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EPA Office of Compliance Sector Notebook Project

Profile of the Rubber and Plastic Industry

2nd Edition

Chapters I., II. and III.

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Office of Enforcement and Compliance Assurance
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http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/rubber.html

I. INTRODUCTION TO THE SECTOR NOTEBOOK PROJECT

I.A. Summary of the Sector Notebook Project

Environmental policies based upon comprehensive analysis of air, water, and land pollution (such as economic sector and community-based approaches) are becoming an important supplement to traditional single-media approaches to environmental protection. Environmental regulatory agencies are beginning to embrace comprehensive, multistatute solutions to facility permitting, compliance assurance, education/outreach, research, and regulatory development issues. The central concepts driving the new policy direction are that pollutant releases to each environmental medium (air, water and land) affect each other, and that environmental strategies must actively identify and address these interrelationships by designing policies for the "whole" facility. One way to achieve a whole facility focus is to design environmental policies for similar industrial facilities. By doing so, environmental concerns that are common to the manufacturing of similar products can be addressed in a comprehensive manner. Recognition of the need to develop the industrial “sector-based” approach within EPA’s Office of Compliance led to the creation of this document.

The Office of Compliance within the Office of Enforcement and Compliance Assurance (OECA) initiated the Sector Notebook Project to provide its staff and managers with summary information for 18 specific industrial sectors. As other EPA offices, states, the regulated community, environmental groups, and the public became interested in this project, the scope of the original project was expanded. The ability to design comprehensive, common-sense environmental protection measures for specific industries is dependent on knowledge of several interrelated topics. The key elements chosen for inclusion in this project are: general industry information (economic and geographic); a description of industrial processes; pollution outputs; pollution prevention opportunities; federal statutory and regulatory framework; compliance history; and a description of partnerships that have been formed between regulatory agencies, the regulated community, and the public.

For any given industry, each topic listed above could alone be the subject of a lengthy volume. However, to produce a manageable document, this project focuses on providing summary information for each topic. This format provides the reader with a synopsis of each issue, and references where more in-depth information is available. EPA used a variety of sources to compile each profile and usually condensed the information from more detailed sources pertaining to specific topics. This approach allows for a wide coverage of activities that can be further explored using the references listed at the end of this profile. As a check on the information included, each Notebook went through an external document review process. The Office of Compliance appreciates the efforts of all those that participated in this process and enabled us to develop more complete, accurate and up-to-date summaries. Many of those who reviewed this Notebook are listed as contacts in Section IX and may be sources of additional information. The individuals and groups on this list do not necessarily concur with all statements within this notebook.

I.B. Additional Information

Providing Comments

OECA's Office of Compliance plans to periodically review and update the notebooks and will make these updates available both in hard copy and electronically. If you have any comments on any of the existing notebooks, or if you would like to provide additional information, please send a hard copy and computer disk to: EPA Office of Compliance, Sector Notebook Project (2224-A), 1200 Pennsylvania Ave., NW, Washington, D.C. 20460. Comments can also be sent via the Sector Notebooks web page at: http://www.epa.gov/compliance/sectornotebooks.html. If you are interested in assisting in the development of new Notebooks, or if you have recommendations on which sectors should have a Notebook, please contact the Office of Compliance at (202) 564-2310.

Adapting Notebooks to Particular Needs

The scope of the industry sector described in this Notebook approximates the national occurrence of facility types within the sector. In many instances, industries within specific geographic regions or states may have unique characteristics that are not fully captured in these profiles. The Office of Compliance encourages state and local environmental agencies and other groups to supplement or repackage the information included in this Notebook to include more specific industrial and regulatory information that may be available. Additionally, interested states may want to supplement the "Summary of Applicable Federal Statutes and Regulations" section with state and local requirements. Compliance or technical assistance providers may also want to develop the "Pollution Prevention" section in more detail.

II. INTRODUCTION TO THE RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS INDUSTRY

This section provides background information on the size, geographic distribution, employment, production, sales, and economic condition of the Rubber and Miscellaneous Plastics Products industry. The type of facilities described within the document are also described in terms of their Standard Industrial Classification (SIC) codes. Additionally, this section contains a list of the largest companies in terms of sales.

II.A. Introduction, Background, and Scope of the Notebook

The Rubber and Miscellaneous Plastics Products (RMPP) industry, as defined by the SIC code 30, includes establishments that manufacture products from plastic resins, natural and synthetic rubber, reclaimed rubber, gutta percha, balata, and gutta siak. The production of the rubber mixture is commonly performed in facilities manufacturing rubber products and is covered under SIC code 30; however, the production of plastic resins is at plastic resin (polymer and resin) manufacturing facilities (SIC code 28). The majority of plastics products facilities purchase plastic resins to manufacture products.

Although this SIC code covers most rubber and plastics products, some important rubber and plastics products are classified elsewhere. These products include boats, which are classified under SIC code 37 (Transportation Equipment), and buttons, toys, and buckles, which are classified under SIC code 39 (Miscellaneous Manufacturing Industries). Buttons, toys, and buckles are grouped according to the final product rather than by process because not all of these products are made out of rubber or plastic. The RMPP industry does include tire manufacture; however, tread manufacturing and associated recapping and retreading are classified under SIC code 7534. EPA recognizes the recapping and retreading process for passenger and truck tires as similar to original equipment tire operation, specifically, tire production. An in-depth discussion of the recapping and retreading industry is not included here. The operations and materials used in retreading tires are similar to the original equipment tire rubber compounding for treads, tire building, grinding for carcass preparation, vulcanizing, and finishing as described in the new tire manufacturing process herein.

Although SIC code 30 groups rubber and plastics products together under some of the three-digit industry codes (e.g., rubber and plastic footwear under SIC code 302), the majority of economic and process information separates plastic from rubber products. In addition, because tire manufacturing accounts for such a large portion (almost 50 percent) of all rubber product manufacturing, tire process and economic information is often discussed separately from that of other rubber products. Therefore, this industry profile often discusses plastics products, rubber products, and rubber tires separately.

The Office of Management and Budget (OMB) established SIC codes to track the flow of goods and services within the economy. OMB has changed the SIC code system to a system based on similar production processes called the North American Industrial Classification System (NAICS). Because most of the EPA data systems still compile data based on SIC codes, this Notebook continues to use the SIC system to define this sector. Table 1 presents the SIC codes for the RMPP industry and the corresponding NAICS codes.

Table 1: SIC and NAICS Codes

1987 SIC	SIC Description	1997 NAICS	NAICS Description
3011	Tires & inner tubes	326211	Tire mfg (except retreading)
3021	Rubber & plastics footwear	316211	Rubber & plastics footwear mfg
3052	Rubber & plastics hose & belting	326220	Rubber & plastics hose & belting mfg
3053	Gaskets, packing, & sealing devices	339991	Gaskets, packing & sealing devices mfg
3061	Mechanical rubber goods	326291	Rubber product mfg for mechanical use
3069	Fabricated rubber products, n.e.c.	313320	Fabric coating mills (pt)
		326192	Resilient floor covering mfg (pt)
		326299	All other rubber product mfg
3081	Unsupported plastics film & sheet	326113	Unsupported plastics film & sheet (except packaging) mfg
3082	Unsupported plastics profile shapes	326121	Unsupported plastics profile shape mfg
3083	Laminated plastics plate & sheet	326130	Laminated plastics plate, sheet, & shape mfg
3084	Plastics pipe	326122	Plastics pipe & pipe fitting mfg
3085	Plastics bottles	326160	Plastics bottle mfg
3086	Plastics foam products	326140	Polystyrene foam product mfg
		326150	Urethane & other foam product (except polystyrene) mfg
3087	Custom compound purchased resins	325991	Custom compounding of purchased resin
3088	Plastics plumbing fixtures	326191	Plastics plumbing fixture mfg
3089	Plastics products, n.e.c.	326122	Plastics pipe & pipe fitting mfg
		326199	All other plastics product mfg
		335121	Residential electric lighting fixture mfg

II.B. Characterization of the RMPP Industry

The following subsections describes the types of products produced by rubber and miscellaneous plastics products facilities, the size and distribution of these types of facilities, and the current and projected economic trends for the RMPP industry.

II.B.1. Product Characterization

The Bureau of the Census divides SIC code 30 into industry groups according to the type of product manufactured. The following is a list of all the three-digit industry groups under SIC code 30:

- SIC Code 301 - Tires and Inner Tubes;
- SIC Code 302 - Rubber and Plastics Footwear;
- SIC Code 305 - Hose and Belting and Gaskets and Packing;

- SIC Code 306 - Fabricated Rubber Products, Not Elsewhere Classified; and
- SIC Code 308 - Miscellaneous Plastics Products, Not Elsewhere Classified.

Several of these three-digit classifications group rubber and plastics products together. However, the four-digit classifications clearly segregate the two industries. The following are four-digit SIC code breakdowns of the rubber and plastics products industries as shown in Figure 1 for SIC code 308:

- Plastics Products, Not Elsewhere Classified (N.E.C.) (SIC code 3089) account for approximately 55 percent of all plastic product production in the United States;

- Unsupported Plastics Film & Sheet (SIC code 3081) account for approximately 12 percent;

- Plastics Foam Products (SIC code 3086) account for approximately 10 percent;

- Custom Compound Purchased Resins (SIC code 3087) account for approximately 6 percent;

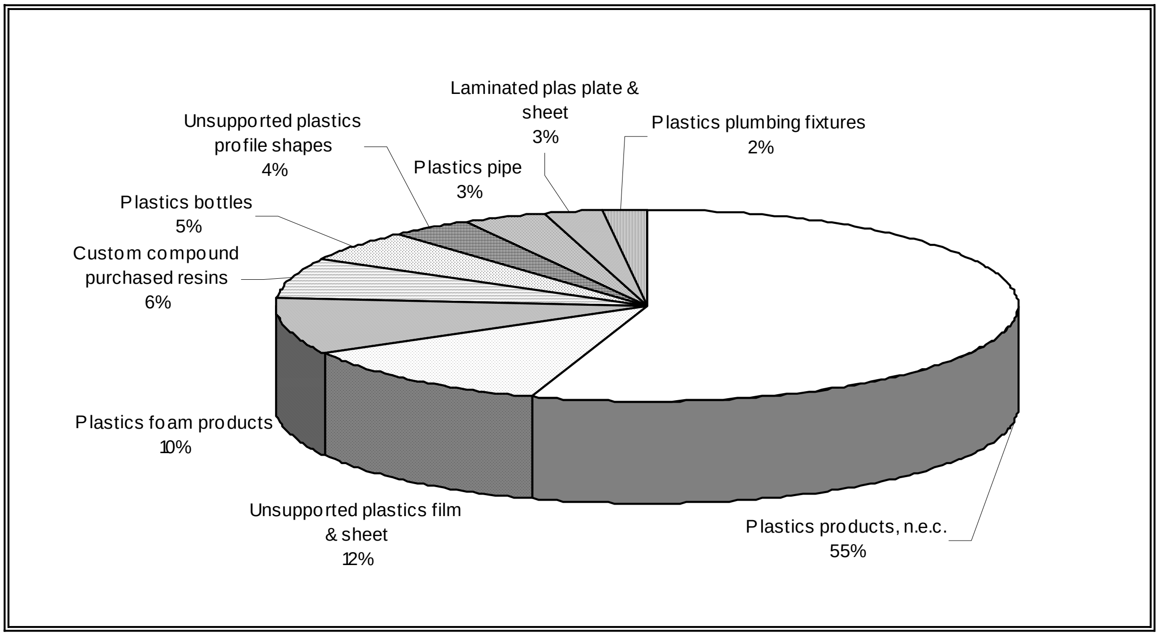
- Plastics Bottles (SIC code 3085) account for approximately 5 percent;

- Unsupported Plastics Profile Shapes (SIC code 3082) account for approximately 4 percent;

- Plastics Pipe (SIC code 3084) and Laminated Plastics Plate & Sheet (SIC code 3083) account for approximately 3 percent each; and

- Plastics Plumbing Fixtures (SIC code 3088) for approximately 2 percent.

Figure 1: Diversity of the Miscellaneous Plastics Products Industry (SIC Code 308)

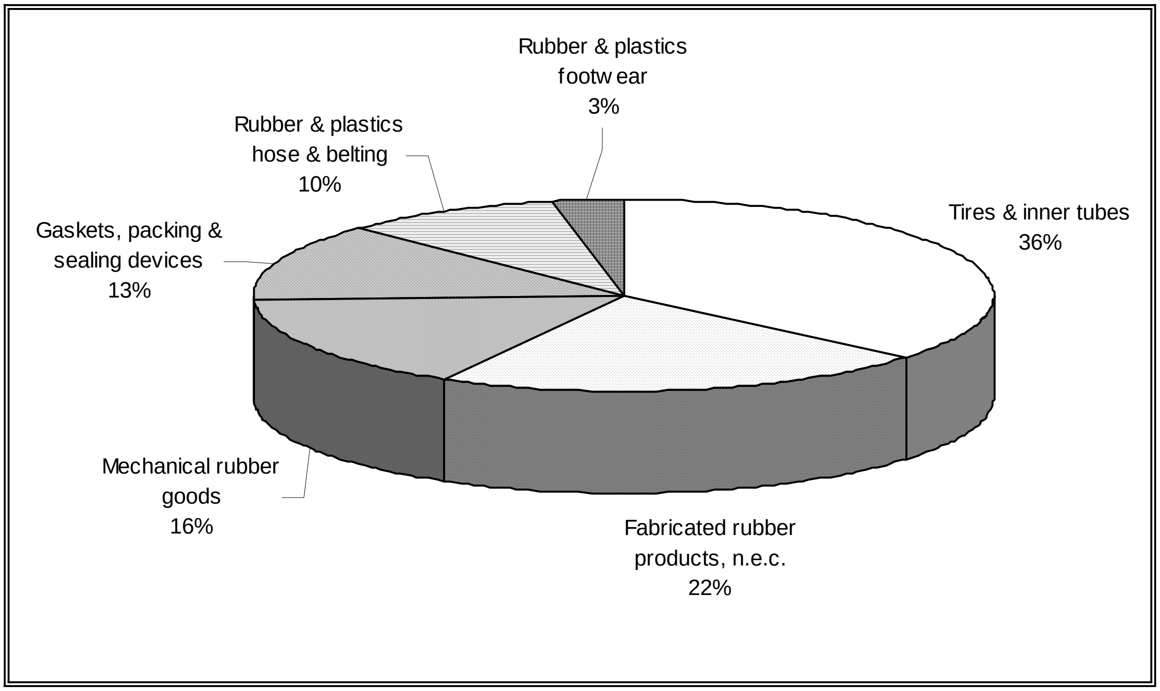


Source: 1997 Bureau of the Census Data.

As shown in Figure 2, in the rubber industry:

- Tire & Inner Tubes (SIC code 3011) manufacturing accounts for approximately 36 percent of all rubber product production in the United States;
- Fabricated Rubber Products, Not Elsewhere Classified (SIC code 3069) account for approximately 22 percent;
- Mechanical Rubber Goods (SIC code 3061) account for approximately 16 percent;
- Gaskets, Packing, & Sealing Devices (SIC code 3053) account for approximately 13 percent;
- Rubber & Plastics Hose & Belting (SIC code 3052) account for approximately 10 percent; and
- Rubber & Plastics Footwear (SIC code 3021) account for 3 percent.

Figure 2: Diversity of the Rubber Products Industry



Source: 1997 Bureau of the Census data.

II.B.2 Industry Size and Geographic Distribution

Variation in facility counts occur across data sources due to many factors, including reporting and definitional differences. This document does not attempt to reconcile these differences, but rather reports the data as they are maintained by each source.

The Bureau of the Census estimates that in 1997, 789,200 people were employed by the miscellaneous plastics products industry and 247,800 were employed by the rubber products industry, of which the tire industry employed 64,400. The value of shipments (revenue associated with product sales) totaled $120.3 billion in 1997 for the miscellaneous plastics products industry and $40.4 billion for the rubber products industry, of which the tire industry contributed $14.7 billion.

Plastic

Because of the wide range of products produced, plastics products are manufactured in all parts of the country. As shown in Table 2, approximately 47 percent of miscellaneous plastics products establishments have fewer than 20 employees. This indicates that there are a large number of small businesses in this industry. Approximately 37 percent of the industry have between 20 and 100 employees, and only 1 percent have more than 500 employees.

Although miscellaneous plastics products facilities are not concentrated in any particular region, a few states account for a large percentage of the facilities, as shown in

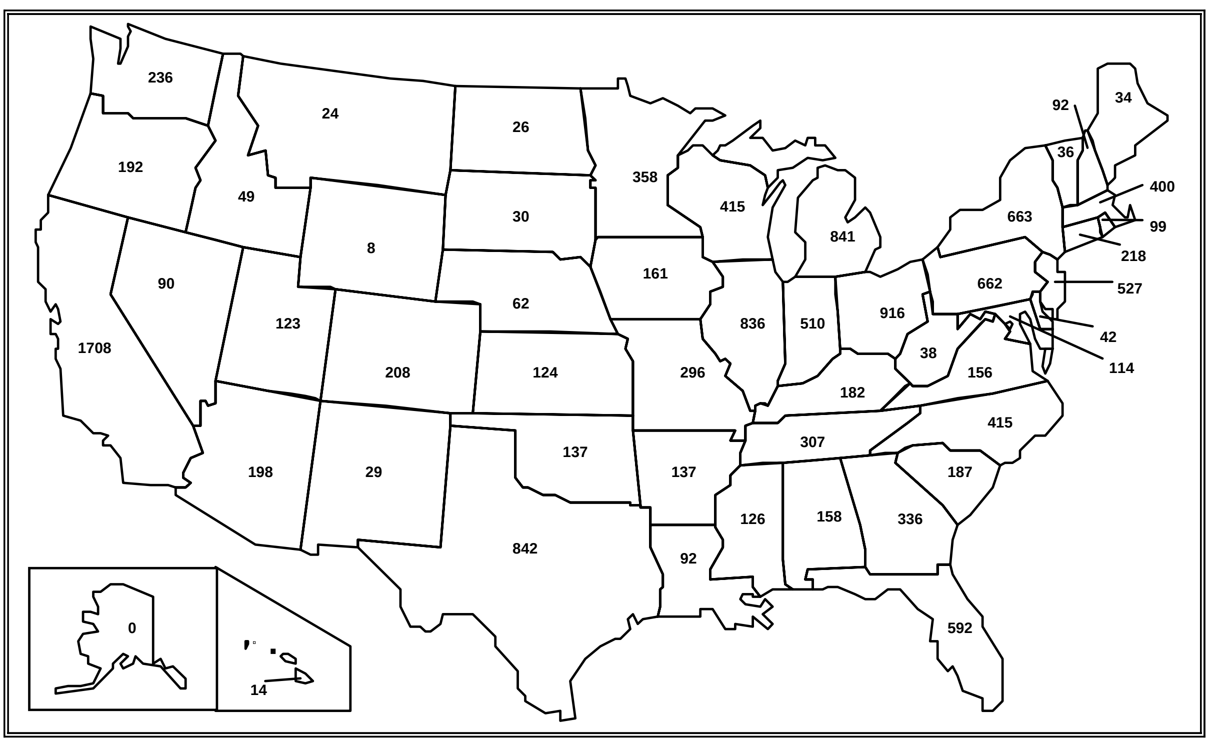
Figure 3. These states include California, Ohio, Texas, Michigan, New York, Pennsylvania, and New Jersey.

Table 2: Facility Size Distribution of the Miscellaneous Plastics Products Industry

Employees per Facility	Number of Facilities	Percentage of Facilities
1 to 4	2649	19
5 to 9	1719	12
10 to 19	2182	16
20 to 49	3107	22
50 to 99	2058	15
100 to 249	1685	12
250 to 499	485	3
500 to 999	117	0 (0.8)
1,000 to 2,499	20	0 (0.1)
2,500 or more	1	0 (0.007)
Total	14,023	100

Source: 1997 Bureau of the Census data.

Figure 3: Geographic Distribution of the Miscellaneous Plastics Products Industry (Number of Facilities)



Source: 1997 Bureau of the Census data.

Rubber

Like the miscellaneous plastics products industry, the rubber products industry produces a wide range of products. Rubber products manufacturing establishments are located all across the country. As shown in Table 3, approximately 57 percent of rubber products establishments, not including tire manufacturers, have fewer than 20 employees. This indicates that there are a large number of small businesses in this industry. Approximately 26 percent of the industry have between 20 and 100 employees and only 3 percent have more than 500 employees.

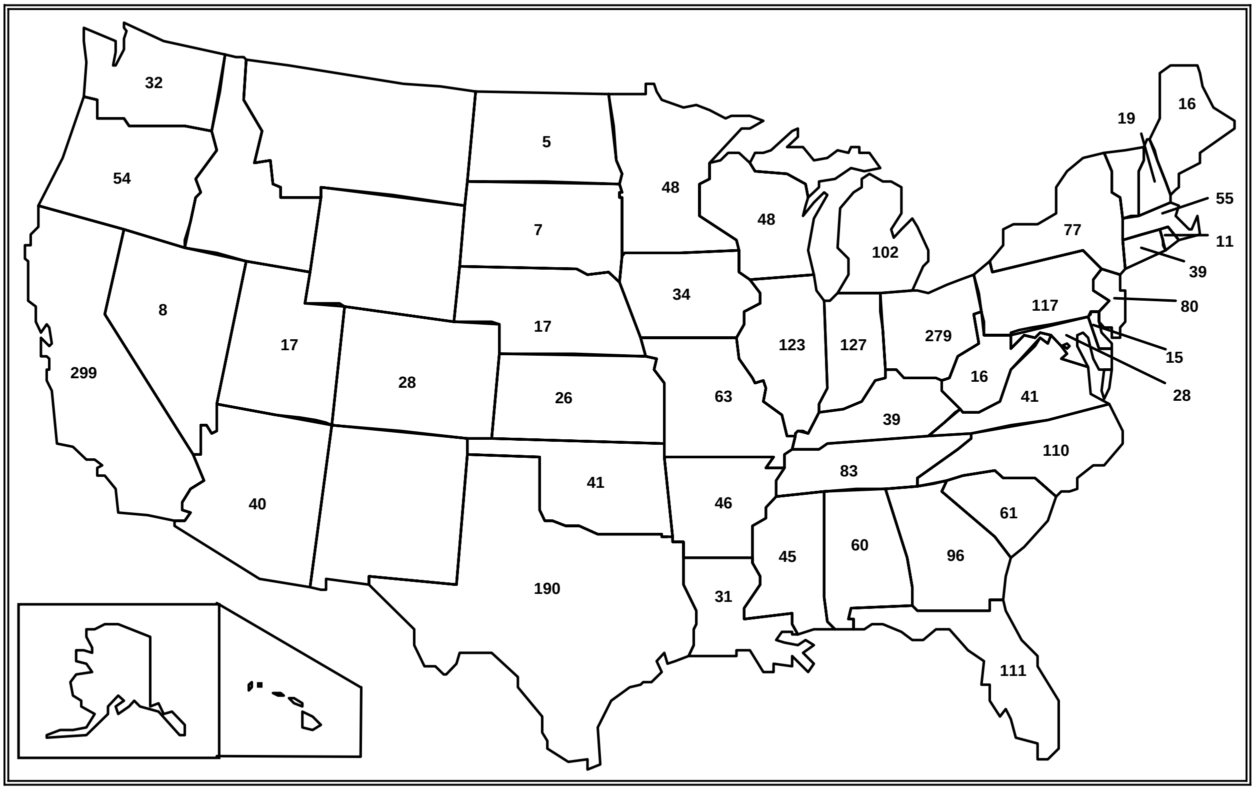
Although these facilities are not concentrated in any particular region, a few states account for a large percentage of the facilities, as shown in Figure 4. These states include California, Ohio, Texas, Indiana, Pennsylvania, Florida, Michigan, and Georgia.

Table 3: Facility Size Distribution of the Rubber Products Industry

Employees per Facility	Number of Facilities	Percentage of Facilities
1 to 4	770	27
5 to 9	401	14
10 to 19	460	16
20 to 49	520	18
50 to 99	237	8
100 to 249	246	9
250 to 499	103	4
500 to 999	44	2
1,000 to 2,499	31	1
2,500 or more	2	0 (0.07)
Total	2,814	100

Source: 1997 Bureau of the Census data.

Figure 4: Geographic Distribution of the Rubber Products Industry (Number of Facilities)



Source: 1997 Bureau of the Census data.

Tires

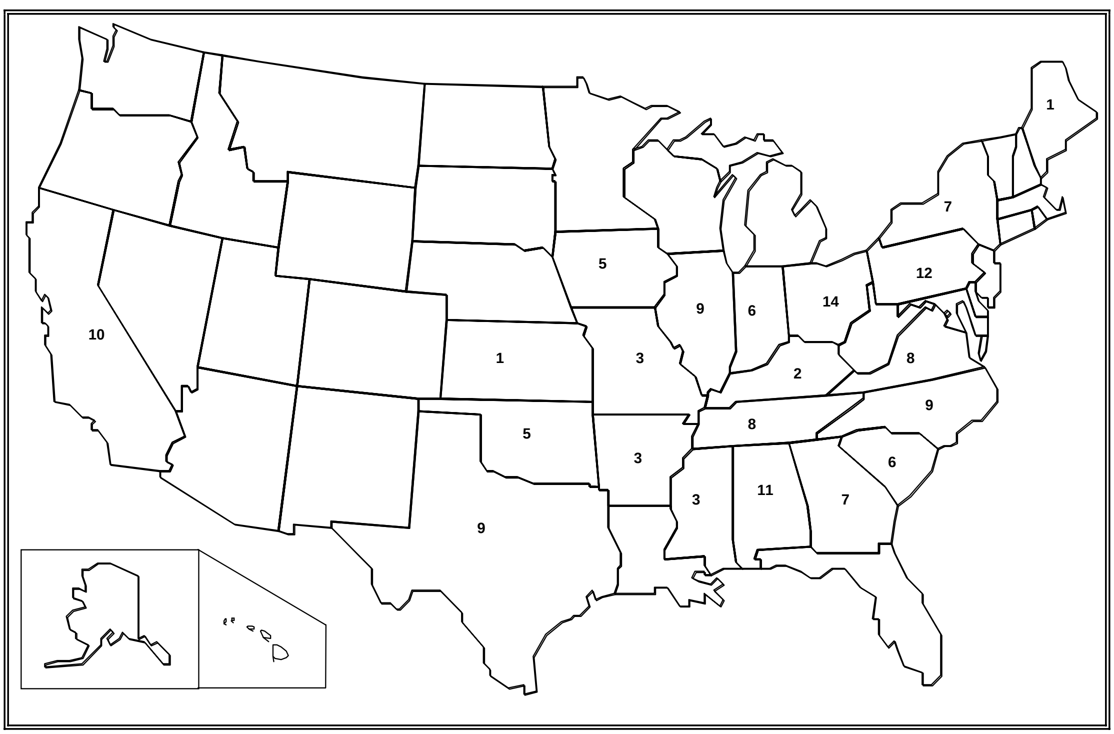
According to the 1997 Census of Manufacturers, there are 160 tire-manufacturing plants (SIC code 3011) in the United States. During the 2002 National Emission Standards for Hazardous Air Pollutants (NESHAP) development for tire manufacturing, EPA identified 112 major facilities along with 19 reporting retreading operations. As shown in Table 4, 46 percent of the identified 160 facilities have less than 20 employees. Labor costs currently represent about 26 percent of the cost of tire and tube production for U.S. manufacturers. States that account for a large percentage of facilities include Ohio, Pennsylvania, and Alabama.

Table 4: Facility Size Distribution of the Tire Industry

Employees per Facility	Number of Facilities	Percentage of Facilities
1 to 4	30	19
5 to 9	21	13
10 to 19	23	14
20 to 49	16	10
50 to 99	8	5
100 to 249	15	9
250 to 499	10	6
500 to 999	9	6
1,000 to 2,499	26	16
2,500 or more	2	1
Total	160	100

Source: 1997 Bureau of the Census data.

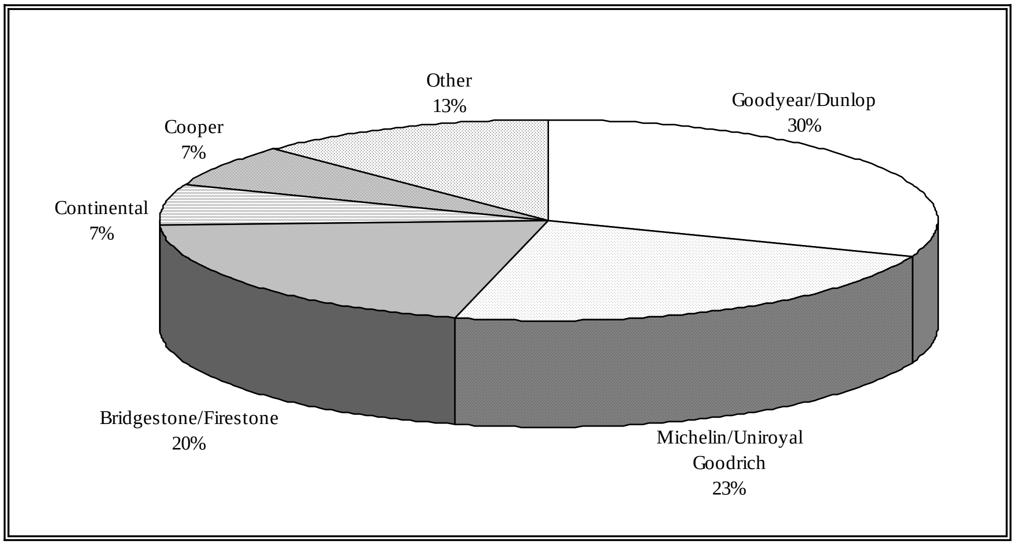
Figure 5: Geographic Distribution of the Tire Industry



Source: 1997 Bureau of the Census data.

The two largest producers of tires, Goodyear and Michelin, accounted for approximately 54 percent of tire production in 2001. As shown in Figure 6, the five largest producers, Goodyear, Michelin, Bridgestone/Firestone, Continental, and Cooper, accounted for 87 percent of production.

Figure 6: North American Tire Sales



Source: Tire Business 2001 Annual Report

II.B.3. Economic Trends

Plastic

Consumption of miscellaneous plastics products is highest in the electronics, health care, construction, transportation, automotive, and food packaging industries. According to Plastics Data Source, shipments in the U.S. plastics industry decreased 6.6 percent from 2000 to 2002. The compound annual growth rate (CAGR) from 1995 to 2000 was 2.2 percent and the CAGR from 2000 to 2002 was -5.4 percent, signifying a downturn in the domestic plastics industry. Categories accounting for the largest increases in growth included Polystyrene Foam Products (16.2 percent) and Plastics Bottles (14.5 percent). Categories accounting for the largest decreases included Resilient Floor Covering (15.5 percent) and Urethane and Other Foam Products (13.9 percent). Long-term, the aging population in the United States will make plastics in healthcare a growth industry but pressures to cut costs will squeeze margins. Plastics in the construction industry will continue to be strong as maintenance, repair, and remodeling expenditures grow, even as new housing construction might slow. Packaging demand growth has slowed during the economic downturn but plastics have continued to gain on other materials based on performance, price, and convenience.

The three largest export markets for the U.S. plastics industry are Canada, Mexico, and Japan. In 2000, the U.S. had a trade surplus in plastics products of $894 million. That surplus turned into a deficit of $132 million in 2001 and a deficit of $1.38 billion in 2002 with the deficit expected to continue to increase. In 2002, the trade deficit in plastics products with China was $3.72 billion. Plastics products from China had been mostly consumer goods like cups, plates, curtains, and kitchenware. Now, products like doors, windows, shutters, and builders' ware are hitting the U.S. market. In 2002, Canada accounted for 28.9 percent of U.S. plastics products imports while China accounted for 27 percent. U.S. plastics products exports no longer compete favorably against lower cost producers in many third-country markets.

Rubber

The sales of industrial rubber products are expected to rise 5.7 percent per year to more than 18 billion in 2006, outpacing growth in the general economy. This market is closely linked to durable goods shipments. Sales for mechanical rubber goods, hose, and belting will be aided by the auto industry. The trend to create quieter and more comfortable cars is promoting sales of weather stripping and vibration control materials. Slower growth is expected in the construction industry through 2006, resulting in lower demands for industrial rubber products such as roofing, flooring, and weatherstripping. The U.S. industrial rubber products industry has been undergoing a major restructuring process for over a decade.

Trading patterns reflect the U.S. rubber industry's position as a moderately competitive producer; the United States is both a major exporter to industrialized nations and an importer of lower-cost products from developing countries. Imports continue to make inroads in the domestic market and stand at a nearly 2:1 ratio to exports.

Tires

The tire industry shows signs of stabilizing after undergoing a period characterized by massive restructuring, the effects of recession in the domestic market, and consistently high levels of imports. With tire durability pushed to what many consider the practical limit, industry strategy has shifted to servicing the fast-growing emerging markets for high-performance, light truck, and recreational vehicle tires.

Replacement tires for passenger cars dropped 4 percent in 2001 while replacement tires for commercial truck tires dropped 10 percent. These declines were offset by 10.6 percent growth in high-performance tires and 10.2 percent growth in light truck tires. The tire industry saw a 2.6 percent growth (anticipated negligible growth) in 2002 and a slight increase of 0.6 percent over 2002 and 2003 (but anticipated growth of over 4 percent in 2003). Industry shipments reached record levels in 2000, with higher than average growth expected for the high-performance, truck, and light truck tires and little or no growth projected for passenger tires installed on new cars.

Key growth figures for segments in the tire industry include the following:

- Original Equipment Passenger Tires - Little or no growth is anticipated from 2004 through 2009 (growth through 2007 expected to be less than 0.3 percent annualized), partially due to greater light vehicle production outside the United States.

- Original Equipment Light Truck Tires - Growth through 2009 expected to be 2.7 percent annualized.

- Original Equipment Medium/Wide-Base Truck Tires - Growth through 2006 expected to be 50 percent from 2003 level, topping out in 2006 due to EPA restrictions on emission standards for these trucks.

- Replacement Passenger Tires - Growth through 2009 expected to be slightly over 2 percent annualized.

- Replacement Light Truck Tires - Growth through 2009 expected to be just under 3 percent annualized.

- Replacement Medium/Wide-Base Truck Tires - The market grew at a 5.5 percent rate in 2003. This growth rate is expected to continue through 2006 and then remain at this level through 2009.

- Tread rubber for retread tires rebounded in the second half of 2003. Shipments through 2005 are expected to increase with an annual growth rate of 2.7 percent through 2005.

During the 1980s, corporate restructuring, mergers, and acquisitions resulted in the globalization of the tire industry. More than half of domestic production capacity is now owned by foreign-based tire manufacturers, mainly European and Japanese. Among the advantages realized by the surviving companies are increased resources for research and development, and economies of scale across procurement, manufacturing, distribution, and service.

All four of the major tire producers in the United States are involved in the production of the synthetic rubber used in tire production, and two of these producers own and operate natural rubber plantations. More than 80 percent of the sales revenue of the four major producers (both foreign and domestic) is derived from tires and related transportation products such as rubber belts and hoses.

III. INDUSTRIAL PROCESS DESCRIPTION

This section describes the major industrial processes within the RMPP industry, including the materials, equipment, and processes used. The section is designed for those interested in gaining a general understanding of the industry, and for those interested in the interrelationship between the industrial process and the topics described in subsequent sections of this profile - pollutant outputs, pollution prevention opportunities, and federal regulations. This section does not attempt to replicate published engineering information that is available for this industry. Refer to Section IX for a list of reference documents that are available.

This section describes commonly used production processes, associated raw materials, the by-products produced or released, and the materials either recycled or transferred off site. Coupled with schematic drawings of the identified processes, this section concisely describes where wastes may be produced in the process and also describes the potential fate (air, water, land) of these waste products.

III.A. Industrial Processes in the RMPP Industry

The processes used to manufacture plastic and rubber are very diverse; therefore, this section presents them individually.

III.A.1. Plastic

The production of plastics products, both solid and foam, is a relatively diverse industry. Simpler processes consist of: (1) imparting the appropriate characteristics to the plastic resin with chemical additives; (2) converting plastic materials in the form of pellets, granules, powders, sheets, fluids, or preforms into either intermediate or final formed plastic shapes or parts via molding operations; and (3) finishing the product, as shown in Figure 7.

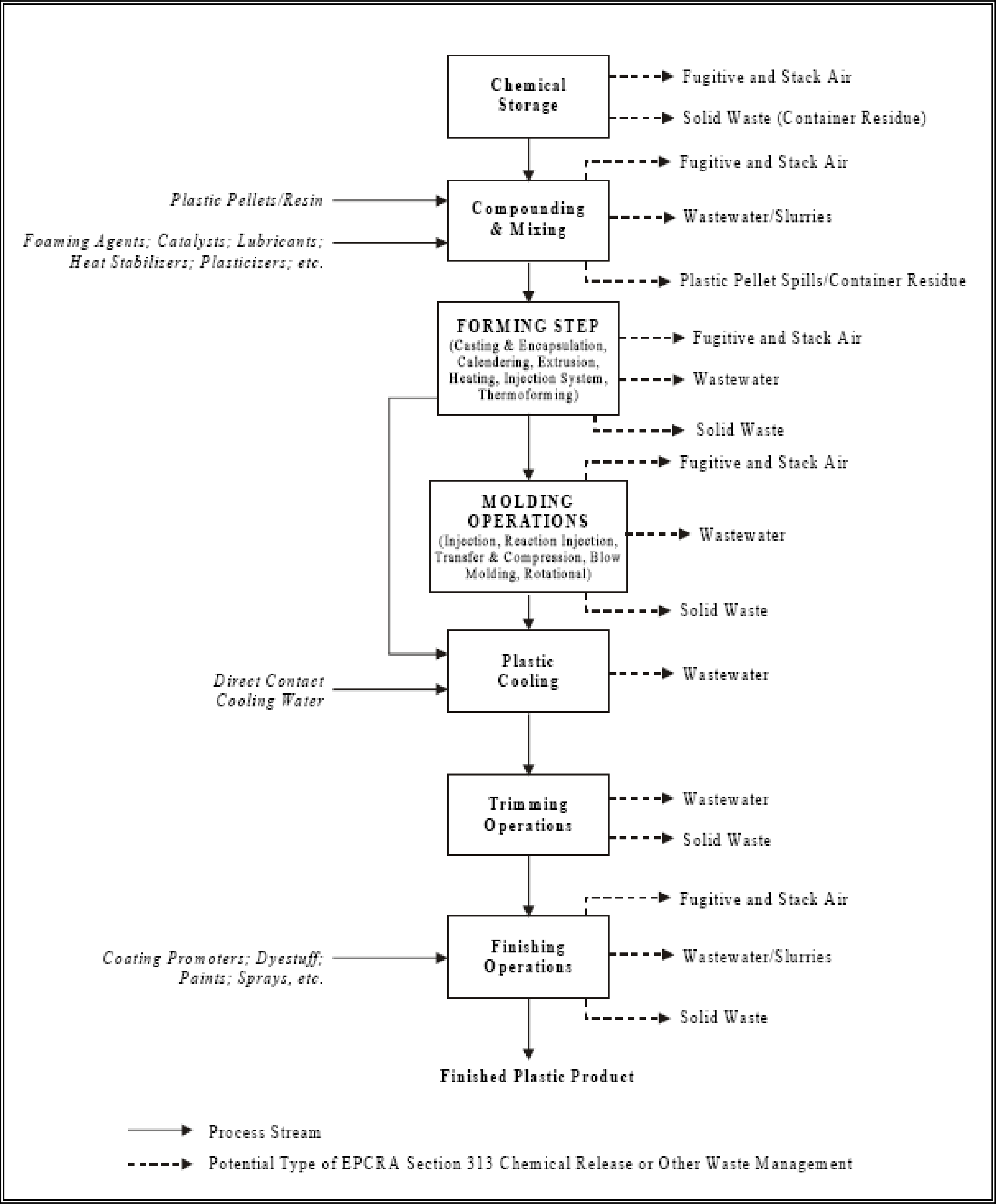
There are also several methods of reacting plastic resin and catalyst materials to form a thermoset plastic material into its final shape, as shown in Figure 8.

Additives are often mixed with the plastic materials to give the final product certain characteristics (some of these additives can also be applied to the shaped product during the finishing process). These plastic additives and their functions, in terms of their effect on the final product, are listed below.

- **Additive Lubricants** assist in easing the flow of the plastic in the molding and extruding processes by lubricating the metal surfaces that come into contact with the plastic.

- **Antioxidants** inhibit the oxidation of plastic materials that are exposed to oxygen or air at normal or high temperatures.

Figure 7: Plastics Products Manufacturing Process



Source: Emergency Planning and Community Right-To-Know Act (EPCRA) Section 313 Reporting Guidance for Rubber and Plastics Manufacturing, May 2000.

- **Antistats** impart a minimal to moderate degree of electrical conductivity to the plastic compound, preventing electrostatic charge accumulation on the finished product.

- **Blowing Agents (foaming agents)** produce a cellular structure within the plastic mass and can include compressed gases that expand upon pressure release, soluble solids that leach out and leave pores, or liquids that change to gases and, in the process, develop cells.

- **Colorants** impart color to the plastic resin.

- **Flame Retardants** reduce the tendency of the plastic product to burn.

- **Heat Stabilizers** assist in maintaining the chemical and physical properties of the plastic by protecting it from the effects of heat such as color changes, undesirable surface changes, and decreases in electrical and mechanical properties.

- **Impact Modifiers** prevent brittleness and increase the resistance of the plastic to cracking.

- **Organic Peroxides** initiate or control the rate of polymerization in thermosets and many thermoplastics.

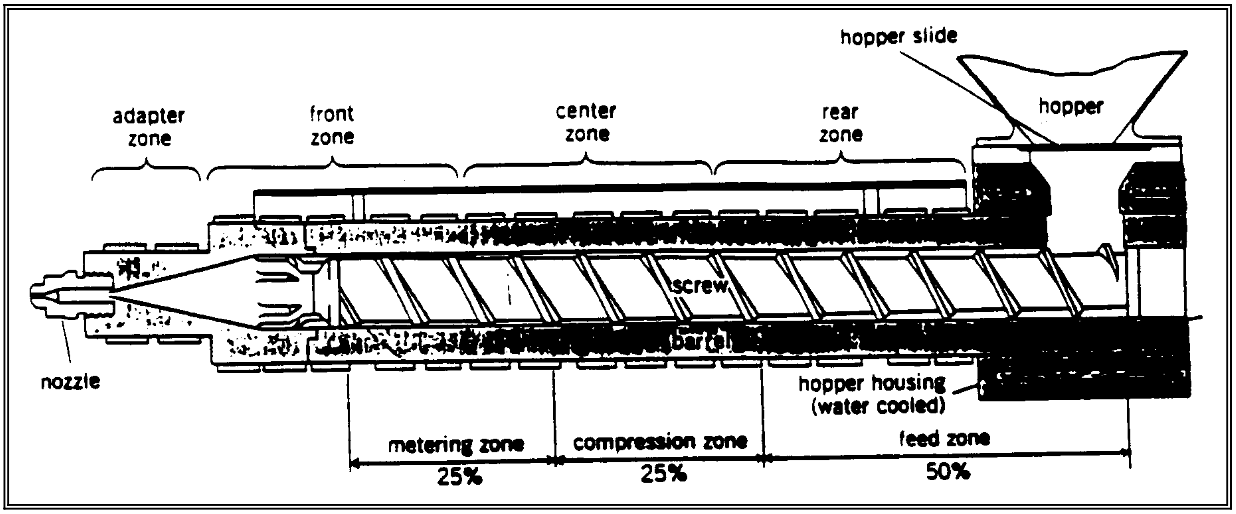
- **Plasticizers** increase the plastic product's flexibility and workability.

- **Ultraviolet Stabilizers (UV light absorbers)** absorb or screen out ultra-violet radiation, thereby preventing the premature degradation of the plastic product.

After adding the necessary additives to the plastic pellets, granules, powders, etc., the plastic mixture is formed into intermediate or final plastics products. To form solid plastics products, a variety of molding processes are used, including injection molding, reaction injection molding, extrusion, blow molding, thermoforming, rotational molding, compression molding, transfer molding, casting, encapsulation, and calendering. Slightly different processes are used to make foamed plastics products. The choice of which plastic forming process to use is influenced by economic considerations, the number and size of finished parts, the adaptability of particular plastic to a process (various plastic will mold, process, etc., differently), and the complexity of the post-forming operations. Below are brief descriptions of the most common molding and forming processes for creating solid plastics products.

Injection Molding: In the injection molding process, plastic granules or pellets are heated and homogenized in a cylinder until they are fluid enough to be injected (by pressure) into a relatively cold mold where the plastic takes the shape of the mold as it solidifies. Advantages of this process include speed of production, minimal post-molding requirements, and simultaneous multipart molding. The reciprocating screw injection machine is the dominant technology used in injection molding. The screw acts as both a material plasticizer and an injection ram. The buildup of viscous plastic at the nozzle end of a cylinder forces the screw backwards as it rotates. When an appropriate charge accumulates, rotation stops and the screw moves forward, thereby becoming an injection ram, forcing the melt (liquefied plastic) into the mold. The screw remains forward until the melt solidifies and then returns to repeat the cycle, as shown in Figure 8. Products made in this way include CDs, DVDs, kitchen utensils, automotive components, garbage cans, and countless others.

Figure 8: Injection Molding



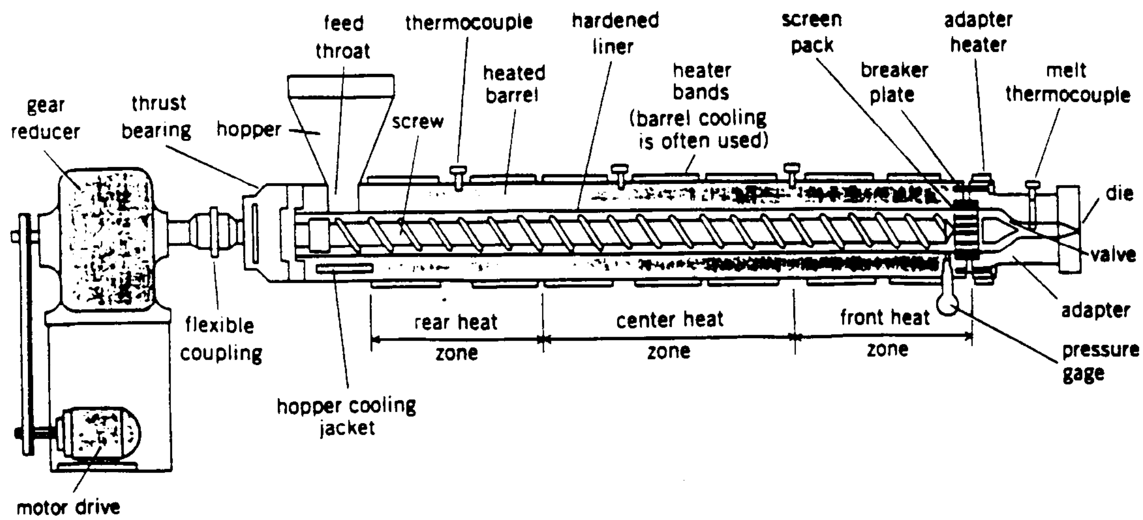
Source: McGraw-Hill Encyclopedia of Science and Technology.

Reaction Injection Molding: In the reaction injection molding process, two liquid plastic components, polyols and isocyanates, are mixed at relatively low temperatures (75 - 140 degrees F) in a chamber and then injected into a closed mold to form polyurethane products. The parts molded using this process can be foams or solids, and they can range from being flexible to extremely rigid. Products include large polyurethane foams for noise abatement and large panels for any indoor or outdoor application. Polyurethane is also used to encapsulate items and protect them from the environment.

Reaction injection molding requires far less energy than other injection molding systems because an exothermic reaction occurs when the two liquids are mixed. Reaction injection molding is a relatively new processing method that is quickly becoming common in the industry. Reinforced reaction injection molding involves placing long fibers or fiber mats in the mold before injection.

Extrusion: In the extrusion process, plastic pellets or granules are fluidized, homogenized, and formed continuously as the extrusion machine feeds them through a die, as shown in Figure 9. The result is a very long plastic shape such as a tube, pipe, sheet, or coated wire. Extruding is often combined with post-extruding processes such as blowing, thermoforming, or punching. Extrusion molding has an extremely high rate of output (e.g., pipe can be formed at a rate of 2,000 lb/hr (900 kg/hr)).

Figure 9: Extrusion



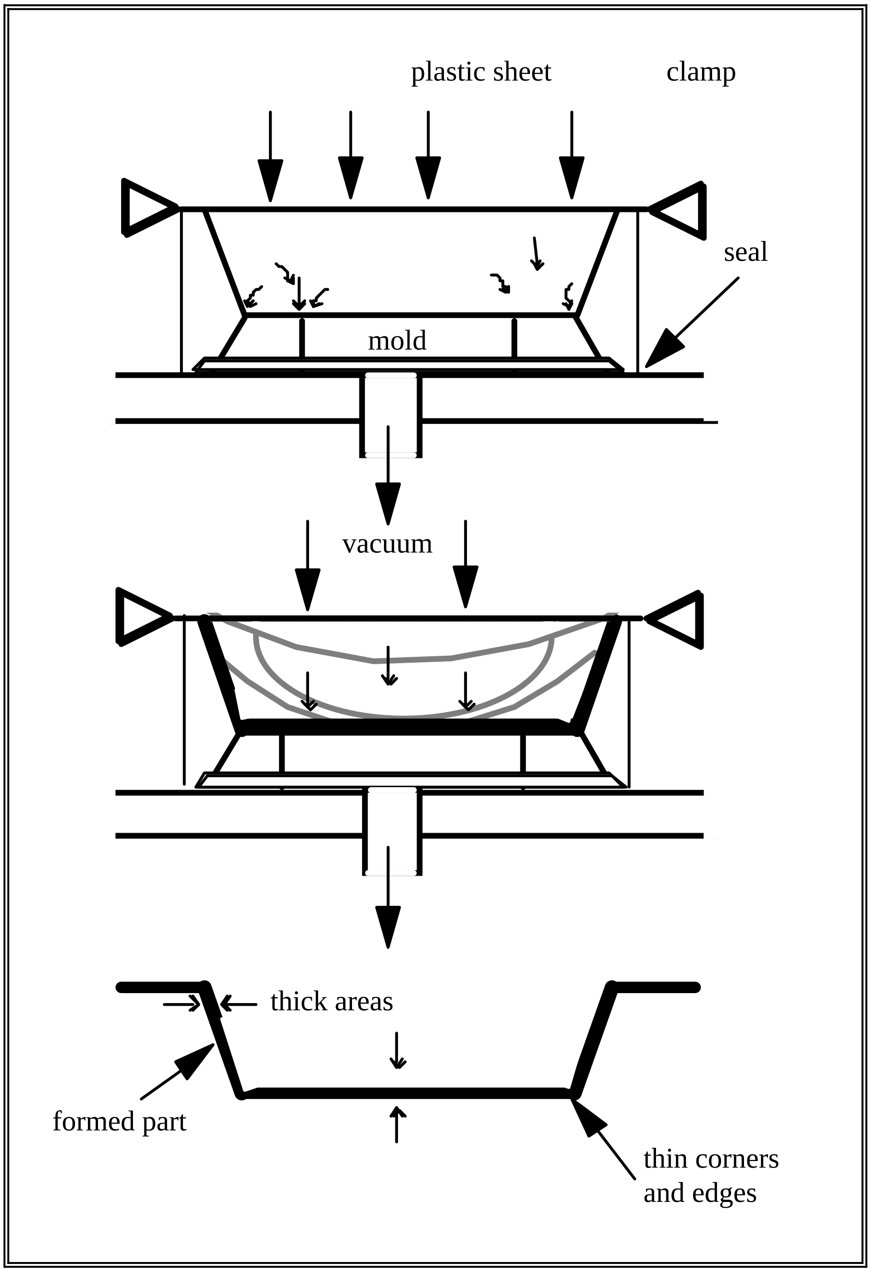
Source: McGraw-Hill Encyclopedia of Science and Technology.

Blow Molding: Blow molding describes any forming process in which air is used to stretch and form plastic materials. In one method of blow molding, a tube is formed (usually by extrusion molding) and then made into a free-blown hollow object by injecting air or gas into the tube. Blow molding can also consist of putting a thermoplastic material in the rough shape of the desired finished product into a mold and then blowing air into the plastic until it takes the shape of the mold, similar to blowing up a balloon. Examples of products include a wide variety of beverage and food containers.

Thermoforming: In the thermoforming process, heat and pressure are applied to plastic sheets, which are then placed over molds and formed into various shapes. The pressure can be in the form of air, compression, or a vacuum, as shown in Figure 10. This process is popular because compression is relatively inexpensive. Products include clam shells and blister packaging for the shipping industry as well as thin plastic components for retail packaging.

Rotational Molding: In the rotational molding process, finely ground plastic powders are heated in a rotating mold to the point of either melting and/or fusion. The inner surface of the rotating mold is then evenly coated by the melted resin. The final product is hollow and produced scrap-free. Products include fuel tanks, side paneling for vehicles, and carrier cases.

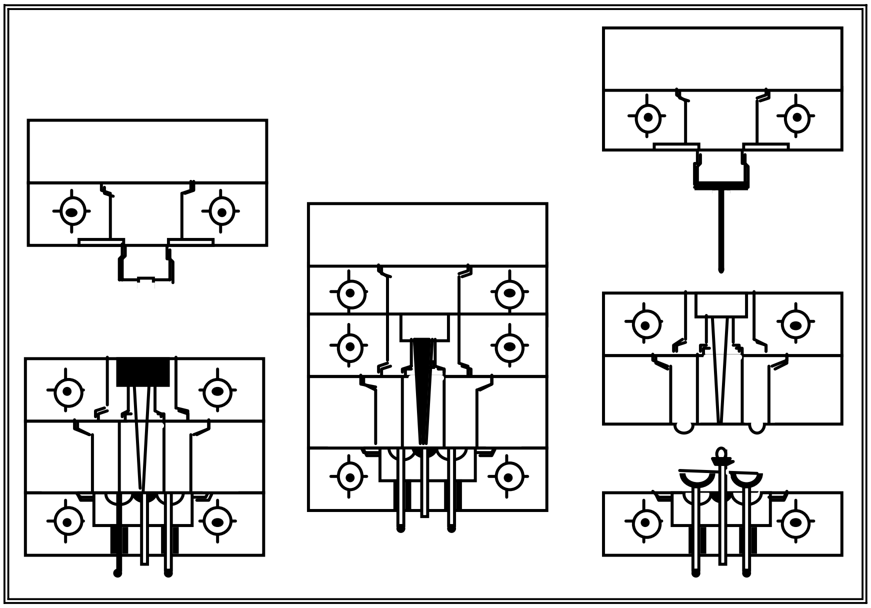
Figure 10: Thermoforming



Source: McGraw-Hill Encyclopedia of Science and Technology.

Compression and Transfer Molding: In the compression molding process, plastic powder or a preformed plastic part is plugged into a mold cavity and compressed with pressure and heat until it takes the shape of the cavity. Transfer molding is similar, except that the plastic is liquefied in one chamber and then injected into a closed mold cavity by a hydraulically operated plunger, as shown in Figure 11. Transfer molding was developed to facilitate the molding of intricate plastics products that contain small deep holes or metal inserts because compression molding often ruins the position of the pins that form the holes and the metal inserts.

Figure 11: Transfer Molding



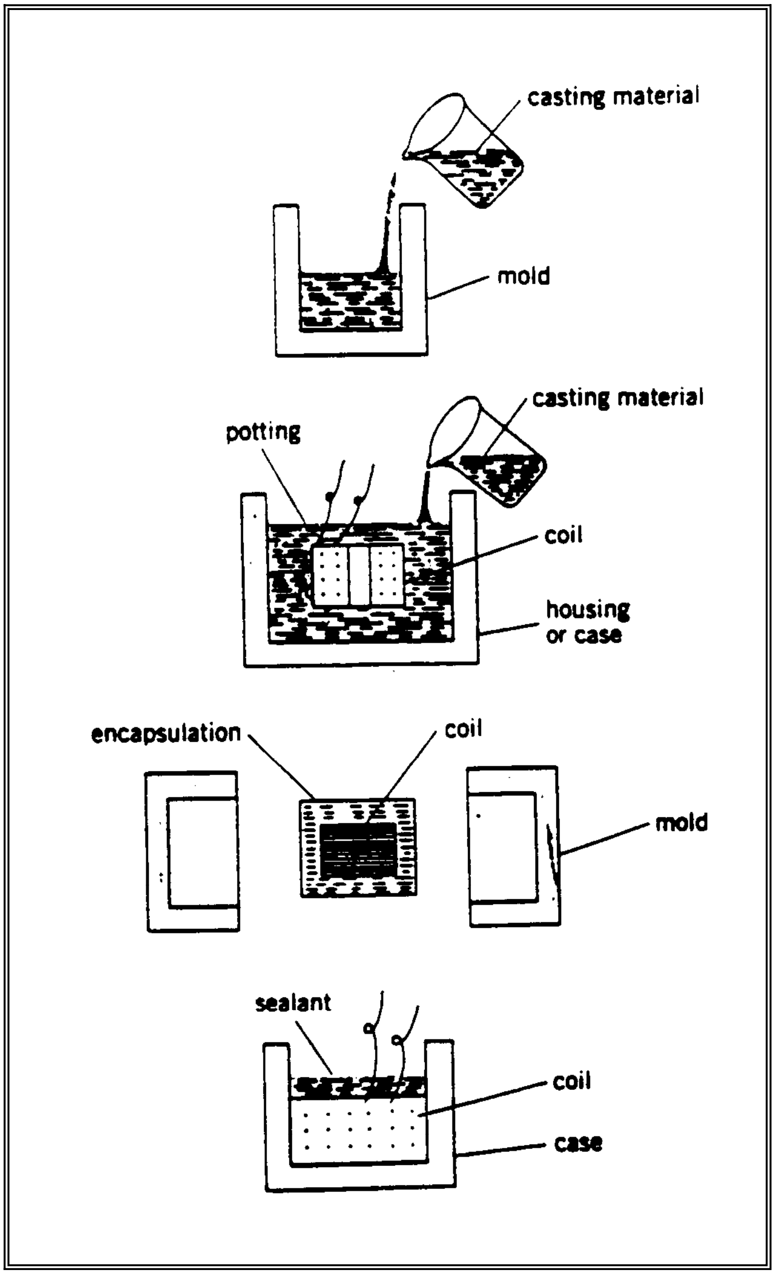
Source: McGraw-Hill Encyclopedia of Science and Technology.

Casting and Encapsulation: In the casting process, liquid plastic is poured into a mold until it hardens and takes the shape of the mold. In the encapsulation or potting process, an object is encased in plastic and then hardened by fusion or a chemical reaction, as shown in Figure 12.

Calendering: In the calendering process, plastic parts are squeezed between two rolls to form a thin, continuous film.

Foamed Plastic: Manufacturing foamed plastics products involves slightly different forming processes than those described above. The three types of foam plastic are blown, syntactic, and structural. Blown foam is an expanded matrix, similar to a natural sponge; syntactic foam is the encapsulation of hollow organic or inorganic micro spheres in the plastic matrix; and structural foam is a foamed core surrounded by a solid outer skin. All three types of foam plastic can be produced using processes such as injection, extrusion, and compression molding to create foam products in many of the same shapes as solid plastics products. The difference is that creating foam products requires processes such as chemical blowing agent addition, different mixing processes that add air to the plastic matrix, or a unique injection molding process used to make structural plastic.

Figure 12: Encapsulation



Source: McGraw-Hill Encyclopedia of Science and Technology.

The following are some basic processes that occur in conjunction with the standard molding and forming operations to produce blown foam plastic and syntactic foam plastic:

- A chemical blowing agent that generates gas through thermal decomposition is incorporated into the polymer melt;

- Gas that is under pressure is injected into the melt and then expands during pressure relief;

- A low-boiling liquid hydrocarbon is incorporated into the plastic compound and volatilized through the exothermic heat of reaction;
- Nonchemical gas-liberating agents (adsorbed gas on finely divided carbon) are added to the resin mix and released during heating;
- Air is dispersed by mechanical means within the polymer (similar to whipping cream); or
- The external application of heat causes small beads of thermoplastic resin containing a blowing agent to expend.

Structural foam plastic is made by injection molding liquid resins that contain chemical blowing agents. Less mixture is injected into the mold than is needed to mold a solid plastic part. At first the injection pressure is very high, causing the blowing agent mixture to solidify against the mold without undergoing expansion. As the outer skin is formed, the pressure is reduced and the remaining resin expands to fill the remainder of the mold. Structural foam plastic parts have a high strength-to-weight ratio and often have three to four times greater rigidity than solid plastic molded parts of equal weight that are made of the same material.

After the solid or foam plastic shape is created, post-forming operations such as welding, adhesive bonding, machining, applying of additives, and surface decorating (painting and metalizing) are used to finish the product.

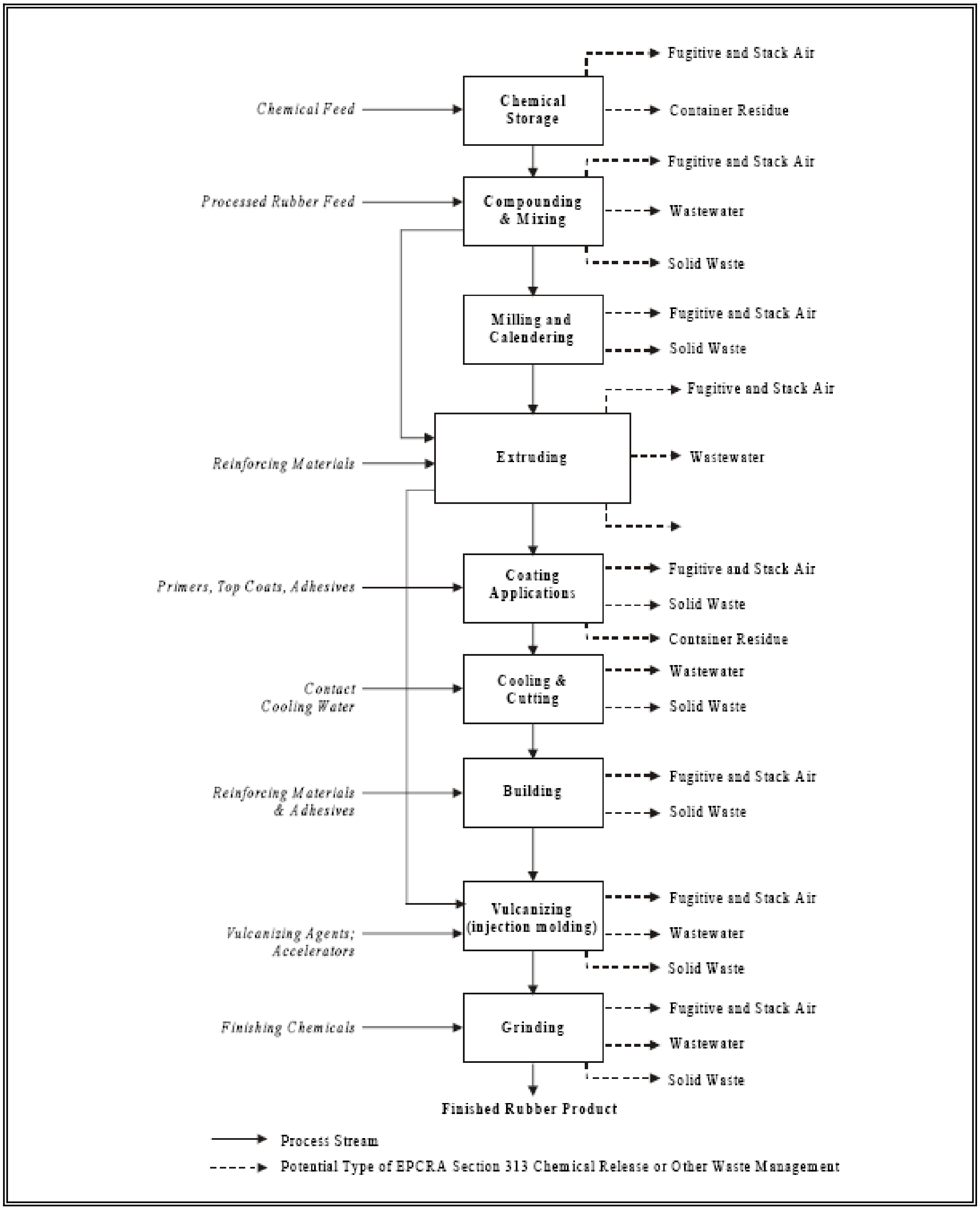
Thermoset Resin: To produce a thermoset plastic material, liquid resins are combined with a catalyst. Resins used for thermoset plastic products include urethane resins, epoxy resins, polyester resins, and acrylic resins. Fillers are often added to the resin-catalyst mixture prior to molding to increase product strength and performance and to reduce cost. Most thermoset plastic products contain large amounts of fillers (up to 70 percent by weight). Commonly used fillers include mineral fibers, clay, glass fibers, wood fibers, and carbon black. After the thermoset material is created, a final or intermediate product can be molded.

Various molding options can be used to create the intermediate or final thermoset product. These processes include vacuum molding, press molding, rotational molding, hand lamination, casting and encapsulation, spray-up lamination, resin transfer molding, filament winding, injection molding, reaction injection molding, and pultrusion.

III.A.2. Rubber

Rubber product manufacturing is as diverse as the number of rubber products produced. Even with this diversity, there are several basic, common processes. This profile focuses on the basic processes of mixing, milling, extruding, calendering, building, vulcanizing, and finishing, as shown in Figure 13.

Figure 13: Rubber Manufacturing Process



Source: Emergency Planning and Community Right-To-Know Act (EPCRA) Section 313 Reporting Guidance for Rubber and Plastics Manufacturing, May 2000.

Mixing: The rubber product manufacturing process begins with the production of a rubber mix from polymers (i.e., raw and/or synthetic rubber), carbon black (the primary filler used in making a rubber mixture), oils, and miscellaneous chemicals. The miscellaneous chemicals include processing aids, vulcanizing agents, activators, accelerators, age resistors, fillers, softeners, and specialty materials. The following is a list of these miscellaneous chemicals and the functions they perform:

- **Processing Aids** modify the rubber during the mixing or processing steps, or aid in a specific manner during the extrusion, calendering, or molding operations.

- **Vulcanizing Agents** create cross links between polymer chains.

- **Activators**, in combination with vulcanizing agents, reduce the curing time by increasing the rate of vulcanization.

- **Accelerators** form chemical complexes with activators and thus aid in maximizing the benefits from the acceleration system by increasing vulcanization rates and improving the final product's properties.

- **Age Resistors** slow down the deterioration of the rubber products that occurs through reactions with materials that may cause rubber failure (e.g., oxygen, ozone, light, heat, radiation).

- **Fillers** reinforce or modify the physical properties of the rubber, impart certain processing properties, and reduce costs by decreasing the quantity of more expensive materials needed for the rubber matrix.

- **Softeners** either aid in mixing, promote greater elasticity, produce tack, or extend (replace) a portion of the rubber hydrocarbon (without a loss in physical properties).

- **Specialty Materials** include retarders, colorants, blowing agents, dusting agents, odorants, etc. Specialty materials are used for specific purposes, and are not required in the majority of rubber compounds.

Rubber mixes differ depending upon the desired characteristics of the product being manufactured. The process of rubber mixing includes the following steps - mixing, milling (or other means of sheeting), antitack coating, and cooling. The appropriate ingredients are weighed and loaded into an internal mixer known as a "Banbury" mixer, which then combines these ingredients. The area where the chemicals are weighed and added to the Banbury is called the compounding area. The polymers and miscellaneous chemicals are manually introduced into the mixer hopper, while carbon black and oils are often injected directly into the mixing chamber from bulk storage systems. The mixer creates a homogeneous mass of rubber using two rotors that shear materials against the walls of the machine's body. The rubber is then cooled as this mechanical action also adds considerable heat to the rubber.

Milling: The mixed rubber mass is discharged to a mill or other piece of equipment that forms it into a long strip or sheet. The hot, tacky rubber then passes through a water-based "antitack" solution that prevents the rubber sheets from sticking together as they cool to ambient temperature. The rubber sheets are placed directly onto a long conveyor belt that, through the application of cool air or cool water, lowers the temperature of the rubber sheets.

After cooling, the sheets of rubber are sent through another mill. These mills "warm up" the rubber for further processing on extruders and calenders. Some extruders can be "cold fed" rubber sheets, making this milling step unnecessary.

Extruding: Extruders transform the rubber into various shapes or profiles by forcing it through dies via a rotating screw. Extruding heats the rubber, which remains hot until it enters a water bath or spray conveyor where it cools.

Calendering: Calenders receive hot strips of rubber from mills and squeeze them into reinforcing fibers or cloth-like fiber matrices, thus forming thin sheets of rubber-coated materials. Calenders are also used to produce nonreinforced, thickness-controlled sheets of rubber.

Building: Extruded and calendered rubber components are combined (layered, built-up) with wire, polyester, aramid, and other reinforcing materials to produce various rubber products. Adhesives, called cements, are sometimes used to enhance the bonding of the various product layers. This assembling, reinforcing, precuring, and bonding process is called building.

Vulcanizing: All rubber products undergo vulcanization (curing). This process occurs in heated compression molds, steam-heated pressure vessels (autoclaves), hot air and microwave ovens, or various molten and fluidized bed units. During the curing process, the polymer chains in the rubber matrix cross-link to form a final product of durable, elastic, thermoset rubber. Increasing the number of cross-links in the rubber matrix gives rubber its elastic quality. One way to visualize this is to think of a bundle of wiggling snakes in constant motion. If the bundle is pulled at both ends and the snakes are not entangled, then the bundle comes apart. The more entangled the snakes are (like the rubber matrix after vulcanization), the greater the tendency for the bundle to bounce back to its original shape.

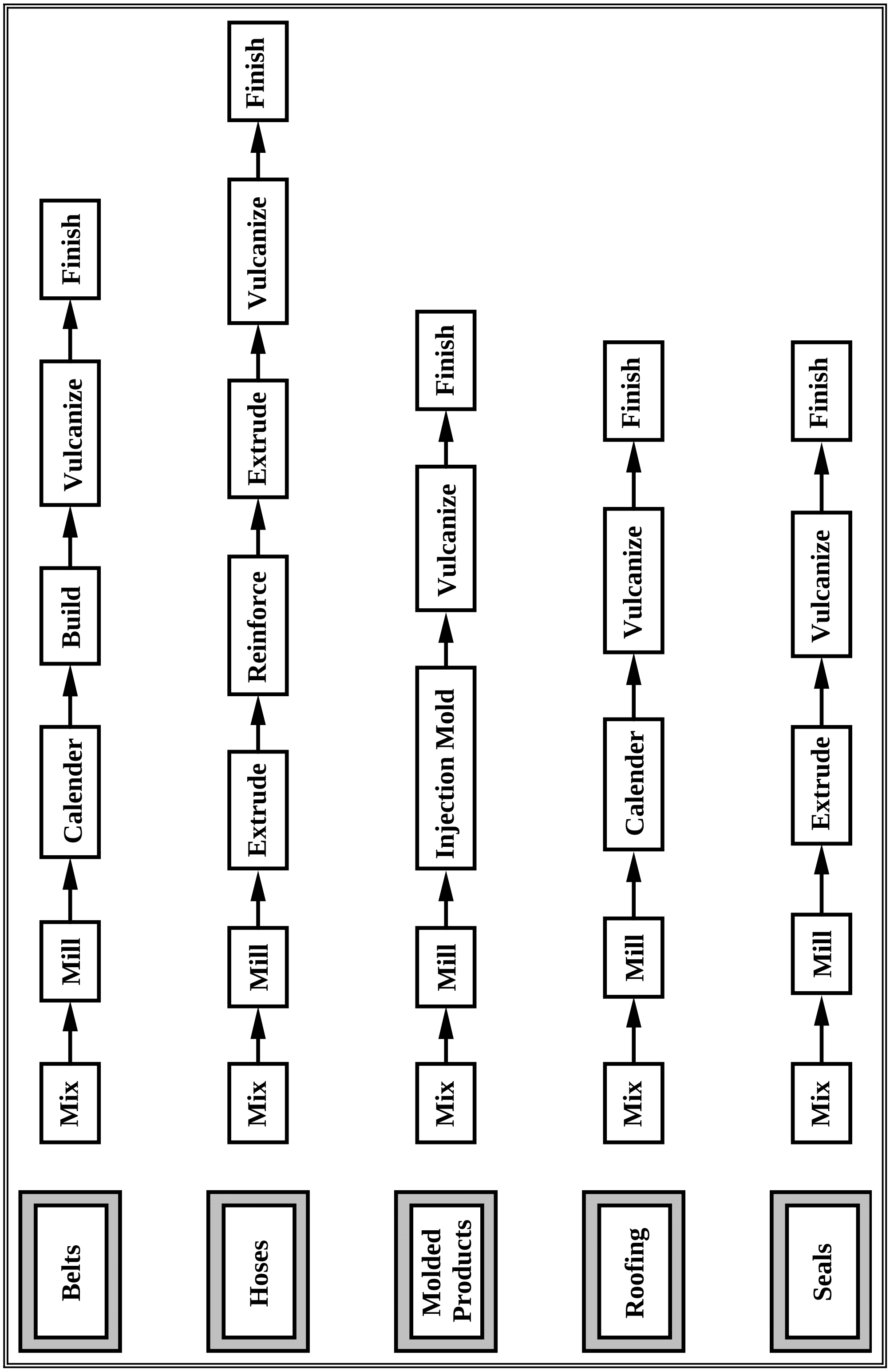
Finishing: Finishing operations are used to prepare the products for delivery to the end user. Finishing operations might include balancing, grinding, printing, washing, wiping, and buffing.

Due to the diversity of products and facilities, not all of the processes shown in Figure 13 are necessary for every product. For example, many plants do not mix rubber but purchase uncured rubber from other facilities.

Figure 14 illustrates the processes used to manufacture the following rubber products:

- **Belts** - A typical belt plant does not have an extruder but uses many layers of calendered material assembled on a lathe type builder to produce a rubber cylinder from which individual belts can be cut.

Figure 14: Processes Used to Manufacture Various Rubber Products



- **Hoses** - A hose plant uses an extruder to produce a tube that is reinforced with cord or wire and covered with a layer of rubber applied by an extruder. The same extruder may be used to produce the initial tube and then to extrude the final "cover" layer onto the reinforced tube.

- **Molded Products** - A molded products plant uses extruded material to feed compression molds, or may cut strips directly from the mixing process to feed the molds.

- **Roofing** - Roofing manufacturers processes rubber through mills and calenders to produce the necessary sheeting.

- **Sealing** - Sealing products manufacturing plants uses extrusion and continuous vulcanization in hot air ovens.

III.A.3. Tires

The tire manufacturing process is similar to that of manufacturing other rubber products. The main difference between the two processes is that the building process for manufacturing tires is generally more complex because there are many rubber components.

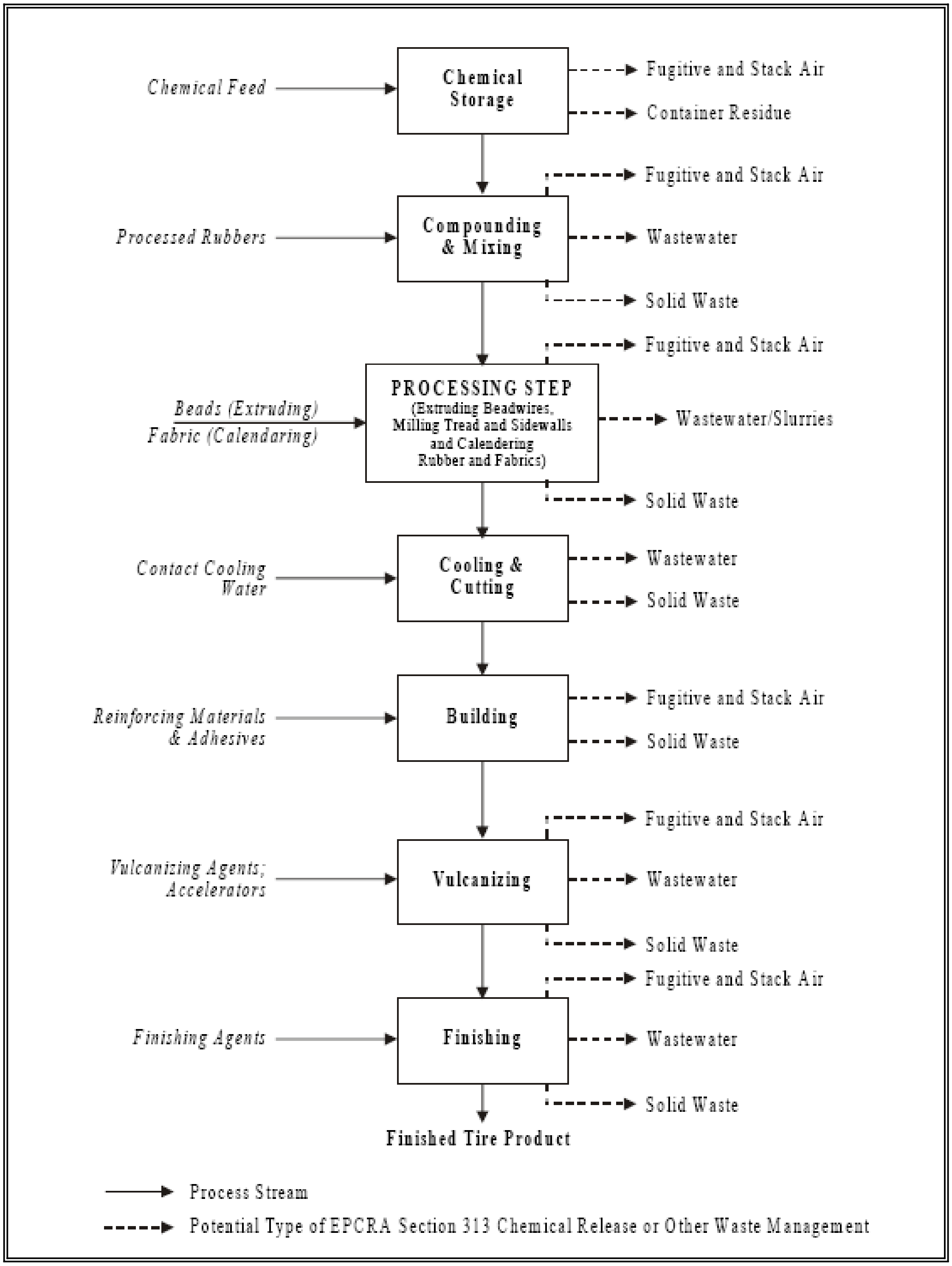
As shown in Figure 15, the tire production process in its most basic form consists of the following sequential steps:

- **Compounding and mixing** elastomers, carbon blacks, pigments, and other chemicals such as vulcanizing agents, accelerators, plasticizers, and initiators. The process begins with mixing basic rubbers with process oils, carbon black, pigments, antioxidants, accelerators and other additives, each of which contributes certain properties to the compound. These ingredients are mixed in Banbury mixers operating under tremendous heat and pressure. They blend the many ingredients into a hot, black gummy compound that will be milled again and again.

- **Milling.** The cooled rubber takes several forms. Most often it is processed into carefully identified slabs that will be transported to breakdown mills. These mills feed the rubber between massive pairs of rollers, over and over, feeding, mixing, and blending to prepare the different compounds for the feed mills, where they are slit into strips and carried by conveyor belts to become sidewalls, treads or other parts of the tire.

- **Extruding** operations use warming mills and either a hot or cold extruder. The equipment forces the rubber compound through dies that create individual or a continuous sidewall and tire tread components for future tire building.

Figure 15: Tire Manufacturing Process



Source: Emergency Planning and Community Right-To-Know Act (EPCRA) Section 313 Reporting Guidance for Rubber and Plastics Manufacturing, May 2000.

- **Tire cord manufacturing and calendering.** Processing fabrics and coating them with rubber is a calendering operation. A specific rubber coats the fabric that is used to make up the tire's body. The fabrics come in huge rolls, and they are as specialized and critical as the rubber blends. Many kinds of fabrics are used, including polyester, rayon, and nylon.

- **Bead wire processing.** It has high-tensile steel wire forming its backbone, which will fit against the vehicle's wheel rim. The strands are aligned into a ribbon coated with rubber for adhesion, then wound into loops that are then wrapped together to secure them until they are assembled with the rest of the tire.

- **Tire building.** Tires are manually built on one or two tire machines. The tire starts with a double layer of synthetic gum rubber called an inner liner that will seal in air and make the tire tubeless. The operator uses the tire building machine to preshape tires into a form very close to their final dimension to make sure the many components are in proper position before the tire goes into the mold. The resulting tire is called a “green” tire, which is uncured.

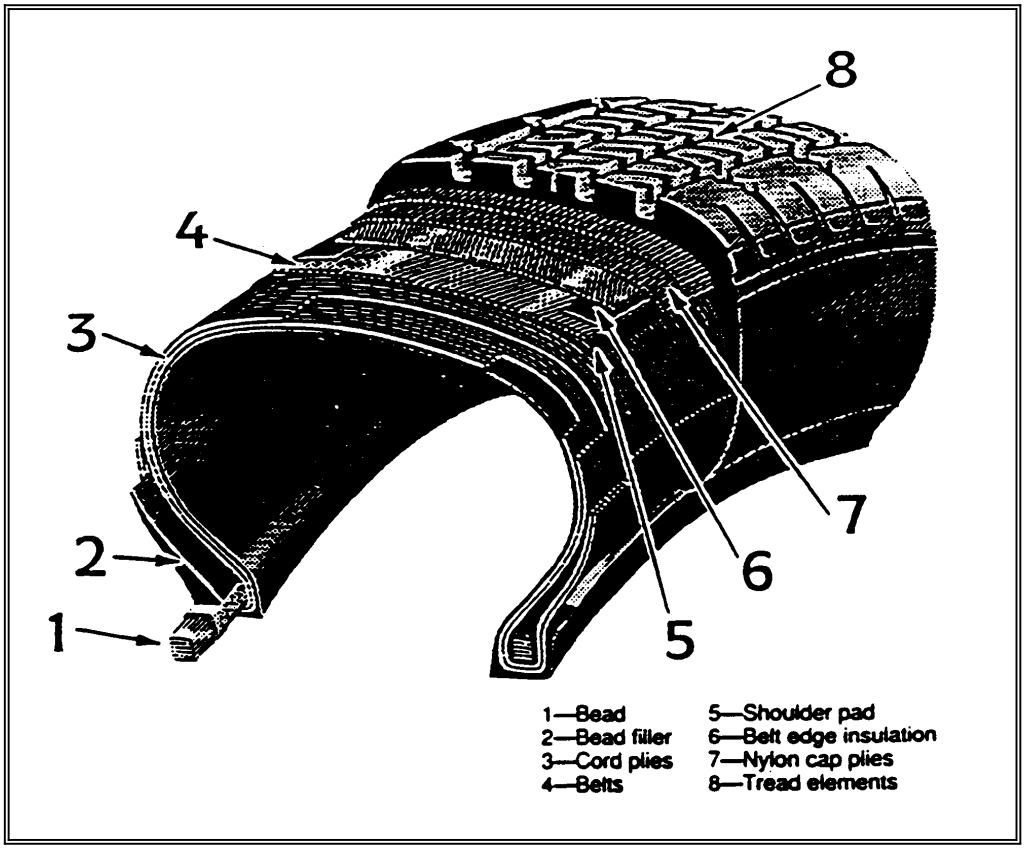
- **Lubricating.** The lubrication or spraying system provides a coating, primarily silicon, on the green tire to afford mold release after curing.

- **Vulcanizing and molding.** The curing press is where tires get their final shape and tread pattern. Hot molds like giant waffle irons shape and vulcanize the tire. The molds are engraved with the tread pattern, the sidewall markings of the manufacturer, and those required by law.

- **Finishing and quality assurance.** The operation includes balancing, grinding, and painting and marking the tire.

The main piece of equipment used in tire-building is the drum, which is a collapsible cylinder shaped like a wide drum that the tire builder can turn and control. The building process begins when carcass plies, also known as rubberized fabric, are placed on a drum one at a time, after which the cemented beads (rubber coated wires) are added and the plies are turned up around them. Narrow strips of fabric are then cemented on for additional strength. At this stage, the belts, tread, and sidewall rubber are wrapped around the drum over the fabric. The drum is then collapsed and the uncured (green) tire is coated with a lubricant (green tire spray) and loaded into an automatic tire press to be molded and cured. Prior to curing, the tire looks like a barrel that is open at both ends. The curing process converts the rubber, fabric, and wires into a tough, highly elastic product while also bonding the various parts of the tire into one single unit, as shown in Figure 16. After curing, the tire is cooled by mounting it on a rim and deflating it to reduce internal stress. Finishing the tire involves trimming, buffing, balancing, and quality control inspection.

Figure 16: Tire Formation



Source: "Tire Materials and Construction" in Automotive Engineering*, October 1992.*

III.B. Raw Material Inputs and Pollution Outputs in the Production Line

III.B.1. Plastic

Most plastic products are grouped into one of three classifications:

- Thermoplastics. Thermoplastics are plastics that can be heated to become soft and harden when cooled. This process can be done repeatedly and the plastics do not normally undergo a chemical change during the forming process. Thermoplastic products are usually manufactured from solid pellets purchased from resin manufacturers. Includes: polyethylene - (HDPE, LDPE, LLDPE, PET); polypropylene - (PP); polystyrene - (PS); polyvinyl chloride - (PVC); and saturated polyester.

- Thermosets. Thermosets undergo a chemical reaction to make them permanently solid from heating, pressurizing or reacting with a hardening agent. They are usually available in liquid or powder form for reacting into products. Unlike thermoplastics, thermosets are not easily remelted or refabricated. Includes: epoxy, phenolic, polyurethanes, unsaturated polyester, and urea-formaldehyde.

- Foamed Plastics (formed using either thermoplastics or thermosets). Includes: polyurethane foam, polystyrene foam, and polyethylene foam.

Four general types of pollution and resource material outputs can occur at one or more stages of the plastics products manufacturing process. In addition, there are some plastics products disposal concerns. Manufacturing outputs include spills, leaks, and fugitive emissions of chemicals when additives are applied prior to molding or during finishing; wastewater discharges during cooling and heating, cleaning, and finishing operations; plastic pellet releases to the environment prior to molding; and fugitive emissions from molding and extruding machines, as shown in Figure 17. Each of these is discussed below. Section 4.2 of the Emergency Planning and Community Right-To-Know Act (EPCRA) Section 313 Reporting Guidance for Rubber and Plastics Manufacturing contains a good description of pollution sources for this industry.

Chemicals

One concern during the plastics products manufacturing process is the potential release of the additive chemicals prior to molding and during the finishing process. Releases could be in the form of: spills during weighing, mixing, and general handling of the chemicals; leaks from chemical containers and molding machines; or fugitive dust emissions from open chemical containers. It should be noted that not all plastics products manufacturers use additives because many purchased pellets already contain the necessary additives. The chemicals used in the plastics products manufacturing process are usually added in such small amounts that most manufacturers do not track them closely; however, some of the additives could be toxic and therefore releases of even small quantities could present significant problems. According to a National Enforcement Investigations Center (NEIC) inspector, the plastic industry is currently looking into both the characteristics of plastic additives and their releases so they can better understand and address any related environmental or worker safety issues. The following is a list of some of the typical chemicals used as additives in the plastics products manufacturing process:

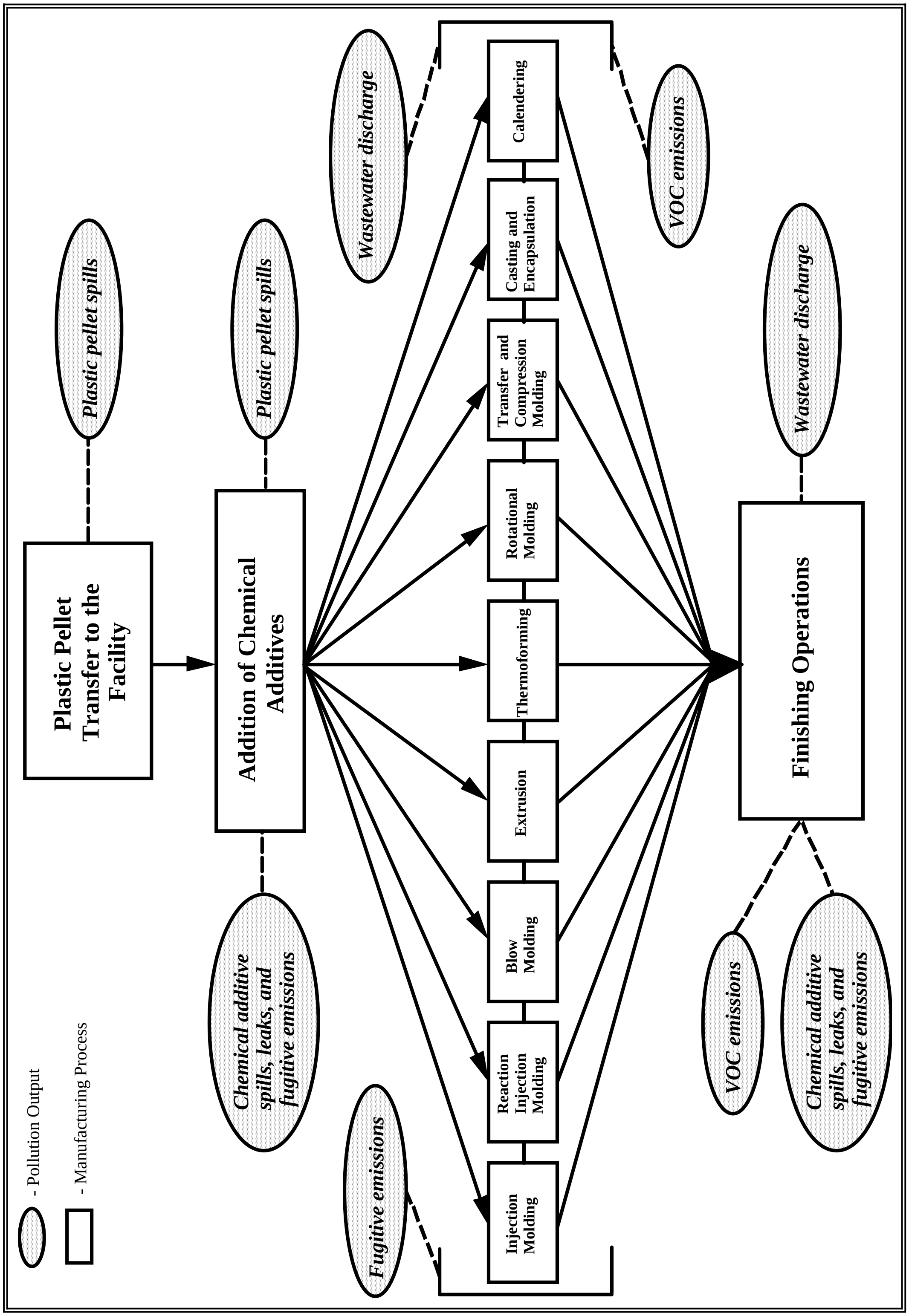
- **Lubricants** - stearic acid, waxes, fatty acid esters, and fatty acid amines.

- **Antioxidants** - alkylated phenols, amines, organic phosphites and phosphates, and esters.

- **Antistats** - quaternary ammonium compounds, anionics, and amines.

- **Blowing/foaming agents** - azodicarbonamide, modified azos, and 4,4'-Oxybis(benzenesulfonyl hydrazide). Auxiliary blowing agents are used to modify foaming and insulation properties. In the past, they were CFCs such as CFC-11, CFC-12, 113, and 114. CFCs are being replaced by butane, pentane, HCFC-22, 134a, 142, and liquid CO_2. A 1992 EPA rule that implemented the CAA Section 604 gradually phased out methyl chloroform and CFCs.

Figure 17: Plastics Products Manufacturing Process Pollution Outputs



- **Colorants** - titanium dioxide, iron oxides, anthraquinones, and carbon black.

- **Flame Retardants** - antimony trioxide, chlorinated paraffins, and bromophenols.

- **Heat Stabilizers** - lead, barium-cadmium, tin, and calcium-zinc.

- **Organic Peroxides** - methyl ethyl ketone (MEK) peroxide, benzoyl peroxide, alkyl peroxide, and peresters.

- **Plasticizers** - adipates, azelates, trimellitates, and phthalates.

- **Ultraviolet Stabilizers (UV light absorbers)** - benzophenones, benzotriazole, and salicylates.

Wastewater

Contaminated wastewater is another concern in the miscellaneous plastics products industry. Water used in the plastic molding and forming processes falls into three main categories: (1) water to cool or heat the plastics products; (2) water to clean the surface of both the plastics products and the equipment used in production; (3) and water to finish the plastics products.

Cooling and heating water usually comes into contact with raw materials or plastics products during molding and forming operations for the purpose of heat transfer. The only toxic pollutant that is found in a treatable concentration in some wastewater discharged by contact cooling and heating processes is bis(2-ethylhexyl) phthalate (BEHP). Since many facilities do not process materials containing BEHP, this is not an issue for those manufacturers.

Cleaning water includes water that is used to clean the surface of the plastic product or the molding equipment that is or has been in contact with the formed plastic product. The types of pollution resulting from cleaning water in treatable concentrations are biochemical oxygen demand (BOD_5), oil and grease, total suspended solids (TSS), chemical oxygen demand (COD), total organic carbon (TOC), total phenols, phenol, and zinc.

Finishing water consists of water used to carry away waste plastic material or to lubricate the product during the finishing operation. TSS, BEHP, di-n-butyl phthalate, and dimethyl phthalate are the pollutants identified in finishing water in treatable concentrations.

Of the pollutants found in all three types of process water, BOD_5, oil and grease, TSS, and pH are considered conventional pollutants, TOC and COD are considered non-conventional pollutants, and BEHP, di-n-butyl phthalate, dimethyl phthalate, phenol, and zinc are considered priority toxic pollutants.

Pellet Release

The third concern in the miscellaneous plastics products industry is the release of plastic pellets into the environment. Plastic pellets and granules used to mold intermediate and final plastics products are often lost to floor sweepings during transport or while being loaded into molding machines, and may end up in wastewater. Although they are inert, plastic pellets are an environmental concern because of the harm they can cause if runoff carries them to wetlands, estuaries, or oceans where they may be ingested by seabirds and other marine species. EPA stormwater regulations classify plastic pellets as "significant materials," and therefore the discovery of a single pellet in stormwater runoff is subject to federal regulatory action.

Fugitive Emissions

Fugitive emissions from the molding processes may be an environmental concern because of the many additives, including cadmium and lead, that can be released during the application of high heat and pressure. Officials from trade associations (e.g., American Plastic Council and The Society of the Plastics Industry, Inc. (SPI)) are currently researching the composition of these emissions and their possible effects on air quality.

Solid Waste Disposal

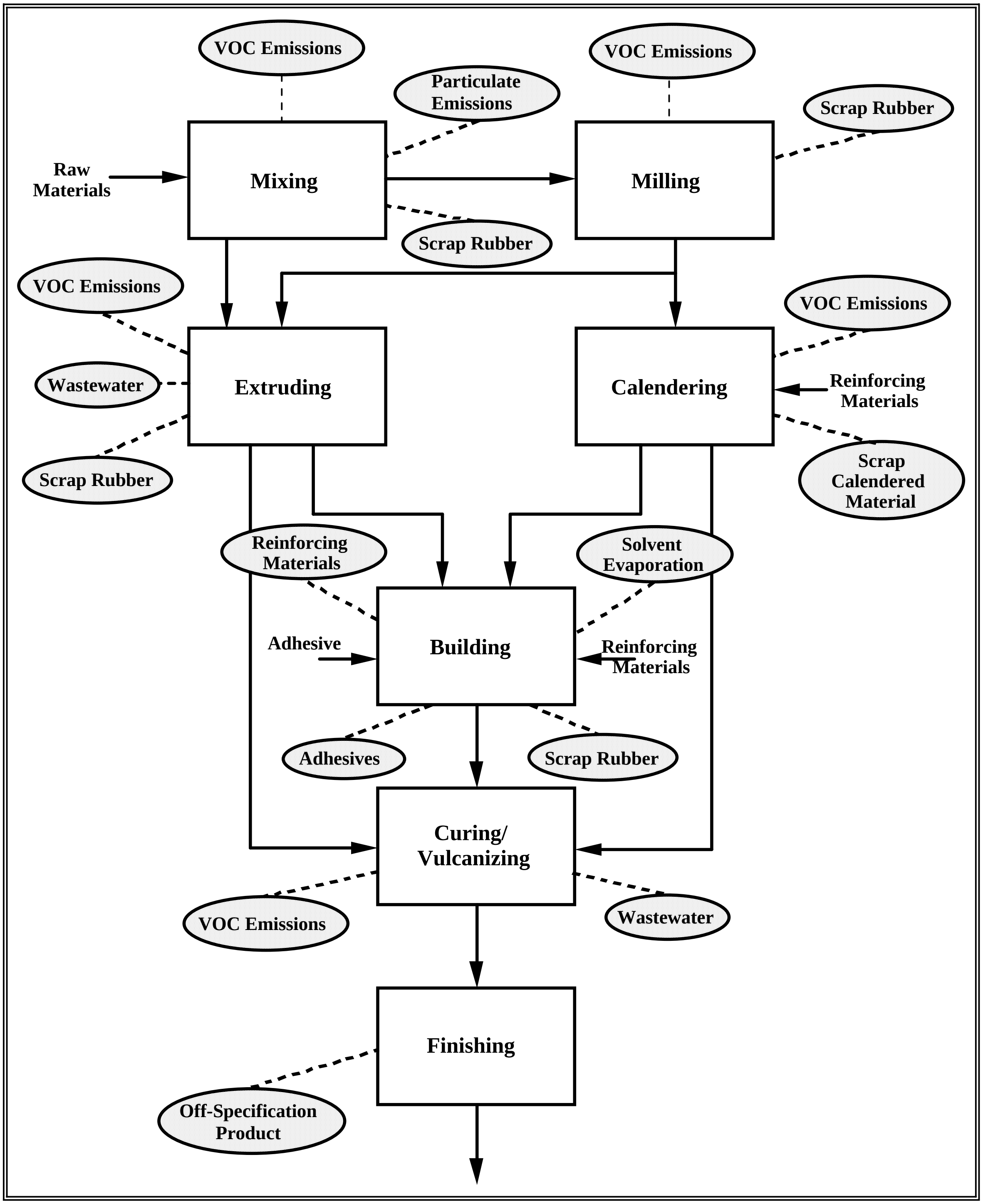
Plastics products also pose solid waste disposal concerns. Discarded plastics products and packaging make up a growing portion of municipal and solid waste. Because only a small percentage of plastic is recycled (less than one percent), virtually all discarded plastics products are put into landfills or incinerated. Current estimates show that plastic constitutes 14 to 21 percent of the waste stream by volume and 7 percent of the waste stream by weight. Because of its resistance to degradation, improper plastic disposal can have particularly serious ecological risks and aesthetic effects in the marine environment.

In terms of landfill disposal, the slow degradation of plastic is not a significant factor in landfill capacity; research has shown that other constituents (e.g., metals, paper, wood, food wastes) also degrade very slowly. However, the additives contained in plastic, such as colorants, stabilizers, and plasticizers, may include toxic constituents such as lead and cadmium, which can leach out into the environment as the plastic degrades. Plastics contribute 28 percent of all cadmium and approximately 2 percent of all lead found in municipal solid waste. Data are too limited to determine whether these and other plastic additives contribute significantly to the leachate produced in municipal solid waste landfills. Plastic that contains heavy metal-based additives may also contribute to the metal content of incinerator ash.

III.B.2. Rubber

In the rubber products industry, the primary environmental concerns are fugitive emissions, solid wastes, wastewater, and hazardous wastes, as shown in Figure 18. Each of these is discussed below.

Figure 18: Rubber Products Manufacturing Process Pollution Outputs



Fugitive Particulate Matter (PM) and Volatile Organic Compound (VOC) Emissions

The compounding area, where dry chemicals are weighed and put into containers prior to mixing, can be a source of fugitive emissions and possibly spills and leaks. Because additives must be preweighed, in some facilities the chemicals sit in big open bins on the scales or while waiting to get on the scales, thus increasing the potential for significant fugitive dust emissions. Most mixing facilities have eliminated this problem by purchasing their chemicals in small, preweighed, sealed polyethylene bags. The sealed bag is put directly into the Banbury mixer thus eliminating a formerly dusty operation. If chemicals are not in preweighed bags, fugitive emissions are also produced as the chemicals are loaded into the mixer. Emissions from the internal mixers are typically controlled by baghouses. Exhausts from the collection hoods are ducted to the baghouses to control particulate and possibly particle-bound semivolatiles and metals. The following is a list of the major chemicals used in the rubber compounding and mixing processes that can constitute these fugitive emissions:

- **Processing Aids** - zinc compounds.
- **Accelerators** - zinc compounds, ethylene thiourea, and diethanolamine.
- **Activators** - nickel compounds, hydroquinone, phenol, alpha naphthylamine, and p-phenylenediamine.
- **Age Restorers** - selenium compounds, zinc compounds, and lead compounds.
- **Initiator** - benzoyl peroxide.
- **Accelerator Activators** - zinc compounds, lead compounds, and ammonia.
- **Plasticizers** - dibutyl phthalate, dioctyl phthalate, and bis(2-ethylhexyl) adipate.
- **Miscellaneous Ingredients** - titanium dioxide, cadmium compounds, organic dyes, and antimony compounds.

VOC and hazardous air pollutant (HAP) emissions are also an environmental concern in the rubber product manufacturing processes. A 1994 Rubber Manufacturers Association (RMA) Emissions Factors study analyzed data on VOC and HAP emissions resulting from the mixing, milling, extruding, calendering, vulcanizing, and grinding processes. The findings showed extremely low VOC and HAP emissions for each pound of rubber processed. A facility must process 100,000 pounds of rubber to produce 10 pounds of VOCs during the mixing process. These emissions may add up, however, at large tire facilities producing 50,000 tires a day. The average weight of finished passenger and light truck tires is 23.5 pounds (approximately 21 pounds without steel and beads); thus, a 50,000 tire per day production facility must process at least 1,050,000 pounds of rubber compound.

The RMA VOC emissions factors have been sent to EPA for review and are included in Chapter 4 of the AP-42, in draft. EPA used the emission factors, which include individual HAP emission factors, in establishing the Maximum Achievable Control Technology (MACT) standards subpart XXXX for rubber tire manufacturing.

Solvent, cement, and adhesive evaporation is another source of VOC and HAP emissions. Solvents are used in various capacities during the rubber product manufacturing process. For example, solvents are used to degrease equipment and tools and as a type of adhesive or cement during building. Typically, releases of solvents occur either when the spent solvent solutions are disposed of as hazardous wastes or when degreasing solvents are allowed to volatilize. Solvent use is decreasing as water, silicon, and non-solvent-based release compounds are now common.

Wastewater

Wastewater from cooling, heating, vulcanizing, and cleaning operations is an environmental concern at many facilities. Contaminants can be added to wastewater in direct contact cooling applications such as extruder cooling conveyors and from direct contact steam used in vulcanizing operations. The residual in adhesive-dispensing containers and contaminated adhesives can also be sources of contaminated wastewater.

Zinc is of particular concern as a constituent of stormwater for the facilities involved in manufacturing and processing rubber products. A study by the RMA identified several processes through which zinc might be introduced into stormwater. Inadequate housekeeping is considered to be the primary source of zinc. Inefficient, overloaded, or malfunctioning dust collectors and baghouses are another source of zinc.

Studies have shown that concern about the leaching potential of rubber products in landfills is unfounded. The RMA assessed the levels of chemicals, if any, leached from waste rubber products using EPA's June 13, 1986 proposed Toxicity Characterization Leaching Procedure (TCLP). TCLP tests were performed on 16 types of rubber products to assess the leaching potential of over 40 different chemicals, including volatile organics, semivolatile organics, and metals. Results of the TCLP study indicate that none of the rubber products tested, cured or uncured, exceeded proposed TCLP regulatory levels. Most compounds detected were found at trace levels (near method detection limits) from 10 to 100 times less than proposed TCLP regulatory limits. The TCLP regulatory levels adopted after June 13, 1986 were even less stringent than the original proposal.

Solid Waste

Solid wastes are also an issue at rubber products manufacturing facilities. Surface grinding activities that generate dust and rubber particles are typically controlled by a primary cyclone and a secondary baghouse or electrostatic precipitator. This baghouse-captured PM (e.g., chemicals, ground rubber) from compounding areas, Banburys, and grinders is a source of solid waste. Used lubricating, hydraulic, and process oils are also prevalent at most manufacturing facilities.

Scorched rubber from mixing, milling, calendering, and extruding is a major solid waste source within rubber products manufacturing facilities, as is waste rubber produced during rubber molding operations. A rubber is scorched when chemical reactions begin to take place in the rubber as it is being heated. A scorched rubber is no longer processable. Waste rubber can be classified into three categories: (1) uncured rubber waste; (2) cured rubber waste; and (3) off-specification products. Currently, much of the uncured rubber waste is recycled at the facility. Cured rubber waste is either recycled at the facility or sold to other companies that use it to make products such as mud flaps and playground mats. Off-specification products can be sold to other companies that make products from shredded or scrap rubber or it can be disposed of. Much of the off-spec, uncured rubber is sold, reprocessed, or recycled. These practices are discussed further in Section V.

Tires

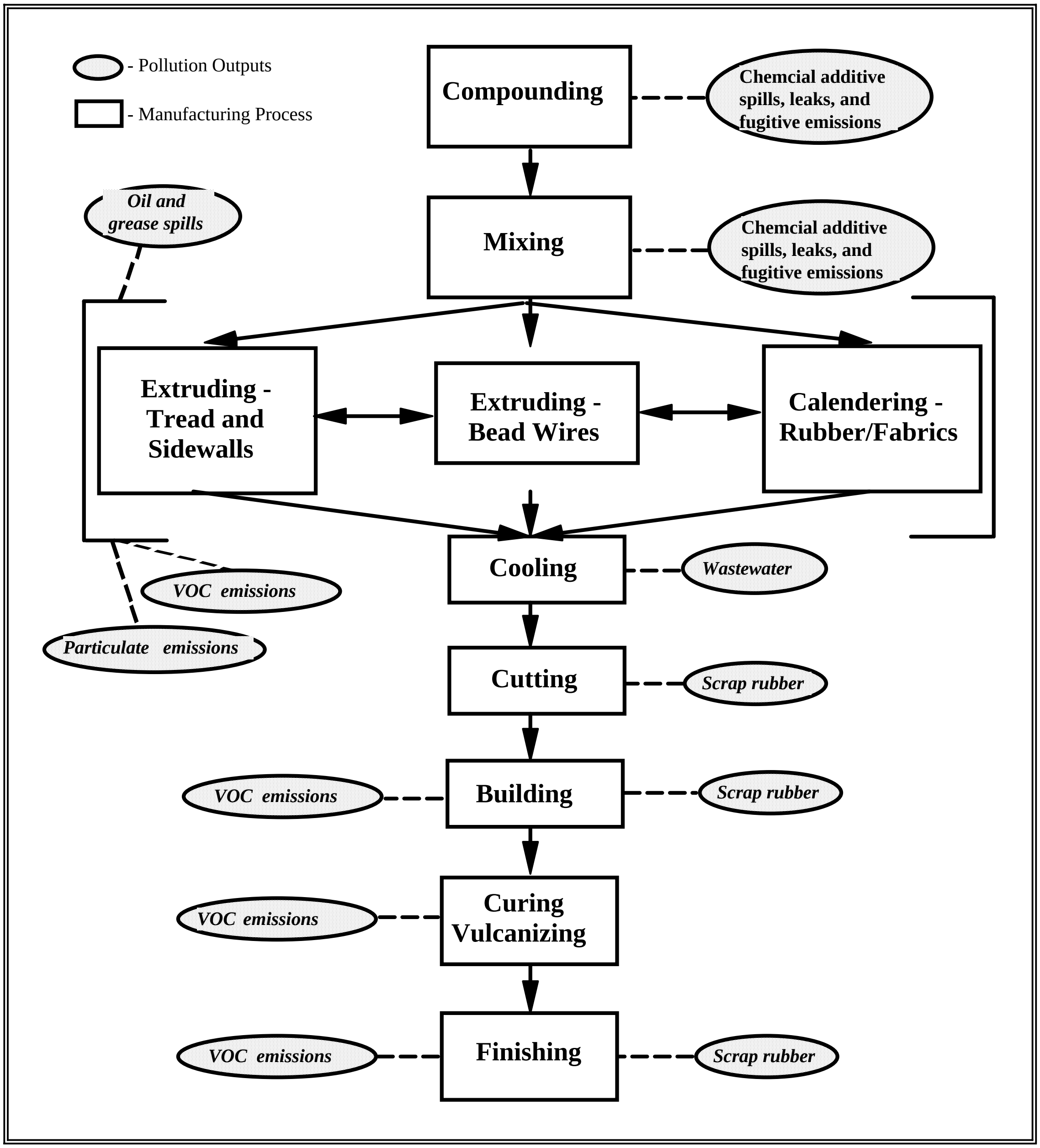
The resource material and pollution outputs from the tire manufacturing process include all of the outputs discussed above in the rubber products manufacturing process. There is, however, an emphasis on the VOC and HAP emissions that result from solvent use in cementing and spraying operations, as shown in Figure 19, and on scrap tire disposal.

Volatile Organic Compound Emissions

VOC and HAP emissions from the rubber tire manufacturing process are caused by solvent application, as a process aide, to the different tire components before, during, and after the building process (these VOC and HAP emissions can also result from the manufacture of other rubber products that require cementing or gluing). The principal VOC and HAP emitting processes affected by New Source Performance Standards (NSPS) and NESHAP regulations are undertread cementing operations, sidewall cementing operations, tread end cementing operations, bead cementing operations, green tire spraying operations, Michelin-B operations, Michelin-C automatic operations, and processes that use solvents and cements in tire production and puncture sealant operations.

All cementing operations refer to the system used to apply cement to any part of the tire. The green tire spraying operation refers to the system used to apply a mold release agent and lubricant to the inside and/or outside of green tires as a process aide during the curing process and to prevent rubber from sticking to the curing press. VOCs and HAPs are also emitted in very limited amounts from operations where rubber is heated, including mixing, milling, extruding, calendering, vulcanizing, and grinding.

Figure 19: Tire Manufacturing Process Pollution Outputs



Scrap Tires

Probably the biggest environmental concern related to rubber tires is the disposal of scrap tires. In 2001, it was estimated that the United States generated approximately 300 million scrap tires. Approximately 80 percent of these tires were recycled, reused, or recovered. Scrap tires pose three environmental threats. One is that tire piles are a fire hazard and burn with an intense heat that gives off dense black smoke. These fires are extremely difficult to extinguish in part because tire casings form natural air pockets that supply the oxygen that feeds the flames. The second threat is that the tires trap rain water, which serves as a nesting ground for various insects such as mosquitoes; areas where there are scrap tire piles tend to have severe insect problems. The third and most important environmental threat associated with scrap tires is that discarded tires are bulky, virtually indestructible, and, when buried, tend to work their way back to the surface as casings compressed by the dirt slowly spring back into shape and "float" the tire upward. This problem has led to either extremely high tipping fees for scrap tires in landfills - at least twice the fee for municipal solid waste - or total bans on whole tires in landfills. As discussed above, the RMA has conducted testing to verify that tires are not hazardous wastes based on TCLP analysis. The many efforts underway to address this problem are discussed in Section V of this profile.

III.C. Management of Chemicals in Waste Stream

The Pollution Prevention Act of 1990 requires facilities to report information about the management of Toxic Release Inventory (TRI) chemicals in waste and efforts made to eliminate or reduce those quantities. EPA has collected these data annually in Section 8 of the TRI reporting Form R beginning with the 1991 reporting year. The data summarized below cover the years 1998-2001 and is meant to provide a basic understanding of the quantities of waste handled by the industry, the methods typically used to manage this waste, and recent trends in these methods. TRI waste management data can be used to assess trends in source reduction within individual industries and facilities and for specific TRI chemicals. This information could then be used as a tool in identifying opportunities for pollution prevention compliance assistance activities.

The quantities reported for 1998 to 2001 are estimates of quantities already managed. EPA requires these projections to encourage facilities to consider future waste generation and source reduction of those quantities as well as movement up the waste management hierarchy.

Table 5 shows that the RMPP industry managed approximately 250,000,000 pounds of production-related waste (total quantity of TRI chemicals in the waste from routine production operations) in 2001 (column B). Approximately 40 percent of the industry's TRI wastes were managed on site through recycling, energy recovery, or treatment, as shown in columns D, E, and F, respectively. The majority of waste that is released or transferred off site can be divided into portions that are recycled off site, recovered for energy off site, or treated off site as shown in columns G, H, and I, respectively. The remaining portion of the production-related wastes (43.0 percent), shown in column J, is either released to the environment through direct discharges to air, land, water, and underground injection, or it is disposed of off site.

Table 5: Quantity of Production-Related Waste Managed by the RMPP Industry

A	B	D	E	F	G	H	I	J
Year	Production-Related Waste Volume (10^6 lbs.)	On Site			Off Site			Remaining Releases and Disposal
		% Recycled	% Energy Recovery	% Treated	% Recycled	% Energy Recovery	% Treated	
1998	263	19.53%	7.26%	17.14%	6.66%	3.15%	3.68%	42.57%
1999	251	19.49%	5.77%	15.78%	7.54%	3.23%	3.74%	44.46%
2000	229	18.78%	6.68%	15.16%	6.66%	2.97%	4.12%	45.63%
2001	205	17.07%	11.38%	14.23%	6.48%	3.66%	4.23%	42.95%

Source: Reduction and Recycling Activity for SIC code 30.

The yearly data presented in Table 5 show that the portion of TRI wastes reported as recycled on site has decreased slightly and the portions treated or managed through energy recovery on site have increased slightly between 1998 and 2001.