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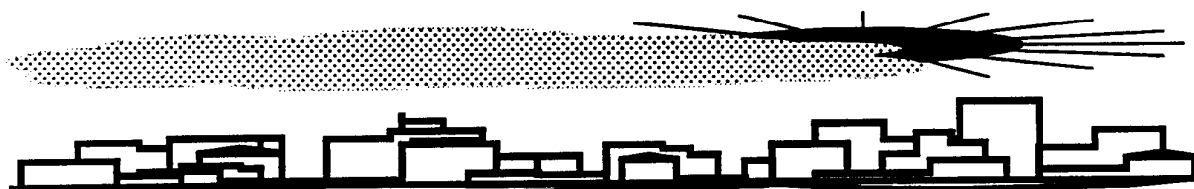
Office of Air Quality
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Research Triangle Park, NC 27711

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Air



LOCATING AND ESTIMATING AIR EMISSIONS FROM SOURCES OF TOLUENE



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LOCATING AND ESTIMATING AIR EMISSIONS
FROM SOURCES OF TOLUENE

Final Report

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EXECUTIVE SUMMARY

Emissions of toluene into the atmosphere are of special significance because of the Clean Air Act Amendments of 1990. These amendments mandate that toluene emissions 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 toluene emissions. This document is designed to assist groups interested in inventorying air emissions of toluene by providing a compilation of available information on sources and emissions of this substance.

Toluene is a man-made aromatic hydrocarbon produced mostly from petroleum. In the U.S., the Virgin Islands and Puerto Rico, toluene is produced by 21 companies at 30 plants. Most toluene produced is derived from petroleum fractions. In 1991, 3,104,000 megagrams (944 million gallons) of toluene were recovered. Growth in demand is expected to be very modest over the next few years.

Toluene is used as a cleaning solvent in the coating, printing and leather industry and in the manufacturing of paints and coatings, inks, adhesives, resins, and pharmaceuticals. It is also used as an intermediate in the production of benzene and toluene diisocyanate, and for gasoline blending.

At the time of publication of this document, estimates of nationwide emissions of toluene 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
Perchloroethylene and Trichloroethylene	EPA-450/2-90-013
1,3-Butadiene	EPA-450/2-89-021
Chromium (supplement)	EPA-450/2-89-002

<u>Substance</u>	<u>EPA Publication Number</u>
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 toluene. Its intended audience includes Federal, State, and local air pollution personnel and others who are interested in locating potential emitters of toluene, and making gross estimates of air emissions therefrom.

Because of the limited amounts of data available on potential sources of toluene emissions, and since the process configurations, control equipment, and operating procedures 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 toluene, (2) process variations and release points that may be expected within these sources, and (3) available emissions information indicating the potential for toluene 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 toluene 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 in some cases a material balance should be considered as the best means to determine air emissions directly from an operation.

Another potential source of emissions data for toluene is the Toxic Chemical Release Inventory (TRI) form required by Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA 313).¹ 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. Accidental releases are also accounted for in the TRI, but are not included in inventories of toxic-air pollutants. In many cases, the TRI data are based on annual estimates of emissions (*e.g.*, 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 toluene, 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 in some cases 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. 52 FR 21152. 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 toluene 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 toluene, 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 toluene. Section 5.0 discusses the uses of toluene as industrial feedstocks and major solvent uses, particularly degreasing and coating operations. Section 6.0 addresses emissions as a result of releases from toluene-containing products after manufacture. Section 7.0 describes emissions sources from the manufacture of products other than toluene, or as a by-product of processes (*e.g.*, burning of fuel oil). 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. Individual companies involved with either the production or use of toluene are reported throughout the document. Information reported is extracted primarily from trade publications.

Section 8.0 of this document summarizes available procedures for source sampling and analysis of toluene. 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 toluene emissions by Standard Industrial Classification (SIC) code and associated description. These potential source categories do not necessarily denote significant sources of toluene emissions. 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 *Volatile Organic Compound (VOC)/Particulate Matter (PM) Speciation Database Management System, Version 1.4* (October 1991).^{1,2} Appendix B lists 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 operations using toluene-containing coatings. Appendix D summarizes, in table format, all the emission factors listed in this document.

Each emission factor listed in Sections 3.0 through 7.0 has been assigned an emission factor grade based on the criteria for assigning data quality and emission factor ratings as required in the document *Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections*. These criteria for rating test data used to develop emission factors are presented below.³ 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 (*e.g.*, 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 also may be evidence of variability within the source category population. Limitations on the use of the emission factor are footnoted in the 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. 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:⁴

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

*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 toluene. 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.

EPA recently acquired air toxics emissions information from the California Air Resources Board (CARB) as part of the California Rule AB-2588. The AB-2588 regulations allow for facilities to perform pooled source testing. The tests may be used to derive emission factors for all sources of the same type. Several of the pooled source test reports contain information on toluene emissions; however, the reports were unavailable when this document was prepared.⁵

Information from the Toluene section of the SRI *Chemical Economics Handbook* was also unavailable. This source is believed to contain the most recent production information and would be useful in confirming toluene facilities, capacities, and production processes.

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*, Draft Document. 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.
5. Memorandum from Theresa K. Moody and Candace R. Blackley, Radian Corporation, to Anne Pope, EIB, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, "Evaluating California Air Toxics Emissions Data for Air Toxics Compounds," February 28, 1992.

SECTION 3.0 BACKGROUND

3.1 NATURE OF POLLUTANT

Toluene is a man-made aromatic hydrocarbon produced mostly from petroleum. This chemical intermediate is the predominant feedstock in benzene production and a key octane-boosting component for gasoline blending. Toluene is also used as a raw material in the production of other chemicals (*e.g.*, toluene diisocyanate and benzoic acid) and as a solvent in paints and coatings, inks, adhesives, and pharmaceuticals.¹

Toluene's molecular formula is $C_6H_5CH_3$; its molecular structure is represented as:

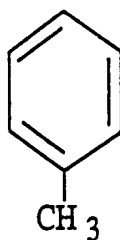


Table 3-1 summarizes the chemical identification information for toluene, and Table 3-2 presents toluene's chemical and physical properties. This colorless liquid is volatile, flammable, and explosive in air. Toluene will react with airborne hydroxyl radicals (OH[•]), atomic oxygen (O), ozone (O₃), and peroxy radicals (RO₂) where R is an alkyl or aryl group to form a variety of oxidation products. Toluene is not corrosive and will not react with dilute acids or bases. Purified toluene (nitration grade) normally contains less than 0.01 percent benzene, while the industrial grade may contain up to 25 percent benzene.²

Toluene is released in the environment from several man-made sources, including the following:²

- inadvertent sources (65 percent), such as emissions from motor vehicles and aircraft exhaust, losses during gasoline marketing activities, chemical spills, and cigarette smoke

**TABLE 3-1.
CHEMICAL IDENTIFICATION OF TOLUENE**

Chemical name	Toluene
Synonyms	Methylbenzene; toluol; phenylmethane; methacide; methylbenzol
Molecular formula	C ₆ H ₅ CH ₃
Identification numbers: ^a	
CAS Registry	108-88-3
NIOSH RTECS	XS 5250000
EPA Hazardous Waste	U220
OHM/TADS	7216928
DOT/UN/NA	UN 1294; Toluene (Toluol)
NCI	C07272
STCC	49 093 05; Toluene

^aCAS (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 (Department of Transportation/United Nations/North America); NCI (National Cancer Institute); STCC (Standard Transport Commodity Code)

Source: References 3-5

TABLE 3-2.
PHYSICAL AND CHEMICAL PROPERTIES OF TOLUENE

Property	Value
Molecular weight (grams)	92.14
Melting point	-95 to -94.5°C (-139 to -138.1°F)
Boiling point (760 mm Hg)	110.63°C (231.13°F)
Density, g/cm ³ at 25°C (77°F) at 20°C (68°F)	0.8623 0.8667
Physical state (ambient conditions)	Liquid
Color	Clear
Odor	Benzene-like
Odor threshold: Range	0.17 ppm 0.17 - 40 ppm
Solubility: Water at 20°C (68°F) Organic solvents	Very slightly soluble (0.05 g/100 mL) Miscible with absolute alcohol, ether, and chloroform Soluble in acetone
Partition coefficients: Log ₁₀ octanol/water	2.69 (at 20°C or 68°F)
Vapor pressure at 20°C (68°F) at 30°C (86°F) at 40°C (104°F)	21.9 mm Hg (2.92 kPa) 36.7 mm Hg (4.89 kPa) 59.3 mm Hg (7.91 kPa)
Auto ignition temperature	480°C (896°F)
Flashpoint ^a	4.4°C (40°F) (C.C.) 16°C (60.8°F) (O.C.)
Conversion factors (Vapor weight to volume)	1 ppm = 3.824 mg/m ³ (at 20°C)

^aC.C. (closed cup); O.C. (open cup)

Source: References 3-5

- processes in which toluene is used (33 percent)
- toluene production (2 percent)

It is estimated that 86 percent of the toluene produced is eventually released into the biosphere (primarily the troposphere), where its lifetime ranges from 4 days (at high-altitudes during the summer) to several months (at low-altitudes during the winter). The average toluene half-life resulting from atmospheric oxidation is estimated to be 12.8 hours.²

Toluene released to water may be removed by activated sludge degradation, biodegradation, and/or volatilization. The expected evaporative half-life of toluene in water is approximately five hours in water one meter in depth (3.28 feet).²

3.2 OVERVIEW OF PRODUCTION AND USE

The total annual capacity of toluene manufacturing facilities in the United States, the Virgin Islands, and Puerto Rico was 5,344,000 megagrams (1,625 million gallons) in 1989.⁶ The majority of toluene (99.5 percent) is produced from petroleum fractions. Catalytic reformates, produced by catalytic reforming, account for approximately 94.5 percent of the production capacity feedstocks. Pyrolysis gasolines, another petroleum feedstock, account for an additional five percent of feedstock materials. Coke-oven light oil comprises the remaining 0.5 percent of production capacity. In 1989, 21 companies produced toluene at 30 manufacturing sites.^{1,6}

Toluene is manufactured for use as an intermediate in the production of benzene (50 percent) and toluene diisocyanate (9 percent), for gasoline blending (34 percent), for solvents (5 percent), and for the production of miscellaneous chemicals (2 percent).¹ As a solvent, toluene is used in paints and coatings, inks, adhesives, resins, pharmaceuticals, and other formulated products requiring a solvent carrier. Toluene is also used as a cleaning solvent in surface coating, printing, and the leather industry. In addition to benzene and toluene diisocyanate, toluene derivatives include benzoic acid, benzyl chloride, trinitrotoluene, vinyl toluene, toluenesulfonic acid, benzaldehyde, and toluenesulfonyl chloride.^{1,3} Figure 3-1 illustrates some

of the end uses of toluene. These uses are discussed in detail in Sections 5.0 and 6.0. A list of all potential toluene emission sources organized according to SIC code and associated description is presented in Appendix A. It is important to note that these source categories do not necessarily denote significant sources of toluene emissions, but only that these sources have the potential to emit toluene.

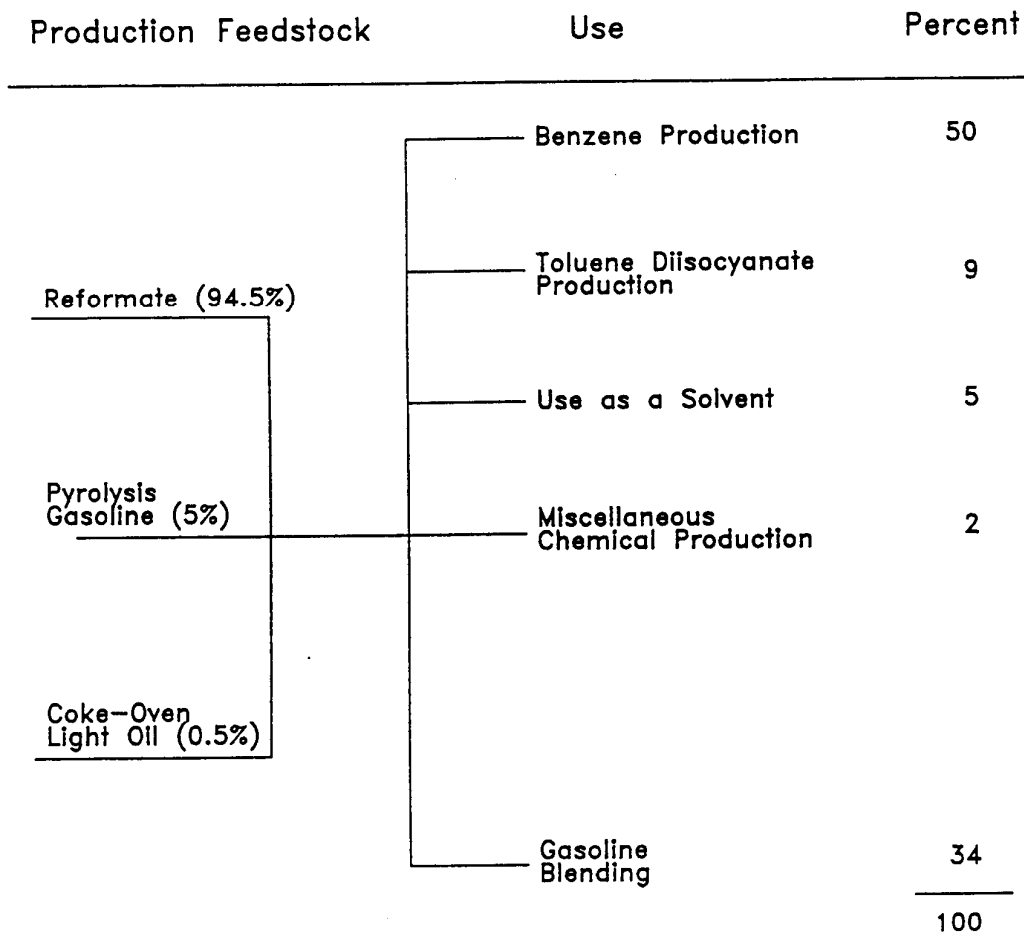


Figure 3-1. Chemical use tree for toluene^{1,3,6}

3.3 REFERENCES FOR SECTION 3.0

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SECTION 4.0 EMISSIONS FROM TOLUENE PRODUCTION

Toluene production and the associated air emissions are described in this section. Process flow diagrams are included as appropriate, with specific streams or vents in the figures labeled to correspond with the discussion in the text. Emission factors for the production processes are presented when available, and associated control technologies are described. If a particular facility is being included in an inventory, 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.

Toluene is currently produced by 21 companies at 30 plants in the United States, the Virgin Islands, and Puerto Rico. The production locations and capacities are presented in Table 4-1.¹ In 1991, 3,104,000 megagrams (944 million gallons) of toluene were recovered compared with a 1989 total annual capacity of approximately 5,344,000 megagrams (1,625 million gallons).^{1,2} In 1989 eight facilities, representing seven companies, had annual capacities exceeding 55 million gallons. Collectively, Amoco, Exxon, BP, Sun, Amerada Hess, Phillips, Mobil, and Chevron accounted for 72 percent of the total toluene capacity in the United States, the Virgin Islands, and Puerto Rico. The capacities listed in Table 4-1 are approximations, as most aromatics operations have some flexibility in the amount of toluene they recover. Table 4-1 also identifies the feedstock (*e.g.*, catalytic reformat (reformat), coke-oven light oil, or pyrolysis gasoline) from which toluene is recovered.¹

Although the domestic extraction and distillation capacity for toluene exceeds 4,932 millions of kilograms (1.5 billion gallons), the projected domestic demand for 1992 is only 2,795 millions of kilograms (850 million gallons) with growth expected to be very modest over the next few years.² No growth or slight growth in toluene demand is anticipated because of the trend to remove aromatics from gasoline blending in favor of adding oxygenated octane enhancers. If significant amounts of toluene are removed from the gasoline pool, toluene surpluses will occur possibly resulting in lower prices and industry-wide containment difficulties. Use of toluene in most solvent and chemical applications has also slowed. Using toluene to

TABLE 4-1.
TOLUENE PRODUCTION LOCATIONS AND CAPACITIES

Facility	Location	1989 Capacity Millions of Kilograms (Millions of Gallons)	Feedstock
Amerada Hess Corporation	St. Croix, WI	460 (140)	Reformate
American Petrofina Incorporated	Port Arthur, TX	170 (52)	Reformate
Amoco Corporation	Texas City, TX	806 (245)	Reformate
Ashland Oil, Inc.	Catlettsburg, KY	79 (24)	Reformate
		26 (8)	Coke-oven light oil
Atlantic Richfield Company	Channelview, TX	105 (32)	Pyrolysis gasoline
	Houston, TX	99 (30)	Reformate
BP America, Inc. (Sohio)	Alliance, LA	197 (60)	Reformate
	Lima, OH	329 (100)	Reformate
Champlin Petroleum Co.	Corpus Christi, TX	99 (30)	Reformate
Chevron Corporation	Philadelphia, PA Port Arthur, TX	79 (24)	Reformate
		92 (28)	Reformate
		39 (12)	Pyrolysis gasoline
Dow Chemical U.S.A.	Freeport, TX	13 (4)	Pyrolysis gasoline
Exxon Corporation	Baytown, TX	605 (184)	Reformate
Kerr-McGee Corporation	Corpus Christi, TX	135 (41)	Reformate
Koch Industries, Inc.	Corpus Christi, TX	247 (75)	Reformate
Mobil Corporation	Beaumont, TX	148 (45)	Reformate
		16 (5)	Pyrolysis gasoline
	Chalmette, LA	109 (33)	Reformate
Occidental Petroleum Corp.	Chocolate Bayou, TX	82 (25)	Pyrolysis gasoline

(continued)

TABLE 4-1.
TOLUENE PRODUCTION LOCATIONS AND CAPACITIES

Facility	Location	1989 Capacity Millions of Kilograms (Millions of Gallons)		Feedstock
Phillips Petroleum Company	Sweeny, TX	95	(29)	Reformate
	Guayama, PR	243	(74)	Reformate
Salomon Inc.	Houston, TX	46	(14)	Reformate
Shell Oil Company	Deer Park, TX	164	(50)	Reformate
Sun Company, Inc.	Marcus Hook, PA	158	(48)	Reformate
	Toledo, OH	233	(71)	Reformate
	Tulsa, OK	76	(23)	Reformate
Texaco, Inc.	Delaware City, DE	135	(41)	Reformate
	El Dorado, KS	36	(11)	Reformate
Unocal Corporation	Beaumont, TX	95	(29)	Reformate
	Lemont, IL	62	(19)	Reformate
USX Corporation (Marathon)	Texas City, TX	66	(20)	Reformate

Source: Reference 1

NOTE: This listing is subject to change as market conditions change, facility ownership changes, plants are closed down, etc. The reader should verify the existence of particular facilities by consulting current listings and/or the plants themselves. The level of toluene emissions from any given facility is a function of variables such as capacity, throughput and control measures, and should be determined through direct contacts with plant personnel. These operating plants and locations were current as of January 1989.

produce benzene via hydrodealkylation is one exception, as benzene demand is expected to grow at approximately three percent per year.³ Table 4-2 shows historical and projected figures for domestic toluene capacity, production, imports, exports and demand. Similarly, other countries anticipate a slow growth or decline in toluene production. Table 4-3 shows historical production in other industrialized nations.

TABLE 4-2.
ESTIMATED DOMESTIC U.S. SUPPLY AND DEMAND OF
TOLUENE

	Millions of Kilograms (Millions of Pounds) By Year								
	1985	1986	1987	1988	1989	1990	1992		
Production									
Petroleum	320 (705)	340 (749 ^E)	439 (967)	397 (874)	365 (804 ^E)	N/A		N/A	
Coke	.45 (1)	-- --	-- --	-- --	--				
Total	320 (705)	340 (749)	439 (967)	397 (874)	365 (804)				
Imports	71 (157)	63 (138)	43 (95)	56 (123)	40 (87)	N/A		N/A	
Exports	13 (28)	12 (27)	62 (136)	35 (76)	49 (108)	N/A		N/A	
Demand	379 (834)	391 (860 ^E)	421 (926)	419 (921)	356 (783)	364	(800)	386	(850)

Since 1982 the United States International Trade Commission (USITC) has not reported toluene production by coke-oven operators. Coke-oven output has been insignificant since 1986. Sales data for toluene produced by petroleum refiners include only high-purity (98 to 100 percent) toluene. It is assumed that all indicated output is high purity.

E - Estimated figure (Mannsville Chemical Products Corp.)³

N/A - Not available

Source: Reference 3

Most of the toluene 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 toluene 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).⁴ It is from this stream that the majority of toluene is produced by catalytic reforming via hydrotreating. A second refinery stream, also used as a feedstock in toluene 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

TABLE 4-3.
WORLD-WIDE TOLUENE PRODUCTION

Country	Millions of Kilograms (Millions of Pounds) By Year				% Change 1990-91
	1988	1989	1990	1991	
France	47 (104)	34 (74)	34 (74)		---
Germany ^{a,b}	605 (1,330)	538 (1,184)	418 (919)	460 (1,013)	10
Italy ^b	218 (480)	152 (338)	192 (423)	165 (363)	-14
Japan	1,019 (2,242)	1,075 (2,365)	1,078 (2,372)	1,119 (2,462)	4
Canada	417 (917)	397 (873)	425 (935)	364 (801)	-14

^aData are for the former West Germany only.

^bData for 1991 are *Chemical & Engineering News* estimates based on nine months reporting.
N/A - Not available

Source: Reference 2

amounts of "pyrolysis gasoline" rich in aromatics.³⁻⁵ Additional toluene production methods include separation from coal tars and recovery as a by-product from styrene manufacture.^{3,5}

4.1 TOLUENE PRODUCTION FROM PETROLEUM FRACTIONS

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 toluene 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).⁶ 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

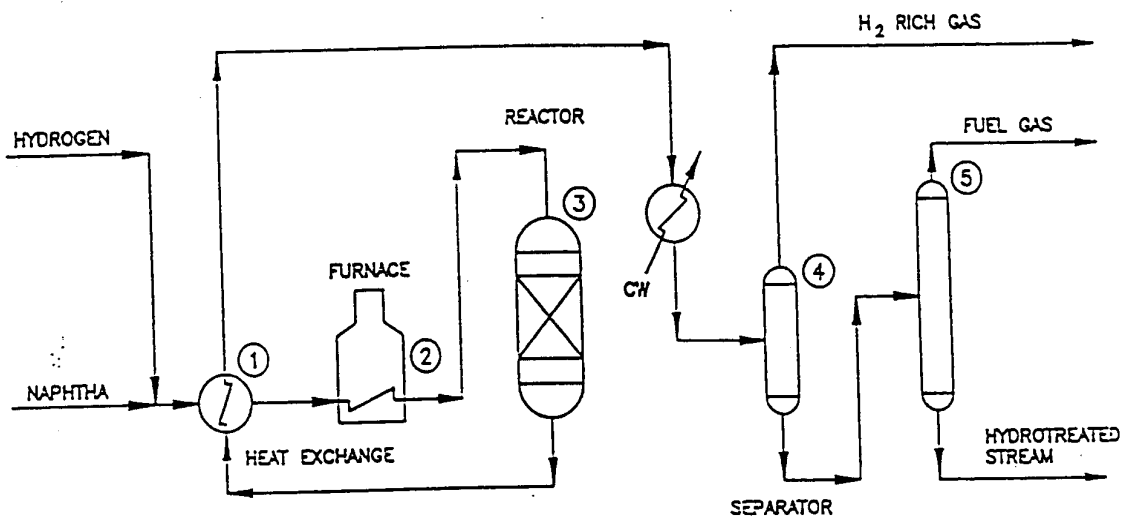


Figure 4-1. Process flow diagram for hydrotreating⁴

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

hydrocarbons dissolved in the separator liquid (Step 5). The stripped, hydrotreated fraction is then routed to the next processing step, either catalytic reforming or secondary hydrogenation.⁷

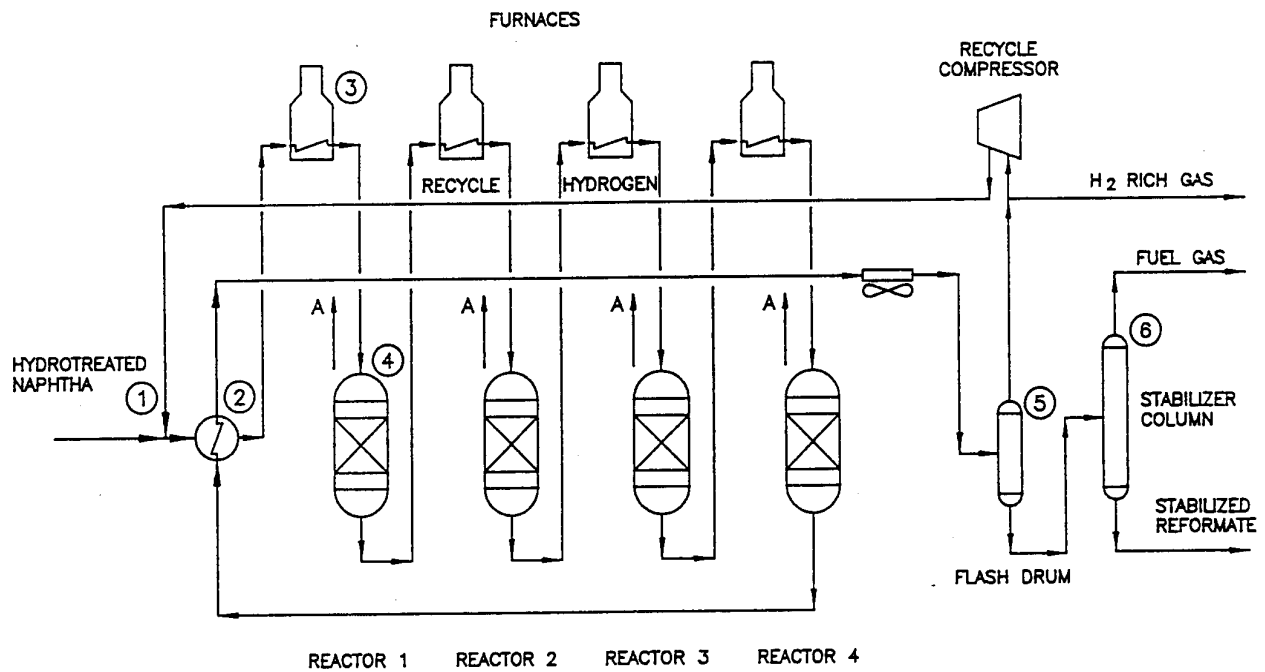
4.1.2 Catalytic Reforming

Catalytic reformat is the major source of toluene, accounting for approximately 87 percent of the toluene produced domestically and approximately 94.5 percent of the production capacity feedstocks.^{1,5} 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).^{4,5} The catalytic reforming process is illustrated in Figure 4-2.

Prior to reforming, the light naphtha, containing the three primary toluene synthesis compounds dimethylcyclopentane, methylcyclohexane, and ethylcyclopentane, is hydrotreated to remove compounds that would act as catalyst poisons in the reforming step.^{4,6} The hydrotreated naphtha is fed to the reformer unit containing the following components:^{4,7}

- 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).⁴ 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.^{4,6}



↑^A DENOTES POTENTIAL LOCATION OF FUGITIVE EMISSIONS

Figure 4-2. Typical reforming unit⁴

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

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 C₄ and lighter hydrocarbons to produce a stabilized reformat. The stabilized reformat is used as a feedstock in the toluene recovery process (described in Section 4.1.4).^{4,7}

Most of the facilities that produce toluene by catalytic reforming have proprietary processes. Table 4-4 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.⁴

**TABLE 4-4.
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 4

4.1.3 Secondary Hydrogenation (for Pyrolysis Gasoline)

Pyrolysis gasoline, a by-product of ethylene and propylene manufacture, accounts for nine percent of domestic toluene production and five percent of production capacity feedstock materials.^{1,5} 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.⁴

Following initial hydrogenation, the pyrolysis gasoline (containing 21 percent toluene) 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 (containing 38 percent toluene) is then stripped of gaseous impurities, such as hydrogen sulfide, and remaining light hydrocarbons before being transferred to toluene recovery units.^{4,7}

Most of the world's facilities that produce toluene 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 4-5 lists the process licensor and the process name.⁴

4.1.4 Toluene Recovery

The hydrotreated and/or catalytically reformed streams are rich in aromatics such as toluene, benzene, and the xylenes, as well as nonaromatics of similar boiling points. Therefore, the most appropriate procedures for separating toluene (and other aromatics) from other process streams are extractive distillation and liquid-liquid extraction.^{4,6} Liquid-liquid extraction is the most commonly used extraction method.⁵ If only one aromatic (*e.g.*, benzene, toluene, or xylene)

TABLE 4-5.
PYROLYSIS GASOLINE HYDROGENATION PROCESSES

Licensor	Name of Process
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 4

is to be recovered in pure form, extractive distillation is preferred as the capital and operating expenses are less than those associated with liquid-liquid extraction.⁴ Figure 4-3 shows a process flow diagram for toluene recovery. The diagram includes prefractionation, extraction/ distillation, and benzene/toluene fractionation.

Liquid-liquid extraction methods are the most commonly used processes to recover toluene. Two compounds commonly used in liquid-liquid extraction are sulfolane and tetraethylene glycol. The sulfolane process was developed by Shell and is licensed by Universal Oil Products (UOP). Union Carbide developed and licensed the tetraethylene glycol method. These two processes have replaced the Udex process which used diethylene glycol as the extractant.⁵ Another commonly used liquid-liquid extraction method is dimethylsulfoxide (DMSO) extraction, commercialized by the Institut Francais du Petrole. This process is different from the other processes in that aromatics are extracted twice, the first time using dimethylsulfoxide (DMSO) and the second time using a light hydrocarbon.⁴

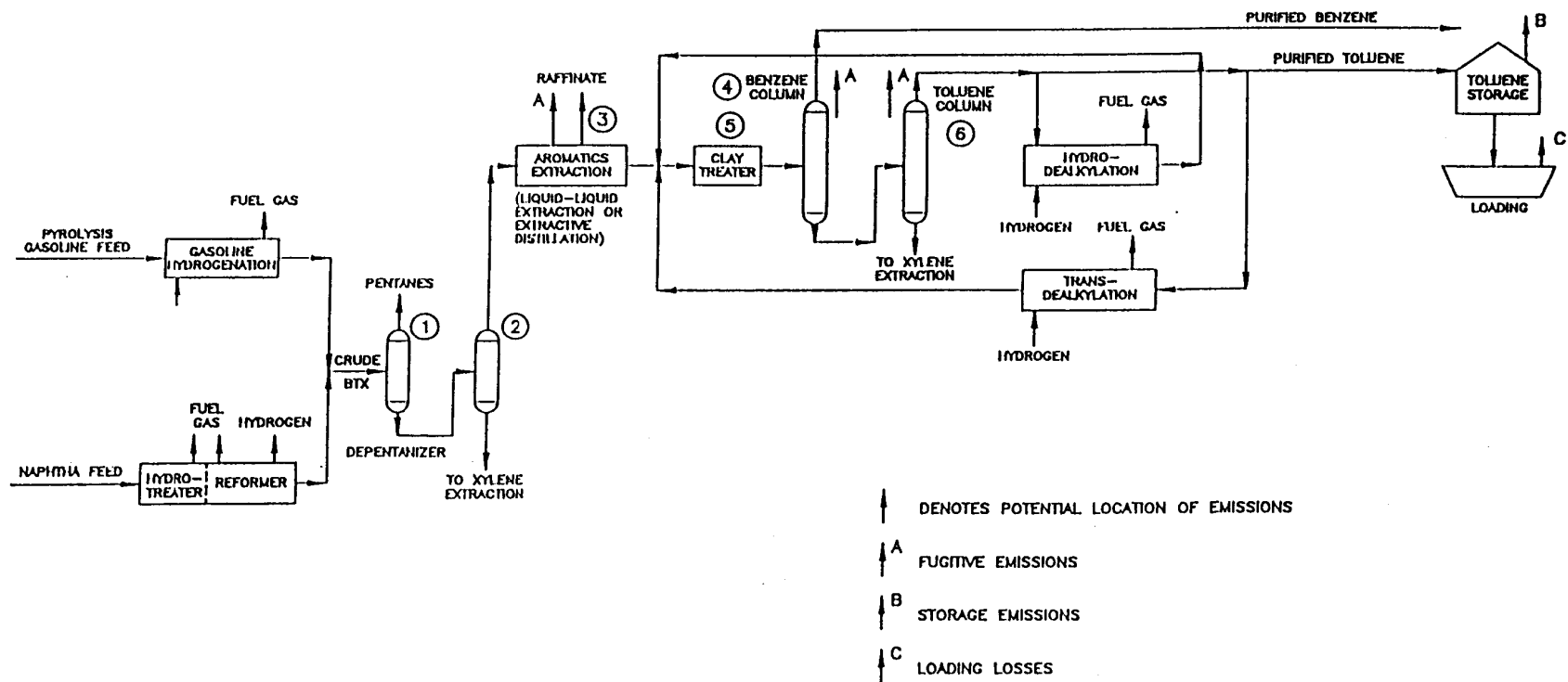


Figure 4-3. Generalized toluene recovery process flow diagram⁴

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

The hydrotreated and/or catalytically reformed streams (crude BTX) are normally prefractionated prior to the recovery of toluene by liquid-liquid extraction to reduce the throughput of the extraction step. The crude BTX stream is first depentanized (Step 1) to remove the majority of components lighter than benzene (*e.g.*, C₅ and lower compounds) and then distilled (Step 2) to remove components heavier than *o*-xylene. The C₅ compounds are removed for gasoline blending, while the xylenes fraction is processed for xylene recovery. The benzene/toluene fraction is fed to a cut column where the top portion is separated and moved to the extraction unit (Step 3). The bottoms are removed and further refined. Nonaromatics (the raffinate phase) leave through the top of the extractor while a mixture of aromatics, solvent and light nonaromatics leave through the bottom. The raffinate is sent to a water wash for removal of solvent. The aromatics/solvent and light nonaromatics stream is transferred from the extractor either directly to a stripper or to an extractive distillation column where nonaromatics are removed to be used later. The stripper removes solvent leaving an aromatic stream rich in toluene. (If only a stripper is used, then it acts as both an extractive distillation column and a solvent stripper, thereby reducing capital expenditures but requiring the facility to install a water washer to further reduce solvent content).⁴

Extractive distillation methods are preferred when only one aromatic (*e.g.*, benzene, toluene, or xylene) is to be recovered in pure form. Extractive distillation methods separate components by introducing a solvent to a mixture. The solvent suppresses the relative vapor pressure of some components compared to other components in the mixture allowing the desired component to be extracted.⁴

The end result of the extractive distillation process description is very similar to that of the liquid-liquid extraction process. The crude BTX stream and the extractive solvent are fed to an extractive distillation column where nonaromatics (the raffinate) are separated (Step 3). The aromatic/solvent stream is transferred to a stripper which removes the solvent leaving the aromatic. Some of the solvents commonly used in extractive distillation units are dimethylformamide, *n*-formylmorpholine, *m*-methylpyrrolidone, and sulfolane.⁴

After a toluene-rich aromatic stream has been extracted from crude BTX by either liquid-liquid extraction or extractive distillation, it can be further processed by conventional distillation to produce pure benzene and toluene. The benzene/toluene fraction is often moved through a clay treatment tower prior to further distillation to remove any trace olefins (Step 4). Benzene is removed from the top of the first distillation column (Step 5) while the distillation bottoms are fed to the toluene column. The purified toluene (99.8 percent) is taken from the top of the second distillation column (Step 6).⁴

4.1.5 Emissions

Most air emissions associated with toluene production from petroleum fractions arise from loading operations, toluene storage, and equipment leaks. Process vents may also contribute to air emissions. Toluene emissions from other sources, such as waste treatment and disposal facilities are discussed in Section 7.0.

Process Emissions--

Figure 4-3 shows that during toluene production, process vent discharges (A) of toluene occur primarily from the vacuum column vents, the reactor process vents, and the reactor process recovery vent. The hydrogen separation vent is only used during startup, shutdown, and during recovery section outages.^{9,10} The vacuum column vents remove air that leaks into the column, as well as light hydrocarbons and hydrogen that form during dehydrogenation, noncombustibles dissolved in the column feed, and any entrained aromatics. The majority of toluene emissions occur at the benzene and toluene columns in the distillation train.

Other sources of process emissions from toluene production are less likely because of the need to operate most processes under a vacuum and because of the heating value of the gases. The available emission estimates for toluene production are given in Table 4-6. Little information was found on specific emission controls. Several types of recovery devices are used in the Synthetic Organic Chemical Manufacturing Industry (SOCMI) to recover hazardous air pollutants including toluene. These control methods include condensers, absorbers, adsorbers,

and incinerators. Recovery devices are used to recover products or by-products for sale or re-use.^{9,10}

**TABLE 4-6.
EMISSION FACTORS FOR TOLUENE PRODUCTION FROM
PETROLEUM FRACTIONS**

Emission Source	Emission Factor	Quality Rating ^e
Storage tank working losses, Toluene recovery ^a	0.66 lb/1000 gallon (0.079 kg/1000 liter) throughput	U
Storage tank breathing losses, Toluene recovery ^a	3.6 lb/1000 gallon (0.43 kg/1000 liter) throughput	U
Toluene recovery, General process emissions ^b	1.7 x 10 ⁻⁴ lb/lb toluene produced	U
Toluene recovery, Storage ^b	4.65 x 10 ⁻⁴ lb/lb toluene produced	U
Toluene recovery from catalytic formate, cracking unit ^b	2.0 x 10 ⁻⁵ lb/lb toluene produced	U
Fugitives from petroleum refining with cracking and reforming ^{b,c}	21 lb toluene/ton (10.5 g/kg) total hydrocarbon	U
Fugitives from petroleum refining without cracking and reforming ^{b,d}	21 lb toluene/ton (10.5 g/kg) total hydrocarbon	U

^aReference 12

^bReference 14, 15.

^cAssumes fugitives are 1.05 percent toluene.

^dAssumes fugitives are 0.105 percent toluene.

^eBased on engineering judgement.

Storage Emissions--

Other possible sources of toluene emissions are storage tank losses (B) and handling losses (C) that occur during product loading into drums, tank trucks, tank cars, barges, or ships. Storage tank losses including 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).¹¹ In the absence of specific data on the storage tank, two emission factors were identified in the literature.¹² Both emission factors are shown in Table 4-6. No information was available regarding the use of floating roof tanks or any other control techniques on storage tanks.

Equipment Leak 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).¹³ The methods differ in complexity; however, the more complex, the more accurate the emission estimate.

The simplest method requires that the number of each component type be known. Furthermore, for each component, the toluene content of the stream and the time the component is in service is needed. This information is then multiplied by the EPA's average emission factors for the Synthetic Organic Chemical Manufacturing Industries (SOCMI) shown in Table 4-7. 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:¹³

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

More complex methodologies may be used to obtain more accurate equipment leak emission estimates. However, these methodologies require that some level of emission measurements (leak concentrations) be made for the facility's process equipment components. These methodologies are briefly described here, and the reader is referred to the EPA *Protocols*

**TABLE 4-7.
AVERAGE EMISSION FACTORS FOR FUGITIVE
EQUIPMENT LEAK EMISSIONS**

Equipment	Service	Emission Factor (kg/hr/source)	Emission Factor (lb/hr/source)	Quality Rating^a
Valves	Gas	0.0056	0.0123	U
	Light Liquid	0.0071	0.0157	
	Heavy Liquid	0.00023	0.00051	
Pump Seals	Light Liquid	0.0494	0.1089	U
	Heavy Liquid	0.0214	0.0472	
Compressor Seals	Gas/Vapor	0.228	0.5027	U
Pressure Relief Seals	Gas/Vapor	0.104	0.2293	U
Flanges	All	0.00083	0.0018	U
Open-Ended Lines	All	0.0017	0.0037	U
Sampling Connections	All	0.0150	0.0331	U

^aBased on engineering judgement.
Source: Reference 13

document or *Fugitive Emission Sources of Organic Compounds--Additional Information on Emissions, Emission Reductions, and Costs* for calculation details.^{13,14}

The first method, the leak/no leak approach, is based on a determination of the number of leaking and nonleaking components. A leaking component is defined by a measured or estimated leak concentration greater than or equal to 10,000 ppmv.¹³ Once the number of leaking/nonleaking equipment components have been determined, the fugitive equipment leak emissions are estimated using the appropriate emission factors and the equation identified previously for the average emission factor method.

The second method differentiates fugitive equipment leak emissions into three leak concentration ranges: 0 - 1,000 ppmv; 1,000 - 10,000 ppmv; and greater than 10,000 ppmv. The number of components falling into a particular range is then multiplied by the component-specific emission factor for that range. The component-specific emission factors can be found in EPA's *Protocols* document.¹³

The third method uses screening data in correlation equations derived by EPA. Correlation equations are only available for flanges, pump seals, and valves in light-liquid and gas service. Finally, the fourth complex method gives each facility an option to develop its own correlation equations, but requires more rigorous testing, bagging, and analysis of equipment leaks to determine mass emission rates.¹⁴

Although no specific information on emissions controls used by the industry was identified, equipment components in toluene service typically have some type of control. Generally, control of fugitive emissions requires the use of low-emission or emissionless process equipment, an inspection and maintenance program, and routine replacement of chronic leaking components. Typical controls for equipment leaks are listed in Table 4-8.¹⁴ In addition, other leakless process equipment is available such as leakless valves and sealless pumps.

4.2 TOLUENE PRODUCTION FROM COAL

Toluene can also be recovered from coal products, although coal is no longer an important source of toluene. When coal is carbonized (*e.g.*, heated in the absence of air) in coke ovens or horizontal retorts, it produces coke residue and volatile matter consisting of gas, tar, and water. Both the coal tar and the coal gas contain small amounts of toluene which can be separated through extraction processes. The coal gas is normally scrubbed with an oil of coal tar or an oil of petroleum origin. These oils absorb the hydrocarbons entrained in the coal gas. The oil can then be distilled and the aromatics recovered as crude benzene.^{4,6}

Crude benzene can be refined either by acid washing or hydrotreating. Hydrotreating is the more commonly used method. The two methods of hydrotreating are the Lurgi

**TABLE 4-8.
CONTROL TECHNIQUES AND EFFICIENCIES APPLICABLE
TO EQUIPMENT LEAK EMISSIONS**

Equipment Component (Emission Source)	Control Technique	Percent Reduction
Pump Seals		
Packed and mechanical	Seal area enclosure vented to a combustion device	100 ^a 61
	Monthly LDAR ^b	32
	Quarterly LDAR	0
	Semiannual LDAR	0
	Annual LDAR	0
Double mechanical ^c	N/A ^d	--
Compressors	Vent degassing reservoir to combustion device	100 ^a
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

^a Combustion devices approach 100 percent control efficiency.

^b LDAR (Leak detection and repair program).

^c 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.

^d N/A (Not applicable). There are no VOC emissions from this component.

Source: Reference 14

Hydrorefining[®] process and the Houdry Litol Hydrorefining[®] process.⁴ Many of the process steps described in the next two paragraphs are the same as those encountered in the previous section, Toluene Production from Petroleum Fractions. The reader should refer to Section 4.1 for further detail.

4.2.1 Process Descriptions

Crude benzene, in the Lurgi Hydrorefining[®] process, is preheated, vaporized and passed through a reactor where hydrodesulfurization, saturation of hydrocarbons, and reduction of oxygen- and nitrogen-containing compounds occurs. The reactor products are cooled and condensed with the condensed hydrocarbon stream undergoing stripping of hydrogen sulfide. The clean hydrotreated stream, the raffinate, is fed to an extractive distillation unit where a toluene mixture is separated from nonaromatics also in the raffinate. The toluene mixture then passes to a recovery column where high purity toluene is recovered.⁴

In the Houdry Litol Hydrorefining[®] process, the crude benzene is first prefractionated as described previously in Section 4.1.4 Toluene Recovery. The prefractionated distillate, containing approximately 17 percent by weight toluene, is mixed with hot hydrogen gas and vaporized. The stream passes to a reactor where olefins are saturated and hydrogen sulfide and butane are produced. The resulting process stream moves to the Lithol reactor where desulfurization, hydrocracking and dealkylation take place. The reactions in the Lithol reactor are exothermic and must be moderated by heat exchangers. After leaving the Lithol reactor, the stream moves to a flash drum where aromatic hydrocarbons are separated, condensed, and forwarded to a stabilizer, a clay tower, and then the benzene tower. The final fractionation takes place in the toluene tower which yields pure toluene.⁴

Several new methods have been developed by which toluene can be produced from coal. Many of these new processes come from the liquification of coal and are still in the developmental stages. One process, the South African Coal, Oil, and Gas Corporation (SASOL) operation has proven commercially feasible in South Africa. These processes, if successful, could

lead to coal refineries that manufacture many of the products currently available from petroleum refineries.⁴

4.2.2 Emissions

No information was located in the literature that discussed process emission sources from toluene production from coal feedstocks. Emissions are expected to be similar to those occurring from petroleum feedstocks where the equipment in use is the same. An overall emission factor for coke manufacture is shown in Table 4-9.

TABLE 4-9.
EMISSION FACTORS FOR TOLUENE PRODUCTION FROM COAL

Emission Source	Emission Factor	Quality Rating^a
Coke manufacture, Coke oven	2.4 x 10 ⁻⁴ lb/lb coke produced	U

^aBased on engineering judgement.
Source: Reference 14.

4.3 TOLUENE PRODUCTION FROM STYRENE

Toluene is a by-product in the production of styrene from ethylbenzene by dehydrogenation. Small amounts of toluene are also produced as a styrene by-product via the isothermal production process. However, because the isothermal method is not currently used in the United States and emissions of toluene are minimal from this process, it will not be discussed in this document. Additional information on the isothermal process can be found in *Locating and Estimating Air Emissions from Sources of Styrene* (EPA-450/4-91-029).⁸

4.3.1 Process Description

In the dehydrogenation process shown in Figure 4-4, purified ethylbenzene is preheated in a heat exchanger (Step 1), and the resultant vapor is mixed continuously with steam at 710°C (1310°F) in the dehydrogenation reactor (Step 2) that contains one of several catalysts. The reaction product exits through the heat exchanger and is further cooled in a condenser (Step 3) where water and crude styrene vapors are condensed. The hydrogen-rich process gas is recovered (Step 4) and used as a fuel and the process water is purified in a stripper (Step 5) and recycled to the boiler. The remaining crude liquid styrene goes to a storage tank (Step 6). The liquid consists of styrene (37 percent), ethylbenzene (61 percent), toluene (1 percent), benzene (0.7 percent), and tars (0.3 percent). Benzene and toluene are removed from the crude styrene in the benzene/toluene column (Step 7). They are then typically separated by distillation (Step 8). The toluene is normally sold, while the benzene is returned to the ethylbenzene production section or sold. In some facilities, an ethylbenzene/benzene/toluene stream is separated from the crude styrene initially (at step 6) and processed separately.

4.3.2 Emissions

Emission factors for the production of toluene from styrene production are shown in Table 4-10. These emission factors were based on engineering judgement, and are therefore given ratings of "U." The emission factor for styrene purification came from engineering calculations at one facility, while the two factors for production process and production fugitive emissions were based on typical composition and design information from two emission sources.¹⁴

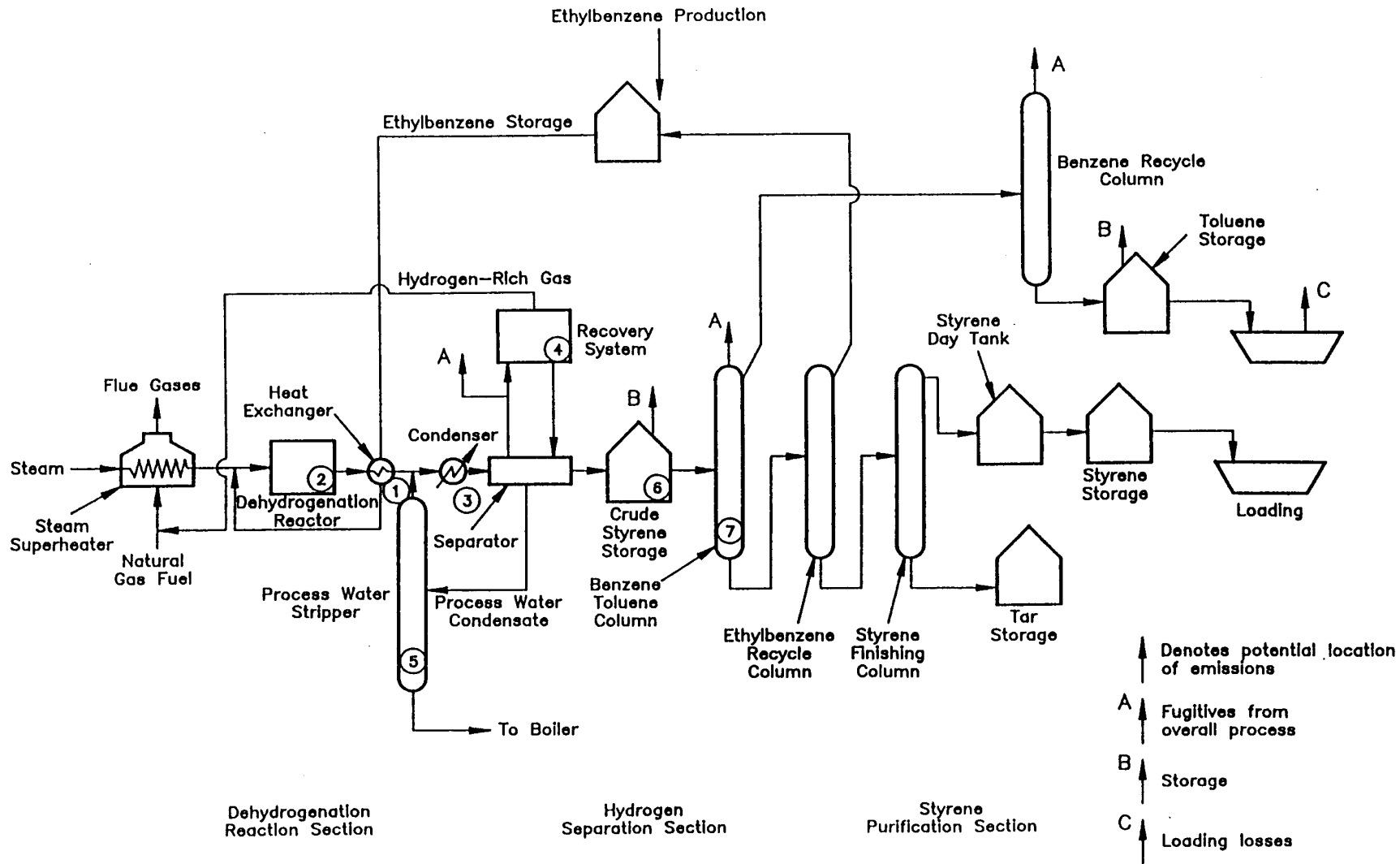


Figure 4-4. Process flow diagram for styrene production by ethylbenzene dehydrogenation.⁸

TABLE 4-10.
EMISSION FACTORS FOR TOLUENE PRODUCTION FROM
STYRENE PRODUCTION

Emission Source	Emission Factor	Quality Rating ^c
Styrene production process emissions ^a	3.04 lb/ton (1.52 g/kg) styrene produced	U
Styrene purification process emissions, Styrene production ^a	2.34 lb/ton (1.17 g/kg) styrene produced	U
Styrene production fugitive emissions ^a	22,840 lb (10,358 kg)/process unit, annually	U
Storage Tank working losses ^b	0.66 lb/1000 gallon (0.079 kg/1000 liter) throughput	U
Storage Tank breathing losses ^b	3.6 lb/1000 gallon (0.43 kg/1000 liter) throughput	U

^aReference 14

^bReference 12

^cBased on engineering judgement.

4.4 REFERENCES FOR SECTION 4.0

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SECTION 5.0 EMISSIONS FROM MAJOR USES OF TOLUENE

This section discusses emissions from major industrial processes that use toluene as a solvent or feedstock. The processes described are the production of benzene, toluene diisocyanate (TDI), trinitrotoluene (TNT), benzoic acid, and benzyl chloride. In addition, product and process descriptions are provided for uses of toluene in solvent applications, such as paint and ink manufacturing and solvent cleaning operations. The application of toluene containing paints, coatings, and inks will be discussed in Section 6.0. Process flow diagrams are included as appropriate, with specific streams or vents in the figures labeled to correspond with the discussion in the text.

Emissions of toluene are expected from all facilities involved in the previously mentioned operations. However, insufficient information is available to develop emission factors for fugitives or process emission sources. Available information is provided in each subsection. The reader is encouraged to contact the Toxic Chemical Release Inventory (TRI) and specific production facilities for information on toluene emissions and control technologies. It should be noted, however, that TRI emission estimates may be based upon engineering estimates, may include accidental releases, and, therefore, may not be reliable.

Residual emissions from toluene-containing materials are discussed separately in Section 6.0. Toluene emissions resulting as a by-product of another process (by-product emissions) are discussed in Section 7.0.

5.1 BENZENE PRODUCTION

Benzene can be produced from catalytic reformat, pyrolysis gasoline, coke-oven light oil, or from toluene by hydrodealkylation (HDA) and disproportionation. Benzene production directly from toluene accounts for approximately 25 percent of the total benzene produced.¹ Major derivatives of benzene, accounting for 98 percent of benzene end uses, include ethylbenzene (for styrene), cumene (for phenol), cyclohexane, nitrobenzene (for aniline), chlorobenzene, and

alkylbenzenes (for detergents).² In addition, approximately two percent of the benzene produced is used as a solvent or feedstock in the following industries and products: laboratories, metal degreasing, pharmaceuticals manufacture, alcohols production, textiles, and miscellaneous small volume chemicals.^{2,3}

Thirteen companies at eighteen facilities currently produce benzene by toluene hydrodealkylation or disproportionation. These facilities and their 1989 production capacities are listed in Table 5-1.¹ The manufacture of benzene accounts for 50 percent of toluene end use.⁴

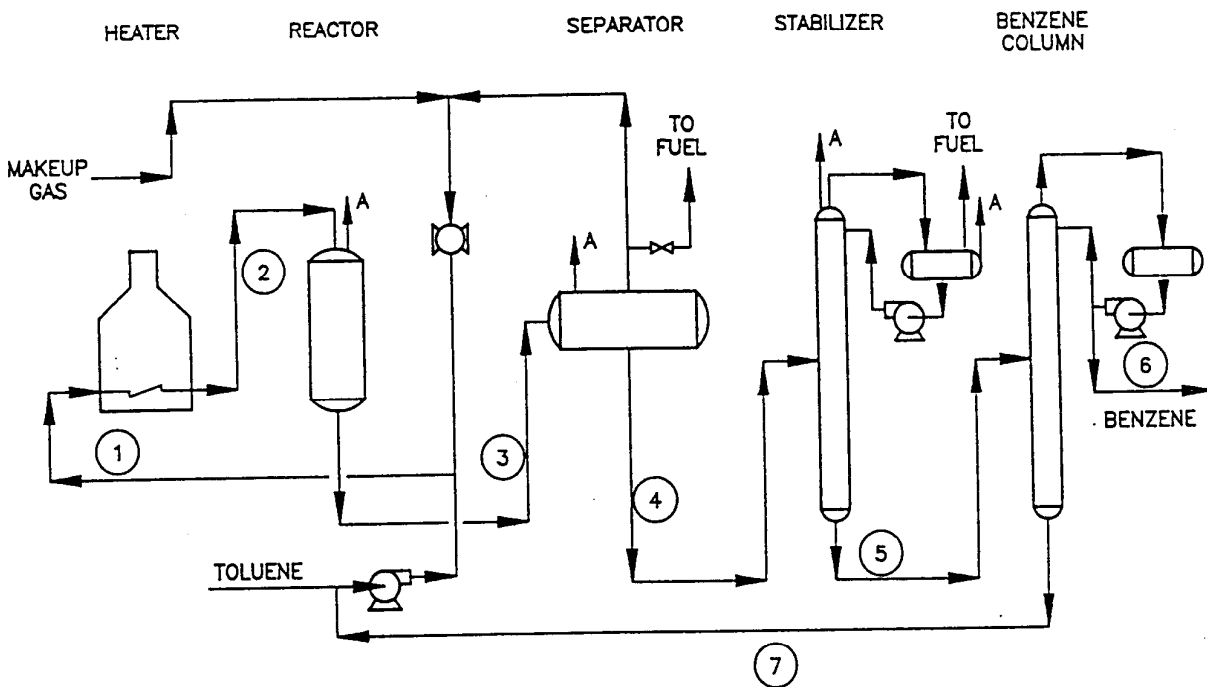
5.1.1 Process Description

Benzene may be produced from toluene through HDA or disproportionation. Hydrodealkylation of toluene can be accomplished through thermal or catalytic processes. The total dealkylation capacity is almost evenly distributed between the two methods. As shown in Figure 5-1, pure toluene (92 to 99 percent), or toluene (85 to 90 percent) mixed with other aromatics or paraffins is heated to 730°C (1,346°F) at a specified pressure (Step 1) and is charged to the reactor (Step 2) in the presence of excess hydrogen.^{1,3} Toluene reacts with the hydrogen, either by thermal initiation or contact with a dealkylation catalyst, to yield benzene and methane. The benzene may be separated from the methane in a low pressure separator (Step 3) by flashing off the methane-containing gas. The product is then stabilized (Step 4) and benzene is recovered by distillation (Step 5). Benzene is sent to storage (Step 6). Unreacted toluene and some heavy by-products are recycled (Step 7). Approximately 70 to 85 percent conversion of toluene to benzene is accomplished per pass through the system, and the ultimate yield is 95 percent of the theoretical yield.³ Many facilities that produce benzene from petroleum sources also have the ability to produce benzene from toluene via HDA. The HDA process is reported to be economically feasible when low-cost hydrogen is available and when benzene is valued at approximately 30 cents per gallon more than toluene.^{1,2}

TABLE 5-1.
BENZENE PRODUCERS USING TOLUENE FEEDSTOCK

Facility	Location	1989 Capacity millions of kilograms (millions of gallons)	Production Method
Amerada Hess Corporation	St. Croix, VI	N/A	Disproportionation
American Petrofina Incorporated	Port Arthur, TX	109 (33)	Disproportionation
Arochem International	Penuelas, PR	115 (35)	HDA
BP America, Inc. (Sohio)	Alliance, LA Lima, OH	155 (47) 263 (80)	HDA HDA
Chevron Corporation	Philadelphia, PA Port Arthur, TX	46 (14) 164 (50)	HDA HDA
Coastal Refining and Marketing	Corpus Christi, TX	53 (16)	HDA
Dow Chemical U.S.A.	Freeport, TX Plaquemine, LA	82 (25) 395 (120)	HDA HDA
Hoechst Celanese	Bayport, TX	49 (15)	HDA
Koch Industries, Inc.	Corpus Christi, TX	197 (60)	HDA
Lyondell Petrochemical Co.	Houston, TX	49 (15)	Disproportionation
Occidental Petroleum Corp.	Chocolate Bayou, TX Corpus Christi, TX	132 (40) 99 (30)	HDA HDA
Phillips Puerto Rico Core Inc.	Guayama, PR	161 (49)	HDA
Sun Company, Inc.	Marcus Hook, PA Tulsa, OK	36 (11) 66 (20)	Disproportionation HDA

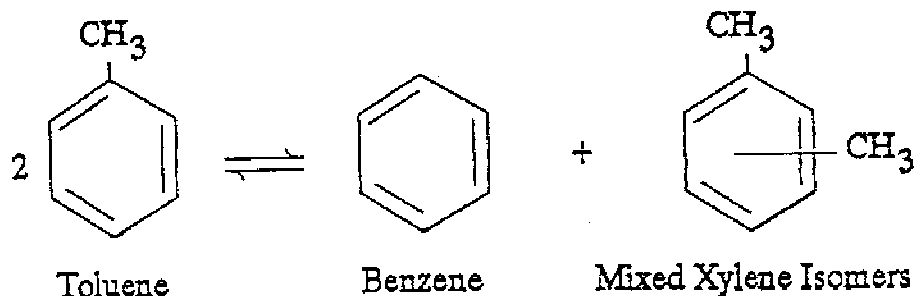
Source: Reference 1
N/A = Not Available
HDA = hydrodealkylation



↑ DENOTES POTENTIAL LOCATION OF EMISSIONS
 ↑^A FUGITIVE EMISSIONS

Figure 5-1. Process flow diagram of a toluene dealkylation unit³

Toluene disproportionation, or transalkylation, catalytically converts two molecules of toluene to one molecule each of benzene and xylenes, as indicated by the reaction:⁵



The transalkylation process is similar to that of toluene HDA but occurs under less severe conditions (*e.g.*, the transalkylation process operates at lower temperatures and consumes less hydrogen). Toluene is heated, combined with hydrogen, and sent to the reactor. The reacted material is moved to a separator for removal of off-gases. The product is stabilized and moved through clay towers. Benzene, toluene, and xylenes are recovered by distillation and unreacted toluene is recycled.^{2,3} Toluene disproportionation is used when the desired product is xylene. If benzene is the only product required, then HDA is a more economical and feasible process.¹

5.1.2 Emissions

Facilities manufacturing benzene emit toluene from process equipment vents, open process equipment, equipment leaks, storage tank vents, secondary sources, and transfer and handling operations. No specific emissions data for any of these sources are available; however, it has been estimated that 5.0×10^{-5} pounds of toluene are emitted for every pound of toluene used in the benzene manufacturing process.⁶

Process equipment sources include heaters, reactors, separation tanks, stabilization columns, distillation columns, and the toluene recovery system. The emissions will vary according to the type of process used (*e.g.*, HDA or disproportionation) and the percentage of toluene in the raw material feed stream.

To control process vent emissions, the process streams can be routed to a flare or blowdown tank. Recovered toluene emissions from the distillation column are recycled with the reactor feed stream. Where feasible, open equipment may be enclosed.

Sources of fugitive emissions and emission estimation procedures are discussed in Section 4.0. Also included in Section 4.0 is a table of emission control options and efficiencies.

A significant source of toluene air emissions occurs from toluene transfer during the loading and unloading of trucks, tank cars, and barges and the filling of toluene storage tanks. Losses of toluene from storage tanks may also occur due to normal tank working and breathing losses. Toluene emissions from storage tanks are discussed in Section 4.1.5 under the topics of Storage and Fugitives.

5.2 TOLUENE DIISOCYANATE PRODUCTION

Toluene diisocyanate (TDI) is produced by a reaction sequence in which toluene is dinitrated to form dinitrotoluene. Dinitrotoluene is hydrogenated to form 2,4-diaminotoluene which is treated with phosgene to yield two isomers of toluene diisocyanate 2,4-TDI and 2,6-TDI. Commercial toluene diisocyanates are available in three isomer ratios. The majority of commercially used TDI is a mixture of 80 parts of the 2,4-TDI isomer and 20 parts of the 2,6-TDI isomer. A 65:35 mixture of the 2,4- and 2,6-TDI isomers is also available, as is pure TDI (greater than 99.5 percent 2,4-TDI).^{5,7} Either nitration-grade toluene or highly refined toluene (99.95+ percent) is used as the basic feedstock by most TDI manufacturers.⁸

Toluene diisocyanates are industrial intermediates used in the production of polyurethane foams, paints, varnishes, elastomers, and coatings. Rigid polyurethane foams, accounting for

about five percent of TDI demand, are used as insulation in refrigeration equipment.⁹ Flexible polyurethane foams, used in furniture cushioning, transportation (*e.g.*, automotive seating), bedding, packaging, and carpet underlay, account for approximately 90 percent of the use of toluene diisocyanates.⁷ Little or no growth in production of TDI is expected for several reasons. Methyl diphenyl diisocyanate (MDI) is replacing TDI in many polyurethane foam applications. TDI can react violently with compounds containing an active hydrogen atom.⁷

Toluene diisocyanate is currently produced by five companies at six facilities in three States. These facilities and their 1990 production capacities are listed in Table 5-2.⁹ Manufacture of toluene diisocyanates accounts for nine percent of toluene end use.⁴

**TABLE 5-2.
TOLUENE DIISOCYANATE PRODUCTION LOCATIONS AND
CAPACITIES**

Facility	Location	1990 Capacity Millions of Kilograms (Millions of Pounds)	
BASF Corp.	Geismar, LA	73	(160)
Dow Chemical	Freeport, TX	63	(140)
ICI Americas	Geismar, LA	32	(70)
Mobay	New Martinsville, WV	45	(100)
Mobay	Baytown, TX	61	(135)
Olin	Lake Charles, LA	88	(195)

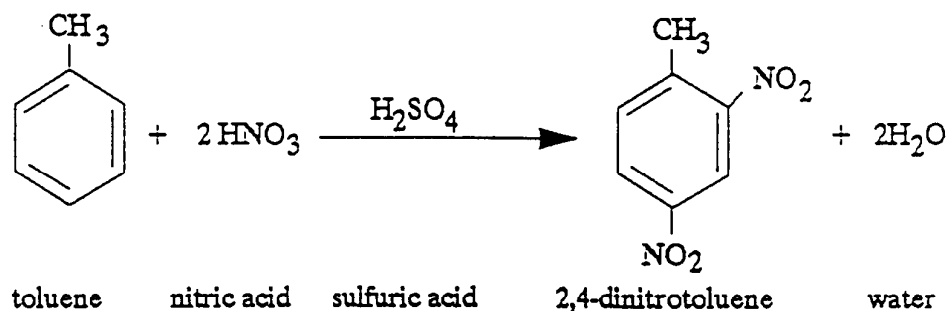
Source: Reference 9

5.2.1 Process Description

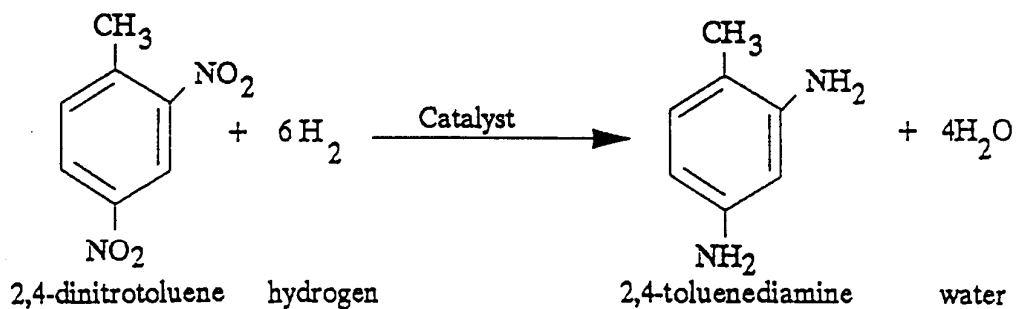
The manufacture of commercial toluene diisocyanates is based on the phosgenation of primary amines. Most commercial TDI plants also produce the intermediates dinitrotoluene (DNT), toluene diamine (TDA) and phosgene.⁸

TDI is produced by the following chemical reactions:

Reaction 1:



Reaction 2:



Reaction 3:

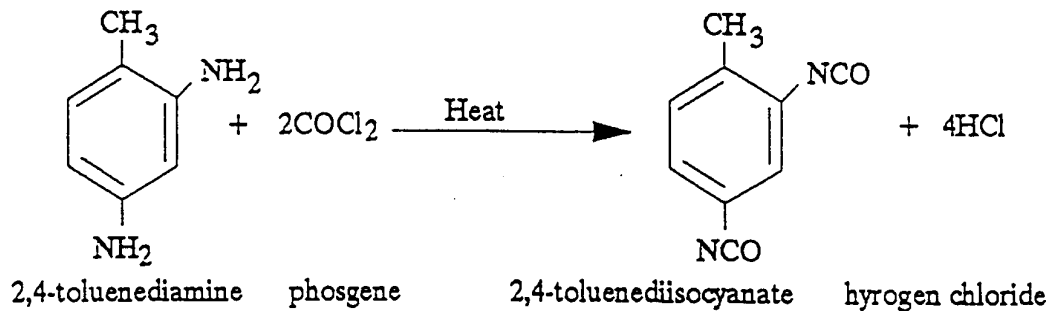


Figure 5-2 illustrates the basic operations that may be used in toluene diisocyanate production. The first step in the manufacture of TDI is the nitration of toluene (Step 1). Nitration grade toluene is reacted with nitric acid to form DNT. The reaction takes place at 65° to 80°C (149° to 176°F) in a well-agitated reactor equipped with cooling coils using sulfuric acid (60 to 70 percent) as the catalyzing agent.¹⁰ The spent sulfuric acid is separated from the DNT reaction mixture, concentrated in a direct contact evaporator, and recycled to the nitration reactor (Step 2).⁸

The DNT is washed in a wash tank (Step 3) and then reacted with hydrogen in catalytic reduction reactors (Step 4), using precious metal, nickel, or carbon catalysts, to form crude TDA. The hydrogenation of DNT normally occurs in an inert diluent (*e.g.*, an alcohol) to avoid explosion hazards and to control the heat resulting from the exothermic process. The crude TDA is purified by filtration and distillation (Step 5).^{8,10}

TDA is reacted with phosgene in a solvent, usually *o*-dichlorobenzene or mono-chlorobenzene to form crude TDI and hydrogen chloride (HCl) (Step 6). Phosgene is condensed out of the HCl by-product and recycled to the reactor. Crude TDI is sent to a distillation column for the removal of residual phosgene (Step 7). After a series of distillation and condensation steps, the phosgene (from the crude TDI) is recycled to the phosgenation reactor. The crude TDI still contains some of the chlorobenzene solvent in which it was reacted. This mixture (TDI and solvent) is transferred to a vacuum distillation column where the solvent is recovered and recycled (Step 8). The remaining crude TDI is vaporized by vacuum flash distillation to separate TDI from any polymeric isocyanates that may have formed (Step 9). The TDI is then condensed and sent to a vacuum distillation column from which purified TDI is removed (Step 10). The purified TDI stream undergoes a final condensation step before being transferred to product storage (Step 11).^{8,10}

5.2.2 Emissions

Typical emission sources at TDI manufacturing facilities include process equipment vents, open process equipment, equipment leaks, storage tank vents, secondary sources, and transfer and

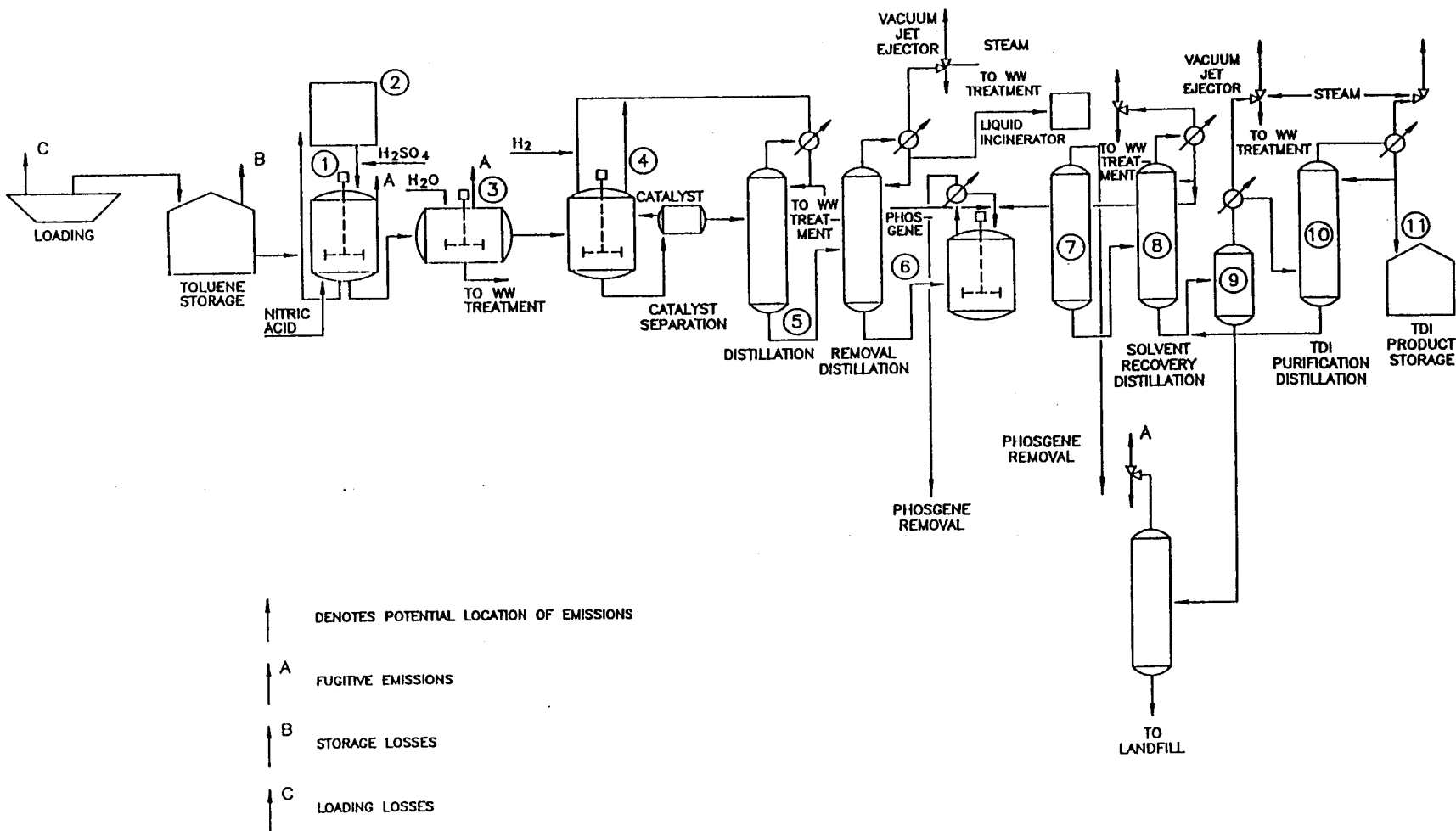


Figure 5-2. Basic operations that may be used in toluene diisocyanate production⁸

handling operations. No specific emissions data for any of these sources are available; however, it has been estimated that 7.7×10^{-4} pounds of toluene are emitted for every pound of toluene used in TDI manufacturing. An additional 1.9×10^{-4} pounds of toluene are released from fugitive sources per pound of toluene used.⁶

Process equipment sources include nitration reactors, evaporators, the DNT wash tank, TDA reactors, filtration units, stabilization columns, and the condensation and distillation units. The emissions will vary according to degree of agitation of the reactors and the level of control on the equipment.

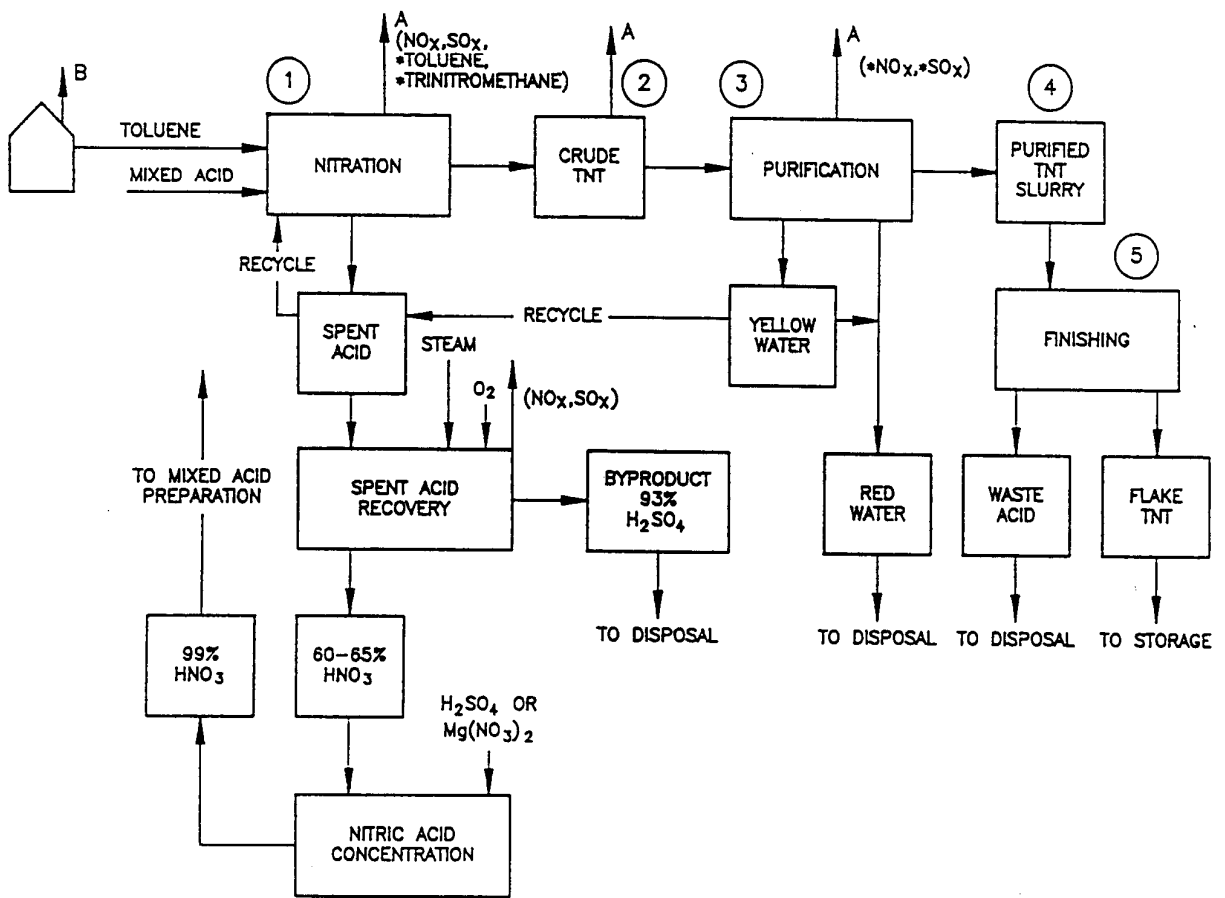
5.3 TRINITROTOLUENE PRODUCTION

At one time, the production of trinitrotoluene (TNT) for explosives was the major end use of toluene. Although TNT is no longer a primary toluene derivative, it is still a modern explosive used mainly for military purposes, but also with commercial applications. TNT provides low manufacturing cost, excellent chemical and thermal stability, and favorable physical properties to allow usage as a bursting-charge in shells, bombs, and grenades and as an ingredient in binary explosives, metallized explosives, propellant compositions and commercial blasting explosives.¹⁰

Once manufactured by private companies, TNT is now produced by government facilities. It is not likely that private manufacture of TNT will resume as less expensive, competitive industrial explosives are now available.¹¹

5.3.1 Process Description^{8,10}

The production of TNT can be accomplished in two or three stage processes and in batch or continuous fashion. The chemical process is the same for both the continuous and batch methods. Figure 5-3 illustrates the TNT manufacturing process. TNT is normally produced by the nitration of toluene in three distinct mononitration stages each consisting of the addition of one nitro (NO₂) group into the aromatic ring. The first nitro group can be introduced easily, but



↑ DENOTES POTENTIAL LOCATION OF EMISSIONS
 ↑ A FUGITIVE EMISSIONS
 ↑ B STORAGE EMISSIONS
 ↑ C LOADING LOSSES
 * INDICATES NEGLIGIBLE AMOUNT

Figure 5-3. TNT production¹²

the second and third nitration steps require reaction forcing conditions using various mixtures of nitric and sulfuric acids in water. Increasing amounts of sulfuric acid (and decreasing amounts of nitric acid) are used with each successive mononitration step.

The mixed acids and the toluene are fed into a series of cooled, agitated reactors (Step 1). The sulfuric acid catalyzes the reaction producing 97 to 98 percent mononitrotoluene, approximately 0.2 percent DNT, 1 percent unreacted toluene, and some nitrocresols.¹⁰ Once the reaction has gone to completion, the spent acid and the mononitrotoluene separate into two phases (Step 2). The mononitrotoluene is purified by a water wash followed by an alkali wash and a second water wash (Step 3). The spent acid (primarily sulfuric acid) is concentrated in a direct contact evaporator using gases from a natural gas burner, recycled to the nitration reactor, and mixed with additional virgin acids to provide nitration acids of the desired strength.

The crude mononitrotoluene is topped to remove unconverted toluene (Step 4) and then separated by fractional distillation into a 2-nitrotoluene (2-NT) stream and a distillation residue which can be further distilled and crystallized (Step 5) to recover the 3- and 4-NT isomers. (End uses for these isomers are discussed in Section 5.6.) The basic nitration process is repeated two additional times to produce DNT and then TNT.

5.3.2 Emissions

Typical emission sources at TNT manufacturing facilities include process equipment vents, open process equipment, equipment leaks, storage tank vents, secondary sources, and transfer and handling operations. No emissions data for any of these sources were available during the preparation of this document.

Process equipment sources include nitration reactors, separation columns, wash tanks, evaporators, filtration units, and distillation units. The emissions will vary according to the type of process used (*e.g.*, two or three stage operations or batch or continuous processing) and the strength of the nitration acid mixture.

5.4 BENZOIC ACID PRODUCTION

Benzoic acid is manufactured from toluene by continuous liquid-phase oxidation. Approximately 52 percent of the benzoic acid produced from toluene is converted to phenol by the only U.S. phenol producer, Kalama Chemical. Phenol, in turn, is used to manufacture phenolic resin for use in adhesives in plywood, binders for insulation, and laminating agents. Other end uses for benzoic acid include plasticizers (20 percent), sodium and potassium benzoate (12 percent), benzoyl chloride (6 percent), alkyd resins (3 percent), and butyl benzoate (2 percent). Miscellaneous uses account for the remaining five percent of benzoic acid end uses. Sodium and potassium benzoate, benzoic acid salts, are used mainly as food and beverage preservatives in the United States. European countries and Japan use sodium benzoate as a corrosion inhibitor in antifreeze.¹³

Benzoic acid is currently produced by three companies. These facilities and their 1990 production capacities are listed in Table 5-3.¹³

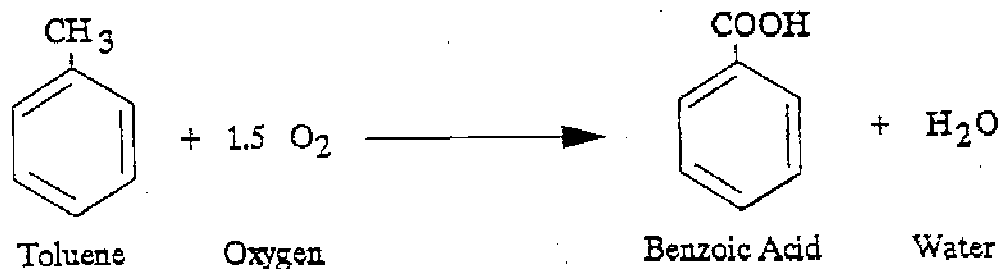
**TABLE 5-3.
BENZOIC ACID PRODUCTION LOCATIONS AND CAPACITIES**

Facility	Location	1990 Capacity Millions of Kilograms (Millions of Pounds)	
Kalama Chemical	Kalama, WA	63	(140)
Pfizer	Terre Haute, IN	4.5	(10)
Velsicol	Chattanooga, TN	29	(65)

Source: Reference 13

5.4.1 Process Description

Benzoic acid is manufactured from toluene in the presence of cobalt catalysts by continuous liquid-phase oxidation according to the following reaction:¹



Approximately 0.87 pounds of toluene are required per pound of benzoic acid produced, with a 40 percent toluene conversion per pass.¹²

Although many of the process details are proprietary, the basic reaction mechanisms are presented. Toluene, the catalyst, and air (the source of oxygen) are fed continuously into a reactor maintained at 150° to 250°C (300° to 480°F) and at a pressure of 5 to 50 atm.¹¹ The temperature and the catalyst concentration determine the reaction rate. The reaction is complete when 40 percent of the toluene has been oxidized to yield crude benzoic acid.¹¹ The reactor effluent moves from the oxidation reactor to an atmospheric stripping column heated by a circulating hot oil reboiler. The unreacted toluene and other intermediates/by-products [*e.g.*, benzaldehyde (one to two percent) and benzyl benzoate (ten percent)] boiling below benzoic acid are removed from the column and recycled.¹⁰ Crude benzoic acid is extracted from the column using water and moved to a small finishing column where pure benzoic acid is removed overhead. The finishing column bottoms are returned to the stripping column.

Vent gases from the oxidation reactor are cooled by exchange with incoming air, then with cooling water, and finally, by ammonia refrigeration. The vent gases are then expanded and vented to the atmosphere through a carbon scrubber. Much of the toluene in the vent gases is recovered for recycle through the cooling process.

5.4.2 Emissions

Typical emission sources at benzoic acid manufacturing facilities include process equipment vents, open process equipment, equipment leaks, storage tank vents, secondary sources, and transfer and handling operations. No specific emissions data for any of these sources are available; however it has been estimated that 1×10^{-3} pounds of toluene are emitted for every pound of toluene used in benzoic acid manufacturing. An additional 1×10^{-4} pounds of toluene are released from fugitive sources.⁶

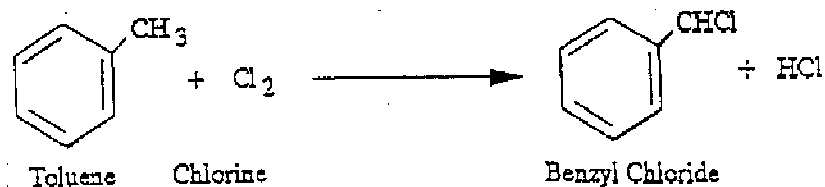
Process equipment sources include reactors, stripping columns, wash tanks, and distillation units. The emissions will vary according to the type of process used (process details are proprietary) and the temperature of the oxidation reactor.

5.5 BENZYL CHLORIDE PRODUCTION

Benzyl chloride is produced commercially by the direct chlorination of boiling toluene. Two facilities in the United States produce benzyl chloride. As of January 1, 1990, Monsanto in Bridgeport, New Jersey, had a capacity of approximately 45 million kilograms (100 million pounds). Akzo Chemical in Edison, New Jersey operated a facility with an 11 million kilogram (25 million pound) capacity. The primary end use of benzyl chloride (69 percent) is as an intermediate in the production of butyl benzyl phthalate which is a plasticizer for vinyl flooring and polyvinyl acetate emulsion adhesives used in packaging. Sixteen percent of benzyl chloride is used in the production of quaternary ammonium compounds (quats). Quats are used in sanitizers, disinfectants, deodorants, fungicides and algicides applied in food production, dairies, bottling plants, restaurants, swimming pools, and industrial water treatment bactericides. Other uses of benzyl chloride include the production of benzyl alcohol, benzyl acetate, butyl benzoate, and benzyl salicylate. Some of the end products of these chemicals are perfumes, cosmetics, and flavorings.¹⁵ The annual growth rate of benzyl chloride in the United States is expected to increase by no more than 1.0 percent from 1988 to 1993.¹

5.5.1 Process Description

Benzyl chloride is produced by the direct chlorination of boiling toluene according to the following reaction:¹



Toluene is heated to 65° to 100°C (150° to 212°F) and chlorinated in the dark (or in an alternate process by photochlorination) until the mixture increases in weight by 37.5 percent.^{1,14} The reaction mixture is agitated with a mild alkali and then distilled. Benzal chloride and benzotrichloride are by-products of the chlorination reaction and occur in ratios with benzyl chloride of 1:0.1:10.¹⁴ Excess toluene is recovered and recycled to the chlorinator while the resulting hydrogen chloride gas is absorbed in water forming muriatic acid. For every pound of benzyl chloride produced, 0.8 pounds of toluene are consumed.¹

5.5.2 Emissions

Typical emission sources at benzyl chloride manufacturing facilities include process equipment vents, open process equipment, equipment leaks, storage tank vents, secondary sources, and transfer and handling operations. No specific emissions data for any of these sources are available; however, it has been estimated that 5.5×10^{-4} pounds of toluene are emitted for every pound of toluene used in benzyl chloride production. An additional 1.5×10^{-4} pounds of toluene are released from fugitive sources.⁶

Process equipment sources include heaters, chlorination reactors, and wash tanks. The emissions will vary according to the type of process used (*e.g.*, dark chlorination or photochlorination).

5.6 OTHER TOLUENE DERIVATIVES

Other toluene derivatives include mono- and dinitrotoluene, vinyl toluene, benzaldehyde, toluenesulfonyl chloride, chlorotoluenes, and toluenesulfonic acid. End uses for these chemicals are discussed below.^{5,10}

The mono- and dinitrotoluene isomers can be hydrogenated to amines and then used as dye intermediates. The 3-nitrotoluene isomer is used in the production of red-violet dyes for polyester fibers, while 4-nitrotoluene is used in fluorescent brightening agents for cellulosic materials.¹⁰

Benzaldehyde is a by-product of toluene in the manufacture of benzoic acid. The primary use of benzaldehyde is as a chemical intermediate in the production of specialty chemicals used for food flavoring, pharmaceuticals, herbicides, and dyestuffs.

The production of vinyl toluene is accomplished by reacting ethylene and pure toluene in the presence of aluminum chloride and hydrogen chloride. Dow Chemical currently holds several patents for this manufacturing process. Vinyl toluene is used in unsaturated polyester and alkyd resins and as a co-polymer with butadiene. The end uses of these chemicals are normally paints, adhesives, and printing inks.^{5,10}

Toluene can be sulfonated with sulfuric acid or sulfur trioxide to form toluene sulfonic acids. Sulfonation with chlorosulfonic acids yields toluene sulfonyl chloride. The largest use of mixed toluene sulfonic acids is in the production of cresols. One of the isomers of toluene sulfonic acid, p-toluene sulfonic acid (PTSA), is used in the production of resins, dyes, adhesives, antidiabetic drugs, and as an additive in electroplating baths. Toluene sulfonyl chlorides are used in disinfectants and in the manufacture of saccharin.^{5,10}

Mono-, di-, and trichlorotoluenes are prepared by the ring-chlorination of toluene. Toluene is reacted with elemental chlorine in the presence of catalysts such as chlorides of iron, aluminum, tin, titanium, and zirconium to yield ortho- and para-chlorotoluene. These isomers

are used as solvents and in paint and rubber stripping formulations and dye carrier formulations. Other eventual end uses include dyestuffs, pharmaceuticals, and preservatives.^{5,10}

5.7 PAINT AND INK MANUFACTURING

Toluene is one of the solvents used as a raw material in the manufacture of paints and inks. In 1989, toluene accounted for 15 percent of the 1,977 kilograms (4,358 million pounds) of solvent consumed in paints and coatings.¹⁵ Consumption in paints and coatings accounts for approximately 45 percent of total toluene solvent sales. A breakdown of the consumption of toluene and its derivatives as they are used in paints and coatings is given in Table 5-4. Figure 5-4 is a flow diagram indicating the uses of toluene in the paint and coatings industry.¹⁵ Section 6.0 discusses the application of toluene containing paints (surface coating) and inks (printing).

Paints and inks 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 a surface in a thin, uniform film and normally play no role in film formation. (In the case of reactive diluents and two- and three-component coatings, the vehicle becomes part of the coating film.) When a paint or ink is deposited on a substrate, the vehicle solvent(s) should evaporate completely. Toluene is only one of the vehicle solvents used by paint and ink manufacturers.¹⁶ Total toluene consumption in paints and coatings has increased since 1980. One explanation for this increased consumption is that toluene is priced lower than other commonly used solvents like ketones and esters.¹⁵

In 1987, Paint and Allied Products facilities were composed of 1,123 companies operating 1,426 plants, two-thirds of which were located in ten states. The 1987 Census of Manufactures shows that the 504 ink manufacturing facilities in the United States are owned by 224 companies in nineteen States and the District of Columbia. *Ward's Business Directory* lists 364 paint and allied products facilities in SIC 2851 with 1990 sales greater than \$1,000,000.¹⁷ *Ward's* also lists

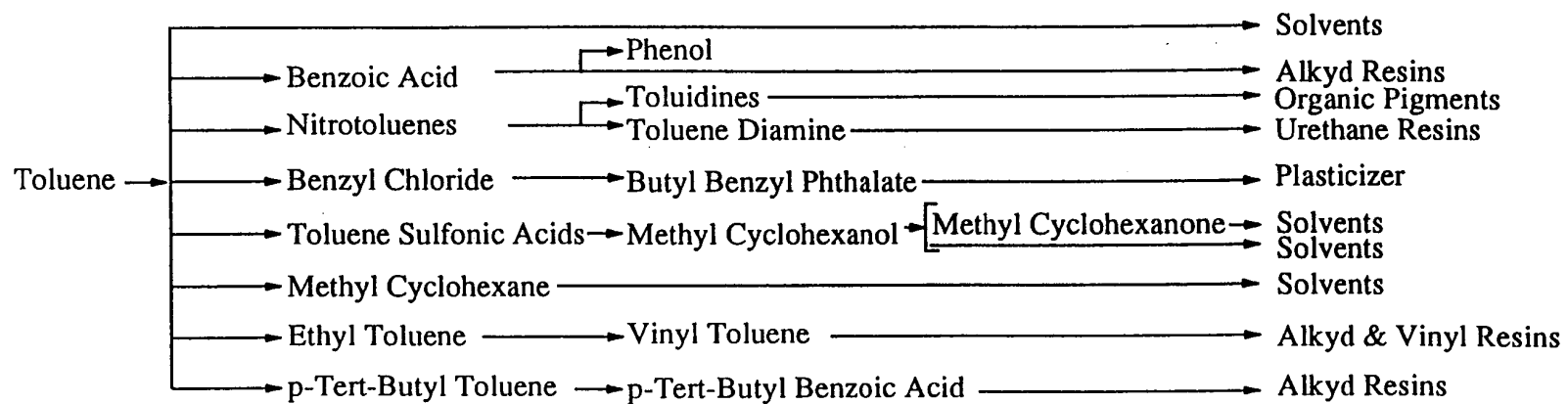


Figure 5-4. Usage of toluene in the paint and coatings industry¹⁵

TABLE 5-4.
ESTIMATED CONSUMPTION OF TOLUENE DERIVATIVES IN
PAINTS AND COATINGS, 1988

Derivative	Millions of Kilograms (Millions of Pounds)							
	Derivative Production from Toluene		Toluene Consumption		Derivative Consumed in Paints and Coatings		Toluene Equivalents for Paints and Coatings	
Solvent	--	--	636	(1,400)	287	(635)	287	(635)
Toluene Diisocyanate	329	(725)	227	(500)	9	(20)	6	(14)
Benzyl Chloride	29	(63)	23	(50)	1	(2)	1	(2)
Benzoic Acid	91	(200)	76	(168)	3	(7)	3	(6)
Other ^a	--	--	278	(612)	16	(35)	11	(25)
Total Toluene			1,241	(2,730)			310	(682)

^a Includes TNT, vinyl toluene, cresols, benzaldehyde, toluene sulfonic acids, toluene sulfonates, benzotriazine chloride, toluene diamine (other than the amount consumed for TDI), nitrotoluenes, chlorotoluenes, p-tert-butyl benzoic acid, toluene sulfonyl chloride, and as a denaturant. Excludes fuel use and benzene/xylenes production.

Source: Reference 15

56 ink manufacturing facilities in SIC 2893 with 1990 sales greater than \$1,000,000. These lists are provided in Appendix B, Table B-1 and Table B-2.

One method used to categorize the products of the paint manufacturing industry is by end-use (*e.g.*, markets served). The use categories are architectural coatings, product coatings for original equipment manufacturers (OEM), and special purpose coatings. A summary of toluene consumption in the paint use divisions by use category and subcategory is found in Table 5-5. No toluene was consumed in architectural coatings in 1988 or 1989. Toluene is commonly used in OEM product coatings such as those for wood furniture and fixtures, containers and closures, automotive finishes, and machinery and equipment.¹⁵

TABLE 5-5.
ESTIMATED CONSUMPTION OF SOLVENTS IN PAINTS AND
COATINGS, BY MARKET

Product Finishes	Total Solvents Millions of Kilograms (Millions of Pounds)		Total Toluene Millions of Kilograms (Millions of Pounds)	
	1988	1989	1988	1989
Wood Furniture and Finishes	127 (280)	123 (270)	33.7 (74.1)	32.5 (71.5)
Wood Flat Stock	3 (7)	3 (6)	0.4 (0.8)	0.3 (0.6)
Metal Furniture and Fixtures	39 (85)	39 (85)	3.8 (8.3)	3.8 (8.3)
Containers and Closures	86 (189)	87 (191)	10.4 (22.8)	10.4 (22.9)
Sheet, Strip and Coil	32 (71)	32 (71)	2.6 (5.8)	2.6 (5.8)
Major Appliances	19 (41)	19 (41)	1.5 (3.3)	1.5 (3.3)
Other Appliances	10 (23)	10 (23)	1.2 (2.7)	1.2 (2.7)
Automotive	-- --	-- --	-- --	-- --
Topcoat	28 (61)	28 (61)	4.5 (10.0)	4.5 (10.0)
Primer	16 (35)	16 (35)	2.5 (5.6)	2.5 (5.6)
Underbody Components and Parts	16 (35)	16 (35)	2.0 (4.5)	2.0 (4.5)
Trucks and Buses	16 (35)	15 (33)	1.8 (3.9)	1.7 (3.7)
Railroad	4 (8)	3 (7)	0.9 (2.0)	0.8 (1.7)
Other Transportation	6 (13)	6 (13)	1.1 (2.4)	1.1 (2.4)
Machinery and Equipment	70 (155)	72 (159)	7.9 (17.3)	8.0 (17.7)
Electrical Insulation	27 (59)	27 (59)	-- --	-- --
Paper, Foil, and Film	18 (40)	18 (40)	2.6 (5.8)	2.6 (5.8)
Other Product Finishes	116 (255)	116 (256)	11.4 (25.0)	11.4 (25.0)
PRODUCT-OEM TOTAL	633 (1,392)	635 (1,398)	87.7 (193)	87.3 (192)

(continued)

TABLE 5-5.
ESTIMATED CONSUMPTION OF SOLVENTS IN PAINTS AND
COATINGS, BY MARKET (Continued)

	Total Solvent Millions of Kilograms (Millions of Pounds)				Total Toluene Millions of Kilograms (Millions of Pounds)			
	1988		1989		1988		1989	
Special Purpose Coatings								
Maintenance	54	(118)	59	(121)	10.5	(23.1)	10.9	(23.9)
Marine	--	--	--	--	--	--	--	--
Pleasure	1	(3)	1	(2)	--	--	--	--
Commercial and Maintenance	15	(33)	15	(33)	2.0	(4.4)	2.0	(4.4)
Auto Refinishing	74	(162)	74	(162)	9.5	(21.0)	9.5	(21.0)
Traffic Paints	59	(130)	59	(130)	28.3	(62.3)	28.3	(62.3)
Aerosol	42	(93)	42	(93)	6.2	(13.7)	6.2	(13.7)
Other	53	(117)	54	(118)	5.5	(12.1)	5.5	(12.2)
TOTAL SPECIAL PURPOSE	298	(656)	300	(659)	62.0	(136.6)	62.4	(137.5)
TOTAL THINNER AND MISC.	488	(1,073)	764	(1,982)	138.6	(305)	141.4	(311)
TOTAL PAINTS AND COATINGS	1,975	(4,345)	1,977	(4,349)	288.6	(635)	290.0	(640)

Note: Totals may not add due to rounding.

Source: Reference 15

No specific information was available relating the amount of toluene consumed in inks. However, toluene (and other organic solvents) are most often used in inks that employ a solvent carrier such as flexographic and rotogravure inks. The other two primary ink classifications, letterpress, and lithographic and offset inks, are of an oil or paste base.¹⁶

5.7.1 Process Description

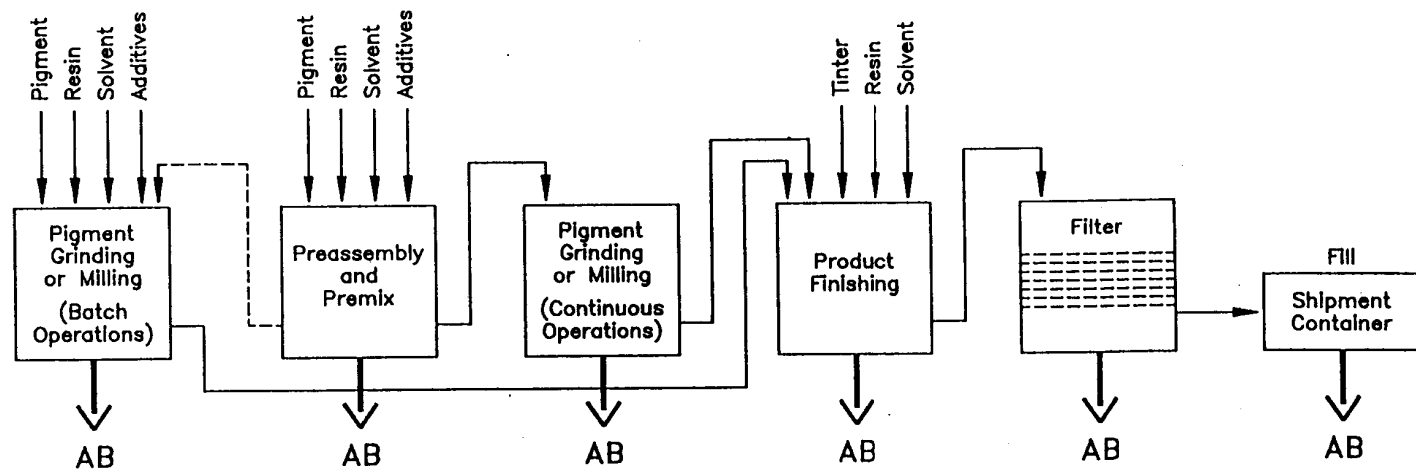
Paint and ink facilities use similar manufacturing processes to produce their respective products in batch scale production fashion. Most small plants (*e.g.*, facilities employing less than 20 people) produce paint in 40 to 2,000 liter (10 to 500 gallon) batches, while larger facilities produce paint in 800 to 11,000 liter (200 to 3,000 gallon) batches with stock items made in 40,000 liter (10,000 gallon) runs. Inks are produced in batches ranging from 4 liters to over 4,000 liters (1 to 1000 gallons).¹⁵

In most cases, manufacturing facilities 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:

- preassembly and premix
- pigment grinding/milling
- product finishing/blending
- product filling/packaging

The manufacturing process is summarized in Figure 5-5.¹⁶

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.



Sources of VOC Emissions

A - Emissions directly to air

B - Emissions resulting from Equipment Cleaning Operations

Figure 5-5. Flow diagram of the paint and ink manufacturing process¹⁶

With further processing, this base with high pigment concentration may become any one of a variety of specific end products.¹⁶

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.¹⁶

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 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.¹⁶

The final step in paint and ink manufacturing is product filling operations. After the material has been blended, it is transferred from the blend tanks into containers for product shipment. The transfer step normally involves product filtration.¹⁶

5.7.2 Emissions

The primary factors affecting the emission of toluene are the types of solvents and resins used in the manufacturing process, the temperature at which these compounds are mixed, and the methods and materials used during cleanup operations.¹⁶

Toluene is released from several types of equipment and handling operations throughout the paint and ink manufacturing process 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. Toluene 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. Toluene 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 toluene. Toluene emissions during filling operations result from product free-fall and material splashing. 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.¹⁶ 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, toluene 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.¹⁶ Emissions from cleaning equipment may be reduced by using rubber wipers, high-pressure spray heads, or automatic tub washers.¹⁶

There is little emission factor information available for the manufacture of paints and inks. Estimates 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 and ink manufacturing facilities calculate total plant VOC emissions based on raw material consumption rather than calculating emissions from processes or equipment by an alternative

method. Total emissions therefore reflect solvent losses during manufacturing, cleaning operations, and storage.¹⁶

5.8 SOLVENT CLEANING OPERATIONS

Surface cleaning or degreasing operations include solvent cleaning or conditioning of metal surfaces and parts, fabricated plastics, electronic and electrical components and other nonporous substrates. These cleaning processes are designed to remove foreign materials, such as grease, waxes, and moisture in preparation for further treatment such as painting, electroplating, galvanizing, anodizing or applying conversion coatings.

The three categories of solvent cleaning operations are cold cleaning, open-top vapor degreasing, and conveyORIZED degreasing which can employ either cold cleaning or vapor degreasing as its major cleaning process. When toluene is used, it is typically in cold cleaning operations.

5.8.1 Process Description

Cold cleaning is a batch process operation in which solvents are applied at room temperature or slightly above room temperature, but always below the solvent's boiling point. The mechanical or industrial parts or tools to be cleaned are placed in a basket inside the cold cleaner and immersed in the solvent. Parts too large for immersion may be sprayed or brushed. The solvent tank is often agitated to enhance its cleaning action. After cleaning, the parts are removed from the tank and allowed to dry.

Cold cleaners are usually the simplest and least expensive of the three types of solvent cleaners. The two basic types of cold cleaners are maintenance cold cleaners and manufacturing cold cleaners.¹⁸ Maintenance cold cleaners are normally simpler, less expensive, and smaller than manufacturing cold cleaners. They are used primarily for automotive and general plant maintenance cleaning. Manufacturing cold cleaners are larger, more specialized cleaners which perform a higher quality of cleaning than maintenance cleaners.¹⁹ Cold cleaners may incorporate

covers and freeboards to limit the evaporative loss of solvents. Freeboard is the distance between the solvent level and the top edge of the unit.¹⁸

5.8.2 Emissions

Cold cleaning can result in both direct and indirect atmospheric emissions of toluene. Cold cleaners are estimated to result in the largest total emissions of the three types of solvent cleaners, primarily due to the large numbers of these units and the high degree of evaporative losses. Emissions from cold cleaners can occur through bath evaporation, solvent carry-out, solvent agitation, waste solvent evaporation, and spray evaporation. These typical sources of emissions from cold cleaners are discussed below.^{19,20}

Bath evaporation from cold cleaners is simply evaporation from an uncovered solvent tank. This form of solvent loss can be reduced by covering the tank with a lid, increasing the freeboard height of the tank over the level of the solvent, and decreasing the amount of ventilation over an uncovered tank. Of these options, covering an open tank with a lid will usually render bath evaporation insignificant. Bath evaporation accounts for approximately 20 percent of the total organic emissions from cold cleaners.¹⁸ Solvent carry-out emissions are due to evaporation of the solvent residue from the part that was cleaned. Several factors regulate the amount of emissions from carry-out sources. Porous or absorbent materials (cloth, leather, wood) absorb the solvent and keep it retained for extended periods of time. The size of the load to be cleaned must be manageable in order to keep the solvent from splashing out of the degreasing unit. Proper drainage racks or shelves need to be employed to provide a place where the parts can dry off. It is recommended that all cold cleaned parts dry for a minimum of 15 seconds while in the drainage facility.^{19,20}

Emissions from the agitation of the solvent depends on use of the cover, agitation system adjustments, and volatility of the solvent. If the cover is kept closed, then usually emissions from agitation are kept low; however, when the tank is left open, emissions due to agitation of the solvent increase dramatically. Poor adjustment of the agitation system, especially the air flow, may lead to increased emissions.

Waste solvent evaporation is the largest source of atmospheric emissions from cold cleaners, accounting for between 50 and 75 percent of the total organic emissions.¹⁸ The degree of evaporation depends on the size of the cold cleaner, the frequency of disposal, and the method(s) of disposal. If the cold cleaning removes large amounts of contaminants, or the parts require a high degree of cleanliness, then the solvent will need replacement more often and emissions will generally be greater. Disposal methods also influence the degree of evaporation from the waste solvent. Some acceptable methods include proper incineration, distillation, and chemical landfilling, and emissions from these methods will vary depending on environmental and operational factors. Some disposal methods will result in total release of the waste solvent into the atmosphere. These methods include flushing the waste solvent into sewers or bodies of water, spreading the waste solvent for dust control, land-farming, and landfilling where the solvent can easily leach into the soil or evaporate into the air.

Evaporative emissions from spraying the solvent over the part to be cleaned vary depending on the pressure of the spray, the fineness of the spray, and the tendency of the solvent to splash and overspray out of the tank. Evaporation is also increased when the spray is used continuously and when the solvents are highly volatile. Generally, however, emissions from spray evaporation can be prevented through careful operation and equipment design.^{19,20}

5.9 OTHER SOLVENT USES

In addition to the previously discussed solvent end uses, toluene is used either alone or as a component of a multi-solvent system, in adhesives, rubbers, photographic film, agricultural sprays, and other chemical derivatives. Available emission factors for some of these miscellaneous uses are included in Table 5-6.

TABLE 5-6.
EMISSIONS FROM MISCELLANEOUS SOURCES OF TOLUENE

Process	Potential Source	Emission Factor	Quality Rating
Neoprene Manufacture	Blend Tank	0.05 g/kg neoprene	E
	Solution Makeup Tank	0.04 g/kg neoprene	E
	Batch Polykettle	0.018 g/kg neoprene	E
	Stripper	0.019 g/kg neoprene	E
	Wash Belts	0.015 g/kg neoprene	E
	Dryer Exhaust	2.0 g/kg neoprene	E

Source: Reference 21

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SECTION 6.0

EMISSIONS FROM THE USE OF TOLUENE-CONTAINING MATERIALS

As discussed in Section 3.0, toluene is present in many materials, including paints and coatings, inks, adhesives, resins, pharmaceuticals, gasoline and other formulated products using a solvent carrier. This section examines residual emissions from the use of toluene-containing materials. Toluene may be emitted when toluene-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 toluene'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, 290 million kilograms (640 million pounds) of toluene were consumed in paints and coatings.¹ Consumption of toluene in specific end-use markets was presented in Section 5.7, Table 5-5. Appendix C contains a listing of some of the surface coating source categories in which toluene is used. Appendix C also indicates associated SIC codes, potential toluene emission points, and emissions reduction opportunities. References are provided for additional information.

The general application methods for surface coating operations are discussed below. 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), 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 which causes the paint to flow 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^{2,3}

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 coating operation. The operations shown include degreasing, surface coating, and drying and curing. Auxiliary facilities include degreasing solvent storage, and surface coating storage and blending. Industrial categories, specific operations and emission points resulting in expected toluene emissions from surface coating operations are presented in Appendix A and in Appendix C.

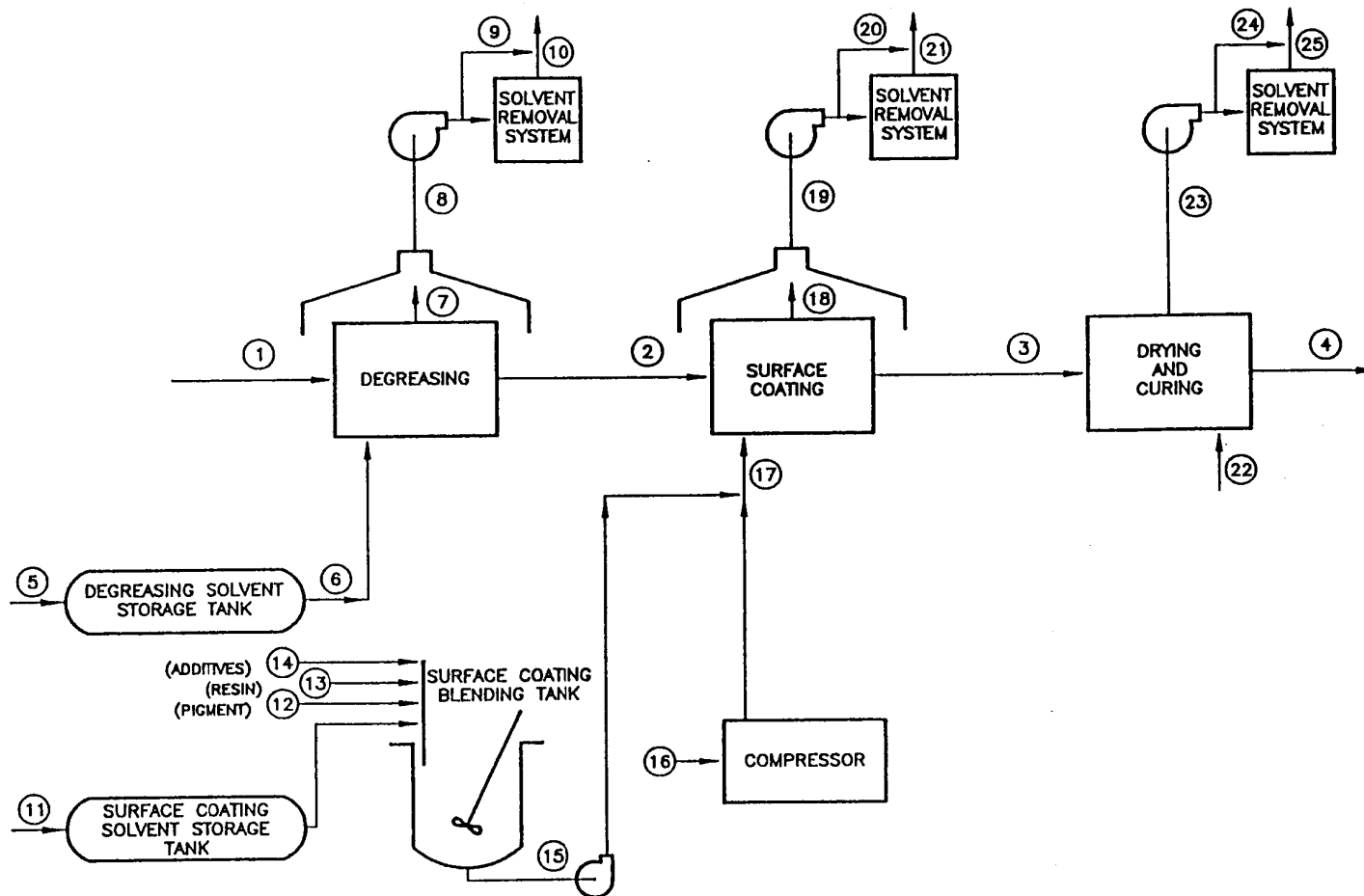


Figure 6-1. Flow diagram of a surface coating operation²

Streams 1, 2, 3, 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. Toluene 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 toluene used may vary.^{2,4-6} Emissions from the mixing and blending of surface coatings are discussed in Section 5.7.2.

Toluene 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.¹

One method of reducing toluene 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.²

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, with control efficiencies of 95 to 98 percent, are the most common control devices used in surface coating operations.^{2,4,5}

6.2 PRINTING AND PUBLISHING

The printing and publishing industry encompasses publishing, commercial printing, and trade services.⁷ 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 toluene. Toluene emissions from off-set lithography processes have not been measured and are thought to be minimal. The reader is encouraged to explore toluene 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.^{7,8} Appendix B, Table B-3 presents the companies in the printing and publishing SIC codes grossing \$1,000,000 or greater in annual sales.⁹

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 second to the last step in the printing process, and the main source of toluene emissions. The final step is cutting and finishing¹⁰

Printing ink composition varies among printing methods as well as among jobs using the same printing press and method. Printing inks in general can 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.² Printing processes using heatset inks that dry through evaporation of the solvent are the major concern for VOC (including toluene) emissions. Only the gravure and flexography printing processes are described here because specific emissions of toluene 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.¹¹

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.¹¹

A low viscosity ink is required for the gravure printing process. Raw ink concentrate generally contains 50 percent solvent by volume. The two most commonly used solvents in gravure printing and inks are toluene and a xylene-toluene-lactol spirit mixture (naphtha). Lactol Spirit is a petroleum solvent component of naphtha used in mixture to hasten evaporation. Toluene is known to produce a higher quality product and dissolves the ink resins well. However, toluene has a limited supply and 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.¹¹

Flexographic Printing Process Description--

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

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.¹² About 15 percent of all flexographic inks used are water-based.¹³ Steam-set inks use glycol solvents but do not contribute significantly to air emissions.¹⁴

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.² 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 percent 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.^{11,15,16} Typical ink formulations contain approximately 50 percent to 85 percent solvents by volume. Water based inks, used in packaging and product printing, contain approximately 5 percent to 30 percent solvents by volume and account for 30 percent to 40 percent of all inks used. Water-based inks account for approximately 15 percent of all inks used in all gravure printing processes.^{13,17}

Although specific emission estimates of toluene 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 toluene used relative to total solvent consumption. Toluene emissions may then

be estimated by multiplying the percentage of toluene 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 1987.¹⁸ 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 41.4 million pounds of virgin solvent purchased, 246.2 million pounds of solvent recovered, and 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. Projected to the entire gravure industry, these figures total 622.3 million pounds of solvent purchased or reused, and 606.7 million pounds of solvent recovered. The GAA projected total gravure publication plants' solvent consumption and fate based upon the percentage (by sales) of this segment responding to the survey.¹⁸ EPA projected solvent consumption and fate for the folding carton and flexible packaging segments based upon the same principle. The estimated ratio of solvent recovered to ink consumed for the publication segment of the industry was 73 percent.¹⁸

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.¹²

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.¹⁹ The average VOC control efficiency at these facilities ranged from 94 to 99.5 percent.

TABLE 6-1.
GRAVURE ASSOCIATION OF AMERICA INDUSTRY
SURVEY RESULTS
MILLIONS OF KILOGRAMS (MILLIONS OF POUNDS)

Printing Process	Reported Results						Projected Gravure Industry Estimates			
	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)	--	--	--	--

^aSurvey results scaled up to make projections for industry segments.

Source: Reference 18

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 Environmental Protection Agency (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)*²⁰
- *Magnetic Tape Manufacturing Industry - Background Information for Promulgated Standards (EPA-450/3-85-029b)*²¹

Capture efficiency may be estimated at 100 percent if all the EPA PTE criteria are met.¹⁹

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 approximate only 60 percent.¹² Alternative emission control techniques include the use of water-based inks and microwave driers.¹⁴

Recent studies have indicated that flexographic printing presses controlled by catalytic and regenerative incineration may achieve a 95 percent overall VOC reduction efficiency.^{13,22} A metal oxide catalyst is used on flexographic printing presses to avoid poisoning by chlorinated solvents.²²

6.3 GASOLINE AND AUTOMOTIVE EMISSIONS

Aromatic hydrocarbons including toluene are added to gasoline to raise the octane rating, thereby suppressing engine knock, increasing power, and providing smoother running engines. Toluene and other hazardous components may then be emitted in automotive exhaust. One study estimates the global release rate of toluene from automobile exhaust to be in the range of 3 to 8 metric tons (6,600 to 17,600 pounds) per year.²³ Automotive emissions have been related to photochemical smog and ozone formation for many years. Atmospheric models recently became sophisticated enough to accommodate compositional variations.²⁴

One recent study involving automotive emissions used 46 vehicles to provide detailed composition of organic emissions under various driving conditions.²⁴ Another study used a mobile TAGA 6000 EM tandem mass spectrometer system to obtain time resolved data for selected aromatic compounds.²⁵ Both of these studies present possible protocols to perform tests that would better characterize emissions and eventually estimate emissions of various VOC

species, including toluene. However, the information presented in these studies was not sufficiently comprehensive for emission factor development.

Table 6-2 lists the existing emission factors for toluene as a result of gasoline use. These emission factors were 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	Quality Rating ^a
Evaporation from automobile fuel tank	2.22 x 10 ⁻⁵ lb/vehicle mile traveled (1.0 x 10 ⁻² g/vehicle mile traveled)	U
Automobile exhaust	8.46 x 10 ⁻⁴ lb/vehicle mile traveled (3.8 x 10 ⁻¹ g/vehicle mile traveled)	U

^aBased on engineering judgement.
Source: Reference 26

6.4 GASOLINE MARKETING

Gasoline storage and distribution activities represent potential sources of toluene emissions. The toluene content of whole gasoline ranges from less than 1 to almost 16 percent (premium gasoline) by weight, but typical concentrations are around 15 percent by weight.²⁷ Therefore, total hydrocarbon emissions resulting from storage tanks, material transfer, and vehicle fueling include emissions of toluene. This section describes sources of toluene 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. The discussion is taken from Reference 28.

The transportation and marketing of petroleum liquids involve many distinct operations, each of which represents a potential source of toluene evaporative losses. Crude petroleum products are transported from production operations to a refinery by pipelines, water carriers (*e.g.*, barges), 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.²⁹

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. The typical bulk gasoline terminals have a daily throughput of 950,000 liters (250,000 gallons) of gasoline.²⁸

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 U.S., with a nationwide consumption of 419 billion liters (111 billion gallons) in 1991.³⁰ There are presently an estimated 1,700 bulk terminals storing gasoline in the U.S.³¹ 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.

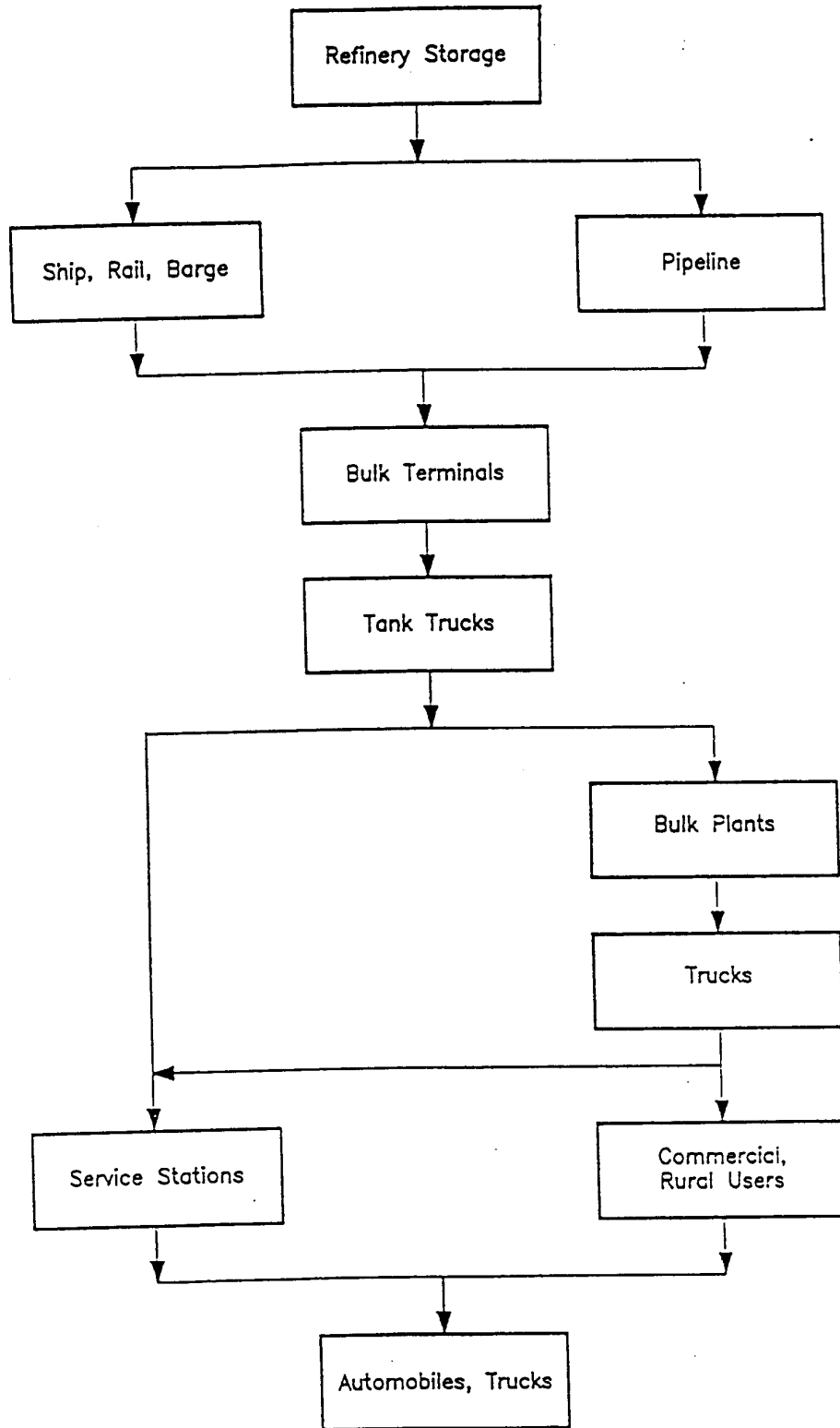


Figure 6-2. The gasoline marketing distribution system in the United States²⁸

Evaporative emissions from the transportation and marketing of petroleum liquids may be separated, by storage equipment and mode of transportation used, into four categories.

- Rail tank cars, tank trucks and marine vessels: loading, transit and ballasting losses
- Service stations: bulk fuel drop losses and underground tank breathing losses
- Motor vehicle tanks: refueling losses
- Large storage tanks: breathing, working and standing storage losses

The emission factors presented in the following discussions were derived from References 2, 28 and 32. A recent EPA memorandum describing speciated motor vehicle emissions identified diurnal, base gasoline evaporative organic emissions as consisting of 10.6 percent toluene. This reference defined a base gasoline (*i.e.*, an industry average summer fuel) as having 32 percent aromatics.³² Diurnal losses occur over a 24-hour period due to normal temperature changes. Although these losses refer to emissions from vehicles when the vehicle is stationary for an extended period with the engine switched off, the diurnal losses also approach the mechanisms that occur during the loading, unloading, and storage of gasoline.³³ To calculate an emission factor for toluene, the 10.6 (0.106) percent toluene factor was applied to the VOC emission factors for evaporative emissions presented in EPA documents.^{2,28,32}

6.4.1 Toluene Emissions From Loading Marine Vessels

Volatile organic compounds (VOC) can be emitted as crude oil and refinery products (gasoline, distillate oil, etc.) and are loaded and transported by marine tankers and barges. Loading losses are the primary source of evaporative emissions from marine vessel operations.²⁸ 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 is difficult to determine.

Assuming an average toluene/VOC ratio of 0.106 (Reference 32), emission factors for toluene from marine vessel loading were calculated and are given in Table 6-3. Factors are

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

Emission Source	Volatile Organic Compound Emission Factor (mg/L Transferred) ^a	Toluene Emission Factor (mg/L Transferred) ^b	Quality Rating ^c
Ship/Ocean Barge: ^d			
Uncleaned; volatile previous cargo	315	33.4	U
Ballasted; volatile previous cargo	205	21.7	U
Cleaned; volatile previous cargo	180	19.1	U
Gas-freed; volatile previous cargo	85	9.0	U
Any condition; nonvolatile previous cargo	85	9.0	U
Typical situation; any cargo	215	22.8	U
Barge: ^d			
Uncleaned; volatile previous cargo	465	49.3	U
Gas-freed; any cargo	245	25.9	U
Typical situation; any cargo	410	43.5	U

^aFactors are for nonmethane-nonethane VOC emissions.

^bBased on an average toluene/VOC ratio of 0.106 (Reference 32).

^cBased on engineering judgement.

^dOcean barge is a vessel with tank compartment depth of 40 feet; barge is a vessel with compartment depth of 10-12 feet.

Source: References 2 and 32

available for crude oil, distillate oil, and other fuels.^{2,28} However, reliable estimates of the toluene content of these fuels were not found. Therefore, it was not possible to provide toluene emission factors for marine vessel loading of fuels other than gasoline.

6.4.2 Toluene Emissions from Bulk Gasoline Plants, Bulk Gasoline Terminals and Service Stations

Each operation in which gasoline is transferred or stored is a potential source of toluene emissions. At bulk terminals and bulk plants, loading and unloading gasoline and storing gasoline are sources of toluene 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.²⁸ Top submerged loading is done by attaching a downspout to 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, top submerged loading and bottom loading reduce the amount of material (including toluene) that is emitted.²⁸

Vapor balancing systems, consisting of a pipeline between the vapor spaces of the truck and the storage tanks, are closed systems. These systems allow the transfer of vapor displaced by liquid in the storage tank into the transfer truck as gasoline is put into the storage tank.²⁸ Table 6-4 lists emission factors for gasoline vapor and toluene from gasoline loading racks at bulk terminals and bulk plants. The gasoline vapor emission factors were taken from Reference 28. The toluene factors were obtained by multiplying the gasoline vapor factor by the average toluene content of the vapor (0.106 percent).³²

A typical bulk terminal may have four or five above ground storage tanks with capacities ranging from 1,500-15,000 m³.²⁸ Most tanks in gasoline service have an external floating roof

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

Loading Method	Gasoline Vapor Emission Factor^a mg/L	Toluene Emission Factor^b mg/L	Quality Rating^c
Splash	1430	151.6	U
Submerged ^d	590	62.5	U
Balance Service	980	103.9	U

^aFrom Reference 28. Gasoline factors represent emissions of nonmethane-nonethane VOC. Factors are expressed as mg gasoline vapor per liter gasoline transferred.

^bBased on an average toluene/VOC ratio of 0.106 (Reference 32).

^cBased on engineering judgement.

^dSubmerged loading is either top or bottom submerged.

Source: References 28 and 32

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. Some tanks may use vapor balancing or processing equipment to control working 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.

The major types of emissions from fixed-roof tanks are breathing and working losses. Breathing loss is the expulsion of vapor from a tank vapor space that has expanded or contracted because of daily changes in temperature and barometric pressure. The emissions occur in the absence of any liquid level change in the tank. Combined filling and emptying losses are called "working losses." Emptying losses occur when the air that is drawn into the tank during liquid removal saturates with hydrocarbon vapor and expands, thus exceeding the fixed capacity of the vapor space and overflowing through the pressure vacuum valve.²⁸

A typical external floating-roof tank consists of a cylindrical steel shell equipped with a deck or roof that floats on the surface of the stored liquid, rising and falling with the liquid level. The liquid surface is completely covered by the floating roof except in the small annular space between the roof and the shell. A seal attached to the roof touches the tank wall (except for small gaps in some cases) and covers the remaining area. The seal slides against the tank wall as the roof is raised or lowered. The floating roof and the seal system serve to reduce the evaporative loss of the stored liquid.²⁸

An internal floating-roof tank has both a permanently affixed roof and a roof that floats inside the tank on the liquid surface (contact roof), or supported on pontoons several inches above the liquid surface (noncontact roof). The internal floating-roof rises and falls with the liquid level, and helps to restrict the evaporation of organic liquids.²⁸

Losses from floating-roof tanks include standing-storage losses and withdrawal losses. Standing-storage losses, which result from causes other than a change in the liquid level, constitute the major source of emissions from external floating-roof tanks. The largest potential source of these losses is an improper fit between the seal and the tank shell (seal losses). As a result, some liquid surface is exposed to the atmosphere. Air flowing over the tank creates pressure differentials around the floating roof. Air flows into the annular vapor space on the leeward side and an air-vapor mixture flows out on the windward side.²⁸

Withdrawal loss is another source of emissions from floating-roof tanks. When liquid is withdrawn from a tank, the floating roof is lowered and a wet portion of the tank wall is exposed. Withdrawal loss is the vaporization of liquid from the wet tank wall.²⁸

Table 6-5 presents emission factors for toluene from storage tanks at a typical bulk terminal. The emission factors were based on EPA (Reference 28) factors and the average weight fraction of toluene in the vapor of 0.106.³²

The two basic types of gasoline loading into tank trucks at bulk plants are the same as those used at terminals. The first is the splash filling method, which usually results in high levels

**TABLE 6-5.
TOLUENE EMISSION FACTORS FOR STORAGE LOSSES AT
A TYPICAL GASOLINE BULK TERMINAL**

Storage Method	Gasoline Vapor Emissions Factor (Mg/yr/Tank)	Toluene Emission Factor Mg/yr/Tank ^a	Quality Rating ^b
Fixed Roof ^c			
Working Loss	34.2	3.6	U
Breathing Loss	8.8	0.9	U
External Floating Roof ^d			
Working Loss	e	e	U
Storage Loss	9.6	1.0	U

^aTerminal with 950,000 liters/day (250,000 gallons/day) with four storage tanks for gasoline.

^bBased on engineering judgement.

^cTypical fixed-roof tank based upon capacity of 2,680 m³ (16,750 barrels).

^dTypical floating-roof tank based upon capacity of 5,760 m³ (36,000 barrels).

^eEmission factor = $9.89 \times 10^{-7} Q$ Mg/yr, where Q is the throughput through the tanks in barrels (References 28 and 32).

Source: References 28 and 32.

of vapor generation and loss. The second method is submerged filling with either a submerged fill pipe or bottom filling, which significantly reduces liquid turbulence and vapor-liquid contact resulting in much lower emissions. Table 6-6 shows the uncontrolled emission factors for toluene from a typical bulk plant.

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 occur less frequently include tank shell flaws, liquid and vapor transfer hoses, improperly installed or loosened overfill protection sensors, and vapor couplers. Since terminal

TABLE 6-6.
UNCONTROLLED GASOLINE VAPOR AND TOLUENE
EMISSION FROM A TYPICAL BULK PLANT

Emission Source ^a	Gasoline Vapor Emission Factor mg/L	Toluene Emission Factor ^b mg/L	Quality Rating ^c
Storage Tanks - Fixed Roof			
Breathing Loss	600	63.6	U
Filling Loss	1150	121.9	U
Draining Loss	460	48.8	U
Gasoline Loading Racks			
Splash Loading	1430	151.6	U
Submerged Loading	590	62.5	U
Submerged Loading (Balance Service)	980	103.9	U

^aTypical bulk plant with a gasoline throughput of 19,000 liters/day (5,000 gallons/day).

^bBased on gasoline emission factor and toluene/vapor ratio of 0.106 (Reference 32).

^cBased on engineering judgement.

Source: References 28 and 32

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 (960 mg/liter x 0.30 = 288 mg/liter).²⁸ Thus, the emission factor for toluene emissions from uncontrolled truck leakage is 30.5 mg/liter, based on a toluene/vapor ratio of 0.106.³²

The 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.²⁸

Toluene Emission from 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.²⁸

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 spillage. The major factors affecting the quantity of emissions are gasoline temperature, auto tank temperature, gasoline Reid vapor pressure (RVP), and dispensing rates. Table 6-7 lists the uncontrolled emissions from a typical gasoline service station. The gasoline vapor emission factors presented in Table 6-7 are from EPA documents.²⁸

6.4.3 Control Technology for Gasoline Transfer

At bulk terminals and bulk plants, toluene emissions from gasoline transfer may be controlled by a vapor processing system in conjunction with a vapor collection system.²⁸ Figure 6-3 shows a Stage I control 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.²⁸

**TABLE 6-7.
UNCONTROLLED GASOLINE VAPOR AND TOLUENE
EMISSIONS FROM A TYPICAL SERVICE STATION**

Emission Source^a	Gasoline Vapor Emission Factor mg/L	Toluene Emission Factor^b mg/L	Quality Rating^c
Underground Storage Tanks			
Tank Filling Losses			
- Submerged Fill	880	93.3	U
- Splash Fill	1380	146.3	U
- Balanced Submerged Filling	40	4.2	U
Breathing Losses	120	12.7	U
Automobile Refueling			
Displacement Losses			
- Uncontrolled	1320	139.9	U
- Controlled	132	13.9	U
Spillage	84	8.9	U

^aTypical service station has a gasoline throughput of 190,000 liters/month (50,000 gallons/month).

^bBased on gasoline vapor emission factor and toluene/vapor ratio of 0.106 (Reference 32).

^cBased on engineering judgement.

Source: References 28 and 32

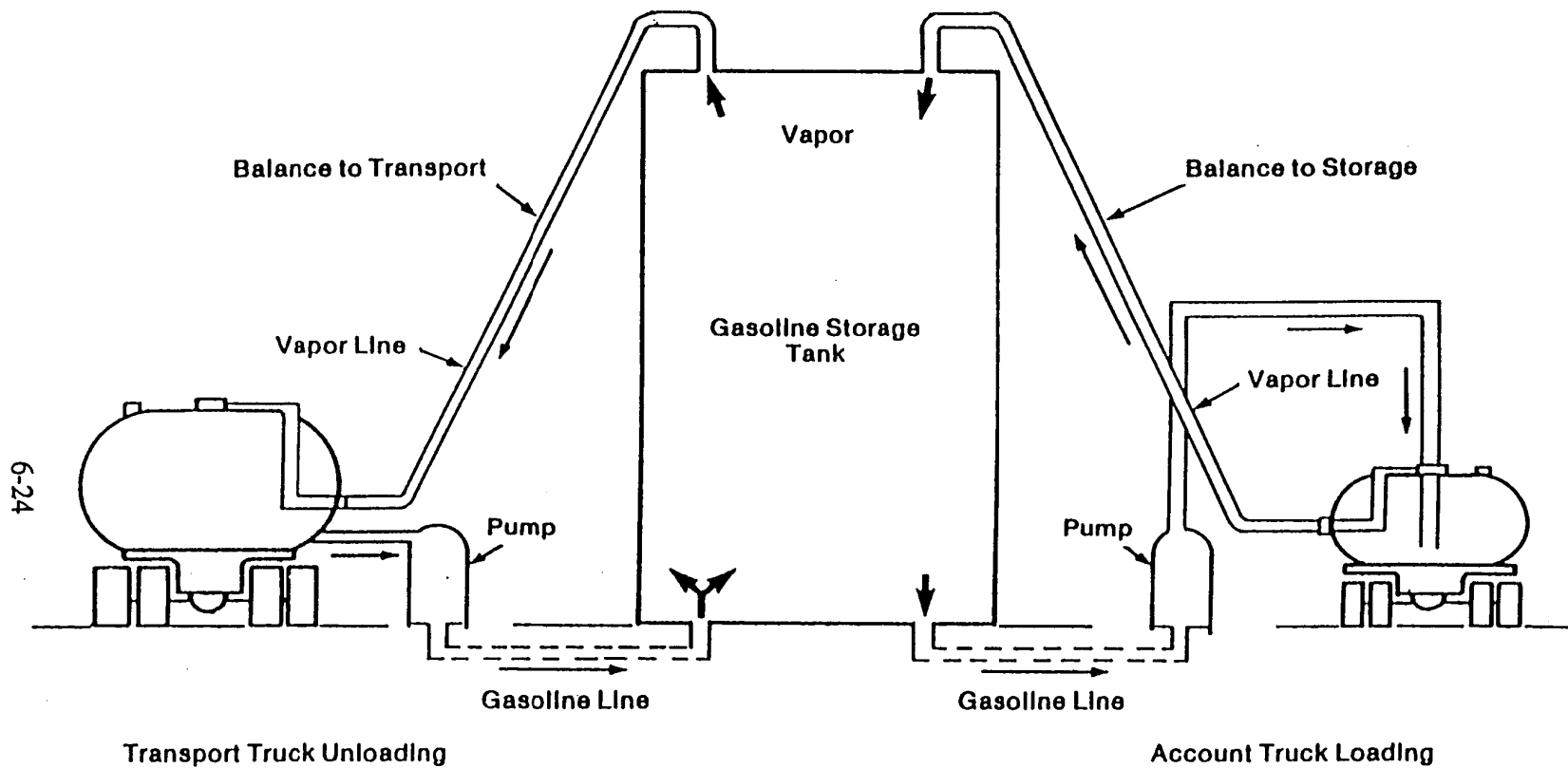


Figure 6-3. Bulk plant vapor balance system²⁸

6-25

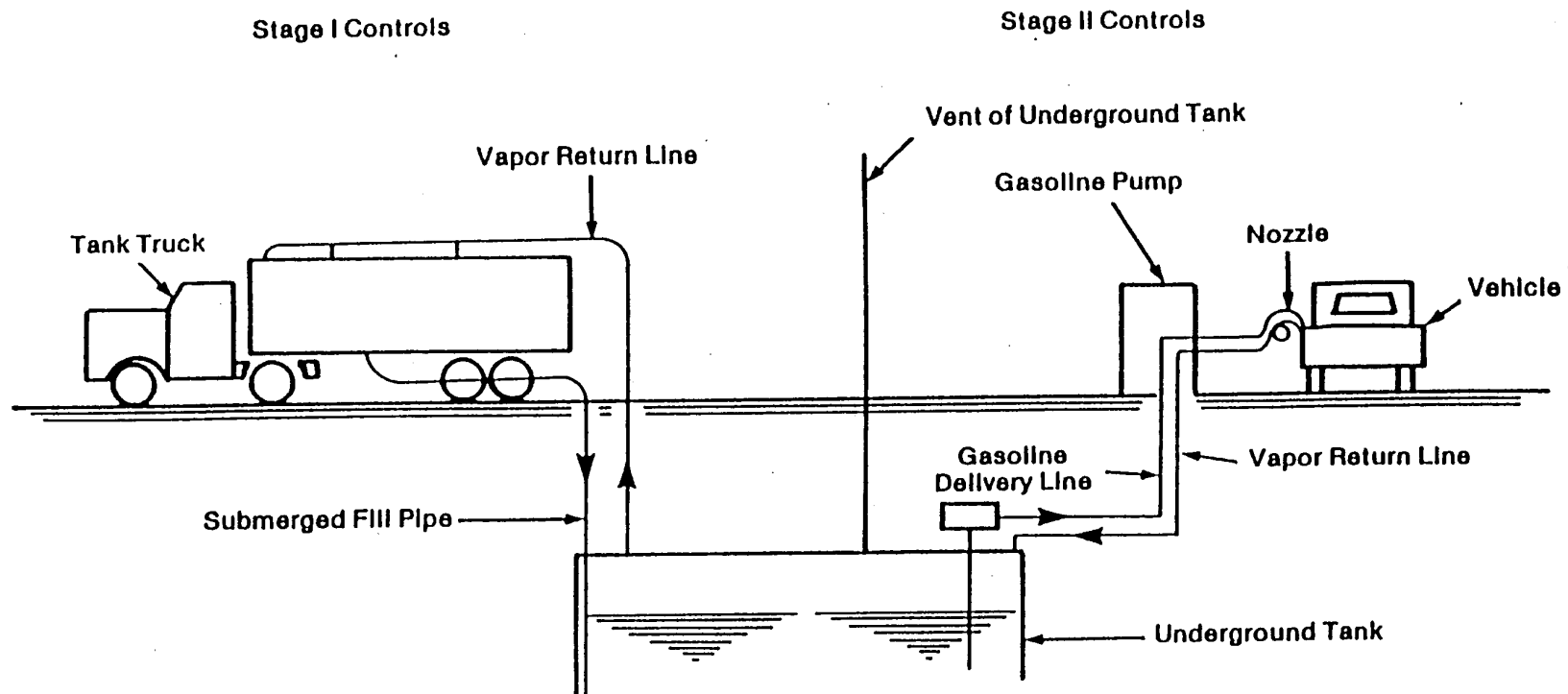


Figure 6-4. Service station vapor balance system²⁸

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.

6.4.4 Control Technology For Gasoline Storage

The control technologies for controlling toluene emissions from gasoline storage involve upgrading the type of storage tank used or addition of a vapor control system. For fixed-roof tanks, emissions are most readily controlled by installation of internal floating roofs.²⁸ 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.²⁸

For external floating-roof tanks, no control measures have been identified for controlling withdrawal losses and emissions.²⁸ 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.²⁸ Metallic shoe seals are more effective than vapor-mounted seals but less effective than liquid mounted seals.²⁸

6.4.5 Control Technology For Vehicle Refueling Emissions

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

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.²⁸

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 not allowing the vapors to escape. 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.²⁸

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 vacuum, while keeping the vacuum low enough so that a minimum level of excess vapor/air is 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 goes 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, and thus there is no need for a secondary processor, such as the vacuum assist's incinerator.²⁸

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.²⁸

6.5 OTHER SOURCES OF RESIDUAL TOLUENE EMISSIONS

Toluene can be emitted during the use of toluene-containing materials in manufacturing another product. Emissions from some of these miscellaneous sources are presented in Table 6-8.

**TABLE 6-8.
RESIDUAL EMISSIONS FROM MISCELLANEOUS SOURCES
OF TOLUENE**

Source	Concentration in Air	Emission Rate	Quality Rating
Particle board with carpet ^a	N/A	0.061 µg/m ² /hour	E
Mineral wool used as thermal insulation ^b	13-90 µg/m ³	N/A	D
Building materials (particle board, plywood, sealing agents, wallpaper, floor coverings, paint foam, and concrete) ^c	39.7 µg/m ³	N/A	D
Clear acrylic latex caulk with silicone ^d	Detected	N/A	U ^g
Synthetic rubber adhesive (for walls and ceilings) ^e	N/A	0.59 µg/g/hour	E
Synthetic rubber adhesive (for vinyl carpet) ^e	N/A	62 µg/g/hour	E
Unspecified polymer adhesive (for subflooring) ^e	N/A	2.4-2.6 µg/g/hour	E
Building materials ^f vinyl cove molding telephone cable urethane insulant	detected detected detected	N/A N/A N/A	U ^g U ^g U ^g

N/A - Not available

a - Reference 34

b - Reference 35

c - Reference 36

d - Reference 37

e - Reference 38

f - Reference 39

g - Not enough available information to apply a rating

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SECTION 7.0
BY-PRODUCT EMISSIONS:
PROCESSES UNRELATED TO PRODUCTION OR USE OF TOLUENE

Toluene 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 toluene as by-product emissions are described in this section. These processes include coal combustion, hazardous and solid waste incineration, and wastewater treatment processes. Data pertaining to emissions from fossil fuel combustion in boilers and heaters were unavailable and therefore are not included in this section.

7.1 COAL COMBUSTION

Two coal combustion studies are briefly described in this section. The first study analyzed samples collected from a gasifier. The second coal combustion study analyzed emissions from a burning coal refuse pile.^{1,2}

A coal 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 toluene existed at the gasifier. However, no data were reported.¹

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 toluene are suspected. Under the direction of EPA, GCA/Technology Division performed a study on the types and quantities of emissions from the gob pile.²

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.²

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.²

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 in elevation above the test area to measure overall regional wind conditions.²

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 toluene resulting from this study.²

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

Parameter	Total Emission Rate	Emission Factor	Quality Rating
Toluene	4.3 ± 3.6 kg/hr (9.4 ± 8.0 lb/hr)	4.1 x 10 ⁻⁵ kg/hr/m ³ (2.5 x 10 ⁻⁶ lb/hr/ft ³) 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.²

7.2 HAZARDOUS AND SOLID WASTE INCINERATION

The majority of atmospheric emissions of pollutants from the various hazardous and solid waste disposal methods comes from incineration. In addition to particulate matter, other pollutants, such as volatile organic compounds (including toluene) 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*.³ Similarly, hazardous waste can

be incinerated by several methods including thermal, catalytic and regenerative incineration. Toluene emission factors from 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 toluene) with decreased emissions of nitrogen oxides. 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).⁴ Although specific toluene emission factors are unavailable, 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 42 percent other compounds (oxygenates, acetylene, and aromatics, including toluene).⁴

7.3 WASTEWATER TREATMENT PROCESSES

Atmospheric emissions of volatile organic compounds such as toluene can occur at any wastewater treatment process where the wastewater comes into contact with the surrounding ambient air. An estimated 5 million kilograms (11 million pounds) of toluene are discharged to the environment annually as a constituent in wastewater.⁵ A study conducted at two Chicago-area wastewater treatment facilities estimated that approximately 94 percent of the toluene in the influent waters biodegraded in activated sludge systems while only 3 percent volatilized. However, if all of the influent toluene at the two facilities were to volatilize, it would account for nearly 29,000 kilograms (64,000 pounds) per year.⁶ Another study conducted in California estimated total air emissions of toluene from statewide municipal wastewater treatment plants to be approximately 250,000 kilograms (550,000 pounds per year).⁷

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.

Because of the many factors that may affect emissions of volatile organics, including toluene, 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. A brief description 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.^{8,9} The Tsivoglou 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).¹⁰

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.^{7,8}

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SECTION 8.0

AMBIENT AIR AND STATIONARY SOURCE TEST PROCEDURES

Toluene 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. If ambient air methodology is applied to stationary source testing, appropriate precautions must be taken to ensure that the capacity of the methodology is not exceeded so that results will be quantitative. 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 is not possible.

- EPA Method TO-1: Determination of Volatile Organic Compounds in Ambient Air Using Tenax[®] Adsorption and Gas Chromatography/Mass Spectrometry (GC/MS)
- EPA Method TO-2: Determination of Volatile Organic Compounds in Ambient Air by Carbon Molecular Sieve 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[®] Passivated Canister Sampling and Gas Chromatographic (GC) Analysis
- 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
- EPA Method 0010: Modified Method 5 Sampling Train with EPA Method 8270: Gas Chromatography/Mass Spectrometry for Semi-volatile Organics: Capillary Column Technique
- NIOSH Method 1501: Aromatic Hydrocarbons

The following subsections briefly describe the recommended sampling and analytical methods for determining toluene emissions.

8.1 EPA METHOD TO-1¹

Ambient air concentrations of toluene can be measured using EPA Method TO-1 from the *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*. This method is used to collect and determine volatile nonpolar organics (aromatic hydrocarbons, chlorinated hydrocarbons) that can be captured on Tenax[®] 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 of the sampling system and Figure 8-2 presents a schematic of typical Tenax[®] cartridge designs.

Ambient air is drawn through the cartridge which contains approximately 1-2 grams (0.035 to 0.07 ounces) of Tenax[®]. Toluene is trapped on the Tenax[®] cartridge which is then capped and sent to the laboratory for analysis utilizing purge-and-trap gas chromatography/mass spectrometry (GC/MS) according to the procedures specified in EPA Method 5040 (see Section 8.6). The recommended GC column is a 50 meter capillary, type SE-30 with an internal diameter of 0.3 mm.

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 (0.3 to 0.7 ft³) of ambient air are sampled. Analysis should be conducted within 14 days of sample collection.

8.2 EPA METHOD TO-2¹

Ambient air concentrations of toluene can be measured using EPA Method TO-2 from the *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*.

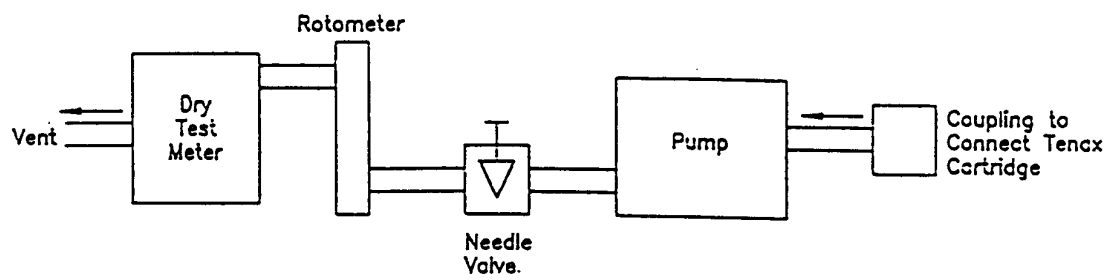
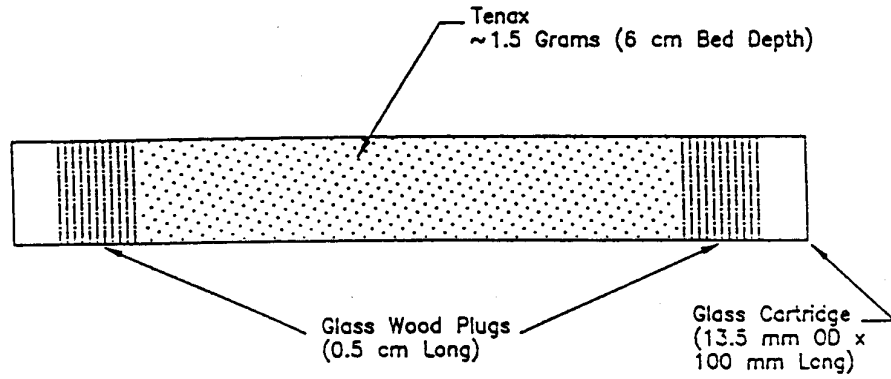
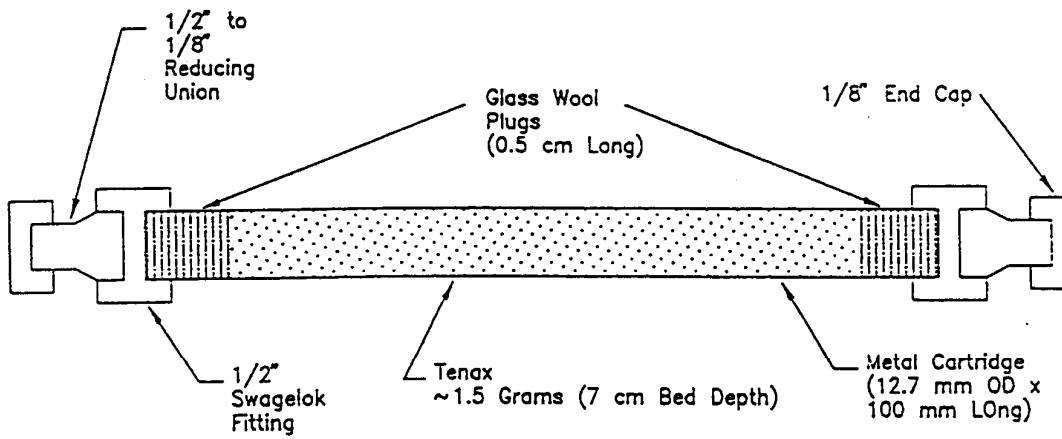


Figure 8-1. EPA Method TO-1 sampling system¹



(a) Glass Cartridge



(b) Metal Cartridge

Figure 8-2. Tenax[®] cartridge design¹

Compounds which can be determined using this method are nonpolar and highly volatile organics that can be captured on carbon molecular sieve (CMS) and determined by thermal desorption techniques. The compounds to be determined by this method have boiling points in the range of -15° to 120°C (5° to 250°F). Toluene can be determined using this method.

In summary, ambient air is drawn through a cartridge containing approximately 0.4 grams (0.01 ounces) of CMS adsorbent. Toluene is captured on the adsorbent while major inorganic compounds pass through. The sample is then capped and sent to the laboratory for analysis.

Prior to analysis, the CMS cartridge is purged with 2 or 3 L (0.07 to 0.1 ft³) of pure dry air to remove any moisture. The cartridge is then heated to 350° to 400°C (660° to 750°F) under a helium purge, and the desorbed toluene is collected in a specially designed cryogenic trap. The collected toluene is then flash evaporated onto a capillary column (SE-30) and quantified using a GC/MS system.

The exact run time, flow rate and volume sampled varies from source to source depending on the expected concentration and the required detection limit. Typically, Method TO-2 is used when ambient air concentrations are expected to be high. CMS has the ability to adsorb large quantities of organics before breakthrough occurs.

Figure 8-1 is representative of both Methods TO-1 and TO-2 sampling systems. Figure 8-3 illustrates a CMS trap.

8.3 EPA METHOD TO-3¹

Ambient air concentrations of toluene can be measured directly at the source using EPA Method TO-3 from the *Compendium Methods for the Determination of Toxic Organic Compounds in Ambient Air*. 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 8-4 presents a schematic of a typical on-line GC sampling system using cryogenic trapping.

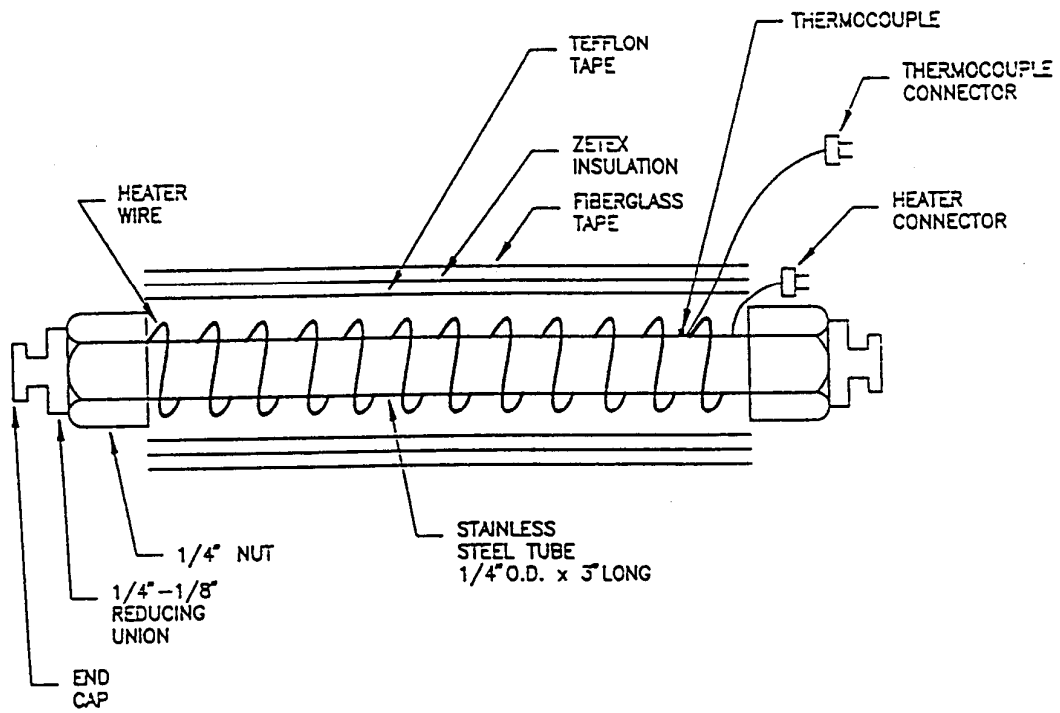


Figure 8-3. Carbon molecular sieve trap (CMS) construction

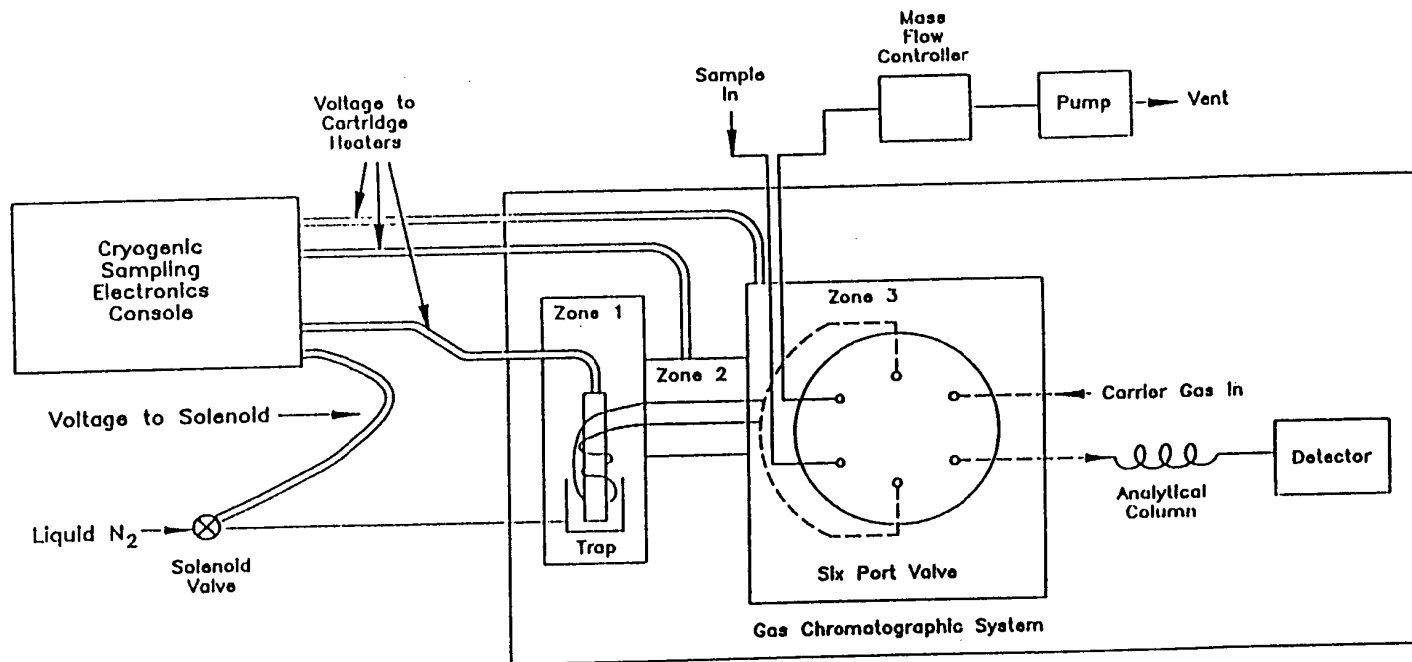


Figure 8-4. Automated sampling and analysis system for cryogenic trapping¹

The ambient air sample is collected in the cryogenic trap using a vacuum pump equipped with a mass flow controller. 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 then heated to the desired temperature and the eluting peaks are identified and quantified using a flame ionization detector (FID).

8.4 EPA METHOD TO-14¹

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

This method is applicable to specific semi-volatiles and volatile organic compounds that have been tested and determined to be stable when stored in pressurized and subatmospheric pressure canisters. Toluene can be successfully measured at the parts per billion by volume (ppbv) level using this method.

Figure 8-5 presents a diagram of the canister sampling system.

8.5 EPA METHOD 0030²

The volatile organic sampling train (VOST) from SW-846, (third edition) is designed for the collection of volatile organic compounds from the stack gas effluents of hazardous waste

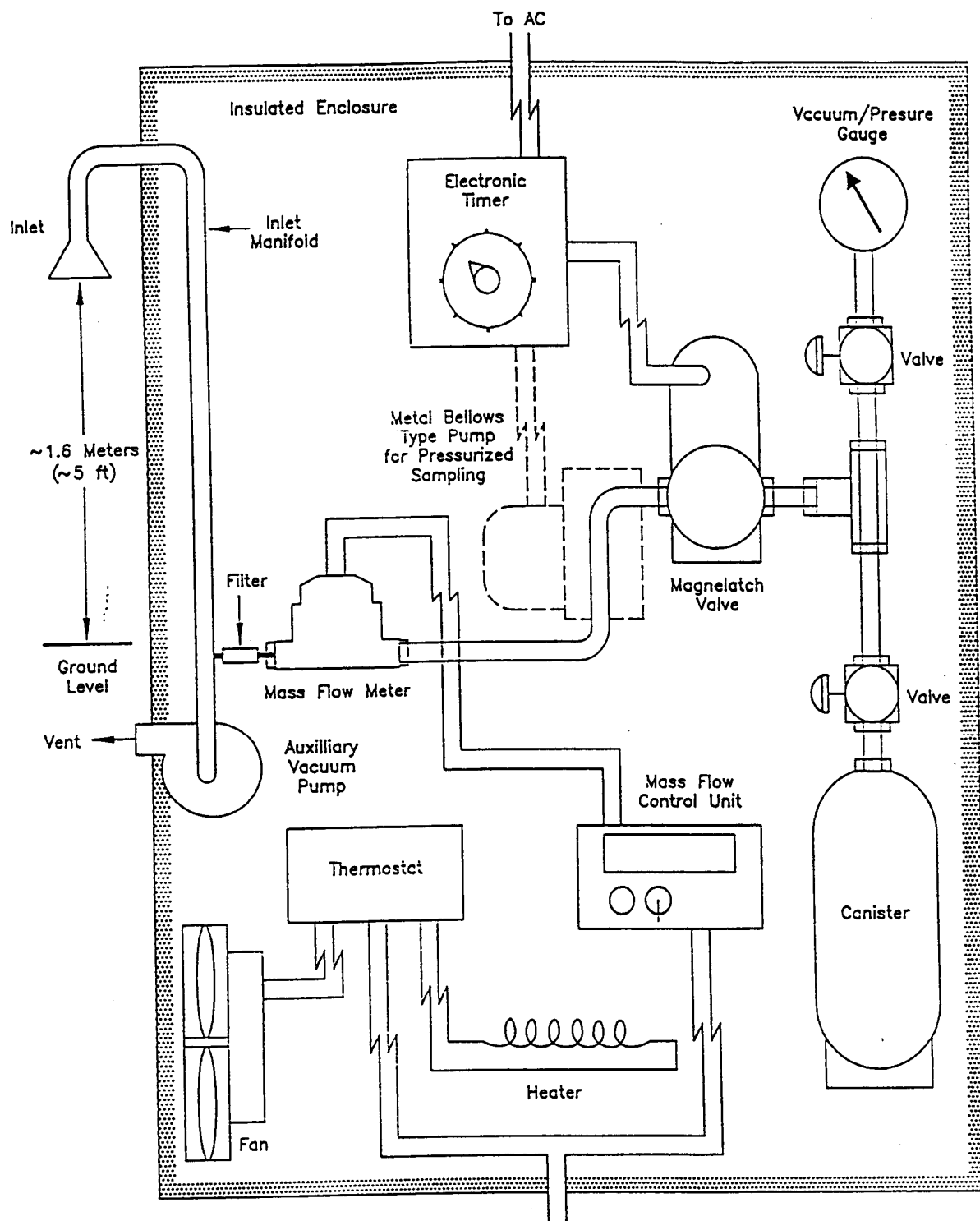


Figure 8-5. Canister Sampling System¹

incinerators. 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. Toluene concentrations can be measured using this method. Figure 8-6 presents a schematic of the principle components of the VOST.

In most cases, 20 L (0.7 ft³) of effluent stack gas are sampled at an approximate flow rate of 1 L/minute (0.04 ft³/min) using a glass-lined heated probe. 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 the impinger located between the two resin traps. The first resin trap contains about 1.6 g (0.06 ounce) Tenax[®] and the second trap contains about 1 g (0.04 ounce) each of Tenax[®] and petroleum-based charcoal.

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

8.6 EPA METHOD 5040²

Principal organic hazardous constituents (POHCs) are collected on Tenax[®] and Tenax[®]/charcoal sorbent cartridges using a VOST, EPA Method 0030. The contents of the sorbent cartridges 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 (2.4 in³)], bubbled through 5 mL (0.3 in³) of organic-free water, and trapped on an analytical adsorbent trap. After the 10 minute desorption, the analytical adsorbent trap is rapidly heated to 180°C (356°F), with the carrier gas flow reversed so that the effluent flow from the analytical trap is directed into the GC/MS. The volatile POHCs are separated by temperature-programmed gas chromatography and detected by low resolution mass spectrometry. The concentrations of the volatile POHCs are calculated using the internal standard technique.

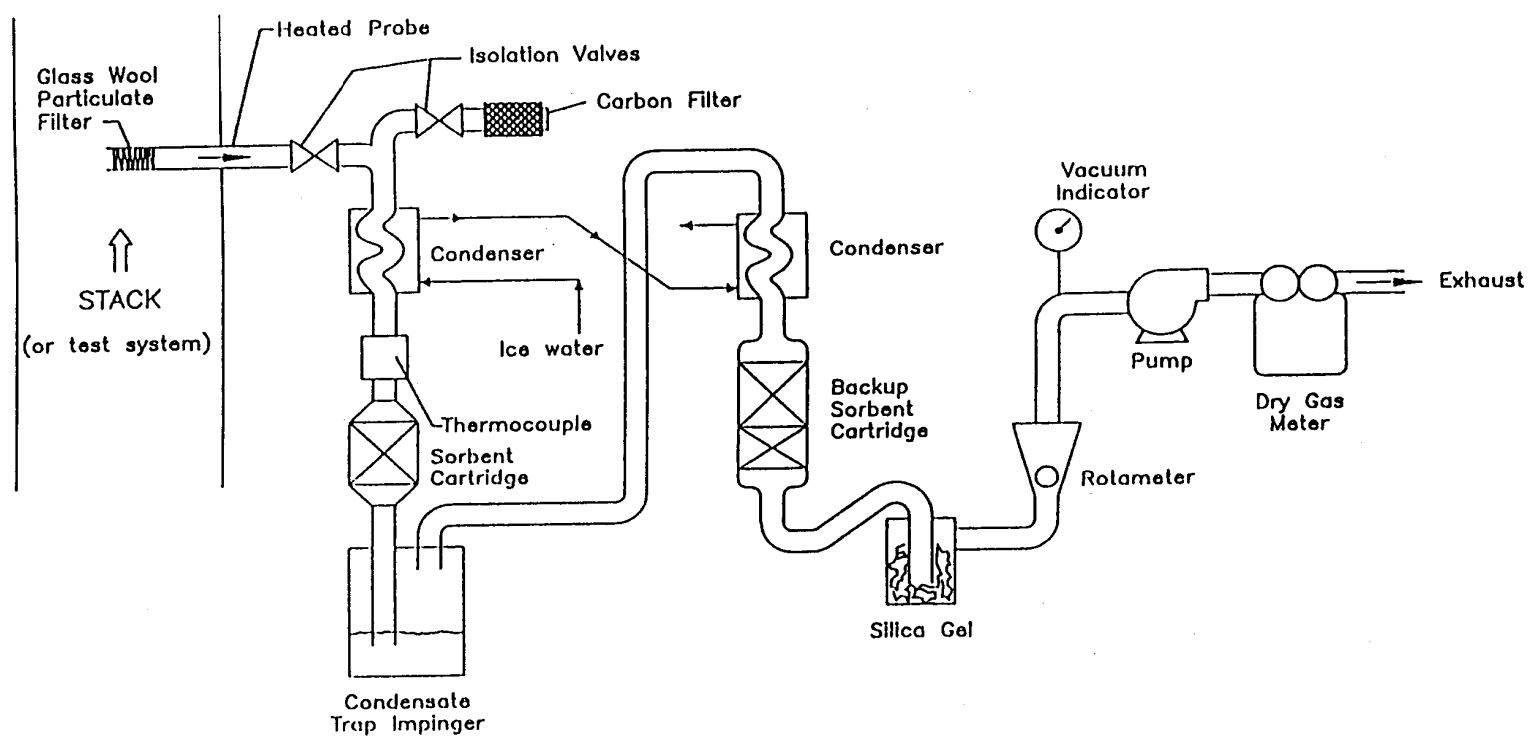


Figure 8-6. Schematic of volatile organic sampling train (VOST)²

EPA Methods 5030 and 8240 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 8-7. The Tenax[®] 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[®] cartridge).

8.7 EPA REFERENCE METHOD 18³

EPA Reference Method 18 from 40 CFR Part 60, Appendix A, can be utilized for the sampling and analysis of approximately 90 percent of the total gaseous organics emitted from industrial sources. 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. Toluene emissions can be measured from stationary sources using this method. Method 18 can be conducted using either the direct interface method (on-line GC with FID) or by the collection of an integrated Tedlar[®] or Mylar[®] bag 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 onto the column of the GC fitted with an FID. Figure 8-8 presents a diagram of the principle components of the direct interface sampling system.

Using the bag in drum technique as presented in Figure 8-9, a sample of the exhaust gas is drawn into a Tedlar[®] or Mylar[®] bag. The bag is placed inside a rigid leakproof container and evacuated. The bag is then connected by a Teflon[®] sample line to a sampling probe located at the center of the stack. The sample is drawn into the bag by pumping air out of the rigid container. The sample is then analyzed on-site or back at the laboratory by GC/FID. The stability of toluene in a Tedlar[®] or Mylar[®] bag is currently unknown. Therefore, it is recommended that the analysis be conducted as soon as possible.

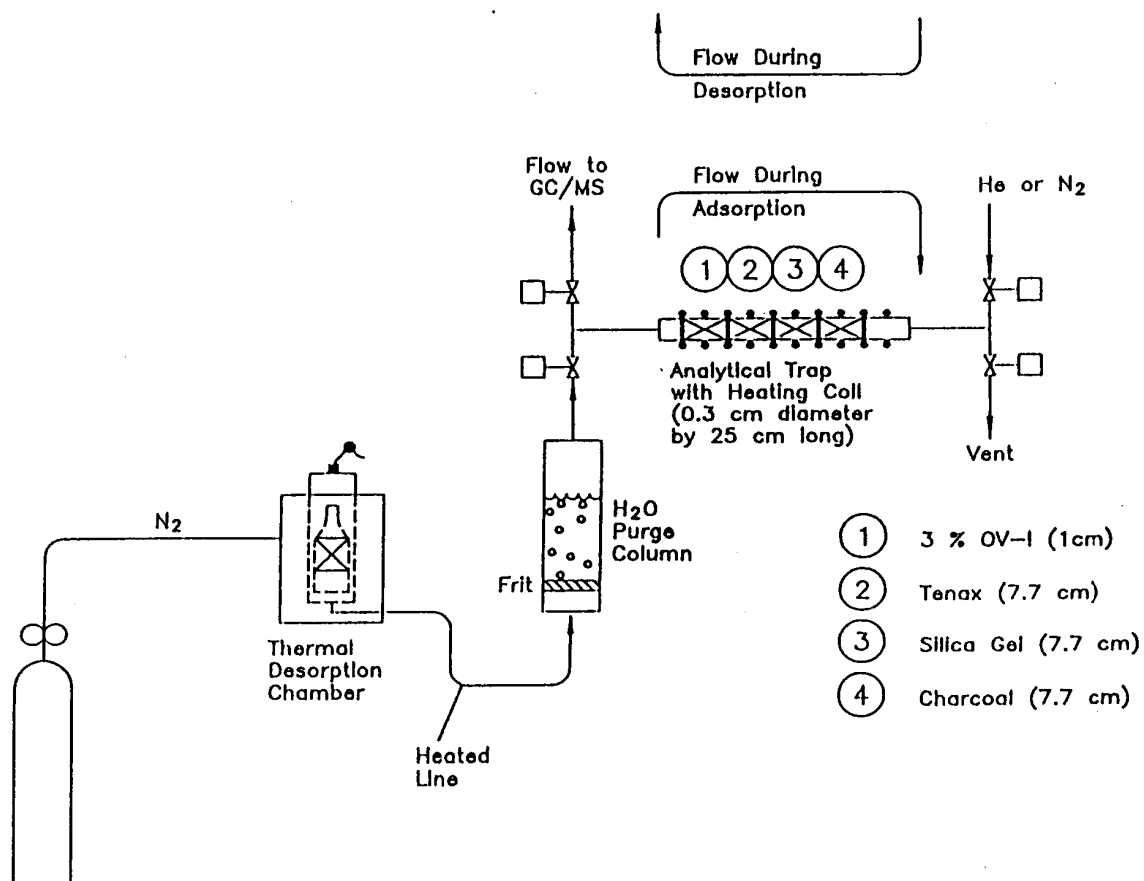


Figure 8-7. Schematic diagram of trap desorption/analysis system²

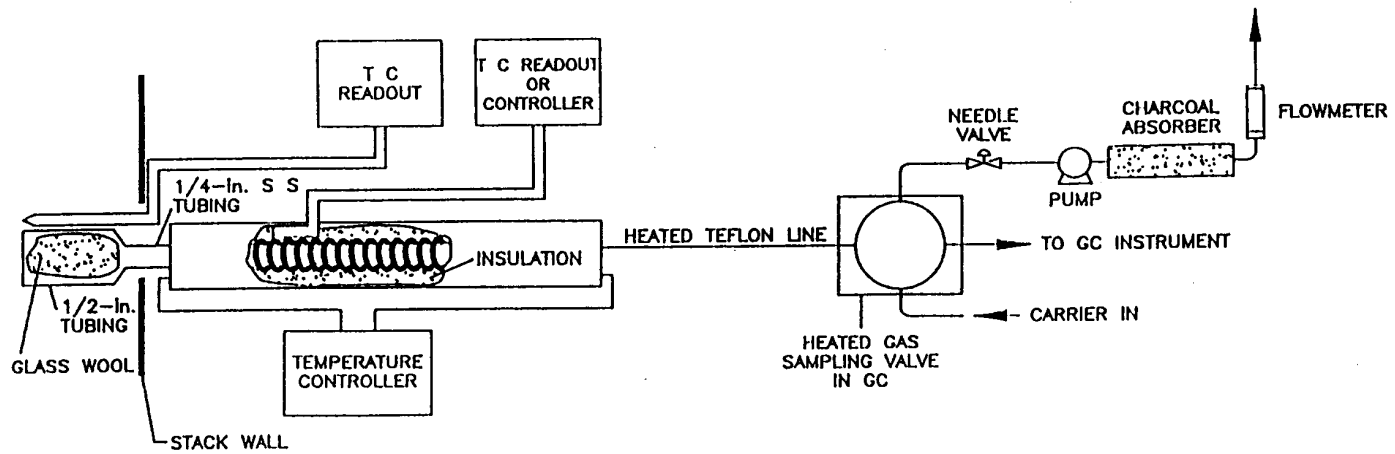


Figure 8-8. Direct interface sampling system³

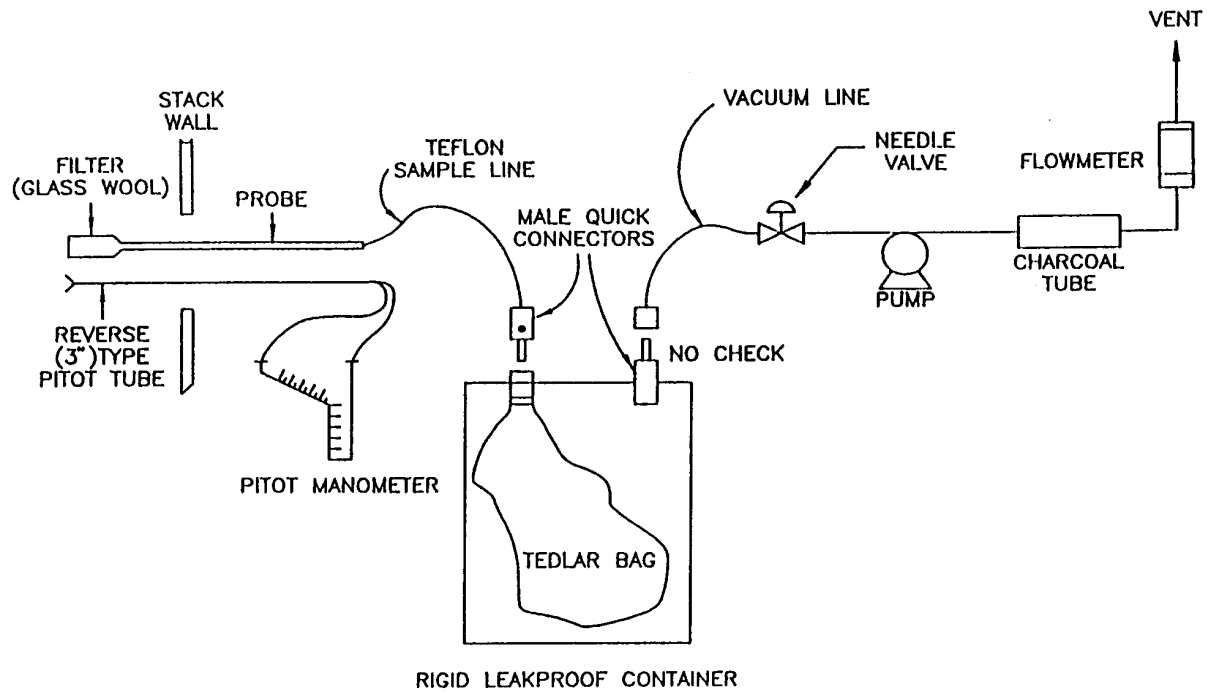


Figure 8-9. Integrated bag sampling train³

8.8 EPA METHOD 0010²

EPA Method 0010 (Modified Method 5 Sampling Train) is used to determine the destruction and removal efficiency of semi-volatile principal organic hazardous constituents (POHCs) from incineration systems. This method may be used for determining toluene emissions.

Gaseous and particulate pollutants are withdrawn isokinetically from an emission source and collected in a multicomponent sampling train. Figure 8-10 presents a schematic of the sampling system. Principal components of the train include a high-efficiency glass- or quartz-fiber filter and a packed bed of porous polymeric adsorbent resin (typically XAD-2[®] or polyurethane foam for PCBs). The filter is used to collect organic-laden particulate materials and the porous polymeric resin to adsorb semi-volatile organic species (compounds with a boiling point above 100°C (212°F)). Comprehensive chemical analyses, using a variety of applicable analytical methodologies, are conducted to determine the identity and concentration of the organic materials.

8.9 EPA METHOD 8270²

EPA Method 8270 is used to determine the concentration of semi-volatile organic compounds in extracts prepared from all types of solid waste matrices, soils, and ground water. It is also applicable to an extract from sorbent media in conjunction with Method 0010. Direct injection of a sample may be used in limited applications.

Method 8270 can be used to quantify most neutral, acidic, and basic organic compounds that are soluble in methylene chloride and capable of being eluted without derivatization as sharp peaks from a gas chromatographic fused-silica capillary column coated with a slightly polar silicone. Toluene is within the boiling point range and may be determined using this methodology.

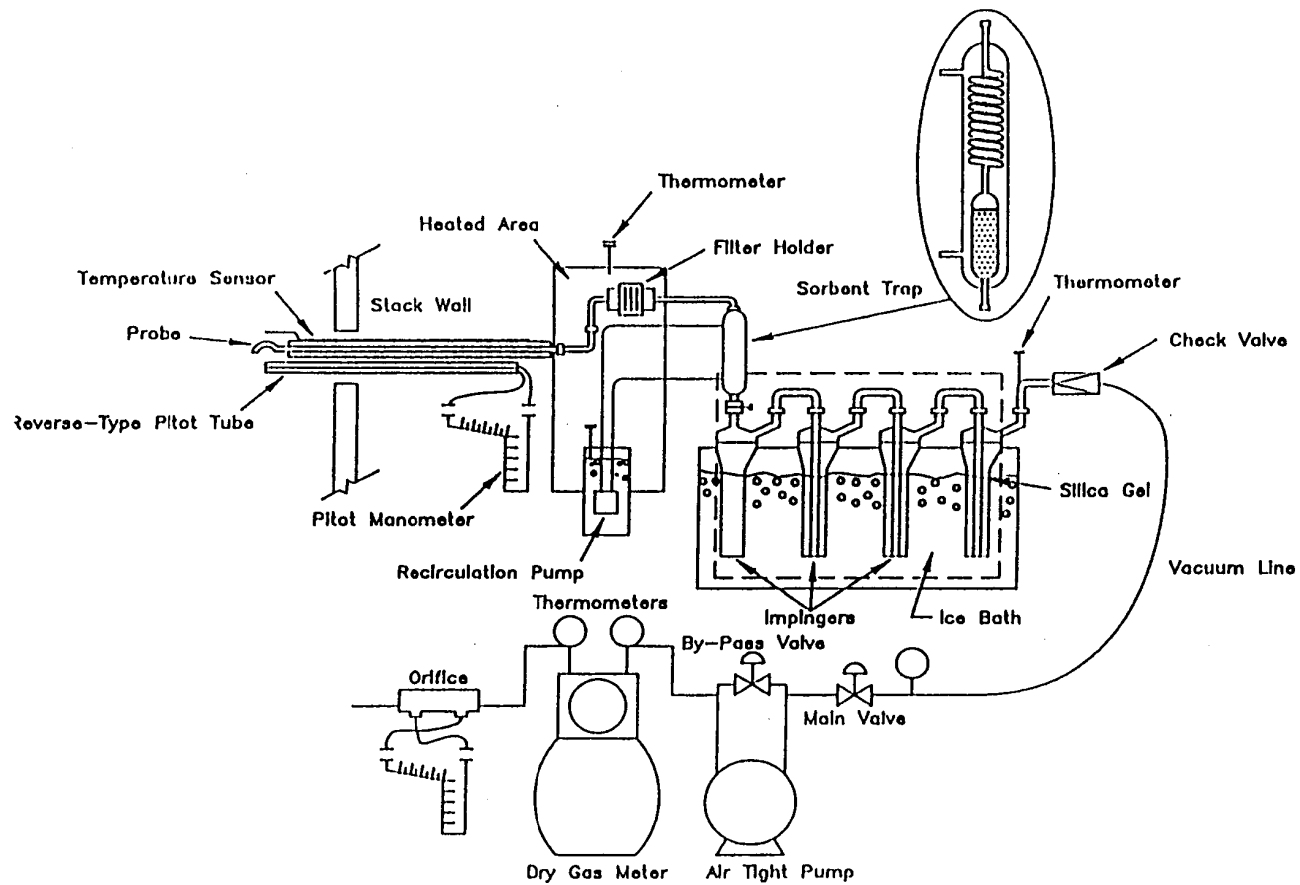


Figure 8-10. Modified Method 5 sampling train²

The practical quantitation limit for Method 8270 is approximately 50 µg/mL of extract. The entire sorbent module with filter is typically extracted and concentrated to 1 mL (0.03 in³) (a final volume of 5 mL (0.2 in³) is used to avoid loss of volatile compounds), and this final extract volume represents the entire volume of gas sampled.

8.10 NIOSH METHOD 1501⁴

Ambient air and exhaust gas concentrations of toluene can also be measured using NIOSH Method 1501. The levels of detection for NIOSH methods are usually much higher than the other procedures discussed. NIOSH methods are designed for worker exposure studies that are usually conducted over an 8 hour period.

Ambient air or exhaust gas samples are collected on a solid sorbent tube containing coconut shell charcoal with 100 mg on the front-half portion and 50 mg on the back-half. Two to 8 L (0.07 to 0.3 ft³) of air are collected, depending on the expected concentrations, using a vacuum pump set at an approximate flow rate of 0.2 L/minute (0.007 ft³/minute). The breakthrough volume for toluene is 12 L (0.4 ft³).

The samples are then capped, sent to the laboratory, desorbed with carbon disulfide (CS₂) 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 100/200 mesh Chromosorb W-AW or equivalent. The stability of the sorbent sample is currently unknown, therefore analysis should be conducted as soon as possible.

Figure 8-11 presents a schematic of the sampling system.

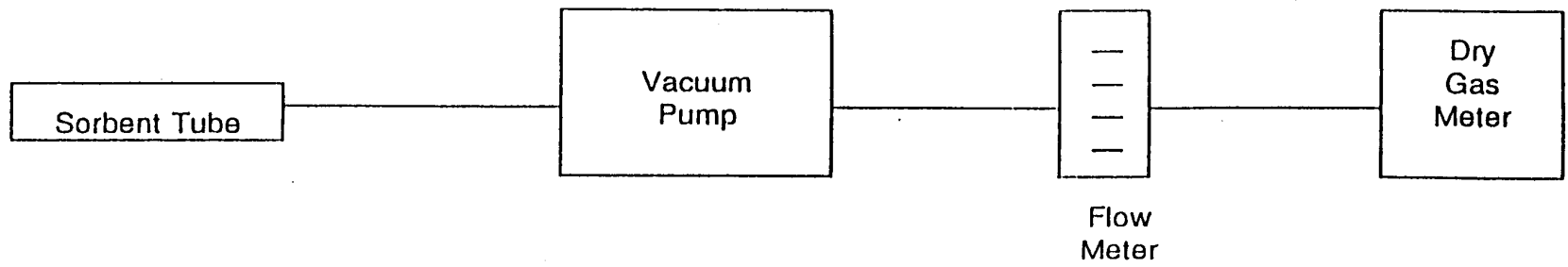


Figure 8-11. Method 1501 sampling system⁴

8.11 REFERENCES FOR SECTION 8.0

1. U.S. Environmental Protection Agency. *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*. EPA/600/4-89/017. June 1988.
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, Volume 1 and 2. February 1984.

APPENDIX A
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
1011	Iron ores: taconite iron ore processing
1099	Metal ores, NEC: aluminum ore (bauxite)
1300	Oil and gas extraction fuel fired process heaters
1311	Oil and gas production: crude oil production
1321	Natural gas liquids
1382	Oil and gas exploration services
1400	Nonmetallic minerals, except fuels (mining operations)
1442	Mineral products: sand and gravel
1475	Mineral products: phosphate rock
1499	Mineral products: salt mining
1611	Highway and street construction
1629	Heavy construction, nec
1781	Water well drilling
1791	Structural steel erection
1799	Special trade contractors, nec
2000	Food and agriculture fuel fired equipment: process heaters
2011	Meat packing plants
2013	Sausages and other prepared meats
2015	Food and kindred products: poultry slaughtering and processing
2023	Dry, condensed, evaporated products
2026	Fluid milk
2032	Organic solvent surface coating: can coating
2033	Canned fruits and vegetables
2034	Dehydrated fruits, vegetables, soups
2037	Frozen fruits and vegetables

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
2043	Cereal breakfast foods
2044	Rice milling
2046	Wet corn milling
2047	Dog and cat food
2048	Prepared feeds, nec
2051	Bread, cake, and related products
2052	Cookies and crackers
2064	Candy & other confectionery products
2076	Vegetable oil mills, nec
2077	Animal and marine fats and oils
2079	Edible fats and oils, nec
2082	Malt beverages
2084	Wines, brandy, and brandy spirits
2085	Distilled and blended liquors
2086	Bottled and canned soft drinks
2087	Flavoring extracts and syrups, nec
2091	Canned and cured fish and seafoods
2099	Food preparations, nec
2111	Cigarettes
2121	Cigars
2200	Organic solvent - textile manufacturing: knit fabric scouring
2211	Broadwoven fabric mills, cotton
2221	Broadwoven fabric mills, manmade
2231	Broadwoven fabric mills, wool
2241	Narrow fabric mills

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
2257	Weft knit fabric mills
2261	Finishing plants, cotton
2262	Finishing plants, manmade
2269	Finishing plants, nec
2281	Yarn spinning mills
2282	Throwing and winding mills
2284	Thread mills
2295	Coated fabrics, not rubberized
2296	Tire cord and fabrics
2297	Nonwoven fabrics
2298	Cordage and twine
2299	Textile goods, nec
2321	Men's and boys' shirts
2326	Men's and boys' work clothing
2341	Women's and children's underwear
2353	Hats, caps, and millinery
2369	Girls' and children's outerwear, nec
2381	Fabric dress and work gloves
2385	Waterproof outerwear
2387	Apparel belts
2389	Apparel and accessories, nec
2392	House furnishings, nec
2394	Canvas and related products
2396	Automotive and apparel trimmings
2399	Fabricated textile products, nec

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
2421	Sawmills and planing mills, general
2426	Hardwood dimension & flooring mills
2429	Special product sawmills, nec
2431	Millwork
2434	Wood kitchen cabinets
2435	Hardwood veneer and plywood
2436	Softwood veneer and plywood
2439	Structural wood members, nec
2449	Wood containers, nec
2451	Mobile homes
2452	Prefabricated wood buildings
2491	Wood preserving
2493	Lumber and wood products: reconstituted wood products
2499	Wood products, nec
2511	Wood household furniture
2512	Upholstered household furniture
2514	Metal household furniture
2515	Mattresses and bedsprings
2517	Wood TV and radio cabinets
2519	Household furniture, nec
2521	Wood office furniture
2522	Office furniture, except wood
2531	Public building & related furniture
2541	Wood partitions and fixtures
2542	Partitions and fixtures, except wood

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
2585	Refrigeration and heating equipment
2591	Drapery hardware & blinds & shades
2599	Furniture and fixtures, nec
2611	Pulp mills
2621	Paper mills
2631	Paperboard mills
2652	Setup paperboard boxes
2653	Corrugated and solid fiber boxes
2655	Fiber cans, drums & similar products
2656	Sanitary food containers
2657	Paper and allied products: folding paperboard boxes
2670	Paper and allied products: miscellaneous converted paper products
2670	Organic solvent surface coating: paper coating
2671	Paper coated & laminated, packaging
2672	Paper coated and laminated, nec
2673	Bags: plastics, laminated, & coated
2674	Bags: uncoated paper & multiwall
2675	Paper and allied products: die-cut paper and board
2676	Sanitary paper products
2677	Envelopes
2679	Paper and allied products: converted paper products
2711	Newspapers
2721	Periodicals
2731	Book publishing
2732	Book printing

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
2741	Miscellaneous publishing
2751	Printing/publishing: printing process
2752	Commercial printing, lithographic
2754	Commercial printing, gravure
2759	Printing and publishing: commercial printing, nec
2761	Manifold business forms
2771	Greeting cards
2782	Blankbooks and looseleaf binders
2789	Bookbinding and related work
2791	Typesetting
2796	Printing and publishing: platemaking services
2800	Chemicals and allied products
2812	Alkalies and chlorine
2813	Industrial gases
2816	Inorganic pigments
2819	Industrial inorganic chemicals, nec
2821	Plastics materials and resins
2822	Synthetic rubber
2823	Cellulosic manmade fibers
2824	Organic fibers, noncellulosic
2833	Medicinals and botanicals
2834	Pharmaceutical preparations
2835	Diagnostic substances
2836	Biological products exc. diagnostic
2841	Soap and other detergents

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
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
2891	Adhesives and sealants
2892	Explosives
2893	Printing ink
2895	Carbon black
2899	Chemical preparations, nec
2900	Petroleum and coal products petroleum industry
2911	Petroleum refining
2922	Petroleum Industry: Lube Oil Refining
2951	Asphalt paving mixtures and blocks
2952	Asphalt felts and coatings
2992	Lubricating oils and greases
2999	Petroleum industry - petroleum refining: sludge converter
3011	Tires and inner tubes
3021	Rubber and plastics footwear
3052	Rubber and plastics products: rubber and plastics hose and belting

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
3053	Gaskets, packing and sealing devices
3061	Mechanical rubber goods
3069	Fabricated rubber products, nec
3079	Organic solvent: surface coating of plastic parts
3080	Rubber and plastics products: miscellaneous plastics products, nec
3081	Unsupported plastics film & sheet
3082	Unsupported plastics profile shapes
3083	Laminated plastics plate & sheet
3086	Plastics foam products
3087	Custom compound purchased resins
3088	Plastics plumbing fixtures
3089	Plastics products, nec
3111	Leather tanning and finishing
3131	Footwear cut stock
3142	House slippers
3143	Men's footwear, except athletic
3144	Women's footwear, except athletic
3149	Footwear, except rubber, nec
3172	Personal leather goods, nec
3199	Leather goods, nec
3211	Flat glass
3221	Glass containers
3229	Pressed and blown glass, nec
3231	Products of purchased glass
3241	Cement, hydraulic

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
3251	Mineral products: brick manufacturing
3253	Ceramic wall and floor tile
3255	Mineral products: castable refractory
3261	Vitreous plumbing fixtures
3263	Semivitreous table & kitchenware
3264	Porcelain electrical supplies
3271	Concrete block and brick
3272	Concrete products, nec
3274	Lime
3275	Mineral products: gypsum manufacturing
3291	Abrasive products
3292	Asbestos products
3295	Minerals, ground or treated
3296	Mineral wool
3297	Nonclay refractories
3299	Nonmetallic mineral products, nec
3300	Secondary metals: misc. casting and fabricating
3312	Blast furnaces and steel mills
3313	Electrometallurgical products
3315	Steel wire and related products
3316	Cold finishing of steel shapes
3317	Steel pipe and tubes
3320	Primary metal industries, iron and steel foundries
3321	Primary metal industries: gray and ductile iron foundries (gray iron)
3324	Steel investment foundries

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
3325	Steel foundries, nec
3331	Primary copper
3334	Primary aluminum
3339	Primary metal industries: primary nonferrous metals, nec (lead production)
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
3357	Nonferrous wiredrawing & insulating
3360	Primary metal industries: nonferrous foundries (castings)
3363	Aluminum die-castings
3364	Nonferrous die-casting exc. aluminum
3365	Aluminum foundries
3366	Copper foundries
3369	Nonferrous foundries, nec
3398	Metal heat treating
3399	Primary metal products, nec
3400	Fabricated metal products: iron and steel general processes
3411	Metal cans
3412	Metal barrels, drums, and pails
3421	Cutlery
3423	Hand and edge tools, nec
3425	Saw blades and handsaws
3429	Hardware, nec

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
3431	Fabricated metal products: porcelain enamel/ceramic glaze spraying
3432	Plumbing fixture fittings and trim
3433	Heating equipment, except electric
3441	Fabricated structural metal
3442	Metal doors, sash, and trim
3443	Fabricated plate work (boiler shops)
3444	Sheet metalwork
3446	Architectural metal work
3448	Prefabricated metal buildings
3449	Miscellaneous metal work
3451	Screw machine products
3452	Bolts, nuts, rivets, and washers
3462	Iron and steel forgings
3463	Nonferrous forgings
3465	Automotive stampings
3466	Crowns and closures
3469	Metal stampings, nec
3471	Plating and polishing
3479	Metal coating and allied services
3482	Small arms ammunition
3483	Ammunition, exc. for small arms, nec
3484	Small arms
3489	Ordnance and accessories, nec
3491	Industrial valves
3492	Fluid power valves & hose fittings

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
3493	Steel springs, except wire
3494	Valves and pipe fittings, nec
3496	Misc. fabricated wire products
3497	Metal foil and leaf
3498	Fabricated pipe and fittings
3499	Fabricated metal products, nec
3511	Turbines and turbine generator sets
3519	Internal combustion engines, nec
3523	Farm machinery and equipment
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
3543	Industrial patterns
3544	Special dies, tools, jigs & fixtures
3545	Machine tool accessories
3546	Power-driven hand tools
3548	Welding apparatus

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
3549	Metalworking machinery, nec
3552	Textile machinery
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
3562	Ball and roller bearings
3563	Air and gas compressors
3564	Blowers and fans
3565	Packaging machinery
3566	Speed changers, drives, and gears
3567	Industrial furnaces and ovens
3569	General industrial machinery, nec
3571	Electronic computers
3572	Computer storage devices
3575	Computer terminals
3577	Computer peripheral equipment, nec
3578	Calculating and accounting equipment
3579	Office machines, nec
3581	Automatic vending machines
3582	Commercial laundry equipment
3585	Refrigeration and heating equipment
3586	Measuring and dispensing pumps

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
3589	Service industry machinery, nec
3592	Carburetors, pistons, rings, valves
3593	Fluid power cylinders & actuators
3594	Fluid power pumps and motors
3599	Industrial machinery, nec
3612	Transformers, except electronic
3613	Switch gear and switchboard apparatus
3621	Motors and generators
3624	Carbon and graphite products
3625	Electronic equipment: 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
3645	Residential lighting fixtures
3646	Commercial lighting fixtures
3647	Vehicular lighting equipment
3648	Lighting equipment, nec
3651	Household audio and video equipment

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
3652	Prerecorded records and tapes
3661	Telephone and telegraph apparatus
3663	Radio & TV communications equipment
3669	Communications equipment, nec
3671	Electron tubes
3672	Printed circuit boards
3674	Semiconductors and related devices
3675	Electronic capacitors
3676	Electronic resistors
3679	Electronic components, nec
3691	Storage batteries
3692	Primary batteries, dry and wet
3694	Engine electrical equipment
3695	Magnetic and optical recording media
3699	Electrical equipment & supplies, nec
3711	Motor vehicles and car bodies
3713	Truck and bus bodies
3714	Motor vehicle parts and accessories
3715	Truck trailers
3716	Motor homes
3721	Aircraft
3724	Aircraft engines and engine parts
3728	Aircraft parts and equipment, nec
3731	Ship building and repairing
3732	Boat building and repairing

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
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
3820	Instruments/related products - measuring/controlling devices:
3821	Laboratory apparatus and furniture
3822	Environmental controls
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 & controlling devices, nec
3840	Instruments and related products - medical instruments and supplies: x-ray
3841	Surgical and medical instruments
3842	Surgical appliances and supplies
3843	Dental equipment and supplies
3844	X-ray apparatus and tubes
3845	Electromedical equipment
3851	Ophthalmic goods

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
3861	Photographic equipment and supplies
3873	Watches, clocks, watchcases & parts
3900	Miscellaneous manufacturing industries: process heaters
3911	Jewelry, precious metal
3914	Silverware and plated ware
3915	Jewelers' materials & lapidary work
3931	Musical instruments
3942	Dolls and stuffed toys
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
3955	Carbon paper and inked ribbons
3961	Costume jewelry
3965	Miscellaneous manufacturing industries: fasteners, buttons, needles, and pins
3991	Brooms and brushes
3993	Signs and advertising specialties
3995	Burial caskets
3996	Hard surface floor coverings, nec
3999	Manufacturing industries, nec
4111	Local and suburban transit
4131	Intercity & rural bus transportation
4173	Bus terminal and service facilities
4212	Local trucking, without storage

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
4215	Courier services, except by air
4226	Special warehousing and storage, nec
4231	Trucking terminal facilities
4491	Water transportation: marine cargo handling
4499	Water transportation services, nec
4510	Air transportation: scheduled air transportation
4512	Air transportation, scheduled
4612	Crude petroleum pipelines
4741	Rental of railroad cars
4785	Inspection & fixed facilities
4789	Transportation services, nec
4900	Solid waste disposal - commercial/institutional: landfill dump
4911	Anthracite coal
4922	Natural gas transmission
4923	Gas transmission and distribution
4925	Gas production and/or distribution
4941	Water supply
4952	Sewerage systems
4953	Refuse systems
4961	Steam and air-conditioning supply
5013	Motor vehicle supplies and new parts
5021	Furniture
5031	Lumber, plywood, and millwork
5040	Wholesale trade (durable goods): professional equipment and supplies

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
5044	Office equipment
5045	Computers, peripherals & software
5046	Commercial equipment, nec
5063	Electrical apparatus and equipment
5078	Refrigeration equipment and supplies
5084	Industrial machinery and equipment
5085	Industrial supplies
5092	Toys and hobby goods and supplies
5093	Scrap and waste materials
5113	Industrial & personal service paper
5130	Apparel, Piece Goods, and Notions
5169	Chemicals & allied products, nec
5171	Petroleum bulk stations & terminals
5172	Petroleum products, nec
5182	Wine and distilled beverages
5191	Farm supplies
5194	Tobacco and tobacco products
5198	Paints, varnishes, and supplies
5211	Lumber and other building materials
5231	Paint, glass, and wallpaper stores
5511	New and used car dealers
5541	Gasoline service stations
5551	Boat dealers
5599	Automotive dealers, nec
5712	Furniture stores

(continued)

TABLE A-1.
POTENTIAL SOURCE CATEGORIES OF TOLUENE EMISSIONS
(continued)

SIC Code	Source Description
5984	Liquefied petroleum gas dealers
5999	Miscellaneous retail stores, nec
6141	Personal credit institutions
6512	Nonresidential building operators
6513	Apartment building operators
6514	Dwelling operators, exc. apartments
7215	Coin-operated laundries and cleaning
7216	Drycleaning plants, except rug
7218	Industrial launderers
7359	Equipment rental & leasing, nec
7372	Prepackaged software
7378	Computer maintenance & repair
7389	Business services, nec
7514	Passenger car rental
7515	Passenger car leasing
7532	Top & body repair & paint shops
7534	Tire retreading and repair shops
7538	General automotive repair shops
7539	Automotive repair shops, nec
7540	Auto repair, services, and parking: automotive services, except repair
7600	Miscellaneous repair services: electrical equipment
7629	Electrical repair shops, nec
7641	Reupholstery and furniture repair
7694	Armature rewinding shops
7699	Repair services, nec

(continued)

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

SIC Code	Source Description
8062	General medical & surgical hospitals
8211	Elementary and secondary schools
8244	Business and secretarial schools
8249	Vocational schools, nec
8331	Job training and related services
8412	Museums and art galleries
8711	Engineering services
8731	Engineering and management services: commercial physical research
8732	Commercial nonphysical research
8734	Testing laboratories
8740	Engineering and management services: management and public relations
8999	Services, nec
9199	General government, nec
9223	Correctional institutions
9224	Solid waste disposal - government: fire fighting
9511	Air, water, & solid waste management
9711	National security
9999	Nonclassifiable establishments

NEC = Not elsewhere classified.

Sources:

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 (XATEF), Version 1.2. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC. October 1991.

Volatile Organic Compound (VOC) Particulate Matter (PM) Speciation Database Management System, Version 1.4. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC. October 1991.

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 Euleess St, Euleess 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
(SIC 2711) Newspapers		
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
(SIC 2721) Periodicals		
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*
(SIC 2731) Book Publishing		
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*
(SIC 2732) Book Printing		
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
(SIC 2741) Misc Publishing		
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*
(SIC 2752) Commercial Printing-Lithographic		
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
(SIC 2754) Commercial Printing-Gravure		
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
(SIC 2759) Commercial Printing Nec		
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*
(SIC 2761) Manifold Business Forms		
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
(SIC 2771) Greeting Cards		
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*

NEC = Not elsewhere classified

* 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
TOLUENE SOURCE CATEGORIES IN SURFACE COATING OPERATIONS

**TABLE C-1.
TOLUENE SOURCE CATEGORIES IN
SURFACE COATING OPERATIONS^a (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.
TOLUENE SOURCE CATEGORIES IN
SURFACE COATING OPERATIONS^a (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.
TOLUENE SOURCE CATEGORIES IN
SURFACE COATING OPERATIONS^a (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.
TOLUENE SOURCE CATEGORIES IN
SURFACE COATING OPERATIONS^a (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

^aReferences 1-6

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APPENDIX D

SUMMARY OF EMISSION FACTORS
LISTED IN THIS DOCUMENT

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

SIC	SIC Description	SCC	SCC Description	Emission Factor	Quality Rating^a	Reference	Note
2869	Industrial Organic Chemicals, n.e.c.	40703616	Organic Chemical Storage	0.66 lb/1000 gallon throughput	U	4-12	Toluene storage-working loss
2869	Industrial Organic Chemicals, n.e.c.	40703616	Organic Chemical Storage	3.6 lb/1000 gallon throughput	U	4-12	Toluene storage-breathing loss
2865	Cyclic Crudes and Intermediates	30125805	Organic Chemical Manufacture-Toluene production-general	1.7×10^{-4} lb/lb toluene produced	U	4-14	Process emissions-general
2865	Cyclic Crudes and Intermediates	407036	Organic Chemical Storage	4.65×10^{-4} lb/lb toluene produced	U	4-14	Toluene storage
2911	Petroleum Refining	306002	Petroleum Refining Catalytic Cracking	2.0×10^{-5} lb/lb toluene produced	U	4-14	Cracking unit-production from catalytic formate
2911	Petroleum Refining	306	Petroleum Refining	21 lb/ton total hydrocarbon	U	4-14	Fugitive emissions-petroleum refining with cracking and reforming-Fugitives are 1.05% toluene
2911	Petroleum Refining	306	Petroleum Refining	2.1 lb/ton total hydrocarbon	U	4-14	Fugitive emissions-petroleum refining without cracking and reforming-Fugitives are 0.105% toluene
3312	By-product Coke Manufacturing	303003	By-product Coke Manufacturing	2.4×10^{-4} lb/lb coke produced	U	4-14	Coke oven leaks
2865	Cyclic Organic Crudes and Intermediates	30120601	Styrene Production-General	1.52 g/kg styrene produced	U	4-14	Process emissions-general
2865	Cyclic Organic Crudes and Intermediates	30120603	Styrene Production-Purification	1.17 g/kg styrene produced	U	4-14	Styrene purification
2865	Cyclic Organic Crudes and Intermediates	30120680	Styrene Production-General	10,358 kg/process unit-annually	U	4-14	Fugitive emissions
2865	Cyclic Organic Crudes and Intermediates	40703616	Organic Chemical Storage	0.66 lb/1,000 gallon throughput	U	4-12	Storage tank working losses

(Continued)

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

SIC	SIC Description	SCC	SCC Description	Emission Factor	Quality Rating ^a	Reference	Note
2865	Cyclic Organic Crudes and Intermediates	40703615	Organic Chemical Storage	3-6 lb/1,000 gallon throughput	U	4-12	Storage tank breathing losses
N/A	N/A	N/A	N/A	2.22x10 ⁻⁵ lb/vehicle mile traveled	U	6-26	Evaporation from automobile fuel tank
N/A	N/A	N/A	N/A	8.46x10 ⁻⁴ lb/vehicle mile traveled	U	6-26	Automobile exhaust
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels-General	33.4 mg/liter transferred	U	6-2 6-32	Uncleaned ship/ocean barge-volatile previous cargo-uncontrolled
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Loading-General	21.7 mg/liter transferred	U	6-2 6-32	Ballasted ship/ocean barge-volatile previous cargo-uncontrolled
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels-General	19.1 mg/liter transferred	U	6-2 6-32	Cleaned ship/ocean barge-volatile previous cargo-uncontrolled
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels-General	9.0 mg/liter transferred	U	6-2 6-32	Gas-freed ship/ocean barge-volatile previous cargo-uncontrolled
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels-General	9.0 mg/liter transferred	U	6-2 6-32	Any ship/ocean barge-nonvolatile previous cargo-uncontrolled
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels-General	22.8 mg/liter transferred	U	6-2 6-32	Typical ship/ocean barge-any previous cargo-uncontrolled
4491	Marine Cargo Handling	406002	Marine Vessels-General	49.3 mg/liter transferred	U	6-2 6-32	Uncleaned barge-volatile previous cargo-uncontrolled
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels-General	25.9 mg/liter transferred	U	6-2 6-32	Gas-freed ship/ocean barge-any previous cargo-uncontrolled
4491	Marine Cargo Handling	406002	Petroleum Marketing-Marine Vessels-General	43.5 mg/liter transferred	U	6-2 6-32	Typical barge-any previous cargo-uncontrolled

(Continued)

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

SIC	SIC Description	SCC	SCC Description	Emission Factor	Quality Rating^a	Reference	Note
5171	Petroleum Bulk Stations and Terminals	404001	Bulk Terminals/ Miscellaneous	151.6 mg/liter transferred	U	6-28 6-32	Splash loading of gasoline
5171	Petroleum Bulk Stations and Terminals	404001	Bulk Terminals/ Miscellaneous	62.5 mg/liter transferred	U	6-28 6-32	Submerged loading of gasoline, top or bottom
5171	Petroleum Bulk Stations and Terminals	404001	Bulk Terminals/Plants Loading Racks	103.9 mg/liter transferred	U	6-28 6-32	Balance service loading of gasoline
5171	Petroleum Bulk Stations and Terminals	404001	Bulk Terminals-Fixed Roof Tanks	3.6 Mg/yr/tank gasoline	U	6-28 6-32	Working loss (typical tank capacity 2,680 m ³) 950,000 liters/day terminal with 4 storage tanks
5171	Petroleum Bulk Stations and Terminals	404001	Bulk Terminals-Fixed Roof Tanks	0.9 Mg/yr/tank gasoline	U	6-28 6-32	Breathing loss (typical tank capacity 2,680 m ³) 950,000 liters/day with 4 storage tanks
5171	Petroleum Bulk Stations and Terminals	404001	Bulk Terminals-Floating Roof Tanks	$9.89 \times 10^{-7} Q$ Mg/yr/tank Q is throughput in barrels	U	6-28 6-32	Working loss (typical tank capacity 5,760 m ³) 950,000 liters/day with 4 storage tanks
5171	Petroleum Bulk Stations and Terminals	404001	Bulk Terminals-Floating Roof Tanks	1.0 Mg/yr/tank gasoline	U	6-28 6-32	Storage loss (typical tank capacity 5,760 m ³) 950,000 liters/day with 4 storage tanks
5171	Petroleum Bulk Stations and Terminals	404002	Bulk Plants-Fixed Roof Tanks	63.6 mg/liter gasoline transferred	U	6-28 6-32	Breathing loss-uncontrolled
5171	Petroleum Bulk Stations and Terminals	404002	Bulk Plants-Fixed Roof Tanks	121.9 mg/liter gasoline transferred	U	6-28 6-32	Filling loss-uncontrolled
5171	Petroleum Bulk Stations and Terminals	404002	Bulk Plants-Fixed Roof Tanks	48.8 mg/liter gasoline transferred	U	6-28 6-32	Draining loss-uncontrolled
5171	Petroleum Bulk Stations and Terminals	40400250	Bulk Terminals/Plants- Loading Racks	103.9 mg/liter gasoline transferred	U	6-28 6-32	Submerged loading (Balance Service) (throughput 19,000 l/day)

(Continued)

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

SIC	SIC Description	SCC	SCC Description	Emission Factor	Quality Rating^a	Reference	Note
5171	Petroleum Bulk Stations and Terminals	40400250	Bulk Terminals/Plants-Loading Racks	151.6 mg/liter gasoline transferred	U	6-28 6-32	Splash loading (throughput 19,000 l/day)
5171	Petroleum Bulk Stations and Terminals	40400250	Bulk Terminals/Plants-Loading Racks	62.5 mg/liter gasoline transferred	U	6-28 6-32	Submerged loading (throughput 19,000 l/day)
5541	Gasoline Service Stations	40600302	Petroleum Marketing-Service Stations-Stage I-No Control	93.3 mg/liter gasoline stored	U	6-28 6-32	Uncontrolled emissions-Submerged filling loss (throughput 190,000 liters/month)
5541	Gasoline Service Stations	40600301	Petroleum Marketing-Service Stations-Stage I	146.3 mg/liter gasoline stored	U	6-28 6-32	Uncontrolled emissions-Splash filling loss (throughput 190,000 liters/month)
5541	Gasoline Service Stations	40600306	Petroleum Marketing-Service Stations-Stage I-Balanced	4.2 mg/liter gasoline stored	U	6-28 6-32	Uncontrolled emissions-Balanced submerged filling loss (throughput 190,000 liters/month)
5541	Gasoline Service Stations	40600307	Petroleum Marketing-Service Stations-Stage I-Breathing-Underground Tanks	12.7 mg/liter gasoline stored	U	6-28 6-32	Uncontrolled emissions-Underground storage tank breathing loss (throughput 190,000 liters/month)
5541	Gasoline Service Stations	40600401	Petroleum Marketing-Service Stations-Stage II-Vapor-No control	139.9 mg/liter gasoline stored	U	6-28 6-32	Vehicle refueling-uncontrolled displacement losses (throughput 190,000 liters/month)
5541	Gasoline Service Stations	40600403	Petroleum Marketing-Service Stations-Stage II-Vapor-Controlled Displacement	13.9 mg/liter gasoline stored	U	6-28 6-32	Vehicle refueling-controlled displacement losses (throughput 190,000 liters/month)
5541	Gasoline Service Stations	40600402	Petroleum Marketing-Service Stations-Stage II-Liquid Spill-No Control	8.9 mg/liter gasoline stored	U	6-28 6-32	Vehicle refueling spillage-uncontrolled (throughput 190,000 liters/month)
N/A	N/A	N/A	N/A	0.061 µg/m ² /hr	E	6-34	Particle board with carpet-emissions from new product

(Continued)

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

SIC	SIC Description	SCC	SCC Description	Emission Factor	Quality Rating ^a	Reference	Note
N/A	N/A	N/A	N/A	0.59 µg/g/hr	E	6-38	Synthetic rubber adhesive for walls and ceilings-post application emissions
N/A	N/A	N/A	N/A	62 µg/g/hr	E	6-38	Synthetic rubber adhesive for vinyl carpet-post application emissions
N/A	N/A	N/A	N/A	2.5 µg/g/hr	E	6-38	Unspecified polymer adhesive for subflooring-post application emissions

^a"U" rating is based on engineering judgement.

(Continued)

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

SIC	SIC Description	SCC	SCC Description	Emission Factor	Quality Rating^a	Reference	Note
2869	Industrial Organic Chemicals	30125805	Toluene Production-General	0.104 kg/hr/source	U	4-13	Fugitives-Gas/vapor pressure relief seals
2869	Industrial Organic Chemicals	30125805	Toluene Production-General	0.00083 kg/hr/source	U	4-13	Fugitives-Flanges
2869	Industrial Organic Chemicals	30125805	Toluene Production-General	0.0017 kg/hr/source	U	4-13	Fugitives-Open ended lines
2869	Industrial Organic Chemicals	30125805	Toluene Production-General	0.015 kg/hr/source	U	4-13	Fugitives-Sampling connections
2869	Industrial Organic Chemicals	30125805	Toluene Production-General	0.0056 kg/hr/source	U	4-13	Fugitives-Gas valves
2869	Industrial Organic Chemicals	30125805	Toluene Production-General	0.0071 kg/hr/source	U	4-13	Fugitives-Light liquid valves
2869	Industrial Organic Chemicals	30125805	Toluene Production-General	0.00023 kg/hr/source	U	4-13	Fugitives-Heavy liquid valves
2869	Industrial Organic Chemicals	30125805	Toluene Production-General	0.0494 kg/hr/source	U	4-13	Fugitives-Light liquid pump seals
2869	Industrial Organic Chemicals	30125805	Toluene Production-General	0.0214 kg/hr/source	U	4-13	Fugitives-Heavy liquid pump seals
2869	Industrial Organic Chemicals	30125805	Toluene Production-General	0.228 kg/hr/source	U	4-13	Fugitives-Gas/vapor compressor seals

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

^aBased on engineering judgement.

TECHNICAL REPORT DATA
(Please read instructions on the reverse before completing)

1. REPORT NO.		2.	3. RECIPIENT'S ACCESSION NO.	
4. TITLE AND SUBTITLE Locating And Estimating Air Emissions From Sources Of Toluene			5. REPORT DATE March 16, 1994	
7. AUTHOR(S)			6. PERFORMING ORGANIZATION CODE	
9. PERFORMING ORGANIZATION NAME AND ADDRESS TRC Environmental Corporation 100 Europa Drive, Suite 150 Chapel Hill, NC 27514			8. PERFORMING ORGANIZATION REPORT NO.	
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Office of Air Quality Planning And Standards Technical Support Division (MD-14) Research Triangle Park, NC 27711			10. PROGRAM ELEMENT NO.	
			11. CONTRACT/GRANT NO. 68-D9-0173	
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			15. SUPPLEMENTARY NOTES EPA Project Officer: Dennis Beauregard	
16. ABSTRACT To assist groups interested in inventorying air emissions of various potentially toxic substances, EPA is preparing a series of documents such as this to compile available information on sources and emission of these substances. This document deals specifically with Toluene. Its intended includes federal, state and local air pollution personnel and others interested in locating potential emitters of Toluene and in making gross estimates of air emissions therefrom. This document presents information on (1) the types of sources that may emit Toluene, (2) process variations and release points for these sources, and (3) available emissions information indicating the potential for Toluene releases into the air from each operation.				
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