Economic Analysis of Air Pollution Regulations: Miscellaneous Cellulose Manufacturing Industry

Industry Profile

Prepared for

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INDUSTRY PROFILE

Cellulose is a natural polymer found in plant cell walls. The cellulose extracted from trees or other plants provides the basic raw material for all of the commercial products produced by the miscellaneous cellulose manufacturing industry. The miscellaneous cellulose manufacturing industry can be divided into two major categories: the viscose category and the cellulose ether category. Both of these categories use some type of cellulose as the primary raw material, normally either wood pulp or cotton linters, but their production processes differ. Although production of viscose products is not identical for all of the viscose outputs, the processes are very similar.

Relatively few firms are involved in the production of these miscellaneous cellulose products. Only 17 miscellaneous cellulose manufacturing facilities are operated in the United States. The final products of these facilities compete in markets with products made from alternative materials, especially plastics. Cellulose products have generally been declining in market share over time as newer noncellulose products have been introduced.

Fourteen of the 17 facilities in the United States are considered major sources of hazardous air pollutants (HAPs). The primary pollutant associated with this industry is carbon disulfide (CS_2), which is used in the viscose production process and may be emitted at several steps during production. Another pollutant generated during the viscose production process is hydrogen sulfide (H_2S). The HAP emitted during the manufacture of cellulose ethers depends primarily on the type of cellulose ether being manufactured. Methanol, methyl chloride, ethylene oxide, and propylene oxide are the primary HAPs released by the cellulose ether manufacturing facilities in the United States.

This industry profile considers five outputs of miscellaneous cellulose manufacturing. The viscose category features four types of products—cellulose food casings, rayon, cellophane, and cellulosic sponges—and cellulose ethers are considered a single category. Brief descriptions of each of these categories are provided below.

- Cellulose food casings: Cellulose food casings were developed in 1925 as a substitute for natural casings and are used in manufacturing meat products such as sausages, hot dogs, salamis, bologna, and other processed meats. The meat is stuffed into a casing that holds the shape of the product during processing. Casings are commonly removed from the meat products prior to retail sale.

- Rayon: Rayon was the first man-made fiber and serves in a wide variety of uses. It is used in apparel, household goods, and various nonwoven fabrics. Textile fabrics may be woven of rayon alone or rayon in combination with other yarns. Nonwoven rayon products include feminine hygiene products, baby wipes, computer disk liners, and surgical swabs.

- Cellophane: Cellophane is a thin, transparent material used in food packaging (especially for candy, cheese, and baked goods); adhesive tapes; and membranes for industrial uses such as batteries.

- Cellulosic sponges: This type of artificial sponge was introduced in 1931 as an alternative to natural sponges. Cellulosic sponges are used for cleaning purposes.

- Cellulose ethers: Various cellulose ethers are produced, including methyl cellulose (MC), carboxymethyl cellulose (CMC), hydroxyethyl cellulose (HEC), hydroxypropyl cellulose (HPC), and hydroxypropyl methyl cellulose (HPMC). These cellulose derivatives are used mainly as thickeners, viscosifiers, and binders in the food, pharmaceutical, paper, cosmetic, adhesive, detergent, and textile industries.

The affected products are classified in the following Standard Industrial Classification (SIC) codes:

- SIC 2823, Cellulosic Manmade Fibers;

- SIC 2869, Industrial Organic Chemicals—Not Elsewhere Classified; and

- SIC 3089, Plastics Products, Not Elsewhere Classified.

Under the North American Industry Classification System (NAICS), the codes for miscellaneous cellulose manufacturing are the following:

- NAICS 32511, Petrochemical Manufacturing;

- NAICS 325199, All Other Basic Organic Chemical Manufacturing;

- NAICS 3252, Resin, Synthetic Rubber, and Artificial and Synthetic Fibers;

- NAICS 326121, Unsupported Plastics Profile Product Manufacturing; and

- NAICS 326199, All Other Plastics Product Manufacturing.

In the remainder of this section, we provide a summary profile of the miscellaneous cellulose industry in the United States as background information for understanding the technical and economic aspects of the industry. Section 2.1 provides an overview of the production processes for the various products of this industry. Section 2.2 discusses the demand side of the markets for these cellulose products. Section 2.3 summarizes the organization of the U.S. miscellaneous cellulose manufacturing industry, including a description of U.S. manufacturing plants and the companies that own them. Finally, Section 2.4 provides market data on U.S. production, consumption, foreign trade, and prices.

2.1 Production Overview

This section provides an overview of the various processes for manufacturing miscellaneous cellulose products.[1] Both the viscose and cellulose ether categories use some type of cellulose as the raw material and begin the production of cellulose products by reacting the cellulose with a sodium hydroxide (NaOH) solution and shredding the cellulose pulp (not necessarily in that order) to produce alkali cellulose. The NaOH breaks the cellulose pulp into shorter lengths by adding a sodium ion to the cellulose chain. This step lowers the viscosity of the generated product (e.g., viscose solution for the viscose category) and creates a site to add constituent groups (e.g., methyl, ethyl, or propyl groups for the cellulose ether category). After this common initial step, the viscose and cellulose ether categories diverge in their production methods. Therefore, process descriptions for the viscose and cellulose ether categories are provided separately below. No major by-products or co-products are associated with the manufacture of miscellaneous cellulose manufacturing process.

2.1.1 Viscose Category Production Process

The manufacturing processes for the different products in the viscose category are very similar. They all essentially include the same raw materials and process steps. The main difference is simply the shape through which the viscose is extruded at the end of the process. The raw materials used in all of the different viscose manufacturing processes include cellulose, NaOH, CS_2, and sulfuric acid (H_2SO_4). The steps in the process are

- production and aging of alkali cellulose,
- reaction with CS_2 to produce sodium cellulose xanthate,

[1]The majority of the information on production processes was drawn from Schmidtke and Holloway (1999).

- production and aging of viscose solution,
- extrusion/regeneration and washing to produce the viscose product, and
- acid or salt recovery.

Figure 2-1 illustrates a generic process flow diagram for the viscose category.

The alkali cellulose is aged to decrease the degree of polymerization of the cellulose. The amount of time for the aging step is based on the desired cellulose chain length. The aged alkali cellulose is then reacted with CS_2 to form sodium cellulose xanthate. Following completion of the reaction, most of the viscose category facilities apply vacuum to the reactor and/or purge the reactor with air or nitrogen (N_2) to remove unreacted CS_2. The CS_2 levels are the most concentrated at the beginning of the reactor evacuation and fall as evacuation continues. The reactor area of the facility is well-ventilated at most of the viscose category facilities, helping to reduce operator exposure to CS_2.

Following the reactor, the sodium cellulose xanthate is dissolved in a caustic solution to form a viscous material referred to by the industry as “viscose.” The viscose solution is aged or “ripened” and then filtered to remove unreacted alkali cellulose. At most of the viscose category facilities, the viscose is also deaerated to remove entrapped air and filtered to remove any undissolved solids. The exception is sponge manufacturing facilities, which do not include these steps. The viscose is then extruded or formed into various shapes or products; the product forming may occur in an acid bath or by electrifying, depending on the type of viscose manufacturing process. At the majority of the viscose manufacturing facilities, the cellulose precipitates out of a H_2SO_4 solution, and the sodium atom on the cellulose polymer reacts with the H_2SO_4 to generate Na_2SO_4 (i.e., the sodium cellulose xanthate decomposes back to cellulose and CS_2). H_2S is also generated in the extrusion/regeneration steps and emitted. The acid bath for the extrusion/regeneration step becomes diluted from the water in the viscose solution, and a portion of the acid bath solution is treated in the acid recovery area and returned to the acid bath. In sponge plants, glauber salts are added to the viscose prior to generation of the product and are recovered and reused as part of the production process. The formed cellulose product is then washed, dried, finished, and packaged.

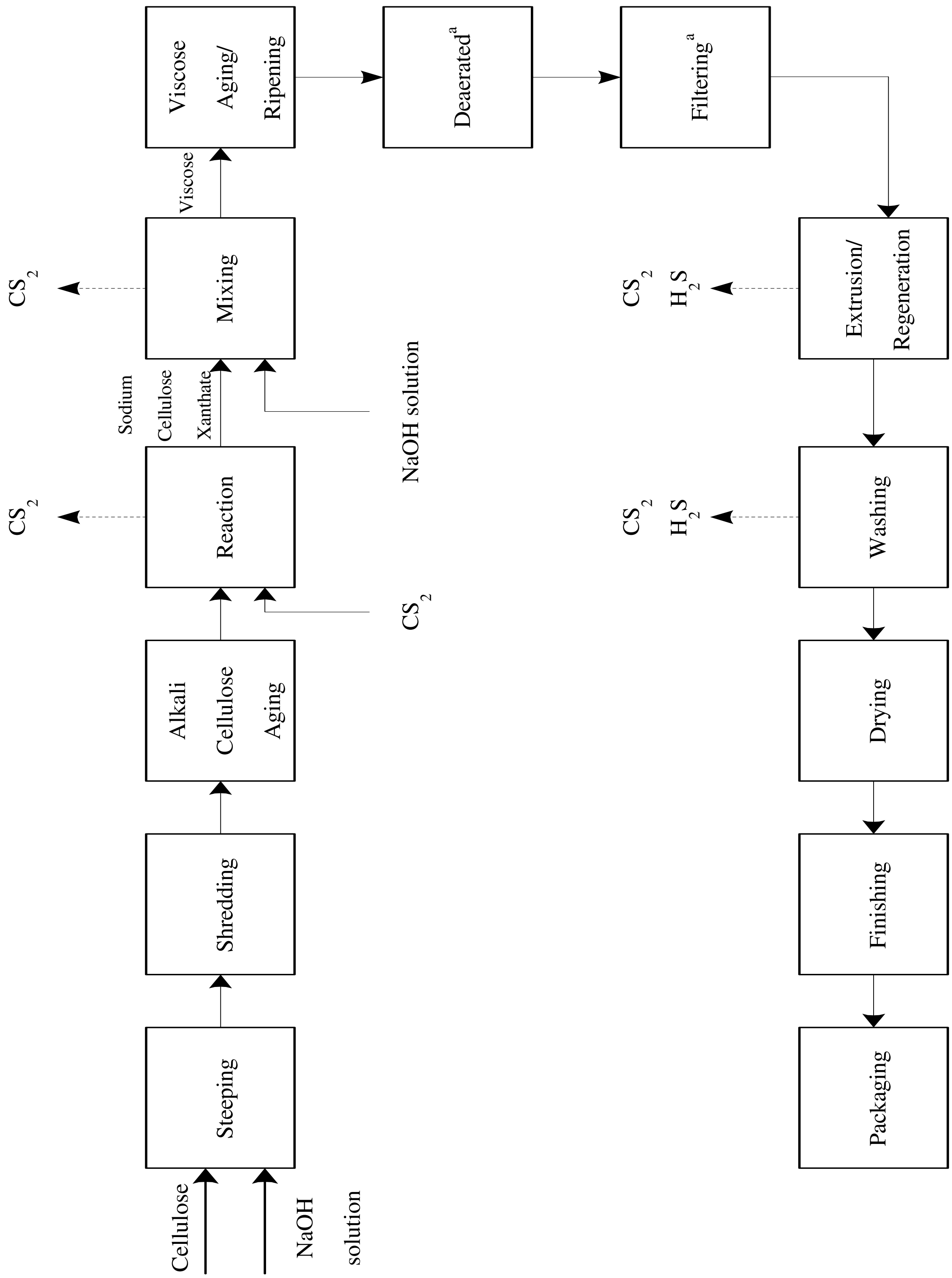

Figure 2-1. Generic Process Diagram for the Viscose Category

[a] Sponge manufacturers do not include the deaeration and filtering steps.

Pollutants can be emitted into the atmosphere from several sources during viscose processing. The primary HAP emitted from the manufacturing process is CS_2. CS_2 is emitted from the reactors and can be emitted from the slurry tanks used to generate viscose solution. Both CS_2 and H_2S are emitted from the regeneration baths and the wash steps.

2.1.2 Cellulose Ether Category Production Process

All cellulose ether processes include the following steps:

- production of alkali cellulose from cellulose and NaOH,
- reaction of the alkali cellulose with chemical compound(s) to produce a cellulose ether product,
- washing and purification of the cellulose ether product, and
- drying of the cellulose ether product. Cellulose ether products may also be ground to uniform size and coated or blended.

Figure 2-2 displays a simplified flow diagram of the processes used to produce cellulose ethers.

Following the production of alkali cellulose, the raw materials used in the cellulose ether process vary according to the particular ether being produced. To produce MC, CMC, HEC, and HPC, alkali cellulose is reacted with methyl chloride, chloroacetic acid, ethylene oxide, and propylene oxide, respectively. HPMC is produced by reacting alkali cellulose with both methyl chloride and propylene oxide. All of these raw materials (methyl chloride, chloroacetic acid, ethylene oxide, and propylene oxide) added to the alkali cellulose to form the various ether products are considered HAPs.

As shown in Figure 2-2, pollutants can be emitted at various points in the manufacturing process. The primary HAP(s) emitted from the manufacturing of cellulose ethers depends on the type of ether product being produced, as mentioned above.

2.1.3 Costs of Production

The input costs into the production of miscellaneous cellulose products are reported as confidential business information (CBI).

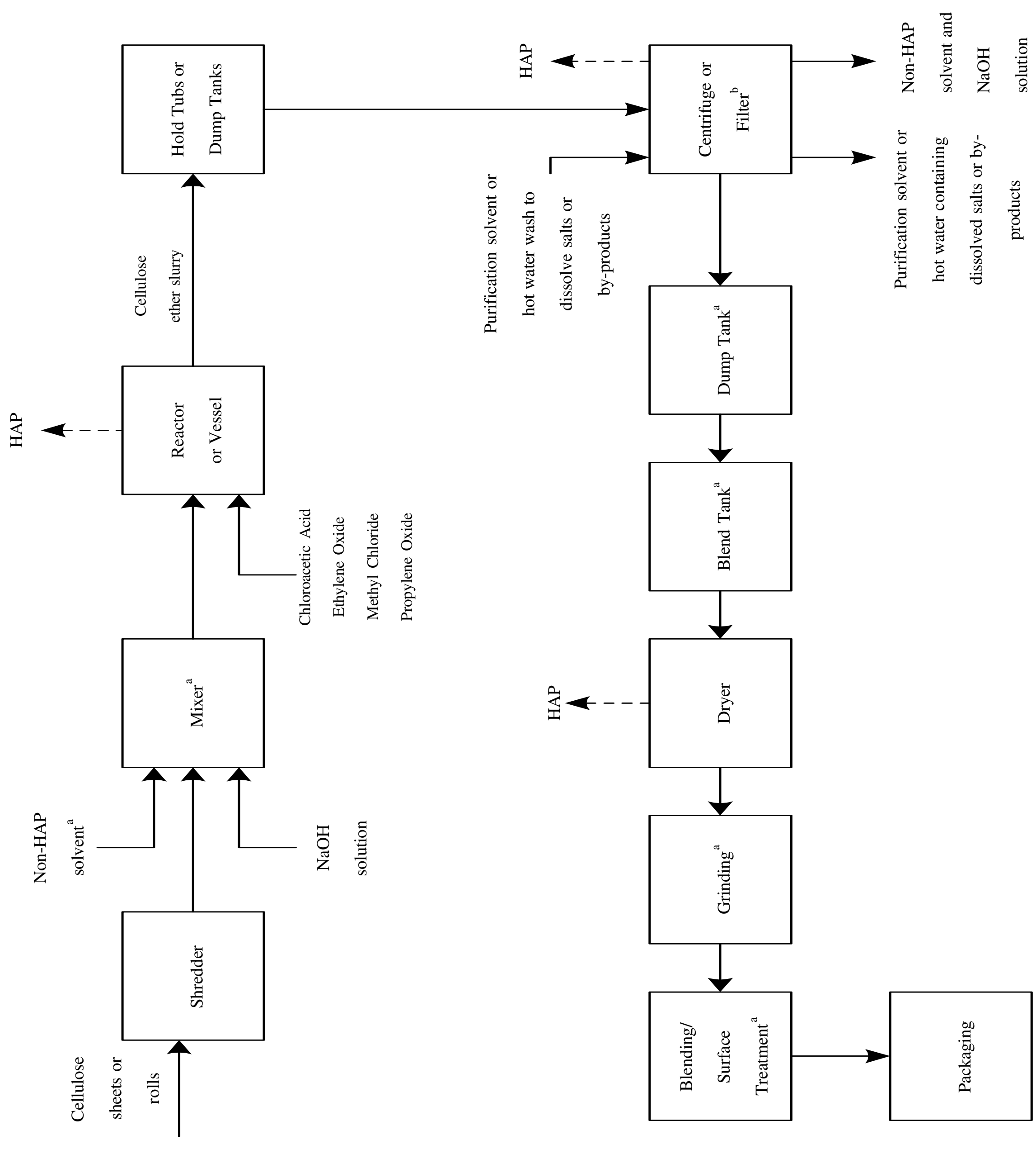

Figure 2-2. Cellulose Ether Manufacturing Process

[a] Not all cellulose ether processes use this material or equipment.

[b] Some cellulose ether processes have multiple centrifuge/filter and wash steps; the solvent is reused and flows countercurrent to the cellulose ether product.

2.2 The Demand Side

In this section, we describe the deman

d side of the market, including product characteristics, the uses of the final products, the consumers of these products, and the substitution possibilities available.

2.2.1 Characteristics of Miscellaneous Cellulose Products

Cellulose products have many advantageous physical attributes that led to their introduction into various markets. Some of the useful characteristics of cellulosics include a unique combination of toughness and transparency at relatively low cost, an almost unlimited color range, good grease resistance, little effect on mechanical properties due to moisture, and suitability of some grades for use with food products. One of the chief disadvantages is that using a natural polymer base causes greater variation in properties than a truly synthetic polymer ("Cellulose," 2000). Since the introduction of these cellulose products, advances in plastics technology have allowed products made from synthetic polymers to enter many of the markets in which the products comprising the miscellaneous cellulose category compete.

2.2.2 Consumption and Uses of Miscellaneous Cellulose Products

The main uses of these products vary depending on which of the outputs is being considered. In general, the miscellaneous cellulose products under consideration are intermediate goods serving as inputs into other production processes.

Cellulose food casings are purchased primarily by meat packers as an input in the production of processed meat products and are used to encase hot dogs, sausages, deli meats, and whole hams. The casing may either be left on the final product or removed following production.

Rayon can be purchased as a continuous filament yarn or as cut (staple) fiber. Rayon is used as an input in the production of a variety of products, but rayon is typically used as an input for two main categories of products: textiles and nonwoven materials. The buyers of textile fibers produce yarn from the fiber, often as a blend with other fiber materials, and weave the yarns into fabrics used to produce apparel and upholstery, among other things. Nonwoven fibers are used by a variety of producers to make wipes, computer diskette liners, and feminine hygiene products.

Cellophane normally serves as an intermediate good as well and is purchased primarily for packaging items such as food and confectionary products (especially candy, cheese, and baked goods) and batteries; it is also used in adhesive tape.

Cellulosic sponges are the one category under consideration here that is not typically an input into the production of another good, although manufacturers of sponges may sell their output to other firms in large blocks and these firms may then cut, package, and sell the sponges. The main use for these sponges is cleaning various surfaces, and they can be purchased by households or businesses for this purpose.

Cellulose ethers are used as an input into a variety of goods. They are chiefly used as thickeners, viscosifiers, and binders and are used in producing paints, personal care products, inks, pharmaceuticals, and industrial coatings.

2.2.3 Substitution Possibilities in Consumption

The markets in which the miscellaneous cellulose outputs compete generally consist of the cellulose product in addition to several viable alternatives. With advances in the production of plastics, plastic alternatives to cellulose products have become increasingly competitive over time. In many cases, the manufacturers of miscellaneous cellulose goods in the United States have seen their market shares shrinking recently under pressure from substitute products and foreign producers of cellulose goods.

In the food casing market, the major alternatives to cellulose are collagen and plastic. Another category in the industry, known as fibrous, actually contains regenerated cellulose and is considered under cellulose casings. Natural (intestine) casings are also used by some producers, especially in making sausage. Buyers of casings make their choice as to which type of casing will be purchased based on the type of meat product being produced, desired shelf life, whether edible casing is desired, smoke permeability, and appearance.

Many fibers, such as cotton, wool, and polyester, among others, can be used in textiles instead of rayon. The textile mills choose which fibers to use for a particular application based on characteristics like comfort, warmth, ease of washing and drying, and resistance to unwanted creasing and wrinkling. As textile production has moved outside of the United States, sales of rayon fibers for use in textiles have declined rapidly. Sales of rayon fibers for use in nonwoven applications have shown much more strength in recent years than sales of textile fibers (Acordis, 1998).

There are very strong substitutes for cellophane as well. Cellophane has been facing increasing competition in recent years from plastics such as polypropylene and polyethylene. Cellophane twist wrap (used for wrapping single-piece candy) fell from a position of about 85 percent of the U.S. market in 1992 to 35 percent by early 1997 (Duschene, 1997). According to *Plastics World* (1995), polypropylene “has all but replaced cellophane in many packaging applications, such as for snack food and tobacco....”

Cellulosic sponges seems to be the category where there is the least competition from alternative products, because natural sponges are far more expensive and have a relatively small market share. Several retailers were contacted and these retailers sold cellulose sponges exclusively. However, there are still substitute products for cleaning such as paper towels and dishtowels.

The cellulose ethers are used in many different end uses and have numerous possible substitutes, depending on the particular application for which they are being used. Ethers generally compete with each other and with water-soluble polymers, both synthetic polymers (polyvinyl alcohol, polyurethane associative thickeners, polyacrylates), and natural polymers(xanthan, carageenan, locust bean gum). The specific product used depends on the tradeoff between performance and price and availability (Chemical Economics Handbook, 1998).

2.3 Industry Organization

This section discusses the products and producers that constitute the market. The affected facilities and parent companies are identified, and their sales and employment distribution are summarized.

2.3.1 Market Structure

Market structure is of interest because it determines the behavior of producers and consumers in the industry. If an industry is perfectly competitive, then individual producers are not able to influence the price of the output they sell or the inputs they purchase. This condition is most likely to hold if the industry has a large number of firms, the products sold and the inputs purchased are homogeneous, and entry and exit of firms are unrestricted. Entry and exit of firms are unrestricted for most industries except, for example, in cases where government regulates who is able to produce, where one firm holds a patent on a product, where one firm owns the entire stock of a critical input, or where a single firm is able to supply the entire market.

Very few U.S. facilities are involved in manufacturing each of the cellulose products under examination, implying imperfectly competitive markets. However, there is vigorous competition from foreign sources in this industry. In addition, there are many viable substitutes for these products. Therefore, despite the small number of domestic producers, the miscellaneous cellulose manufacturing facilities are likely to behave fairly competitively.

2.3.2 Manufacturing Plants

Based on facility responses to the Section 114 letters, the Agency identified 17 plants in the United States currently manufacturing miscellaneous cellulose products. These facilities are identified in Table 2-1. Figure 2-3 shows the geographic distribution of U.S. miscellaneous cellulose manufacturing plants by final product. As shown, many of these plants are concentrated in the north-central region of the United States. Since only 14 of the 17 facilities are major sources subject to the maximum achievable control technology (MACT) standard, subsequent discussion focuses on this subset of the miscellaneous cellulose manufacturing facilities affected by the proposed regulation.

Table 2-1. Miscellaneous Cellulose Manufacturing Facilities

Facility	Facility Location	Major Product(s)
Devro-Teepak, Inc.	Danville, IL	Cellulose food casings
Viskase Corp.	Loudon, TN	Cellulose food casings
Viskase Corp.	Osceola, AR	Cellulose food casings
Acordis Cellulosic Fibers, Inc.	Axis, AL	Rayon
Lenzing Fibers Corp.	Lowland, TN	Rayon
UCB Films, Inc.	Tecumseh, KS	Cellophane
Nylonge Corp.	Elyria, OH	Cellulosic sponges
Spontex, Inc.	Columbia, TN	Cellulosic sponges
3M Corp.	Prairie du Chien, WI	Cellulosic sponges
3M Corp.	Tonawanda, NY	Cellulosic sponges
Dow Chemical Co.	Midland, MI	Cellulose ethers (MC, HPMC)
Dow Chemical Co.	Plaquemine, LA	Cellulose ethers (MC)
Hercules Inc., Aqualon Co.	Hopewell, VA	Cellulose ethers (CMC, HEC, HPC)
Hercules Inc., Aqualon Co.[a]	Parlin, NJ	Cellulose ethers (HEC)
MAK Chemical Corp.[a]	Muncie, IN	Cellulose ethers (crude CMC)
Penn Carbose, Inc.[a]	Somerset, PA	Cellulose ethers (crude CMC)
Union Carbide Corp.	Institute, WV	Cellulose ethers (HEC)

[a] Hercules-Parlin, MAK, and Penn Carbose are area sources not subject to the MACT standard.

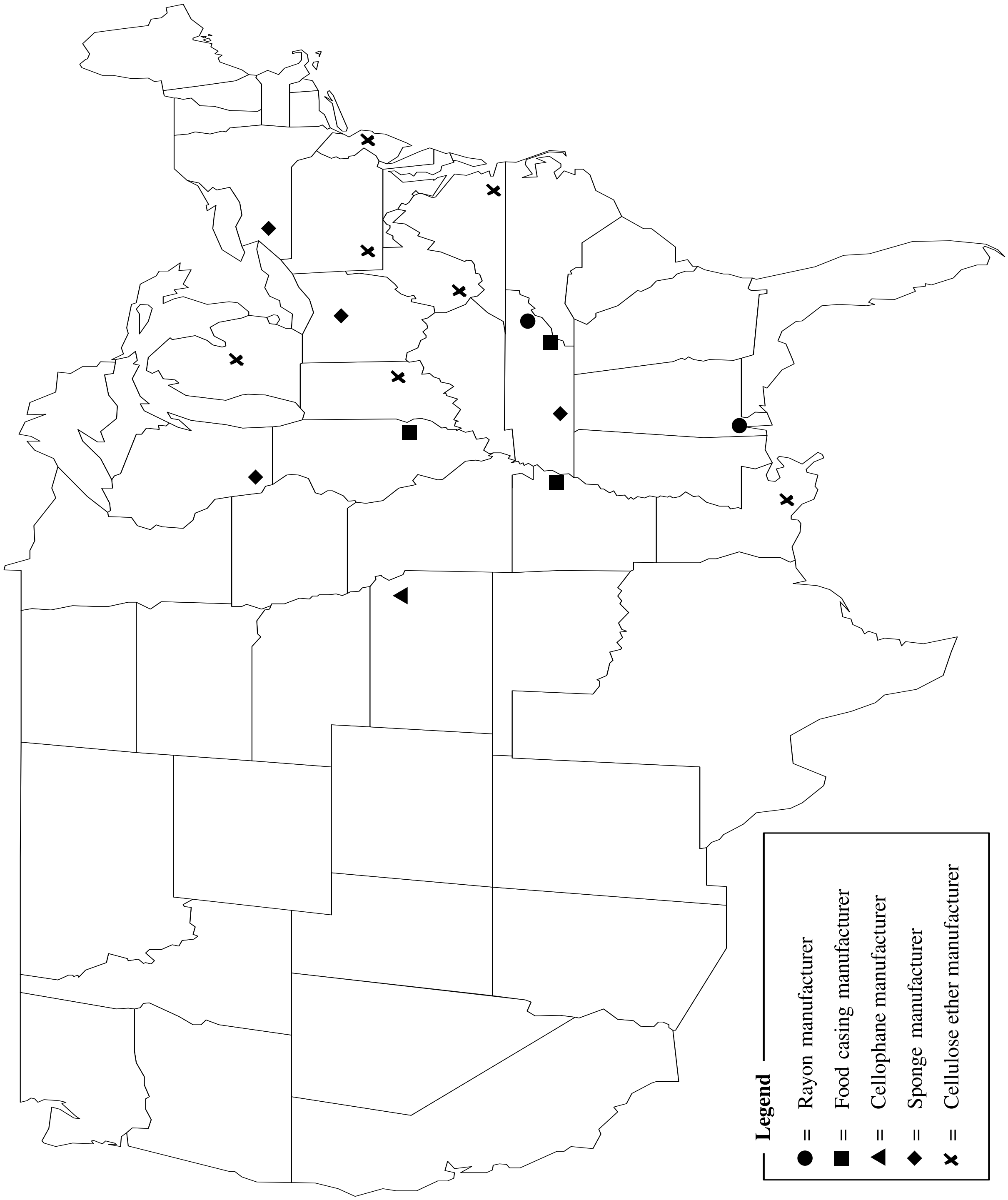

Figure 2-3. Geographic Distribution of Miscellaneous Cellulose Manufacturing Plants in the United States

Facility-level sales and employment data are available for 11 of the 14 affected facilities, as reported in Table 2-2. The Spontex facility has the lowest employment and sales, while Dow Chemical in Plaquemine, LA, has the highest. For the facilities with available data, using the midpoint of the reported ranges gives an average employment of 510 employees and an average of $103 million in sales. For facilities that reported this data as CBI, the more accurate CBI data will be used for our economic analysis. We will provide data by final product as CBI.

2.3.3 Companies

Table 2-2. Facility Employment and Sales, 1998

Company	Facility Location	Employment Range	Sales ($ millions)
Food Casings			
Devro-Teepak, Inc.	*Danville, IL*	*501-750*	*NA*
Viskase Corp.	*Loudon, TN*	*230*	*50-100*
Viskase Corp.	*Osceola, AR*	*170*	*20-50*
Rayon			
Acordis Cellulosic Fibers Inc.	*Axis, AL*	*425*	*NA*
Lenzing Fibers Corp.	*Lowland, TN*	*400*	*100-500*
Cellophane			
UCB Films, Inc.	Tecumseh, KS	100-249	20-50
Sponges			
Nylonge Corp.	Elyria, OH	100-249	10-20
Spontex, Inc.	*Columbia, TN*	*140*	*NA*
3M Corp.	Prairie du Chien, WI	500-999	100-500
3M Corp.	Tonawanda, NY	250-499	20-50
Ethers			
Dow Chemical Co.	*Midland, MI*	*60*	*NA*
Dow Chemical Co.	*Plaquemine, LA*	*50*	*NA*
Hercules Inc., Aqualon Co.	Hopewell, VA	395	NA
Union Carbide Corp.	Institute, WV	134	20-50

Note: Italicized rows indicate companies for which we have CBI data.

Sources: InfoUSA Inc. 1999. American Business Disc. Omaha, NE.
Section 114 requests and plant trip reports.

Companies that are directly affected by the regulation include entities that own miscellaneous cellulose manufacturing plants. As shown in Figure 2-4, the chain of ownership may be as simple as one plant owned by one company or as complex as multiple plants owned by subsidiary companies. Based on survey and publicly available source data, the Agency identified 11 ultimate parent companies that own and operate the 14 directly affected facilities. For the economic analysis, EPA obtained sales and employment data from one of the following secondary data sources:

- Hoover's Company Profiles (Hoover's, 2000)
- Business and Company ProFile (Information Access Corporation, 2000)
- *Ward's Business Directory* (Gale Research, 1998)
- Wrights Research Service (Winthrop Corporation, 2000)

Data are available for all 11 companies and are included in Table 2-3.

2.3.3.1 Employment and Sales Distribution

Company size is likely to be a factor in the distribution of the regulatory action's financial impacts. The parent companies affected by this regulation are relatively large in general. The 11 firms owning the 14 affected manufacturing facilities range in size from 200 to 73,600 employees, with all but one firm having over 3,000 employees. Over half of the companies have more than 10,000 employees. Table 2-3 shows the size distribution of potentially affected firms by total company employment. Company sales ranged from $15 million to $28 billion in 1998 for the potentially affected firms. Seven of the 11 companies had sales over $1 billion.

2.3.3.2 Identifying Small Businesses

The Regulatory Flexibility Act (RFA) of 1980 as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996 requires that the Agency give special consideration to small entities affected by federal regulation. Companies operating miscellaneous cellulose manufacturing plants can be grouped into small and large categories using Small Business Administration (SBA) general size standard definitions. The SBA defines a small business in terms of the sales or employment of the owning entity, and these thresholds vary by industry classification (SIC code) of the affected company. For this analysis the Agency identified three primary SIC codes with small business definition ranges

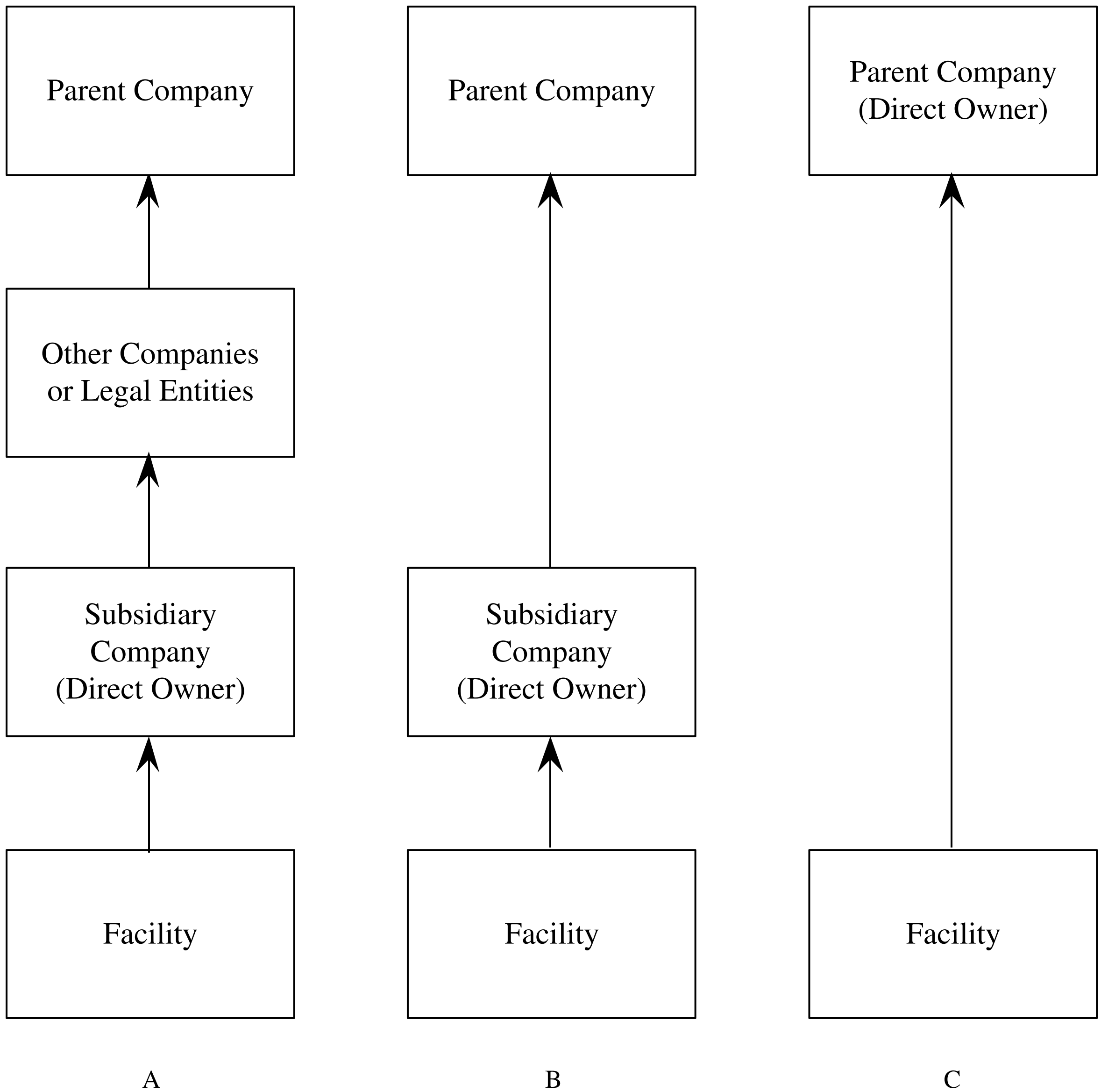

Figure 2-4. Chain of Ownership

as follows:

- 2823 and 2869—1,000 or fewer employees
- 3089—500 or fewer employees

Table 2-3. Affected Parent Companies

Company	Sales ($ millions)	Employment	Small Business
3M	15,659	73,564	no
Acordis	2,285	18,300	no
Devro-Teepak	438	3,687	no
Dow Chemical	18,929	39,000	no
Hercules	2,145	12,357	no
Lenzing AG	751	4,723	no
Nylonge	15	200	yes
Total Fina S.A.	28,418	57,126	no
UCB Films	1,597	8,726	no
Union Carbide	5,870	11,627	no
Viskase	409	3,050	no

Sources: Hoover's Incorporated. 2000. Hoover's Company Profiles. Austin, TX: Hoover's Incorporated. <http://www.hoovers.com/>.
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Based on the reported company employment and SIC size standard, one company can be classified as small, or 9.1 percent of the total (see Figure 2-5).

2.3.3.3 Issue of Vertical and Horizontal Integration

Vertical integration is a potentially important dimension in analyzing firm-level impacts because the regulation could affect a vertically integrated firm on more than one level. The regulation may affect companies for whom cellulose manufacturing is only one of several processes in which the firm is involved. For example, a company may produce cellulose products as part of a vertical operation that manufactures and assembles the final

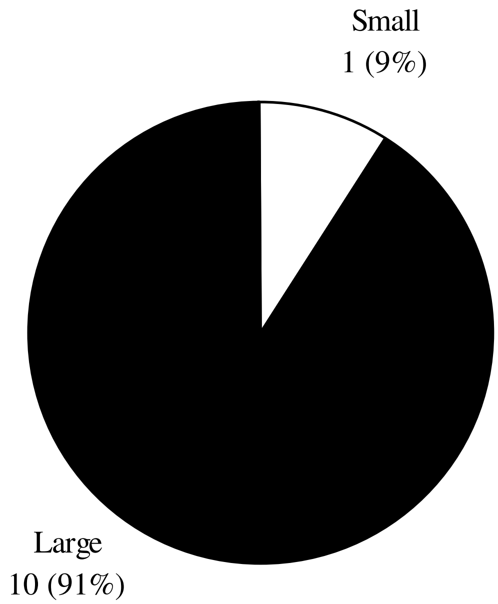

Figure 2-5. Distribution of Miscellaneous Cellulose Companies by Size

commodity. Increased production costs of cellulose manufacturing will affect the cost of the final products that use these as intermediate inputs.

Horizontal integration is also an important dimension in firm-level impact analysis because diversified firms may own facilities in unaffected industries. This may give them resources to spend on complying with this regulation—if they so choose. Several of the larger firms are involved in several different industries other than cellulose manufacturing. For example, Total Fina S.A.'s other operations include petroleum, natural gas, and tires while 3M provides pharmaceutical, automotive, and dental products (Hoover's, 1999; Information Access Corporation, 2000).

2.3.3.4 Trends

Recently, some of the industries potentially affected by this regulation have experienced consolidation and plant closings. According to UCB Films, Inc.'s site visit report, the cellophane manufacturing industry has been declining since the 1950s. At one time, there were 10 to 12 cellophane plants operating in the U.S. By the mid-1990s, only Flexel, Inc. still produced cellophane in the U.S. Flexel, Inc. filed for bankruptcy in 1997 and sold one of its two U.S. facilities to Belgium's UCB Films, Inc. (*Chemical Market Reporter*, 1997). They have stopped producing cellophane at the other plant, leaving UCB as the only Western cellophane producer remaining. The domestic market for rayon has also been in decline as textile production moves out of the United States. Only two rayon manufacturers are left in the United States, and they are currently involved in joint venture discussions (Westervelt, 1999).

2.4 Market Data [WILL BE INCLUDED AS A CBI SECTION]

2.4.1 Market Quantities

This section includes data on production, exports, imports, and apparent consumption of cellulose food casings, rayon, cellophane, cellulose sponges, and cellulose ethers, but it is provided as a CBI section.

2.4.2 Market Prices

Historical price data are presented as CBI.

2.4.3 Future Projections

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