455, Bayonne NJ 07002	42
Muralo Co. Inc. Olympic Paint & Chem Co.	5928 S Garfield Ave, Los Angeles CA 90040	2*
N Siperstein Inc.	415 Montgomery St, Jersey City NJ 07302	40
National Paint Co. Inc.	3441 E 14th St, Los Angeles CA 90023	3
National Lacquer & Paint Co.	7415 S Green St, Chicago IL 60621	2
Nelson Tech Coatings Inc.	2147 N Tyler Ave, South El Mon CA 91733	2
New York Bronze Powder Co. Inc.	519 Dowd Ave, Elizabeth NJ 07201	30
Niles Chem Paint Co.	PO Box 307, Niles MI 49120	16*
Norton & Son Inc.	148 E 5th St, Bayonne NJ 07002	15*
Nu-Brite Chem Co. Inc. Kyanize Paints	2nd & Boston St, Everett MA 02149	20
O'Brien Corp.	450 E Grand Ave, South San Francisco CA 94080	150*
O'Brien Corp. Powder Coatings Div.	5300 Sunrise Rd, Houston TX 77021	40
O'Brien Corp. Southeast Region	PO Box 864, Brunswick GA 31521	11*

(continued)

**TABLE B-1.  
PAINT AND ALLIED PRODUCTS FACILITIES (SIC 2851) WITH  
ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Name	Address	Sales in \$ Millions
Old Quaker Paint Co.	2209 S Main St, Santa Ana CA 92707	31
Orelite Chem Coatings	62 Woolsey St, Irvington NJ 07111	4
Pacific Coast Lacquer Co. Inc.	3150 E Pico Blvd, Los Angeles CA 90023	3
Palmer Paint Products Inc.	PO Box 1058, Troy MI 48099	7
Pan Chem Corp.	1 Washington Ave, Hawthorne NJ 07506	5
Paragon Paint & Varnish Corp.	5-49 46th Ave, Long Island NY 11101	14*
Parker Paint Manufacturing Co.	PO Box 11047, Tacoma WA 98411	26
Parks Corp.	PO Box 5, Somerset MA 02726	20
Parks Paint & Varnish Co. Inc.	660 Tonnelle Ave, Jersey City NJ 07307	3*
Passonno Paints	500 Broadway, Watervliet NY 12189	10
Pave-Mark Corp.	PO Box 94108, Atlanta GA 30318	20
PavePrep Corp.	141 Central Ave, Westfield NJ 07090	14*
Penn Color Inc.	400 Old Dublin Pike, Doylestown PA 18901	40
Pentagon Chem & Paint Co.	24 Woodward Ave, Ridgewood NY 11385	16*
Perfection Paint & Color Co.	715 E Maryland St, Indianapolis IN 46202	6*
Performance Coatings Inc.	PO Box 1569, Ukiah CA 95482	3
Perry & Derrick Co.	2510 Highland Ave, Cincinnati OH 45212	15
Pervo Paint Co.	6624 Stanford Ave, Los Angeles CA 90001	13
PFI Incorporated-Paints for Industry	921 Santa Fe Springs Rd, Santa Fe Spr CA 90670	2
Pierce & Stevens Corp.	710 Ohio St, Buffalo NY 14203	50
Plasti-Kote Co. Inc.	PO Box 708, Medina OH 44258	50
Plasticolors Inc.	2600 Michigan Ave, Ashtabula OH 44004	17
Plextone Corp. of America	2141 McCarter Highway, Newark NJ 07104	3
PMC Inc. Gen Plastics Div.	55-T La France Ave, Bloomfield NJ 07003	4
Ponderosa Paint Manufacturing Co. Inc.	PO Box 5466, Boise ID 83705	10
Porter Paint Co.	PO Box 1439, Louisville KY 40201	121
Potter Paint Co. Inc.	PO Box 265, Cambridge Ci IN 47327	2*
PPG Indus Architectual Finishes Inc.	2233 112th Ave NE, Bellevue WA 98004	110*
PPG Indus Inc. Automotive Products Group	PO Box 3510, Troy MI 48007	20*
Pratt & Lambert Inc.	75 Tonawanda St, Buffalo NY 14207	246
Pratt & Lambert Inc. Western Div.	PO Box 668, Marysville CA 95901	10
Premier Coatings Inc.	2250 Arthur Ave, Elk Grove Vi IL 60007	20
Preservative Paint Co. Inc.	5410 Airport Way S, Seattle WA 98108	13
Pro-Line Paint Manufacturing Co. Inc.	2646 Main St, San Diego CA 92113	7*
Proctor Paint & Varnish	38 Wells Ave, Yonkers NY 10701	20
Progress Paint Manufacturing Co.	PO Box 33188, Louisville KY 40232	10
Pruett-Schaffer Chem Co.	PO Box 4350, Pittsburgh PA 15204	4

(continued)

**TABLE B-1.**  
**PAINT AND ALLIED PRODUCTS FACILITIES (SIC 2851) WITH**  
**ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Name	Address	Sales in \$ Millions
Pyrolac Corp.	55 Schoon Ave, Hawthorne NJ 07506	4*
Quality Coatings Inc.	1700 N State, Chandler IN 47610	2
Raffi & Swanson Inc.	100 Eames St, Wilmington MA 01887	15
Randolph Products Co.	Park Place E, Carlstadt NJ 07072	9
Red Spot Paint Varnish Co. Red Spot Westland Inc.	550 S Edwin St, Westland MI 48185	15
Red Spot Paint Varnish Co.	PO Box 418, Evansville IN 47703	56
Reliable Coatings Inc.	13108 Euless St, Euless TX 76040	14*
Republic Clear Thru Corp.	211 63rd St, Brooklyn NY 11220	6
Republic Powdered Metals Inc.	PO Box 777, Median OH 44258	15
Riley Bros Inc.	860 Washington Ave, Burlington IA 52601	3
River Valley Coatings Inc.	PO Box 580, Aurora IL 60507	2*
Riverside Labs Inc.	411 Union St, Geneva IL 60134	3*
RJ McGlennon Co. Inc.	198 Utah St, San Francisco CA 94103	3
Roymal Inc.	Route 103, Newport NH 03773	4
RPM Inc.	PO Box 777, Medina OH 44258	380
Rudd Co. Inc.	1630 15th Ave W, Seattle WA 98119	10
Rust-Oleum Corp.	11 Hawthorne Parkway, Vernon Hills IL 60061	89
Rutland Fire Clay Co.	PO Box 340, Rutland VT 05702	2
Sampson Paint Manufacturing Co.	1900 Ellen Rd, Richmond VA 23224	42
Sampson Coatings Inc.	PO Box 6625, Richmond VA 23230	9
Sandstrom Products Co.	218 S High, Port Byron IL 61275	7
Saxon Paint & Home Care Centers Inc. Dreeblan Paint Co.	3729 W 49th St, Chicago IL 60632	15*
Schalk Chems Inc.	2400 Vauxhall Rd, Union NJ 07083	7
Scott Paint Corp.	5940 Palmer Blvd, Sarasota FL 34232	16*
Seagrave Coatings Corp. Clover Leaf Paint & Varnish	320 Paterson Plank Rd, Carlstadt NJ 07072	14*
Seaside Inc.	PO Box 2809, Long Beach CA 90801	3
Seibert-Oxidermo Inc.	6455 Strong Ave, Detroit MI 48211	11
SEM Products Inc.	120 Sem Ln, Belmont CA 94002	7
Sentry Paint Technologies Inc.	237 Mill St, Darby PA 19023	10
Seymour of Sycamore Inc.	917 Crosby Ave, Sycamore IL 60178	10
Sheboygan Paint Co.	PO Box 417, Sheboygan WI 53082	12
Sheffield Bronze Paint Corp.	17814 S. Waterloo Rd, Cleveland OH 44119	3
Sherwin-Williams Co.	101 Prospect Ave NW, Cleveland OH 44115	2,124
Sherwin-Williams Co. Automotive Div.	101 Prospect Ave NW, Cleveland OH 44115	160
Sherwin-Williams Co. Consumer Div.	101 Prospect Ave NW, Cleveland OH 44115	170*

(continued)

**TABLE B-1.  
PAINT AND ALLIED PRODUCTS FACILITIES (SIC 2851) WITH  
ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Name	Address	Sales in \$ Millions
Sherwin-Williams Co. Oakland	1450 Sherwin Ave, Oakland CA 94608	32*
Sherwin-Williams Co. Chem Coatings Div.	11541 S Champlain Ave, Chicago IL 60628	250
Sigma Coatings Co.	PO Box 816, Harvey LA 70059	15
Smiland Paint Co.	620 Lamar St, Los Angeles CA 90031	10
Snyder Bros Co.	PO Box 760, Toccoa GA 30577	7
Southern Coatings Inc.	PO Box 160, Sumter SC 29151	40
Southwestern Petroleum Corp.	PO Box 961005, Fort Worth TX 76161	26
Spatz Paints Inc.	1439 Hanley Industrial Ct, St. Louis MO 63144	5
Specialty Coating & Chem	7360 Varna Ave, North Hollywood CA 91605	3
Spectra-Tone Paint Corp.	9635 Klingerman St, South El Mon CA 91733	7
Spraylat Corp. Los Angeles	3465 S La Cienega, Los Angeles CA 90016	5
Stanchem Inc.	401 Berlin St, East Berlin CT 06023	10
Standard Detroit Paint Co.	8225 Lyndon Ave, Detroit MI 48238	8
Standard T Chem Co. Inc.	290 E Joe Orr Rd, Chicago Heights IL 60411	14*
Star Finishing Products Inc.	360 Shore Dr, Hinsdale IL 60521	15
Star Bronze Co.	PO Box 2206, Alliance OH 44601	11
STD Coating Corp.	461 Broad Ave, Ridgefield NJ 07657	3
Steelcote Manufacturing Corp.	3418 Gratiot St, St. Louis MO 63103	4
Sterling Twelve Star Paint	PO Box 791, Little Rock AR 72203	15
Sterling-Clark-Lurton	184 Commercial St, Malden MA 02148	9
Stevens Paint Corp.	38 Wells Ave, Yonkers NY 10701	15
Stonhard Inc.	PO Box 308, Maple Shade NJ 08052	62
Strathmore Products Inc.	1970 W Fayette St, Syracuse NY 13204	6
Sullivan Coatings Inc.	410 N Hart St, Chicago IL 60622	2*
Sunnyside Corp	225 Carpenter Ave, Wheeling IL 60090	14
Superior Varnish & Drier Co.	PO Box 1310, Merchantville NJ 08109	7*
Superior Sealants Inc.	1135 Sylvan SW, Atlanta GA 30310	11*
Supro Corp.	2650 Pomona Blvd, Pomona CA 91768	4
Technical Coatings Laboratory Inc.	PO Box 565, Avon CT 06001	6
Technical Coatings Inc.	PO Box 3337, Austin TX 78764	8
Technical Coatings Co.	1000 Walsh Ave, Santa Clara CA 95050	6
Tenax Finishing Products	390 Adams St, Newark NJ 07114	6*
Tera Lite Inc.	1631 S 10th St, San Jose Ca 95112	3
Testor Corp.	620 Buckbee St, Rockford IL 61106	43*
Thompson & Formby Inc.	825 Crossover Ln, Memphis TN 38117	44*
Ti-Kromatic Paints Inc.	2492 Doswell Ave, St. Paul MN 55108	3
Tnemec Co. Inc.	PO Box 411749, Kansas City MO 64141	50

(continued)

**TABLE B-1.**  
**PAINT AND ALLIED PRODUCTS FACILITIES (SIC 2851) WITH**  
**ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Name	Address	Sales in \$ Millions
Touraine Paints Inc.	1760 Revere Beach Parkway, Everett MA 02149	17
Tower Paint Manufacturing	620 W 27th St, Hialeah FL 33010	10
Trail Chem Corp.	9904 Gidley St, El Monte CA 91731	4
Triangle Coatings Inc.	1930 Fairway Dr, San Leandro CA 94577	5
United Paint & Chem Corp.	24671 Telegraph Rd, Southfield MI 48034	11*
United Coatings Inc.	2850 Festival Dr, Kankakee IL 60901	65
United Paint Co.	404 E Mallory, Memphis TN 38109	25
United Gilsonite Labs	PO Box 70, Scranton PA 18501	22*
Universal Paint Corp.	PO Box 1218, La Puente CA 91749	20
Universal Chems & Coatings Inc.	1975 Fox Ln, Elgin IL 60123	10
Universe Paint Co.	PO Box 668, Marysville CA 95901	3*
Valspar Corp. MCI Quality Coatings	6110 Gunn Highway, Tampa FL 33625	12
Valspar Corp. Colony Paints Div.	PO Box 418037, Kansas City MO 64141	15
Valspar Corp.	1101 S 3rd St, Minneapolis MN 55415	527
Valspar Corp. Masury Paint Co.	1401 Severn St, Baltimore MD 21230	8
Vanex Color Inc.	1700 Shawnee St, Mount Vernon IL 62864	4
VJ Dolan & Co. Inc.	1830 N Laramie Ave, Chicago IL 60639	5
Vogel Paint & Wax Inc. Marwin Paints Inc.	2100 N 2nd St, Minneapolis MN 55411	8*
Vogel Paint & Wax Inc.	Industrial Air Park Rd., Orange City IA 51041	100
Voplex Corp. Allerton Chem Div.	763 Linden Ave, Rochester NY 14625	1
Waterlox Chem & Coatings Corp.	9808 Meech Ave, Cleveland OH 44105	4
Watson-Standard Co. Jordan Paint Manufacturing Co.	7250 Franklin St, Forest Park IL 60130	4
Watson-Standard Co.	PO Box 11250, Pittsburgh PA 15238	29*
Wattyl Group Precision Paint Group	5275 Peachtree, Atlanta GA 30341	15
WC Richards Co. Inc.	3555 W 123rd St, Blue Island IL 60406	15*
Welco Manufacturing Co. Inc.	1225 Ozark St, North Kansas MO 64116	10
Wellborn Paint Manufacturing Co.	215 Rossmoor Rd SW, Albuquerque NM 87102	15
Western Automotive Finishes	1450 Ave R, Grand Prairi TX 75050	17*
Westfield Coatings Corp.	PO Box 815, Westfield MA 01086	7
Westinghouse Elec Corp. Insulating Materials Div.	Route 993, Manor PA 15665	15
Whittaker Corp. Whittaker Decatur Coatings	PO Box 2238, Decatur AL 35602	12*
William Zinsser & Co.	31 Belmont Dr, Somerset NJ 08873	16
Wiltech Corp.	PO Box 517, Longview WA 98632	2
Wisconsin Protective Coatings Corp.	PO Box 216, Green Bay WI 54305	10
WM Barr & Co. Inc.	PO Box 1879, Memphis TN 38113	95
Yenkin Majestic Paint Corp.	PO Box 369004, Columbus OH 43236	80

(continued)

**TABLE B-1.**  
**PAINT AND ALLIED PRODUCTS FACILITIES (SIC 2851) WITH**  
**ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Name	Address	Sales in \$ Millions
Zehrunge Corp	3273 Casitas Ave, Los Angeles CA 90039	2*
Zolatone Process Inc.	3411 E 15th St, Los Angeles CA 90023	6
ZPC Indus Coatings Inc.	120 E Minereal St, Milwaukee WI 53204	2
Zynolyte Products Co.	PO Box 6244, Carson CA 90749	25

\* Indicates an estimated financial figure.

Source: Gale Research, Inc. *Ward's Business Directory of U.S. Private and Public Companies-1991*, Volume 4. Detroit, MI. 1991.

**TABLE B-2.**  
**PRINTING INK MANUFACTURING FACILITIES (SIC 2893) WITH**  
**ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Name	Address	Sales in \$ Millions
Acme Printing Ink Co. Packaging Inc. Corp.	5001 S Mason Ave, Chicago IL 60638	100
Acme Printing Ink Co.	165 Bond St, Elk Grove Vi IL 60007	140*
AJ Daw Printing Ink Co.	3559 S Greenwood Ave, Los Angeles CA 90040	13
American Inks & Coatings Corp.	PO Box 803, Valley Forge PA 19482	15
Autoroll Machine Corp.	11 River St, Middleton MA 01949	12
BASF Corp. Coatings & Colorants Div.	1255 Broad St, Clifton NJ 07015	105*
Bomark Inc.	601 S 6th Ave, City of Indu CA 91746	3
Borden Inc. Coatings & Graphics Group	630 Glendale - Milford, Cincinnati OH 45215	17*
Braden Sutphin Ink Co.	3650 E 93rd St, Cleveland OH 44105	25
Celia Corp.	320 Union St, Sparta MI 49345	15
Central Ink & Chem	1100 N Harvester Rd, West Chicago IL 60185	9
Colonial Printing Ink Corp	180 E Union Ave, East Rutherford NJ 07073	17
Converters Ink Co.	1301 S Park Ave, Linden NJ 07036	16*
Croda Inks Corp.	7777 N Merrimac, Niles IL 60648	32*
Custom Chem Corp.	30 Paul Kohner Pl, Elmwood Park NJ 07407	40
Del Val Ink & Color Co. Inc.	1301 Taylors Ln, Riverton NJ 08077	5
Excello Color & Chem	1446 W Kinzie St, Chicago IL 60622	84*
Flint Ink Corp.	25111 Glendale Ave, Detroit MI 48234	235
Flint Ink Corp. Capitol Printing Ink	806 Channing Pl NE, Washington DC 20018	23
Flint Ink Corp.	1404 4th St, Berkeley CA 94710	30*
Gans Ink & Supply Co. Inc.	1441 Boyd St, Los Angeles CA 90033	18
Gotham Ink & Color Co. Inc.	5-19 47th Ave, Long Island NY 11101	4
Graphic Color Corp.	750 Arthur Ave, Elk Grove Vi IL 60007	18
Handschy Ink & Chems Inc.	120 25th Ave, Bellwood IL 60104	30
Ink Masters Inc.	2842 S 17th Ave, Broadview IL 60153	3
James River Corp. of Virginia CZ Inks Div.	4150 Carr Ln, St. Louis MO 63119	28
JM Huber Corp. Carbon Div.	9300 Needlepoint Rd, Baytown TX 77521	18*
Kerley Ink Engineers Inc.	2839 19th Ave, Broadview IL 60153	4*
Kohl & Madden Printing Ink Corp.	222 Bridge Plz Sq, Hackensack NJ 07601	45
Lakeland Laboratory Inc. Alfa Ink Div.	655 Washington Ave, Carlstadt NJ 07072	2*
Lakeland Laboratory Inc.	655 Washington Ave, Carlstadt NJ 07072	3
Lawter Intl Inc.	990 Skokie Blvd, Northbrook IL 60062	136
Merit Printing Inc. Co.	1451 S Lorena St, Los Angeles CA 90023	4*

(continued)

**TABLE B-2.**  
**PRINTING INK MANUFACTURING FACILITIES (SIC 2893) WITH**  
**ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Name	Address	Sales in \$ Millions
Midland Color Co.	651 Bonnie Ln, Elk Grove Vi IL 60007	85
Miller-Cooper Co.	1601 Prospect Ave, Kansas City MO 64127	6
Morrison Printing Ink Co.	4801 W 160th St, Cleveland OH 44135	14*
Naz-Dar Co.	1087 N Northbranch St, Chicago IL 60622	15*
Nor-Cote Intl Inc.	PO Box 668, Crawfordsville IN 47933	5
North American Printing Ink	1524 David Rd, Elgin IL 60123	14
Northern Printing Ink Corp.	8360 10th Ave N, Minneapolis MN 55427	8
Polypore Inc.	4601 S 3rd Ave, Tucson AZ 85714	10
Polytex Color & Chem	820 E 140th St, Bronx NY 10454	3
PPG Indus Inc. PPG Ink Products Co.	1835 Airport Exchange Blvd, Covington KY 41018	15
Rexart Chem Corp.	1183 Westside Ave, Jersey City NJ 07306	6*
Ron Ink Co. Inc.	61 Halstead St, Rochester NY 14610	7
Sicpa Indus of America Inc.	8000 Research Way, Springfield VA 22153	25
Sinclair & Valentine LP	2520 Pilot Knob Rd, St. Paul MN 55120	186
Sun Chem Corp.	PO Box 1302, Fort Lee NJ 07024	1,100
Sun Chem Corp. Gen. Printing Ink Div.	135 W Lake St, Northlake IL 60164	410*
Superior Printing Ink Co. Inc.	70 Bethune St, New York NY 10014	50
United States Printing Ink Corp. Leber Ink Div.	PO Box 88700, Seattle WA 98138	6
United States Printing Ink Corp.	343 Murray Hill Pkwy, East Rutherford NJ 07073	65
Van Son Holland Corp. of America	92 Union St, Mineola NY 11501	42
Vivitone Inc.	110 E 27th St, Paterson NJ 07514	8
Walter W Lawrence	9715 Alpaca St, South El Mon CA 91733	1
Wikoff Color Corp.	PO Box W, Fort Mill SC 29715	45*

\*Indicates an estimated financial figure.

Source: Gale Research, Inc. *Ward's Business Directory of U.S. Private and Public Companies-1991*, Volume 4. Detroit, MI. 1991.

**TABLE B-3.  
PRINTING AND PUBLISHING FACILITIES (SIC 27) WITH  
ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Company	Location	Sales in \$ Millions
<b>(SIC 2711) Newspapers</b>		
Advance Publications Inc.	Staten Island, NY	2,200*
Affiliated Publications Inc.	Boston, MA	542
Chicago Tribune Co.	Chicago, IL	500
Cox Enterprises Inc.	Atlanta, GA	1,970
Dow Jones & Co. Inc.	Washington, DC	1,444
EW Scripps Co.	Wilmington, DE	1,266
Freedom Newspapers Inc.	Irvine, CA	500
Gannett Co. Inc.	Arlington, VA	3,518
Hearst Corp.	New York, NY	1,900*
Ingersoll Publications Co.	Princeton, NJ	1,010*
Knight-Ridder Inc.	Miami, FL	2,268
Media Gen Inc.	Richmond, VA	606
New York Times Co.	New York, NY	1,769
News America Publishing Inc.	New York, NY	3,000
Thomson Newspapers Corp.	Des Plaines, IL	550*
Times Mirro Co.	Los Angeles, CA	3,475
Tribune Co.	Chicago, IL	2,455
<b>(SIC 2721) Periodicals</b>		
ABC Publishing	New York, NY	310*
Billboard Publications Inc.	New York, NY	100
BPI Communications Inc.	New York, NY	105
Cahners Publishing Co. New York Magazine Div.	New York, NY	102
Chilton Co.	Radnor, PA	150
CMP Publications Inc.	Manhasset, NY	187*
Conde Nast Publications Inc.	New York, NY	280*

(continued)

**TABLE B-3.  
PRINTING AND PUBLISHING FACILITIES (SIC 27) WITH  
ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Company	Location	Sales in \$ Millions
Crain Communicating Inc.	Chicago, IL	145
Diamonds Communications Inc.	New York, NY	470*
Edgell Communications Inc.	Cleveland, OH	205
Forbes Inc.	New York, NY	200
International Data Group Inc.	Framingham, MA	500
Meredith Corp.	Des Moines, IA	792
Meredith Corp. Ladies' Home Journal	New York, NY	100
National Enquirer Inc.	Lantana, FL	180
National Geographic Soc.	Washington, DC	425
Newsweek Inc.	New York, NY	256
Official Airline Guides Inc.	Oak Brook, IL	130*
Penthouse Intl. Ltd.	New York, NY	160*
Penton Publishing Inc.	Cleveland, OH	151
Peterson Publishing Co.	Los Angeles, CA	140*
Playboy Enterprises Inc.	Chicago, IL	160
Reader's Digest Assn. Inc.	Pleasantville, NY	1,832
Reed Publishing (USA) Inc. Cahners Publishing Co.	Newton, MA	430
Reed Publishing (USA) Inc.	Newton, MA	600
Rodale Press Inc.	Emmaus, PA	150*
Scholastic Inc.	New York, NY	250*
Simon & Shuster Inc. Bur of Bus Practice	Waterford, CT	100*
Standard & Poor's Corp.	New York, NY	260*
Thompson Corp. Thompson Bus. Info.	Stamford, CT	160*
Time Inc. Magazine Co.	New York, NY	1,500*
Times Mirror Magazines Inc.	New York, NY	470*

(continued)

**TABLE B-3.**  
**PRINTING AND PUBLISHING FACILITIES (SIC 27) WITH**  
**ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Company	Location	Sales in \$ Millions
Trader Publications Inc.	Clearwater, FL	270*
US News & World Report Inc.	New York, NY	140*
Warren Gorham & Lamont Inc.	New York, NY	130
Whittle Communications Inc.	Knoxville, TN	210*
Ziff Communications Co.	New York, NY	340*
Ziff Communications Co. Zif-Davis Publishing Co.	New York, NY	160*
<b>(SIC 2731) Book Publishing</b>		
Addison-Wesley Publishing Co.	Reading, MA	120*
Bantam Doubleday Dell Publishing Group Inc.	New York, NY	180*
David C. Cook Publishing Co.	Elgin, IL	100
Encyclopedia Britannica Inc.	Chicago, IL	624
Field Publications	Middletown, CT	100*
Grolier Inc.	Danbury, CT	440*
Harcourt Brace Jovanovich Inc.	Orlando, FL	1,341
Harper Collins Publishers Inc.	New York, NY	450
Houghton Mifflin Co.	Boston, MA	370
Insilco Corp.	Midland, TX	450*
John Wiley & Sons Inc.	New York, NY	282
Lawyers Co-Operative Publishing Co. Inc.	Rochester, NY	150*
Macmillan Inc.	New York, NY	950*
Macmillan Inc. Info Svcs & Instruction	New York, NY	416
MacMillan Intl. Inc.	New York, NY	146*
Macmillan-McGraw-Hill School Publishing Co. School Div.	New York, NY	200

(continued)

**TABLE B-3.**  
**PRINTING AND PUBLISHING FACILITIES (SIC 27) WITH**  
**ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Company	Location	Sales in \$ Millions
Macmillian-McGraw-Hill School Publishing Co.	Lake Forest, IL	390*
McGraw-Hill Inc. McGraw-Hill Intl Book Group	New York, NY	115
Mosby Year Book Inc.	St. Louis, MO	150
Prentice Hall Inc.	New York, NY	970*
Putnam Publishing Group, Inc.	New York, NY	100
Rand McNally & Co.	Skokie, IL	430*
Random House, Inc.	New York, NY	325
RR Donnelley & Sons Co. Willard Div.	Willard, OH	150
Simon & Schuster Inc.	New York, NY	1,320
South-Western Publishing Co.	Cincinnati, OH	112
Sunday School Bd of the Southern Baptist Convention	Nashville, TN	172
Time-Life Books Inc.	Alexandria, VA	350
West Publishing Co.	St. Paul, MN	450*
Western Publishing Group Inc.	Racine, WI	480
World Book Inc.	Chicago, IL	330*
Zondervan Corp.	Grand Rapids, MI	100*
<b>(SIC 2732) Book Printing</b>		
Arcata Graphics Co. Arcata Graphics Book Group	Kingsport, TN	170*
Banta Corp.	Menasha, WI	568
Bertelsmann Printing & Mfg. Corp.	Berryville, VA	220*
Brown Printing Co. (Waseca Minnesota)	Waseca, MN	363
Great Lakes Color Printing Corp.	Brentwood, TN	210*
Harper & Row Publishers	New York, NY	450

(continued)

**TABLE B-3.  
PRINTING AND PUBLISHING FACILITIES (SIC 27) WITH  
ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Company	Location	Sales in \$ Millions
Jostens Inc. Printing & Publishing Div.	Minneapolis, MN	121
RR Donnelley & Sons Co.	Chicago, IL	3,122
<b>(SIC 2741) Misc Publishing</b>		
Commerce Clearing House Inc.	Riverwoods, IL	678
Donnelley Directory	New York, NY	1,300*
GTE Telephone Operations Inc. GTE Directories Corp.	Dallas-Fort, TX	360*
McGraw-Hill Info. Svcs. Co.	New York, NY	668
NYNEX Info Resources Co.	Middleton, MA	800
RL Polk & Co.	Detroit, MI	280
Simplicity Holdings, Inc.	New York, NY	110*
Simplicity Pattern Co.	New York, NY	101
Southwestern Bell Yellow Pages Inc.	St. Louis, MO	240*
Southwestern Bell Publications Inc.	St. Louis, MO	280*
U.S. West Direct (U.S. West Marketing Resources Group Inc.)	Aurora, CO	160*
Wonderland Music Co. Inc.	Burbank, CA	200*
<b>(SIC 2752) Commercial Printing-Lithographic</b>		
American Signature Graphics Foote & Davies Div.	Atlanta, GA	195
American Bank Stationary Co.	Baltimore, MD	110*
Avery Intl Corp. Avery Label Co.	Azusa, CA	110*
Graphic Controls Corp.	Buffalo, NY	140
Graphisphere Corp.	Des Plaines, IL	110
HS Crocker Co. Inc.	South San Francisco, CA	140*
Judd's Inc.	Washington, DC	114
NMG Inc.	Los Angeles, CA	105

(continued)

**TABLE B-3.**  
**PRINTING AND PUBLISHING FACILITIES (SIC 27) WITH**  
**ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Company	Location	Sales in \$ Millions
Perry Printing Corp.	Waterloo, WI	175
Quebecor Printing (USA) Inc.	St. Paul, MN	770
Queens Group Inc.	Long Island, NY	100
Ringler America Inc.	Itasca, IL	700
RR Donnelley & Sons Co. Mattoon Mfg. Div.	Mattoon, IL	110*
RR Donnelley & Sons Co. Lancaster Mfg. Div.	Lancaster, PA	190*
Shea Communications Co.	Louisville, KY	120
Taylor Corp.	Mankato, MN	540*
Treasure Chest Advertising Co. Inc.	Glendora, CA	550*
Valassis Inserts Inc.	Livonia, MI	400*
World Color Press Inc.	Effingham, IL	650
<b>(SIC 2754) Commercial Printing-Gravure</b>		
All-State Legal Supply Co.	Cranford, NJ	43
Arcata Graphics Co.	Baltimore, MD	500*
Beck Co. (Langhorne Pennsylvania)	W, Langhorne, PA	10
Clark Printing Co. Inc.	North Kansas, MO	14*
ColorArt Inc.	St. Louis, MO	30
Dennison Mfg. Co. IPC Dennison Co.	Rogersville, TN	60
Dinagraphics Inc.	Cincinnati, OH	20
Golden Belt Mfg. Co.	Durham, NC	70
Graphic Ctr. Cos. Inc. Blake Printery	St. San Luis Obi, CA	11
International Label Co.	Clarksville, TN	30
JW Fergusson & Sons	Richmond, VA	34
Maxwell Communications Corp. Atglen	Atglen, PA	50*
McCleery-Cumming Co.	Washington, IA	22

(continued)

**TABLE B-3.**  
**PRINTING AND PUBLISHING FACILITIES (SIC 27) WITH**  
**ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Company	Location	Sales in \$ Millions
Meredith-Burda Corp.	Des Moines, IA	500
Perry Printing Corp. Norway Div.	Norway, MI	25*
Printing House Inc. (Quincy Florida)	Quincy, FL	24
Ringier America Inc. Corinth Div.	Corinth, MS	80
Sheridan Press	Hanover, PA	15
Southern Gravure Svc. Inc.	Louisville, KY	58*
Stevens Graphics Inc.	Atlanta, GA	150
Technographic Inc. Decotone	Lexington, SC	30
World Color Press Inc. Salem Gravure Div.	Salem, IL	80
<b>(SIC 2759) Commercial Printing Nec</b>		
Alden Press Inc.	Elk Grove Village, IL	170*
Avery Intl. Corp. Soabar Products Group	Philadelphia, PA	100*
Bowne & Co. Inc.	New York, NY	190
Curtis 1000 Inc.	Atlanta, GA	160*
Data Documents Inc. (Omaha)	Omaha, NE	200
Deluxe Corp.	St. Paul, MN	1,316
Duplex Products Inc.	Sycamore, IL	327
Graphic Indus. Inc.	Atlanta, GA	310
John H. Harland Co.	Atlanta, GA	345
Maxwell Commun Corp.	St. Paul, MN	720*
Meehan-Tooker Inc.	East Rutherford, NJ	110
Quad Graphics Inc.	Pewaukee, WI	380
RR Donnelley & Sons Co. Warsaw Mfg. Div.	Warsaw, IN	160*
Webcraft Technologies Inc.	North Brunswick, NJ	220*
Williamhouse-Regency Inc.	New York, NY	230

(continued)

**TABLE B-3.**  
**PRINTING AND PUBLISHING FACILITIES (SIC 27) WITH**  
**ANNUAL SALES GREATER THAN \$1 MILLION (continued)**

Company	Location	Sales in \$ Millions
World Color Press Inc. Spartan Printing Co.	Sparta, IL	100*
<b>(SIC 2761) Manifold Business Forms</b>		
Allied Paper Inc. Allied-Energy Syss Inc.	Dayton, OH	130*
American Bus Products Inc.	Atlanta, GA	387
Arnold Corp.	Dayton, OH	200
CST Group Inc.	Wheeling, IL	110
Ennis Bus. Forms Inc.	Ennis, TX	130
McGregor Printing Corp.	Washington, DC	125
Moore Corp. Ltd. Moore Bus. Forms & Syss. Div.	Glenview, IL	1,675
New England Bus. Svc. Inc.	Groton, MA	226
Office Electronic Inc.	Itasca, IL	105
Standard Register Co.	Dayton, OH	709
Uarco Inc.	Barrington, IL	520*
Vanier Graphics Corp. (American Bus. Products Inc.)	Santee, CA	133
Wallace Computer Svcs. Inc.	Hillside, IL	429
<b>(SIC 2771) Greeting Cards</b>		
American Greetings Corp.	Cleveland, OH	1,309
American Greetings Corp. Seasonal Div.	Oscoola, AR	110
Current Inc. (Colorado Springs Colorado)	Colorado Springs, CO	160
Gibson Greetings Inc.	Cincinnati, OH	463
Hallmark Cards Inc.	Kansas City, MO	2,500
Hallmark Cards Inc. Topeka Products	Topeka, KS	120*

\* Indicates an estimated financial figure

Source: Gale Research, Inc. *Ward's Business Directory of U.S. Private and Public Companies-1991*, Volume 4. Detroit, MI. 1991.

APPENDIX C  
XYLENE SOURCE CATEGORIES IN SURFACE COATING OPERATIONS

**TABLE C-1.  
XYLENE SOURCE CATEGORIES IN  
SURFACE COATING OPERATIONS<sup>a</sup> (continued)**

General Source Category	Associated SIC(s)	Emission Point Sources	Emissions reduction by process/product modification	Additional References
Large Appliances	3585,3631-3639,3651	[1] Application area [2] Flashoff area [3] Oven areas [4] Coating mixing [5] Coating and solvent storage [6] Equipment cleanup [7] All solvent used and not recovered or destroyed may be considered potential emission sources	[1] Thermal incineration [2] Catalytic incineration [3] Carbon adsorbers [4] Waterborne coatings [5] High solids materials	7,8
Magnet Wire	3546, 3621, 3643, 3351, 3357	[1] Coating application (low emissions) [2] Exhaust oven (high emissions) [3] Coating mixing [4] Coating and solvent storage [5] Equipment cleanup [6] All solvent used and not recovered or destroyed can be considered potential emission sources	[1] Thermal incineration [2] Catalytic incineration [3] Ultraviolet cure coatings [4] Waterborne coatings [5] Powder coatings	9
Automobiles and Light Duty Trucks. (Locomotives and heavy-duty trucks, hopper car and tank interiors, and paint and drum interiors are covered under metal products.)	3711-16	[1] Cleaning pretreatment [2] Application area [3] Flashoff area [4] Oven areas [5] Coating mixing [6] Coating and solvent storage [7] Equipment cleanup [8] All solvent used and not recovered or destroyed can be considered potential emission sources	[1] Thermal incineration [2] Catalytic incineration [3] Carbon adsorber [4] Waterborne coatings [5] Powder coatings	10,11,12

(continued)

**TABLE C-1.  
XYLENE SOURCE CATEGORIES IN  
SURFACE COATING OPERATIONS<sup>a</sup> (continued)**

General Source Category	Associated SIC(s)	Emission Point Sources	Emissions reduction by process/product modification	Additional References
Can Two-piece  Three-piece	3411-12	[1] Coating area [2] Flashoff area: two piece and exterior base coating, interior spray coating, sheet basecoating (interior), sheet basecoating (exterior), side seam spray coating, end sealing compound, lithography, over varnish [3] Oven areas [4] Coating mixing [5] Coating and solvent storage [6] Equipment cleanup [7] All solvent used and not recovered or destroyed can be considered potential emission sources	[1] Thermal incineration [2] Catalytic incineration [3] Waterborne coatings for two piece cans [4] High solids coatings [5] Powder coating-side seam coating of uncemented three piece cans [6] Carbon adsorption-low temperature processes [7] Ultraviolet cure coatings	10,13,14
Metal Coils	3444, 3449, 3353, 3354, 3479	[1] Application area [2] Flashoff area: prime coating, finish coating, [3] Exhaust oven area [4] Quench area [5] Fugitive emissions [6] Solvent mixing [7] Solvent storage [8] Equipment cleanup [9] All solvent used and not recovered or destroyed can be considered potential emission sources	[1] Thermal incineration [2] Catalytic incineration [3] Waterborne coatings	10,15,16
Paper and Paperboard	2621, 2631, 2652-53, 2656, 2657, 2671-72, 2675, 2676, 2678-79	[1] Application area [2] Oven areas [3] Coating mixing [4] Coating and solvent storage [5] Equipment cleanup [6] All solvent used and not recovered or destroyed can be considered potential emission sources	[1] Carbon adsorber [2] Thermal incinerator [3] Catalytic incinerator [4] Condensers	10

(continued)

**TABLE C-1.  
XYLENE SOURCE CATEGORIES IN  
SURFACE COATING OPERATIONS<sup>a</sup> (continued)**

General Source Category	Associated SIC(s)	Emission Point Sources	Emissions reduction by process/product modification	Additional References
Adhesives and Sealants	2891	[1] Adhesive application [2] Drying oven exhaust [3] Solvent mixing [4] Solvent storage [5] All solvent used and not recovered or destroyed can be considered potential emission sources	[1] Thermal incineration [2] Carbon adsorption	17,18
Wood Products	2426-29, 2434, 452, 2511-12, 2515, 2517, 2519, 2521, 2531, 2541, 3995	[1] Application area [2] Flashoff coating operations [3] Oven areas [4] Coating mixing [5] Coating and solvent storage [6] Equipment cleanup [7] All solvent used and not recovered or destroyed can be considered potential emission sources	[1] Waterborne coatings [2] Carbon adsorption [3] Thermal incineration [4] Catalytic incineration	19
Flatwood Products	2435-36, 2491-99	[1] Application area [2] Flashoff area: Filler, sealer, basecoat, topcoat, inks [3] Oven areas [4] Coating mix [5] Coating and solvent storage [6] Equipment cleanup [7] All solvent used and not recovered or destroyed can be considered potential emission sources	[1] Waterborne coatings specially in filler and basecoat [2] Ultraviolet cure coatings [3] Afterburners [4] Carbon adsorption	11,20
Misc. Metal Parts and Products	2514, 2522, 2542, 2599, 3412-99, 3511-69, 3581-82, 3586-99	[1] Application area [2] Flashoff area: flow coating, dip coating or spray application [3] Oven areas [4] Coating mixing [5] Coating and solvent storage [6] Equipment cleanup [7] All solvent used and not recovered can be considered potential emission sources	[1] Thermal incinerator [2] Catalytic incinerator [3] Carbon adsorbers [4] Waterborne coatings [5] Powder coatings [6] High solids coating	21,22,23,24

(continued)

**TABLE C-1.  
XYLENE SOURCE CATEGORIES IN  
SURFACE COATING OPERATIONS<sup>a</sup> (continued)**

General Source Category	Associated SIC(s)	Emission Point Sources	Emissions reduction by process/product modification	Additional References
Plastic Products	2821, 2823, 3079, 3080, 3081-89, 3432, 3731	[1] Coating application [2] Flashoff area: flow coating, dip coating or spray application [3] Coating mixing [4] Coating and solvent storage [5] Equipment cleanup [6] All solvent used and not recovered can be considered potential emission sources	[1] Carbon adsorber [2] Thermal incinerator [3] Catalytic incinerator	25
Large Ships	3731	[1] Coating application [2] Flashoff: prime coat operation, topcoat operation [3] Oven areas [4] Coating mixing [5] Coating and solvent storage [6] Equipment cleanup [7] All solvent used and not recovered or destroyed can be considered potential emission sources	None	26
Large Aircraft	3721-28	[1] Coating application [2] Flashoff: prime coat operation, topcoat operating [3] Oven areas [4] Coating and solvent storage [5] Equipment cleanup [6] All solvent used and not recovered or destroyed can be considered potential emission sources	Unknown	26

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APPENDIX D  
SUMMARY OF XYLENE EMISSION FACTORS  
LISTED IN THIS DOCUMENT

**TABLE D-1.  
SUMMARY OF XYLENE EMISSION FACTORS**

<b>SIC</b>	<b>SIC Description</b>	<b>SCC</b>	<b>SCC Description</b>	<b>Emission Factor</b>	<b>Quality Rating</b>	<b>Reference</b>	<b>Note</b>
2865	Cyclic Crudes and Intermediates	407	Organic Chemicals Storage	0.02 g of o-xylene/kg xylene used	U	5-4	Storage of phthalic anhydride
2865	Cyclic Crudes and Intermediates	407	Organic Chemicals Storage-Fixed Roof Tanks	0.2 g/kg phthalic anhydride produced	E	5-4	Storage of phthalic anhydride from the xylene process-uncontrolled
2865	Cyclic Crudes and Intermediates	30101901	Chemical Manufacturing	0.14 g of o-xylene/kg xylene used	U	5-4	Phthalic anhydride - process emissions
2865	Cyclic Crudes and Intermediates	301019	Chemical Manufacturing	0.04 g of o-xylene/kg xylene used	U	5-4	Phthalic anhydride - fugitive emissions
2865	Cyclic Crudes and Intermediates	407	Organic Chemicals Storage-Fixed Roof Tanks	0.002 g/kg phthalic anhydride produced	E	5-4	Controlled emissions Storage of phthalic anhydride from the xylene process
2865	Cyclic Crudes and Intermediates	301100	Chemical Manufacturing-Maleic anhydride	11.6 g/kg maleic anhydride produced	U	5-4	Maleic anhydride - process emissions
2865	Cyclic Crudes and Intermediates	301100	Chemical Manufacturing-Maleic anhydride	0.4 g/kg maleic anhydride produced	U	5-4	Maleic anhydride - fugitive emissions
2865	Cyclic Crudes and Intermediates	301100	Chemical Manufacturing-Maleic anhydride	0.075 g/kg maleic anhydride produced	U	5-4	Storage of maleic anhydride
2865	Cyclic Crudes and Intermediates	30116901	Chemical Manufacturing-Ethylbenzene-General	0.1 kg/Mg xylene used	U	4-10	Process emissions
2865	Cyclic Crudes and Intermediates	30116980	Chemical Manufacturing-Ethylbenzene-Fugitives	0.05 g/kg xylene used	E	4-10	Fugitive emissions - equipment leaks
2865	Cyclic Crudes and Intermediates	407036	Organic Chemical Storage-Fixed Roof Tanks	0.05 kg/Mg xylene used	U	4-10	Storage of mixed benzenes
2869	Industrial Organic Chemicals	301258	Chemical Manufacturing-Organic Chemicals	1.58 kg/Mg m-xylene produced	U	4-10	m-xylene production - process emissions
2869	Industrial Organic Chemicals	301258	Chemical Manufacturing-Organic Chemicals	0.3 kg/Mg m-xylene produced	U	4-10	Fugitive emissions - equipment leaks

(continued)

**TABLE D-1.  
SUMMARY OF XYLENE EMISSION FACTORS (continued)**

SIC	SIC Description	SCC	SCC Description	Emission Factor	Quality Rating	Reference	Note
2869	Industrial Organic Chemicals	301258	Chemical Manufacturing-Organic Chemicals	0.12 kg/Mg m-xylene produced	U	4-10	Storage of m-xylene
2869	Industrial Organic Chemicals	301258	Chemical Manufacturing-Organic Chemicals	2.09 kg/Mg o-xylene produced	D	4-10	o-xylene production - process emissions
2869	Industrial Organic Chemicals	301258	Chemical Manufacturing-Organic Chemicals	0.38 kg/Mg o-xylene produced	D	4-10	Fugitive emissions - equipment leaks
2869	Industrial Organic Chemicals	301258	Chemical Manufacturing-Organic Chemicals	0.06 kg/Mg o-xylene stored	D	4-10	Storage of o-xylene
2869	Industrial Organic Chemicals	30125810	Chemical Manufacturing - p-xylene: General	1.14 kg/Mg p-xylene produced	D	4-10	p-xylene production - process emissions
2869	Industrial Organic Chemicals	30125810	Chemical Manufacturing - p-xylene: General	0.24 kg/Mg p-xylene produced	D	4-10	Fugitive emissions - equipment leaks
2869	Industrial Organic Chemicals	30125810	Chemical Manufacturing - p-xylene: General	0.19 kg/Mg p-xylene produced	D	4-10	Storage of p-xylene
2869	Industrial Organic Chemicals	30125815	Chemical Manufacturing Mixed Xylenes: General	0.5 kg/Mg xylene produced	U	4-10	Coal-derived mixed xylene treating tanks
2869	Industrial Organic Chemicals	30125815	Chemical Manufacturing Mixed Xylenes: General	0.15 kg/Mg xylene produced	U	4-10	Fugitive emissions - equipment leaks from xylene production from coal-derived mixed xylenes
2869	Industrial Organic Chemicals	30125815	Chemical Manufacturing Mixed Xylenes: General	0.6 kg/Mg xylene produced	U	4-10	Storage of coal-derived mixed xylenes
2869	Industrial Organic Chemicals	30125815	Chemical Manufacturing Mixed Xylenes: General	0.07 kg/Mg xylene produced	D	4-10	Process emissions - ethylene cracking unit from production of xylene from pyrolysis gasoline
2869	Industrial Organic Chemicals	30125815	Chemical Manufacturing Mixed Xylenes: General	0.03 kg/Mg xylene produced	D	4-10	Fugitive emissions - equipment leaks from xylene production from pyrolysis gasoline

(continued)

**TABLE D-1.  
SUMMARY OF XYLENE EMISSION FACTORS (continued)**

SIC	SIC Description	SCC	SCC Description	Emission Factor	Quality Rating	Reference	Note
2869	Industrial Organic Chemicals	30125815	Chemical Manufacturing Mixed Xylenes: General	0.3 kg/Mg xylene produced	D	4-10	Storage of mixed xylene produced from pyrolysis gasoline
2869	Industrial Organic Chemicals	30125815	Chemical Manufacturing Mixed Xylenes: General	0.03 kg/Mg xylene produced	D	4-10	Fugitive emissions - equipment leaks from xylene production from catalytic reforming
2869	Industrial Organic Chemicals	30125815	Chemical Manufacturing Mixed Xylenes: General	0.06 kg/Mg xylene produced	D	4-10	Storage of mixed xylene produced from catalytic reformat
2869	Industrial Organic Chemicals	30125815	Chemical Manufacturing Mixed Xylenes: General	0.05 kg/Mg xylene produced	U	4-10	Fugitive emissions - equipment leaks from xylene production from toluene disproportionation
2869	Industrial Organic Chemicals	30125815	Chemical Manufacturing Mixed Xylenes: General	0.1 kg/Mg xylene produced	U	4-10	Storage of mixed xylene produced from toluene disproportionation
2869	Industrial Organic Chemicals	30103102	Chemical Manufacturing - Terephthalic Acid Reactor Vent	6 g/kg crude terephthalic acid produced	D	5-4	Uncontrolled
2869	Industrial Organic Chemicals	30103102	Chemical Manufacturing - Terephthalic Acid-Reactor Vent	0.18 g/kg crude terephthalic acid produced	D	5-4	Controlled by carbon adsorption, 97 percent reduction
2869	Industrial Organic Chemicals	30103101	Chemical Manufacturing - Terephthalic Acid-General	2.54 g of p-xylene/kg xylene used	D	5-4	Process emissions
2869	Industrial Organic Chemicals	301031	Chemical Manufacturing - Terephthalic Acid	0.11 g of p-xylene/kg xylene used	D	5-4	Storage of mixed xylenes for terephthalic acid production
2869	Industrial Organic Chemicals	301031	Chemical Manufacturing - Terephthalic Acid	0.11 g/kg crude terephthalic acid produced	D	5-4	Storage p-xylene - tank vents-filling emissions, uncontrolled
2869	Industrial Organic Chemicals	30103180	Chemical Manufacturing - Terephthalic Acid	0.07 g of p-xylene/kg xylene used	D	5-4	Fugitive emissions

(continued)

**TABLE D-1.  
SUMMARY OF XYLENE EMISSION FACTORS (continued)**

SIC	SIC Description	SCC	SCC Description	Emission Factor	Quality Rating	Reference	Note
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels	4.39 mg/liter gasoline transferred (winter blend*) 0.82 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Gasoline loading - Any typical barge (any previous cargo)
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels	2.62 mg/liter gasoline transferred (winter blend*) 0.49 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Gasoline loading - Gas-freed barge (any previous cargo)
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels	4.98 mg/liter gasoline transferred (winter blend*) 0.93 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Gasoline loading - Uncleaned barge (volatile previous cargo)
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels	2.19 mg/liter gasoline transferred (winter blend*) 0.41 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Gasoline loading - Ballasted ship/ocean barge (volatile previous cargo)
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels	2.3 mg/liter gasoline transferred (winter blend*) 0.43 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Gasoline loading - Typical ship/ocean barge (any previous cargo)
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels	1.07 mg/liter gasoline transferred (winter blend*) 0.2 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Gasoline - Tanker ballasting
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels	3.37 mg/liter gasoline transferred (winter blend*) 0.63 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Gasoline loading - Uncleaned ship/ocean barge (volatile previous cargo)

(continued)

**TABLE D-1.  
SUMMARY OF XYLENE EMISSION FACTORS (continued)**

SIC	SIC Description	SCC	SCC Description	Emission Factor	Quality Rating	Reference	Note
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels	0.91 mg/liter gasoline transferred (winter blend*) 0.17 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Gasoline loading - Any condition ship/ocean barge (non-volatile previous cargo)
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels	0.91 mg/liter gasoline transferred (winter blend*) 0.17 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Gasoline loading - Gas-freed ship/ocean barge (volatile previous cargo)
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels	1.93 mg/liter gasoline transferred (winter blend*) 0.36 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Gasoline loading - Cleaned ship/ocean barge (volatile previous cargo)
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels	3.42 mg/liter gasoline transferred (winter blend*) 0.64 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Gasoline loss - Marine vessel transit
4953	Refuse Systems	502002	Solid Waste Disposal - Open Burning	0.480 kg/metric ton of tires	E	7-7	Shred tire scrap (burn rate 2.3 kg/hr) - uncontrolled
4953	Refuse Systems	502002	Solid Waste Disposal - Open Burning	1.036 kg/metric ton of tires	E	7-7	Shred tire scrap (burn rate 1.4 kg/hr) - uncontrolled
4953	Refuse Systems	502002	Solid Waste Disposal - Open Burning	1.063 kg/metric ton of tires	E	7-7	Shred tire scrap (burn rate 1.3 kg/hr) - uncontrolled
4953	Refuse Systems	502002	Solid Waste Disposal - Open Burning	0.736 kg/metric ton of tires	E	7-7	Shred tire scrap (burn rate 1.5 kg/hr) - uncontrolled
4953	Refuse Systems	502002	Solid Waste Disposal - Open Burning	1.962 kg/metric ton of tires	E	7-7	Shred tire scrap (burn rate 0.8 kg/hr) - uncontrolled
4953	Refuse Systems	502002	Solid Waste Disposal - Open Burning	3.212 kg/metric ton of tires	E	7-7	Chunk tire scrap (burn rate 0.5 kg/hr) - uncontrolled

(continued)

**TABLE D-1.  
SUMMARY OF XYLENE EMISSION FACTORS (continued)**

SIC	SIC Description	SCC	SCC Description	Emission Factor	Quality Rating	Reference	Note
4953	Refuse Systems	502002	Solid Waste Disposal - Open Burning	0.111 kg/metric ton of tires	E	7-7	Chunk tire scrap (burn rate 2.27 kg/hr) - uncontrolled
4953	Refuse Systems	502002	Solid Waste Disposal - Open Burning	0.381 kg/metric ton of tires	E	7-7	Chunk tire scrap (burn rate 1.27 kg/hr) - uncontrolled
4953	Refuse Systems	502002	Solid Waste Disposal - Open Burning	0.294 kg/metric ton of tires	E	7-7	Chunk tire scrap (burn rate 3.5 kg/hr) - uncontrolled
4953	Refuse Systems	502002	Solid Waste Disposal - Open Burning	0.147 kg/metric ton of tires	E	7-7	Chunk tire scrap (burn rate 6.63 kg/hr) - uncontrolled
4953	Refuse Systems	502002	Solid Waste Disposal - Open Burning	0.454 kg/metric ton of tires	E	7-7	Chunk tire scrap (burn rate 1.7 kg/hr) - uncontrolled
4953	Refuse Systems	502002	Solid Waste Disposal - Open Burning	1.208 kg/metric ton of tires	E	7-7	Chunk tire scrap (burn rate 0.9 kg/hr) - uncontrolled
5171	Petroleum Bulk Stations and Terminals	40400250	Bulk Plants-Miscellaneous-Loading Racks	6.3 mg/liter gasoline transferred (winter blend*) 1.2 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Top or bottom submerged loading of gasoline at a typical gasoline bulk plant (throughput of 5,000 gal/day) - uncontrolled
5171	Petroleum Bulk Stations and Terminals	404001	Bulk Terminals-Miscellaneous	6.3 mg/liter gasoline transferred (winter blend*) 1.2 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Top or bottom submerged loading
5171	Petroleum Bulk Stations and Terminals	40400250	Bulk Plants-Miscellaneous-Loading Racks	10.5 mg/liter gasoline transferred (winter blend*) 2.0 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Balance service loading of a typical gasoline bulk plant (throughput of 5,000 gal/day) - uncontrolled
5171	Petroleum Bulk Stations and Terminals	404001	Bulk Terminals-Miscellaneous	10.5 mg/liter gasoline transferred (winter blend*) 2.0 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Balanced service gasoline loading

(continued)

**TABLE D-1.  
SUMMARY OF XYLENE EMISSION FACTORS (continued)**

SIC	SIC Description	SCC	SCC Description	Emission Factor	Quality Rating	Reference	Note
5171	Petroleum Bulk Stations and Terminals	40400250	Bulk Plants-Miscellaneous-Loading Racks	15.3 mg/liter gasoline transferred (winter blend*) 2.9 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Splash loading of gasoline of a typical gasoline bulk plant (throughput of 5,000 gal/day) - uncontrolled
5171	Petroleum Bulk Stations and Terminals	40400250	Bulk Terminals-Miscellaneous	15.3 mg/liter gasoline transferred (winter blend*) 2.9 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Splash loading
5171	Petroleum Bulk Stations and Terminals	404002	Bulk Plants-Fixed Roof Tanks	6.4 mg/liter gasoline transferred (winter blend*) 1.2 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Breathing loss (throughput of 5,000 gal/day) - uncontrolled - typical gasoline bulk plant
5171	Petroleum Bulk Stations and Terminals	404002	Bulk Plants-Fixed Roof Tanks	12.3 mg/liter gasoline transferred (winter blend*) 2.3 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Filling loss (throughput of 5,000 gal/day) - Uncontrolled
5171	Petroleum Bulk Stations and Terminals	404002	Bulk Plants-Fixed Roof Tanks	4.9 mg/liter gasoline transferred (winter blend*) 0.9 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Drainage losses - Gasoline throughput of 19,000 l/day - Uncontrolled emissions
5171	Petroleum Bulk Stations and Terminals	404001	Bulk Terminals-Fixed Roof Tanks	0.36 mg/year/tank gasoline (winter blend*) 0.067 mg/year/tank gasoline (summer blend*)	U	6-28 6-33	Working loss - Terminals with tank capacity 2680 m <sup>2</sup> Throughput of 950,000 l/day with 4 storage tanks
5171	Petroleum Bulk Stations and Terminals	404001	Bulk Terminals-Fixed Roof Tanks	0.09 mg/year/tank gasoline (winter blend*) 0.017 mg/year/tank gasoline (summer blend*)	U	6-28 6-33	Breathing loss - Tank capacity 2680 m <sup>3</sup> - Terminal with 950,000 l/day throughput with 4 storage tanks

(continued)

**TABLE D-1.  
SUMMARY OF XYLENE EMISSION FACTORS (continued)**

SIC	SIC Description	SCC	SCC Description	Emission Factor	Quality Rating	Reference	Note
5171	Petroleum Bulk Stations and Terminals	404001	Bulk Terminals-External Floating Roof Tanks	1.68 x 10 <sup>-7</sup> Q mg/year gasoline throughput (winter blend*) 3.13 x 10 <sup>-8</sup> Q mg/year gasoline throughput (summer blend*) where Q is the throughput through the tank in barrels	U	6-28 6-33	Working loss - Tank capacity 5760 m <sup>3</sup> - Terminal with 950,000 l/day throughput with 4 storage tanks
5171	Petroleum Bulk Stations and Terminals	404001	Bulk Plants-External Floating Roof Tanks	0.04 mg/year/tank (winter blend*) 0.0067 mg/year/tank (summer blend*)	U	6-28 6-33	Storage loss-tank with secondary metallic shoe seal and a capacity of 36,000 barrels
5171	Petroleum Bulk Stations and Terminals	404001	Bulk Plants-Floating Roof Tanks	0.09 mg/year/tank (winter blend*) 0.017 mg/year/tank (summer blend*)	U	6-28 6-33	Storage loss-tank with primary seal only and a capacity of 36,000 barrels
5541	Gasoline Service Stations	40600307	Petroleum Marketing-Service Stations-Stage I-Breathing-Underground Tank	120 mg/liter gasoline stored (winter blend*) 7.6 mg/liter gasoline stored (summer blend*)	U	6-28 6-33	Breathing losses from underground storage tank throughput of 190,000 l/month - Uncontrolled emissions
5541	Gasoline Service Stations	40600306	Petroleum Marketing-Service Stations-Stage I-Submerged Filling-Balanced	1.3 mg/liter gasoline stored (winter blend*) 0.2 mg/liter gasoline stored (summer blend*)	U	6-28 6-33	Balanced submerged filling of underground tanks (throughput of 190,000 l/month) Uncontrolled emissions
5541	Gasoline Service Stations	40600302	Petroleum Marketing-Service Stations-Stage I-Submerged Filling-No control	9.4 mg/liter gasoline stored (winter blend*) 1.8 mg/liter gasoline stored (summer blend*)	U	6-28 6-33	Submerged filling of underground tanks (throughput of 190,000 l/month) Uncontrolled emissions
5541	Gasoline Service Stations	40600301	Petroleum Marketing-Service Stations-Stages I-Splash Filling	14.8 mg/liter gasoline stored (winter blend*) 2.8 mg/liter gasoline stored (summer blend*)	U	6-28 6-33	Splash filling of underground tanks (throughput of 190,000 l/month) Uncontrolled emissions

(continued)

**TABLE D-1.  
SUMMARY OF XYLENE EMISSION FACTORS (continued)**

SIC	SIC Description	SCC	SCC Description	Emission Factor	Quality Rating	Reference	Note
5541	Gasoline Service Stations	40600403	Petroleum Marketing-Service Stations Stage II-Vapor-Controlled Displacement	0.6 mg/liter gasoline transferred (winter blend*) 0.3 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Controlled displacement vehicle refueling losses (throughput of 190,000 l/month)
5541	Gasoline Service Stations	40600401	Petroleum Marketing-Service Stations Stage II-Vapor-No Control	5.5 mg/liter gasoline transferred (winter blend*) 2.6 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Uncontrolled displacement vehicle refueling losses (throughput of 190,000 l/month)
5541	Gasoline Service Stations	40600402	Petroleum Marketing-Service Stations-Stage II-Liquid Spill-No control	0.4 mg/liter gasoline transferred (winter blend*) 0.2 mg/liter gasoline transferred (summer blend*)	U	6-28 6-33	Vehicle refueling spillage losses (throughput of 190,000 l/month) Uncontrolled
N/A	N/A	N/A	N/A	$2.57 \times 10^{-3}$ gram/vehicle mile travelled	U	6-27	Evaporation from automobile fuel tank
N/A	N/A	N/A	N/A	0.109 gram/vehicle mile travelled	U	6-27	Automobile exhaust

\*Based on typical fractions of xylene in winter and summer gasoline.

(continued)

**TABLE D-2.  
SUMMARY OF VOC EMISSION FACTORS\***

<b>SIC</b>	<b>SIC Description</b>	<b>SCC</b>	<b>SCC Description</b>	<b>Emission Factor</b>	<b>Quality Rating</b>	<b>Reference</b>	<b>Note</b>
2869	Industrial Organic Chemicals	30125815	Mixed Xylene Production-General	0.104 kg/hr/source	U	4-12	Fugitives-Gas/vapor pressure relief seals
2869	Industrial Organic Chemicals	30125815	Mixed Xylene Production-General	0.00083 kg/hr/source	U	4-12	Fugitives-Flanges
2869	Industrial Organic Chemicals	30125815	Mixed Xylene Production-General	0.0017 kg/hr/source	U	4-12	Fugitives-Open ended lines
2869	Industrial Organic Chemicals	30125815	Mixed Xylene Production-General	0.015 kg/hr/source	U	4-12	Fugitives-Sampling connections
2869	Industrial Organic Chemicals	30125815	Mixed Xylene Production-General	0.0056 kg/hr/source	U	4-12	Fugitives-Gas valves
2869	Industrial Organic Chemicals	30125815	Mixed Xylene Production-General	0.0071 kg/hr/source	U	4-12	Fugitives-Light liquid valves
2869	Industrial Organic Chemicals	30125815	Mixed Xylene Production-General	0.00023 kg/hr/source	U	4-12	Fugitives-Heavy liquid valves
2869	Industrial Organic Chemicals	30125815	Mixed Xylene Production-General	0.0494 kg/hr/source	U	4-12	Fugitives-Light liquid pump seals
2869	Industrial Organic Chemicals	30125815	Mixed Xylene Production-General	0.0214 kg/hr/source	U	4-12	Fugitives-Heavy liquid pump seals
2869	Industrial Organic Chemicals	30125815	Mixed Xylene Production-General	0.228 kg/hr/source	U	4-12	Fugitives-Gas/vapor compressor seals

Note: To obtain xylene leak emission factor for each component, multiply VOC emission factor above by the fraction of xylene in the stream.