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Economic Impact Analysis of the Hazardous Organic NESHAP

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This report contains portions of the economic impact analysis report that are related to the industry profile.

CHAPTER 4
CHEMICAL INDUSTRY PROFILE

4.1 INTRODUCTION

Organic chemicals are substances that contain the elements carbon and hydrogen. Basic organic compounds (hereafter basic organics), which are obtained almost exclusively from crude oil, natural gas, and coal, serve as the building blocks for the production of all synthetic organic chemicals. Basic organics include aliphatics; aromatics; methyl alcohol (methanol); and tars, tar crudes, and pitches -- which are derived mainly from coal. The most important aliphatics are ethylene, propylene, and 1,3-butadiene. In the U.S., natural gas is the primary feedstock for aliphatics. Basic aromatics consist of benzene, toluene, and the xylenes. They are derived primarily from petroleum. Downstream from basic chemicals are their derivatives: chemical intermediates and solvents, and end-product (finished) chemicals. End-product chemicals include functional chemical products that are either fabricated by other industries into a variety of industrial and consumer goods or are used directly by the final consumer. End-product chemicals also include additives, which can be either single-purpose, used by a specific end-use industry; or multi-purpose, performing a particular function for a variety of end-use industries. The distinctions among different classifications of organic chemicals are often blurred. For example, some basic organics and intermediates are also sold as end-product chemicals.

The U.S. International Trade Commission, which compiles data on synthetic organic chemicals, defines synthetic organic chemicals to include intermediate and end-product organic chemicals, because they are formed by chemical reactions in man-made plants.[1] Basic organics, which are of natural origin, are considered raw materials and are excluded from the definition. For purposes of this report, however, the "synthetic organic chemicals industry" will be taken to include all organic chemicals, including basic organics. This recognizes the interdependence of basic organics and their derivatives, and the fact that basic organics are sometimes sold as end products. This is also consistent with definitions in previous studies for EPA.

In this report, the U.S. synthetic organic chemicals industry is profiled. The purpose of the profile is to identify factors and trends likely to influence the nature and magnitude of the economic impacts of the Hazardous Organics NESHAP (HON), which will involve the regulation of some 450 synthetic organic chemicals. Because of the large number and diversity of chemicals that will be regulated under HON, the scope of the present profile is broad. Recent trends in the synthetic organic chemicals industry are highlighted and the general outlook for the industry is discussed. Topics covered include the structure of the industry, market characteristics, production trends, capacity utilization, demand, end uses, foreign trade, pricing, profitability, and capital structure. In some cases, where specific information for the synthetic organic chemicals industry was not available, the U.S. chemical industry as a whole is addressed. In the last section of this report, synopses of selected important basic organic chemicals and categories of synthetic organic chemicals are presented. The synopses supplement the general profile of the synthetic organic chemicals industry by offering more detailed information for the categories covered.

4.2 INDUSTRY STRUCTURE AND MARKET CHARACTERISTICS

Perhaps the most distinguishing characteristic of the synthetic organic chemicals industry is its diversity. The industry produces more than 7,000 chemicals for such diverse applications as automotive products, packaging, consumer products, housing and construction, pharmaceuticals, and agriculture.[2] Table 4-1 lists the top 29 organic chemicals in the U.S. by 1989 production. The table also highlights production trends in these chemicals since 1979. The fastest-growing chemicals have been vinyl chloride, propylene, caprolactam, and terephthalic acid. Since 1979, output has declined for methanol, acetone, cyclohexane, and isopropyl alcohol.

The synthetic organic chemicals industry is also defined by its complexity. For example, many synthetic organic chemicals are produced as coproducts of other chemicals. Also, many synthetic organic chemicals can be produced by more than one process. This leads to the possibility of process substitution depending on price conditions. Two-thirds of current U.S. petrochemical capacity, for example, has some capability to switch back and forth between heavy liquids (e.g., petroleum) - based feedstocks and natural gas liquids-based feedstocks.[3] As a result of the interdependence of many synthetic organic chemicals -- through either coproduct relationships or vertical production links -- many producers of synthetic organic chemicals are horizontally and/or vertically integrated.

In all, there are about 1,500 firms in the U.S. that produce chemicals and allied products.[4] The top 25 producers are listed in Table 4-2. The ranking is by total chemical sales, including chemicals

TABLE 4-1

THE TOP 29 ORGANIC CHEMICALS IN THE U.S. BY 1989 PRODUCTION

	Production (billions of kgs.)			Percent Change	
	1989	1984	1979	1984-1989	1979-1989
Ethylene	15.85	14.23	13.56	11.4%	16.9%
Propylene	9.18	7.06	6.44	30.0%	42.5%
Urea	7.02	N.A.	N.A.	N.A.	N.A.
Ethylene Dichloride	6.21	4.86	5.35	27.7%	16.0%
Benzene	5.29	N.A.	N.A.	N.A.	N.A.
Vinyl Chloride	4.36	2.76	2.90	58.2%	50.5%
Ethylbenzene	4.18	3.43	3.83	22.0%	9.1%
Terephthalic Acid	3.77	2.68	2.79	40.6%	34.9%
Styrene	3.69	3.50	3.39	5.4%	8.7%
Methanol	3.24	3.71	3.34	-12.8%	-3.1%
Formaldehyde	2.89	2.64	2.71	9.5%	6.7%
Toluene	2.65	N.A.	N.A.	N.A.	N.A.
Xylene	2.63	N.A.	N.A.	N.A.	N.A.
Ethylene Glycol	2.49	2.19	2.15	14.1%	16.3%
p-Xylene	2.49	1.93	2.11	28.9%	18.1%
Ethylene Oxide	2.41	2.59	2.57	-6.7%	-6.2%
Methyl Tert-Butyl Ether	2.26	N.A.	N.A.	N.A.	N.A.
Cumene	2.05	1.70	1.77	20.8%	15.9%
Phenol	1.76	1.31	1.35	34.6%	30.5%
Acetic Acid	1.74	1.19	1.48	46.2%	17.1%
Propylene Oxide	1.45	N.A.	N.A.	N.A.	N.A.
1,3-Butadiene	1.40	1.11	1.62	26.1%	-13.7%
Acrylonitrile	1.19	1.01	0.92	18.0%	29.7%
Acetone	1.13	0.84	1.20	34.4%	-5.7%
Vinyl Acetate	1.12	0.92	0.90	22.3%	24.7%
Cyclohexane	1.08	0.90	1.10	20.1%	-1.6%
Adipic Acid	0.74	N.A.	N.A.	N.A.	N.A.
Isopropyl Alcohol	0.65	0.63	0.86	2.9%	-24.7%
Caprolactam	0.59	0.47	0.43	27.2%	37.9%
Total	95.54	N.A.	N.A.	3.6%	1.4%

N.A. - Not available.

Sources: <u>Chemical & Engineering News</u>, April 9, 1990, p. 12; and June 18, 1990, p. 39.

TABLE 4-2

THE TOP 25 CHEMICAL PRODUCERS IN THE U.S., 1989

Company	Chemical Sales, 1989 ($ million)	Chemical Sales as a Percent of Total Sales
Du Pont	15,249	42.9%
Dow Chemical	14,179	80.6%
Exxon	10,559	11.1%
Union Carbide	7,962	91.1%
Monsanto	5,782	66.6%
Hoechst Celanese	5,658	94.0%
Occidental Petroleum	5,203	25.9%
General Electric	4,929	9.0%
BASF	4,461	82.3%
Amoco	4,274	17.8%
Mobil	4,039	7.3%
Shell Oil	3,833	16.2%
Eastman Kodak	3,522	19.1%
Chevron	3,328	10.4%
W.R. Grace	3,256	53.2%
Allied-Signal	2,993	25.1%
Arco Chemical	2,663	100.0%
Rohm & Haas	2,661	100.0%
Air Products	2,481	93.9%
Phillips Petroleum	2,449	19.8%
Bayer USA	2,300	42.4%
American Cyanamid	2,241	46.4%
Ashland Oil	2,230	26.3%
Quantum Chemical	2,015	75.4%
B.F. Goodrich	1,977	81.7%
Total	120,244	

Source: Chemical & Engineering News, June 18, 1990, p. 46.

that are not organic. The right-hand column indicates the degree of specialization in chemicals. This ranges from 100 percent for Arco Chemical and Rohm & Haas to less than 10 percent for Mobil and General Electric. The wide range reflects the differing degrees of diversification by chemical companies, as well as the differing degrees of forward vertical integration by oil companies. Of the top 25 companies, nine are oil companies or subsidiaries of oil companies.

The U.S. chemical industry underwent a massive restructuring in the late 1990s, beginning in 1985. This took the form of acquisitions, spin-offs, plant closings, and early retirement and layoff programs. Many of the acquisitions were highly leveraged and financed by junk bonds. Future takeover activity could be limited due to the demise of the junk bond market.[5]

The leading state for the manufacture of synthetic organic chemicals is Texas. Louisiana, another Gulf Coast state, is also a significant producer of synthetic organic chemicals. In SIC 2869 -- Industrial Organic Chemicals, N.E.C. -- which accounts for the biggest share of employment in the synthetic organic chemicals industry, Texas and Louisiana had the most employment in 1987.[6] Total employment in SIC 2869 in 1987 was 100,300, with Texas contributing 26,200 (26.1%) and Louisiana contributing 9,900 (9.9%). Other than the Gulf Coast states, synthetic organic chemicals are primarily manufactured in industry-intensive states such as New Jersey, Ohio, Illinois, and California. An exception is the man-made fibers industry, which is centered in the southern textile states.

Plant capacities in the manufacture of synthetic organic chemicals vary widely, from under 500 kilograms per year to over 2,000 million kilograms.[7] Plants producing basic and intermediate chemicals tend to have larger capacities than plants producing end-product chemicals. This is because basic and intermediate chemicals are generally produced in larger volumes than end-product chemicals.

Despite layoffs and restructurings, employment in the chemical industry managed to grow in the late 1980s. After declining from 1,044,000 in 1985 to 1,022,000 in 1986, employment in the Department of Labor's definition of the "chemicals and allied products" industry increased continuously up to 1989.[8] Employment reached 1,093,000 in 1989, the highest level for the industry since the record-high of 1,109,000 in 1981. The 1989 amount represented 5.6 percent of total employment in the manufacturing sector (19.6 million). Average hourly earnings in the chemicals and allied products industry in 1989 were $13.06, as against $10.47 for all manufacturing.[9]

Tables 4-3 through 4-5 present selected Census data for eight four-digit SIC categories that can be considered to comprise the synthetic organic chemicals industry. Table 4-4 gives an indication of the incidence of small facilities in the industry. In every category but SIC 2824, establishments with fewer than 20 employees account for one-third or more of all establishments. The highest incidence is in SIC 2833, in which 62.7 percent of all establishments have fewer than 20 employees. SIC 2824 has the highest incidence of establishments with over 100 or more employees, at 72.2 percent. Table 4-5 shows the distribution of value of shipments by establishment size. Because they are, by definition, small, establishments with fewer than 20 employees account in all cases for a lower share of the total value of shipments than of the total number of establishments. In every category other than SIC 2891, establishments with 100 or more employees contribute more than 50 percent of total value of shipments, ranging up to 99.1 percent for SIC 2824. The highest contribution to total value of shipments by establishments with fewer than 20 employees is 15.3 percent in SIC 2891.

4.3 PRODUCTION, SHIPMENTS, AND CAPACITY UTILIZATION

In Table 4-6, 1987 and 1988 production and sales data compiled by the U.S. International Trade Commission for synthetic organic chemicals and their raw materials (basic organics) are displayed. Data are presented for 13 major categories of synthetic organic chemicals -- based principally on end use -- and two categories of basic organics. Total production of organic chemicals in 1988 amounted to 175,839 million kilograms. However, the ITC data necessarily reflect duplication because production and sales of some chemicals are measured at more than one stage of the manufacturing process. For example, intermediates will be double-counted if production and sales of the finished chemicals in which they are consumed are also reported. Nevertheless, the table gives a good indication of the comparative sizes of the various different major categories of synthetic organic chemicals. In each category, the quantity sold is less than the quantity produced because a portion of output is consumed captively. This is particularly the case in categories --such as "primary products from petroleum and natural gas" and "cyclic intermediates" -- where the products are generally intended for further processing downstream. Due to some definitional changes, the 1987 and 1988 data are not strictly comparable.

TABLE 4-3

SELECTED 1982 AND 1987 CENSUS DATA FOR THE SYNTHETIC ORGANIC CHEMICALS INDUSTRY

SIC Code	Industry	Number of Establishments (10^3)		Employment (10^3)		Value of Shipments ($ million)		Capital Expenditures ($ million)	
		1982	1987	1982	1987	1982	1987	1982	1987
2821	Plastics Materials, Synthetic Resins, and Nonvulcanizable Rubber	440	480	54.7	56.3	15,769.2	26,245.5	898.8	1,247.2
2822	Synthetic Rubber	78	68	11.9	10.4	3,156.4	3,283.0	246.4	170.5
2824	Manmade Organic Fibers, Except Cellulosic	70	72	60.2	45.7	8,262.7	10,111.6	442.9	460.0
2833	Medicinal Chemicals and Botanical Products	228	225	17.8	11.6	3,397.9	3,350.2	283.6	114.5
2843	Surface Active Agents, Finishing Agents, Sulfonated Oils, and Assistants	210	217	8.5	9.1	2,067.2	3,002.2	86.6	103.4
2865	Cyclic Organic Crudes and Intermediates, and Organic Dyes and Pigments[a]	189	186	27.3	22.8	7,138.2	8,859.4	454.7	378.8
2869	Industrial Organic Chemicals, N.E.C.[b]	688	699	111.8	100.3	30,394.4	42,189.1	2,580.5	1,986.9

TABLE 4-3

(Continued)

SIC Code	Industry	Number of Establishments (10³)		Employment (10³)		Value of Shipments ($ million)		Capital Expenditures ($ million)	
		1982	1987	1982	1987	1982	1987	1982	1987
2891	Adhesives and Sealants	684	714	18.2	20.9	2,857.9	4,678.1	70.1	111.7

[a] Redefined in 1987 to include two establishments (aromatics facilities that are not petroleum refineries) previously classified in SIC 2911.

[b] Redefined in 1987 to include 22 establishments (aliphatics facilities that are not petroleum refineries) previously classified in SIC 2911.

Source: U.S. Department of Commerce, Bureau of the Census, 1987 Census of Manufactures.

TABLE 4-4

DISTRIBUTION BY EMPLOYMENT OF ESTABLISHMENTS IN THE SYNTHETIC ORGANIC CHEMICALS INDUSTRY, 1987 CENSUS

SIC Code	Industry	Total No. of Establishments	Distribution by Employment			Percent of Total Establishments[a]		
			1-19	20-99	100+	1-19	20-99	100+
2821	Plastics Materials, Synthetic Resins, and Nonvulcanizable Rubber	480	160	199	121	33.3%	41.5%	25.2%
2822	Synthetic Rubber	68	37	9	22	54.4%	13.2%	32.4%
2824	Manmade Organic Fibers, Except Cellulosic	72	9	11	52	12.5%	15.3%	72.2%
2833	Medicinal Chemicals and Botanical Products	225	141	62	22	62.7%	27.6%	9.8%
2843	Surface Active Agents, Finishing Agents, Sulfonated Oils, and Assistants	217	118	75	24	54.4%	34.6%	11.1%
2865	Cyclic Organic Crudes and Intermediates, and Organic Dyes and Pigments	186	65	57	64	34.9%	30.6%	34.4%
2869	Industrial Organic Chemicals, N.E.C.	699	268	236	195	38.3%	33.8%	27.9%
2891	Adhesives and Sealants	714	440	227	47	61.6%	31.8%	6.6%

[a] Rows may not sum to 100% due to rounding.

Source: U.S. Department of Commerce, Bureau of the Census, <u>1987 Census of Manufactures</u>.

TABLE 4-5

DISTRIBUTION BY EMPLOYMENT PER ESTABLISHMENT OF THE VALUE OF SHIPMENTS IN THE SYNTHETIC ORGANIC CHEMICALS INDUSTRY, 1987 CENSUS

SIC Code	Industry	Total Value of Shipments ($ million)	Distribution by Employment Per Establishment ($ million)			Percent of Total Value of Shipments[a]		
			1-19	20-99	100+	1-19	20-99	100+
2821	Plastics Materials, Synthetic Resins, and Nonvulcanizable Rubber	26,245.5	371.3	4,865.6	21,008.6	1.4%	18.5%	80.0%
2822	Synthetic Rubber	3,283.0	30.7	212.6	3,039.7	0.9%	6.5%	92.6%
2824	Manmade Organic Fibers, Except Cellulosic	10,111.6	10.1	80.9	10,020.6	0.1%	0.8%	99.1%
2833	Medicinal Chemicals and Botanical Products	3,350.2	228.9	405.9	2,715.4	6.8%	12.1%	81.1%
2843	Surface Active Agents, Finishing Agents, Sulfonated Oils, and Assistants	3,002.2	223.8	1,125.9	1,652.5	7.5%	37.5%	55.0%
2865	Cyclic Organic Crudes and Intermediates, and Organic Dyes and Pigments	8,859.4	384.9	1,268.4	7,206.1	4.3%	14.3%	81.3%
2869	Industrial Organic Chemicals, N.E.C.	42,189.1	1,065.9	3,706.2	37,417.0	2.5%	8.8%	88.7%

TABLE 4-5

(Continued)

SIC Code	Industry	Total Value of Shipments ($ million)	Distribution by Employment Per Establishment ($ million)			Percent of Total Value of Shipments[a]		
			1-19	20-99	100+	1-19	20-99	100+
2891	Adhesives and Sealants	4,678.1	714.8	2,372.7	1,590.6	15.3%	50.7%	34.0%

[a] Rows may not sum to 100% due to rounding.

Source: U.S. Department of Commerce, Bureau of the Census, 1987 Census of Manufactures.

TABLE 4-6

PRODUCTION AND SALES OF SYNTHETIC ORGANIC CHEMICALS AND THEIR RAW MATERIALS (BASIC ORGANICS) IN THE U.S., 1987 and 1988

	Production (10^6 kilograms)		Sales			
			Quantity[a] (10^6 kilograms)		Value ($ million)	
	1988	1987	1988	1987	1988	1987
Basic Organics						
Tar[b]	894	1,039	N.A.	N.A.	N.A.	N.A.
Primary Products from Petroleum and Natural Gas[c]	51,002	55,846	26,669	27,069	10,517	7,620
Total	51,896	56,885	N.A.	N.A.	N.A.	N.A.
Synthetic Organic Chemicals[d]						
Cyclic Intermediates	26,492	25,037	12,016	10,526	9,369	7,562
Dyes	127	116	114	104	766	677
Organic Pigments	53	43	39	38	595	586
Medicinal Chemicals	117	118	103	76	1,831	1,534
Flavor and Perfume Materials	73	57	43	37	866	726
Plastics and Resin Materials	28,819	26,980	25,056	23,210	33,831	26,066
Rubber-Processing Chemicals	160	173	121	131	424	359
Elastomers	2,226	2,127	1,467	1,410	2,982	2,714
Plasticizers	1,043	906	850	851	1,001	896
Surface-Active Agents	3,318	2,844	1,933	1,779	2,303	1,713
Pesticides and Related Products	528	472	424	413	4,354	4,171
Misc. End-Use Chemicals and Chemical Products[e]	12,940	11,441	10,214	9,530	9,449	7,355
Misc. Cyclic and Acyclic Chemicals[f]	48,046	44,470	19,147	18,288	15,118	12,032
Total[g]	123,943	114,784	71,528	66,393	82,889	66,392
Grand Total	175,839	171,669	N.A.	N.A.	N.A.	N.A.

N.A. - Not available.

[a] Because of captive consumption, the quantity of sales is always less than production. Part of the difference is also attributable to changes in inventory.

[b] Includes coal tar, water-gas tar, oil-gas tar, and their derivatives (crudes and pitches).

TABLE 4-6

(Continued)

[c] Data were not collected for ethane, propane, and butane in 1988. In 1987, production of these three chemicals -- amounting to about 9,072 kilograms -- is included in the reported total of 55,846 kilograms.

[d] Includes intermediates and end-product chemicals.

[e] Mostly urea in compounds and mixtures (40.9 percent of 1988 production) and man-made fibers (23.9 percent).

[f] Predominantly intermediates and solvents. Also includes fluorocarbons (1.3 percent of 1988 production).

[g] Figures may not sum to total due to rounding.

Source: U.S. International Trade Commission, Synthetic Organic Chemicals, September 1989.

As shown in Table 4-7, the Federal Reserve Board (FRB) production index for the entire chemical industry, including allied products -- SIC 28 -- increased by 2.9 percent from 1988 to 1989. This followed higher increases of 5.4 percent in 1988 and 5.7 percent in 1987. Growth in 1990 continues to be slow, as production increased by only 0.2 percent from January to April. Table 4-8 shows that the general industry slowdown has not affected all sectors. While output of synthetic materials decreased by 1.2 percent from 1988 to 1989, output of industrial organic chemicals actually increased by 5.9 percent, surpassing its 1987-1988 increase of 3.1 percent. Table 4-8 also indicates that production in SIC 28 has closely followed total manufacturing output since 1985. However, since 1979, while total manufacturing output has increased by 34.6 percent, output in SIC 28 has increased by only 18.8 percent. This reflects the absence of growth in the chemical industry from 1979 to 1985.

Production of the top 29 organic chemicals listed in Table 4-1 declined 3.3 percent from 1988 to 1989. This followed growth of 7.8 percent from 1987 to 1988. Average growth from 1984 to 1989 was 3.6 percent per year. From 1979 to 1989, average annual growth was only 1.4 percent, however. Among the top 29 organic chemicals, the biggest gains from 1988 to 1989 were registered by acetic acid, + 21.1 percent; phenol, + 9.3 percent; acetone, + 8.4 percent; vinyl chloride, + 6.2 percent; xylene, + 5.8 percent; and ethylene dichloride, + 5.0 percent.[10] The biggest losses were registered by terephthalic acid, -18.8 percent; methyl tert-butyl ether, - 12.4 percent; methanol, - 12.3 percent; ethylene oxide, - 10.6 percent; styrene, - 9.5 percent; toluene, - 8.0 percent; and ethylene, - 6.0 percent.

Table 4-9 summarizes polymers production from 1985 to 1989. Over this period, production of man-made fibers increased by 12.0 percent, synthetic rubber by 25.2 percent, and plastics resins by 22.3 percent. There was an overall decline in production from 1988 to 1989, however, echoing Table 4-8's indication of a drop in the FRB production index for synthetic materials from 1988 to 1989. The decline in plastics production in 1989 partly explains the decline in output in 1989 of the three most important plastics feedstocks: in order, ethylene, benzene, and propylene. In 1989, production of ethylene decreased by 6.0 percent, benzene by 0.5 percent, and propylene by 4.7 percent.[11]

Tables 4-10 and 4-11 show the value of shipments from 1987 to 1989, with a forecast for 1990, for selected SIC groupings that include

TABLE 4-7

PRODUCTION INDEXES[a] FOR SIC 28, "CHEMICALS AND PRODUCTS," 1979-1990 (1987=100)

Year/Month	Index	Percent Change From Prior Year
1990		
April	110.1 (est.)	N/A
March	109.7	N/A
February	110.0	N/A
January	109.9	N/A
1989	108.5	2.9%
1988	105.4	5.4%
1987	100.0	5.7%
1986	94.6	3.5%
1985	91.4	0.0%
1984	91.4	4.5%
1983	87.5	7.0%
1982	81.8	(8.3%)
1981	89.2	1.6%
1980	87.8	(3.8%)
1979	91.3	N/A

N/A - Not applicable.

[a] Compiled by the Federal Reserve Board.

Sources: Federal Reserve Board, Federal Reserve Bulletin, July 1990; and Chemical & Engineering News, June 18, 1990, p. 38.

TABLE 4-8

COMPARATIVE PRODUCTION INDEXES,[a] 1979-1989
(1987=100)

Year	All Manufacturing	SIC 28, "Chemicals and Products"	Industrial Organic Chemicals	Synthetic Materials
1989	108.9	108.5	109.2	103.1
1988	105.8	105.4	103.1	104.4
1987	100.0	100.0	100.0	100.0
1986	94.3	94.6	95.1	91.6
1985	91.6	91.4	94.1	86.9
1984	89.3	91.4	93.4	88.9
1983	80.9	87.5	89.9	84.3
1982	76.6	81.8	81.0	71.8
1981	80.3	89.2	97.0	79.5
1980	78.8	87.8	92.8	71.2
1979	80.9	91.3	101.8	85.8

[a] Compiled by the Federal Reserve Board.

Source: Chemical & Engineering News, June 18, 1990, p. 38.

TABLE 4-9

U.S. POLYMERS PRODUCTION, 1985-1989

	1989	1988	1987	1986	1985
Man-Made Fibers (millions of kg)					
Noncellulosic					
Acrylic	246	267	269	279	286
Nylon	1,243	1,211	1,220	1,140	1,063
Olefin	743	720	678	632	567
Polyester	1,630	1,670	1,606	1,499	1,515
Cellulosic[a]	263	279	274	281	253
Total	4,126	4,146	4,047	3,831	3,684
Synthetic Rubber (millions of kg)					
Ethylene-Propylene	260	263	254	230	215
Nitrile	69	76	69	59	53
Polybutadiene	411	407	371	336	330
Styrene-Butadiene Rubber	874	909	850	792	735
Other	688	679	638	596	505
Total	2,302	2,334	2,182	2,013	1,838
Plastics Resins (millions of kg)					
Thermosetting					
Epoxy (Unmodified)	231	220	196	180	175
Melamine	101	94	96	78	87
Phenolic	1,305	1,390	1,300	1,240	1,188
Polyester (Unsaturated)	598	636	620	576	554
Urea	669	646	626	576	548
Total	2,904	2,986	2,839	2,651	2,552
Thermoplastic					
Polyethylene					
Low Density	4,398	4,716	4,354	4,038	4,032
High Density	3,675	3,810	3,626	3,258	3,026
Polypropylene	3,283	3,299	3,015	2,636	2,331
Styrene Polymers					
Polystyrene	2,315	2,353	2,168	2,028	1,839
Styrene-Acrylonitrile	51	67	57	42	39
Acrylonitrile-Butadiene-Styrene and Other Styrene Polymers	1,086	1,097	1,022	996	924
Polyamide, Nylon Type	258	257	230	211	181
Vinyl Resins					
Polyvinyl Chloride and Copolymers	3,846	3,788	3,616	3,291	3,072
Other	100	101	96	88	86
Thermoplastic Polyester	739	749	632	533	438
Total[b]	19,751	20,237	18,817	17,121	15,967

[a] Not organic.

[b] For those products listed. Some small-volume plastics are excluded.

Source: Chemical & Engineering News, June 18, 1990, pp. 40-41.

TABLE 4-10

CURRENT-DOLLAR VALUE OF SHIPMENTS IN THE CHEMICAL INDUSTRY, 1987-1989 AND 1990 FORECAST

($ million)

	1990 (Forecast)	1989	1988	1987
SIC 28 (Chemicals and Allied Products)	N.A.	274,459	258,924	229,015
SICs 2821, 2822, 2824, 2843, 2865, 2869, 2873, 2895 (Petrochemicals)	N.A.	123,578	111,748	96,514
SICs 2865, 2869 (Organic Chemicals)	66,252	63,754	56,745	50,972
SIC 2821 (Plastics Materials and Resins)	38,096	36,616	33,800	26,144
SIC 2822 (Synthetic Rubber)	N.A.	3,390	3,339	3,310
SICs 2823, 2824 (Man-Made Fibers)	N.A.	13,486	12,411	11,444
SIC 2891 (Adhesives and Sealants)	N.A.	5,514	5,154	4,685
SIC 2843 (Surface Active Agents)	N.A.	3,829	3,376	2,980
SIC 2833 (Medicinals and Botanicals)	N.A.	3,928	3,721	3,348

N.A. - Not available.

Source: U.S. Department of Commerce, International Trade Administration, 1990 U.S. Industrial Outlook.

synthetic organic chemicals. Table 4-10 is in current dollars, while Table 11 is in constant (price-adjusted) dollars. Table 4-10 indicates that the value of shipments in SIC 28, Chemicals and Allied Products, was $274.5 billion in 1989. In the SICs defined by the Commerce Department to represent the petrochemicals industry, value of shipments was $123.6 billion, about one-half of which was contributed by SICs 2865 and 2869. Because of an increase in the price level, growth in constant-dollar value of shipments has been less than growth in current-dollar value of shipments. Constant-dollar value of shipments is usually a good proxy for the physical volume of shipments. Despite the previously discussed production decline in 1989, constant-dollar value of shipments increased from 1988 to 1989 in each category shown in Table 4-11. This is most likely a reflection that in 1989, inventories were drawn down, causing shipments (or sales) to exceed production. The increase in the constant-dollar value of shipments from 1988 to 1989 may also be partly explained by a change in product mix. Specifically, an increase in the average quality of shipments would not be factored into the price adjustment, but rather would be reflected in an increase in value of shipments.

Due to record demand and modest capacity additions in the 1980s, average capacity utilization in the chemical industry increased to a peak in January 1989 of 89.3 percent, its highest level since 1951.[12] In 1987, 1988, and early 1989, many chemicals (e.g., ethylene, some plastics) were running at nearly 100 percent of capacity. However, from the first quarter to the fourth quarter in 1989, while production was up only 1.8 percent, capacity was up 3.9 percent. The result was a decrease in capacity utilization from 88.9 percent to 87.0 percent.[13]

4.4 DEMAND AND END-USE MARKETS

After a continuous increase for several years, the demand for synthetic organic chemicals leveled off in 1989. Contributing greatly to the problem were weak markets for automotive products and housing, two of the most important end uses for synthetic organic chemicals. PVC and thermoset resins, for example, are used substantially in housing and construction, and ABS resins and synthetic rubber are key materials in automotive products. Production of motor vehicles declined 4 percent in 1989 to the lowest level since 1983.[14] In the fourth quarter of 1989, motor vehicle output was down 22.5 percent from the third quarter. In the first five months of 1990, motor vehicle output was down 20 percent from the same period in 1989.

TABLE 4-11

CONSTANT-DOLLAR VALUE OF SHIPMENTS IN THE CHEMICAL INDUSTRY, 1987-1989 AND 1990 FORECAST
(millions of 1987 dollars)

	1990 (Forecast)	1989	1988	1987
SIC 28 (Chemicals and Allied Products)	245,458	241,350	233,877	229,015
SICs 2821, 2822, 2824, 2843, 2865, 2869, 2873, 2895 (Petrochemicals)	101,855	100,049	97,316	96,514
SICs 2865, 2869 (Organic Chemicals)	51,947	51,166	49,797	50,972
SIC 2821 (Plastics Materials and Resins)	28,730	28,166	27,614	26,144
SIC 2822 (Synthetic Rubber)	3,406	3,340	3,274	3,310
SICs 2823, 2824 (Man-Made Fibers)	N.A.	12,010	11,716	11,444
SIC 2891 (Adhesives and Sealants)	5,462	5,106	4,862	4,685
SIC 2843 (Surface Active Agents)	3,430	3,267	3,120	2,980
SIC 2833 (Medicinals and Botanicals)	3,575	3,501	3,423	3,348

N.A. - Not available.

Source: U.S. Department of Commerce, International Trade Administration, 1990 U.S. Industrial Outlook.

Meanwhile, new housing starts in 1989 were at the lowest level since 1982, falling 7 percent from 1988.[15]

The decrease in domestic demand in 1989 was offset somewhat by strong export demand. This was not enough, though, to prevent an overall decrease in demand. Demand (consumption) in 1989 did not decline as much as production, however. This is because demand was met not only by production, but also by a reduction in inventory. This followed an inventory build-up in 1988 in anticipation of supply shortages. The inventory correction was expected to have been completed by the end of 1989, and it has been predicted that "production of synthetics should better than match final demand in 1990."[16]

Synthetic materials (i.e., polymers) enjoyed particularly strong demand in the 1980s, at least up until 1989. Part of the reason for this is that the 1980s generally saw stronger consumer markets -- in which many synthetic materials are consumed as end products -- than industrial and agricultural markets.[17] About 30 percent of all plastic materials, for example, are consumed in packaging, mainly for consumer products. The second biggest end use for plastics is housing and construction, which accounts for about 23 percent of consumption. Synthetic materials also achieved some of their growth in the 1980s by replacing such natural materials as wood, metals, glass, and paper.[18] High prices for synthetic materials in 1988 threatened a switch to less-expensive alternative materials.[19] But with the decline in prices in 1989, synthetic materials are now expected to continue replacing competing materials. The price of crude oil prevailing in November 1989 -- $18-20 per barrel -- was considered to give synthetic materials a competitive advantage over natural materials.[20]

The demand for specialty chemicals has also outpaced general economic activity in recent years. Current high growth areas include separation chemicals, specialty polymers, oil field and refinery chemicals, adhesives, water treatment chemicals, processing aids, lubricant additives, and industrial coatings.

A U.S. International Trade Commission document in April 1983 cited an unpublished demand elasticity estimate for chemicals and allied products of -0.7 to -0.9.[21] According to this estimate, the demand for chemicals is in general relatively inelastic. This is consistent with the notion that most chemicals are producer goods that are needed as inputs by other producers -- both other producers in the chemical industry (the largest market for chemicals is the chemical industry itself) and producers in other industries. Producers are often reliant on a chemical input because they have a heavy investment in their existing processes. Nevertheless, the elasticity of demand for chemicals must really be evaluated on a case-by-case basis. Demand could be relatively elastic if a substitute is readily available at comparable cost. As mentioned previously, for example, two-thirds of the petrochemical industry has the capability to switch between petroleum-based and natural gas-based feedstocks. And synthetic materials face competition from such natural materials as wood, metals, paper, and glass. As another example, one trade journal article, referring to the surfactants business, states that "intermediates producers don't always have the luxury of passing cost hikes along to customers ... because of the pressures of potential substitutions ..."[22]

4.5 FOREIGN TRADE

The chemical industry is the leading export industry in the U.S. As Table 4-12 indicates, exports in SIC 28, Chemicals and Allied Products, amounted to $38.0 billion dollars in 1989. Imports were only $23.2 billion, so the trade balance was +$14.8 billion. SIC 2821, Plastics Materials and Resins, contributed 28 percent of this with a trade balance of +$4.2 billion in 1989. The trade surplus in SIC 28 has increased by 54.7 percent since 1987, based on impressive export growth of 42.4 percent that exceeded import growth of 35.6 percent. In 1989, the only two SIC groupings listed in Table 4-12 with trade deficits were SIC 2843, Surface Active Agents (-$10 million), and SIC 2833, Medicinals and Botanicals (-$886 million).

U.S. exports and imports from 1979 to 1989 for a slightly different Commerce Department definition of chemicals and related products are shown in Table 4-13. According to this definition, exports in 1989 were $36.5 billion, imports were $20.8 billion, and the balance of trade was +$15.7 billion. From 1979 to 1986, exports were sluggish, and the trade surplus declined. Since 1986, however, exports have taken off, and as a result the trade surplus has more than doubled. The improvement in the balance of trade is primarily attributable to a decline in the value of the dollar, which has made U.S.-produced chemicals less expensive overseas and foreign-produced chemicals more expensive in the U.S.; and cost reductions by the U.S. industry in the early 1980s, which has improved the competitiveness of U.S. products.[23]

TABLE 4-12

U.S. EXPORTS AND IMPORTS IN THE CHEMICAL INDUSTRY, 1987-1989
($ million)

	Exports			Imports			Balance of Trade		
	1989	1988	1987	1989	1988	1987	1989	1988	1987
SIC 28 (Chemicals and Allied Products)	38,035	32,551	26,701	23,219	20,504	17,122	14,816	12,047	9,579
SICs 2821, 2822, 2824, 2843, 2865, 2869, 2873, 2895 (Petrochemicals)	18,517	17,607	13,833	12,641	11,441	9,693	5,876	6,166	4,140
SICs 2865, 2869 (Organic Chemicals)	10,131	9,906	7,957	9,234	8,477	7,217	897	1,429	740
SIC 2821 (Plastics Materials and Resins)	5,437	5,034	3,688	1,273	1,158	927	4,164	3,876	2,761
SIC 2822 (Synthetic Rubber)	899	985	858	605	461	393	294	524	465
SICs 2823, 2824 (Man-Made Fibers)	1,701	1,361	1,070	522	472	424	1,179	889	646
SIC 2891 (Adhesives and Sealants)	155	169	129	128	99	105	27	70	24
SIC 2843 (Surface Active Agents)	290	244	202	300	225	171	(10)	19	31
SIC 2833 (Medicinals and Botanicals)	2,963	2,463	1,982	3,849	3,056	2,468	(886)	(593)	(486)

Source: U.S. Department of Commerce, International Trade Administration, 1990 U.S. Industrial Outlook.

TABLE 4-13

U.S. EXPORTS AND IMPORTS OF CHEMICALS AND RELATED PRODUCTS[a], 1979-1989

($ million)

Year	Exports	Imports	Balance of Trade
1989	36,485	20,752	15,733
1988	32,300	19,876	12,424
1987	26,381	16,213	10,168
1986	22,766	15,001	7,765
1985	21,759	14,533	7,226
1984	22,336	13,697	8,639
1983	19,751	10,779	8,972
1982	19,850	9,493	10,357
1981	21,187	9,446	11,741
1980	20,740	8,593	12,147
1979	17,306	7,485	9,821

[a] Close, but not identical, to SIC 28.

Sources: U.S. Department of Commerce, Bureau of the Census, Statistical Abstract of the United States 1989; and Chemical & Engineering News, June 18, 1990, p. 67.

The composition by industry segment of U.S. foreign trade in chemicals and related products in 1989 is detailed in Table 4-14. Plastics and resins and organic chemicals lead the way, accounting for over half of all exports and over half of the total trade surplus. In Table 4-15, U.S. foreign trade in chemicals and related products in 1989 is disaggregated by country or region. The U.S. runs its biggest surpluses with the "Other Asia" segment and Latin America. The leading destination for U.S. exports is Western Europe. However, U.S. exports to Western Europe, $10.9 billion, were nearly matched by imports, $10.6 billion.

In Table 4-16, the U.S.'s share of world trade in chemicals and related products in 1989 is revealed. The U.S. accounted for 13.5 percent of world exports and 7.7 percent of world imports. The U.S. ranked second behind West Germany in all three measures of foreign trade in Table 4-16: exports, imports, and the balance of trade.

Foreign trade statistics for some major petrochemicals are presented in Table 4-17. The leading export petrochemicals in 1989 were polypropylene, styrene, and ethylene glycol. By far, the petrochemical imported the most was methanol. In 1989, the U.S. imported 1.5 billion kilograms of methanol and exported only 86.6 million kilograms. Domestic production of methanol in 1989 was 3.2 billion kilograms (see Table 4-1). Another petrochemical for which the U.S. depends heavily on imports is 1,3-butadiene. Imports of butadiene in 1989 amounted to 348 million kilograms, compared to exports of only 24 million kilograms. U.S. production of butadiene in 1989 was 1.4 billion kilograms.

4.6 PRICING

As Table 4-18 indicates, prices of chemicals and related products recorded their biggest gains in 1988 and 1989 since 1981. The 5.8 percent increase in 1989 masks a decline in prices that began in the middle of the year, however. The Department of Labor index peaked in April and May of 1989, and by December had fallen 3.1 percent. Still, in December 1989, prices were 7.2 percent higher than in January 1988. Prices have rebounded somewhat in 1990, increasing by 1.2 percent from December 1989 to June 1990.

The decline in prices in the second half of 1989 can be attributed to lower demand and capacity increases. The fall in prices was most pronounced for organic chemicals and plastics materials.[24]

TABLE 4-14

U.S. EXPORTS AND IMPORTS OF CHEMICALS AND RELATED PRODUCTS, 1989

($ million)

	Exports	Imports	Balance of Trade
Organic Chemicals	10,609	7,042	3,567
Plastics and Resins	7,928	3,316	4,612
Medicinals and Pharmaceuticals	3,660	2,086	1,574
Inorganic Chemicals	2,986	2,239	747
Fertilizers, Manufactured	2,821	999	1,822
Pesticides and Disinfectants	32	28	4
Radioactive Materials	1,333	992	341
Flavors, Perfumes, Cosmetics, and Toiletries	1,053	968	85
Pigments, Paints, and Varnishes	772	515	257
Cleaning and Polishing Materials	416	197	219
Dyeing, Tanning, and Coloring Materials	325	618	(293)
Explosives and Pyrotechnics	123	131	(8)
Misc.	4,427	1,621	2,806
Total	36,485	20,752	15,733

Source: Chemical & Engineering News, June 18, 1990, p. 67.

TABLE 4-15

DISTRIBUTION OF U.S. EXPORTS AND IMPORTS OF CHEMICALS AND RELATED PRODUCTS IN 1989 BY COUNTRY/REGION

($ million)

	Exports	Imports	Balance of Trade
Canada	4,210	3,938	272
Latin America	5,419	1,200	4,219
Western Europe	10,891	10,582	309
Eastern Europe	409	208	201
Communist Asia	1,137	273	864
Japan	4,664	2,373	2,291
Middle East	542	371	171
Other Asia	6,624	985	5,639
Australia	1,364	291	1,073
Africa	702	61	641
Other	522	474	48
Total	36,485	20,752	15,733

Source: Chemical & Engineering News, June 18, 1990, p. 67.

TABLE 4-16

WORLD TRADE IN CHEMICALS AND RELATED PRODUCTS, 1989
($ million)

	Exports	Imports	Balance of Trade
U.S.	36,485	20,752	15,733
Canada	6,184	7,791	(1,607)
EC			
Belgium/Luxembourg	14,010	11,648	2,362
France	23,980	20,637	3,343
Italy	10,782	17,220	(6,438)
The Netherlands	19,321	11,577	7,744
U.K.	20,038	17,431	2,607
West Germany	44,184	23,361	20,823
Other	15,091	18,234	(3,143)
Switzerland	10,890	6,552	4,338
Japan	14,776	15,948	(1,172)
Other	54,739	99,329	(44,590)
Total	270,480	270,480	-

Source: Chemical & Engineering News, June 18, 1990, p. 67.

TABLE 4-17

ESTIMATED U.S. EXPORTS AND IMPORTS OF SELECTED MAJOR PETROCHEMICALS, 1989
(millions of kg)

	Exports	Imports	Balance of Trade
Benzene	19.2	49.4	-30.1
Butadiene	23.6	348.2	-324.6
Ethylene	1.8	86.2	-84.5
Ethylene Glycol	493.8	162.9	330.9
High-Density Polyethylene	418.3	88.6	329.7
Low-Density Polyethylene	448.6	363.8	84.8
Methanol	86.8	1,458.3	-1,371.5
PET	57.4	-	57.4
Polypropylene	614.5	23.8	590.8
Polystyrene	52.0	5.8	46.2
PVC	330.4	36.6	293.7
Propylene	107.3	118.3	-11.0
Propylene Glycol	98.77	2.4	96.3
Styrene Monomer	608.1	189.3	418.8
Styrene Butadiene Rubber	187.2	92.8	94.3

Source: Chemical Marketing Reporter, April 2, 1990, p. SR18.

TABLE 4-18

PRODUCER PRICE INDEXES[a] FOR SIC 28, CHEMICALS AND ALLIED PRODUCTS, 1979-1990

(1982=100)

Year/Month	Index	Percent Change From Prior Year
1990		
June	122.4	N/A
May	122.3	N/A
April	122.0	N/A
March	122.1	N/A
February	121.7	N/A
January	121.2	N/A
1989	123.0	5.8%
1988	116.3	9.3%
1987	106.4	3.7%
1986	102.6	(1.1%)
1985	103.7	0.8%
1984	102.9	2.6%
1983	100.3	0.3%
1982	100.0	1.6%
1981	98.4	10.6%
1980	89.0	17.1%
1979	76.0	N/A

N/A - Not applicable.

[a] Compiled by the U.S. Department of Labor.

Sources: U.S. Department of Commerce, Bureau of Economic Analysis, Survey of Current Business, July 1990; and U.S. Department of Commerce, Bureau of the Census, Statistical Abstract of the United States 1989.

In January 1990, prices for industrial petrochemicals were on average 5-6 percent lower than their peak in the second quarter of 1989.[25] The price of ethylene declined from 71-75 cents per kilogram in early 1989 to 51 cents per kilogram by the end of the year. The price decreases in the second half of 1989 occurred despite increases in labor and raw materials costs. This suggests that industry demand has some degree of price elasticity, and the more elastic demand is the more difficult it is to recover compliance costs without sacrificing excessive amounts of output. In general, it is likely that producers of end-product chemicals have more pricing flexibility than producers of basic and intermediate chemicals. Basic and intermediate chemicals are essentially commodity products, produced to standard specifications with little or no product differentiation. They also tend to be produced by a large number of producers. In the U.S., basic chemicals, for example, are produced on average by 25 different producers.[27] Both of these factors could inhibit pricing flexibility. End-product chemicals are generally produced in smaller volumes and sold at higher prices than basic and intermediate chemicals. They are produced to perform a specific function and are more differentiated than basic and intermediate chemicals. Consequently, their producers are likely to have a degree of pricing discretion.

4.7 FINANCIAL PROFILE

Profitability in the U.S. chemical industry turned downward in mid-1989 when prices began falling. By the end of 1989, profit margins for plastics materials, for instance, had fallen to 1986 levels.[28]

Still, 1989 was a very profitable year for U.S. chemical companies. In a sample of 30 companies, Chemical & Engineering News found an average after-tax profit margin of 8.6 percent in 1989.[29] This was higher than in any other year in the 1980s other than 1988. For the same sample, the average profit margin was 5.0 percent in 1986, 6.8 percent in 1987, and 9.6 percent in 1988.

Specialty chemicals tend to be more profitable than commodity chemicals. This is because specialty chemical producers tend to have more pricing discretion and face less competition than commodity chemical producers. In 1980, four of the five most profitable chemical companies were producers of specialty chemicals.[30]

Capital spending in the U.S. chemical industry from 1980 to 1989 is summarized in Table 4-19. The table also shows the Commerce Department forecast for 1990. Total capital spending in 1989 was

TABLE 4-19

CAPITAL SPENDING IN THE U.S. CHEMICAL INDUSTRY, 1980-1989 and 1990 FORECAST
($ billion)

Year	Capital Spending
1990[a]	20.75
1989	20.35
1988	19.25
1987	16.42
1986	16.81
1985	16.44
1984	15.32
1983	12.96
1982	12.66
1981	13.11
1980	11.63

[a] U.S. Department of Commerce forecast.

Source: Chemical & Engineering News, June 18, 1990, p. 50.

$20.35 billion. This was up 5.7 percent from 1988. From 1987 to 1988, capital spending increased by 17.2 percent, the biggest increase of the decade. The average annual rate of increase from 1980 to 1989 was 6.4 percent. Capital spending is forecast to increase by only 2.0 percent in 1990.

In a spring 1989 survey of the chemical industry, Data Resources Inc. found that 33 percent of planned capital spending in 1989 and 1990 was for plant expansions and 67 percent for plant replacement and modernization.[31] The focus of capital spending in 1989 was expected to be on synthetic materials, drugs, and agricultural chemicals. In 1986, capital outlays in the chemical industry for pollution controls amounted to $624 million.[32]

From a sample of 19 chemical companies with sales over $1 billion, Chemical & Engineering News calculated that the median ratio of long-term debt to total capitalization (long-term debt plus equity) in 1989 was 32.6 percent, the median ratio of capital spending to sales was 9.0 percent, and the median ratio of R&D spending to sales was 2.7 percent.[33] For 17 companies with sales under $1 billion, the debt to total capitalization ratio was 29.4 percent, capital spending was 6.5 percent of sales, and R&D was 3.2 percent of sales. This indicates that large companies tend to devote a greater portion of their budgets to capital spending and the smaller companies allocate more to R&D. Also, large companies are on average more highly leveraged. The Commerce Department estimates that the average ratio of debt to total capitalization in SIC 28, Chemicals and Allied Products, in 1989 was 33.5 percent.[34] This was the highest level in the 1980s, though it was exceeded by the average ratio for all manufacturing, 37.2 percent. The major reason why the U.S. chemical became more leveraged in the 1980s is that many acquisitions were financed by debt. Some firms are now very highly leveraged. Georgia Gulf, Vista Chemical, Sterling Chemicals, and Rexene, for example, all have no book equity value (total debt exceeds total assets.)[35] Such firms are at risk if there is a slowdown in their markets.

4.8 OUTLOOK

Output in the U.S. chemical industry is expected to grow slowly in the early 1990s as growth in the U.S. economy as a whole abates. The Commerce Department projects that in the next five years, petrochemicals will grow by 2 percent per year, and organic chemicals by 1.5 to 2 percent per year.[36] These are substantially lower than the robust growth rates of the late 1980s. Lagging automobile and housing sales, as well as slowing export markets, will contribute to the slower growth in the U.S. chemical industry. Standard & Poor's predicts that output of organic chemicals in the U.S. will grow in the long term at a slightly faster rate than real GND, mainly due to overall growth in the demand for synthetic materials.[37]

Some segments of the U.S. chemical industry are expected to have healthy growth in the early 1990s. Plastics materials, for example are projected by the Commerce Department to grow by 4 percent per year in the early 1990s.[38] One consultant expects the three fastest-growing engineering thermoplastics -- polyketones, liquid crystal polymers, and polyphenylene sulfide -- to continue experiencing double-digit growth well into the 1990s.[39] The demand for specialty chemicals is forecast to increase by 5.5 percent per year over the next 5 years.[40] Particularly fast growth -- 12 percent per year -- is projected for diagnostic aids (chemicals used in laboratory and clinical work). In general, thermoplastics have more growth potential than thermosetting plastics, which are consumed in mature markets and which are heavily dependent (two-thirds of final demand) on construction, a slow-growing sector of the economy.[41]

The U.S. chemical industry was threatened by higher crude oil prices during the war with Iraq. Increased feedstock costs could have eroded profit margins. However, producers were temporarily able to maintain their margins during the early part of the war. They were able to do so because customers sought to build up their chemical inventories in the face of soaring crude oil prices. The price of crude oil fell back to its pre-war level following the resolution of the conflict.

A major concern for U.S. chemical producers in the early 1990s is the prospect of overcapacity. Based on announced capacity expansions through 1993, the WEFA Group expects "virtually every major player involved in feedstocks and resins to be adding capacity."[42] Projected capacity increases in the U.S. through 1993 include ethylene by 30 percent, propylene by 30 percent, styrene by 50 percent, vinyl chloride monomer by 25 percent, PVC by 30 percent, and polyethylene by 30 percent.[43] Based on a survey in 1989 of producers, Data Resources Inc. projects that capacity in the U.S. chemical industry will increase by 7.0 percent in 1990 and by 5.4 percent in 1991.[44] Already, the average industry operating rate is forecast to decline to 84.3 percent in 1990 from 86.8 percent in 1989.[45] The capacity additions are expected to occur in the face of weakened demand. This will create pricing pressures for chemical producers. Ethylene and propylene prices, for example, "are likely to take a big hit at the end of 1991 and the beginning of 1992 when new monomer capacity starts coming on-line."[46] Falling prices, at least, should enable synthetic materials to continue replacing such competing materials as glass, metals, paper, and wood.[47]

Significant capacity additions are also expected overseas, particularly in the Far East. This could negatively affect U.S. foreign trade. The U.S. trade balance in chemicals is also expected to be under pressure from domestic environmental regulations that add to the U.S. cost of production. Overall, however, U.S. exports are expected to continue to grow, and the chemical trade balance will remain positive.[48]

Data Resources Inc. estimates that after-tax profits in the U.S. chemical industry will fall 5.3 percent from $26.3 billion in 1989 to $24.9 billion in 1990.[49] Profits on commodity petrochemicals in particular are expected to be considerably lower in 1990. The long-term outlook for profitability will depend on the balance of supply and demand. As discussed, demand growth is only expected to be moderate. With the prospect of excess capacity, it is possible that profitability in the early 1990s will not match the high levels of the late 1980s. A new period of lower profits, at least for the next few years, may have been heralded by the general decline in industry profitability in late 1989. In general, specialty chemicals are expected to be more profitable than commodity chemicals in the next five years.[50]

4.9 CHEMICAL SYNOPSES

4.9.1 Ethylene

Ethylene is the largest-volume organic chemical produced in the U.S. Fabricated plastics (polyethylene, polyvinyl chloride, and polystyrene) account for about three-quarters of final demand.[51] Other important uses include antifreeze, synthetic fibers, elastomers, solvents, and detergents.

Worldwide ethylene production capacity on June 1, 1989 was 52.0 billion kilograms, per year.[52] The U.S. accounted for 19.6 billion kilograms, or 37.7 percent, of this. Two years earlier, on June 1, 1987, worldwide capacity was 48.3 billion kilograms and U.S. capacity was 16.8 billion kilograms. From June 1, 1987 to June 1, 1989, therefore, worldwide capacity increased 7.7 percent while U.S. capacity increased 16.7 percent. The increase in U.S. capacity was achieved through debottlenecking and modernization.

Rising demand for ethylene derivatives and shortages caused by explosions at a couple of U.S. refineries in 1988 combined to cause ethylene prices and profits to increase in the late 1980s. In the fall of 1989, olefins profitability was described as being "the best it has been during the decade."[53] In 1988, ethylene capacity was running at over 100 percent.[54]

In the latter part of 1989, the ethylene market quickly changed. As a result of the aforementioned buildup in capacity and weaknesses in derivatives markets, capacity utilization began to decline and prices and profits followed suit. Operating rates slipped to about 90 percent in March 1990, while the price of ethylene in January 1990 was 51-53 cents per kilogram, about 22 cents per kilogram lower than one year earlier.[55]

Industry operating rates are projected to continue to decline in the early 1990s as additional capacity comes on stream. Announced expansions through 1993 would increase U.S. capacity by 34 percent.[56] Meanwhile, ethylene demand is projected to grow by only 3.5 percent per year.[57] According to one forecast, operating rates will decline to 86 percent in 1992.[58] Despite looming overcapacity, the profitability outlook is mixed. One analyst foresees "profitability for ethylene as relatively low for much of the 1990s."[59] Standard & Poor's, on the other hand, believes that despite the decline in capacity utilization, ethylene still has "relatively healthy profit potential."[60]

4.9.2 Propylene

Propylene is the second-largest organic chemical produced in the U.S. The most important end market is polypropylene film, packaging, and fibers.[61] Other important end uses include acrylic fibers, resin applications, foams and coatings, and solvents.

After doubling in 1987, prices were stable in 1988. In early 1989, prices rose to 53 cents per kilogram, the highest level in years. By the end of 1989, the price had fallen to 34 cents per kilogram. In August 1990, the price stood at 32 cents per kilogram. The cause of the price decline has been overcapacity. In the fourth quarter of 1989, average capacity utilization in the U.S. propylene industry was only 75 percent.[62]

The demand for propylene is forecast to grow by three percent per year in the long term.[63] Demand growth will be driven mainly by expanding markets for polypropylene in acrylic fibers and resins.

4.9.3 Benzene

Benzene, along with toluene and the xylenes, is one of the aromatic chemicals. Aromatics are used to increase the octane rating of unleaded gasoline. Other major end uses of aromatics include plastics (films and fabricated products), fibers, resins, and rubber. Benzene is used almost exclusively as an intermediate in the production of other chemicals. Styrene accounts for 55 percent of benzene demand; and cumene/phenol, cyclohexane, and chlorobenzenes another 40 percent.[64,65]

The supply of benzene is linked to the demand for gasoline. For example, one source of benzene is toluene hydrodealkylation. An increase in the demand for gasoline, resulting in increased demand for octane boosters such as toluene, reduces the amount of toluene available for benzene production. The supply of benzene is also dependent on the demand for ethylene, the manufacture of which pyrolysis gasoline -- another source of benzene -- is a byproduct.

Because the supply of benzene is dependent on such exogenous factors as the demand for gasoline and the demand for ethylene, and because benzene demand is cyclical (varying generally with GNP), benzene prices can be volatile. In 1986, benzene prices fell to 80 cents per gallon with the decline in the price of crude oil, benzene's feedstock. Prices rebounded in 1987 and 1988 as a result of strong derivatives demand (worldwide, styrene facilities were at 100 percent of capacity in 1989, for example) and an increase in the gasoline demand for octane.[66] At one point in the spring of 1987, the price of benzene surged to $2.50 per gallon. In 1989, the price stood at $1.55 per gallon in March, fell to $1.00 per gallon in August, and rebounded to $1.50/gallon by the end of the year as a result of a supply shortage caused by downed facilities. In August 1990, the price of benzene was $1.30 per gallon. In January 1990, aromatics were considered to be profitable, but profitability was declining to a "more reasonable profit/product relationship."[67]

According to one forecast, benzene demand in the U.S. is expected to increase from 8.9 billion kilograms in 1988 to 11.7 billion kilograms in 1993.[68] This computes to robust average annual growth of 5.6 percent. This may be optimistic, considering that world styrene demand is only forecast to increase by three percent per year through 1993.[69] Operating rates are forecast to increase from 78 percent in March 1990 to 85 percent in 1992.[70] This is counter to the general downward trend expected for the petrochemical industry in the next several years. If the current unrest in the Middle East leads to a long-term crude oil supply disruption, ethylene capacity utilization could run a different course, however. Higher crude oil prices and hence higher gasoline prices could reduce the demand for aromatics for the gasoline pool. This, in turn, would increase the supply of aromatics available for chemical conversion, which would represent an increase in available capacity.

4.9.4 Rubber-Processing Chemicals

Rubber-processing chemicals are organic compounds that are added to rubber to give it qualities necessary for conversion into finished rubber goods. In 1988, according to the U.S. International Trade Commission (ITC), 160 million kilograms of rubber-processing chemicals were produced in the U.S., and 121 million kilograms were sold on the merchant market at a value of $424 million.[71]

There are 23 U.S. producers of rubber-processing chemicals. However, four producers -- Monsanto, Uniroyal Chemical Co., Mobay, and Goodyear -- supply 85 percent of the market.[72] Monsanto has the highest market share with 39 percent. The industry underwent consolidation in the second half of the 1980s, as mergers, breakups, and restructurings reduced the number of firms in the field. The reduction in the number of suppliers "eased competition, enabling the survivors to earn respectable profits in the very slowly growing market."[73] Because of the complexity of manufacturing rubber-processing chemicals, entry into the market is considered to be relatively difficult.[74]

Growth in the rubber-processing chemicals industry is tied to the markets for rubber products, in particular tires, which account for 60 percent of rubber consumption in the U.S.[75] Total consumption in the U.S. of rubber-processing chemicals in 1989 was an estimated 106.8 million kilograms.[76] This is significantly less than the ITC's estimate of domestic output. Since the difference is not explainable by exports, "most industry analysts discount these (the ITC data) as unreliable."[77] Consumption in 1989 was composed of 65.5 million kilograms of antidegradants (antioxidants and antiozonants), 35.9 million kilograms of accelerators, and 5.3 million kilograms of miscellaneous rubber-processing chemicals (e.g., peptizers, blowing agents). Domestic consumption is forecast to be 111.4 million kilograms in 1990, and to increase to 121.9 million kilograms in 1995.[78] This represents only 1.8 percent annual growth. Growth in the use of rubber-processing chemicals is expected to lag synthetic rubber growth mainly because of the continuing switch to radial tires, which have a longer useful life then bias tires, and which contain proteins and lipids that function as antioxidants.[79] Despite the slow growth, capacity, which was fully utilized in 1988, is likely to remain tight, as there are currently no plans worldwide to build large units.

The outlook for antioxidants, only 38 percent of which are consumed as rubber processing chemicals, is very bright. From $538 million in 1987, the antioxidant market is projected to grow to $725 million in 1992 and $1.1 billion by 2000 -- an average annual growth rate of 6.1 percent.[80]

4.9.5 Surfactants

Surface active agents, or surfactants, are organic chemicals that reduce the surface tension of water or other solvents. About 40 percent of surfactant use is in household cleaning products such as soaps and detergents.[81] By reducing surface tension, surfactants loosen and suspend dirt deposits and stains, allowing for them to be washed away. Surfactants contributed about 0.6 billion kilograms of the 2.6 billion kilogram heavy-duty detergent market in 1989.[82]

In the 1987 Census, 45 percent of total employment in SIC 2843 -- Surface Active Agents, Finishing Agents, Sulfonated Oils, and Assistants -- was concentrated in four states: Illinois, New Jersey, North Carolina, and Louisiana. Total employment in each of these states ranged from 800 to 1,400. Total U.S. employment in SIC 2843 in 1987 was 9,100.

Total production of surfactants in the U.S. in 1989 amounted to 3.6 billion kilograms, up from 3.3 billion kilograms in 1988.[83] At the beginning of 1990, the surfactants industry was operating at or near full capacity.[84] Surfactants have benefitted from the shift to liquid and automatic dishwashing detergents, though "market growth has slowed somewhat in the past few years."[85] In 1988, 2.0 billion kilograms of surfactants were sold at a value of $2.3 billion.[86]

Surfactants are derived from ethylene and ethylene oxide, and surfactant prices rose in 1988 and 1989 in response to the increase in the price of ethylene. In 1989, for example, surfactant prices were up 5.8 percent.[87] However, prices did not increase to fully recover the ethylene cost increase.[88] This is because surfactants face competition from natural oil-based alcohols, such as alcohols derived from coconuts and palm kernel oil. In the first half of the 1990s, world capacity for natural oil-based detergent alcohols is expected to increase by at least 181 million kilograms, with growth concentrated in developing countries with the raw material resources.

Real (price-adjusted) value of shipments of surfactants in the U.S. is projected to grow an average of 3.8 percent per year through 1994.[90] According to the Commerce Department, "tightened profit margins could cause some firms, especially smaller ones, to stop manufacturing surfactants."[91]

4.9.6 Plasticizers

Plasticizers are organic chemicals that are added to plastics and resin materials. U.S. production of plasticizers in 1988 totalled 1.0 billion kilograms, up 15.0 percent from 0.9 billion kilograms in 1987.[92] Sales in 1988 were 0.9 billion kilograms, valued at $1.0 billion.

There are over 25 manufacturers of plasticizers in the U.S., but six are considered to control the market: Exxon Chemical Co., Eastman Chemical Products Inc., BASF Corp., Aristech Chemical Corp., Monsanto Chemical Co., and Huels America Inc.[93] The market is considered to be highly competitive.[94]

Seventy percent of the plasticizers market is accounted for by phthalate esters. The leading phthalate ester, with a 22 percent share of the plasticizers market, is dioctyl phthalate (DOP). Exports of DOP dropped to 4 million kilograms in 1989 from 20 million kilograms in 1988. This was due to the absence of China and Taiwan from the market. Excluding exports, the U.S. plasticizers market has been static the past ten years.[95]

Pricing is generally not considered to be a major priority when choosing a plasticizer. The properties of the chemical are more important.[96] Nevertheless, the linear phthalates, which comprise 19 percent of the plasticizers market, lost share in 1988 and early 1989 when the price of ethylene soared. This indicates that customers are somewhat sensitive to price, and that there is competition among alternative plasticizers.

Plasticizers are dependent on the PVC market. PVC producers consume 80-82 percent of plasticizers output in the U.S., and plasticizers constitute 10 to 35 percent of PVC by weight.[97] With the outlook for sluggish PVC sales, plasticizers consumption in the U.S. is only expected to grow on average by 1.5 percent per year through 1992.[98]

4.9.7 Adhesives and Sealants

The value of shipments in SIC 2891, Adhesives and Sealants, was $5.5 billion in 1989.[99] The world market for adhesives and sealants is estimated at $10 billion.[100] The largest classes of adhesives and sealants, in order, are amino resins, phenolics, starches, styrene butadienes, polyvinyl acetates, acrylics, and polyurethanes. The major markets for adhesives and sealants, in order, are construction, automotive products, packaging, aerospace, and electronics.

There are about 550 companies in the U.S. that derive more than half of their sales from adhesives and sealants. The ten-firm concentration ratio is 34 percent.[101] The biggest producers are 3M with 7 percent of the market, and National Starch and H.B. Fuller with 6 percent each. There has been a great deal of merger activity in the industry lately. Among the factors driving the consolidations are the benefits of sharing the high costs of R&D and environmental compliance. The consolidation trend is expected to continue, with the number of companies in the industry declining to 500 in the next five years.[102]

Total employment in SIC 2891 in 1987 was 20,900.[103] Four states -- Ohio, California, Illinois, and New Jersey -- accounted for about one-half of the total.

The U.S. adhesives and sealants market grew 3.2-3.5 percent in 1989. This represented a slowdown from previous years. The market is expected to grow 3 percent in 1990.[104] Pricing is currently soft. This is in part due to excess capacity. In March 1990, for example, a recently opened H.B. Fuller plant was operating at only 10 percent of capacity.[105] Also, large customers are increasingly giving accounts to one supplier in return for, among other things, price concessions.[106]

4.9.8 Pesticides

Pesticides are chemicals used to destroy or repel plant or animal pests. The major types are herbicides, insecticides, and fungicides. U.S. production of pesticides from 1979 to 1988 is summarized in Table 4-20. Production has been flat since 1982, after declining from higher levels in previous years.

In 1988, 70 pesticide companies operated in the U.S. The top six companies accounted for half of domestic sales.[107] There has been a wave of mergers in the industry, and the 20-30 "major players" may shrink to about 10 in the next few years.[108]

In 1988, $4.8 billion of pesticides were consumed in the U.S. Of this, $3.9 billion was supplied by domestic producers and $0.9 billion was imported.[109] The U.S. exported $2.3 billion of pesticides in 1985. Agricultural crops consumed $4.0 billion of pesticides in 1988,

TABLE 4-20

U.S. PESTICIDES PRODUCTION,
1979-1988
(millions of kg)

	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
Herbicides[a]	318	252	329	343	325	274	283	381	366	298
Insectcides[b]	160	172	155	168	159	139	172	203	230	280
Fungicides[c]	50	48	51	49	56	48	50	65	71	70
Total	528	472	535	560	539	461	505	649	666	648

[a] Includes plant growth regulators.
[b] Includes rodenticides, soil conditioners, and fumigants.
[c] Includes dithiocarbarnates.

Source: Chemical & Engineering News, June 18, 1990, p. 43.

while the remaining $0.8 billion was consumed in noncrop applications such as forestry, industrial, turf, nursery, and home and garden. The size of the world market for pesticides in 1988 was estimated to be $21 billion.

Pesticides demand in the U.S. was flat in 1989 due to weather conditions that limited agricultural output and technological improvements that reduced per-acre application rates. Growth in 1990 and in the long term is also expected to be slow. Worldwide, long-term growth is projected to be 2 percent per year.[110] But growth will be highest in developing countries. The U.S. market is mature, and can expect little growth. One industry insider predicts that "total poundage produced by the pesticides industry will continue to decline, while dollar values will rise."[111] Growth will be constrained by continued efficiency gains resulting from technological improvements and a slow-down in planted acreage. Also, genetically engineered products could cut into pesticides markets. Export demand for U.S. pesticides has been slowing down due to a number of factors: 1) slowing growth in planted acreage and 2) reduced per-acre application rates; 3) tougher U.S. export controls for hazardous chemicals; 4) increased environmental concerns in export markets; and 5) increased production in foreign markets as patents on U.S. products expire.

4.9.9 Medicinal Chemicals

Medicinal chemicals include the medicinal and feed grades of all organic chemicals having therapeutic value. The definition encompasses bulk chemicals only, not derivative pharmaceutical preparations in the form of pills, tablets, capsules, or other measured doses. Total U.S. production of bulk medicinals in 1988 amounted to 117.1 million kilograms.[112] Sales were 103.4 million kilograms, valued at $1.8 billion. By weight, 38.6 percent were gastrointestinal agents and therapeutic nutrients, 16.6 percent analgesics, 14.9 percent vitamins, 11.2 percent antibiotics, 7.4 percent anti-infective agents, 5.8 percent dermatological agents, and 5.5 percent other.

In 1987, 11,600 workers were employed in SIC 2833, Medicinal Chemicals and Botanical Products (which includes inorganic chemicals).[113] Fully 62 percent of total employment was concentrated in New Jersey, Missouri, California, and Indiana.

The Commerce Department projects the constant-dollar value of shipments in SIC 2833 to increase by 2.5 percent in 1990 and by 2.2 percent per year over the next five years.[114] The U.S. had a trade deficit of - $886 million in SIC 2833 in 1988. The trade deficit is expected to increase at a moderate rate.[115]

4.9.10 Chlorofluorocarbons (CFCs)

Because of their effect of depleting the ozone layer, CFCs are scheduled to be phased out in the U.S. and in other industrialized countries. The impending decline was already evident in 1989, as U.S. production of all three major CFCs decreased from 1988. Table 4-21 summarizes U.S. production of CFCs from 1979 to 1989.

4.9.11 Synthetic Rubber

Synthetic rubber accounted for about 71 percent of North American rubber consumption in 1988.[116] Natural rubber, which is all imported, accounted for the remaining 29 percent. About 50 percent of the demand for synthetic rubber in the U.S. comes from tires and other rubber products for automobiles.[117]

SIC 2822, Synthetic Rubber, employed 10,400 workers in 1987.[118] There is substantial geographic concentration in the category. Texas, Louisiana, New York, and Ohio accounted for 81 percent of total employment in 1987.

U.S. production of synthetic rubber in 1988 -- 2.335 billion kilograms -- was the highest level of the decade, but was still eight percent below the all-time high in 1979.[119] The decline from the late 1970s is attributable to increased imports of tires and motor vehicles equipped with foreign-made tires; automobile downsizing; competition from plastics; and increased use of radial tires, which use more natural rubber and have longer useful lives than alternative bias-ply tires. Offsetting these factors somewhat have been the expansion of the replacement market, reflecting growth in the number of vehicles on the road, and the increased popularity of high-performance tires, which have a relatively short replacement cycle. In 1989, production of synthetic rubber in the U.S. fell 1.4 percent to 2.302 billion kilograms.[120]

The Commerce Department forecasts real shipments of synthetic rubber in the U.S. to grow by 2 percent in 1990 and by 1-2 percent per year through 1993.[121] Growth will be constrained and prices will be kept down from competition with other materials, such as rubber-plastic alloys, composite materials, and general-purpose polymer resins. The International Institute of Synthetic Rubber Producers similarly projects North American consumption to increase by 1.5 percent per year from 1989 to 1993.[122]

TABLE 4-21

U.S. PRODUCTION OF CHLOROFLUOROCARBONS, 1979-1989
(millions of kg)

	1989[a]	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
Chlorodifluoromethane (F-22)	148	151	125	123	107	115	107	79	114	103	96
Dichlorodifluoromethane (F-12)	178	188	152	146	137	153	132	117	147	134	133
Trichlorofluoromethane (F-11)	88	113	90	92	80	84	98	64	74	72	76
Other	N.A.	172	161	156	139	153	127	N.A.	N.A.	N.A.	92
Total	N.A.	624	527	517	462	505	463	N.A.	N.A.	N.A.	396

[a] Preliminary.

N.A. - Not available.

Source: Chemical & Engineering News, June 18, 1990, p. 43.

4.9.12 Man-Made Fibers

The four major synthetic (noncellulosic) fibers are polyester, nylon, acrylics, and polypropylene (a polyolefin). The primary sources of demand for all man-made fibers -- including cellulosic fibers (mainly rayon and acetate), which are not organic -- are floor coverings (33 percent of total demand in 1988), apparel (27 percent in 1988), and home textiles (10 percent in 1988).[123]

Less than a dozen companies -- all horizontally integrated and multinational -- account for about 90 percent of U.S. production of man-made fibers.[124] DuPont is the largest U.S. fiber producer. Four southern textile states -- South Carolina, Virginia, North Carolina, and Tennessee -- accounted for 80 percent of the total employment of 45,700 in SIC 2824 -- Manmade Organic Fibers, except Cellulosic -- in 1987.[125]

There were widespread capacity reductions in the U.S. man-made fibers industry in the 1980s, so that by the end of the decade, capacity utilization was at an historical high. Polyester is currently at 90 percent, an all-time high. The overall operating rate in the man-made fibers industry increased from 69 percent in 1982 to 89 percent in 1988.[126]

U.S. production of man-made fibers fell 0.5 percent from 4.146 billion kilograms in 1988 to 4.126 billion kilograms in 1989.[127] From 1984 to 1989, output grew at an average annual rate of 2.3 percent. From 1979 to 1989, however, output declined by -0.4 percent per year. The lack of growth in the market can be attributed mainly to an increase in imports of finished textiles. Imports of apparel, for example, now satisfy more than 50 percent of domestic demand.[128] Acrylics and polyester, both of which are heavily dependent on textiles and apparel (80 percent of acrylics consumption, 70 percent of polyster consumption), experienced weak demand in the 1980s. In contrast, there has been strong demand since the mid-1980s for nylon, almost 75 percent of which goes into carpets. Polyolefins, which are also used primarily in carpets (over 50 percent), have enjoyed the strongest growth of the noncellulosic fibers. From 1978 to 1988, the polyolefin fiber market grew by an average of 9 percent per year.[129]

The outlook is for consumption of noncellulosic fibers to be flat or slightly down in 1990. In the longer term, nylon and acrylics should benefit from projected 2-3 percent per year growth in carpets. Long-term demand for polyester, however, is expected to be flat.[130]

4.9.13 Polyethylene

After a shortage in 1989 caused by an explosion at a Phillips 66 facility, new polyethylene capacity in 1990 is expected to put pressure on prices. Worldwide, 12.0 billion kilograms of new polyethylene capacity is in the pipeline.[131] Exxon predicts that worldwide polyethylene capacity will increase by 3.8 percent per year from 27.5 billion kilograms in 1988 to 43.0 billion kilograms in 2000. Meanwhile, Exxon believes that North American demand will increase by only 2.8 percent per year over this period.[132]

More than half of all polyethylene is consumed in packaging. Low-density polyethylene (LDPE) growth is slowing, though linear LDPE, which accounts for about one-third of LDPE production, is forecast to grow 4-6 percent per year in the next few years. By the middle of the 1990s, linear LDPE is expected to account for one-half of all LDPE production.[133] High-density polyethylene (HDPE), at 7 percent per year, was one of the fastest-growing plastics segments in the 1980s. New applications are expected to drive continued strong growth for HDPE at 6-8 percent per year over the long term.[134]

4.9.14 Polypropylene

Polypropylene was the fastest-growing plastics segment in the 1980s with growth of 9 percent per year.[135] The major applications are fibers and filaments, primarily for textiles and carpets (26 percent); and injection moldings for packaging, transportation, and consumer products (25 percent).

Polypropylene is the number-one U.S. petrochemical export product. In 1989, 635 million kilograms of polypropylene were exported, representing about one-fifth of output. U.S. imports of polypropylene are negligible -- only 24 million kilograms in 1989.

The outlook is for price declines resulting from capacity additions. Around the world, 29 new plants are due on stream in 1990 (three in the U.S.), presenting the prospect of "severe overcapacity" in the industry.[136] Continued strong growth, spurred in part from new applications, will help to absorb some of the new capacity, however. Exxon forecasts that demand until 2000 will increase by 5.2 percent per year worldwide and 4.9 percent per year in North America.[137] The increase in production capacity overseas may "cause a major reduction in U.S. export opportunities," however.[138]

4.9.15 Polystyrene

The distribution of polystyrene's major uses is approximately 20 percent for disposable food service ware, 17 percent for other types of packaging, 14 percent for consumer and institutional products, and 12 percent for electrical/electronic products.[139]

Polystyrene faces environmental problems relating to the difficulty of its disposal, and competition in many applications from cheaper HDPE, polypropylene, and polyethylene terephthalate (PET). As a result, demand is only expected to increase by 1-3 percent in 1990.[140] Long-term growth is also likely to be limited. The industry is currently in a state of excess supply. As a result, hardly any additional capacity is due on stream.

4.9.16 Polyvinyl Chloride (PVC)

Like polystyrene, PVC faces particular environmental pressures. In addition, over 60 percent of PVC output is consumed in housing and construction, a depressed market.[141] Consequently, PVC demand is forecast to increase by only 1-3 percent in 1990.[142] Long-term growth is projected to be 3 percent per year.[143] Along with the sluggish demand, capacity additions are expected to "further aggravate pricing pressure."[144] In 1989, the industry operated at 85 percent of capacity.[145]

4.9.17 Acrylonitrile-Butadiene Styrene (ABS)

The primary uses of ABS are automotive products, appliances, electronics (business machines, telecommunications equipment), and construction. In 1989, U.S. exports declined to 61 million kilograms from 111 million kilograms in 1988, while imports increased from 21 million kilograms to 30 million kilograms. Long-term growth is projected to be 4 percent per year.[146]

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CHAPTER 5
BUTADIENE PRODUCTION

5.1 INDUSTRY PROFILE

Butadiene is an unsaturated hydrocarbon that exists in two isomeric forms, of which 1,3-butadiene is commercially important. A gas at ordinary temperatures, this olefin readily forms many products. Most of these products are elastomers and rubbers, including styrene-butadiene, polybutadiene, chloroprene (neoprene), and nitrile.

5.1.1 Brief Market Introduction

5.1.1.1 Historical Overview

Most synthetic organic chemicals (such as butadiene) are produced from petroleum-related feedstocks (mainly crude oil and natural gas). Since these feedstocks typically account for about two-thirds of production costs, petroleum prices have a significant effect on market prices of synthetic organic chemicals.[1] As shown in Table 5-1, the price of butadiene was closely tied to crude oil prices in the 1980s. Both butadiene and crude oil prices peaked in the 1981-1982 period. The price of butadiene fell precipitously from 1985 to 1986, in response to similar movement in the price of crude oil. Since 1986, the price of butadiene has fluctuated from year to year with changes in the price of crude oil.

The principal use for butadiene is to make synthetic rubber, a key input to the tire industry. Consequently, sales of butadiene have been greatly influenced by sales of tires and, in turn, motor vehicles. Butadiene consumption and tire production in the U.S. in the 1980s are compared in Table 5-2. Butadiene consumption slumped in 1982 due to the recession, as did tire output (and motor vehicle sales). Butadiene consumption and tire production were both down in 1985 due to sluggish economic growth. Since 1986, both butadiene consumption and tire output have increased continuously.

5.1.1.2 Recent Developments

The price of butadiene was relatively high in the first half of 1990 -- ranging from 60 to 65 cents per kilogram -- due to a temporary supply shortage. This has been alleviated and the price of butadiene is currently 51 cents per kilogram. The decline in the price of butadiene is attributable to slow growth in butadiene's end-use markets. Early in 1990, the International Institute of Synthetic

TABLE 5-1. AVERAGE U.S. BUTADIENE AND CRUDE OIL PRICES, 1980-1989

	Butadiene (¢/kg)	Crude Oil[a] ($/bbl)
1989	57b	17.70 (est.)
1988	48	14.76
1987	52	17.76
1986	37	14.82
1985	74	26.66
1984	65	28.53
1983	66	28.27
1982	77	31.22
1981	75	34.33
1980	60	24.23

[a] Refiner acquisition cost of domestically produced crude oil.

[b] End-of-year price.

Sources: Research Triangle Institute, "Economic Analysis of Proposed Hazardous Organics NESHAP Controls," 1987; U.S. International Trade Commission, Synthetic Organic Chemicals, 1984-1988; Chemical Marketing Reporter, January 1, 1990; U.S. Department of Commerce, International Trade Administration, U.S. Industrial Outlook 1990, p. 3-4.

TABLE 5-2. APPARENT CONSUMPTION OF BUTADIENE AND PRODUCTION OF CAR, TRUCK, AND BUS TIRES IN THE U.S., 1980-1989

	Butadiene Consumption[a] (10^6 kg)	Tire Production (10^6 Units)
1989	1,728 (est.)	N.A.
1988	1,731	211.0
1987	1,667	204.1
1986	1,266	190.3
1985	1,241	195.9
1984	1,610	209.4
1983	1,425	186.9
1982	1,164	178.5
1981	1,513	181.8
1980	1,472	159.3

[a] Production plus imports, minus exports. Because inventory changes are ignored, this is a simplified estimate of consumption.

Sources: Research Triangle Institute, "Economic Analysis of Proposed Hazardous Organics NESHAP Controls," 1987; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Butadiene," January 1990; <u>Chemical and Engineering News</u>, March 21, 1988 and April 17, 1989.

Rubber Producers forecast that butadiene consumption in North America would increase by only 0.7 percent in 1990.[2] The decline in the price of butadiene has occurred despite a steep rise in the price of crude oil, brought on by the invasion of Kuwait by Iraq. The divergence of butadiene and crude oil prices in 1990 -- which is an exception to the close correlation evidenced throughout the 1980s -- is highlighted in Figure 5-1.

5.1.2 Demand Conditions

5.1.2.1 Uses for Butadiene

Butadiene is an intermediate good with a variety of uses. About 70 percent of butadiene is used in the production of synthetic rubber.[3] Notable butadiene-based synthetic rubbers are styrene-butadiene rubber (SBR), polybutadiene rubber, polychloroprene (neoprene) rubber, and nitrile rubber. SBR is the most important end use for butadiene, accounting for over one-third of sales in 1989 (see Table 5-3). Polybutadiene rubber manufacturing is the next largest use of butadiene (23 percent of sales in 1989). About one-eighth of butadiene production is used for the manufacture of hexamethylene-diamine, which is a chemical used for making nylon fiber and resin. Styrene-butadiene latex and acrylonitrile-butadiene-styrene (ABS) consume 11 percent and 6 percent of butadiene, respectively. These are synthetic elastomers used in fabricated rubber products.

In terms of final goods, motor vehicle tires account for about two-thirds of butadiene sales.[4] Other fabricated rubber products, fabricated plastic products, and various fibers each consume about 10 percent of butadiene production (RTI, 1987).

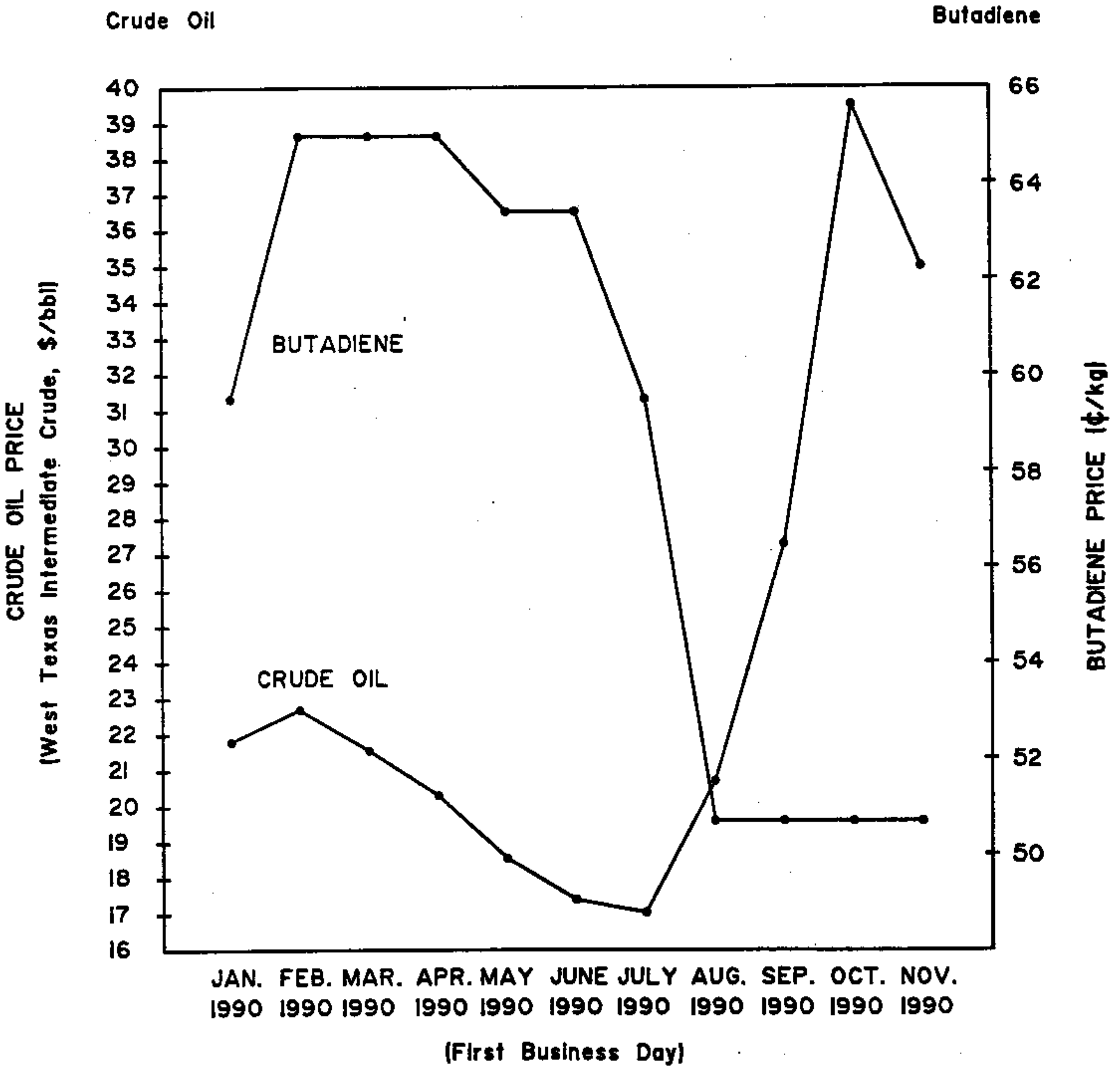
5.1.2.2 Exports

Export demand for butadiene has historically consumed a small fraction of U.S. production (see Table 5-4). In the 1980s, exports rose to a peak of 84.8 million kilograms in 1985, representing 8.0 percent of U.S. output. Since 1985, the absolute and relative amounts of butadiene exported have diminished.

5.1.2.3 Future Prospects

The demand for synthetic rubber, and in turn butadiene, was hampered in the 1980s by increased imports of tires and automobiles equipped with foreign-made tires, the switch to radial tires (which last longer than bias-ply tires), other performance improvements on tires, lower speed limits, and automobile downsizing. Some of these

FIGURE 5-1. RECENT PRICES OF BUTADIENE AND CRUDE OIL



Sources: The <u>Wall Street Journal</u>, various issues;
and <u>Chemical Marketing Reporter</u>, various issues.

TABLE 5-3. BUTADIENE USES (BY 1989 CONSUMPTION)

	Percent of Total Consumption
Styrene-butadiene rubber	35%
Polybutadiene rubber	23%
Adiponitrile/Hexamethylenediamine (HMDA)	12%
Styrene butadiene latex	11%
Acrylonitrile-butadiene-styrene (ABS)	6%
Polychloroprene (neoprene) rubber	6%
Nitrile rubber	3%
Other	4%

Source: Chemical & Engineering News, June 25, 1990, p. 19.

TABLE 5-4. U.S. EXPORTS OF BUTADIENE, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1989	23.6 (est.)	1.7%
1988	59.9	4.2%
1987	68.0	5.1%
1986	81.6	7.1%
1985	84.8	8.0%
1984	65.8	5.9%
1983	43.8	4.1%
1982	46.4	5.3%
1981	50.8	3.8%
1980	58.9	4.6%

[a] See Table 5-6.

Sources: Research Triangle Institute, "Economic Analysis of Proposed Hazardous Organics NESHAP Controls," 1987; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Butadiene," January 1990; <u>Chemical Marketing Reporter</u>, April 2, 1990, p. SR 18.

factors are expected to continue to restrict growth in demand for synthetic rubber. For example, new designs may more than double the useful life of radial tires to over 100,000 miles.[5] Competition from natural rubber, which is expected to be in greater supply because of overplanting, could also reduce the demand for synthetic rubber.[6] ABS, styrene-butadiene latex, and some specialty applications (all non-elastomers) are expected to be growth markets, however. Overall, in the long term, Standard & Poor's projects butadiene growth to be flat or up slightly.[7] In 1988, Chemical Marketing Reporter forecast that butadiene demand would increase by 0.5 percent per year through 1992.[8] Mannsville Chemical Products Corp., on the other hand, expects that butadiene demand will decline in the long term.[9] They believe that 1989 may have been the "high water mark" for U.S. butadiene consumption.

5.1.3 Supply Conditions

5.1.3.1 Production Processes

Two different production processes can be used to produce butadiene: dehydrogenation of butylenes and coproduction with olefins using steam crackers. Virtually all butadiene in the U.S. is produced by the latter process, which involves two major production steps. The olefins process produces unsaturated hydrocarbons (such as ethylene) and a mixed-C4 stream. Butadiene is then recovered from the mixed-C4 stream. In March 1990, the average butadiene coproduct yield from 100 pounds of ethylene was 7.31 pounds.[10]

A variety of feedstocks can be used in the coproduction process. Ethane, propane, and butane are considered "light" feedstocks. They yield very little butadiene. The "heavier" feedstocks, such as naphtha, yield up to ten times more butadiene.[11] It is estimated that 25-30 percent of olefin production capacity is flexible enough to use either light or heavy feedstocks.[12] The choice of which feedstock to use depends usually on relative feedstock costs and the relative prices of coproducts. Output of butadiene, then, can be highly variable.

5.1.3.2 Domestic Producers and Total Production

Butadiene has been produced in the United States since the 1940s. Presently there are 12 facilities in the U.S. that produce butadiene. They are all located in Texas or Louisiana, near the major sources of feedstocks. A listing of the 12 plants and their finished production capacities appears in Table 5-5. Texas Petrochemicals is

TABLE 5-5. U.S. PRODUCERS OF BUTADIENE, 1990

Company	Plant Location	Finished Capacity (10^6 kg/year)
Amoco Chemical	Chocolate Bayou, TX	81.6
Cain Chemical[a]	Chocolate Bayou, TX	61.2
	Corpus Christi, TX	99.8
Dow Chemical	Freeport, TX	18.1
Exxon Chemical Americas	Baton Rouge, LA	145.1
	Baytown, TX	131.5
Lyondell Petrochemical[b]	Channelview, TX	204.1
Mobil Chemical	Beaumont, TX	27.2
Shell Chemical	Deer Park, TX	113.4
	Norco, LA	226.8
Texaco Chemical	Port Neches, TX	226.8
Texas Petrochemicals[c]	Houston, TX	362.9
		1,698.5

[a] Subsidiary of Occidental Petroleum Co.

[b] Division of Atlantic Richfield Co.

[c] Subsidiary of Texas Olefins Co.

Source: Chemicalweek, May 2, 1990, p. 14.

the only producer with on-purpose butylene dehydrogenation capacity, which accounts for about half of its total capacity of 362.9 million kilograms. This capacity is utilized or idled depending on market conditions.[13] All other butadiene in the U.S. is produced as a coproduct of ethylene production at steam crackers.

U.S. production of butadiene from 1979 to 1989 is shown in Table 5-6. Output has rebounded since 1985, after falling from higher levels in the late 1970s and early 1980s. However, from 1988 to 1989, production declined 2.4 percent from 1,437 million kilograms to 1,403 million kilograms. Production in 1989 represented 82.6 percent of U.S. capacity.

5.1.3.3 Costs of Production

Butadiene production is capital-intensive and utilizes only a small skilled work force. In 1982, approximately 300 people worked at 14 plants producing butadiene; two-thirds were production workers.[14] On average there were 21 total workers and 14 production workers per plant.

As in most chemical production, the cost of raw materials constitutes the majority of the variable costs of butadiene production. Thus, variable costs are tied to the plant's choice of feedstock. The recent surge in petroleum prices has probably increased the cost of butadiene production (to the extent that feedstock costs are not contractually locked-in). Generally, an increase in petroleum prices encourages a switch to lighter feedstocks, which have a lower butadiene yield. Therefore, higher petroleum prices can result in upward pressure on the price of butadiene not only directly by increasing feedstock costs, but also indirectly by reducing the supply of butadiene (causing the supply curve to shift up and to the left).

5.1.3.4 Imports

Production of butadiene kept pace with demand for many years. However, by 1970, demand had increased beyond the domestic industry's ability to meet it, and as a result, U.S. firms began importing butadiene, chiefly from European producers. European producers use heavy naphtha feedstocks and tend to have excess supplies of butadiene.[15] In 1970, imports of butadiene were about 52 million kilograms; by 1980, they had risen to 261 million kilograms. As shown

TABLE 5-6. U.S. PRODUCTION OF BUTADIENE, 1979-1989

	Quantity (10^6 kg)
1989	1,403
1988	1,437
1987	1,329
1986	1,155
1985	1,061
1984	1,112
1983	1,067
1982	869
1981	1,354
1980	1,270
1979	1,625

Source: Chemical & Engineering News, June 18, 1990, p. 39.

in Table 5-7, imports peaked in 1983 at 401.3 million kilograms (over one-quarter of the butadiene sold in the United States that year). Imports plunged in 1985 and 1986, but rebounded in 1987. The decrease in imports in 1985 was largely due to the nearly proportionate drop in consumption that year (see Table 5-2). The decline in imports in 1986 can be attributed to low crude oil prices, which caused domestic producers to crack heavy gas oils, yielding increased volumes of butadiene (note the increase in U.S. production in Table 5-6). In 1989, imports were 348.3 million kilograms, representing 20.2 percent of U.S. consumption. Imports from Europe in 1989 amounted to about 200 million kilograms of specific butadiene and 105 million kilograms of recoverable butadiene in crude C4 compounds.[16]

5.1.3.5 Future Prospects

Thus far, the price of butadiene has not responded to the surge in the price of crude oil beginning in August 1990. Perhaps this is because feedstock prices have been contractually fixed. Eventually, however, the price of butadiene is likely to rise. This would result both from an increase in feedstock costs and a reduction in butadiene output as producers switch to lighter feedstocks with lower butadiene yields.

Two debottlenecking projects will increase U.S. production capacity for butadiene in 1991.[17] Texas Petrochemicals will be adding 500 million pounds (226.8 million kilograms) of capacity at its Houston facility, while Texaco will be adding 150 million pounds (68.0 million kilograms) in Port Neches, Texas. Significant new ethylene capacity is also due on stream in 1991, but this will have little impact on butadiene production because ethane will be the feedstock. Despite the new capacity, U.S. production of butadiene is still projected to fall 280 million kilograms short of annual demand in 1993.[18] Europe will have an ample surplus, however, to make up for this deficit.[19]

5.1.4 Future Market Prospects

The U.S. butadiene market, with its dependence on synthetic rubber, is mature. In the long term, demand is expected to grow very slowly or perhaps even decline. The U.S. relies greatly on imports to meet its supply needs (20.2 percent of consumption in 1989). With 295 million kilograms of new capacity due on stream in the U.S. in 1991, this dependence on imports may be lessened. Still, in 1993, it is projected that U.S. production will fall 280 million kilograms short

TABLE 5-7. U.S. IMPORTS OF BUTADIENE, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Consumption[a]
1989	348.2 (est.)	20.2%
1988	353.3	20.4%
1987	373.3	22.4%
1986	193.2	15.3%
1985	264.9	21.3%
1984	396.0	24.6%
1983	401.3	28.2%
1982	341.7	29.4%
1981	209.6	13.9%
1980	261.1	17.7%

[a] See Table 5-2.

Sources: Research Triangle Institute, "Economic Analysis of Proposed Hazardous Organics NESHAP Controls," 1987; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Butadiene," January 1990; Chemical Marketing Reporter, April 2, 1990, p. SR 18.

of demand. Excess supplies in Europe will be able to make up the shortfall, however.

The price of butadiene, currently at 23 cents per pound (50.7 cents per kilogram), has not yet responded to the recent increase in crude oil prices. Normally, an increase in crude oil prices causes the price of butadiene to increase. This presents the possibility that the price of butadiene will rise in the near future. Upward price pressure may be alleviated, however, by the new capacity due on stream in the U.S. in 1991.

5.2 ECONOMIC IMPACT ANALYSIS

5.2.1 Hon Compliance Costs

A synopsis of annualized cumulative control costs and summary statistics for butadiene production facilities, and control costs by process, is presented in Table 5-8. Costs are displayed for option one, which is an estimate of the actual control cost that a facility will incur. Figure 5-2 illustrates control costs graphically. Eleven facilities are displayed.

Butadiene is currently produced by two processes: as a coproduct in the manufacture of ethylene (process A), and by dehydrogenation of C4 compounds (process B). Process B is referred to as on-purpose production of butadiene, because plants using process B are dedicated to butadiene production, as opposed to producing butadiene as a coproduct of ethylene. Since it is more profitable to produce butadiene as a coproduct of ethylene, on-purpose butadiene production has been phased out over the last decade. Only Facility 1 currently utilizes process B, but, as of this writing, the plant is idle.

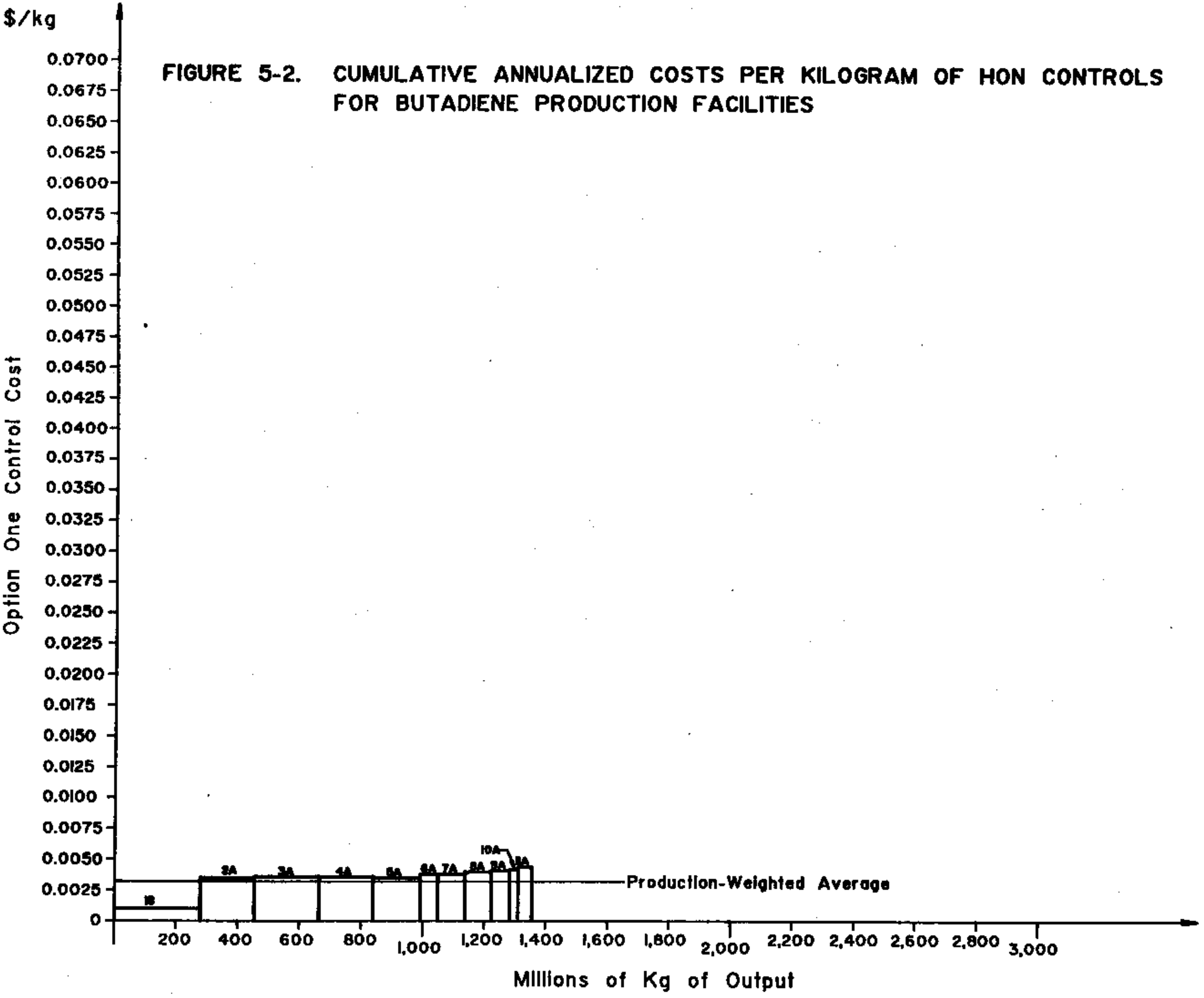
5.2.2 Pricing

Butadiene prices are determined by a combination of feedstock costs, end-use demand, and competition for capacity from other chemical production. The average realized price in 1989 was 43 cents per kilogram. Prices in 1990 were uniformly higher, peaking at 64 cents per kilogram. This was due to supply shortages caused by plant outages, as well as increasing feedstock costs. The most recent spot price available at the time of this writing is 35 cents per kilogram, a significant decline due to lower feedstock costs and capacity expansion. Prices could go lower still in tandem with feedstock costs and sluggish end-use demand. Since this analysis uses the 1989 price of 43 cents per kilogram, impacts could be understated.

TABLE 5-8. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR BUTADIENE PRODUCTION FACILITIES AND BUTADIENE PRODUCTION PROCESSES

Facility	Annual Production (10^6 kg)	Option One Control ($/kg)
1B	279.5	$.0010
2A	174.8	$.0035
3A	209.4	$.0036
4A	174.8	$.0036
5A	122.4	$.0035
6A	87.4	$.0038
7A	87.4	$.0038
8A	77.0	$.0040
9A	70.1	$.0041
10A	27.7	$.0042
11A	45.4	$.0044
Control Costs by Process		
Process A (coproduct of ethylene)	1,076.5	$.0037
Process B (dehydrogenation of C4 compounds)	279.5	$.0010
Summary Statistics		
Mean		$.0036
Production Weighted Average		$.0032

FIGURE 5-2. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR BUTADIENE PRODUCTION FACILITIES



5.2.3 Elasticities

Demand elasticities for butadiene will be estimated on the basis of available substitutes for butadiene as well as substitutes for end-users. The potential for import substitution is also examined.

5.2.3.1 Demand Elasticities

5.2.3.1.1 Synthetic Rubbers

Synthetic rubbers account for over 80 percent of U.S. butadiene consumption. Synthetic rubbers fall into two categories: general-purpose rubbers, the bulk of which are used in tire manufacture, and specialty rubbers, which have a wide variety of end uses. Butadiene is an essential element in the manufacture of these products, making up between 20 percent and 80 percent of each compound. It is therefore necessary to examine the potential substitutes for synthetic rubbers.

Because of their cost advantage and low temperature buildup during use, general-purpose synthetic rubbers have extracted notable market share from natural rubbers for commercial use, especially for automobile tires, since their inception in the early 1940s. Also, natural rubbers cannot be used in applications where there is contact with naphtha because the solvent swells the rubber. When these performance characteristics are important, synthetic rubber is the material of choice.

Still, natural rubbers have not been replaced for many uses. For example, natural rubber performs better than synthetics for use in large, heavy duty truck and bus tires. In addition, natural rubbers are blended with synthetic rubbers (most notably styrene-butadiene rubber and polybutadiene rubber), for use in automobile tire manufacturing. The recent shift from bias to radial tires has led to an increase in natural rubber use, since natural rubber has a higher degree of cohesive bonding than synthetic rubbers in the manufacture of radial tires. Based on the potential for substitution in some cases, butadiene demand for use in general purpose rubbers is deemed to be slightly inelastic.

Specialty rubbers are less apt to be substituted for. Nitrile rubbers and polychloroprene rubber are useful for their fire-retardant, solvent-resistent, and high-temperature stability properties. These rubbers are used in such applications as gaskets, oil and gas hoses, and solvent-resistent electrical insulation. Natural rubber, unless modified, is not suitable for these purposes, which account for 27 percent of butadiene demand. Here, butadiene demand is considered moderately to highly inelastic.

Styrene-butadiene latex (SBL) is the remaining end use for butadiene. SBL is used in the manufacture of foam rubber, adhesives, fabric treating, and paints. A variety of output substitutes exist for these butadiene uses, but the flexibility of styrene butadiene compounds is very attractive to manufacturers. Specifically, modifying the amount of styrene allows the production of a myriad of final goods. Butadiene demand in this sector is estimated to be slightly to moderately inelastic.

5.2.3.2 Imports

Imports, which have played a significant role in the butadiene market since 1970, could well be diminishing in importance. This is due to increases in U.S. capacity and projections of slow growth in butadiene demand. Nevertheless, butadiene is a bulk-commodity chemical with a standardized production process easily assimilated throughout the world. With imports still at 20 percent of U.S. consumption, and capacity increases in Europe and the Far East, the ability to recover compliance costs through price increases are, to some extent, hindered by potential losses in market share to imported butadiene.

5.2.3.3 Elasticity Estimate

The demand elasticity varies somewhat from sector to sector, but doesn't appear to extend into the elastic range. Given the importance of natural rubber substitutes and imports, demand elasticity for butadiene is estimated to be in the slightly inelastic range of -.67 to -1.00.

5.2.4 Market Structure

Table 5-9 summarizes the parameters for the market structure of butadiene. Nine firms are currently producing butadiene. The four-firm concentration ratio is 71.0 percent, signifying substantial market power. The HHI is 1,562.3, which falls moderate range of market power. Captive consumption is 3 percent, indicating a slight level of vertical integration. On average, 5 chemical compounds are produced at butadiene sites, suggesting a substantial level of horizontal integration. Imports in the industry are important, serving to undermine pricing discretion of domestic producers. In summary, the butadiene market is moderately oligopolistic, and firms will likely absorb a portion of HON compliance costs.

TABLE 5-9. MARKET STRUCTURE CHARACTERISTICS FOR BUTADIENE

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced At Site (Horizontal Integration)	Imports
9	71.0%	1,562.3	3%	5	Important

[a] HHI- Herfindahl-Hirschman Index

5.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the butadiene industry, option one control costs are presented in Table 5-10.

5.2.5.1 Option One Control Costs

Option one control costs represent the actual estimated control cost that an industry will incur. The weighted average percentage price increase of 0.74 percent leads to a price increase of $.0032 per kilogram. For the two elasticity levels of -.67 and -1.00, the output reduction is 6.6 million kilograms (.49%) and 9.9 million kilograms (0.73%), respectively.

Facility 10A, which is the smallest plant in the industry, accounts for 27.7 million kilograms of industry production. If this plant absorbs the entire decline in output, it would lose from 24 to 36 percent of its production, which could lead to closure of one facility of this size. The loss in employment is estimated to be from 8 to 12 employees.

5.2.6 Conclusion

Control costs at the facility level range from $.0010 per kilogram to $.0044 per kilogram, with 10 of 11 facilities incurring costs greater than $.0035. Thus, the production-weighted price increase is probably an accurate estimate of the actual price increase. Butadiene is a commercially important chemical produced in large volumes -- ranked 22nd in U.S. organic chemical production. It is produced globally, with technology readily available on the international market. The end uses for butadiene are mature, and significant new specialty uses are not on the horizon. Hence, substantial price increases could be of detriment to the U.S. butadiene market. However, if the highest cost plant is the marginal plant, the maximum price increase will be $.0044 per kilogram. The maximum impact in the industry would be the possible closure of one plant.

TABLE 5-10. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE BUTADIENE INDUSTRY[1] OPTION ONE CONTROL COSTS

	Elasticity	
	-0.67	-1.00
%Δ Price (%/kg)	0.74%	0.74%
Δ Price ($/kg)	$.0032	$.0032
%Δ Output (%/kg)	(0.49%)	(0.73%)
Δ Output (10^6 kg)	(6.6)	(9.9)
%Δ Total Revenue	0.24%	0.00%
Δ Total Revenue (10^6 $)	$1.4	$0.00
Δ Employment (# of Employees)	(8)	(12)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

Δ = Change In

Market Price = $0.43/kg

1995 Output = 1,356 x 10^6 kg (based on 1989 production at 0% annual compound growth)

1995 Total Revenue = $583,067,100.00 (market price x 1995 output)

1995 Employment = 1,589

5.2.7 References

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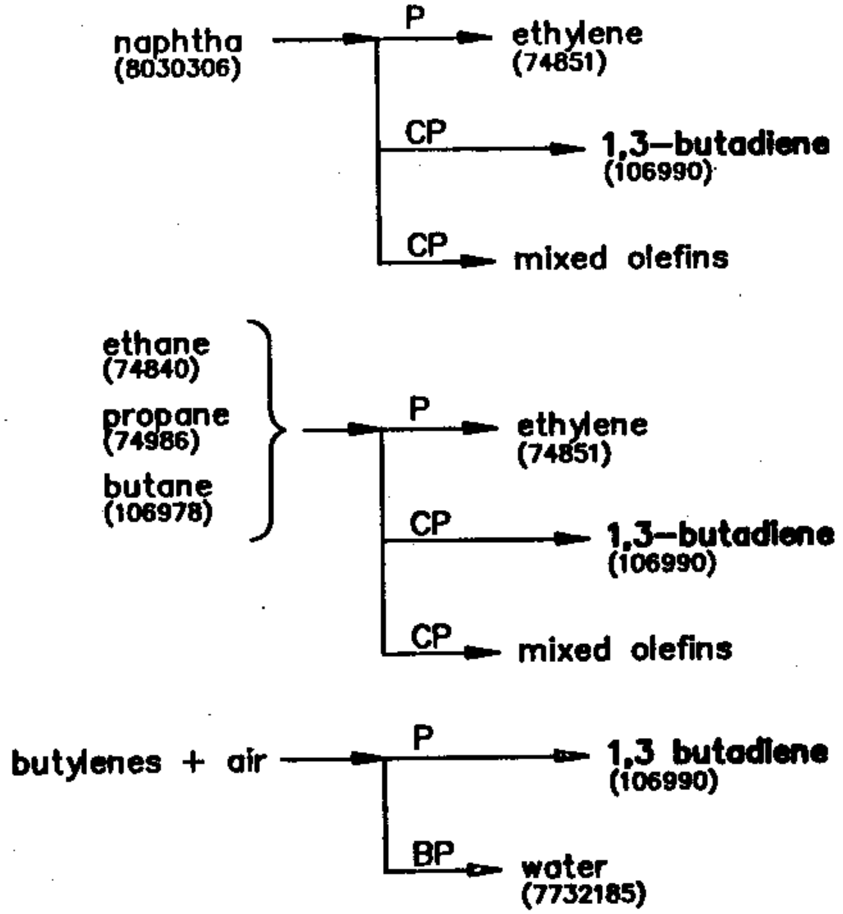
15. "Butadiene Levels Off." Chemicalweek, May 2, 1990, p. 13.
16. Reference 10.
17. Reference 15.
18. Reference 10.
19. Reference 10.

FIGURE 5-3
CHEMICAL TREE
1,3 – BUTADIENE



NOTE:

P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 6

STYRENE-BUTADIENE RUBBER PRODUCTION

6.1 INDUSTRY PROFILE

Styrene-butadiene rubber (SBR) is a synthetic rubber made by the polymerization of styrene and butadiene.* Approximately two-thirds of all SBR is used in tires and tire products.[1] As a result, market conditions for SBR are closely related to the automobile industry. A decline in the U.S. automobile tire market led to several major shutdowns of SBR plants in the first half of the 1980s. From 1981 to 1984, Phillips Petroleum, Firestone, and American Synthetic Rubber all shut down facilities with a combined annual capacity of 380 thousand metric tons.[2] The main survivors of these shutdowns were tire manufacturers who produce SBR for captive use.[3]

6.1.1 Brief Market Introduction

6.1.1.1 Historical Overview

SBR had the largest share -- 37 percent -- of the synthetic rubber market in the U.S. in 1989.[4] SBR's share has been dwindling since 1976, however. In the North American market, SBR had a 54 percent share in 1976 and a 45 percent share in 1984.[6] Smaller-volume specialty rubbers have gained the lost ground.[7]

Experts have labeled the SBR industry as cyclical, noting peaks and valleys every 3 to 4 years.[8] Overall, though, SBR experienced a

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*The group of compounds collectively referred to as styrene-butadiene copolymers are diverse in nature. As discussed later, styrene-butadiene can be in one of two forms at the end of the production process: dry (solid) or latex. In addition, the styrene content, which helps determine the characteristics of the final product, can range from 5 to over 70 percent.[5] The styrene content also determines the classification of a copolymer as either a synthetic rubber or plastic. Copolymers which contain 50 percent or more styrene are generally considered to be plastics, but there is no strict industry-wide definition. The percentage varies not only between the two forms of styrene-butadiene (dry and latex) but also among producers and data sources. Therefore, there are occasional discrepancies in the data on the styrene-butadiene industry, as well as possible double-counting. This profile focuses on dry SBR (SBR elastomer) with a styrene content of 50 percent or less (i.e., not a plastic), which will be referred to simply as SBR.

general decline from 1974 to 1985, and has rebounded somewhat since 1985. From 1974 to 1985, SBR production in the U.S. declined at an average annual rate of 6 percent.[9] The main reasons for the decline were 1) increased imports of tires and automobiles equipped with foreign-made tires; 2) downsizing of automobiles and, in turn, their tires; 3) the increased use of radial tires, which are not only longer-lasting than bias-ply tires, but also have less SBR content (85% on average for bias-ply tires, 61% for radials); and 4) as mentioned, the switch to specialty rubbers.[10]

From a low of 735 million kilograms in 1985, U.S. production was up 19 percent to 874 million kilograms in 1989. Much of the production growth since 1985 is attributable to increased exports, however. SBR consumption in the U.S. hasn't enjoyed the same resurgence since the mid-1980s as production. This is demonstrated in Table 6-1. Consumption of SBR in the U.S. fell almost continuously from 1980 to 1986. Since 1986, the demand for SBR has been stagnant. Table 6-1 also shows that average yearly SBR prices were fairly constant in the 1980s.

6.1.1.2 Recent Developments

U.S. production of SBR fell from 909 million kilograms in 1988 to 874 million kilograms in 1989. This can be traced to a stagnant domestic tire market. U.S. shipments of passenger car, truck, and bus tires declined slightly from 264.7 million units in 1988 to 263.9 million units in 1989.[11]

SBR prices increased by about 2¢ per kilogram in November 1989, and were scheduled for a similar increase in late February/early March 1990. The price hikes were necessary to recover an approximate 4.5¢/kg cumulative increase since the summer of 1989 in the price of butadiene, the chief input to SBR. The price hikes were expected to restore SBR profit margins of a year earlier.[12]

6.1.2 Demand Conditions

6.1.2.1 Uses for Styrene-Butadiene Rubber

As mentioned, about two-thirds of all SBR is consumed in tire and tire products. Mechanical and industrial applications, such as hosing and belts, are the second most important use of SBR, comprising 18 percent of demand in 1988.[13] Automotive industrial applications make up about 9 percent of demand. Therefore, over three-quarters of total demand is related to the automotive industry. SBR has been

TABLE 6-1. AVERAGE REALIZED PRICE AND APPARENT CONSUMPTION OF STYRENE-BUTADIENE RUBBER IN THE U.S., 1980-1989

	Price ($/kg)	Apparent Consumption (10^6 kg)
1989	1.15	793.1
1988	1.17	778.1
1987	1.02	770.8
1986	0.90	771.2
1985	0.84	838.4
1984	1.01	921.3
1983	0.92	887.0
1982	0.99	907.4
1981	1.06	1,014.6
1980	N.A.	1,006.2

Sources: Research Triangle Institute, "Economic Analysis of Proposed Hazardous Organics NESHAP Controls," 1987; U.S. International Trade Commission, Synthetic Organic Chemicals, 1984-1989; Rubber World, May 1990, p. 6; Rubber World, April 1988, p. 11.

losing ground to nitrile rubber, ethylene-propylene rubber (EP), and ethylene-propylene diene monomer rubber (EDPM) in automotive under-the-hood and wire and cable applications.[14]

6.1.2.2 Exports

U.S. export activity for SBR from 1980 to 1989 is summarized in Table 6-2. Exports were more or less flat through 1986. From 1986 to 1987, however, exports increased by 54 percent. This is probably attributable to the decline in the value of the dollar. Exports remained at high levels in 1988 and 1989. Since 1987, exports have accounted for just over 20 percent of U.S. output. The leading markets for U.S. exports of SBR in 1989 were, in order, Canada, Japan, France, and Venezuela.[15] Combined, these four countries accounted for 61.7 percent of U.S. exports.

6.1.2.3 Future Prospects

The demand for SBR in the U.S. is projected to grow very slowly in the next few years. Standard & Poor's, citing "industry participants," predicts that growth will be "flat to very modest" over the next several years.[16] This may be optimistic, though, because it is predicated on "a steady domestic automobile market." In 1988, Chemical Marketing Reporter forecast that domestic and export demand for SBR would grow by only 0.1 percent per year from 1988 to 1992.[17] The main reason for the projected slow growth is that the U.S. tire market is expected to grow slowly. The Commerce Department forecasts that the U.S. tire market will grow no faster than 2 percent per year over the next 3 to 5 years.[18] Moreover, synthetic rubbers are being replaced in the manufacture of tires by rubber/plastic alloys, composite materials, and general-purpose polymer resins.[19] Finally, specialty rubbers are expected to continue to replace SBR in non-tire applications.[20]

6.1.3 Supply Conditions

6.1.3.1 Production Processes

SBR can be produced by two methods: the emulsion process or the solution process. The difference in the two methods is the agent in which the polymerization occurs. The monomer is dispersed in water in the emulsion process and dissolved in a solvent in the solution process. Both processes involve washing the butadiene and styrene

TABLE 6-2. U.S. EXPORTS OF STYRENE-BUTADIENE RUBBER, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1989	175.7	20.1%
1988	189.1	20.8%
1987	172.1	20.2%
1986	111.7	14.1%
1985	82.5	11.2%
1984	103.6	10.8%
1983	85.4	9.4%
1982	86.4	9.9%
1981	110.6	10.7%
1980	145.5	13.5%

[a] See Table 6-4.

Sources: Research Triangle Institute, "Economic Analysis of Proposed Hazardous Organics NESHAP Controls," 1987; Rubber World, May 1990, p. 6; Rubber World, April 1988, p. 11.

monomers and feeding them into polymerization reactors. There the monomers are transformed by the introduction of various catalysts, activators, and emulsifiers. At a specified time, the polymer emulsion (latex) and the unreacted monomer are removed and the monomer is recycled. The emulsion can then take one of two forms. It is either blended into a homogeneous emulsion (latex) or coagulated and dried to form solid (dry) SBR.

SBR is not a homogeneous product; there are at least 30 different types of SBR on the market. The reason for the variations is the need for certain properties of the rubber for the various end uses of SBR. The differentiations are achieved in the production process by varying the relative quantities of styrene and butadiene that are fed into the polymerization reactors.

6.1.3.2 Domestic Producers and Total Production

As of January 1, 1989, there were 6 plants that produce solid SBR in the United States. The plants are all located in Texas or Louisiana. A listing of the plants and their production capacities appears in Table 6-3. Industry capacity is little-changed from 1984. No facilities have shut down, and the only new facility is Goodyear's in Beaumont, Texas, which has an annual capacity of only 20 million kilograms.

U.S. production of SBR from 1979 to 1989 is shown in Table 6-4. Until 1985, there was a downward trend. Since 1985, however, production has picked up, in part due to the increase in exports (see Table 6-2). The recent surge in production was halted in 1989, when output fell 3.9 percent from 1988.

6.1.3.3 Costs of Production

On average, SBR is 76.5 percent butadiene and 23.5 percent styrene.[21] As of November 2, 1990, the price of butadiene was 23 cents per pound (50.7 cents per kilogram) and styrene was 50 cents per pound ($1.10 per kilogram). The average materials cost for SBR is therefore 64.6 cents per kilogram. The cost to manufacture SBR is estimated to be 22 cents per kilogram.[22] Therefore, raw materials currently account for 75 percent of the cost of SBR.

At the beginning of 1990, butadiene was 26 cents per pound (57.3 cents per kilogram) and styrene was 36.5 cents per pound (80.5 cents per kilogram). Therefore, at the beginning of 1990, the average

TABLE 6-3. U.S. PRODUCERS OF STYRENE-BUTADIENE RUBBER, JANUARY 1, 1989

Company	Plant Location	Process Type	Finished Capacity (10^6 kg/yr)
Ameripol Synpol Co.[a]	Port Neches, TX	Emulsion	336
Copolymer Rubber & Chemical Corp.	Baton Rouge, LA	Emulsion	125
Firestone	Lake Charles, LA	Solution	120
General Tire[b]	Odessa, TX	Emulsion	90
Goodyear	Beaumont, TX	Solution	20[c]
	Houston, TX	Emulsion	305
			996

[a] Subsidiary of Uniroyal Goodrich Tire Co.
[b] Owned by Continental AG (Germany).
[c] For captive use.

Source: SRI International, "1989 Directory of Chemical Producers."

TABLE 6-4. U.S. PRODUCTION OF STYRENE-BUTADIENE RUBBER, 1979-1989

	Quantity (10^6 kg)
1989	874
1988	909
1987	850
1986	792
1985	735
1984	958
1983	904
1982	876
1981	1,032
1980	1,074
1979	1,378

Source: Chemical & Engineering News, June 18, 1990, p. 41.

materials cost for SBR was 62.7 cents per kilogram. It is seen, then, that the materials cost of SBR increased by about 2 cents per kilogram in the first ten months of 1990.

6.1.3.4 Imports

Imports of SBR increased fairly steadily in the 1980s, as demonstrated in Table 6-5. Imports represented 13.7 percent of U.S. consumption in 1989, compared to 4.1 percent in 1980. Despite the rising level of imports, the U.S. was a net exporter of SBR in every year in the 1980s except 1985 (compare Table 6-5 with Table 6-2).

The price increase that was scheduled for late February/early March 1990 was expected to "invite more reliance on imports from Mexico and the Netherlands."[23] Other major sources of imports to the U.S. include Japan and Argentina.[24] Freight from Japan to the West Coast of the U.S. is estimated to cost 8 cents per pound (17.6 cents per kilogram), while freight from Europe to the East Coast is estimated to cost 6 to 6.5 cents per pound (13.2 - 14.3 cents per kilogram).[25]

6.1.3.5 Future Prospects

The decline in production of SBR from 1988 to 1989 may have signaled an end to the resurgence of the industry since 1985. Demand is currently stagnant and is projected to grow at a very slow rate over the next few years. U.S. producers may continue to be dependent on strong export demand to increase, and maybe even maintain, their level of output.

6.1.4 Future Market Prospects

With the recent surge in crude oil prices, there may be upward pressure on the price of butadiene. Because butadiene is the chief constituent of SBR, it follows that SBR prices may increase in the near future. This would result in a reduction in the quantity demanded. Already, SBR demand is sluggish. Apparent consumption of SBR has been stagnant, and was at a lower level in 1989 than at the beginning of the 1980s. SBR faces competition from alternative rubbers like nitrile, ED, and EPDM. New materials like rubber/plastic alloys, composites, and general-purpose polymer resins are making inroads on synthetic rubbers in the manufacture of tires. Further,

TABLE 6-5. U.S. IMPORTS OF STYRENE-BUTADIENE RUBBER, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Consumption[a]
1989	109.0	13.7%
1988	91.5	11.8%
1987	83.3	10.8%
1986	95.8	12.4%
1985	95.5	11.4%
1984	71.6	7.8%
1983	63.2	7.1%
1982	54.8	6.0%
1981	51.3	5.1%
1980	41.2	4.1%

[a] See Table 6-1.

Sources: Research Triangle Institute, "Economic Analysis of Proposed Hazardous Organics NESHAP Controls," 1987; <u>Rubber World</u>, May 1990, p. 6; <u>Rubber World</u>, April 1988, p. 11.

natural rubber, SBR's chief competitor, is expected to be available in greater supply due to overplanting.[26] Although the U.S. is a net exporter of SBR, there is still a substantial reliance on imports, which accounted for 13.7 percent of consumption in 1989. All of this suggests that U.S. production of SBR will grow very slowly in the next several years.

6.2 ECONOMIC IMPACT ANALYSIS

6.2.1 HON Compliance Costs

A synopsis of annualized cumulative control costs and summary statistics for styrene-butadiene rubber production facilities is presented in Table 6-6. Costs are presented for option one controls. Option one controls are estimates of the actual costs that facilities are likely to incur. Figure 6-1 illustrates control costs graphically. Five facilities are displayed.

Styrene-butadiene rubber is currently produced from styrene and butadiene. Since this is the only commercial process, no analysis of separate process costs is necessary.

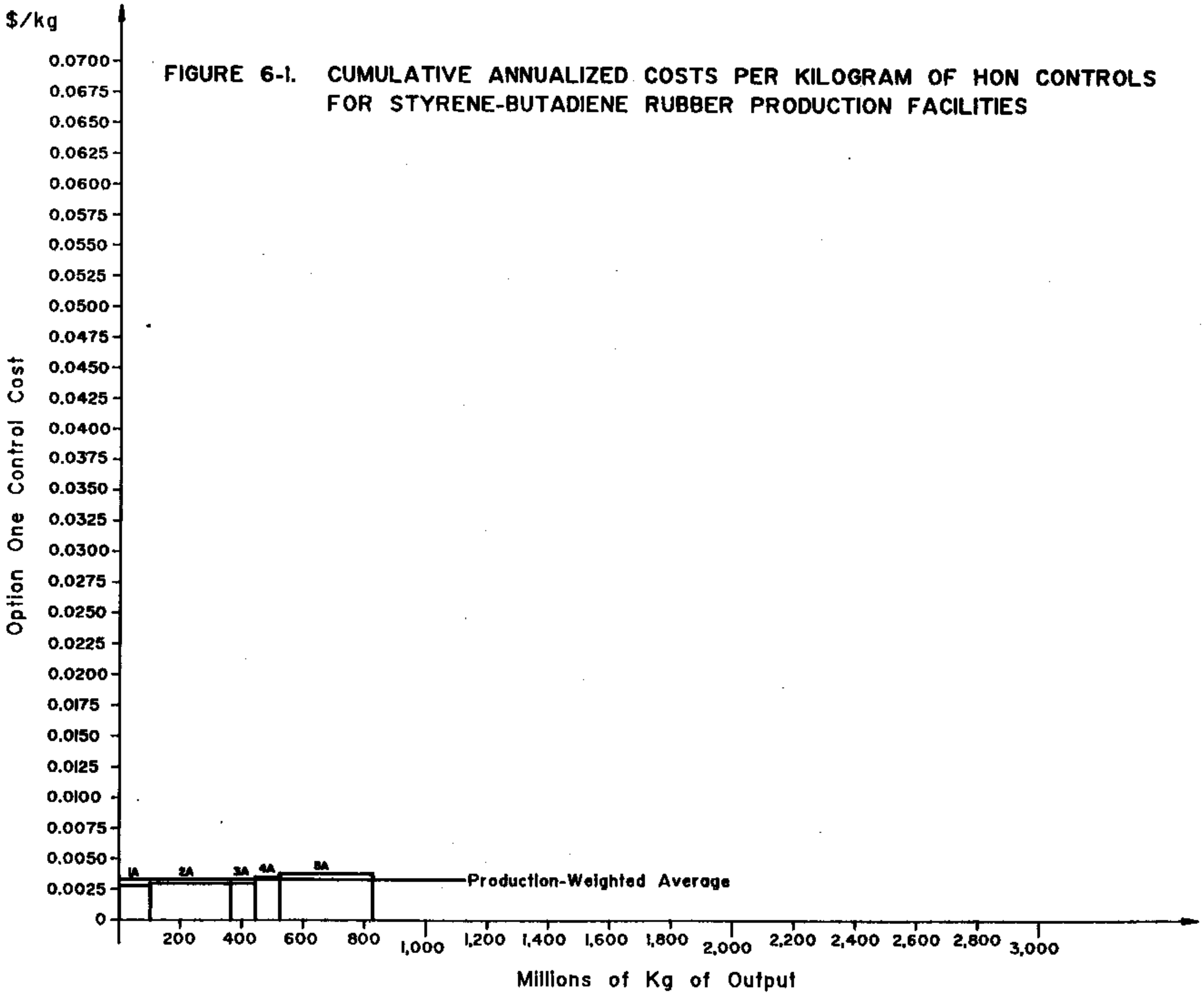
6.2.2 Pricing

SBR prices are determined by a combination of feedstock costs and end-use demand. Styrene and butadiene are the principal inputs in SBR, with approximately a 25 to 75 ratio. In turn, benzene is the feedstock of styrene, and ethylene streams make up the bulk of butadiene inputs. Projected to increase by 5.6 percent annually, benzene demand could put upward pressure on styrene-butadiene rubber prices through styrene pass-throughs. It should be noted that benzene prices themselves are dependent on a variety of exogenous factors and have been volatile. On the other hand, ethylene feedstock has been dropping in price sharply, due to capacity expansions. Average realized prices for SBR in 1989 were $1.15 per kilogram. Continued slow growth in the U.S. tire market, projected even if the general economy begins to expand, will constrain prices. Demand is projected to grow .1 percent annually through 1992. Growth beyond 1992 will continue to be lethargic, as styrene-butadiene rubber producers lose market share to a variety of competitors. If prices drop, as they might, HON impacts will be understated.

TABLE 6-6. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR STYRENE-BUTADIENE RUBBER PRODUCTION FACILITIES

Facility/Process	Annual Production (10^6 kg)	Option One Controls ($/kg)
1A	106.3	$0.0028
2A	259.3	0.0030
3A	76.5	0.0030
4A	285.6	0.0035
5A	102.0	0.0038
<u>Summary Statistics</u>		
Mean		$0.0032
Production Weighted Average		$0.0033

FIGURE 6-1. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR STYRENE-BUTADIENE RUBBER PRODUCTION FACILITIES



6.2.3 Elasticities

Demand elasticities for styrene-butadiene rubber will be estimated on the basis of available substitutes for styrene-butadiene rubber, as well as substitutes for end-users. The potential for import substitution is also examined.

6.2.3.1 Demand Elasticities

6.2.3.1.1 General-Purpose Rubbers

About two thirds of all SBR is consumed in tire and tire products. Considered a general-purpose rubber, SBR accounts for about 37 percent of all synthetic rubbers. Because of their cost advantage and low temperature buildup during use, general-purpose synthetic rubbers have extracted notable market share from natural rubbers for commercial use, especially for automobile tires, since their inception in the early 1940s. Also, natural rubbers cannot be used in applications where there is contact with naphtha because the solvent swells the material. When these performance characteristics are important, synthetic rubber is the material of choice.

Still, natural rubbers have not been replaced for many uses, and in 1989 made up 30 percent of U.S. consumption. For example, natural rubber performs better than synthetics for use in large, heavy-duty truck and bus tires. In addition, natural rubbers are blended with SBR for use in automobile tire manufacturing. The recent shift from bias to radial tires has led to an increase in natural rubber use, since natural rubber has a higher degree of cohesive bonding than synthetic rubbers in the manufacture of radial tires. Moreover, several synthetic materials are emerging as feasible substitutes for SBR, including nitrile, ED, and EDPM rubbers; rubber/plastic alloys and composites; and general-purpose polymer resins. Based on the potential for substitution, styrene-butadiene rubber demand for use in general purpose rubbers is considered to be slightly inelastic.

6.2.3.2 Imports

Imports in the styrene-butadiene rubber market are important, accounting for 13.7 percent of 1989 U.S. consumption. Exports are considerably larger, making up 20.1 percent of U.S. production in 1989. The presence of such an abundance of styrene-butadiene rubber traded on the international market suggests that SBR producers should be sensitive to the prospects for import substitution.

6.2.3.3 Elasticity Estimate

The demand elasticity SBR is estimated to be in the slightly inelastic range of -.67 to -1.

6.2.4 Market Structure

Table 6-7 summarizes the parameters for the market structure of SBR. Five firms are currently producing SBR. The four-firm concentration ratio is 91 percent, ranked ninth of the 20 chemicals analyzed, signifying substantial market power. The HHI is 2,587.1, well above the highly significant level of 1,800. Imports in this industry are very important, serving to undermine pricing discretion for domestic producers. In summary, the SBR industry is moderately to highly oligopolistic, and producers will likely absorb a portion of HON compliance costs.

6.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the Butadiene industry for option one controls are presented in Table 6-8.

6.2.5.1 Option One Control Costs

Option one control costs (TIC) are estimates of the actual control cost that an industry will incur. The weighted average percentage price increase of .28 percent leads to a price increase of $.0033 per kilogram. For the two elasticity levels of -.67 and - 1.00, the output reduction is 1.6 million kilograms (.19%) and 2.4 million kilograms (.28%), respectively.

The smallest plant in the industry is Facility 3A, which accounts for 76.5 million kilograms of industry production. If this plant absorbs the entire decline in output, it would lose from 2 to 3 percent of its production, which probably won't lead to closure. The highest cost plant accounts for 102 million kilograms of industry output. If faced with the same price increase, its output reduction would be even smaller. The decline in employment is five to seven employees. While imports are important, this small price increase is unlikely to spur import substitution.

6.2.6 Conclusion

Styrene-butadiene rubber is a slow growth chemical tied to a lethargic tire industry. The impact of HON controls might help to reinforce the slowing of this ebbing industry, but very imperceptibly.

TABLE 6-7. MARKET STRUCTURE CHARACTERISTICS FOR STYRENE-BUTADIENE RUBBER

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced At Site (Horizontal Integration)	Imports
5	91%	2,587.1	N.A.	N.A.	Important

N.A. - Not Available

[a] Herfindahl-Hirschman Index

TABLE 6-8. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE STYRENE-BUTADIENE RUBBER INDUSTRY[1]

	Elasticity	
	-0.67	-1.00
%Δ Price (%/kg)	0.28%	0.28%
Δ Price ($/kg)	$.0033	$.0033
%Δ Output (%/kg)	(0.19%)	(0.28%)
Δ Output (10^6 kg)	(1.6)	(2.4)
%Δ Total Revenue	0.09%	0.00%
Δ Total Revenue (10^6 $)	$0.90	$0.00
Δ Employment (# of Employees)	(5)	(7)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

Δ = Change In

Market Price = $1.15/kg

1995 Output = 834.6 x 10^6 kg (based on 1989 production at .1% annual compound growth)

1995 Total Revenue = $959,778,569.70 (market price x 1995 output)

1995 Employment = 2,615

The range of cost increases between facilities is $.0038 per kilogram to $.0028 per kilogram. The cost differential is small, so the production-weighted average is probably an accurate measure of the actual price increase. Closure is highly unlikely, and the loss in employment is small. Impacts are negligible in the SBR industry.

6.2.7 References

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21. Reference 12.

22. Reference 12.

23. Reference 12.

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25. Reference 12.

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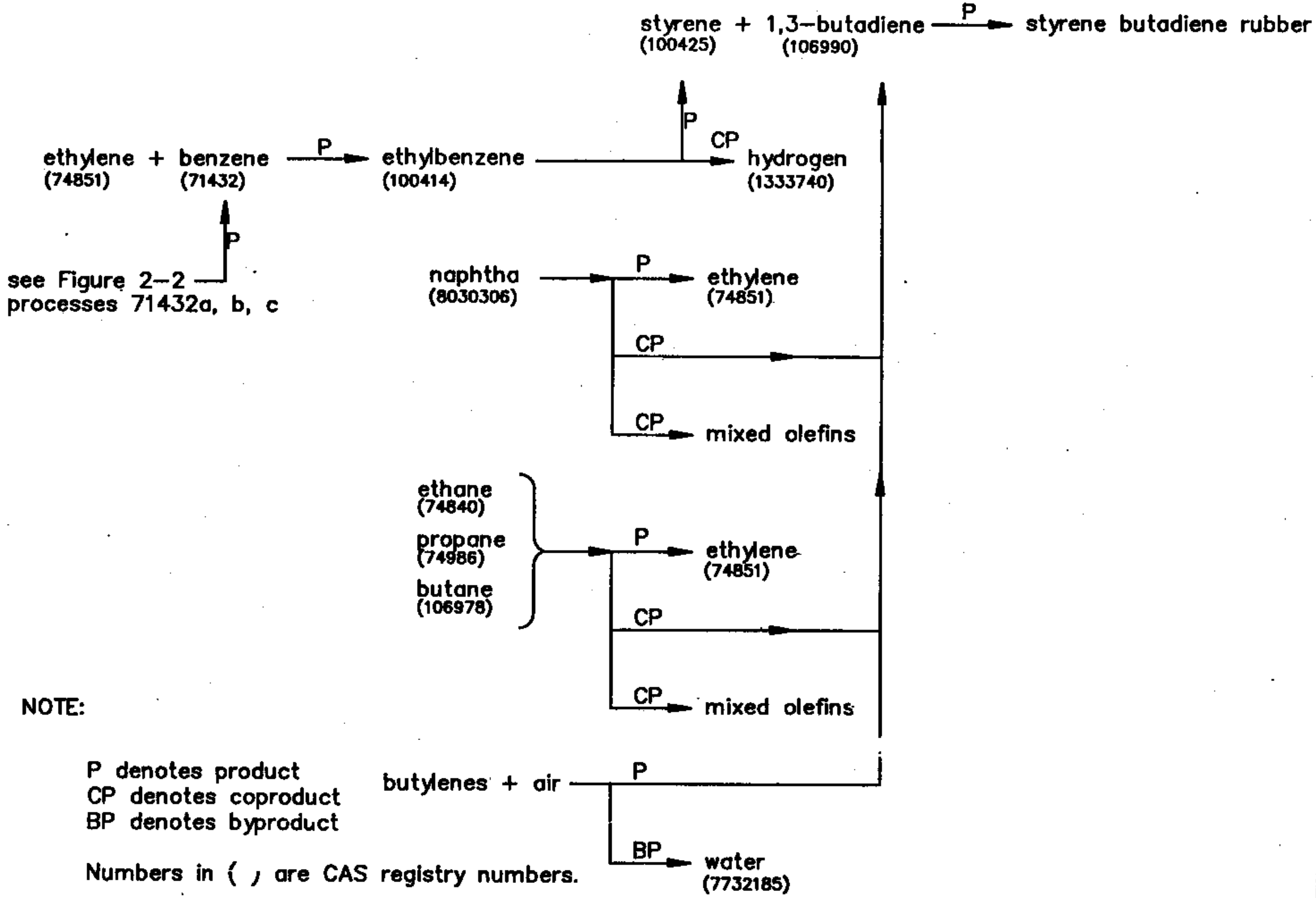
FIGURE 6-2

CHEMICAL TREE

STYRENE BUTADIENE RUBBER



NOTE:

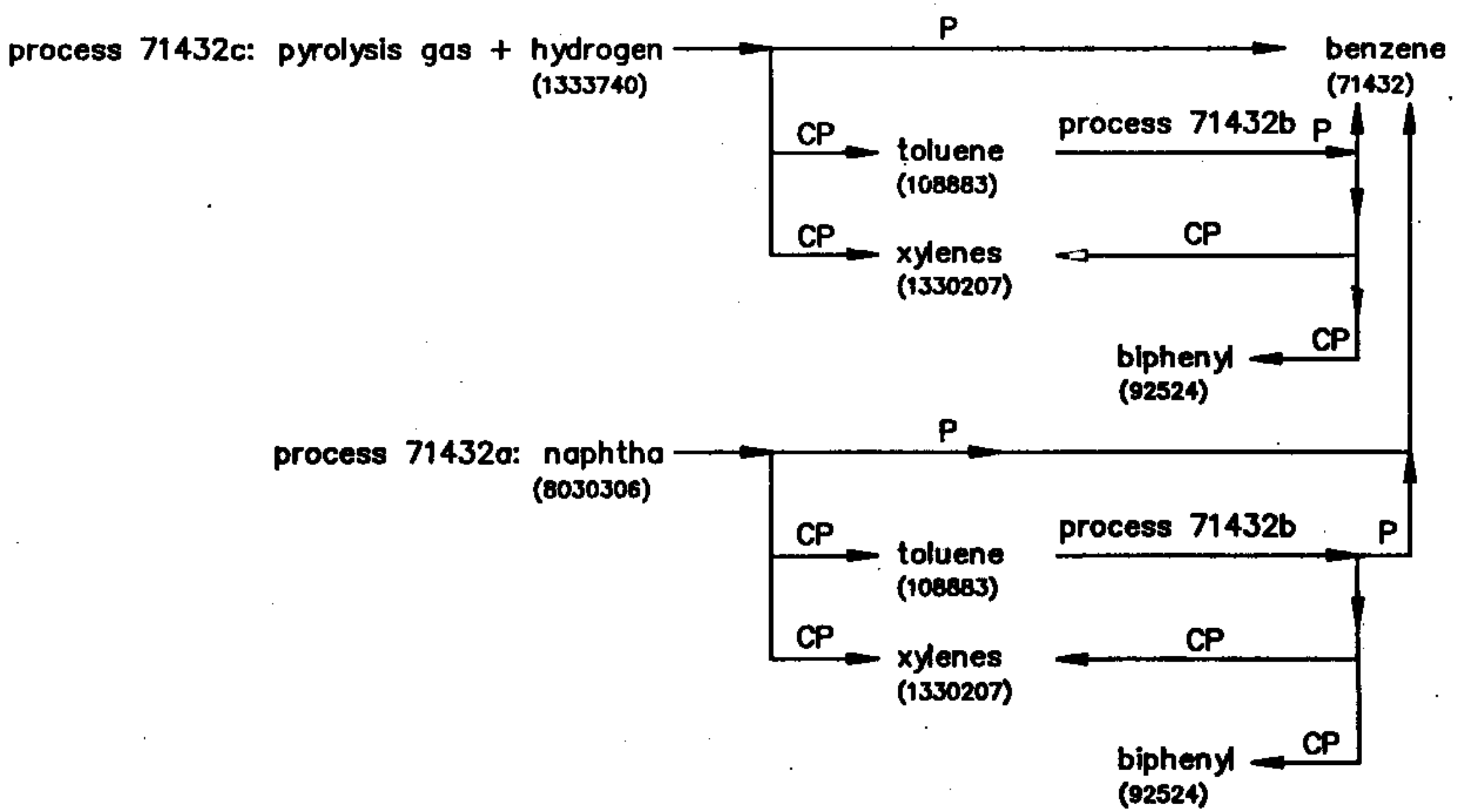
P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

FIGURE 6-3

CHEMICAL TREE

BENZENE



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 7

POLYBUTADIENE PRODUCTION

7.1 INDUSTRY PROFILE

7.1.1 Brief Market Introduction

7.1.1.1 Historical Overview

Polybutadiene is a synthetic rubber made from the polymerization of butadiene. Since 79 percent of all polybutadiene in the U.S. is consumed in tires and tire products, the industry is closely tied to the automobile industry.[1] After SBR, polybutadiene is the second-largest synthetic rubber, with 17 percent of the U.S. market.[2] Average realized prices and apparent consumption of polybutadiene from 1980 to 1989 are shown in Table 7-1. Prices have declined a little from 1984-1985, while consumption seems to have had cyclical peaks in 1984 and 1988. In 1989, for the first time since 1980, the U.S. was a net exporter of polybutadiene.

7.1.1.2 Recent Developments

From March 1989 to September 1990, there was no change in any polybutadiene list prices (e.g., Stereon 840A).[3] However, it is suspected that discounting off of list is common, and therefore list prices are not very meaningful. In 1988, for example, prices were described as being "significantly below list."[4] Consequently, the recent course of polybutadiene prices is not known.

U.S. demand for polybutadiene in 1989 was down 7.7 percent from 1988. Production increased by 1.0 percent, however, thanks to a 22.8 percent increase in exports.

7.1.2 Demand Conditions

7.1.2.1 Uses for Polybutadiene

The main use of polybutadiene is in the manufacture of tires, which makes up 79 percent of sales. The other major end use, representing 17 percent of sales, is high-impact resin modifiers, primarily polystyrene. Industrial products such as hosing, belts, seals, and gaskets account for the remaining four percent of consumption.

Although it is also commercially important as an end product, the bulk of polybutadiene is blended with natural rubber or copolymers such as SBR and acrylonitrile-butadiene-styrene (ABS).[5] For use in tire treads, for example, it is blended with natural rubber or SBR.

TABLE 7-1. AVERAGE REALIZED PRICE AND APPARENT CONSUMPTION OF POLYBUTADIENE IN THE U.S., 1980-1989

	Price ($/kg)	Apparent Consumption (10^6 kg)
1989	1.04	374.8
1988	1.09	406.1
1987	0.99	394.4
1986	1.08	366.8
1985	1.23	374.2
1984	1.21	411.6
1983	N.A.	355.5
1982	N.A.	314.8
1981	N.A.	346.3
1980	N.A.	325.8

Sources: Research Triangle Institute, "Economic Analysis of Proposed Hazardous Organics NESHAP Controls," 1987; U.S. International Trade Commission, <u>Synthetic Organic Chemicals</u>, 1984-1989; <u>Rubber World</u>, May 1990, p. 6; <u>Rubber World</u>, April 1988, p. 11.

7.1.2.2 Exports

Table 7-2 shows U.S. exports of polybutadiene from 1980 to 1989. From 1986 to 1987, exports more than doubled, probably due to the decline in the value of the dollar. Since 1987, exports have remained at high levels. In 1989, exports accounted for 20 percent of U.S. production, the highest level of the decade. In 1989, 58.7 percent of U.S. exports went to Canada, France, and Belgium.[6]

7.1.3.2 Future Prospects

Like SBR, the demand for polybutadiene has been hurt by the sluggishness of the domestic tire market. Nevertheless, the consensus is that polybutadiene demand will grow by one to two percent per year in the next few years. In 1988, Chemical Marketing Reporter forecast that polybutadiene demand would increase by 1.5 percent per year from 1988 to 1992.[7] It was conceded that demand growth in commodity segments (e.g., tires) has reached its limit, but it was added that the demand for new specialty materials, including blends of polybutadiene and SBR, may grow by four to six percent per year and "eventually dominate the tire market." The International Institute of Synthetic Rubber Producers has forecast that polybutadiene demand will increase by 1.6 percent per year in North America from 1990 to 1994.[8] Finally, Standard & Poor's forecasts growth of one to two percent per year through 1992.[9]

7.1.7 Supply Conditions

7.1.3.1 Production Processes

The polymerization of butadiene can yield several different isomeric polymers, but the major one used in polybutadiene production is the cis-1,4 isomer. This polymer is produced primarily by solution polymerization, and to a lesser extent by emulsion polymerization.

The cis-polybutadiene rubber process consists of four steps. In the first step, feed butadiene is dried and combined with a recycled butadiene stream. A solvent is also dried along with a recycled solvent stream. The next step involves feeding these streams to a reactor where the polymerization takes place. Reactor effluent is fed to the concentrator where unreacted butadiene is removed for recycling purposes. In step three, the stream leaving the concentrator is stripped of solvent. Finally, in the last step, the resulting polybutadiene crumb/water stream is dried, compressed, and packaged.

TABLE 7-2. U.S. EXPORTS OF POLYBUTADIENE, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1989	82.3	20.0%
1988	67.0	16.5%
1987	60.8	16.4%
1986	23.7	7.1%
1985	24.5	7.4%
1984	24.4	6.8%
1983	16.3	4.9%
1982	14.6	5.1%
1981	28.1	8.2%
1980	34.9	11.2%

[a] See Table 7-4.

Sources: Research Triangle Institute, "Economic Analysis of Proposed Hazardous Organics NESHAP Controls," 1987; Rubber World, May 1990, p. 6; Rubber World, April 1988, p. 11.

7.1.3.2 Domestic Producers and Total Production

The five facilities in the United States that produce polybutadiene are listed in Table 7-3. The structure of the industry is unchanged from 1984, when a 64 million kilogram facility jointly owned by Phillips Petroleum, Armstrong Rubber, and General Tire was shut down. The American Synthetic facility in Louisville was due for a capacity expansion by the end of 1989.[10] In May 1988, the industry was operating at 98 percent of nameplate capacity.[11]

U.S. production of polybutadiene from 1980 to 1989 is shown in Table 7-4. There was a general upward trend in the 1980s, with output reaching its highest level of the decade in 1989.

7.1.3.3 Costs of Production

The production of polybutadiene is capital-intensive, and it requires a relatively small labor force. Raw materials are therefore the chief variable cost. Butadiene is the major raw material used. From August to November 1990, the price of butadiene fell from 27 cents per pound (59.52 cents per kilogram) to 23 cents per pound (50.71 cents per kilogram).

7.1.3.4 Imports

Imports of polybutadiene have been fairly constant since 1984, after the recessionary years of the early 1980s. In 1989, imports satisfied 17.5 percent of U.S. consumption. The biggest sources of U.S. imports of polybutadiene are, in order, Canada, Japan, Mexico, and the Netherlands.[12] In 1989, these four countries accounted for 83 percent of U.S. imports.

7.1.4 Future Market Prospects

The recent increase in crude oil prices may eventually cause an increase in the price of butadiene. This would increase the cost of polybutadiene production.

Polybutadiene, like SBR, is very dependent on the U.S. tire market. Although the U.S. tire market is expected to remain sluggish, new applications for polybutadiene are predicted to help demand increase by one to two percent per year over the next few years.

TABLE 7-3. U.S. PRODUCERS OF POLYBUTADIENE, JANUARY 1, 1989

Company	Plant Location	Process Type	Annual Capacity (10^6 kg)
American Synthetic Rubber Corp.	Louisville, KY	Solution	70
Ameripol Synpol Co.	Port Neches, TX	Emulsion	a
Firestone	Orange, TX	Solution	110
Goodyear	Beaumont, TX	Solution	180
Polysar, Inc.	Orange, TX	Solution	65
Total			425

[a] Flexible SBR/polybutadiene capacity. Actual production of polybutadiene is unknown, but it is described by the source below to be "very small."

Source: SRI International, "1989 Directory of Chemical Producers," p. 596.

TABLE 7-4. U.S. PRODUCTION OF POLYBUTADIENE, 1980-1989

	Quantity (10^6 kg)
1989	411
1988	407
1987	371
1986	336
1985	330
1984	359
1983	333
1982	288
1981	342
1980	311

Source: Chemical & Engineering News, June 18, 1990, p. 41.

7.2 ECONOMIC IMPACT ANALYSIS

7.2.1 HON Compliance Costs

A synopsis of annualized cumulative control costs and summary statistics for polybutadiene production facilities is presented in Table 7-5. Costs are presented for option one controls. Option one controls are estimates of the actual costs that facilities are likely to incur. Figure 7-1 illustrates the same information graphically. Four facilities are displayed.

Polybutadiene is currently produced by the polymerization butadiene. Since this is the only commercial process, no analysis of separate process costs is necessary.

7.2.2 Pricing

Polybutadiene prices are determined by a combination of feedstock costs and end-use demand. Polybutadiene is produced by the polymerization of butadiene, and butadiene is the principal raw material input. Butadiene prices tied closely to crude oil prices, have been falling in the wake of the Persian-Gulf conflict. Butadiene prices might continue to drop as feedstock costs decline and end-use demand is sluggish. Average realized prices for polybutadiene in 1989 were $1.04 per kilogram. Specialty end-uses will help to keep prices firm.

7.2.3 Elasticities

Demand elasticities for styrene-butadiene rubber will be estimated on the basis of available substitutes for styrene-butadiene rubber, as well as substitutes for end-users. The potential for import substitution is also examined.

7.2.7.1 Demand Elasticities

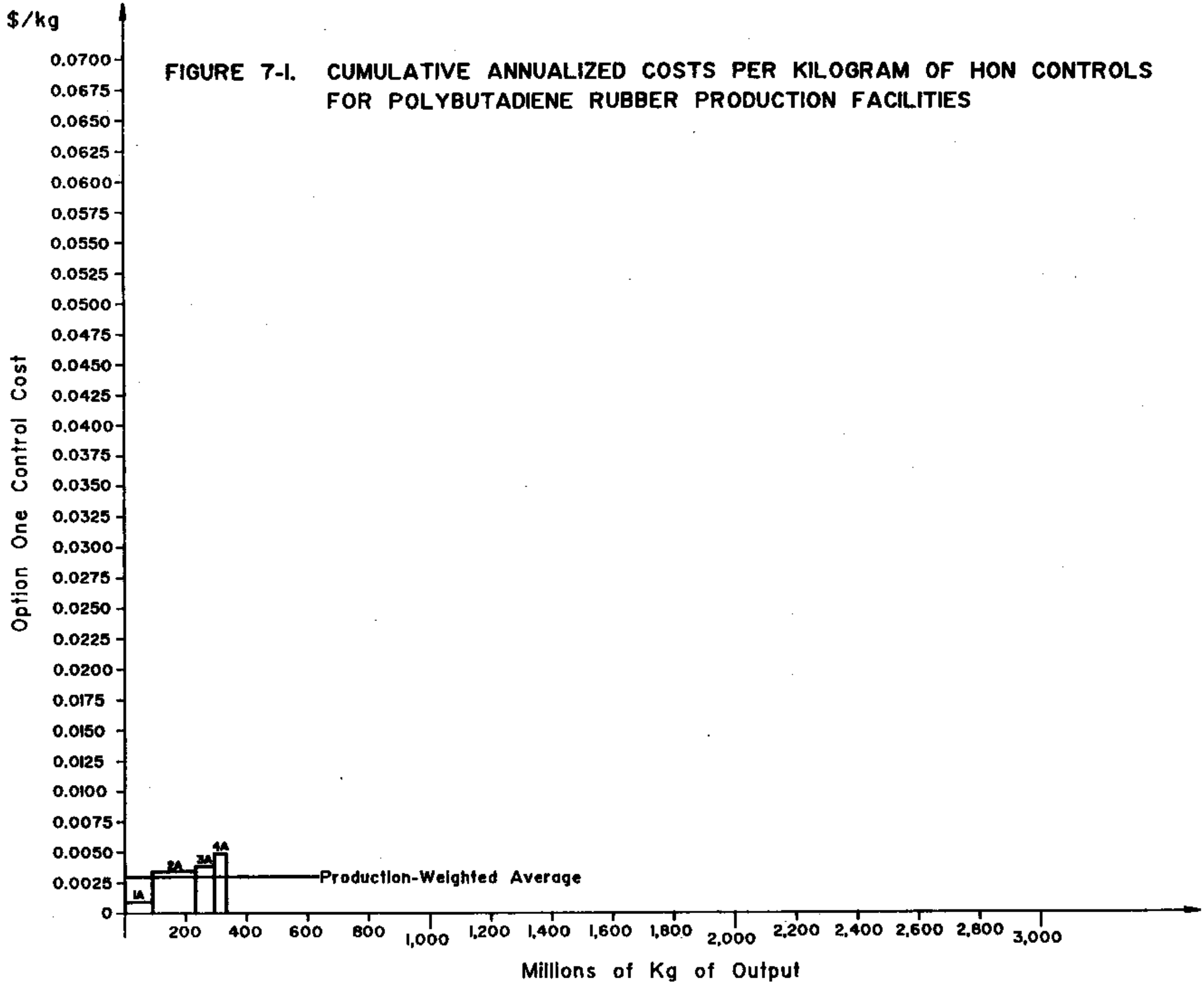
7.2.3.1.1 General-Purpose Rubbers

Seventy-nine percent of all polybutadiene is consumed in tire and tire products. Considered a general-purpose rubber, polybutadiene accounts for about 17 percent of all synthetic rubbers. Because of their cost advantage and low temperature buildup during use, general-purpose synthetic rubbers have extracted notable market share from natural rubbers for commercial use, especially for automobile tires, since their inception in the early 1940s. Also, natural rubbers cannot be used in applications where there is contact with naphtha because the solvent swells the material. When these performance characteristics are important, synthetic rubber is the

TABLE 7-5. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR POLYBUTADIENE RUBBER PRODUCTION FACILITIES

Facility/ Process	Annual Production (10^6 kg)	Option One Controls ($/kg)
1A	89.1	$0.0010
2A	145.8	$0.0035
3A	56.7	$0.0038
4A	52.7	$0.0048
<u>Summary Statistics</u>		
Mean		$0.0033
Production Weighted Average		$0.0031

FIGURE 7-1. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR POLYBUTADIENE RUBBER PRODUCTION FACILITIES



Still, natural rubbers have not been replaced for many uses, and in 1989 made up 30 percent of U.S. consumption. For example, natural rubber performs better than synthetics for use in large, heavy-duty truck and bus tires. In addition, natural rubbers are blended with polybutadiene for use in automobile tire manufacturing.

7.2.3.1.2 High-Impact Resin Modifiers

Polybutadiene is used as a high-impact resin modifier primarily in polystyrene production. It is therefore necessary to examine polystyrene market and the potential for substitution.

The physical properties of polystyrene can be altered by addition of modifying agents to make an extensive variety of end-use products. Many specialty uses for polystyrene are difficult to substitute for. However, as disposable food service ware and packaging material, polystyrene faces competition from cheaper high-density polyethylene, polypropylene, polyethylene terephthalate, and natural fibers (e.g. paper), all of which are encroaching on the polystyrene market. In addition, environmental problems associated with disposal are spurring substitution away from polystyrene. Future growth prospects for polystyrene are expected to be limited. In this sector, demand elasticity for polybutadiene is estimated to be slightly inelastic.

7.2.3.2 Imports

Imports in the polybutadiene market are important, accounting for 17.7 percent of 1989 U.S. consumption. Exports are also notable, making up 20. percent of U.S. production in 1989. The presence of such an abundance of polybutadiene traded on the international market suggests that polybutadiene producers should be sensitive to the prospects for import substitution.

7.2.3.3 Elasticity Estimate

Based on the above evidence, the demand elasticity for SBR is estimated to be in the slightly inelastic range of -.67 to -1.

7.2.4 Market Structure

Table 7-6 summarizes the parameters for the market structure of polybutadiene. Four firms are currently producing polybutadiene. Thus, the four firm concentration ratio is 100 percent, signifying substantial market power. The HHI is 2968.9, which falls in the range of substantial market power. Imports in the industry are important,

TABLE 7-6. MARKET STRUCTURE CHARACTERISTICS FOR POLYBUTADIENE

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced at Site (Horizontal Integration)	Imports
4	100%	2,968.9	N.A.	N.A.	Important

N.A. - Not Available

[a] Herfindahl-Hirschman Index

serving to undermine the pricing discretion of domestic producers. In summary, the polybutadiene industry is moderately to substantially obgopolistic, and producers are likely to absorb a portion of HON controls.

7.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the polybutadiene industry for option one controls are presented in Table 7-7.

7.2.5.1 Option One Control Costs

Option one control costs are estimates of the actual cost that an industry will incur. The weighted average percentage price increase of .30 percent leads to a price increase of $.0031 per kilogram. For the two elasticity levels of -.67 and -1.00, the output reduction is 748 thousand kilograms (.19%) and 1.1 million kilograms (.29%), respectively.

The highest cost and the smallest plant in the industry is Facility 4A, which accounts for 52.7 million kilograms of industry production. If this plant absorbs the entire decline in output, it would lose from 1.4 to 2.1 percent of its production, which won't lead to closure. While imports are important, this small price increase is unlikely to spur import substitution. The loss in employment is estimated to be from 2 to 3 employees.

7.2.6 Conclusion

Polybutadiene is a slow growth chemical tied to a lethargic tire industry. Its success rests with specialty applications. The impact of HON controls might help to reinforce the slowing of this ebbing industry, but very imperceptibly. The range of price increases under the option one control scenario is $.0010 per kilogram to $.0048 per kilogram. This is a small differential, and the production-weighted price increase is probably an accurate estimate of the actual price increase. Closure is highly unlikely, and the employment loss is negligible.

TABLE 7-7. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE POLYBUTADIENE INDUSTRY[1]

	Elasticity	
	-0.67	-1.00
%Δ Price (%/kg)	0.30%	0.30%
Δ Price ($/kg)	$.0031	$.0031
%Δ Output (%/kg)	(0.20%)	(0.30%)
Δ Output (10^6 kg)	(.749)	(1.1)
%Δ Total Revenue	0.10%	0.00%
Δ Total Revenue (10^6 $)	$.384	$0.00
Δ Employment (# of Employees)	(2)	(3)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

Δ = Change In

Market Price = $1.04/kg

1995 Output = 376.4 x 10^6 kg (based on 1989 production at 1.7 percent annual compound growth)

1995 Total Revenue = $391,474,557.36 (market price x 1995 output)

1995 Employment = 1,067

7.2.7 References

1. "Chemical Profile -- Polybutadiene." *Chemical Marketing Reporter*, May 23, 1988.

2. *Chemical & Engineering News*, May 21, 1990, p. 46.

3. *Rubber World*, several issues, March 1989 - September 1990.

4. Reference 1.

5. JACA Corp. "Preliminary Economic Analysis of the Proposed Revision to the Standard for 1,3-Butadiene." Prepared for the U.S. Department of Labor, Occupational Safety and Health Administration, Office of Regulatory Analysis. Fort Washington, PA, August 14, 1987, pp. 2-25 through 2-33.

6. U.S. Department of Commerce, Bureau of the Census. Report FT447: "U.S. Exports." Washington, DC, August 1990.

7. Reference 1.

8. *Rubber World*, June 1990, p. 13.

9. Standard & Poor's Corp. *Industry Surveys*. "Chemicals -- Basic Analysis." New York, NY, November 2, 1989, p. C 34.

10. Reference 1.

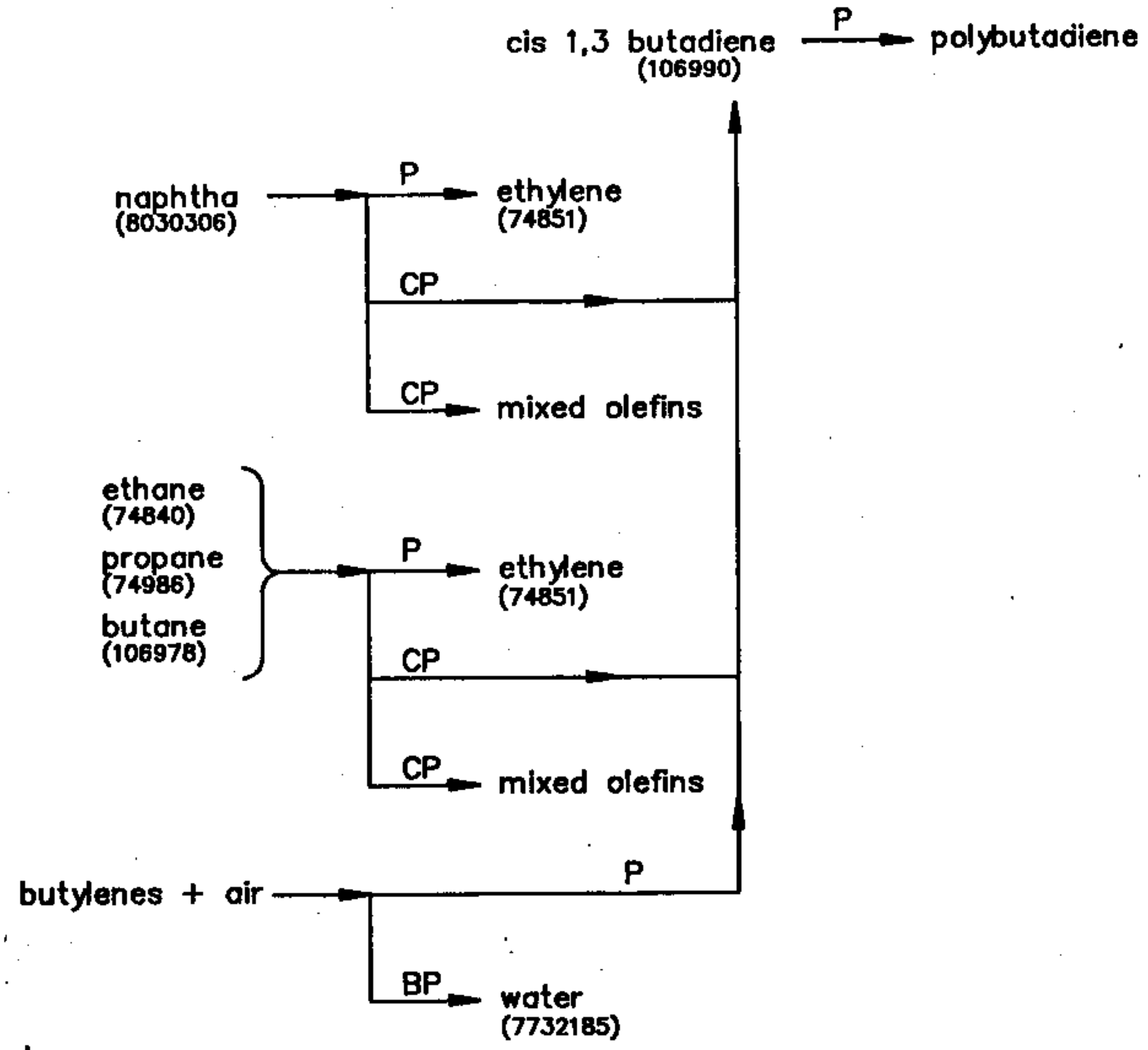
11. Reference 1.

12. U.S. Department of Commerce, Bureau of the Census. Report FT247: "U.S. Imports for Consumption." Washington, DC, August 1990.

FIGURE 7-2

CHEMICAL TREE

POLYBUTADIENE



NOTE:

P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 8

ETHYLENE DICHLORIDE PRODUCTION

8.1 INDUSTRY PROFILE

Ethylene dichloride (EDC) is produced through the chlorination of ethylene. Approximately 97 percent of all EDC is used to make vinyl chloride monomer (VCM), which itself is used principally to make polyvinyl chloride (PVC).[1] About 65 percent of PVC demand derives from housing and construction.[2] Consequently, EDC is closely tied to the U.S. housing and construction market.

8.1.1 Brief Market Introduction

8.1.1.1 Historical Overview

Apparent consumption of EDC from 1980 to 1989 is estimated in Table 8-1 as production plus imports, minus exports. This is a simplification because changes in inventory are ignored. There has been an upward trend in consumption since 1982, a recessionary year. Consumption in 1989 was at its highest of the decade, with the possible exception of 1988, for which data were not available.

Almost 90 percent of all EDC produced in the U.S. is consumed captively (mostly in the manufacture of VCM). In 1988, only 12 percent of EDC output in the U.S. was sold on the merchant market.[3]

Average realized prices of EDC from 1980 to 1989 are also shown in Table 8-1. These prices are generally lower than list prices because discounting in the industry is the norm.[4] The price of EDC is controlled by the price of VCM, which in turn is dependent on the price of PVC. (Of course, for the majority of EDC that is consumed captively -- i.e., not sold on the merchant market -- the market price of EDC is not realized in any transaction, but rather represents an opportunity cost). From 1980 to 1989, average realized prices fluctuated within a 15-24 cents per kilogram band.

8.1.1.2 Recent Developments

Throughout 1990, the list price of EDC has been 35.3 cents per kilogram. Actual transaction prices are not known. In 1989, transaction prices were 28.7 - 33.1 cents per kilogram in May, and declined to 17.6 cents per kilogram in August.[5] At that time, there were "strong indicators of even further price deterioration in the near future."[6] The softness in prices was due mainly to 1) lower overseas demand, especially from Japan and Taiwan; 2) diminishing domestic

TABLE 8-1. AVERAGE REALIZED PRICE AND APPARENT CONSUMPTION OF ETHYLENE DICHLORIDE IN THE U.S., 1980-1989

	Price (¢/kg)	Apparent Consumption[a] (10^6 kg)
1989	24	5,679
1988	24	N.A.
1987	18	5,117
1986	18	5,636
1985	21	5,054
1984	24	4,535
1983	22	4,807
1982	15	3,160
1981	18	4,327
1980	22	4,781

[a] Production plus imports, minus exports. Because inventory changes are ignored, this is a simplified estimate of consumption.

Sources: Research Triangle Institute, "Economic Analysis of Proposed Hazardous Organics NESHAP Controls," 1987; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Ethylene Dichloride," June 1988; U.S. International Trade Commission, Synthetic Organic Chemicals, 1984-1989; Chemical Marketing Reporter, January 1, 1990; Chemical & Engineering News, June 18, 1990, p. 39; U.S. Dept. of Commerce, Bureau of the Census, "U.S. Exports, 1989," Report FT447 and "U.S. Imports for Consumption, 1989," Report FT247.

demand for PVC; and 3) increased supplies of chlorine, a major input to EDC.

8.1.2 Demand Conditions

8.1.2.1 Uses for Ethylene Dichloride

As mentioned, PVC, the end-use of VCM, is used primarily in housing and construction. Other uses for PVC include automotive materials, packaging, and, more recently, electrical and electronic applications. The PVC market is about equally divided between two types of the polymer: flexible and rigid. Rigid PVC is used typically in pipe and construction profiles, while flexible PVC's major applications include packaging films, calendared sheeting, vinyl-coated fabrics, consumer products, and under-the-hood automotive products.

Only about 3 percent of EDC production in the U.S. is not used to manufacture VCM. Chlorinated solvents and ethyleneamines are the primary miscellaneous uses of EDC.

8.1.2.2 Exports

U.S. exports of EDC, shown from 1980 to 1989 in Table 8-2, have been on the rise due to increasing VCM capacity overseas. The primary overseas destinations are Japan and Taiwan, which together in 1989 accounted for 81 percent of U.S. exports.[7] Exports had an 8.7 percent share of U.S. production of EDC in 1989.

8.1.2.3 Future Trends

The end uses of EDC are mature and no major technical breakthroughs that will result in new applications are expected.[8] Hence, the demand for EDC is expected to follow the demand for PVC, which is tied to the business cycle. Chemical Marketing Reporter, in 1988, forecast that the demand for EDC would increase by 2-3 percent per year through 1993, compared to average growth of 1.6 percent per year from 1979 to 1988.[9] Growth was forecast to pick up due to anticipated VCM and PVC capacity expansions in the U.S. Standard & Poor's forecast in 1989 that PVC demand in the U.S. would increase by 3 percent per year in the long term.[10]

New integrated EDC-VCM plants are coming on stream overseas in response to the increase in demand for PVC. This should reduce the demand in the near future for U.S. exports of EDC.[11]

TABLE 8-2. U.S. EXPORTS OF ETHYLENE DICHLORIDE, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1989	541	8.7%
1988	N.A.	N.A.
1987	432	7.8%
1986	264	4.5%
1985	442	8.1%
1984	345	7.1%
1983	441	8.4%
1982	362	10.5%
1981	280	6.2%
1980	278	5.5%

[a] See Table 8-4.

Sources: Research Triangle Institute, "Economic Analysis of Proposed Hazardous Organics NESHAP Controls," 1987; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Ethylene Dichloride," June 1988; U.S. Department of Commerce, Bureau of the Census, "U.S. Exports, 1989," Report FT447.

8.1.3 Supply Conditions

8.1.3.1 Production Process

Until the mid-1970s, EDC was produced as a coproduct of ethylene oxide by the chlorohydrin process. Since that time all EDC has been made either by chlorination or oxychlorination of ethylene. The chlorination process involves combining ethylene with chlorine in the liquid phase to produce EDC. In the oxychlorination process, ethylene, oxygen, and hydrogen chloride (HCl) react in the vapor phase.

Ethylene dichloride is usually made as an intermediate in the production of VCM and other chlorinated solvents. However, some EDC is produced either at plants that have no internal use for it, or with the intent of being sold in small quantities for other purposes. When the EDC is used on site to manufacture VCM, the chlorination and oxychlorination processes are combined with the thermal cracking of EDC into the "balanced process." VCM is then the only product (a result of the cracking process), and all the HCl required for the oxychlorination is formed as a product of the cracking of EDC. The balanced process can use externally made HCl and can also produce EDC and/or HCl as coproducts.

8.1.3.2 Domestic Producers and Total Production

As of May 1989, there were 9 companies with 16 plants in the U.S. that produce EDC. The plants are listed in Table 8-3 along with their effective capacities.

Industry capacity utilization in mid-1989 was near 95 percent.[12] This compared to 85 percent in mid-1988 and 45 percent in 1982.[13,14] 454 million kilograms of U.S. capacity has been idled and could be restarted if there is sufficient demand.[15] In May 1989, Formosa Plastics intended to double capacity at its Point Comfort facility by the end of the year.[16]

All EDC facilities in the U.S. with the exception of Vulcan Materials' in Geismar, La. and Occidental's 771 million kilogram facility in Deer Park, Tx. also manufacture VCM.[17] Vulcan produces chlorinated solvents from EDC while Occidental sells on the merchant market.

As shown in Table 8-4, U.S. output of EDC reached its highest levels of the decade in 1988 and 1989. This is attributable to strong export demand (see Table 8-2) and strong domestic demand for PVC. In the second half of 1989, the demand for PVC began to abate as the U.S. housing and construction market entered a slump.

TABLE 8-3. U.S. PRODUCERS OF ETHYLENE DICHLORIDE, MAY 1989

Company	Plant Location	Capacity (10^6 kg/yr)
Borden	Geismar, LA	338
Dow	Freeport, TX	726
	Oyster Creek, TX	499
	Plaquemine, LA	771
Formosa Plastics Corp.	Baton Rouge, LA	227
	Point Comfort, TX	209
Georgia Gulf	Plaquemine, LA	823
B.F. Goodrich	Calvert City, KY[a]	454
	La Porte, TX	719
Occidental Petroleum	Convent, LA	363
	Corpus Christi, TX	363
	Deer Park, TX	79
	Deer Park, TX	771
PPG	Lake Charles, LA	1,225
Vista Chemical	Lake Charles, LA	522
Vulcan Materials Co.	Geismar, LA	136
		8,225

[a] The Westlake Group (Houston, Texas), owned by Taiwan-based China General Plastics, entered into an agreement in October 1989 to purchase this facility, pending FTC approval.18

Source: Chemical Marketing Reporter, May 22, 1989.

TABLE 8-4. U.S. PRODUCTION OF ETHYLENE DICHLORIDE, 1980-1989

	Quantity (10^6 kg)
1989	6,202
1988	5,909
1987	5,532
1986	5,869
1985	5,489
1984	4,858
1983	5,219
1982	3,456
1981	4,524
1980	5,039

Source: Chemical & Engineering News, June 18, 1990, p. 39.

8.1.3.3 Costs of Production

The production of EDC, like other synthetic organic chemicals, is probably capital-intensive. The major raw material inputs are ethylene and chlorine. The list price of chlorine has remained at $209-220 per metric ton since the beginning of 1990. The price of ethylene was 50.7 cents per kilogram from the beginning of 1990 until October, but then shot up in late October and early November to 72.8 cents per kilogram. This same price prevailed at the start of 1989, before a capacity build-up and weak derivative markets caused the price to decline through the course of the year.

8.1.3.4 Imports

U.S. imports of EDC are relatively insignificant. As indicated in Table 8-5, since 1983, imports have always amounted to less than one percent of U.S. consumption.

8.1.3.5 Future Prospects

U.S. EDC facilities are currently running at high capacity utilization rates. However, idled capacity that can be restarted ensures that there will be ample supplies of EDC for the production of VCM and PVC.

The recent 43 percent jump in the price of ethylene suggests that EDC production costs will increase. However, planned ethylene capacity additions in 1991 could help alleviate the cost pressure.

8.1.4 Future Market Prospects

With its dependence on PVC and, in turn, housing and construction, EDC is likely to experience slow demand growth as long as the slump in the U.S. housing and construction continues. U.S. producers are also likely to be hurt by an anticipated increase in overseas EDC production capacity, which will decrease U.S. export demand. EDC profitability is likely to be squeezed from two sides: the weak housing and construction market, which will affect downstream PVC prices; and the recent (October/November 1990) 43 percent increase in the price of ethylene, a key input to EDC. Ethylene prices may ease in 1991 when new capacity comes on stream, however.

TABLE 8-5. U.S. IMPORTS OF ETHYLENE DICHLORIDE, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Consumption[a]
1989	17.9	0.3%
1988	N.A.	N.A.
1987	17.2	0.3%
1986	31.3	0.6%
1985	6.4	0.1%
1984	12.1	0.3%
1983	18.2	0.4%
1982	58.6	1.9%
1981	73.2	1.7%
1980	10.0	0.2%

[a] See Table 4-1.

Sources: Research Triangle Institute, "Economic Analysis of Proposed Hazardous Organics NESHAP Controls," 1987; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Ethylene Dichloride," June 1988; U.S. Department of Commerce, Bureau of the Census, "U.S. Imports for Consumption, 1989," Report FT247.

8.2 ECONOMIC IMPACT ANALYSIS

8.2.1 Compliance Costs

A synopsis of annualized cumulative control costs and summary statistics for EDC production is presented in Table 8-6. Costs are displayed for option one controls, which estimate the actual control costs a facility will incur. Figure 8-1 illustrates control costs graphically. EDC is currently produced via chlorination/oxichlorination of ethylene. Since this is the only commercial process, no analysis of separate process costs is necessary.

8.2.2 Pricing

EDC prices are determined by a combination of feedstock costs and end-use demand. Ethylene, a principal input in EDC production, is also the largest volume synthetic organic chemical in the world today. Ethylene prices are expected to fall over the next several years as new capacity becomes operational and lower cost feedstocks, particularly butane, increase in availability.[18] Feedstock costs are unlikely to put upward pressure on EDC prices through the mid-1990s. Ninety-seven percent of EDC finds its ultimate use in PVC, and EDC prices are closely tied to PVC. Prices could soften in the years to come, given mature end-uses for PVC, decreasing overseas demand, and increased supplies of chlorine, which is the other major input for EDC. If prices decline, the impact of HON controls will be understated.

8.2.3 Elasticities

Demand elasticities for EDC will be estimated on the basis of available substitutes for EDC, as well as substitutes for end-users. The potential for import substitution is also examined.

8.2.3.1 Vinyl Chloride Monomer

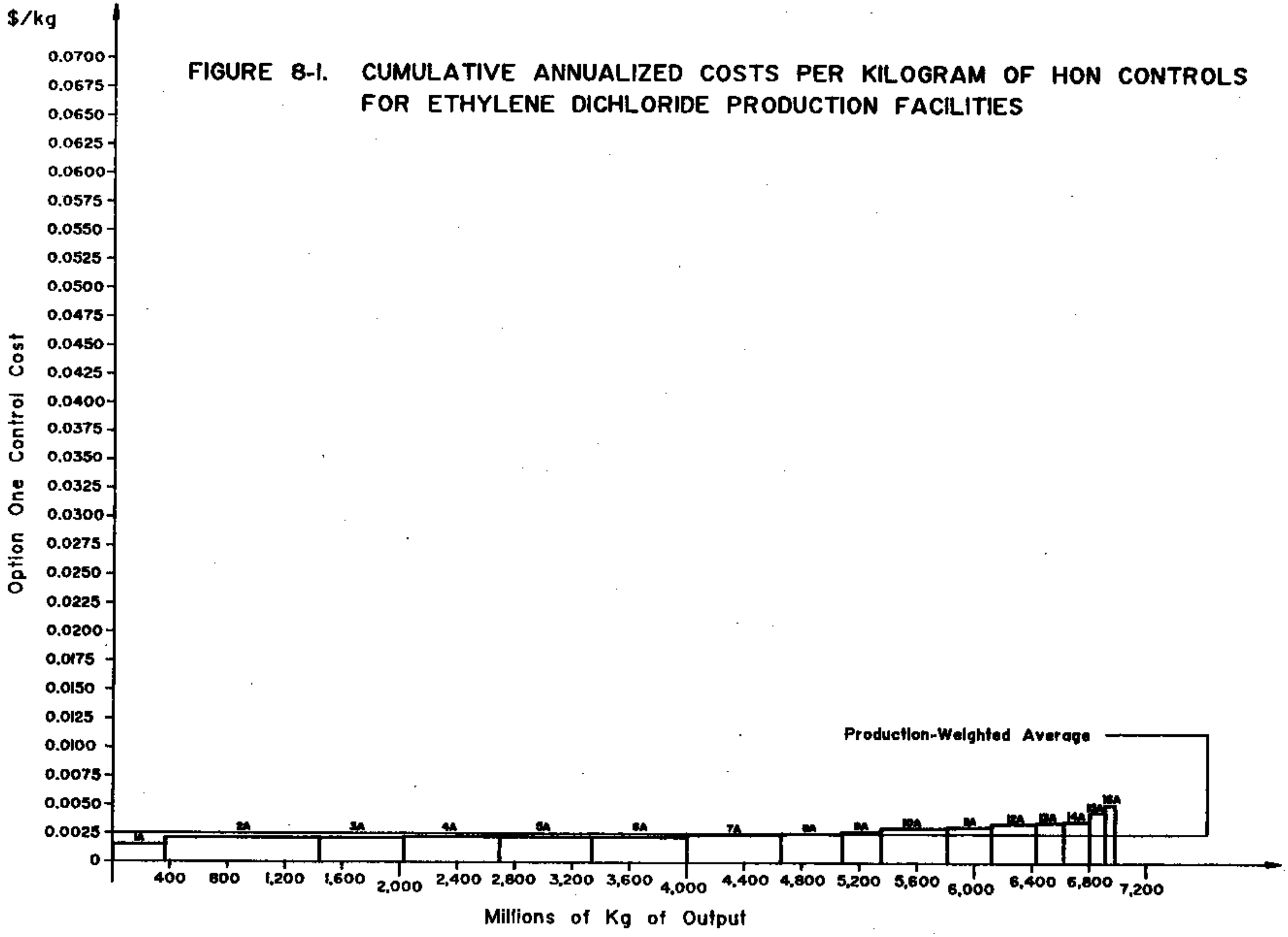
Vinyl chloride monomer is the primary derivative of EDC, accounting for 97 percent of EDC demand. Since EDC is essential in the production of vinyl chloride monomer, substitutes for vinyl chloride monomer are of primary interest.

Vinyl chloride monomer is used principally for PVC production. Hence, EDC demand is derived ultimately from PVC demand and PVC end-use demand. PVC has a wide variety of end-uses, including rigid pipe and tubing, sheet and film, siding, containment liners for liquid and solid waste, and others. All of these applications have several substitutes, including fiberglass reinforced plastic, polyethylene, aluminum and concrete. Alternatives could come into use given PVC cost increases.

TABLE 8-6. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR ETHYLENE DICHLORIDE PRODUCTION FACILITIES

Facility	Annual Production (10^6 kg)	Option One Control ($/kg)
1A	368.8	$0.0015
2A	1,043.0	$0.0021
3A	618.0	$0.0021
4A	701.3	$0.0022
5A	657.1	$0.0022
6A	612.0	$0.0022
7A	657.1	$0.0024
8A	425.0	$0.0025
9A	288.2	$0.0027
10A	444.6	$0.0030
11A	309.4	$0.0031
12A	309.4	$0.0034
13A	193.0	$0.0035
14A	177.0	$0.0036
15A	115.6	$0.0044
16A	68.0	$0.0052
<u>Summary Statistics</u>		
Mean		$0.0029
Production Weighted Average		$0.0025

FIGURE 8-1. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR ETHYLENE DICHLORIDE PRODUCTION FACILITIES



However, PVC has performance advantages for pipe and tubing -- its primary end-use -- due to its rigidity. Also, PVC is very low-cost.

8.2.3.2 Imports

Imports of EDC are insignificant. However, imports of PVC resins are important, reducing demand for domestic EDC.

8.2.3.4 Elasticity estimate

Demand elasticity for EDC estimated to be in the moderately inelastic range of -.34 to -.67.

8.2.4 Market Structure

Table 8-7 summarizes the parameters for the market structure of EDC. None firms are currently producing EDC. The four-firm concentration ratio is 72.6 percent, signifying substantial market power. The HHI is 1569.3, which falls moderate range of market power. Captive consumption is 88 percent, indicating a substantial level of vertical integration. On average, 5 chemical compounds are produced at EDC sites, suggesting a substantial level of horizontal integration. Imports of EDC are not important, but imports of PVC resins impact EDC pricing. In summary, EDC industry is highly oligopolistic, and firms will likely absorb a significant portion of HON compliance costs.

8.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the EDC industry are presented in Table 8-8.

8.2.5.1 Option One Control Costs

Option one control costs represent the estimated actual cost that an industry will incur. The weighted average percentage price increase of 1.03 percent leads to a price increase $.0025 per kilogram. For the two elasticity levels of -.34 and -.67, the output reduction is 28.3 million kilograms (.35%) and 55.7 million kilograms (.69%), respectively.

The smallest plant in the industry is facility 15A, which accounts for 68.0 million kilograms of industry production. This is also the highest cost plant. If this plant absorbs the entire reduction in output, it would lose from 42 to 82 percent of its production, which is likely to lead to closure. However, the cost differential between this plant and the other facilities in the industry is about one-third of a

TABLE 8-7. MARKET STRUCTURE CHARACTERISTICS FOR EDC

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced at Site (Horizontal Integration)	Imports
9	72.6%	1569.3	88%	5	Relatively Important (PVC)

[a] Herfindahl-Hirschman Index

TABLE 8-8. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE ETHYLENE DICHLORIDE INDUSTRY[1], OPTION ONE CONTROL COSTS

	Elasticity	
	-0.34	-0.67
%Δ Price (%/kg)	1.03%	1.03%
Δ Price ($/kg)	$.0025	$.0025
%Δ Output (%/kg)	(0.35%)	(0.69%)
Δ Output (10^6 kg)	(28.3)	(55.7)
%Δ Total Revenue	0.68%	0.34%
Δ Total Revenue (10^6 $)	$13.3	$6.6
Δ Employment (# of Employees)	(19)	(37)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

Δ = Change In

Market Price = $0.24/kg

1995 Output = 8,124 x 10^6 kg (based on 1989 production at 2.5 percent annual compound growth)

1995 Total Revenue = $1,949,871,403.19 (market price x 1995 output)

1995 Employment = 5,313

cent. Thus, the output reduction is apt to be spread out across the industry. The decline in employment is estimated to be from 19 to 37 employees.

8.2.5 Conclusion

The range of compliance costs is $.0015 per kilogram to $.0052 per kilogram. The differential is small, and the production weighted average is probably a good estimate of the actual price increase in the industry. Closure is possible in the extreme case that the high cost firm absorbs all of the reduction in output. However, it cannot be predicted with any certainty.

8.2.6 References

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2. Mannsville Chemical Products Corp. "Chemical Products Synopsis -- Ethylene Dichloride." Asbury Park, NJ, June 1988.
3. U.S. International Trade Administration. Synthetic Organic Chemicals -- United States Production and Sales, 1988. Washington, DC, September 1989, p. 15-7.
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10. Standard & Poor's Corp. Industry Surveys. "Chemicals -- Basic Analysis." New York, NY, November 2, 1989, p. C 30.
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12. Reference 5.
13. Reference 2.
14. Research Triangle Institute, Center for Economics Research. "Economic Analysis of Proposed Hazardous Organics NESHAP Controls." Chapter 9, "Ethylene Dichloride Production." Prepared for the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, June 1987.
15. Reference 2.
16. Reference 1.
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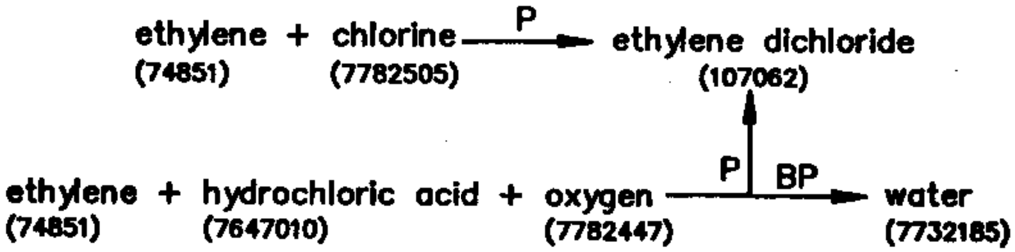
18. "VCM/EDC Deal for Goodrich." Chemicalweek, October 11, 1989, p. 9.

19. Mansville Chemical Products Corp. "Chemical Product Synopsis--Ethylene." Asbury Park, NJ, January 1990.

FIGURE 8-2

CHEMICAL TREE

ETHYLENE DICHLORIDE



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 9

ETHYLENE OXIDE PRODUCTION

9.1 INDUSTRY PROFILE

Most ethylene oxide is used captively in the manufacture of other intermediate chemicals; in 1988, only 11 percent of all ethylene oxide in the U.S. was sold on the merchant market.[1] The majority of ethylene oxide consumed on site is used to make ethylene glycol. There are currently thirteen plants in the U.S. that manufacture ethylene oxide; six are located in Texas, four in Louisiana.

9.1.1 Brief Market Introduction

9.1.1.1 Historical Overview

In the early 1980s, low profitability and competition from overseas caused several ethylene oxide plants in the U.S. to shut down or curtail operations. In 1987 and 1988, a shortage of ethylene oxide developed, largely in response to a shortage of its feedstock, ethylene. Two manufacturers, Olin and Union Carbide, re-started capacity. Other companies increased capacity by debottlenecking (increasing the capacity of relatively low-capacity steps in a manufacturing process to match the capacity of relatively high-capacity steps). As a result, from March 1987 to February 1990, total annual capacity in the U.S. for ethylene oxide increased 13 percent from 6,330 million pounds (2,871 million kilograms) to 7,150 million pounds (3,243 million kilograms.)[2,3]

Average realized prices and apparent consumption of ethylene oxide from 1980 to 1989 are shown in Table 9-1. Due to the shortage, the average price almost doubled from 1987 to 1988. Average realized price further increased appreciably from 1988 to 1989.

After hitting a decade-low in 1987, consumption of ethylene oxide in 1989 was back to a level typical of the mid-1980s.

Ethylene oxide is the least profitable of the major ethylene derivatives.[4] The 1980s were considered a "poor decade for (ethylene oxide) profits."[5]

9.1.1.2 Recent Developments

Since mid-1989, the demand for derivatives of ethylene oxide has in general been weak.[6] As a result, the price of ethylene oxide declined by 22 cents per kg from mid-1989 to February 1990. Prior to mid-1989, there had been a price run-up. Discounting in the

TABLE 9-1. AVERAGE REALIZED PRICE AND APPARENT CONSUMPTION OF ETHYLENE OXIDE IN THE U.S., 1980-1989

	Price ($/kg)	Apparent Consumption[a] (10^6 kg)
1989	1.30	2,424
1988	0.84	N.A.
1987	0.44	2,167
1986	0.45	2,452
1985	0.47	2,445
1984	0.56	2,580
1983	0.62	2,509
1982	0.68	2,266
1981	0.75	2,233
1980	0.75	2,332

[a] Production plus imports, minus exports. Because inventory changes are ignored, this is a simplified estimate of consumption.

Sources: Research Triangle Institute, "Economic Analysis of Proposed Hazardous Organics NESHAP Controls," 1987; U.S. International Trade Commission, Synthetic Organic Chemicals, 1984-1989; Chemical Marketing Reporter, January 1, 1990; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Ethylene Oxide," August 1988; Chemical & Engineering News, June 18, 1990, p. 39; U.S. Dept. of Commerce, Bureau of the Census, "U.S. Exports, 1989," Report FT447 and "U.S. Imports for Consumption, 1989," Report FT247.

industry is common. List prices didn't decrease until April 1990, when they fell from $1.32-$1.43 per kilogram to $1.10 per kilogram. Since that time, list prices have remained at $1.10-1.12 per kilogram.

Ethylene oxide was hurt in 1989 by weak demand for its major end use, ethylene glycol. Export sales of ethylene glycol diminished in 1989, and there was a large inventory carryover from 1988 to 1989 of antifreeze, which accounts for about one-third of ethylene glycol consumption. This was prompted by shortages of ethylene and its derivatives in 1987 and 1988. As a consequence of the high antifreeze inventory levels going into 1989, sales of antifreeze in the U.S. declined from 216 million gallons in 1988 to 161 million gallons in 1989.[7]

9.1.2 Demand Conditions

9.1.2.1 Uses for Ethylene Oxide

Ethylene oxide has several intermediate uses that are shown in Table 9-2. Ethylene glycol is the primary derivative, consuming 58 percent of ethylene oxide output. Over 90 percent of ethylene glycol, in turn, is used as antifreeze and to manufacture polyester resins and film. Antifreeze accounts for 41 percent of ethylene glycol consumption in the U.S., while polyester fibers account for 35 percent, polyester bottle resin (PET) 11 percent, and polyester film and other resins 6 percent.[8]

Ethoxylates are the second most important end use of ethylene oxide, and account for the majority (70 percent) of ethylene oxide sold on the merchant market.[9] Ethoxylates are used primarily as non-ionic surfactants. The demand for non-ionic surfactants grew significantly in the 1980s due to growth in the use of heavy-liquid detergents, which contain high concentrations of the surfactants. From 1978 to 1988, heavy-duty liquid detergents increased their share of the U.S. detergent market from 15 percent to 40 percent.[10] Increased supplies of ethoxylates to produce non-ionic surfactants have not been that forthcoming, though. For one, ethylene oxide producers are often reluctant to sell on the merchant market (e.g., to ethoxylate producers) because there are potential hazards of shipping bulk quantities of ethylene oxide.[11] Also, from time to time, there have been ethylene oxide supply shortages. Perhaps most importantly, it is less profitable for ethylene oxide producers to sell on the merchant market than to consume ethylene oxide captively and manufacture derivatives.[12] As a result, several U.S. ethylene oxide producers

TABLE 9-2. USES OF ETHYLENE OXIDE, 1990

	Percent of Total Consumption
Ethylene glycol	58%
Ethoxylates	14%
Di-,tri-, and polyethylene glycols	9%
Ethanolamines	9%
Glycol ethers	6%
Other[a]	4%

[a] Includes polyether polyols, and tetraethylene glycol as an intermediate in various products and as a fumigant/sterilant.

Source: <u>Chemical & Engineering News</u>, July 30, 1990, p. 11.

have been de-emphasizing their merchant market sales (e.g., to ethoxylate producers) in favor of captive consumption.[13]

Diethylene glycol is used to produce unsaturated polyester resins, textile lubricants and conditioners, plasticizers, and several other items. It is also used in natural gas dehydration. Triethylene glycol is also used in natural gas dehydration, and is used as a humectant and in the manufacture of vinyl plasticizers. Polyethylene glycol is used mainly in surface active agents.[14]

Ethanolamines are used for detergents and gas purification. Glycol ethers have solvent applications. The "other" category in Table 9-2 includes the end use of ethylene oxide as a sterilant/fumigant for medical products. Like ethoxylates, this use derives principally from sales of ethylene oxide on the merchant market.

9.1.2.2 Exports

Table 9-3 reveals that exports account for a very small share of U.S. production of ethylene oxide. In 1989, the U.S. exported only 5.5 million kilograms of ethylene oxide. It is worth noting, though, that the U.S. exported an estimated 494 million kilograms of ethylene glycol in 1989.[15]

9.1.2.3 Future Trends

Chemical Marketing Reporter forecasts that ethylene oxide demand in the U.S. will grow by 2 to 2.5 percent per year from 1990 to 1994.[16] In comparison, demand grew by only 1 percent per year from 1980 to 1989. Relatively high-growth end uses are surfactants and ethanolamines, which are growing by 3 percent per year or more. Glycol ethers, on the other hand, are expected to lose markets because of environmental and occupational health regulations.

Most derivatives of ethylene oxide and uses of ethylene glycol are mature products. An exception is polyester resins used in bottles and other packaging. Overall, Chemical Marketing Reporter projects that ethylene glycol demand will increase by 2 percent per year in the early 1990s.[17] Another forecaster expects ethylene glycol growth of 1.4 percent per year up to 1997.[18]

9.1.3 Supply Conditions

9.1.3.1 Production Processes

Ethylene oxide is produced by the direct, vapor-phase oxygen-oxidation of ethylene over a silver catalyst and by the air

TABLE 9-3. U.S. EXPORTS OF ETHYLENE OXIDE, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1989	5.5	0.2%
1988	N.A.	N.A.
1987	16.3	0.8%
1986	12.7	0.5%
1985	28.1	1.1%
1984	11.3	0.4%
1983	6.3	0.2%
1982	1.5	0.1%
1981	24.9	1.1%
1980	38.8	1.6%

[a] See Table 9-5.

Sources: Research Triangle Institute, "Economic Analysis of Proposed Hazardous Organics NESHAP Controls," 1987; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Ethylene Oxide," August 1988; U.S. Department of Commerce, Bureau of the Census, "U.S. Exports, 1989," Report FT447.

oxidation process. Carbon dioxide and water are the only significant byproducts produced. Ethylene oxide is recovered as a crude aqueous solution, which is then either used to produce ethylene glycol by hydration or fractionated to produce pure ethylene oxide. Ethylene oxide may be emitted during both production and captive use of the chemical. New processes for producing ethylene oxide based on such raw materials as synthesis gas and ethanol are being developed, although the feasibility of these developments will depend on future relative ethylene values.[19]

9.1.3.2 Domestic Producers and Total Production

As of February 1990, 12 companies with 13 plants produced ethylene oxide in the U.S. The plants and their production capacities are listed in Table 9-4. Total capacity for the industry is 3,241 million kilograms. This represents an increase of 13 percent from 2,871 million kilograms in 1987.[20] Average utilization of nameplate capacity in the industry in 1989 was 84 percent.[21]

U.S. production of ethylene oxide from 1980 to 1989 is shown in Table 9-5. After slumping severely in 1987, output increased in 1988 to 2,700 million kilograms, the highest level of the decade. Output fell 10.6 percent in 1989 to 2,414 million kilograms, however.

9.1.3.3 Cost of Production

The primary input into ethylene oxide production is ethylene. The cost of ethylene oxide is closely tied to the cost of this input. The price of ethylene was 23 cents per pound (50.7 cents per kilogram) from the beginning of 1990 until October, but then shot up in late October and early November to 33 cents per pound (72.8 cents per kilogram). This same price prevailed at the start of 1989, before a capacity build-up and weak derivative markets caused the price to decline through the course of the year.

9.1.3.4 Imports

Table 9-6 contains data on U.S. imports of ethylene oxide. Like exports, imports of ethylene oxide are negligible. However, the U.S. imported an estimated 163 million kilograms of ethylene glycol in 1989.[22] Ethylene glycol had the third-largest trade surplus -- 331 million kilograms -- among U.S. petrochemicals in 1989, trailing only polypropylene and styrene.[23]

TABLE 9-4. U.S. PRODUCERS OF ETHYLENE OXIDE, FEBRUARY 1990

Company	Plant Location	Capacity (10^6 kg/yr)
BASF	Geismar, LA	218
Dow	Plaquemine, LA	204
Eastman	Longview, TX	95
Hoechst Celanese	Clear Lake, TX	249
Olin	Brandenburg, KY	50
Oxy Petrochemicals	Bayport, TX	265
PD Glycol	Beaumont, TX	249
Quantum Chemical Corp.	Morris, ILL	104
Shell	Geismar, LA	374
Sun Refining	Claymont, DE	50
Texaco	Port Neches, TX	408
Union Carbide	Seadrift, TX	372
	Taft, LA	603
		3,241

Source: Chemical Marketing Reporter, February 12, 1990.

TABLE 9-5. U.S. PRODUCTION OF ETHYLENE OXIDE, 1980-1989

	Quantity (10^6 kg)
1989	2,414
1988	2,700
1987	2,170
1986	2,463
1985	2,463
1984	2,585
1983	2,510
1982	2,262
1981	2,239
1980	2,368

Source: Chemical & Engineering News, June 18, 1990, p. 39.

TABLE 9-6. U.S. IMPORTS OF ETHYLENE OXIDE, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Consumption[a]
1989	15.3	0.6%
1988	N.A.	N.A.
1987	12.7	0.6%
1986	1.4	0.1%
1985	10.4	0.4%
1984	5.7	0.2%
1983	4.1	0.2%
1982	4.3	0.2%
1981	17.7	0.8%
1980	2.6	0.1%

[a] See Table 9-1.

Sources: Research Triangle Institute, "Economic Analysis of Proposed Hazardous Organics NESHAP Controls," 1987; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Ethylene Oxide," August 1988; U.S. Department of Commerce, Bureau of the Census, "U.S. Imports for Consumption, 1989," Report FT247.

9.1.3.5 Future Prospects

Several planned expansions will add significantly to U.S. ethylene oxide production capacity in the next few years.[24] PD Glycol will be adding 90 million pounds (41 million kilograms) in 1991. Oxy Petrochemicals was scheduled to add 30 million pounds (14 million kilograms) in May 1990. More significantly, Shell is building a 450 million pound (204 million kilogram) plant on the Gulf of Mexico, scheduled for start-up in 1993. And Union Carbide plans to increase capacity at its Taft, La. facility in 1992 by 410 million pounds (186 million kilograms).

Overall, U.S. capacity for ethylene oxide is projected to increase 17 percent to 3,788 million kilograms in 1993.25 With even more rapid expansion on line in Canada, total North American capacity is projected to increase by 20 percent from 3,674 million kilograms currently to 4,400 million kilograms in 1993. Since demand is not expected to keep pace with the increases in capacity, operating rates in the U.S. ethylene oxide industry are likely to decline in the next few years.

9.1.4 Future Market Prospects

Since most end uses of ethylene oxide are mature, the demand for ethylene oxide is expected to grow modestly in the near future. Growth of around 2 to 2.5 percent per year is expected over the next five years.

The price of ethylene oxide will likely be kept in check in the next several years by an increase in industry capacity. Capacity expansions in excess of forecast growth in demand will probably also cause ethylene oxide to continue to be relatively unprofitable.

9.2 ECONOMIC IMPACT ANALYSIS

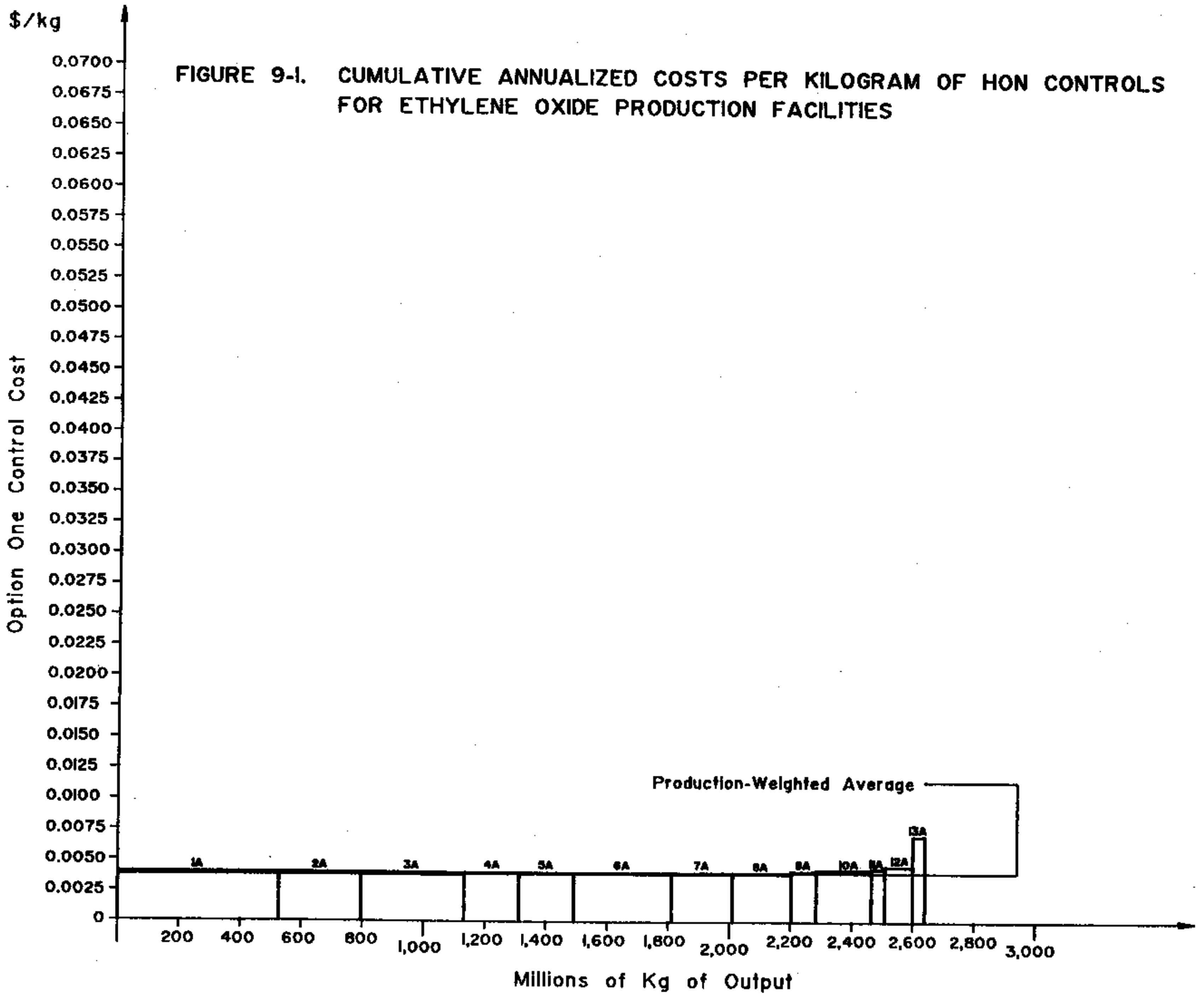
9.2.1 Compliance Costs

A synopsis of annualized cumulative control costs and summary statistics for ethylene oxide production is presented in Table 9-8. Costs are displayed for option one controls, which are estimates of the actual control costs that facilities are likely to incur. Figure 9-1 presents the option one control scenario information graphically. Thirteen facilities are displayed. Ethylene Oxide (EO) is currently produced via air oxidation of ethylene. Since this is the only commercial process, no analysis of separate process costs is necessary.

TABLE 9-8. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR ETHYLENE OXIDE PRODUCTION FACILITIES

Facility	Annual Production (10^6 kg)	Option One Control ($/kg)
1A	527.1	$0.0038
2A	267.5	$0.0038
3A	337.0	$0.0038
4A	179.5	$0.0039
5A	179.5	$0.0039
6A	319.4	$0.0039
7A	199.8	$0.0039
8A	191.8	$0.0039
9A	83.6	$0.0041
10A	179.5	$0.0042
11A	44.0	$0.0043
12A	91.5	$0.0045
13A	39.6	$0.0070
<u>Summary Statistics</u>		
Mean	$0.0099	$0.0042
Production Weighted Average	$0.0084	$0.0040

FIGURE 9-1. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR ETHYLENE OXIDE PRODUCTION FACILITIES



9.2.2 Pricing

EO prices are determined by a combination of feedstock costs and end-use demand. Ethylene, the principal input in EO production, is also the largest volume synthetic organic chemical in the world today. Ethylene prices are expected to fall over the next several years as new capacity becomes operational and lower cost feedstocks, particularly butane, increase in availability.[25] Feedstock costs are unlikely to put upward pressure on EO prices through the mid-1990s. End uses for EO tend to be mature, leading to modest growth in demand for EO -- 2 to 2.5 percent per year. Already a low profit industry, EO prices are projected to continue falling, stemming from the aforementioned feedstock costs and increased capacity for captively consumed EO. The 1989 average realized price of $1.30 per kilogram can be considered an upper-bound price. This is probably an overstatement given the common practice of discounting in the EO industry. Two developments might, however, help to buoy EO prices. First, the low profitability is encouraging exit from the merchant market, which is already being undertaken by Union Carbide, Dow Chemical, Hoechst Celanese Corporation, and Texaco Chemical Company.[26] Also, strong demand for surfactants should moderate the slide. Nevertheless, the high-volume, mature EO industry is apt to face a continued softening of prices and profitability. If prices drop, HON impacts will be understated.

9.2.3 Elasticities

Demand elasticities for ethylene oxide will be estimated on the basis of available substitutes for EO, as well as substitutes for end-users. The potential for import substitution is also examined.

9.2.3.1 Ethylene Glycol

Ethylene glycol(EG) is the primary derivative of EO, accounting for 58 percent of EO demand. Forty-one percent of EG is used as antifreeze, and 35 percent is used in the manufacture of polyester fibers. These two end uses will be addressed in turn.

While manufacture of antifreeze from compounds other than EG is chemically feasible, EG dominates the market. EG is both low in cost and easily analyzed for its thermal properties. Demand for EG in the antifreeze market is considered highly inelastic. As such, the derived demand for EO is highly inelastic in this instance.

Polyester also appears to be highly dependent on EG as an input. Polyester is the material used in the largest quantity by the textile industry. Moreover, the character of polyester fiber (i.e. texture, washability, durability, etc.) stems from its EO component. However, polyester fibers themselves do have substitutes,including other synthetics, and natural fibers like cotton and wool. Cotton has made notable inroads into the polyester market in recent years. The demand for EG, and in turn EO, is judged to be highly to moderately inelastic in this end-use sector.

9.2.3.2 Ethoxylates

Ethoxylates rank second in EO demand, accounting for 14 percent of consumption. Ethylene-based ethoxylates, inexpensive and highly biodegradable, have experienced growth through the last decade due to a shift towards liquid detergent use in favor of powdered detergents. Alkyl benzene sulfonates play the same role in powdered detergents. The benzene-based surfactants, also subject to HON regulations, are inexpensive as well, but probably don't biodegrade as readily. Biodegradability, however, is not the primary determinant of consumer choice. Consumers have demonstrated a preference for liquid detergents because of its particular attributes. This leads to a demand estimate of moderate inelasticity in this range.

9.2.3.3 Imports

While imports of EO are inconsequential, EG imports are significant, accounting for 7.9 percent of U.S. consumption in 1989. Sizable price increases in EO, which will be reflected in EG prices, could stimulate import substitution. Nonetheless, it is doubtful that EO prices will escalate to the point where imports become attractive. Import substitution should have a minor affect on the domestic EO market.

9.2.3.4 Elasticity estimate

Within each end-use sector, demand elasticity is thought to be well below unity, and varies between highly inelastic and moderately inelastic. Given the negligible impact of imports, and the importance of antifreeze in EO end uses, which is highly inelastic, the overall demand elasticity for EO is estimated to be in the highly inelastic range of .1 to .34.

9.2.4 Market Structure

Table 9-9 summarizes the parameters for the market structure of ethylene oxide. Twelve firms are currently producing ethylene oxide. The four-firm concentration ratio is 62.4 percent, signifying moderate market power. The HHI is 1,490.1, which falls in the range of moderate

TABLE 9-9. MARKET STRUCTURE CHARACTERISTICS FOR ETHYLENE OXIDE

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced at Site (Horizontal Integration)	Imports
12	62.4%	1,490.1	89%	6	Insignificant

[a] Herfindahl-Hirschman Index

market power. Captive consumption is 89 percent, indicating a substantial level of vertical integration. On average, six chemical compounds are produced at ethylene oxide sites, suggesting a substantial level of horizontal integration. Imports in the industry are not important. In summary, the ethylene oxide market is estimated as moderately oligopolistic, and producers will likely absorb a portion of HON compliance costs.

9.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the ethylene oxide are presented in Table 9-10.

9.2.5.1 Option One Control Costs

Total industry control costs represent the maximum control cost that an industry will incur. The weighted average percentage price increase of .31 percent leads to a price increase $.0040 per kilogram. For the two elasticity levels of -.1 and -.34, the output reduction is 91 thousand kilograms (.0037%) and 3.1 million kilograms (.104%), respectively.

The smallest plant in the industry is facility 12A, which accounts for 39.6 million kilograms of industry production. If this plant absorbs the entire reduction in output, it would lose from .2 to 8 percent of its production. This loss of output is unlikely to lead to closure. Option one costs range from $.0038 to $.0070 per kilogram. Thus, with this uniformity of control costs, it is likely that output reductions will be shared across the industry.

9.2.6 Conclusion

Prospects for ethylene oxide are not particularly strong. This large-volume chemical -- ranked 16th in U.S. organic chemical production -- suffers from low profitability, declining feedstock costs, and mature end-uses. The range of cost increases is from $.0038 per kilogram to $.0070 per kilogram. The differential is small, so the production-weighted price increase is probably a good estimate of the actual industry price increase. Closure seems unlikely and the impact of HON controls is minimal.

TABLE 9-10. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE ETHYLENE OXIDE INDUSTRY[1], OPTION ONE CONTROL COSTS

	Elasticity	
	-0.1	-0.34
%Δ Price (%/kg)	0.31%	0.31%
Δ Price ($/kg)	$.0040	$.0040
%Δ Output (%/kg)	(0.003%)	(0.104%)
Δ Output (10^6 kg)	(.091)	(3.1)
%Δ Total Revenue	0.30%	0.20%
Δ Total Revenue (10^6 $)	$11.7	$7.8
Δ Employment (# of Employees)	(0)	(11)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

Δ = Change In

Market Price = $1.30/kg

1995 Output = 2,973 x 10^6 kg (based on 1989 production at 2% annual compound growth)

1995 Total Revenue = $3,864,989,422.91 (market price x 1995 output)

1995 Employment = 10,742

9.2.7 References

1. U.S. International Trade Commission. Synthetic Organic Chemicals -- United States Production and Sales, 1988, Washington, DC, September 1989, p. 15-8.
2. "Chemical Profile -- Ethylene Oxide." Chemical Marketing Reporter, February 12, 1990.
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11. Reference 9.
12. Reference 4.
13. Reference 4.
14. This paragraph was excerpted from U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, "Air Oxidation Processes in Synthetic Organic Chemical Manufacturing Industry - Background Information for Proposed Standards," Research Triangle Park, NC, October 1983.
15. "Trade Surplus Level Expected to Weaken." Chemical Marketing Reporter, April 2, 1990.
16. Reference 2.
17. Reference 4.
18. Reference 6.
19. Reference 9.
20. Reference 3.
21. Reference 6.
22. Reference 15.
23. Reference 15.

24. Reference 6.

25. Reference 6.

26. Mannsville Chemical Products Corp. "Chemical Product Synopsis--Ethylene." Asbury Park, NJ, January 1990.

27. "Glycol Prices Are Up But Maybe Not For Long." Chemical Marketing Reporter, February 25, 1991, p.5.

FIGURE 9-2

CHEMICAL TREE

ETHYLENE OXIDE

$$\text{process 75218a: } \underset{(74851)}{\text{ethylene}} + \text{air} \xrightarrow{P} \underset{(75218)}{\text{ethylene oxide}}$$

NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 10

CYCLOHEXYLAMINE PRODUCTION

10.1 INDUSTRY PROFILE

10.1.1 Brief Market Introduction

10.1.1.1 Historical Overview

Cyclohexylamine is an amine with a variety of end uses. It is produced from one of two feedstocks, aniline or cyclohexanol, From 1980 to 1989, demand grew on average by 5.5 percent per year.[1] Price erosion characterized the mid-1980s, despite rising feedstock costs. It was not until April 1, 1988 that cyclohexylamine producers were able to push up prices.[2] This was due to an increase in the demand for amines that share capacity with cyclohexylamine.

10.1.1.2 Recent Developments

Prices have recently remained stable after six consecutive quarters of growth from April 1988 to August 1989.[3] Table 10-1 tabulates prices over the last year.

10.1.2 Demand Conditions

10.1.2.1 Uses for Cyclohexylamine

Table 10-2 shows the various end uses. Cyclohexylamine's use as a boiler water treatment chemical is stable according to Chemical Marketing Reporter.[4] The chemical is relatively resistant to at least minor recessions because manufacturers' boilers must continue to run, even if demand for their product is on the wane. Internal treatment of industrial and institutional water for boilers requires specialty products, such as cyclohexylamine, formulated for specific needs of various applications and local conditions, often varying from plant to plant. Cyclohexylamine is used by water management chemical companies such as Betz, Nalco, and Calgon.[5]

10.1.2.2 Consumption

Total U.S. consumption for 1989 was 5.2 million kilograms.[6]

10.1.2.3 Exports

U.S. Exports in 1989 were approximately 1.59 million kilograms.[7] High production of alternative amines restricted cyclohexylamine output (facilities are flexible since they produce a variety of

TABLE 10-1. CYCLOHEXYLAMINE PRICES, 1990

Week Ending	Price range ($/kg)	
December 21, 1990	$2.98	$3.09
July 6, 1990	$2.87	$3.09
January 12, 1990	$2.87	-

Note: The historical price (1952-1990):
high $2.87 per kg
low $0.77 per kg
Discounting is common, especially for large-volume orders.

Sources: Chemical Marketing Reporter, December 24, 1990; Chemical Marketing Reporter, July 9, 1990; Chemical Marketing Reporter, January 15, 1990.

TABLE 10-2. USES OF CYCLOHEXYLAMINE, 1990

	Percent of Total Consumption
Boiler water treatment	60%
Rubber chemicals	12%
Nylon chain terminator	10%
Agricultural chemicals	10%
Miscellaneous:	8%
Oil field corrosion inhibitors	
Photographic chemicals	
Intermediates	
Metal extraction	

Source: *Chemical Marketing Reporter*, February 19, 1990, p. 46.

amines). With export prices weakening, the majority of cyclohexylamine went to domestic consumers.[8] Of U.S. exports a good portion (1.36 million kilograms) was destined for cyclamate production in the Far East.[9] Cyclamate is an artificial sweetener.

10.1.2.4 Future Prospects

U.S. demand in 1989 was 5.9 million kilograms; it is forecasted to reach 6.6 million kilograms by 1994 (representing a 2 percent growth rate).[10] Growth is expected to come from three smaller end markets.

The first market concerns DuPont. The company is expected to begin production in the United States of a herbicide intermediate based on purchased cyclohexylamine. DuPont had been buying the cyclohexylamine-based intermediate from BayerAG in West Germany. The company's annual CHA requirement is forecasted to be 453,593 kilograms (8% of 1989 production), most of which is expected to be supplied by U.S. producers.[11]

Another market that producers have been watching is the morpholine market. Cyclohexylamine is a substitute for this rubber accelerator. Rubber accelerators speed the curing or vulcanization process in rubber products manufacturing. Overseas, morpholine has been under scrutiny for several years as a potential carcinogen. If morpholine is banned or substituted for, cyclohexylamine will gain an additional 1.4 to 1.8 million kilograms per year of extra demand (24% to 31% 1989 production).[12]

Besides these two markets, cyclohexylamine has a significant potential market gain in the cyclamate area. Cyclamate is an artificial sweetener which uses cyclohexylamine as a feedstock. It is currently being examined by the FDA; approval is expected.[13] This market represents a potential 2.3 to 6.8 million kilogram gain (39% to 115% of 1989 production).[14]

10.1.3 Supply Conditions

10.1.3.1 Production Processes

As previously stated, cyclohexylamine is produced using either one of two feedstocks. It can be produced through the amination of cyclohexanol or through the hydrogenation of aniline.

10.1.3.2 Domestic Producers and Total Production

There are only two producers of cyclohexylamine in the United States. They are Air Products and Hoechst Celanese. As indicated by

Table 10-3, their combined capacity is 13.6 million kilograms per year from three different facilities.[15] Although nominal cyclohexylamine capacity is well in excess of U.S. demand, in practice this capacity is shared with other amines made in the same facilities. Thus, capacities are considered to be flexible. Air Products' Pensacola, Florida plant uses cyclohexanol amination while its Wichita, Kansas plant uses aniline hydrogenation. Both processes are used at the Hoechst Celanese plant.

Total U.S. production in 1989 was 5.9 million kilograms.[16] (This figure was derived by adding exports and subtracting imports from total U.S. consumption. It was assumed that there was no change in inventory.)

10.1.3.3 Costs of Production

According to one source, from 1986 to 1989, cyclohexylamine producers were "plagued by rising costs for both possible raw materials," aniline and cyclohexanol.[17] Despite the cost increases, cyclohexylamine prices eroded in the mid-1980s. This happened because demand declined for boiler water treatment chemicals and agricultural chemicals. It was not until 1988 -- when there was increased demand for amines, which are also produced at facilities that produce cyclohexylamine -- that tightened supplies of cyclohexylamine allowed producers to increase prices. Demand for all of the major end uses of cyclohexylamine rose and also helped to increase prices.

Both aniline and cyclohexanol are derived ultimately from benzene. In 1990, list prices for both aniline and cyclohexanol were relatively unchanged.[18]

10.1.3.4 Imports

Cyclohexylamine is also imported to the domestic market. The predominant foreign supplier is BASF, which has production flexibility at its plant in Germany. Other firms that have been factors from time to time are Imperial Chemical Industries PLC and Bayer AG. It should be noted that BASF has picked up most of Bayer's business.

Imports in 1989 totalled 907,186 kilograms.[19] Currency exchange rates continue to determine the degree of market penetration that imports will achieve.

Cyclohexylamine growth will be fueled by its continued use in boiler water treatment and by the three smaller end markets previously mentioned. These include herbicide intermediate production,

TABLE 10-3. U.S. PRODUCERS OF CYCLOHEXYLAMINE, 1990

Company	Plant Location	Capacity (10^6 kg/yr)
Air Products	Pensacola, Florida	4.53
	Wichita, Kansas	4.53
Hoechst Celanese	Bucks, Alabama	4.53
		13.59

Source: Chemical Marketing Reporter, February 19, 1990, p. 46.

10.1.4 Future Market Prospects

substitution for morpholine accelerators, and cyclamate production. All three, especially cyclamate, provide growth opportunities.

10.2 ECONOMIC IMPACT ANALYSIS

10.2.1 HON Compliance Costs

A synopsis of annualized control costs and summary statistics for cyclohexylamine production facilities and production processes is presented in Table 10-4. Costs are displayed for option one control costs, which are estimates of the actual control costs that facilities are likely to incur. Figure 10-1 presents the option one control scenario graphically. Two facilities are displayed.*

Cyclohexylamine is currently produced by two processes: hydrogenation of aniline (process A) and amination of cyclohexanol (process B). Option one control production weighted average costs are $.0242/kg for process A, and $.0012/kg for process B. The sizable cost differential between processes is masked by the industry production weighted average of $.0184 per kilogram. This differential could encourage use of process B. Facility 1 A&B, which has the capability to use both processes, could devote more of its capacity to producing via process B, alleviating its cost burden. Facility 2A, which uses only process A, could be at a competitive disadvantage.

10.2.2 Pricing

The price employed in the HON analysis for cyclohexylamine is $2.87/kg. Spot prices routinely exceed actual contract prices in this industry, as discounting is common. As such, impacts based on this spot price are apt to be understated. However, the most recent spot price available is $3.09/kg. If this is indicative of increasing contract prices, it may help to offset the understatement.

10.2.3 Elasticities

The demand elasticity for cyclohexylamine is estimated on the basis of available substitutes for cyclohexylamine, as well as substitutes for end-uses. The potential for import substitution is also examined.

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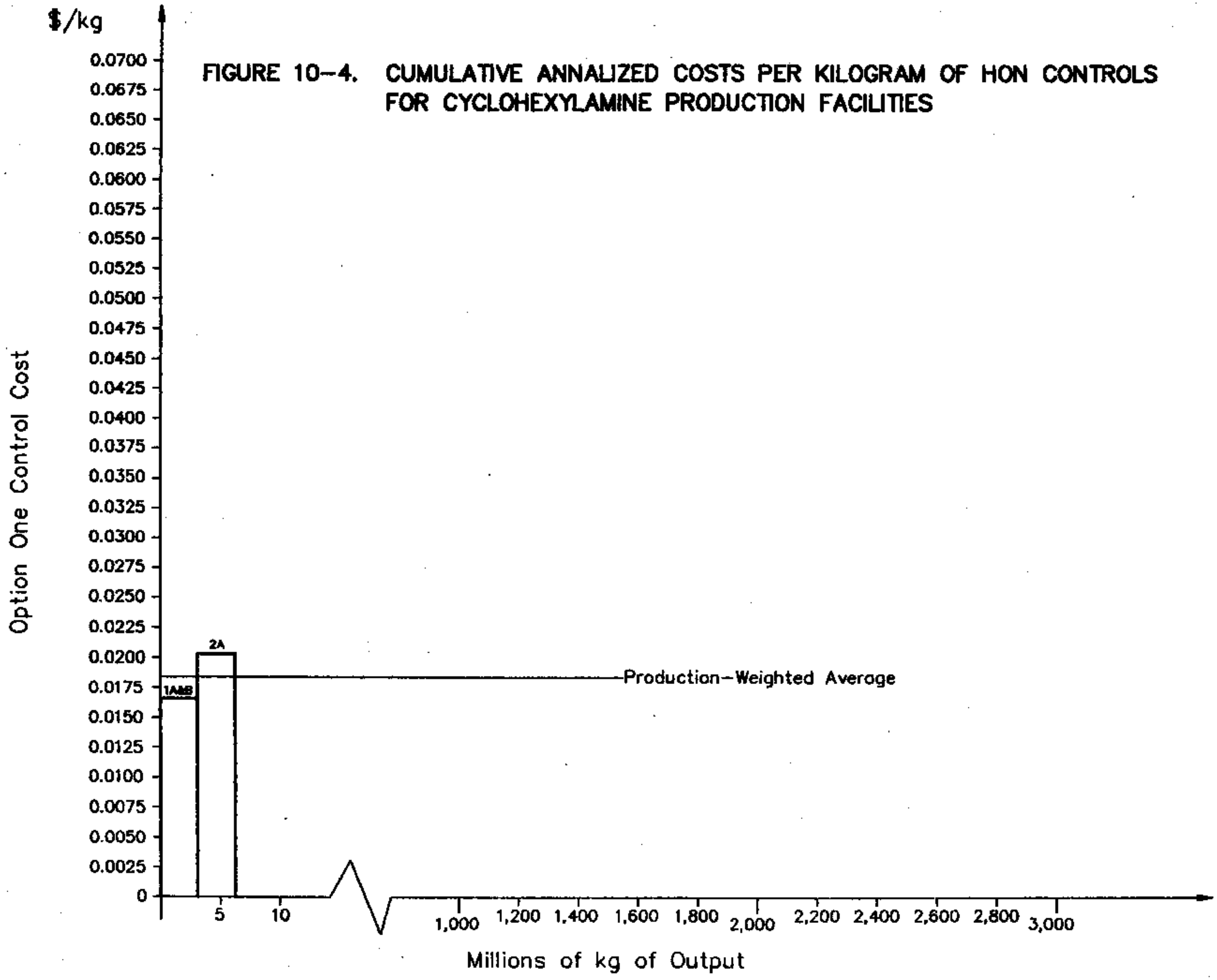
*In May 1989, a new facility was opened, with a capacity of 4.53 x 10^6 kg/yr. This facility employs process B. This plant is subject to HON controls, but opened after industry control costs were calculated.

TABLE 10-4. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR CYCLOHEXYLAMINE PRODUCTION FACILITIES AND PRODUCTION PROCESSES

Facility/(Process)	Annual Production (10^6 kg)	Control Costs
		Option One Control ($/kg)
1A&B	2.95	$.0166
2A	2.95	$.0203
<u>Control Costs By Process</u>		
Process A (hydrogenation of aniline)	4.426	$.0242
Process B (amination of cyclohexanol	1.476	$.0012
<u>Summary Statistics</u>		
Mean		$.0178
Production Weighted Average		$.0184

FIGURE 10-4. CUMULATIVE ANNALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR CYCLOHEXYLAMINE PRODUCTION FACILITIES



10.2.3.1 Demand Elasticities

10.2.3.1.1 Boiler Water Treatment. Currently, 60 percent of cyclohexylamine is used as a corrosion inhibitor in steam boiler systems. Corrosion inhibitors are sold in inhibitor packages for specific steam boiler systems. While a variety of different packages are available, these packages are tailored to unique applications and local conditions. Given this specialization, it is safe to assume that firms would be reluctant to alter the inhibitor package if it would alter the performance of the whole system. Elasticity is judged as moderately inelastic in this sector.

10.2.3.1.2 Rubber Chemicals. Twelve percent of cyclohexylamine is used in the rubber chemical market as a rubber accelerator. A close substitute, morpholine, is under legislative scrutiny in the Far East and Europe, due to stable, carcinogenic nitrosamine emissions. Cyclohexylamine and other amines emit nitrosamines which are less stable and break down more easily in the atmosphere. Already, a shift towards cyclohexylamine has begun. Both Goodrich and Goodyear Tire and Rubber Company have ceased development of morpholine-based projects. In this market, the demand for cyclohexylamine is regarded as moderately inelastic, owing to the declining attractiveness of morpholine as a substitute.

10.2.3.1.3 Nylon Chain Terminator. As a nylon chain terminator, cyclohexylamine makes up a minuscule share of the input requirements for nylon production. In addition, attempts to substitute terminators must be tempered by concerns about altering the polymerization process, and, ultimately, the quality of the finished product. However, other terminators are available on the market. Here, demand appears to be moderately inelastic.

10.2.3.1.4 Agricultural Chemicals. A variety of amines are used in the agricultural chemical (agchem) industry, predominantly as herbicides. Value of sales for agricultural chemicals in 1991 is estimated to exhibit real growth of 5.9 percent.[20] Herbicides are the fastest-growing sector in the agchem market.

A recent development in this market is E.I. du Pont de Nemours & Co.'s start-up of an intermediate plant geared for the production of Velpar (an herbicide). Cyclohexylamine is a necessary input in the Velpar production process, which indicates moderately inelastic demand, at least in this particular production process. Currently, 10 percent, or 590,000 Kg of cyclohexylamine output is used annually in the agchem industry. DuPont's projected annual cyclohexylamine requirement is 453,593 Kg, which is a 76 percent increase in domestic cyclohexylamine demand within the agchem sector.[21]

10.2.3.2 Imports

In 1989, imports were 15.4 percent of domestic production. Historical trends are unavailable. The ability to recover compliance costs through price increases could be hindered by potential losses in market share to imported cyclohexylamine.

10.2.3.3 Elasticity Estimate

In each case, the demand elasticity is clearly in the inelastic range. Based on this evidence, the demand elasticity for cyclohexylamine is estimated to be in the moderately inelastic range of -.34 to -.67.

10.2.4 Market Structure

Table 10-5 summarizes the parameters for the market structure of cyclohexylamine. Two firms are currently producing cyclohexylamine. Thus, two-firm concentration ratio is 100 percent, signifying substantial market power. The HHI is 5,555.5, which falls in the substantial range of market power. Only cyclohexylamine is produced at each facility. Imports in the industry are moderately important, and might affect the pricing discretion of domestic producers. In addition, it is a specialty chemical produced in small volumes and tailored to specific needs. In summary, the market structure for cyclohexylamine is highly oligopolistic, and firms will likely absorb a significant portion of HON compliance costs.

10.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the cyclohexylamine industry are presented in Table 10-6.

10.2.5.1 Option One Control Costs

Option one control costs represents the actual estimated cost that an industry will incur. The production weighted average percentage price increase of .64 percent leads to a price increase of $.0184 per kilogram. For the two elasticity levels of -.34 and -.67, the output reduction is 15 thousand kilograms (.22%) and 29 thousand kilograms (.43%), respectively.

TABLE 10-5. MARKET STRUCTURE CHARACTERISTICS FOR CYCLOHEXYLAMINE

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced At Site (Horizontal Integration)	Imports
2	100%	5,555.5	N.A.	1	Moderate

N.A. - Not Available

[a] Herfindahl-Hirschman Index

TABLE 10-6. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE CYCLOHEXYLAMINE INDUSTRY[1], OPTION ONE CONTROL COSTS

	Elasticity	
	-0.34	-0.67
%Δ Price (%/kg)	0.64%	0.64%
Δ Price ($/kg)	$.0184	$.0184
%Δ Output (%/kg)	(0.22%)	(0.43%)
Δ Output (10^6 kg)	(.015)	(.029)
%Δ Total Revenue	0.42%	0.21%
Δ Total Revenue (10^6 $)	$.083	$.041
Δ Employment (# of Employees)	(0)	(0)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

Δ = Change In

Market Price = $2.87/kg

1995 Output = 6,779.5 x 10^6 kg (based on 1989 production at 2 percent annual compound growth)

1995 Total Revenue = $19,457,287.87 (market price x 1995 output)

1995 Employment = 55

Both plants are of the same size, each accounting for 2.95 million kilograms of industry production. Facility 2A is the highest cost plant. If this facility absorbs the entire output loss, it would lose from .5 percent to .98 percent of its production. This reduction is not likely to lead to closure. In this scenario, no employment loss is projected.

10.2.6 Conclusion

Compliance costs at the facility level range from $.0166 per kilogram to $.0203 per kilogram. This is a small differential, and so the production-weighted average price increase is probably an accurate estimate of the actual price increase. Cyclohexylamine is a small-volume, specialty chemical. If the highest cost plant is the marginal facility, the maximum price increase will be $.0203. In this scenario, plant closure is nevertheless unlikely. However, a shift in process, favoring process B, is possible.

10.2.7 References

1. "Chemical Profile -- Cyclohexylamine." Chemical Marketing Reporter, February 19, 1990, p. 46.
2. "Cyclohexylamine Seen Reaching Fair Value." Chemical Marketing Reporter, August 28, 1989, p. 5.
3. Reference 2.
4. Reference 2.
5. "Specialties '90." Chemical Marketing Reporter, April 30, 1990, p. SR34.
6. Reference 1.
7. Reference 1.
8. Reference 2.
9. Reference 2.
10. Reference 1.
11. "Amines Market Shift Favors Cyclohexylamine." Chemical Marketing Reporter, May 7, 1990, p. 5.
12. Reference 11.
13. Reference 11.
14. Reference 11.
15. Reference 1.

16. Reference 1.

17. Reference 2.

18. Chemical Marketing Reporter, December 31, 1990, p. 24, 26; Chemical Marketing Reporter, July 9, 1990, p. 30, 32; Chemical Marketing Reporter, January 8, 1990, p. 26, 28.

19. Reference 1.

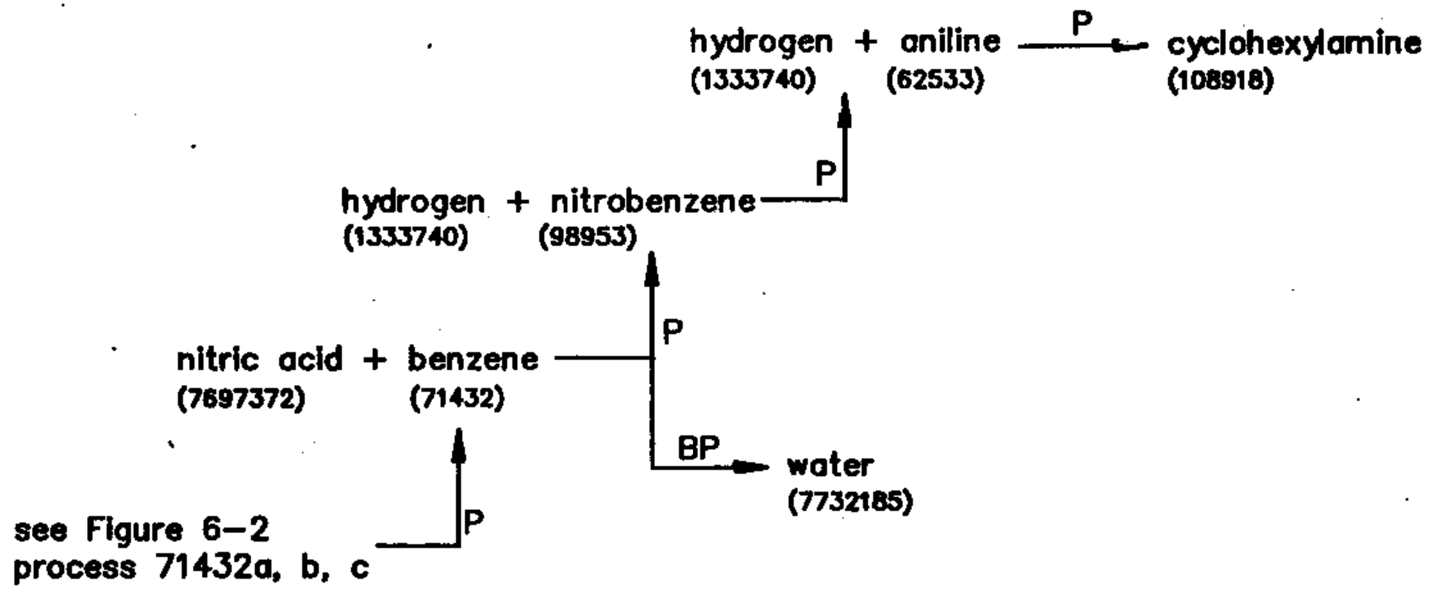
20. 1991 U.S. Industrial Outlook, p. 7-10.

21. DuPont was previously importing CHA for its herbicide requirements.

FIGURE 10-2

CHEMICAL TREE

CYCLOHEXYLAMINE



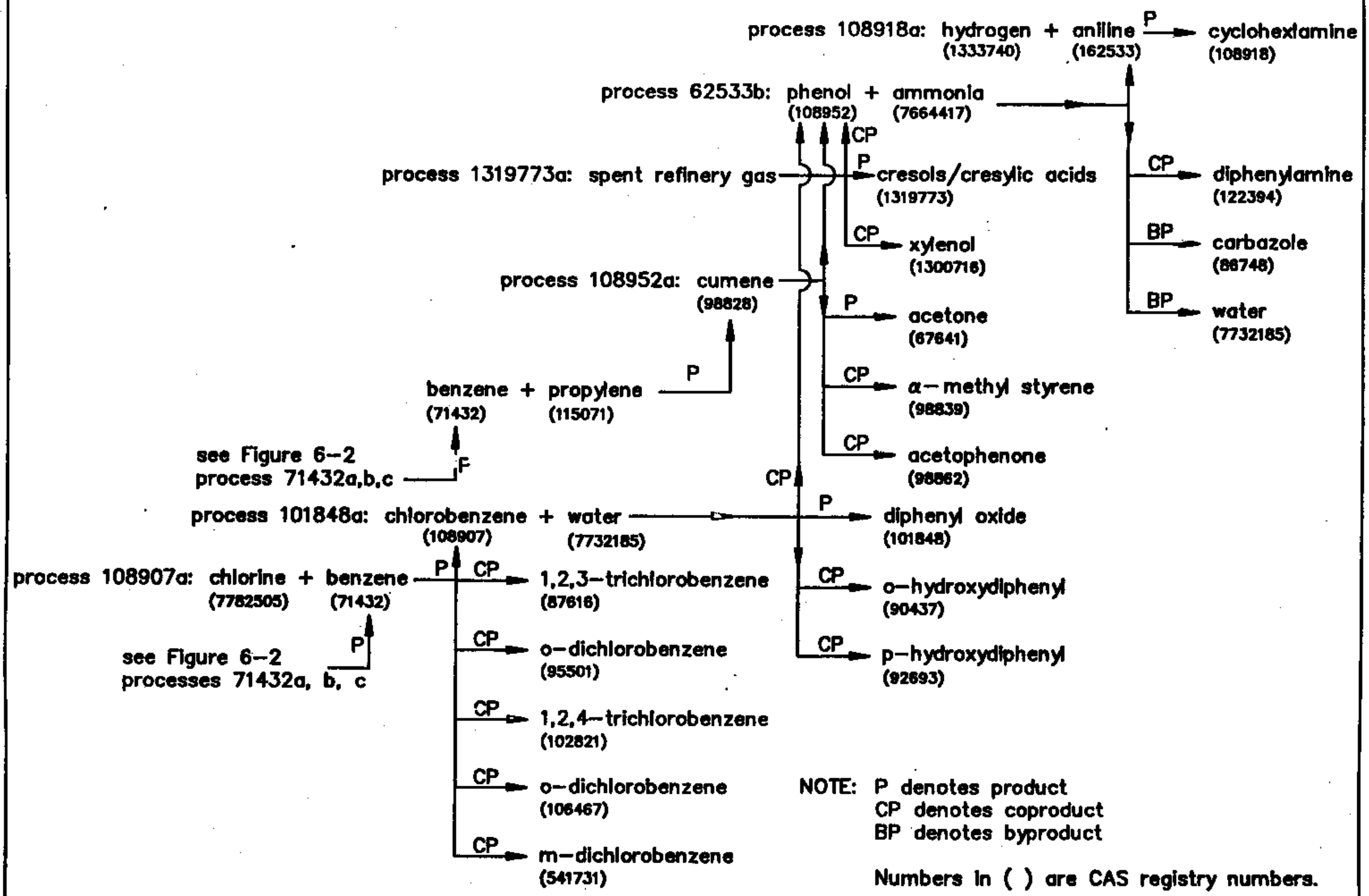
NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

FIGURE 10-2 (CONT.)

CHEMICAL TREE

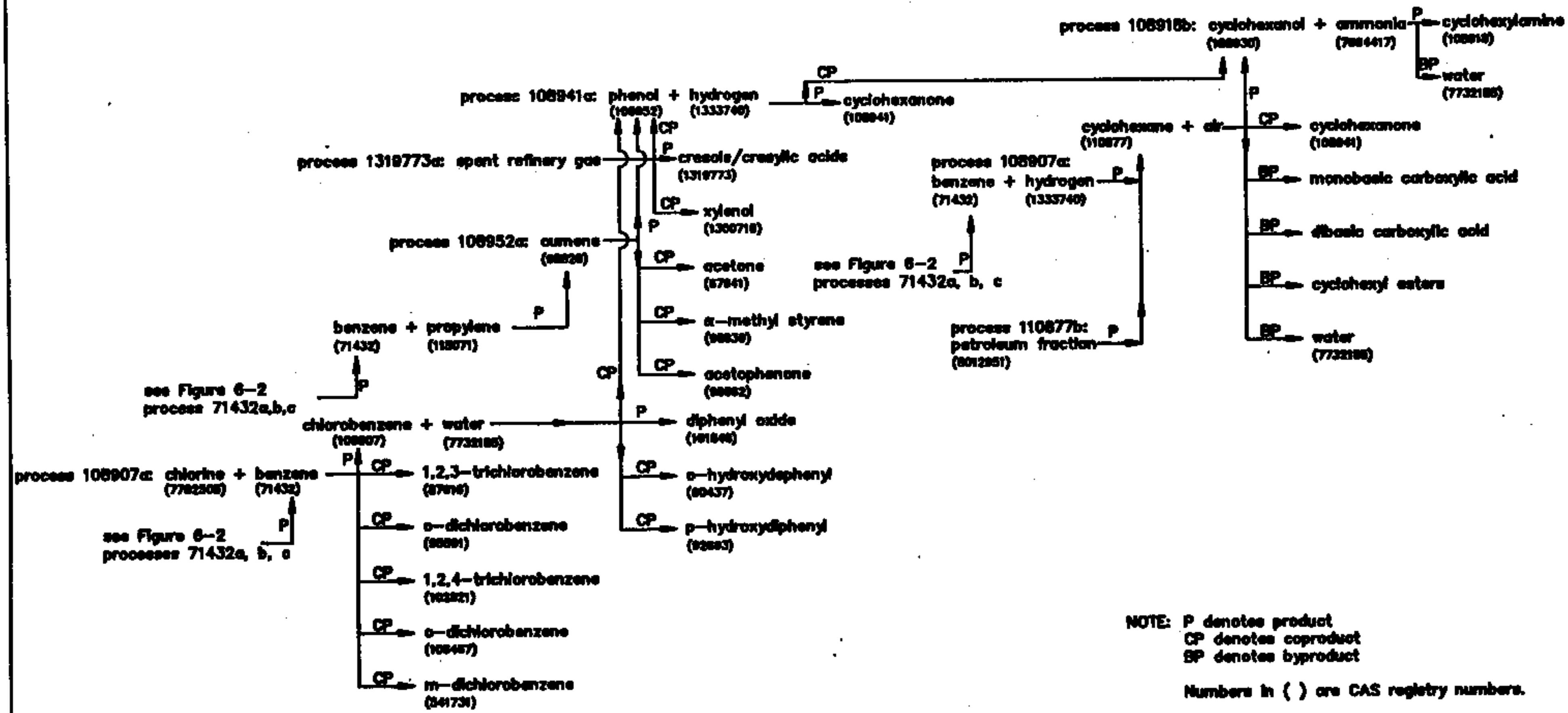
CYCLOHEXYLAMINE



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

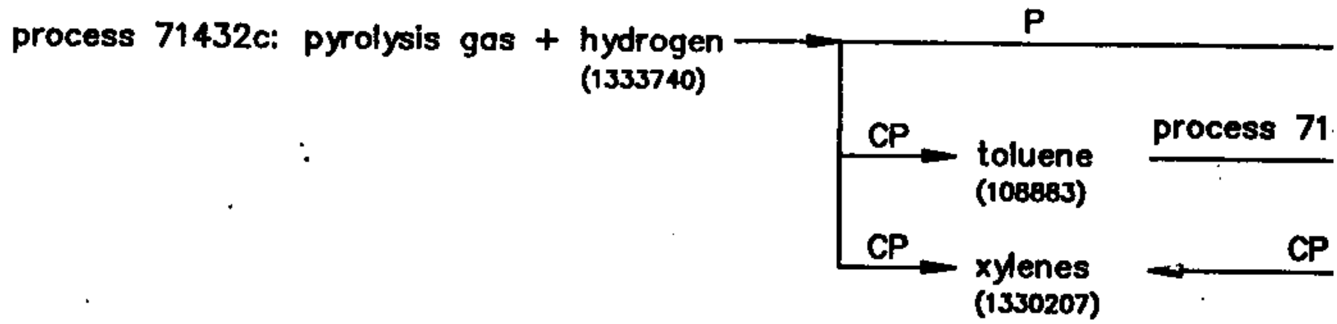
FIGURE 10-2 (CONT.)
CHEMICAL TREE
CYCLOHEXYLAMINE



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

FIGURE 10-3
CHEMICAL TREE
BENZENE



Hydroquinone is used princi
industry and as a developing agen
intermediate in the manufacture o
monomer inhibitors.

Estimated demand for hydroq
at an average rate of 3 percent p
the 1980-1982 recession, demand d
for rubber antioxidants in tire r
used to make vinyl and acrylic re
increased after the recession in
economic sectors revived.

11.1.1.2 Recent Development

The list price (in current
little from 1980 to 1991. In 198
quinone was $4.85 per kilogram an
$4.19 per kilogram.[3] The 1991 pri
to $5.60 per kilogram; technical-
It should be noted that actual se
20 percent off of list.[4]

11.1.2 Demand Conditions

11.1.2.1 Uses for Hydroquin

As previously mentioned, hy
photographic developing and in an
production of hydroquinone result
technical-grade. The photo-grade
in black and white photography.
intermediate in the manufacture o
well as monomer inhibitors. Hydr
hydroquinone are also used as dep
melasma, freckles, senile lentigi
hyperpigmentation.

11.1.2.2 Consumption

Current U.S. demand for hydroquinone is unknown. However, it is known that world demand is around 29.9 million to 34.9 million kilograms per year.[5] In 1983, U.S. demand was 11.8 million kilograms.[6] At that time, Mannsville Chemical Products Corporation forecast that demand would be 12.2 million kilograms a year from 1984 to 1989.[7]

11.1.2.3 Exports

U.S. exports of hydroquinone in 1989 totalled 950,463 kilograms with a value of 4,469,090 dollars.[8] From January to October 1990, exports were 1,160,123 kilograms, valued at 3,980,993 dollars.[9]

11.1.2.4 Future Prospects

Growth is expected to be 3 to 5 percent annually.[10] Hydroquinone is being scrutinized as a potential carcinogen which may affect all end uses but particularly depigmenting agents.

11.1.3 Supply Conditions

11.1.3.1 Production Processes

In the U.S. hydroquinone is manufactured either by aniline-oxidation or the hydroperoxidation of diisapropylbenzene. The aniline-oxidation process involves the oxidation of aniline with manganese dioxide to quinone followed by iron-catalyzed reduction to hydroquinone. Quinone formed in the first step is removed from the oxidation solution by steam stripping. The quinone-steam mixture can be reduced with either an aqueous solution of iron or by catalytic hydrogenation. Technical grade hydroquinone is prepared from the reaction solution by crystallization, centrifugation, and drying. Alternatively, hydroquinone is manufactured by the hydroperoxidation of diisapropylbenzene. Aniline-oxidation has been used since the 1930s.[11] However, it is being phased out in favor of the hydroperoxidation of diisapropylbenzene process. The latter is used in two of the three hydroquinone facilities.

Sources: Chemical Marketing Repo
SRI International, <u>199</u>
<u>United States</u>.

Goodyear has a capacity of 5.2 million kilograms tons a year.[13] Eastman Kodak has stated in its 1989 annual report that its facility is operating at full capacity. Eastman Kodak uses both production processes, while Goodyear only uses the hydroperoxidation of diisapropylbenzene.

Total production is not known. However, in 1983, output of U.S. producers was 10.4 million kilograms.[14]

11.1.3.3. Costs of Production

Hydroquinone raw materials are benzene, propylene, phenol, and aniline. Costs of production will vary with supply and demand conditions for these four feedstocks.

11.1.3.4 Imports

In 1989 total imports were 1,370,769 kilograms, valued at 3,875,593 dollars.[15] For the period January to October 1990, total imports were 1,272,639 kilograms, valued at 4,150,721 dollars.16 These totals are in contrast to an estimated 907,186 kilograms imported in 1981.17 Major foreign producers include Rhone-Poulenc Inc. (France), Ube Industries Ltd. (Japan), Mitsui Petrochemical Company (Japan), and Enimont (through its subsidiary Enichem Synthesis in Italy).

11.1.3.5 Future Prospects

Rhone-Poulenc has begun construction of a hydroquinone/catechol plant in Baton Rouge, Louisiana. This facility is scheduled to start production in early 1992. Ube Industries has done some minor expansion at its facility in Japan, and Mitsui Petrochemical is considering expansion at its Japanese facility. According to Chemical Marketing Reporter, "growth trends indicate that hydroquinone availability will further tighten."[18] Due to this, other expansions are probable in the near future.

11.1.4 Future Market Prospects

graphically. Two facilities are

Hydroquinone is currently
aniline oxidation followed by red
and by hydroperoxidation of dii
weighted average costs are $.026
process B. The cost differential
masked by the industry productio
kilogram.

11.2.2 Pricing

Hydroquinone prices are det
costs and end-use demand conditi
available commercially, photo-gr
will be assessed on photo-grade
$.80 to $1.50 above technical-gr
are apt to be conservative when
hydroquinone. End-use markets f
and growth potential appears to
look to be tight over the next fi
firm. The price employed for thi
price, and it should be noted tha
as much as 20 percent.

11.2.3 Elasticities

The demand elasticity for
of available substitutes for hyd
end-uses. The potential for imp

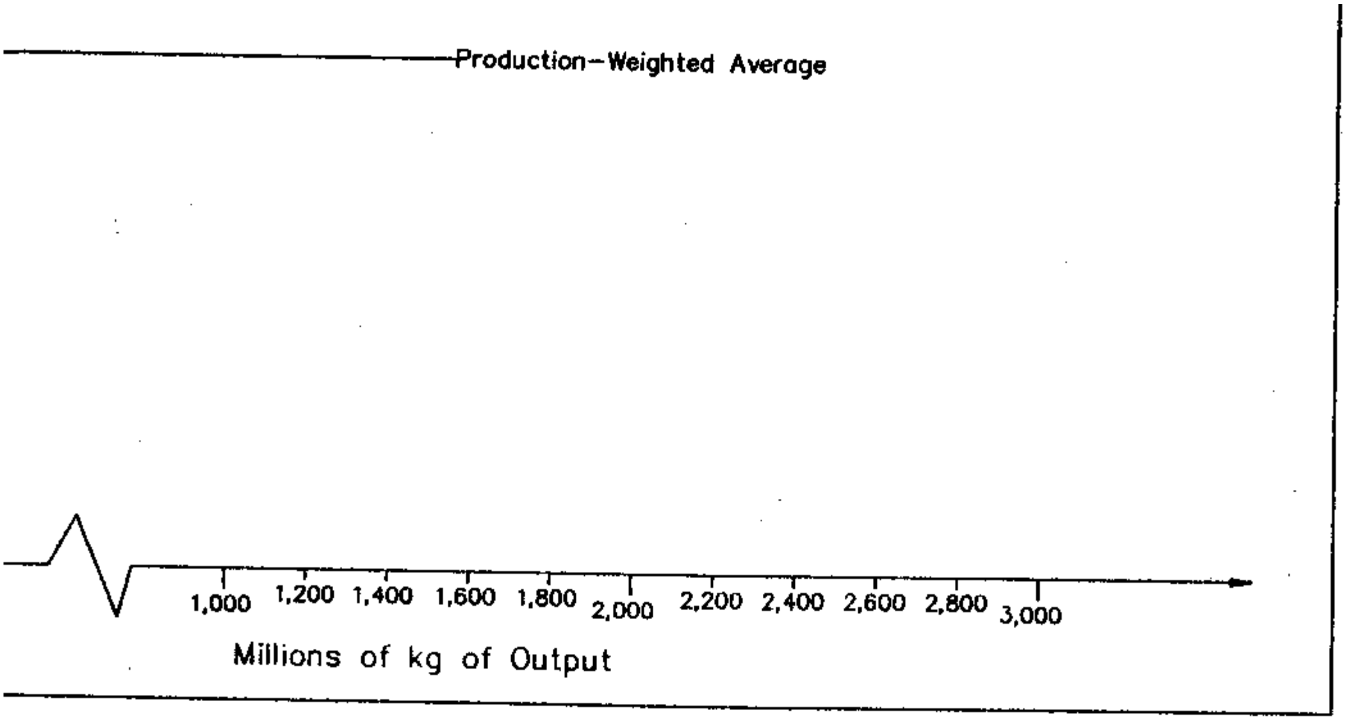
11.2.3.1 Demand Elasticiti

11.2.3.1.1 Photographic Dev

Photographic-grade hydroqui
photographic applications. Deman

TABLE 11-2. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR HYDROQUINONE PRODUCTION FACILITIES AND HYDROQUINONE PRODUCTION PROCESSES

Facility/(Process)	Annual Production (10^6 kg)	Control Costs Option One Control ($/kg)
1A&B	7.6	$.0241
2A	3.4	$.0476
<u>Control Costs By Process</u>		
Process A (quinone reduction)	3.8	$.0260
Process B (diisopropylbenzene hyperoxidation)	7.2	$.0341
<u>Summary Statistics</u>		
Mean		$.0320
Production Weighted Average		$.0313


Production–Weighted Average
1,000
1,200
1,400
1,600
1,800
2,000
2,200
2,400
2,600
2,800
3,000
Millions of kg of Output

decline as consumers reveal preferences for color film. Even for use in black and white developing, several substitutes are in use, including phenylenediamines and pyrogallol. Elasticity is regarded as slightly inelastic in this sector.

11.2.3.1.2 Antioxidants

Hydroquinone is used as an intermediate in the manufacture of rubber, plastic and food antioxidants. While the growth of the rubber industry has slowed in tandem with tire manufacturing, future growth for hydroquinone end uses will be concentrated in the plastics industry. There are a variety of alkylated phenols that can substitute for hydroquinone in this use. Demand in this sector is judged to be slightly inelastic.

11.2.3.2 Imports

Comprehensive import data for hydroquinone is not readily available, but imports do appear to be important. In August 1984 it was estimated that one third of the hydroquinone merchant market was supplied by imports. This is probably no longer the case, as both Goodyear and Eastman have stepped up their domestic production since then. Nevertheless, hydroquinone is produced in Europe and Japan, so domestic manufacturers must pay attention to the possibility for import substitution.

11.2.3.3 Elasticity Estimate

End-use industries for hydroquinone are characterized by slightly inelastic demand, and imports appear to be important. Based on this evidence, the demand elasticity for hydroquinone is estimated to be in the slightly inelastic range of -.67 to -1.00.

11.2.4 Market Structure

Table 11-3 summarizes the parameters for the market structure of hydroquinone. Two firms are currently producing hydroquinone. Thus, the four-firm concentration ratio is 100 percent, signifying substantial

TABLE 11-3. MARKET STRUCTURE CHARACTERISTICS FOR HYDROQUINONE

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced At Site (Horizontal Integration)
2	100%	5,683.4	N.A.	6

[a] Herfindahl-Hirschman Index

of domestic producers. Importantly, facility 2B produces technical grade hydroquinone, while the other facility produces both technical and photographic grade hydroquinone. Thus, competition is limited because the market is segmented. In summary, the hyroquinone industry is substantially oligopolistic, and producers are likely to absorb a significant portion of HON control costs.

11.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the hydroquinone industry are presented in Table 11-4, for option one control costs.

11.2.5.1 Option One Control Costs

Option one control costs represent the actual estimated cost that an industry will incur. The weighted average percentage price increase of .61 percent leads to a price increase $.0313 per kilogram. For the two elasticity levels of -.67 and -1.00, the output reduction is 56.4 thousand kilograms (.41%) and 84.1 thousand kilograms (.61%), respectively.

Facility 2B, which is the smallest plant in the industry as well as the highest cost plant, accounts for 3.4 million kilograms of industry production. If this facility absorbs the entire output loss, it would lose from 1.7 percent to 2.5 percent of its production, which is not likely to lead to closure. The loss in employment is from one to two employees. While these cost increases seem modest at the facility level, producers must be conscious of imports, which could be encouraged by potential price increases.

Two processes are used to produce hydroquinone. Process A costs are slightly higher than Process B costs. However, the two processes cater to different markets, so that HON controls are unlikely to stimulate process change.

11.2.6 Conclusion

Hydroquinone producers will likely experience two price increases -- one for technical grade and one for photographic grade. Thus, the

Δ Output (10^6 kg)

%Δ Total Revenue

Δ Total Revenue (10^6 \$)

Δ Employment
(# of Employees)

---

[1] Based on Production Weightec

DEFINITIONS:

Δ = Change In

Market Price = \$5.12/kg

1995 Output = 13.8 x 10^6 kg (

1995 Total Revenue = \$70,750
1995 ou

1995 Employment = 193

unlikely, since each process fills a market niche. The notable impact of HON controls is the possibility of import substitution.

11.2.7 References

1. Mannsville Chemical Products Corp. "Chemical Product Synopsis -- Hydroquinone." Asbury Park, NJ, August 1984.
2. Reference 1.
3. Chemical Marketing Reporter, January 7, 1991.
4. "Hydroquinone Supply Tight; Scarcity Invites Expansions." Chemical Marketing Reporter, August 13, 1990, p. 11.
5. Reference 4.
6. Reference 1.
7. Reference 1.
8. U.S. Department of Commerce, International Trade Administration, Trade Data Services, (Phone Conversation, 1/10/91).
9. Reference 8.
10. Reference 4.
11. Reference 1.
12. Reference 4.
13. Reference 4.
14. Reference 1.
15. Reference 8.
16. Reference 8.
17. Reference 1.
18. Reference 4.
19. "Specialties 1990." Chemical Marketing Reporter, April 30, 1990, p. SR26.

FIGURE 11-2
CHEMICAL TREE
BENZENE

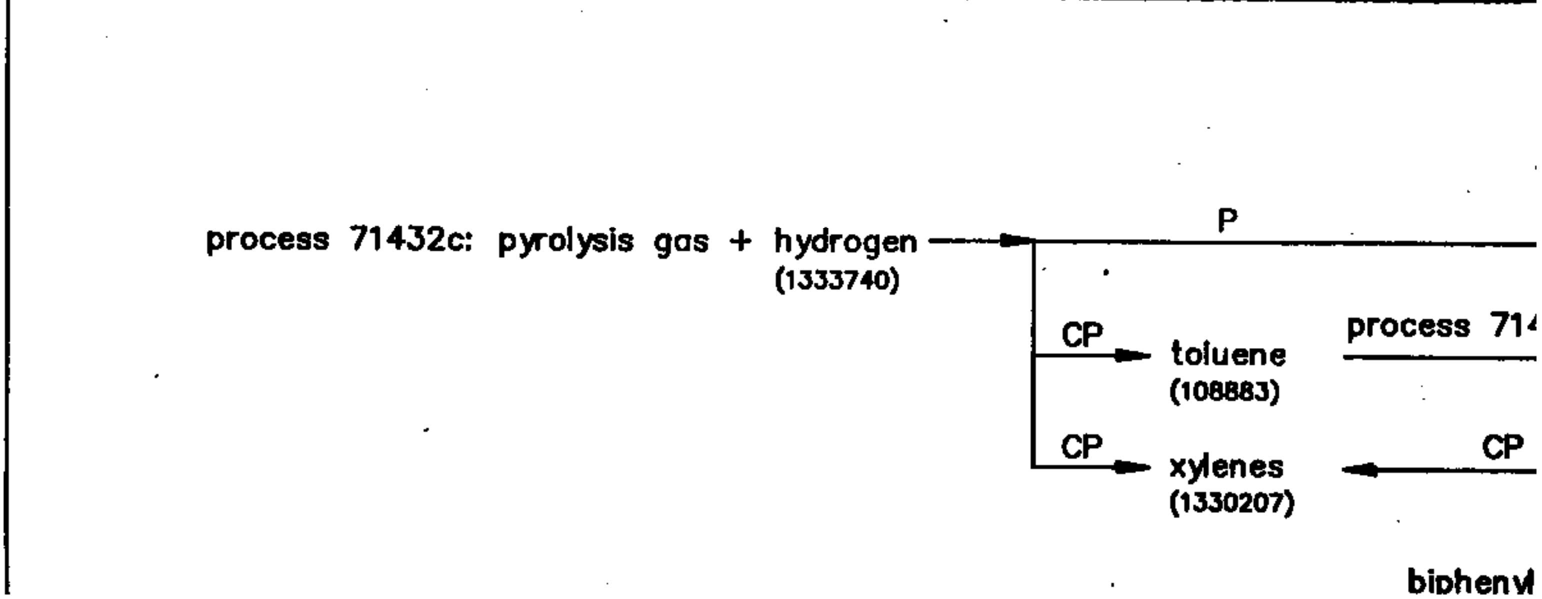
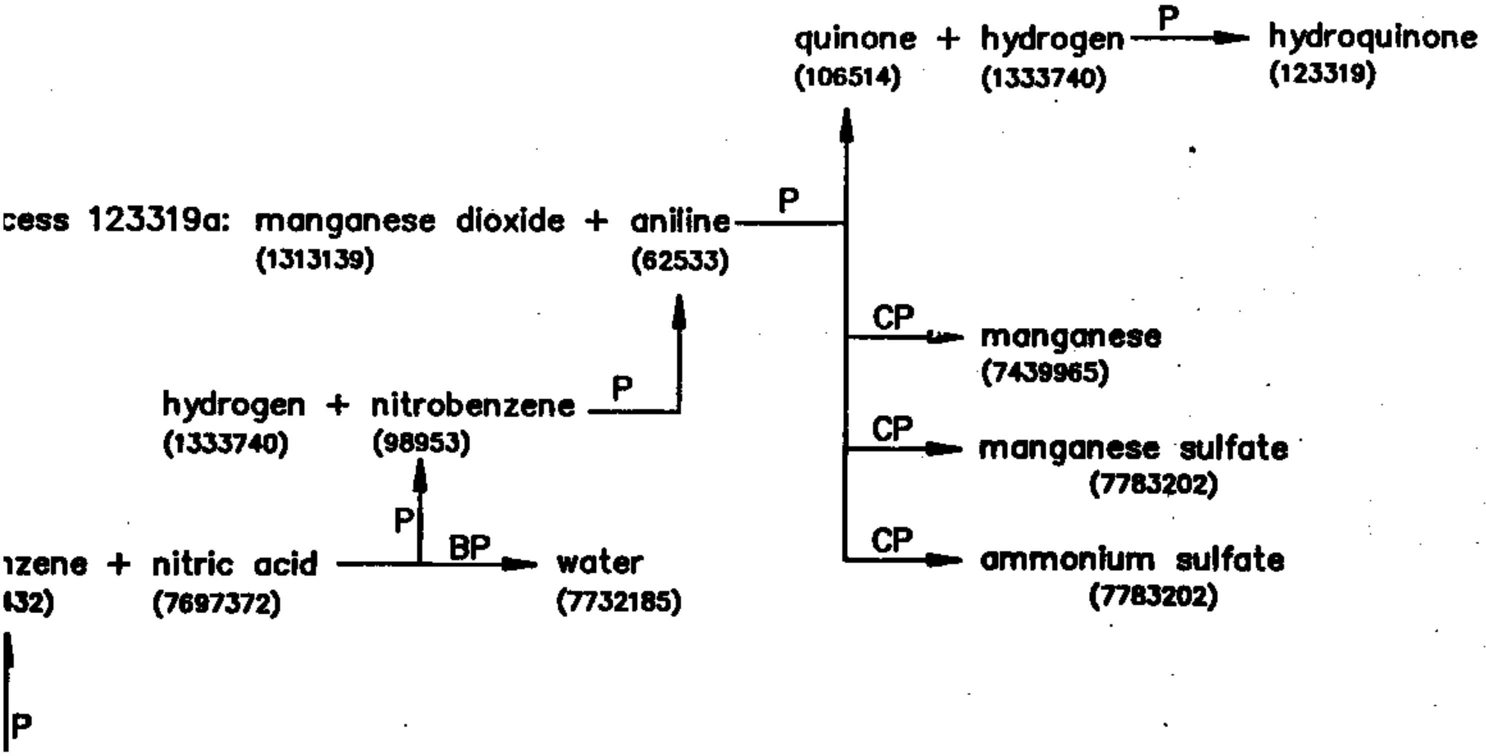


FIGURE 11-3

CHEMICAL TREE

HYDROQUINONE



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re CAS registry numbers.

FIGURE 11-3

CHEMICAL TREE

HYDROQUINONE

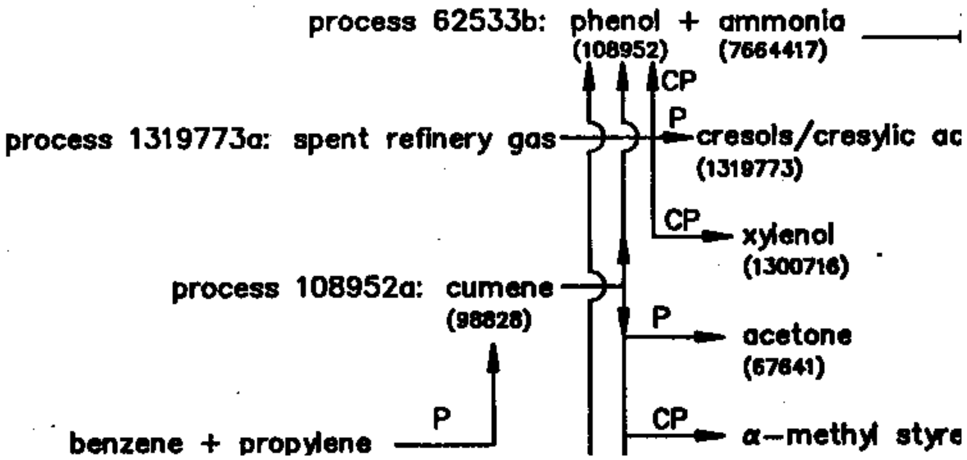
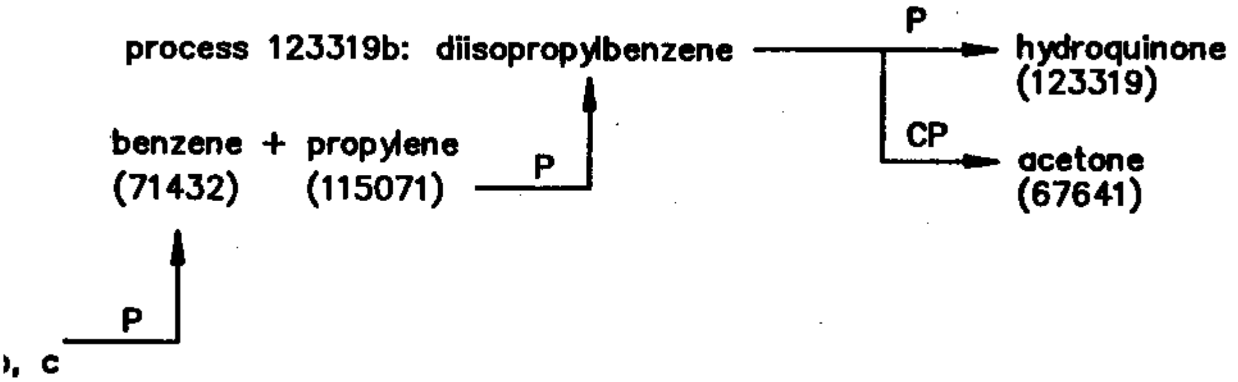


FIGURE 11-3
CHEMICAL TREE
HYDROQUINONE



luct
luct

CAS registry numbers.

Ethylene glycol (also refer principal derivative of ethylene of total ethylene oxide consumpti the ethylene glycol produced in t merchant market.[2]

12.1.1 Brief Market Introduction

12.1.1.1 Historical Overvi

Table 12-1 lists the averag from 1980 to 1989. Prices reache 1989 after a low of 37 cents in 1 attributable in part to the fast

12.1.1.2 Recent Developmen

Preliminary list prices in range of 60 to 62 cents per kilog than 1989 because of excess suppl decline in exports to the Far Eas with the onset of winter as deman was up.[5] The current Middle East There is some worry about how the producer of ethylene glycol.[6]

12.1.2 Demand Conditions

12.1.2.1 Uses for Ethylene

Table 12-2 shows the variou Antifreeze is the largest end use consumption. Polyester fibers (3 products including textiles, carp uses of ethylene glycol (17 perce polyester film, and other polyest

TABLE 12-1. AVERAGE REALIZED PRICE OF ETHYLENE GLYCOL, 1980-1989

	Price (¢/kg)
1989	88
1988	73
1987	40
1986	40
1985	37
1984	46
1983	N.A.
1982	N.A.
1981	N.A.
1980	60

N.A. - Not available.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Ethylene Glycol," August 1988; U.S. International Trade Commission, Synthetic Organic Chemicals, 1988-1989.

Polyester bottle resin

Polyester film and other resins

Other[a]

---

[a] Used as a solvent, alkyd, in poly
intermediate for various esters a

Source: <u>Chemical & Engineering Ne</u>

as a solvent for stains, dyes, and resins and as an intermediate for various esters and ethers.

12.1.2.2 Consumption

In 1989 apparent consumption of ethylene glycol in the United States dropped to 2,181 million kilograms after being 2,328 million kilograms in 1988 (see Table 12-3). Consumption was affected by low demand for antifreeze. In 1988 216 million gallons of antifreeze were sold.[7] However, 1989 sales were less than 161 million gallons because consumers hoarded supplies in 1988.[8] This was due in part to a large inventory carryover of antifreeze from 1988 to 1989. Forecasting future demand is difficult due in part to the volatility of antifreeze demand (which seems to follow a cycle of record sales then slumps due to hoarding).[9]

12.1.2.3 Exports

U.S. exports of ethylene glycol from 1980 to 1989 are listed in Table 12-4. Exports in 1989 were four times the level in 1980. Data was not available for the 1981 to 1983 period, but growth between 1984 and 1988 was fairly steady. However, exports jumped by almost 200 million kilograms between 1988 and 1989. Most of this growth was fueled by shipments of ethylene glycol to the Far East. It is also worth noting that exports accounted for almost 19 percent of total domestic production.

12.1.2.4 Future Prospects

The average annual growth rate for U.S. demand of ethylene glycol is forecast to be somewhere between 1.4 to 2 percent.[10,11] This low rate of growth is due in part to the fact that the majority of end uses for ethylene glycol are "mature products".[12] The end use with the highest growth rate will be polyester resins used in bottling and packaging.

Turning to the overseas market, exports are expected to be lower since China has reduced its purchases of ethylene glycol. China was

1987
1986
1985
1984
1983
1982
1981
1980

[a]Production plus imports, tory changes are ignored of consumption.

N.A. - Not available.

Sources: <u>Chemical & Engi</u>
p. 39; Mannsvil
"Chemical Produ
Glycol." August
of Commerce, In
tion, Trade Dat
tion, 1/24/91).

TABLE 12-4. U.S. EXPORTS OF ETHYLENE GLYCOL, 1980-1989

	Quantity (10^6 Kg)	Percent of U.S. Production[a]
1989	468.5	18.9%
1988	273.8	10.9%
1987	271.2	11.5%
1986	262.2	12.1%
1985	269.4	14.2%
1984	320.2	14.6%
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	111.6	5.6%

[a] See Table 12-6.

N.A. - Not available.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Ethylene Glycol." August 1988; U.S. Department of Commerce, International Trade Administration, Trade Data Services, (Phone Conversation, 1/24/91).

reactor. The ethylene oxide is hy
glycol and di- and triethylene gly
the preferred product, water is us
heavier glycols. Enough residence
non-catalytically react just about
feed. The water is stripped from
ends column after a series of evap
vacuum towers produces specificati
triethylene glycol.

12.1.3.2 Domestic Producers

There are ten companies prod
States.[15] In Table 12-5 the plant
firm are listed. For 1990 total i
kilograms. Capacity utilization r
percent in 1989 and were expected

Total U.S. production in 198
level (see Table 12-6). Despite i
slightly because of the inroads ma
of consumption in 1988 to 7.9 perc

12.1.3.3 Costs of Productio

Production costs for ethylen
price of its feedstock, ethylene o
dependent on the price of ethylene
ethylene oxide.

12.1.3.4 Imports

Import data from 1980 to 198
Imports have reached a level of 17
somewhat of a dip in 1987 and 1988

TABLE 12-5. U.S. PRODUCERS OF ETHYLENE GLYCOL, SEPTEMBER 1990

Company	Location	Capacity (10^6 Kg/yr)
BASF Corporation	Geismar, LA	170
Dow Chemical	Plaquemine, LA	206
Eastman Kodak	Longview, TX	95
Hoechst Celanese	Clear Lake, TX	249
Occidental Petroleum	Bayport, TX	272
PD Glycol[a]	Beaumont, TX	218
Quantum Chemical	Morris, IL	100
Shell Chemical	Geismar, LA	238
Texaco Chemical	Port Neches, TX	272
Union Carbide	Seadrift, TX	249
	Taft, LA	635
		2,704

[a] PD Glycol is a 50-50 joint venture between Occidental and Du Pont.

Sources: Chemicalweek, September 12, 1990, p. 25; Chemical Marketing Reporter, January 22, 1990.

1986

1985

1984

1983

1982

1981

1980

Source: Chemical & Engin
p. 39; U.S. Inte
Synthetic Organi

TABLE 12-7. U.S. IMPORTS OF ETHYLENE GLYCOL, 1980-1989

	Quantity (10^6 Kg)	Percent of U.S. Consumption[a]
1989	172.4	7.9%
1988	99.3	4.3%
1987	106.1	4.9%
1986	156.9	7.6%
1985	130.6	7.4%
1984	105.7	5.4%
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	10.9	0.6%

[a] See Table 12-3.

N.A. - Not available.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Ethylene Glycol." August 1988; U.S. Department of Commerce, International Trade Administration, Trade Data Services, (Phone Conversation, 1/24/91).

Canadian plant and adding capacit
this planned capacity does come c
down to 67 percent by 1995 (versu

Costs of production will hi
in particular. Ethylene prices a
capacity and lower feedstock cost

With respect to imports, ma
part on currency exchange rates a
for ethylene glycol.

12.1.4 Future Market Prospects

The forecasted growth rate
very well prove true, since most
mature products.[20] The cyclical n
to a low forecast. The majority
used in bottling and packaging.[21]
export levels will continue depen
East.[22]

12.2 ECONOMIC IMPACT ANALYSIS

12.2.1 HON Compliance Costs

A synopsis of annualized cu
statistics for ethylene glycol fa
Costs are presented for option on
estimate of the actual control cc
incur. Figure 12-1 illustrates
graphically. Eleven facilities a

Ethylene Glycol (EG) is cur
ethylene oxide. Since this is th
analysis of separate process cost

TABLE 12-8. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR ETHYLENE GLYCOL PRODUCTION FACILITIES

Facility	Annual Production (10^6 kg)	Option One Controls ($/kg)
1A	457.2	$.0033
2A	146.9	$.0033
3A	180.0	$.0034
4A	244.8	$.0034
5A	180.0	$.0034
6A	171.4	$.0035
7A	215.3	$.0035
8A	74.9	$.0037
9A	176.4	$.0038
10A	117.4	$.0041
11A	65.5	$.0043
<u>Summary Statistics</u>		
Mean		$.0036
Production Weighted Average		$.0035

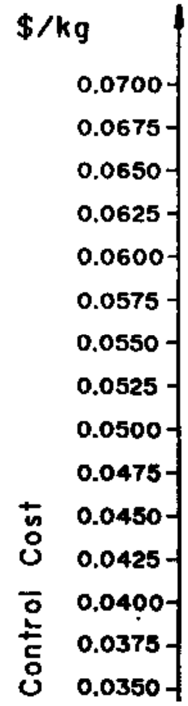


FIGURE 12-1. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF
FOR ETHYLENE GLYCOL PRODUCTION FACILITIES

12.8.2 Pricing

EG prices are determined by a combination of feedstock costs and end-use demand. The average realized price in 1989 was 88 cents per kilogram. The most recent spot price available at the time of this writing is 57 cents per kilogram. While some of this decline is cyclical, it is also characteristic of ethylene derivatives. Ethylene is saddled by persistent overcapacity and slow growth. Thus, some of this decline is likely to be permanent, enlarging HON impacts.

12.2.3 Elasticities

The demand elasticity for ethylene glycol is estimated on the basis of available substitutes for ethylene glycol, as well as substitutes for end-uses. The potential for import substitution is also examined.

12.2.3.1 Demand Elasticities

12.2.3.1.1 Antifreeze. Forty-one percent of EG is used as antifreeze. While manufacture of antifreeze from compounds other than EG is chemically feasible, EG dominates the market. EG is both low in cost and easily analyzed for its thermal properties. Demand for EG in the antifreeze market is considered highly inelastic.

12.2.3.1.2 Polyester Fibers. Polyester fibers, accounting for 35 percent of EG demand, appear to be highly dependent on EG as an input. Polyester is the material used in the largest quantity by the textile industry. Moreover, the character of polyester fiber (i.e. texture, washability, durability, etc.) stems from its EG component. However, polyester fibers themselves do have substitutes, including other synthetic fibers, and natural fibers like cotton and wool. Cotton has made notable inroads into the polyester market in recent years. The demand for EG, is judged to be to moderately inelastic in this end-use sector.

12.2.3.2 Imports

EG imports are significant, accounting for 7.9 percent of U.S.

market power. The HHI is 1,670.5
market power. Captive consumptic
level of vertical integration. C
produced at ethylene glycol sites
horizontal integration. Imports
summary, the market structure for
oligopolistic, and firms will lik
costs.

12.2.5 Impacts on Price, Output,

Impacts on price, output, t
ethylene glycol industry for opti
Table 12-10.

12.2.5.1 Option One Contro

Option one control costs re
control cost that an industry wil
percentage price increase of .40
$.0035 per kilogram. For the two
the decrease in output is 3.0 mil
kilograms (.27%), respectively.

Facility 11A, which is the
in the industry, accounts for 65.
production. If this facility abs
lose from 4.6 percent to 9.2 perc
unlikely to lead to closure. Los
7 to 15 employees.

12.2.6 Conclusion

Ethylene glycol is a large
chemical, ranked 14th in U.S. org
of costs in the option one contro
The cost differential is small, s

TABLE 12-9. MARKET STRUCTURE CHARACTERISTICS FOR ETHYLENE GLYCOL

4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced at Site (Horizontal Integration)	Imports
66.1%	1,670.5	9%	6	Important

hman Index

· Δ Output (10^6 kg)

%Δ Total Revenue
Δ Total Revenue (10^6 \$)

Δ Employment
(# of Employees)

---

[1]Based on Production Weighte

DEFINITIONS:

Δ = Change In

Market Price = \$0.88/kg

1995 Output = 2,246 x 10^6 kg
percent annual compound grow

1995 Total Revenue = \$1,976,
output)

1995 Employment = 5,385

probably an accurate measure of the actual price increase. Only 9 percent of ethylene glycol is consumed captively, so price increases will be felt at ethylene glycol facilities. Price increases associated with HON controls should be achievable, so impacts are apt to be small.

12.2.7 References

1. "Ethylene Oxide/Glycol Profitability In Doldrums." Chemical & Engineering News, July 30, 1990, p. 11-12.
2. U.S. International Trade Commission. Synthetic Organic Chemicals -- United States Production and Sales, 1989, Washington, DC, December 1990, p. 15-6.
3. Reference 1.
4. "Cool EG Starts Heating Up Again." Chemicalweek, September 12, 1990, p. 25.
5. Reference 4.
6. Reference 4.
7. Reference 1.
8. Reference 1.
9. Reference 1.
10. Reference 1.
11. "Chemical Profile -- Ethylene Glycol." Chemical Marketing Reporter, January 22, 1990.
12. Reference 1.
13. Reference 4.
14. Reference 4.
15. Reference 4.
16. "Shell Plans for More EO/EG." Chemicalweek, November 15, 1989, p. 12-16.
17. "Trade Surplus Level Expected to Weaken." Chemical Marketing Reporter, April 2, 1990, p. SR18.

FIGURE 12-2

CHEMICAL TREE

ETHYLENE GLYCOL

process 107211a: ethylene oxide + water → P → ethyl

(75218) (7732185)

Styrene is the largest derivative
its precursor ethylbenzene -- for
consumption in the U.S.[2] Styrene
production of polymers (synthetic
used in such broad applications a
transportation, appliances, and e

13.1.1 Brief Market Introduction

13.1.1.1 Historical Overvi

Average realized prices of
in Table 13-1. Data were not ava
doubled from 1986 to 1988, in par
styrene derivatives markets. Als
prices from 1986 to 1988 were tig
rationalizations (reductions) in
subsequent scheduled and unschedu
of styrene reached an all-time hi
pound ($1.10 per kilogram). The
second half of 1989 in response t
markets and lower raw materials c

From 1979 to 1988, domestic
demand for U.S.-produced styrene
percent per year.[3]

13.1.1.2 Recent Developmen

From the first week of 1990
contract (list) price of styrene
(77-84 cents per kilogram) to 44.
kilogram). This did not reflect

TABLE 13-1. AVERAGE REALIZED PRICE OF STYRENE, 1980-1989

	Price (¢/kg)
1989	72
1988	94
1987	86
1986	42
1985	53
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	66

N.A. - Not available.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis--Styrene," January 1990; U.S. International Trade Commission, Synthetic Organic Chemicals, 1988, 1989.

kilogram.

13.1.2 Demand Conditions

13.1.2.1 Uses for Styrene

Styrene is used to make pol
synthetic rubber. It is also use
derivatives have a broad range of
construction, automotive, and hou
end-use industries are cyclical,
conditions. Packaging is the sin

The distribution of styrene'
Polystyrene is by far the most im
percent of styrene consumption.
primarily in disposable food serv
packaging (17%), consumer and ins
electrical/electronic products (1
increased by an average of 8.5 pe
before declining by 1.6 percent f
1990, production of polystyrene i
the same period in 1989.[7] Polysty
problems related to the difficult

The second most important u
butadiene-styrene (ABS). Like pol
plastic resin. Principal uses of
appliances, electronic products s
telecommunications equipment, and
production of ABS in the U.S. was
period in 1989.[8]

Styrene-butadiene rubber (S
account for six percent of styren
largest-volume synthetic rubber i
of production in 1989.[9] Approxima

TABLE 13-2. STYRENE DERIVATIVES IN THE U.S., BY 1989 CONSUMPTION

	Percent of Total Consumption
Polystyrene	63%
Acrylonitrile-butadiene-styrene (ABS)	11%
Styrene-butadiene rubber (SBR)	6%
Styrene-butadiene latex	6%
Unsaturated polyester resins	6%
Misc., including other copolymers and styrene-acrylonitrile (SAN)	8%

Source: Chemical Marketing Reporter, August 14, 1989, p. 46.

depends on conditions in the mark

13.1.2.2 Consumption

Apparent consumption (produ styrene in the U.S. in 1980 and f 13-3. Consumption increased each record year for styrene consumpti strong growth in derivatives mark Consumption declined in 1989, in production of derivatives.

13.1.2.3 Exports

Table 13-4 tracks U.S. expo end of the decade, exports were a However, exports increased 16.3 p 1988 to 607 million kilograms in in the U.S., styrene was second c volume exported.[11] Exports in 198 styrene output.

U.S. exports of styrene wer 1990.[12] Following the Iraqi invas the Far East were running short c result, they were importing U.S.- needs.

13.1.2.4 Future Prospects

The consensus forecast for both in the U.S. and worldwide, i Mannsville Chemical Products Corp percent per year forecast is "ass 1990 does not persist into 1991." represents an improvement from th 1988 in domestic and export deman

TABLE 13-3. APPARENT CONSUMPTION OF STYRENE IN THE U.S., 1980-1989

	Apparent Consumption (10^6 kg)
1989	3,262
1988	3,766
1987	3,315
1986	3,130
1985	2,949
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	2,577

N.A. - Not available.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Styrene," January 1990; <u>Chemical Marketing Reporter</u>, March 5, 1990, p. 5; <u>Chemical & Engineering News</u>, June 18, 1990, p. 39.

1986	593
1985	603
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	547

N.A. - Not available.

[a]See Table 13-6.

Sources: Mannsville C
"Chemical Pr
Styrene," Ja
<u>Marketing Re</u>
p. 12.

Polystyrene growth is likely to be restricted in the long term as a result of growing environmental concerns over the disposal of packaging containing polystyrene.[15] ABS demand, on the other hand, is expected to grow by four percent per year in the long term.[16]

It was seen that exports account for a significant share -- 16.5 percent in 1989 -- of U.S. production of styrene. In the future, exports of styrene are expected to decline as new capacity is installed in the Far East, the prime destination for U.S. overseas shipments. Several new styrene plants came on stream in the Far East in 1990, the first new styrene projects in the world since 1985.[17] Styrene capacity in the Far East is expected to more than double from 1988 to 1994.[18] By 1992, the Far East may become self-sufficient in styrene. In 1989, by contrast, styrene output in the Far East was 820 thousand metric tons short of demand.[19]

13.1.3 Supply Conditions

13.1.3.1 Production Process

Except for the Arco facility in Channelview, Texas, all styrene in the U.S. is manufactured by dehydrogenating ethylbenzene, which is derived from ethylene and benzene. Ethylbenzene is synthesized by alkylating benzene, and then the ethylbenzene is dehydrogenated. In Arco's process, styrene is manufactured from ethylbenzene in co-production with propylene oxide via air oxidation.

13.1.3.2 Domestic Producers and Total Production

In August 1989, there were nine companies in the U.S. that produced styrene. These companies and their facilities are listed in Table 13-5. The nine companies have a total of nine facilities. While Arco has two facilities -- one in Beaver Valley, Pennsylvania and one in Channelview, Texas -- Fina and GE Plastics have an equal share in a production facility in Carville, Louisiana. All other participants in the market have one facility. Total U.S. styrene capacity in August 1989 was 4,026 million kilograms. This represented 29 percent of total world capacity of 14.7 billion kilograms.[20]

TABLE 13-5. U.S. PRODUCERS OF STYRENE, JANUARY 1991, WITH PLANNED CAPACITY EXPAN

Company	Plant Location	Capacity, August 1989 (10^3 Mg/yr)	Changes to Capacity, August 1989-January 1991 (10^3 Mg/yr)	Planned Capa	
				10^3 Mg/yr	Comp
Amoco	Texas City, TX	408	-	-	
Arco	Beaver Valley, PA[a]	102	-	-	
	Channelville, TX[b]	594	-	510	Late 1
Chevron	St. James, LA	283	-	408	Februa
Dow	Freeport, TX	680	-	454	Origin
Fina	Carville, LA[c]	340	+ 91 (1Q 1990)	-	
GE Plastics	Carville, LA[c]	340	+ 91 (1Q 1990)	-	
Hoechst Celanese	Bayport, TX[d]	454	+ 91 (2Q 1990)	-	
Rexene[e]	Odessa, TX	145	-	-	
Sterling Chemicals	Texas City, TX[f]	680	-	-	
Deltech Corp./Polyser[g]	Baton Rouge, LA	-	-	454	Delaye

As shown in Table 13-6, U.S. styrene production increased almost continuously from 1982 to 1988, before declining in 1989. 1988 was a record year for U.S. styrene production. In mid-1989, styrene demand began to ease. This accounted for the decrease in production in 1989. Also contributing to the decline was the shutdown of several plants for extended periods.

The production drop-off in 1989 continued into 1990. Through the first three quarters of 1990, production was 6.6 percent lower than in the same period in 1989.[23]

In 1989, 52 percent of total U.S. styrene production was sold on the merchant market.[24] Therefore, slightly under half of U.S. output is consumed captively.

13.1.3.3 Costs of Production

As mentioned, styrene is derived from benzene and ethylene. Benzene is the more important input into the manufacture of styrene, and is the primary determinant of the cost of production. For example, it is considered that "market conditions for benzene are normally the main factor in setting (styrene) prices."[25] When the price of benzene is $1.40 per gallon, styrene costs around 28-32 cents per pound (62-71 cents per kilogram) to make.[26]

The current prices of 44.5 cents per pound (98 cents per kilogram) for styrene and $1.50 per gallon for benzene are resulting in a "favorable" 14 cent per pound (31 cent per kilogram) margin over the cost of production."[27]

13.1.3.4 Imports

As Table 13-7 shows, U.S. imports of styrene increased from 1980 to 1989. In 1989, imports accounted for 5.6 percent of U.S. styrene consumption. After methanol, LDPE, and butadiene, styrene was the fourth-most-imported petrochemical in the U.S. in 1989.[28] However, as comparison with Table 13-4 indicates, U.S. imports of styrene in 1989 were less than one-third of exports.

1986

1985

1984

1983

1982

1981

1980

Source: Chemical & Engi
1990, p. 39.

TABLE 13-7. U.S IMPORTS OF STYRENE, 1980-1989

	Quantity (10^6 kg/yr)	Percent of U.S. Consumption[a]
1989	182	5.6%
1988	213	5.7%
1987	193	5.8%
1986	145	4.6%
1985	95	3.2%
1984	N.A.	N.A.
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	14	0.5%

N.A. - Not available.

[a] See Table 13-3.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Styrene," January 1990; Chemical Marketing Reporter, March 5, 1990, p. 12.

With capacity expected to i
demand, styrene operating rates w
operating rates in the U.S. have
90 percent of nameplate capacity,
1990.[30] One forecaster predicts t
fall to 82 percent in 1991 and 78

13.1.4 Future Market Prospects

Both in the U.S. and worldw
increase by around three percent
Overcapacity threatens, however,
capacity has been projected at 5.
likely be lower operating rates,
profitability. Because a lot of
Far East, a key export market for
of styrene are likely to diminish

The current contract price
cents per kilogram), is affording
cent per pound (31 cent per kilog
This margin is not likely to last
expected very soon to be under pr
impetus behind falling prices sho
markets and new capacity, includi
Channelview, Texas facility, down
Chevron's new capacity in St. Jam

13.2 ECONOMIC IMPACT ANALYSIS

13.2.1 HON Compliance Costs

A synopsis of annualized co
for styrene production facilities
presented in Table 13-8. Costs a

TABLE 13-8. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND STATISTICS FOR STYRENE PRODUCTION FACILITIES AND STYRENE PRODUCTION PROCESSES

Facility	Annual Production (10^6 Kg)	Option One Controls ($/kg)
1A	619.7	$0.0021
2A	619.7	$0.0021
3A	619.7	$0.0021
4A	412.2	$0.0021
5A	346.7	$0.0022
6A	257.5	$0.0022
7A	132.0	$0.0025
8A	91.0	$0.0028
9B	495.0	$0.0045
Control Costs by Process		
Process A (dehydrogenation of ethylbenzene	3,098.6	$0.0021
Process B (dehydration of methyl benzyl alcohol)	495.0	$0.0045
Summary Statistics		
Mean		$0.0025
Production Weighted Average		$0.0025

competitive
advantage.

13.2.2 Pricing

Styrene prices are determine
costs and end-use demand. Benzene
processes, and is an important det
Projected to increase by 5.6 perce
put upward pressure on styrene pri
benzene prices themselves are depe
factors and have been volatile. A
in 1989 were 72 cents per kilogram
available at the time of this writ
Stable growth in the styrene marke

13.2.3 Elasticities

Demand elasticities for styr
of available substitutes for styre
end-uses. The potential for impor

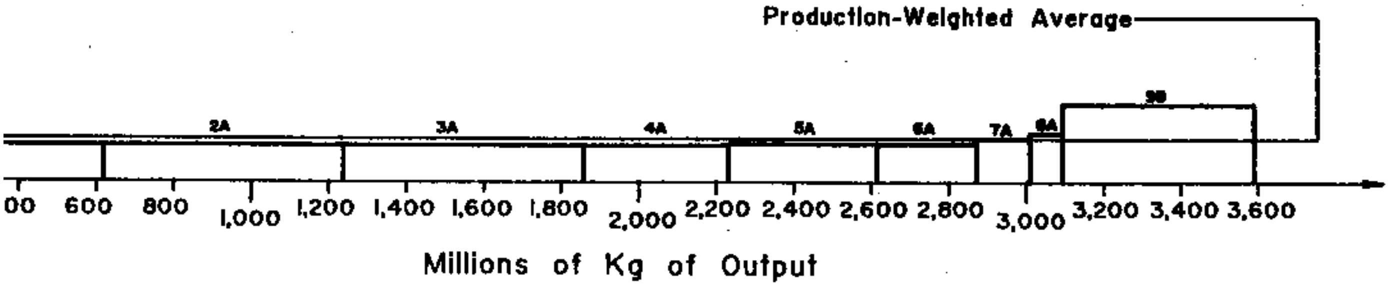
13.2.3.1 Demand Elasticities

13.2.3.1.1 Polystyrene

Polystyrene is far and above
styrene, accounting for 63 percent
the polymerization of styrene, pot
must be examined.

The physical properties of p
addition of modifying agents to ma
products. Many specialty uses for
substitute for. However, as dispo
packaging material, polystyrene fa
high-density polyethylene, polypro
and natural fibers (e.g. paper), a

JRE 13-1. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR STYRENE PRODUCTION FACILITIES



rubbers, the bulk of which are us
rubbers, which have a wide variet
for 17 percent of U.S. styrene co
styrene, a specialty synthetic ru
styrene-butadiene rubber, a gener
remaining 6 percent. The share o
synthetic rubbers generally varie

Because of their cost advan
during use, general-purpose synth
market share from natural rubbers
automobile tires, since their inc
addition, natural rubbers cannot
is contact with naphtha because t
This, too, encourages the use of
rubber, and indicates a moderatel

Still, natural rubbers have
For example, natural rubber perfo
large, heavy-duty truck and bus t
are blended with synthetic rubber
for use in automobile tire manufa
to radial tires has led to an inc
natural rubber has a higher degre
rubbers in the manufacture of rad
for substitution, styrene demand
considered to be slightly inelast

Acrylonitrile-butadiene-sty
for. This nitrile rubber is solv
applications as gaskets, oil and
electrical insulation, and food w
suitable for these purposes. Her
moderately inelastic.

13.2.3.1.3 <u>Styrene-Butadien</u>
The addition of more than 5

more like plastic and less like rubber. Styrene butadiene latex (SBL) is such a compound, and makes up the most of remaining end use for styrene. SBL is used in the manufacture of foam rubber, adhesives, fabric treating, and paints. A variety of output substitutes exists for these styrene uses, but the flexibility of styrene butadiene compounds allows the production of a myriad of final goods. Styrene demand in this sector is estimated to be slightly to moderately inelastic.

13.2.3.2 Imports

Imports play a reasonably significant role in the styrene market, accounting for 5.6 percent of 1990 U.S. consumption. Exports are considerably larger, accounting for 16.5 percent of U.S. production in 1989. However, capacity increases in the Far East, which accounts for the bulk of U.S. exports, could reduce export levels. Nevertheless, domestic capacity increases and sluggish growth in demand should diminish the prospect for import substitution.

13.2.3.3 Elasticity Estimate

The demand elasticity varies somewhat from sector to sector, and might hover near unity in the polystyrene market, but doesn't appear to extend into the elastic range. Given the environmental and competitive pressures facing polystyrene, and importance of natural rubber substitutes, demand elasticity for styrene is estimated to be in the slightly inelastic range of -.67 to -1.

13.2.4 Market Structure

Table 13-9 summarizes the parameters for the market structure of styrene. Twelve firms are currently producing styrene. The four-firm concentration ratio is 62.3 percent, signifying moderate market power. The HHI is 1,304.4, which falls in the moderate range of market power. Captive consumption is 48 percent, indicating a moderate level of vertical integration. On average, four chemical compounds are produced at styrene sites, suggesting a moderate level of horizontal integration. Imports in the industry are important serving to undermine the pricing

TABLE 13-9. MARKET STRUCTURE CHARACTERISTICS FOR STYRENE

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced at Same Site (Horizontal Integration)
12	62.3%	1,304.4	48%	4

[a] Herfindahl-Hirschman Index

13.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the styrene industry for option one control costs are presented in Table 13-10.

13.2.5.1 Option One Control Costs

Option one control costs represent the actual estimated cost that an industry will incur. The weighted average percentage price increase of .34 percent leads to a price increase $.0025 per kilogram. For the two elasticity levels of -.67 and -1.00, the decrease in output is 9.9 million kilograms (.23%) and 14.6 million kilograms (.34%), respectively.

Facility 9B is the highest cost plant in the industry. It accounts for 40.5 million kilograms of industry production. If this facility absorbs the entire output loss, it would lose from two percent to three percent of its production, which is unlikely to lead to closure. The decline in employment is 19 to 29 employees.

Facility 8A is the smallest plant in the industry. If this is the marginal plant, it would lose from 11 percent to 16 percent of its output. This facility would be on the borderline of closure if it absorbed the entire loss in output.

Two processes are used to produce styrene. As with the total industry control scenario, the cost differential favors process A, which already accounts for about 85 percent of industry production.

13.2.6 Conclusion

Styrene is a high volume, commercially important chemical, ranked ninth in U.S. organic chemical production. The range of cost increases in industry is $.0021 per kilogram to $.0056 per kilogram for process A. The cost differential is small, so the production-weighted average is probably an accurate measure of the actual price increase. Closure of the smallest size plant is possible, but cannot be predicted with certainty. The primary impact could be the competitive disadvantage placed on process B, which incurs control costs $.0024 per kilogram higher than those in process A.

Δ Output (10 kg)

%Δ Total Revenue
Δ Total Revenue (10^6 $)

Δ Employment
(# of Employees)

---

[1] Based on Production Weight

DEFINITIONS:

Δ = Change In

Market Price = $0.72/kg

1995 Output = 4,290 x 10^6 k

1995 Total Revenue = $3,089

1995 Employment = 8,418

13.2.7 References

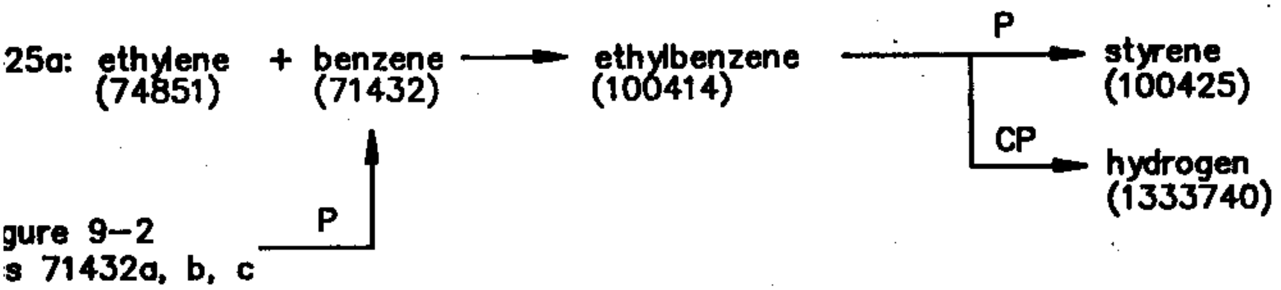
1. "Top 50 Chemicals Production Slowed Markedly Last Year." Chemical & Engineering News, April 9, 1990, p. 12.
2. "Aromatics Entering Readjustment Phase." Chemical Marketing Reporter, January 1, 1990, p. SR 18.
3. Chemical Marketing Reporter, August 14, 1989, p. 46.
4. "Styrene Tabs Get Heated Up by Tighter Supply." Chemicalweek, June 6, 1990, p. 8.
5. Standard & Poor's Corp. Industry Surveys. "Chemicals -- Basic Analysis." New York, NY, November 2, 1989, p. C 30.
6. "Facts & Figures for the Chemical Industry." Chemical & Engineering News, June 18, 1990, p. 39.
7. "Styrene Slowdown Stalls Expansion." Chemical Marketing Reporter, November 12, 1990, p. 13.
8. Reference 7.
9. "EO/EG Marketers: Cautious Optimism." Chemical Marketing Reporter, February 12, 1990, p. 3.
10. Reference 4.
11. "Trade Surplus Level Expected to Weaken." Chemical Marketing Reporter, April 2, 1990, p. SR 18.
12. "Heavy Far East Buying Taxes the Styrene Market." Chemicalweek, October 3, 1990, p. 17.
13. Mannsville Chemical Products Corp. "Chemical Products Synopsis -- Styrene." Asbury Park, NJ, January 1990.
14. Reference 3.
15. Reference 5, p. C 31.
16. Reference 15.
17. "A Surfeit of Projects in Styrene." Chemicalweek, August 29, 1990, p. 38.
18. Reference 17.
19. Reference 17.

29. Reference 7, p. 3.

30. Reference 27, p. 13.

31. Reference 22.

FIGURE 13-2
CHEMICAL TREE
STYRENE



ct
oduct
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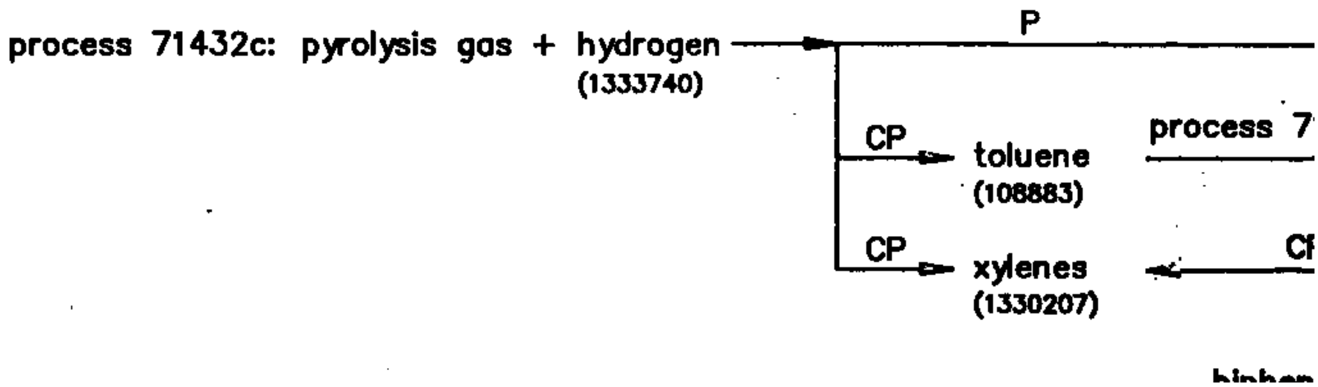
are CAS registry numbers.

FIGURE 13-3

CHEMICAL TREE

BENZENE



derived from methanol and is the
percent of total consumption in 1
formaldehyde uses have some conne

14.1.1 Brief Market Introduction

14.1.1.1 Historical Overv

Table 14-1 lists the avera
from 1980 to 1989. Prices were s
per kilogram rose to 20 cents bec
price fell back to 16 cents in 19
slump in the construction sector.

Discounting is common. Tr
misleading. The price of formald
its feedstock, methanol. The acc
each 1.0 cent per gallon change i
0.22 cent per kilogram change in

14.1.1.2 Recent Developme

The trade list price of fo
cents per kilogram in January to
recent price (February 1991) was
rose despite the downturn in the
because the price of methanol rose
1990 to 57 cents per gallon in Fe
4 cent price increase for formald
increase in raw material cost.

14.1.2 Demand Conditions

14.1.2.1 Uses for Formalde

Table 14-2 lists the variou
consumption. Almost a third of f
the manufacture of urea formaldehy
resins are used as bonding adhesiv

TABLE 14-1. AVERAGE REALIZED PRICE OF FORMALDEHYDE, 1980-1989

	Price (¢/kg)
1989	16
1988	20
1987	13
1986	13
1985	13
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	15

N.A. - Not available.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis--Formaldehyde," July 1990; U.S. International Trade Commission, Synthetic Organic Chemicals, 1988, 1989.

1,4-butanediol

Acetal resins

Hexamethylenetetramine

Pentaerythritol

Melamine formaldehyde resins

Methyl diphenyl diisocyanates

Miscellaneous

Source: Mannsville Chemical Prod
Synopsis -- Formaldehyde

Particle board used 70 to 80 percent of UF resin output in 1989 while plywood used 8 to 10 percent.[11] UF resins are also used in protective coatings, textile and paper treatments, and fertilizer applications.

The next largest use of formaldehyde is in the manufacture of phenol formaldehyde (PF) resins. Sixty percent of PF resin output is consumed by plywood and particle board applications.[12] Another 15 percent is used as a binder for fiberglass insulation.[13] Other smaller uses for PF resins are molding compounds, laminating adhesives, friction material and abrasive binders, and protective coatings.

The production of 1,4-butanediol accounts for 12 percent of formaldehyde consumption. 1,4-butanediol is used to make polybutylene terephthalate resins, polyvinyl pyrrolidone, and tetrahydrofuran. Formaldehyde is used as a co-reactant with acetylene in the production process.

Acetal resins are molded into plastic parts for use in appliances, consumer products, plumbing and hardware, and automobiles. Hexamethylenetetramine is used primarily to cure phenolic molding compounds; it is also used in explosives and bactericides. Melamine formaldehyde resins are used in molding compounds, decorative laminates, dinnerware, protective coatings, and paper and textile treatments. Methyl diphenyl diisocyanates are consumed in the production of foamed polyurethanes.

14.1.2.2 Consumption

Growth in domestic demand from 1980 to 1987 was relatively flat except for a dip in 1986 due to a building slump.[14] However, consumption jumped by 246 million kilograms from 1987 to 1988 with the rise in construction. Subsequently, the economy began to slump in mid-1989; total domestic demand fell 180 million kilograms from 1988. Table 14-3 lists consumption data from 1980 to 1989.

14.1.2.3 Exports

Exports of formaldehyde are not significant. Table 14-4

1988

1987

1986

1985

1984

1983

1982

1981

1980

---

[a] Production plus import
inventory changes are
fied estimate of consu

[b] Derived in part from t
itself an estimate.

N.A. - Not available.

Sources: Chemical & En
1990, p. 39;
March 5, 1990
Products Corp
Synopsis -- F
U.S. Internat
Synthetic Org

TABLE 14-4. U.S. EXPORTS OF FORMALDEHYDE, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1989	10.7	0.4%
1988	8.6	0.3%
1987	6.4	0.2%
1986	8.2	0.3%
1985	4.1	0.2%
1984	N.A.	N.A.
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	7.3	0.3%

[a] See Table 14-6.

N.A. - Not available.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Formaldehyde," July 1990; Chemical Marketing Reporter, March 5, 1990.

mature.[18] The best growth prospe
growth annually through 1994) an
been growing at 10 percent per y
alternative production processes
being developed.[20]

In July 1990, total domes
forecast to reach 3.4 billion ki
represents an average annual gro
1994.[22] This may depend on the l
recession, however.

14.1.3 Supply Conditions

14.1.3.1 Production Proc

Formaldehyde is manufactu
The first is the silver-catalyze
dehydrogenation and oxidation is
methanol, air, and steam is preh
silver-crystal catalyst. Formal
dehydrogenation of methanol. To
solution, exit gases are quenche

Alternatively, the metal
the oxidation of methanol over a
oxide. An air and methanol mixt
catalyst-packed reactor tubes.
absorption tower where demineral
the formaldehyde solution is col

Comparing the two manufac
provides a greater formaldehyde
higher than in the silver-cataly

14.1.3.2 Domestic Produc

Table 14-5 lists the dome
there are 15 firms with a total

TABLE 14-5. U.S. PRODUCERS OF FORMALDEHYDE, 1990

Company	Location	Capacity (10^6 kg/yr)
Borden	Demopolis, AL	36
	Diboll, TX	57
	Fayetteville, NC	202
	Fremont, CA	79
	Kent, WA	43
	LaGrande, OR	32
	Louisville, KY	52
	Missoula, MT	61
	Sheboygan, WI	79
	Springfield, OR	136
	Vicksburg, MS	32
	Geismar, LA	263
		1,072
BTL Specialty Resins	Houston, TX	50
	Malvern, AR	50
		100
Chembond	Andalusia, AL	32
	Moncure, NC	54
	Springfield, OR	64
	Winnfield, LA	32
		182
D.B. Western	Virginia, MN	18
	Las Vegas, NM	23
		41
Degussa	Theodore, AL	29
DuPont	Belle, WV	159
	Healing Spring, NC	91
	Laporte, TX	145
	Parkersburg, WV	181
	Toledo, OH	113
		689
GAF	Calvert City, KY	45
	Texas City, TX	45
		90

	Hampton, SC Lufkin, TX Russellville, S Taylorsville, M Vienna, GA
Hercules	Louisiana, MO
Hoechst Celanese	Bishop, TX Newark, NJ Rock Hill, SC
Monsanto	Alvin, TX Springfield, MA
Questra Chemicals[b]	Allentown, PA
RVP	White City, OR
Spurlock	Waverly, VA
Wright Chemical	Acme, NC

---

[a] To be closed in early 1991.

[b] Subsidiary of Rhone-Poulenc Inc.

Sources: Mannsville Chemical Pro
Synopsis -- Formaldehyd
"1990 Directory of Chem

year, four companies (Borden, DuPont, Georgia-Pacific and Hoechst Celanese) control about 77 percent of total capacity.[24] The industry is in a state of overcapacity; 1989 production (2,673 million kilograms) represented only 61 percent of total industry capacity.[25,26]

Because formaldehyde is costly to transport, many production plants are located near the production facilities of the end uses (UF and PF resins, for example). Capital costs have been characterized as not being significant.[27] The cost of building a new facility has been estimated to be only about 5 million dollars.[28]

While low capital costs imply low barriers to entry, entry is also dependent on the degree of vertical integration. This is a key market strategy, according to Chemical Marketing Reporter.[29] Three of the four major formaldehyde producers (Borden, DuPont, Hoechst Celanese) accounted for 43 percent of total methanol capacity in 1989.[30] Formaldehyde production was the largest end use of methanol in 1989 accounting for 30 percent of total consumption.[31]

Total domestic production grew from 2,520 million kilograms in 1980 to 2,849 million kilograms in 1988 (Table 14-6). However, as the construction industry slumped in mid-1989, so did demand; production fell back to 2,673 million kilograms. This was much like the 1982-1983 recession which also affected production.

14.1.3.3 Costs of Production

Methanol accounts for over 70 percent of formaldehyde production costs.[32]

14.1.3.4 Imports

Import data from 1980 to 1989 are listed in Table 14-7. In no year were imports a significant percentage of domestic consumption.

14.1.3.5 Future Prospects

Concerning production processes, formaldehyde may soon be manufactured by the direct oxidation of methane. Another alternative production process currently being developed involves the oxidation of

1987
1986
1985
1984
1983
1982
1981
1980

Sources: <u>Chemical &</u>
18, 1990, p
Trade Commi
<u>Chemicals</u>,

TABLE 14-7. U.S. IMPORTS OF FORMALDEHYDE, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Consumption[a]
1989	2.3[b]	0.1%
1988	5.0	0.2%
1987	5.0	0.2%
1986	4.5	0.2%
1985	4.1	0.2%
1984	N.A.	N.A.
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	4.5	0.2%

[a] See Table 14-3.

[b] Estimate.

N.A. - Not available.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Formaldehyde," July 1990.

if these regulations will become m
Total domestic demand is for
by 1994 (an average annual growth
Production will also be depe
demand for formaldehyde derivative
is not expected to change.[37] Futur
may employ two new processes. Cur
methods are the direct oxidation o
methylal.

14.2 ECONOMIC IMPACT ANALYSIS

14.2.1 HON Compliance Costs

A synopsis of annualized cum
statistics for formaldehyde facili
Costs are displayed for option one
estimates of the actual costs that
Figure 14-1 illustrates the contro
facilities are displayed.

Formaldehyde is currently pr
hydrogenation of methanol (process
(process B). It is noted that the
processes is masked by the product

14.2.2 Pricing

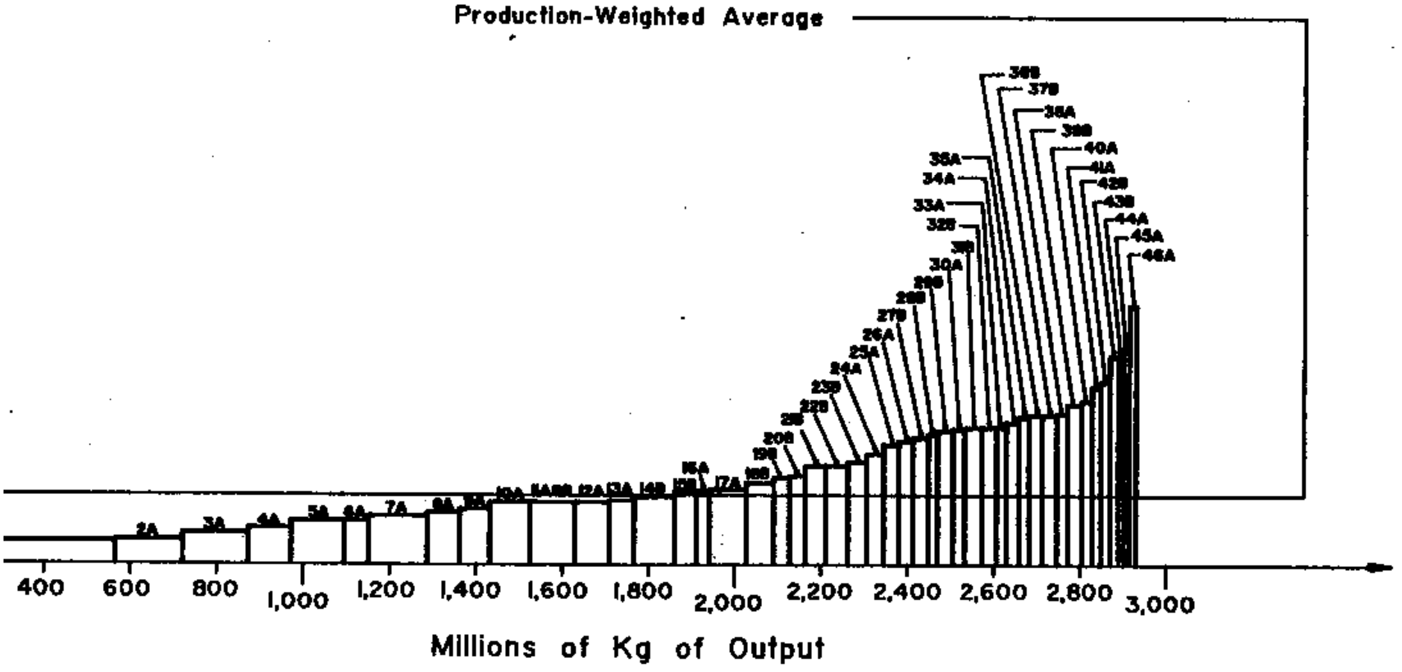
Average realized prices for
for most of the 1980s. The 1989 p
penny higher than the 1980 price.
on prices is the seemingly perpetu
industry and moderate-growth end u
overstated due to discounting, inc
prices stemming from the Persian G
pre-war levels. In addition, lowe

TABLE 14-8. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR FORMALDEHYDE PRODUCTION FACILITIES AND FORMALDEHYDE PRODUCTION PROCESSES

Facility/ Process	Annual Production (10^6 kg)	Option One Controls ($/kg)
1A	561.0	$0.0013
2A	160.5	$0.0014
3A	154.4	$0.0018
4A	98.6	$0.0021
5A	123.1	$0.0025
6A	55.8	$0.0025
7A	136.0	$0.0028
8A	74.1	$0.0030
9A	70.7	$0.0032
10A	91.1	$0.0036
11A&B	102.0	$0.0036
12A	85.0	$0.0036
13A	55.8	$0.0037
14B	92.5	$0.0039
15B	51.0	$0.0042
16A	46.2	$0.0042
17A	69.4	$0.0043
18B	67.3	$0.0047
19B	34.0	$0.0050
20B	36.7	$0.0051
21B	49.6	$0.0057
22B	49.6	$0.0057
23B	42.8	$0.0059
24A	41.5	$0.0064
25A	32.6	$0.0069

34A	29.2
35A	24.5
36B	32.6
37B	32.6
38A	26.5
39B	30.6
40A	21.8
41A	19.7
42B	21.8
43B	18.4
44A	15.6
45A	15.6
46A	12.2
Control Costs by Process	
Process A (Hydrogenation of Methanol)	2,161.0
Process B (Air oxidation of Methanol)	770.4
Summary Statistics	
Mean	
Production Weighted Average	

URE 14-1. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR FORMALDHYDE PRODUCTION FACILITIES



substitutes for end-users. The p
also examined.

14.2.3.1 Demand Elasticitie

14.2.3.1.1 Urea Formaldehyd

Urea formaldehyde resins an
principal end use for formaldehyd
consumption. These amino resins
plywood and particle board manufa
resins, another end use accountin
demand, can be a substitute for U
used in conjunction. Not only th
other would result in minimal cha
both are made with formaldehyde.
in existence for UFR in this indu
inelastic in this sector.

14.2.3.1.2 Phenol Formaldeh

Phenolic resins make up 24
There are many alternatives to th
attractive owing to their low cos
re-use/recycling, and deficiency
more expensive thermosets such as
products are sometimes employed.
moderately inelastic in this sect

14.2.3.1.3 1,4-Butanediol

1,4-butanediol accounts for
and has been the fastest growing
however, at least two other proce
1,4-butandiol which don't use for
process routes are likely to be p

formaldehyde increases in cost. The demand elasticity in this sector is regarded as slightly inelastic.

14.2.3.1.4 Acetal Resins

Nine percent of formaldehyde is used to make acetal resins. These thermoplastic engineering resins compete with nylon for an extensive assortment of commercial applications. This suggests some potential for substitution, but it must be recognized that nylon raw materials -- either hexamethylenediamine and adipic acid or caprolactam -- are also subject to HON controls. Demand elasticity is judged to be moderately inelastic in this sector.

14.2.3.2 Imports

Formaldehyde imports are insignificant, and will not be analyzed.

14.2.3.3. Elasticity Estimate

Formaldehyde demand elasticity varies from sector to sector. On the whole it is estimated to be in the moderately inelastic range of -.34 to -.67.

14.2.4 Market Structure

Table 14-9 summarizes the parameters for the market structure of formaldehyde. Seventeen firms are currently producing formaldehyde. The four-firm concentration ratio is 77.5 percent, signifying substantial market power. The HHI is 1,627.4, which falls in the moderate range of market power. Captive consumption is 49 percent, indicating a moderate level of vertical integration. In addition, there is evidence of considerable vertical integration into methanol and formaldehyde derivatives. On average, only one chemical compound is produced at formaldehyde sites, suggesting a minimal horizontal integration. Imports in the industry are insignificant, and foreign competition is not currently a threat to domestic producers. In summary, the formaldehyde industry is moderately oligopolistic, and

TABLE 14-9. MARKET STRUCTURE CHARACTERISTICS FOR FORMALDEHYDE

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Vertical Integration	Horizontal Integration
17	77.5%	1,627.4	49%	1

[a] Herfindahl-Hirschman Index

TABLE 14-10. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE FORMALDEHYDE INDUSTRY[1], OPTION ONE CONTROL COSTS

	Elasticity	
	-0.34	-.67
%Δ Price (%/kg)	2.51%	2.51%
Δ Price ($/kg)	$.0040	$.0040
%Δ Output (%/kg)	(0.84%)	(1.65%)
Δ Output (10^6 kg)	(31.2)	(61.2)
%Δ Total Revenue	1.65%	0.82%
Δ Total Revenue (10^6 $)	$9.8	$4.9
Δ Employment (# of Employees)	(14)	(27)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

Δ = Change In

Market Price = $0.16/kg

1995 Output = 3,709 x 10^6 kg (based on 1989 production at 4% annual compound growth)

1995 Total Revenue = $593,481,183.41 (market price x 1995 output)

1995 Employment = 1,617

approximately equivalent to the co
facilities in the industry. Hence
formaldehyde industry, if these fa
entire loss in output. However, i
adjustment will be shared across t
is estimated to be from 14 to 27 e

It is quite possible that HO
substitution, and the introduction
horizon. Process B costs exceed p
process A users a competitive adva
processes are currently in the dev
these processes involve feedstocks
regulations. While process B cost
unlikely that HON controls will le
process A if these new processes a
compliance costs will probably imp
This will not, however, cause a de
market, as output will simply shif
possible effect to look for would

14.2.6 Conclusion

Formaldehyde is a large volu
ranked 11th in U.S. organic chemic
\$.0013 to \$.0149 per kilogram. Pr
controls could lead to closure, as
relatively small, and most produce
should be minimal as new processes
industry is expanding at approxima
help to alleviate impacts.

14.2.7 References

1. Mannsville Chemical Products
-- Formaldehyde." Asbury Pa

2. United States International Trade Commission. Synthetic Organic Chemicals -- United States Production and Sales, 1989. Washington, DC, December 1990, p. 15-5.

3. "Chemical Profile -- Methanol." Chemical Marketing Reporter, September 25, 1989.

4. Reference 1.

5. Reference 1.

6. Chemical Marketing Reporter, January 8, 1990, p. 29.

7. Chemical Marketing Reporter, December 31, 1990, p. 27.

8. Chemical Marketing Reporter, February 11, 1991, p. 31.

9. Chemical Marketing Reporter, January 8, 1990, p. 31.

10. Chemical Marketing Reporter, February 11, 1991, p. 33.

11. Reference 1.

12. Reference 1.

13. Reference 1.

14. Reference 1.

15. Reference 1.

16. U.S. Department of Commerce, International Trade Administration. U.S. Industrial Outlook, 1991, Washington, DC, p. 6-2.

17. Reference 1.

18. Reference 1.

19. "Chemical Profile -- Formaldehyde." Chemical Marketing Reporter, September 18, 1989.

20. Reference 1.

21. "Formaldehyde Demand Forecast to Hit 7.4 Billion Pounds in '94." Chemical Marketing Reporter, July 2, 1990, pp. 5, 20.

22. Reference 2.

23. U.S. Environmental Protection Agency. Air Oxidation Processes in Synthetic Organic Chemical Manufacturing Industry-Background Information for Proposed Standards. Research

34. Reference 1.

35. Reference 1.

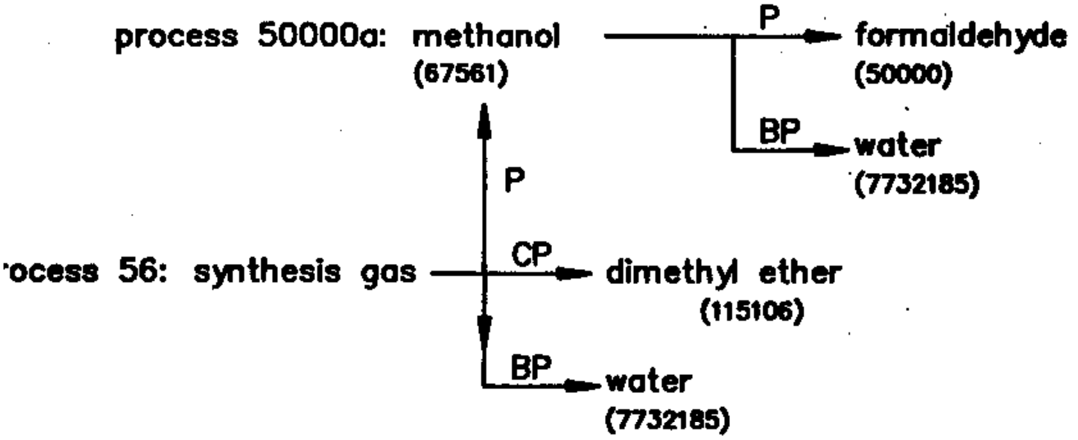
36. Reference 21.

37. Reference 1.

FIGURE 14-2

CHEMICAL TREE

FORMALDEHEYDE



t
oduct
oduct

re CAS registry numbers.

and lacquers. Acetone is also a
for pharmaceuticals and antioxida
acetone production was sold on th

15.1.1 Brief Market Introduction

15.1.1.1 Historical Overv

Average realized prices of
in Table 15-1. Data were not ava
price increases from 1987 to 1989
demand. Acetone has experienced
for coproduct phenol, which has d
"producers are not going to make
prices."[3] Phenol demand is down b
automobile and construction, are

15.1.1.2 Recent Developme

The list price for acetone
cents per pound (84 to 90 cents p
8 to 10 cents per pound (17 to 22
1990.[4,5] The price increase result
benzene and propylene.[6] Continued
the price increase. Prices are e
1991, particularly if phenol dema

15.1.2 Demand Conditions

15.1.2.1 Uses for Acetone

The distribution of acetone
Methyl methacrylate (MMA) and othe
derivatives of acetone, accountin
Two major consumers of MMA are the
industries.[8] MMA is used in a var
production of cast and extruded s

TABLE 15-1. AVERAGE REALIZED PRICE OF ACETONE, 1980-1989

	Price (¢/kg)
1989	41
1988	35
1987	33
1986	37
1985	40
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	44

N.A. - Not available.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Acetone," October 1990; U.S. International Trade Commission, Synthetic Organic Chemicals, 1989.

Solvent-direct use

Bisphenol-A

Methyl isobutyl ketone

Other solvent derivatives

Miscellaneous

Source: Mannsville Chemical Pr
Synopsis -- Acetone,"

(24%), surface coatings (20%), impact modifiers (11%), and emulsion polymers (9%).[9]

The second most important derivative of acetone is direct-use solvents. Acetone can be used directly as a solvent in spinning cellulose acetate fiber, protective coatings, nail polish, films, vinyl and acrylic resin solutions, adhesives, printing inks, paper coatings, and cements. Film coating, fiber formation, lacquers, inks, cleaners, and thinners are other direct-use solvent applications. As a processing solvent, acetone can be used in making cellulose acetate fibers, photographic films, acetate and pyroxylin plastics, and smokeless powders and other explosives. High purity acetone is used in the electronics industry to clean and dry printed circuit boards and for cleaning submicron particles from wafers.

Accounting for 14 percent of acetone consumption is its use in bisphenol-A production. Bisphenol-A is an intermediate for epoxy and polycarbonate resins. A large part of bisphenol-A consumption is accounted for by the automotive and construction industries.[10]

In addition to direct-use solvents, acetone is used as a raw material in other solvents. Examples of these solvents are methyl isobutyl ketone and methyl isobutyl carbinol.

15.1.2.2 Consumption

Apparent consumption of acetone in the U.S. in 1980 and from 1985 to 1989 are shown in Table 15-3. Total consumption for 1989 was 1,122 million kilograms, the highest level reached during the ten-year period. Acetone consumption grew about 3.4 percent annually from 1980 to 1989. The primary impetus behind the growth has been the growth in demand for methyl methacrylate, its primary derivative. Increased use in the production of bisphenol-A also was a factor in growing acetone consumption.

15.1.2.3 Exports

Table 15-4 shows U.S. exports of acetone for 1980-1989. U.S. exports in 1989 were approximately 72.6 million kilograms, which is

1987

1986

1985

1984

1983

1982

1981

1980

---

[a] Production plus import
inventory changes are
estimate of consumpti

N.A. - Not available.

Sources: <u>Chemical & E</u>
39; Mannsvil
Products Syn
Internationa
<u>Chemicals</u>, 1

TABLE 15-4. U.S. EXPORTS OF ACETONE, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1989	72.6	6.3%
1988	100.2	9.6%
1987	117.9	14.1%
1986	38.1	4.4%
1985	39.9	4.9%
1984	N.A.	N.A.
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	111.1	11.8%

[a] See Table 15-6.

N.A. - Not available.

Source: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Acetone," October 1990.

decline due to environmental conce
solvent recovery, and control of
as some chlorinated solvents are

15.1.3 Supply Condition

15.1.3.1 Production Proce

Acetone is produced almost
or isopropyl alcohol (isopropanol
acetone is produced as a coproduc
hydroperoxide. Phenol is conside
isopropanol-based process, aceton
with no byproducts. A small amou
hydroquinone production.

15.1.3.2 Domestic Produce

In July 1990, there were n
produced acetone via cumene perox
15-5 details the nine companies a
facilities produce acetone as a c
peroxidation. These facilities a
kilograms, or 80 percent, of tota
produce acetone via the isopropyl
capacity). Isopropanol-based fac
discretionary suppliers based on
companies produce acetone as a by
Eastman, at Kingsport, Tennessee,
kilograms of capacity and Goodyea
million kilograms.[17] U.S. acetone
million kilograms.

As shown in Table 15-6, U.
9.6 percent from 1988 to 1989, re
level of the 1980s (1,145 millio

TABLE 15-5. U.S. PRODUCERS OF ACETONE, 1990

Company	Location	Process[a]	Capacity (10^6 kg/yr)
Allied-Signal	Frankford, PA	C	204
Aristech	Haverhill, OH	C	172
BTL Specialty Resins Corp.	Blue Island, IL	C	25
Dow	Freeport, TX	C	150
Eastman Kodak	Kingsport, TN	H	11
Georgia Gulf	Pasadena, TX	C	43
	Plaquemine, LA	C	98
Goodyear	Bayport, TX	H	5
Mt. Vernon Phenol[b] Plant Partnership	Mount Vernon, IN	C	172
Shell Chemical	Deer Park, TX	IPA	45
	Deer Park TX	C	163
	Wood River, IL	IPA	136[c]
Texaco	El Dorado, KS	C	25
Union Carbide	Institute, WV	IPA	68
			1,317

[a] C = cumene peroxidation, H = hydroquinone byproduct, IPA = isopropyl alcohol dehydrogenation.

[b] Joint venture of General Electric, Champlin Petroleum Co, and JLM Industries.

[c] Standby capacity.

Sources: Chemical Marketing Reporter, July 30, 1990; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Acetone," October 1990; SRI International, "1990 Directory of Chemical Producers, United States."

1986

1985

1984

1983

1982

1981

1980

Sources: Chemical &
18, 1990,
Trade Comm
Chemicals,

total in 1989 represented 87 percent of 1990 acetone capacity. From 1980 to 1989, production increased by 2.2 percent per year.

15.1.3.3 Costs of Production

As mentioned, acetone is derived mainly from cumene-based and isopropanol-based processes. The trade list price of cumene has been in the range of 49 to 56 cents per kilogram from January 1990 to February 1991.[18,19] Traditionally phenol has been considered the "on-purpose" product, with acetone generally considered a coproduct or byproduct.[20] However, the economic viability of the cumene process depends heavily on the value attained for coproduct acetone.

In May 1990, the spread between isopropyl alcohol and acetone was 3 to 5 cents per pound (7 to 11 cents per kilogram).[21] This was not considered to be high enough for Shell and Union Carbide, the two producers of acetone from isopropanol, to expand their acetone production.[22]

The costs of production for acetone are dependent on the price of its raw materials, cumene and isopropanol. Cumene and isopropanol are in turn dependent on benzene and propylene. The rising feedstock prices of benzene and propylene have also increased production costs of acetone.

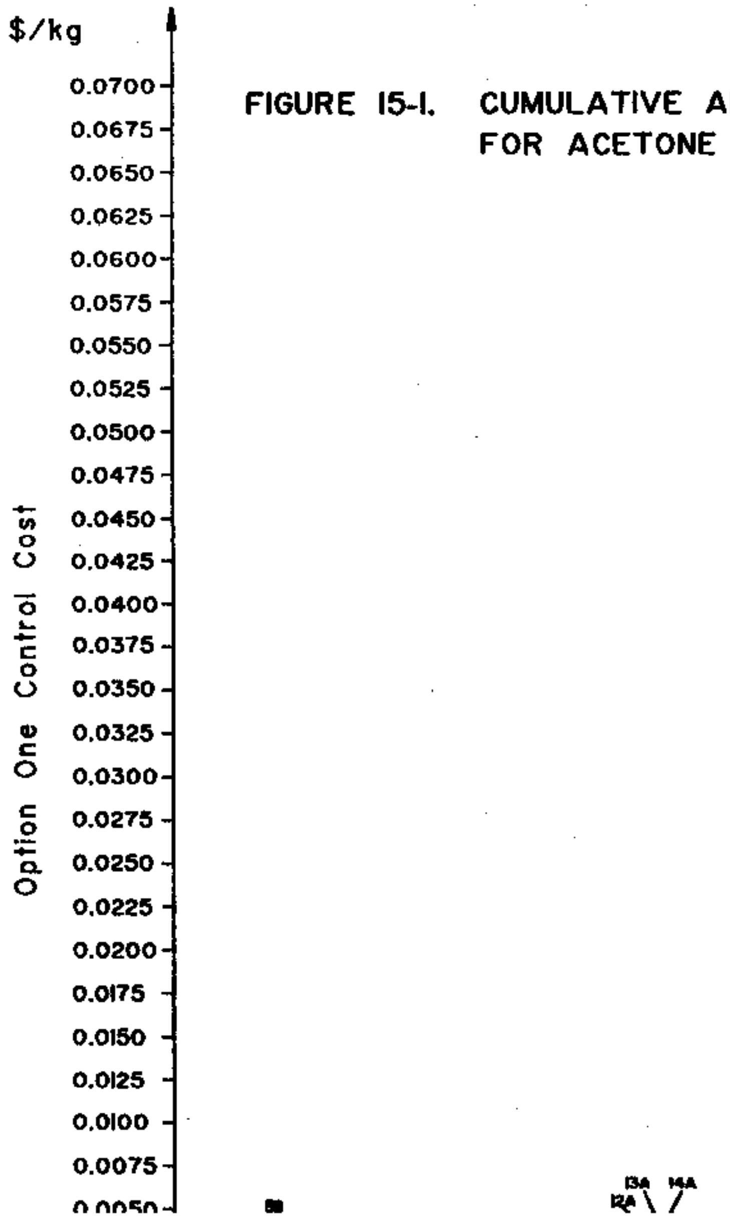
15.1.3.4 Imports

Table 15-7 shows that U.S. imports of acetone dropped in 1989 after peaking in 1987. In 1987, 75.3 million kilograms were imported, accounting for 9.5 percent of consumption. In comparison, imports totalled 49.4 million kilograms in 1989 and accounted for 4.4 percent of consumption. Acetone imports were relatively insignificant prior to 1982.

15.1.3.5 Future Prospects

Acetone supply is to a large extent dependent on the demand for and production of the coproduct phenol. This is because the majority of acetone is produced from the peroxidation of cumene, in which

FIGURE 15-1. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM FOR ACETONE PRODUCTION FACILITIES



1986	51.3
1985	48.9
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	0

*See Table 15-3.

N.A. - Not available.

Source: Mannsville Chemical Pr
Synopsis -- Acetone,"

:one supplies are expected tc

ıs been forecast at three to
:ors driving increasing acetc
ıf methyl methacrylate and
:ure and expected to decline.
' that there will be increase
ıecause the demand for phenol
ımene-based process, is growi
ıe. Supplies are expected tc
growth.

.ive control costs and summar
.lities and acetone productic
Costs are displayed for opt
: estimates of the actual con
ıcur. Figure 15-1 shows cont
:s are displayed.
' three processes: cumene
ıproduct of phenol (process A
.s B), and by dehydrogenation
s costs differ, the range is
ction-weighted average appea
increase. Process C incurs

a combination of feedstock
d-use demand conditions. Th
ocess A, with cumene as the

TABLE 15-8. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR ACETONE PRODUCTION FACILITIES AND ACETONE PRODUCTION PROCESSES

Facility/ Process	Annual Production (10^6 kg)	Option One Controls ($/kg)
1C	132.1	$0.0000
2C	99.3	$0.0000
3C	49.6	$0.0000
4B	4.0	$0.0018
5B	3.6	$0.0038
6A	107.9	$0.0038
7A	146.7	$0.0038
8A	160.2	$0.0039
9A	112.7	$0.0039
10A	95.5	$0.0039
11A	165.1	$0.0039
12A	23.2	$0.0041
13A	38.3	$0.0044
14A	21.0	$0.0045
<u>Control Costs by Process</u>		
Process A (Cumene Peroxidation)	870.6	$0.0039
Process B (Coproduct of Hydroquinone)	7.5	$0.0017
Process C (Dehydrogenation of Isopropanol)	281.0	$0.0000
<u>Summary Statistics</u>		
Mean		$0.0030
Production Weighted Average		$0.0030

upward pressure on acetone prices. End-use demand for acetone is likely to be driven by strong demand for methyl-methacrylates and bisphenol-A. Thus, acetone prices are likely to remain firm, or increase.

15.2.3 Elasticities

Demand elasticities for acetone will be estimated on the basis of available substitutes for acetone, as well as substitutes for end-uses. The potential for import substitution will also be examined.

15.2.3.1 Demand Elasticities

15.2.3.1.1 Methyl Methacrylates

Methyl methacrylates account for 36 percent of acetone demand. These compounds, used in automotive and construction applications, do have a chemically feasible process substitutes which don't require acetone input. Manufacturing MMA via C4 oxidation technology has been examined. To date, however, this process has not proved commercially viable. MMA does have at least one potential end-use substitute in polycarbonates. These compounds have been growing in use over the past several years. However, as substitutes for MMA, the impact on acetone would be small, as polycarbonates are also derivatives of acetone through bisphenol-A. Also, other engineering plastics, such as nylons and polyesters, could be explored as competitors if acetone becomes too costly. Nevertheless, acetone derived MMA appear to dominate the market. Hence, the demand for acetone in this market is regarded as highly inelastic.

15.2.3.1.2 Solvents

Acetone is used widely in solvent applications, accounting for 17 percent of end-use demand. While a variety of alternatives exist, to date acetone has advantages stemming from its low cost and diverse uses. This is likely to change, since acetone has disadvantages concerning its environmental impact and volatility. Demand in this sector is judged to be slightly inelastic.

15.2.3.1.3 Bisphenol-A

Bisphenol-A accounts for 14 percent of acetone demand. It is used in epoxy and polycarbonate resins, and can only be produced via acetone (in combination with phenol). As discussed above, polycarbonates and MMA can be substituted for each other, but this would have little impact on acetone elasticity. In addition, other engineering plastics are potentially feasible on the commercial level, but have not yet emerged as viable competitors. Epoxy resins also are dependent on BPA, and in turn acetone, as an input. Epoxy resins themselves have quite a few substitutes, including a variety of other plastics, as well as glues. The derived demand for acetone as used for epoxy resins is deemed slightly inelastic.

15.2.3.2 Imports

Acetone imports were 4.4 percent of U.S. consumption in 1989, dropping from 9.5 percent in 1987. While in decline, imports could have a slight effect on the pricing behavior of U.S. producers.

15.2.3.3 Elasticity Estimate

Demand elasticities for acetone vary from sector to sector, ranging from highly inelastic to slightly inelastic. Thus, the demand elasticity for acetone is estimated to be in the moderately inelastic range of -.34 to -.67.

15.2.4 Market Structure

Table 15-9 summarizes the parameters for the market structure of acetone. Eleven firms are currently producing acetone in 14 facilities. The four-firm concentration ratio is 67.7%, signifying moderate market power. The HHI is 1,542.4, which falls moderate range of market power. Captive consumption is 38%, indicating a moderate level of vertical integration. On average, 5 chemical compounds are produced at acetone sites, suggesting a substantial level of horizontal integration. Imports in the industry are moderately important, and will have a slight effect on domestic pricing behavior. In summary, the acetone industry is moderately oligopolistic, and firms will likely absorb a portion of HON control costs.

15.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the acetone industry for option control costs are presented in Table 15-10.

15.2.5.1 Option One Control Costs

Option one control costs represent the estimated actual HON control cost that an industry will incur. The production weighted average percentage price increase of .72 percent leads to a price

TABLE 15-9. MARKET STRUCTURE CHARACTERISTICS FOR ACETONE

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced at Site (Horizontal Integration)	Imports
11	67.7%	1,524.4	38%	5	Slightly Important

[a] Herfindahl-Hirschman Index

TABLE 15-10. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE ACETONE INDUSTRY[1], OPTION ONE CONTROL COSTS

	Elasticity	
	-0.34	-0.67
%Δ Price (%/kg)	0.72%	0.72%
Δ Price ($/kg)	$0.0030	$.0030
%Δ Output (%/kg)	(0.24%)	(0.48%)
Δ Output (10^6 kg)	(3.6)	(7.1)
%Δ Total Revenue	0.48%	0.24%
Δ Total Revenue (10^6 $)	$2.9	$1.4
Δ Employment (# of Employees)	(4)	(8)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

Δ = Change In

Market Price = $0.41/kg

1995 Output = 1,466 x 10^6 kg (based on 1989 production at 4% annual compound growth)

1995 Total Revenue = $601,354,644.29 (market price x 1995 output)

1995 Employment = 1,639

increase $.0030 per kilogram. For the two elasticity levels of -.34 and -.67, the reduction output is 3.6 million kilograms (0.24%) and 7.1 million kilograms (.48%), respectively.

Since the majority of acetone is produced as a coproduct, it is difficult to determine the how the change in output will be distributed across the industry. The smallest facilities are 4B and 5B, which together account for 7.6 million kilograms, and make up all of process B production. Even if they had to absorb the entire decline in output, closure cannot be predicted, as acetone is a coproduct of hydroquinone at these facilities.

The highest cost plant is 14A, which accounts for 21.0 million kilograms of output. The maximum decline in output of 7.1 million kilograms is 34 percent of this plant's output. Again, closure is not likely in that acetone is a coproduct of phenol at this facility.

The loss in employment is estimated to be from four to eight employees.

15.2.6 Conclusion

Acetone is a large volume, commercially important chemical, ranked 24th in U.S. organic chemical production. The range of costs in the total industry control scenario is $.0000 to $.0045. It cannot be said that the process with zero control costs will have a competitive advantage, as the other processes yield acetone as a coproduct, and the cost burden is shared. In general, the percentage price increase is modest, and impacts will most likely be minimal.

15.2.7 References

1. Mannsville Chemical Products Corp. "Chemical Products Synopsis -- Acetone," Asbury Park, NJ, October 1990.
2. U.S. International Trade Commission. Synthetic Organic Chemicals -- United States Production and Sales, 1989, Washington, DC, December 1990, p. 15-5.
3. "Phenol and Acetone on a Seesaw." Chemicalweek, May 16, 1990, p. 7.
4. Chemical Marketing Reporter, February 18, 1991, p. 32.
5. Chemical Marketing Reporter, January 8, 1990, p. 26.
6. Thomson Financial Networks Inc. "Organic Chemical Prices Escalate - Industry Report," Investext, Boston, MA, 1990.
7. Reference 1.
8. "Chemical Profile -- Methyl Methacrylate." Chemical Marketing

Reporter, January 14, 1991, p. 42.

9. Reference 8

10. "Chemical Profile -- Bisphenol-A." Chemical Marketing Reporter, September 24, 1990.

11. Reference 1.

12. Reference 8.

13. Reference 1.

14. Mannsville Chemical Products Corp. "Chemical Products Synopsis -- Bisphenol-A," Asbury Park, NJ, August 1990.

15. Reference 1.

16. Reference 1.

17. "Chemical Profile -- Acetone." Chemical Marketing Reporter, January 14, 1991, p. 42.

18. Chemical Marketing Reporter, January 8, 1990, p. 28.

19. Chemical Marketing Reporter, February 18, 1991, p. 34.

20. Reference 1.

21. Reference 3.

22. Reference 3.

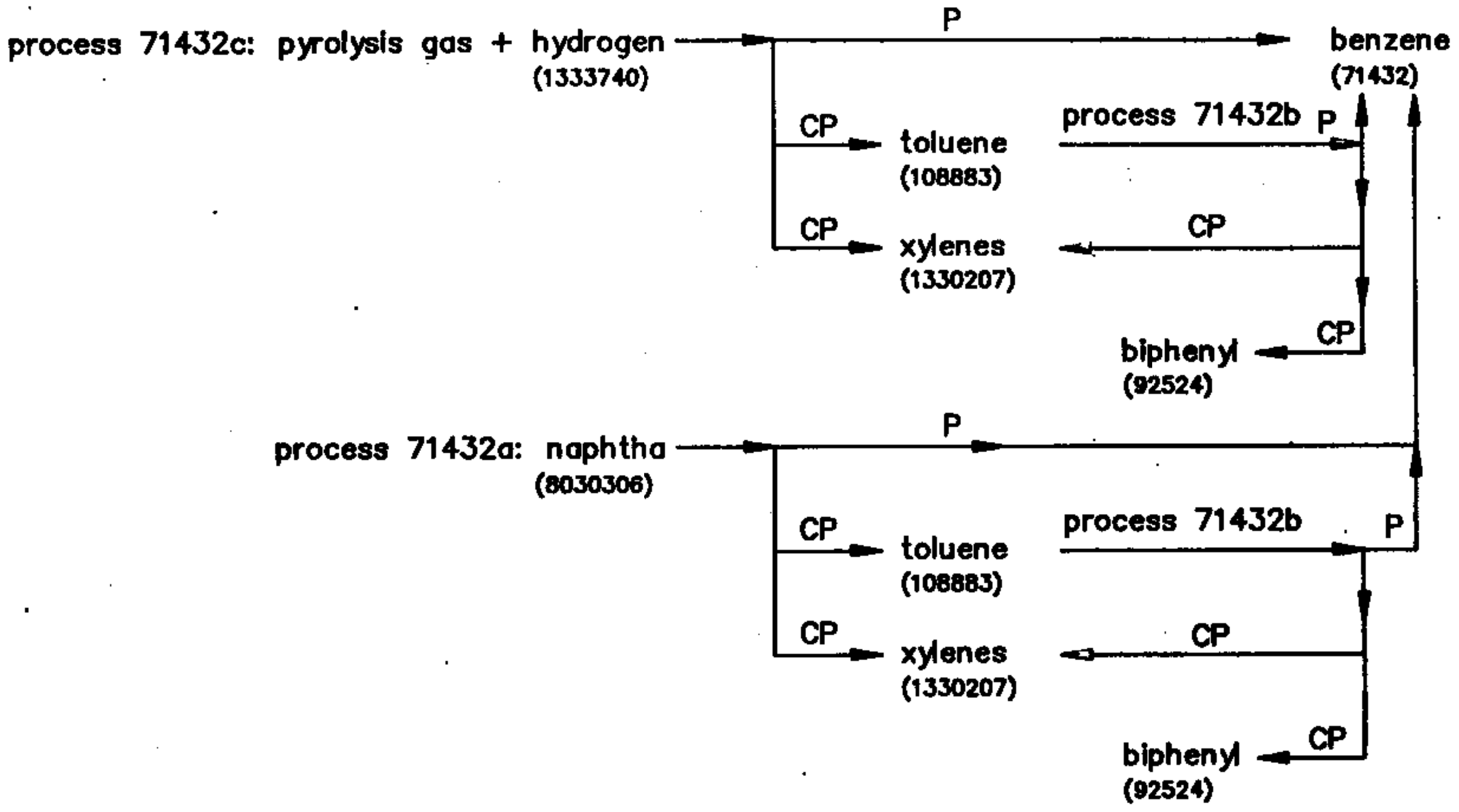
23. Reference 1.

24. Reference 1.

25. Reference 1.

26. Reference 1.

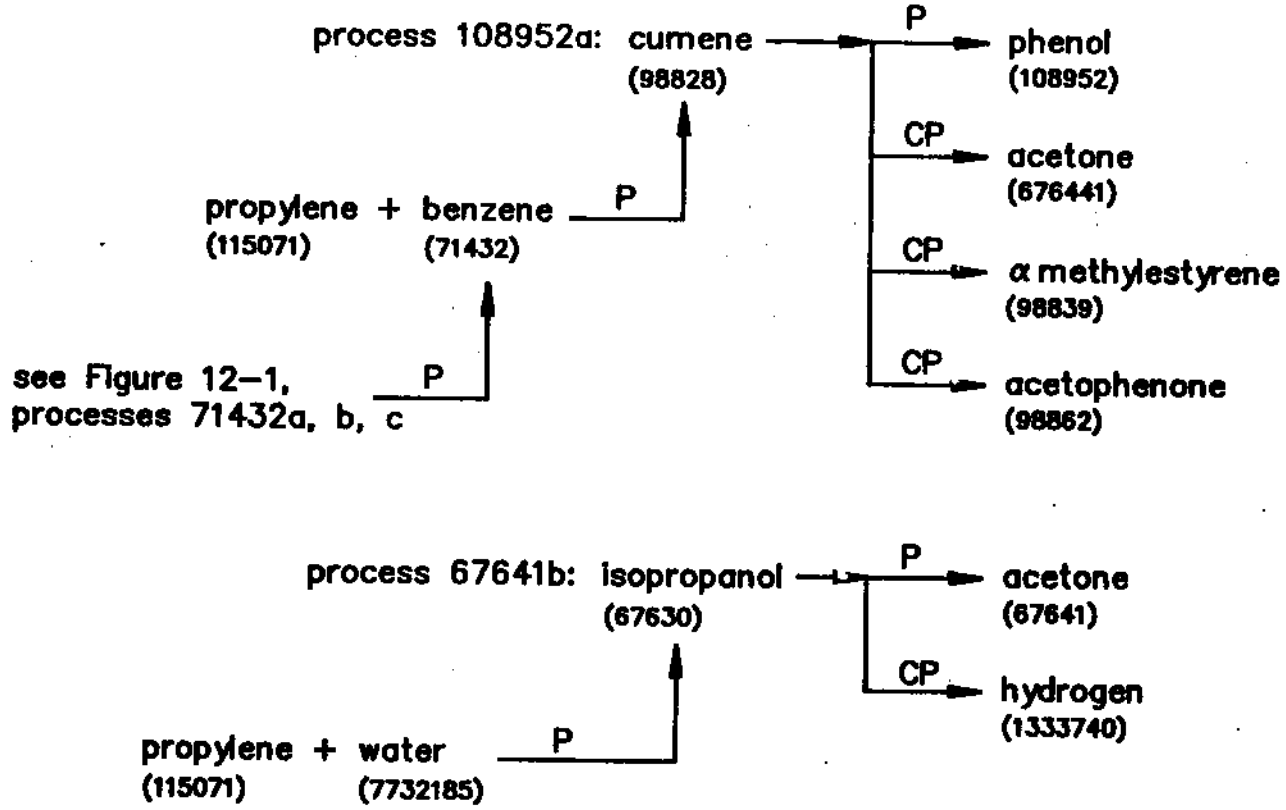
FIGURE 15-2
CHEMICAL TREE
BENZENE



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

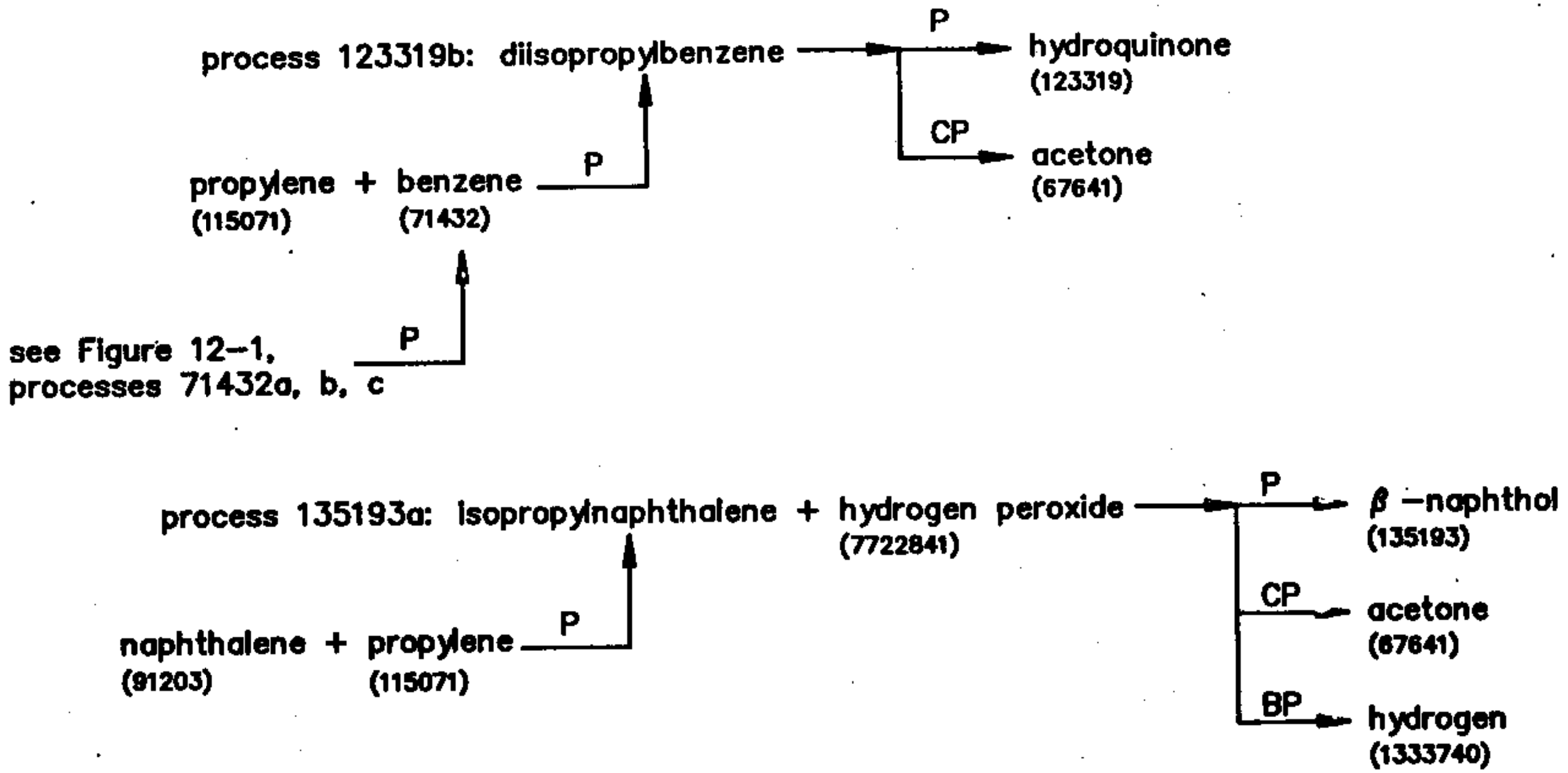
FIGURE 15-3
CHEMICAL TREE
ACETONE



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

FIGURE 15-3
CHEMICAL TREE
ACETONE



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 16

CHLOROFORM PRODUCTION

16.1 INDUSTRY PROFILE

Chloroform, also known as trichloromethane, is a member of the chlorinated hydrocarbons family of chemicals. It is produced primarily by the chlorination of methyl chloride. Over 95 percent of domestic consumption of chloroform is accounted for by Fluorocarbon 22 (F-22, or CFC 22), a chlorofluorocarbon (CFC). About 70 percent of all F-22 is used as a refrigerant.

16.1.1 Brief Market Introduction

16.1.1.1 Historical Overview

Table 16-1 shows that average realized prices of chloroform changed little from 1980 to 1989. Discounting off of list is common in the industry.[1] For example, while from 1985 to 1988 net price fluctuated from 40 to 44 cents per kilogram, the trade list price was constant at 76 cents per kilogram.[2]

Chloroform enjoyed very strong growth in the second half of the 1980s as F-22 was substituted for F-11 and F-12, two other CFCs that have been regulated under the Montreal Protocol, an international agreement that mandates a worldwide phase-down in the production of certain CFCs. F-22 is not subject to the phase-down because it is less harmful to the earth's ozone layer. F-22 is reported to have 95 percent less ozone-draining potential than F-12, for example.[3]

16.1.1.2 Recent Developments

With the surge in demand for F-22 and its precursor chloroform, supplies of chloroform have recently been extremely tight. In late 1989, all U.S. chloroform producers were reported to be on "order control."[4] In this instance, customers' monthly orders were not being allowed to deviate significantly from one-twelfth of the prior year's purchases. In 1989, the demand for chloroform began to exceed domestic production capacity.[5]

The list, or contract, price of chloroform did not change much in 1990. At the beginning of the year, it ranged from 36 to 40 cents

TABLE 16-1. AVERAGE REALIZED PRICE OF CHLOROFORM, 1980-1989

	Price (¢/kg)
1989	44
1988	40
1987	44
1986	44
1985	44
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	46

N.A. - Not available.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Chloroform," September 1988; U.S. International Trade Commission, Synthetic Organic Chemicals, 1988, 1989.

per pound (79-88 cents per kg).[6] At the end of the year, the range was 32-40 cents per pound (71-88 cents per kg).

16.1.2 Demand Conditions

16.1.2.1 Uses for Chloroform

Fully 97 percent of all chloroform in the U.S. is used to produce F-22.[7] Demand for F-22, in turn, is accounted for about two-thirds by refrigerants and about one-third by fluoropolymers.[8] F-22 also has miscellaneous uses as a propellant gas, foam blowing agent, and solvent.

F-22 is used as a refrigerant in refrigerators and air conditioners, particularly small units in automobiles and households. As might be expected, the demand for chloroform is therefore somewhat seasonal, peaking in the summer when more air conditioners are installed and when air conditioner maintenance is highest.

Fluoropolymers are plastic resins with such applications as lining pipes and process vessels, insulating, and coating. Polytetrafluoroethylene, for example, is a fluoropolymer derived from chloroform used for coating household appliances and utensils subjected to high temperatures.

Because of the dependence of refrigerants and fluoropolymers on housing construction and consumer spending on such durable goods as automobiles, refrigerators, and air conditioners, chloroform can be said to be linked to the construction, automotive, and consumer durable goods industries.[9]

As mentioned, F-22 has benefitted from world-wide restrictions on two alternative CFCs, F-11 and F-12. F-22 is one of the few significant CFCs not regulated by the Montreal Protocol. F-22 has been able to replace F-12 in some refrigeration and air conditioning applications, and F-11 in some foam-blowing applications.[10]

In addition to F-22, chloroform has miscellaneous uses (3 percent of consumption) as a solvent and in the manufacture of dyes, resins, and fire-extinguishing agents. Another minor use is as an anesthetic in veterinary applications. Chloroform has been largely replaced as an anesthetic, however.[11]

16.1.2.2 Consumption

Apparent consumption (production plus imports, minus exports) of chloroform in the U.S. is shown in Table 16-2 for 1980 and 1985-88.

TABLE 16-2. APPARENT CONSUMPTION OF CHLOROFORM IN THE U.S., 1980-1989

	Apparent Consumption (10^6 kg)
1989	N.A.
1988	229 (est.)
1987	205
1986	184
1985	170
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	152

N.A. - Not available.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Chloroform," September 1988; Chemical Marketing Reporter, February 27, 1989.

Data were not available for other years. Chloroform consumption increased steadily from 1985 to 1988, at a robust average annual rate of 10.4 percent.

16.1.2.3 Exports

U.S. exports of chloroform in the 1980s are tracked in Table 16-3. For the years reported, exports were highest in 1985 and 1988 at 20 million kilograms. In relation to U.S. output, exports peaked at 16 percent in 1985. In 1988, exports accounted for 8.4 percent of U.S. output.

16.1.2.4 Future Trends

Chloroform demand growth is expected to remain strong in the near term. In one 1989 forecast, total demand -- domestic and export -- was projected to increase by 5.5 percent per year from 1989 to 1993.[12] This compares to average annual growth of 3.8 percent from 1979 to 1988. In another 1989 forecast, average growth over the next five years of 7-9 percent was predicted.[13]

Growth will be spurred by continued penetration of F-22 in refrigeration, foam-blowing, and other markets previously held by F-11 and F-12. Once the replacement of F-11 and F-12 is complete, most growth will result from an increase in the use of residential air conditioning (both new installations and replacements).[14] The short-term outlook also depends on developments in chloroform's major end-use markets: construction, automotive, and consumer durables. A slowdown in these markets, as is the case in 1991, might counteract the effects of opportunities to substitute for F-11 and F-12.

Long-term demand growth prospects for chloroform are also considered to be excellent, though there does remain the risk that F-22 will also one day be regulated for its deleterious effect on the ozone layer.[15]

16.1.3 Supply Conditions

16.1.3.1 Production Process

Chloroform is produced mainly by hydrochlorinating methanol with hydrogen chloride. The initial derivative of this process is methyl chloride. Further chlorination yields such derivatives as chloroform and methylene chloride. The derivative mix can be adjusted according to market conditions.

TABLE 16-3. U.S. EXPORTS OF CHLOROFORM, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1989	N.A.	N.A.
1988	20 (est.)	8.4%
1987	16	7.6%
1986	19	9.9%
1985	20	16.0%
1984	N.A.	N.A.
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	8	6.5%

N.A. - Not available.

[a] See Table 16-5.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Chloroform," September 1988; Chemical Marketing Reporter, February 27, 1989.

Chloroform can also be produced by chlorinating methane. "However, flexibility, economics, and product mix have made the hydrochlorination of methanol the dominant process."[16]

16.1.3.2 Domestic Producers and Total Production

U.S. producers of chloroform and their facilities are listed in Table 16-4. As of January 1990, total U.S. production capacity was 240 million kg/year. This compared to 220 million kilograms in February 1986.[17] Dow Chemical accounts for 54 percent of U.S. capacity. All but one of the units in Table 16-4 use methanol as the raw material. The exception is Vulcan's Wichita plant, which uses 33 percent methane, and 67 percent methanol.[18] None of the producers are integrated forward into the production of CFCs.[19] Consequently, there is no, or virtually no, captive consumption of chloroform.

As mentioned, chloroform producers can also produce other methyl chloride derivatives (termed chloromethanes), such as methylene chloride. With process changes, producers can switch from one chloromethane to another. The capacities in Table 16-4 are therefore flexible.

In 1988, chloroform supplies were tight, though there was overall excess capacity for chloromethanes. This is because there was overcapacity for methylene chloride.[20]

Chloroform's rapid production growth in the late 1980s is chronicled in Table 16-5. After dropping to 125 million kilograms in 1985, U.S. output increased 52.8 percent to 191 million kilograms in 1986, and then by an average of 11.8 percent per year from 1986 to 1989. Chloroform's 12.2 percent output increase in 1989 was the second-highest among major organic chemicals, trailing only acetic acid (+21%).[21] The impetus behind the growth has been the aforementioned substitution for F-11 and F-12.

16.1.3.3 Costs of Production

Methanol is the primary raw material input to the production of chloroform. In 1990, the list price of methanol increased from 35 cents to 55 cents per gallon. Most of this increase occurred in December. In the first two months of 1991, the price increased another 2-3 cents per gallon.

TABLE 16-4. U.S. PRODUCERS OF CHLOROFORM,
JANUARY 1990

Company	Plant Location	Capacity (10^6 kg/yr)
Dow	Freeport, TX	61
	Plaquemine, LA	68
LCP Chemicals[a]	Moundsville, WV	18[b]
Occidental Chemical	Belle, WV	16
Vulcan Materials Co.	Geismar, LA	27
	Wichita, KS	50
		240

[a] Division of the Hanlin Group, Inc.

[b] This facility was due to be replaced by a new unit with 27 million kg of capacity. However, an explosion damaged the new unit shortly after it started up in August 1989. The new unit was shut down, and had still not been reactivated in early 1990.

Sources: SRI International, <u>1990 Directory of Chemical Producers</u>, p. 531; <u>Chemical Marketing Reporter</u>, February 27, 1989.

TABLE 16-5. U.S. PRODUCTION OF CHLOROFORM, 1980-1989

	Quantity (10^6 kg)
1989	267
1988	238
1987	210
1986	191
1985	125
1984	184
1983	164
1982	136
1981	184
1980	124

Sources: Chemical & Engineering News, June 18, 1990, p. 39; U.S. International Trade Commission, Synthetic Organic Chemicals, 1989.

16.1.3.4 Imports

As Table 16-6 shows, U.S. imports of chloroform increased from a negligible amount in 1980 to 15 million kilograms in 1985, and then declined to 11 million kilograms in 1987 and 1988. In 1988, imports accounted for 4.8 percent of U.S. chloroform consumption.

16.1.3.5 Future Prospects

U.S. chloroform producers should benefit from the prospect of continued rapid growth in the demand for chloroform. Since by 1989 U.S. chloroform demand was expected to surpass annual production capacity, it may be difficult for U.S. producers to satisfy all demand unless capacity is added or chloroform production is substituted for the production of other chloromethanes. Such an effort might be aided by an anticipated long-term decline in the demand for methylene chloride.[22]

16.1.4 Future Market Prospects

Mainly due to continuing replacement of F-11 and F-12 in some applications, growth prospects for F-22 and its precursor chloroform, both in the near term and long term, are excellent. However, chloroform is still subject to conditions in three markets that are currently depressed: construction, automotive, and consumer durables. Also, in the long term, it cannot be ruled out that F-22 will also one day be regulated for its harmful effect on the ozone layer.

Chloroform supplies have recently been very tight. Producers will probably have to add capacity or make process changes in order to satisfy all demand in the future.

16.2 ECONOMIC IMPACT ANALYSIS

16.2.1 HON Compliance Costs

A synopsis of annualized costs and summary statistics for chloroform production facilities and production processes is presented in Table 16-7. Costs are displayed for option one controls. Option one controls are the estimated actual costs that facilities are likely to incur. Figure 16-1 presents the control scenario graphically.

Chloroform is currently produced by two processes: halogenation of methyl chloride (process A), and halogenation of methane (process B). Production-weighted average costs are $.0053 per kilogram for process A, and $.0005 per kilogram for process B. However, the difference is small enough -- $.0049 per kilogram for

TABLE 16-6. U.S. IMPORTS OF CHLOROFORM, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Consumption[a]
1989	N.A.	N.A.
1988	11 (est.)	4.8%
1987	11	5.4%
1986	14	7.6%
1985	15	8.8%
1984	N.A.	N.A.
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	-	-

N.A. - not available.

[a] See Table 16-2.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Chloroform," September 1988; Chemical Marketing Reporter, February 27, 1989.

TABLE 16-7. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR CHLOROFORM PRODUCTION FACILITIES AND CHLOROFORM PRODUCTION PROCESSES

Facility/ Process	Annual Production (10^6 kg)	Option One Controls ($/kg)
1A	41.5	$0.0026
2A	22.4	$0.0045
3A&B	44.8	$0.0055
4A	44.8	$0.0055
5A	14.9	$0.0065
6A	11.6	$0.0074
<u>Control Costs by Process</u>		
Process A (halogenation of methyl chloride)	166.4	$0.0053
Process B (halogenation of methane)	13.7	$0.0005
<u>Summary Statistics</u>		
Mean		$0.0053
Production Weighted Average		$0.0049

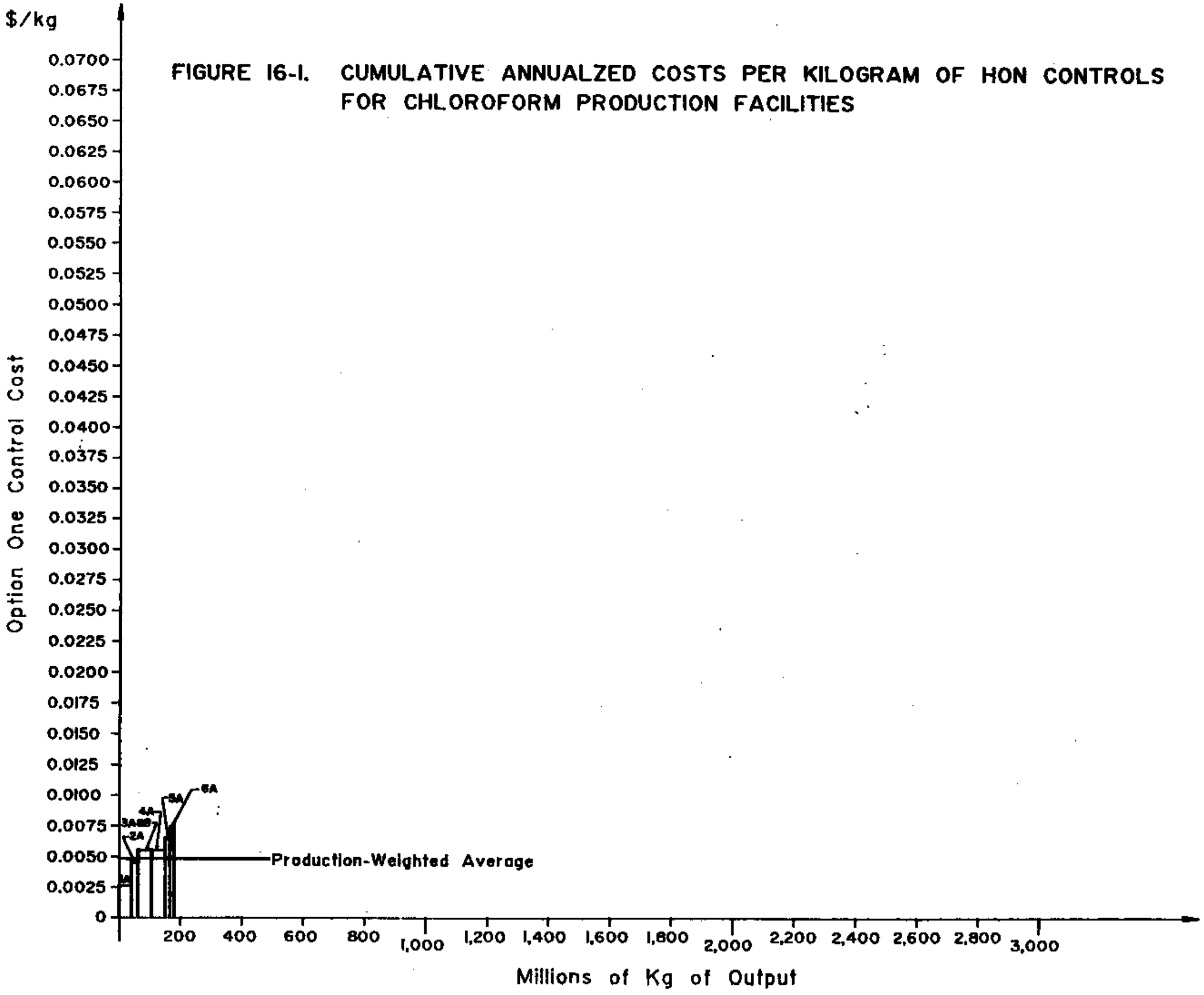


FIGURE 16-1. CUMULATIVE ANNUALZED COSTS PER KILOGRAM OF HON CONTROLS FOR CHLOROFORM PRODUCTION FACILITIES

option one -- that it is unlikely to spur process changes in favor of process B. Moreover, Process B is used by facility 3A&B, which can employ both processes, and will likely devote more capacity to process B if process A is at a competitive disadvantage.

16.2.2 Pricing

Chloroform prices in the 1980s were fairly uniform, ranging from 40 to 46 cents per kilogram. Average realized price in 1989 was 44 cents per kilogram, 2 cents less than 1980. The most recent spot price available at the time of this writing was 79 cents per kilogram. This is not indicative of a substantial increase, as contract prices are considerably lower than list prices. Nevertheless, chloroform prices should remain firm due to the market's favorable growth prospects.

16.2.3 Elasticities

The demand elasticity for chloroform is estimated on the basis of available substitutes for chloroform, as well as substitutes for end-uses. The potential for import substitution is also examined.

16.2.3.1 Demand Elasticities

16.2.3.1.1 Fluorocarbon 22

Fluorocarbon 22 (F-22) accounts for over 95 percent of U.S. chloroform consumption. Seventy percent of this is used as a refrigerant. Chloroform is an indispensable raw material in the production of F-22. Substitutes do exist for F-22. However, as was noted, the available chlorofluorocarbons are generally being phased out due to their suspected role as ozone depleters. New products, such as other hydrochlorofluorocarbons (HCFCs), are becoming commercially viable. As these come on line, the demand elasticity for F-22 will increase. Of course, it is true that commodities in general have long-run elasticities that are larger than short-run elasticities. Also, F-22 might possibly be subject to regulation for its detrimental effects on the ozone. Nevertheless, through the mid-1990s F-22 is the CFC of choice. Chloroform demand is estimated to be highly inelastic in this sector.

16.2.3.2 Imports

Imports account for less than 5 percent of U.S. production, and should therefore have an insignificant impact on the behavior of U.S. firms.

16.2.3.4 Elasticity Estimate

The demand elasticity for chloroform is based on only one end-use market. It is estimated to be in the highly inelastic range of -.1 to -.34.

16.2.4 Market Structure

Table 16-8 summarizes the parameters for the market structure of chloroform. Four firms are currently producing chloroform. Thus, the four-firm concentration ratio is 100 percent, signifying substantial market power. The HHI is 4,019.1, which falls in the range of substantial market power. On average, nine chemical compounds are produced at chloroform sites, suggesting a substantial level of horizontal integration. Imports in the industry are insignificant. In summary, the chloroform industry is highly oligopolistic, and firms will likely absorb a significant portion of HON control costs.

16.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the chloroform industry for option one control costs are presented in Table 16-9.

16.2.5.1 Option One Control Costs

Option one control costs represent the actual estimated cost that an industry will incur. The weighted average percentage price increase of 1.09 percent leads to a price increase $.0049 per kilogram. For the two elasticity levels of -.1 and -.34, the output reduction is 285 thousand kilograms (.11%) and 969 thousand kilograms (.37%), respectively.

Facility 6A is the highest cost and smallest plant in the industry, accounting for 11.6 million kilograms of annual production. If this facility absorbs the entire reduction in output, it would lose from 2.5 percent to 8.4 percent of its output. Thus, control costs in the option one scenario are unlikely to lead to closure of the smallest size facilty. The reduction in employment is from 0 to 1 employees. While two processes are in use for producing chloroform, the cost differential is so small that process change is not apt to be stimulated by HON controls. Since imports are negligible, this price increase is not likely to spur import substitution.

TABLE 16-8. MARKET STRUCTURE CHARACTERISTICS FOR CHLOROFORM

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced at Site (Horizontal Integration)	Imports
4	100%	4,019.1	N.A.	9	Insignificant

N.A. - Not Available

[a] Herfindahl-Hirschman Index

TABLE 16-9. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE CHLOROFORM INDUSTRY[1], OPTION ONE CONTROL COSTS

	Elasticity	
	-0.1	-0.34
%Δ Price (%/kg)	1.09%	1.09%
Δ Price ($/kg)	$.0049	$.0049
%Δ Output (%/kg)	(0.11%)	(0.37%)
Δ Output (10^6 kg)	(.285)	(.969)
%Δ Total Revenue	(0.98%)	(0.72%)
Δ Total Revenue (10^6 $)	$1.2	$.851
Δ Employment (# of Employees)	(0)	(1)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

Δ = Change In

Market Price = $0.45/kg

1995 Output = 262.8 x 10^6 kg (based on 1989 production at 6.5% annual compound growth)

1995 Total Revenue = $118,262,753.56 (market price x 1995 output)

1995 Employment = 322

16.2.6 Conclusion

The range of costs in the chloroform industry under the total industry control scenario is from $.0109/kg to $.0201/kg. The cost differential is small, and the production-weighted price increase is probably an accurate estimate of the actual price increase. At the upper end of compliance costs, closure of the smallest size facility is possible under the total industry control scenario, but unlikely given option one control costs. HON controls are not likely to elicit process changes, or spur import substitution.

16.2.7 References

1. Mannsville Chemical Products Corp. "Chemical Products Synopsis -- Chloroform." Asbury Park, NJ, September 1988.
2. Reference 1.
3. Reference 1.
4. "Chloroform Problem Clouds CFC Outlook." Chemical Marketing Reporter, September 11, 1989, pp. 3, 15.
5. Reference 4.
6. Chemical Marketing Reporter, January 8, 1990, p. 28.
7. Reference 1.
8. "Chemical Profile -- Chloroform." Chemical Marketing Reporter, February 27, 1989.
9. Reference 1.
10. Reference 1.
11. Reference 1.
12. Reference 8.
13. Reference 4.
14. Reference 1.
15. Reference 1.
16. Reference 1.
17. "Chemical Profile -- Chloroform." Chemical Marketing Reporter, February 17, 1986, p. 50.
18. SRI International. 1990 Directory of Chemical Producers, p. 531.
19. Reference 1.
20. Reference 1.

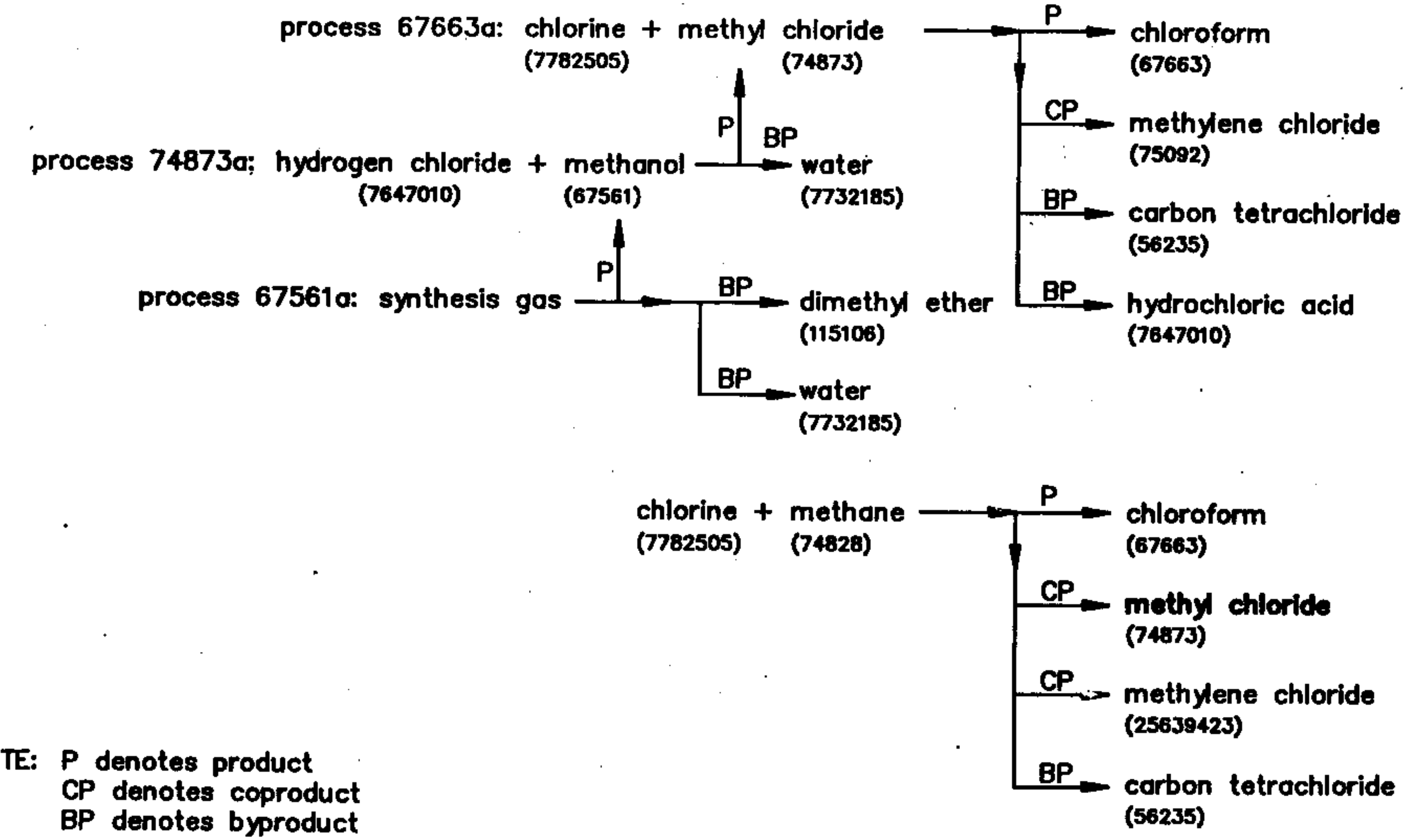
21. Chemical & Engineering News, June 18, 1990, p. 39.

22. Reference 1.

FIGURE 16-2

CHEMICAL TREE

CHLOROFORM



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 17

TRIETHYLENE GLYCOL PRODUCTION

17.1 INDUSTRY PROFILE

Triethylene glycol (TEG) is a coproduct in the production of ethylene glycol. It is categorized as a member of the glycols and triols family. Merchant market sales accounted for 95 percent of total production in 1989.[1] Triethylene glycol's largest end use is in natural gas dehydration.[2]

17.1.1 Brief Market Introduction

17.1.1.1 Historical Overview

Triethylene glycol is considered to be one of the more profitable ethylene glycols.[3] Compared to lower glycols (ethylene glycol, diethylene glycol), its end-use markets are more specialized.[4] Also, the end-use market demand usually exceeds the TEG supply resulting from ethylene glycol production.[5] For this reason, TEG is also produced "on-purpose." Specifically, additional triethylene glycol is manufactured by reacting diethylene glycol (also a coproduct of ethylene glycol production) with additional ethylene oxide. In this way excess demand can be satisfied and excess diethylene glycol is profitably used.

Two commercial grades of TEG are sold, technical and high purity. Discounting is common.[6] The average realized price of triethylene glycol (technical grade) from 1980 to 1989 is listed in Table 17-1. A decade-high of $1.33 per kilogram occurred in 1989 despite a decrease in exports and a decrease in quantity demanded. The implication is that supply contracted. Two arguments support this implication. First of all, there was an increase in the cost of ethylene oxide, the feedstock for ethylene glycol. Ethylene oxide's average realized price rose 46 cents per kilogram from 1988 to 1989 (a 55% increase).[7,8] Secondly, demand for ethylene glycol dropped due in part to weak demand for its major end use, antifreeze. As a result, ethylene glycol output dropped by one percent, constricting triethylene glycol supply; TEG production varies directly with

TABLE 17-1. AVERAGE REALIZED PRICE OF TRIETHYLENE GLYCOL (TECHNICAL GRADE), 1980-1989

	Price ($/kg)
1989	1.33
1988	0.82
1987	0.64
1986	0.62
1985	0.62
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	0.90

N.A. - Not available.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Triethylene Glycol," January 1989; U.S. International Trade Commission, <u>Synthetic Organic Chemicals</u>, 1988, 1989.

ethylene glycol. Also, the diethylene glycol supply was lessened; this affected additional "on-purpose" production of TEG.

17.1.1.2 Recent Developments

The trade list price of TEG in 1990 ranged from $1.61 per kilogram in January to $1.41 per kilogram in December.[9,10] The most recent price (February 1991) was $1.46 per kilogram.[11]

17.1.2 Demand Conditions

17.1.2.1 Uses for Triethylene Glycol

Triethylene glycol uses are summarized in Table 17-2. Triethylene glycol is a hygroscopic chemical; hygroscopicity refers to an ability to absorb water vapor from gases.[12] This explains why natural gas dehydration is the major end use, accounting for 49 percent of 1989 consumption. Triethylene glycol also dehydrates various hydrocarbon gases, compressed air, carbon dioxide, synthesis gases, flue gas, nitrogen, and cracked gases.

The second largest end use for TEG is as a raw material for esters, used as specialized plasticizers for vinyl and other resins (14%). Accounting for 13 percent of consumption is TEG's use in the production of unsaturated polyester resins and polyester polyols for urethanes. Polyester fiber and polyester plastic producing plants use TEG as a solvent (12%). PET (polyethylene terephthalate) plants are the biggest users of triethylene glycol in solvent applications. Triethylene glycol is used as a humectant for tobacco products and cork compounds.

Included among miscellaneous uses are triethylene glycol's use in solvent extraction, as an intermediate in the manufacture of polyglycols, as a sterilizing agent, as an emulsifying agent, and as a solvent and lubricant in textile dyeing and printing.

17.1.2.2 Consumption

Table 17-3 lists domestic apparent consumption data from 1980 to 1989. Quantity demanded has gone up and down throughout the decade. Increased demand for triethylene glycol pushed apparent consumption from 49.6 million kilograms in 1980 to a decade-high of 63.0 million kilograms in 1985.[13] According to Chemical Marketing Reporter, however, in 1985 oil and gas prices collapsed and TEG consumption in natural gas dehydration fell about 20 percent from 1985 to the beginning of 1987.[14] Apparent consumption fell 17.2 million

TABLE 17-2. USES OF TRIETHYLENE GLYCOL, 1990

	Percent of Total Consumption
Natural gas dehydration	49%
Plasticizer raw material	14%
Polyester resins and polyols for urethanes	13%
Solvent	12%
Humectant	7%
Miscellaneous	5%

Sources: Chemical Marketing Reporter, February 5, 1990; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Triethylene Glycol," January 1989.

TABLE 17-3. APPARENT CONSUMPTION OF TRIETHYLENE GLYCOL IN THE U.S., 1980-1989

	Apparent Consumption[a] (10^6 kg)
1989	46.9
1988	54.7
1987	46.7
1986	45.8
1985	63.0
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	49.6

[a] Production plus imports, minus exports. Because inventory changes are ignored, this is a simplified estimate of consumption. Because imports for triethylene glycol are not significant, they are also not factored into the calculation.

Sources: Chemical Marketing Reporter, February 5, 1990; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Triethylene Glycol," January 1989; U.S. International Trade Commission, Synthetic Organic Chemicals, 1988, 1989.

kilograms between 1985 and 1986. Beginning in 1987, the quantity demanded recovered due in part to increased consumption of unsaturated polyester resins and polyurethanes by the automotive and housing construction industries. From 1988 to 1989 apparent consumption dropped again by 7.8 million kilograms. This resulted from an upward shift in supply of triethylene glycol due to increased feedstock costs and decreased ethylene glycol production.

17.1.2.3 Exports

U.S. exports of triethylene glycol from 1980 to 1989 are listed in Table 17-4. In 1987 exports reached a high of 7.3 million kilograms. This represented 13.5 percent of production, the highest for any of the 10 years. Most recently, exports totalled 4.1 million kilograms in 1989, 8.0 percent of domestic production.

17.1.2.4 Future Prospects

The triethylene glycol market has been characterized by Chemical Marketing Reporter as being mature.[15] This is supported by the fact that there are no new significant end uses. For the current uses only moderate growth is expected. While natural gas is projected to be the fastest growing source of energy in the 1990s, its growth rate will only be about 1.8 percent annually.[16,17] Thus, moderate growth should be expected for TEG use in natural gas dehydration. The same is true for use as a plasticizer raw material. Plasticizer growth is dependent on PVC growth, whose long-term rate is forecast at 3 percent annually.[18] Triethylene glycol's use as a humectant may decline if cigarette makers continue to use the substitute glycerine.[19]

Consequently, the forecasted demand of TEG (including both domestic demand and exports) for 1994 is 57.6 million kilograms.[20] This represents a growth rate of 2 percent per year through 1994.[21]

17.1.3 Supply Conditions

17.1.3.1 Production Processes

In the production of ethylene glycol by ethylene oxide hydration, di- and triethylene glycol are coproducts which are separated from ethylene glycol through vacuum distillation. The hydration of ethylene oxide generally yields about 90 percent ethylene glycol, 8 to 10 percent diethylene glycol, and 1 percent triethylene

TABLE 17-4. U.S. EXPORTS OF TRIETHYLENE GLYCOL, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1989	4.1 (est.)	8.0%
1988	7.3 (est.)	11.7%
1987	7.3	13.5%
1986	3.2	6.5%
1985	5.0	7.4%
1984	N.A.	N.A.
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	6.4	11.4%

[a] See Table 17-6.

N.A. - Not available.

est. - Estimate.

Sources: Chemical Marketing Reporter, February 5, 1990; Mannsville Chemical Products Corp.," Chemical Products Synopsis -- Triethylene Glycol," January 1989; U.S. International Trade Commission, Synthetic Organic Chemicals, 1989.

glycol; these ratios vary by plant and production levels.[22] To supply excess demand, "on-purpose" production of TEG can be achieved by reacting additional ethylene oxide with diethylene glycol.

17.1.3.2 Domestic Producers and Total Production

There are nine domestic producers of triethylene glycol with a total capacity of 89.3 million kilograms. This total includes capacity resulting from ethylene glycol production and on-purpose triethylene glycol production. Two additional firms, Chemical Exchange Industries (Houston, TX) and Dixie Chemical Company (Bayport, TX), obtain TEG from purchased mixed glycols. Capacities are flexible, which is characteristic of the production of higher glycols.[23] For example, triethylene glycol output increases as producers manufacture more on-purpose diethylene glycol.[24] When more tetraethylene glycol is made, triethylene glycol output is reduced.[25] Production capacity also depends on ethylene glycol capacity. Potential TEG capacity is usually considered to be 1 percent of total ethylene glycol capacity.[26] Table 17-5 lists the U.S. producers along with plant location and capacity data.

Total domestic production is in Table 17-6. Though production data are not available for the years 1981 to 1984, output increased from 56 million kilograms in 1980 to 68 million kilograms in 1985 (a 21% increase). As demand for triethylene glycol use in natural gas dehydration began to decline in mid-1985, production dropped by 19 million kilograms to 49 million kilograms in 1986. In fact, there was no on-purpose production of triethylene glycol in that year.[27] Production then grew until 1989, when supply contracted and output dropped by 11 million kilograms. The contraction in 1989 was attributable to the increased cost of ethylene oxide (the feedstock) and lower ethylene glycol production.

Output in 1989 represented 57 percent of domestic TEG capacity. This rate is low because there was no on-purpose production; triethylene glycol capacity includes both ethylene glycol coproduct capacity and on-purpose capacity.[28]

17.1.3.3 Costs of Production

The primary source of costs is ethylene oxide, and in turn its ethylene feedstock. Ethylene oxide has dropped from $1.43 per kilogram (trade list) in January 1990 to $1.12 per kilogram in February 1991.[29,30] Overcapacity in the ethylene oxide industry

TABLE 17-5. U.S. PRODUCERS OF TRIETHYLENE GLYCOL, FEBRUARY 1990

Company	Location	Capacity[a] (10^6 kg/yr)
BASF	Geismar, LA	3.6
Dow Chemical	Plaquemine, LA	22.7
Eastman Chemical	Longview, TX	3.6
Hoechst Celanese	Clear Lake, TX	4.5
Oxy Petrochemicals	Bayport, TX	10.4
PD Glycol	Beaumont, TX	2.7[b]
Shell Chemical	Geismar, LA	4.1
Texaco Chemical	Port Neches, TX	8.2
Union Carbide[c]	Seadrift, TX and Taft, LA[d]	29.5
		89.3

[a] Includes capacity resulting from ethylene glycol production and on-purpose TEG production.

[b] PD Glycol will raise its capacity by 453,593 kilograms in 1991.

[c] At its Texas City, TX plant, Union Carbide refines higher ethylene glycol mixtures from Seadrift, TX and Taft, LA to produce di-, tri-, and tetraethylene glycols.

[d] Forced production of triethylene glycol.

NOTE: Chemical Exchange Industries, Inc. (Houston, TX) and Dixie Chemical Company (Bayport, TX) obtain triethylene glycol from purchased mixed glycols.

Sources: Chemical Marketing Reporter, February 5, 1990; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Triethylene Glycol," January 1989; SRI International, "1990 Directory of Chemical Producers, United States."

TABLE 17-6. U.S. PRODUCTION OF TRIETHYLENE GLYCOL, 1980-1989

	Quantity (10^6 kg)
1989	51
1988	62
1987	54
1986	49
1985	68
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	56

N.A. - Not available.

NOTE: These production figures are only from TEG co-product production; on-purpose production is not included.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Triethylene Glycol," January 1989; U.S. International Trade Commission, Synthetic Organic Chemicals, 1988, 1989.

should keep feedstock costs down if there is no large increase in ethylene oxide demand.

17.1.3.4 Imports

According to Chemical Marketing Reporter, imports are not significant.[31]

17.1.3.5 Future Prospects

Total production of triethylene glycol as a coproduct is entirely dependent on ethylene glycol production. Future ethylene glycol growth in the U.S. is forecast to be about 2 percent annually through 1994.[32] This implies that triethylene glycol production will also be at this level. On-purpose production will also be affected slow growth of ethylene glycol.

17.1.4 Future Market Prospects

Since most of its uses are mature, triethylene glycol will experience only moderate future growth of 2 percent annually through 1994.[33] It will be highly dependent on the natural gas market because 49 percent of TEG consumption is used in natural gas dehydration.

With respect to production, triethylene glycol will continue to be dependent on ethylene glycol production levels and the cost of ethylene oxide. Capacity utilization rates will vary with the amount of on-purpose production.

17.2 ECONOMIC IMPACT ANALYSIS

17.2.1 HON Compliance Costs

A synopsis of annualized cumulative control costs and summary statistics for triethylene glycol facilities is presented in Table 17-7. Costs are presented for option one controls. Option one control costs are estimates of the actual costs that facilities are likely to incur. Figure 17-1 illustrates control costs graphically. Eleven facilities are displayed.

Triethylene Glycol is currently produced as a coproduct of the lower glycols, ethylene glycol (EG) and diethylene glycol (DEG). Since this is the only commercial process, no analysis of separate process costs is necessary.

TABLE 17-7. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR TRIETHYLENE GLYCOL PRODUCTION FACILITIES ($/kg)

Facility/ Process	Annual Production (10^6 kg)	Option One Controls ($/kg)
1A	13.70	$0.0011
2A	4.41	$0.0011
3A	5.40	$0.0012
4A	7.34	$0.0013
5A	5.40	$0.0013
6A	6.46	$0.0015
7A	5.14	$0.0015
8A	2.25	$0.0017
9A	5.29	$0.0019
10A	3.52	$0.0024
11A	1.97	$0.0027
<u>Summary Statistics</u>		
Mean		$0.0016
Production Weighted Average		$0.0014

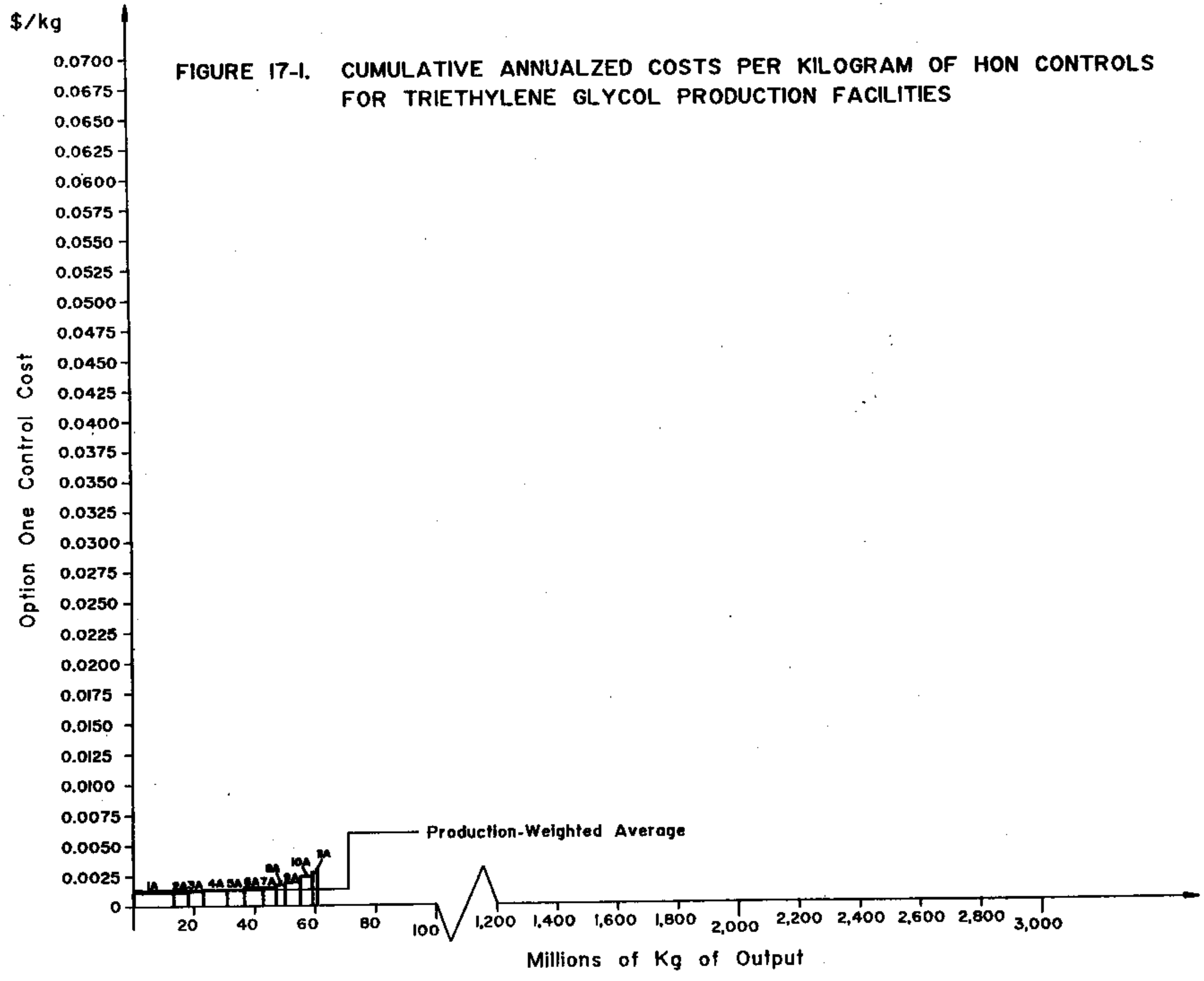


FIGURE 17-1. CUMULATIVE ANNUALZED COSTS PER KILOGRAM OF HON CONTROLS FOR TRIETHYLENE GLYCOL PRODUCTION FACILITIES

17.2.2 Pricing

Triethylene glycol prices are determined by a combination of feedstock costs, supply conditions and end-use demand. It is generally thought that triethylene glycol is the most profitable of the ethylene derivatives, suggesting an ability to secure a relatively sizable margin of price over marginal cost. Supply conditions are important in the triethylene glycol market. In general, triethylene glycol as a coproduct tends to be produced in quantities far less than the market will bear, while DEG is produced in quantities generally determined to be "to large," i.e. not profitable enough. Firms then tend to force production of triethylene glycol directly by reacting DEG with EO. In this way, firms might possess some price discretion by varying supply. This explains some of the profitability. Also, end-use demands tend to be more specialized in comparison with the lower glycols. The 1989 average realized price was $1.33/kg. The most recent spot price available at the time of this writing is $1.45. Prices appear to be firm, despite declining feedstock costs.

17.2.3 Elasticities

The demand elasticity for triethylene glycol is estimated on the basis of available substitutes for ethylene glycol, as well as substitutes for end-uses. The potential for import substitution is also examined.

17.2.3.1 Demand Elasticities

17.2.3.1.1 Natural Gas Dehydrator. Forty-nine percent of triethylene glycol is used in natural gas dehydration. A variety of substitutes exist, including silica gel, activated alumina, and molecular sieves. Triethylene glycol tends to have a cost advantage over these compounds when normal dehydration is required. However, when extremely dry gas is needed, triethylene glycol performance is substandard. triethylene glycol demand is estimated as moderately inelastic in this sector.

17.2.3.1.2 Plasticizer Raw Material. Fourteen percent of triethylene glycol is used as a plasticizer raw material. In this end-use market, many substitutes exist for triethylene glycol, including phthalates, which are low-cost, general-purpose plasticizers. Triethylene glycol demand is estimated to be slightly inelastic in this market, possibly leaning towards unity.

17.2.3.1.3 Polyester Resins. Thirteen percent of triethylene glycol is used in polyester resins to impart flexibility. Other glycols, including propylene glycol, are readily available substitutes for this use. Here too, triethylene glycol demand is judged slightly inelastic, hovering in the area of unity.

17.2.3.1.4 Solvent. Twelve percent of triethylene glycol is used as a solvent, primarily in aircraft deicing formulas. Ethylene glycol and propylene glycol are available as substitutes. Triethylene glycol demand is judged to be slightly inelastic in this industry.

17.2.3.2 Imports

Triethylene glycol imports are insignificant. Therefore, pricing decisions will be made on domestic considerations, without fear of import substitution.

17.2.3.3 Elasticity Estimate

Within each end-use sector except one, demand elasticity is near unity. However, the primary end-use, natural-gas dehydration, accounts for 49% of triethylene glycol demand, and has the more moderate demand elasticity. Also, imports appear to be insignificant. A demand elasticity of moderately inelastic, or -.34 to -.67, is deemed to cover the range of triethylene glycol elasticity.

17.2.4 Market Structure

Table 17-8 summarizes the parameters for the market structure of triethylene glycol. Nine firms are currently producing triethylene glycol. The four-firm concentration ratio is 79.3 percent, signifying moderate to substantial market power. The HHI is 2,045.6, which falls in the range of substantial market power. Captive consumption is five percent, indicating a slight level of vertical integration. On average, six chemical compounds are produced at triethylene glycol sites, suggesting a substantial level of horizontal integration. Imports in the industry are insignificant. In summary, the market structure of the triethylene glycol industry is highly oligopolistic, and firms are likely to absorb a significant portion of HON compliance costs.

17.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the ethylene glycol industry for option one control costs are presented in Table 17-9.

TABLE 17-8. MARKET STRUCTURE CHARACTERISTICS FOR TRIETHYLENE GLYCOL

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced At Same Site (Horizontal Integration)	Imports
9	79.3	2,045.6	5%	6	Insignificant

N.A. - Not Available

[a] Herfindahl-Hirschman Index

TABLE 17-9. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE TRIETHYLENE GLYCOL INDUSTRY[1], OPTION ONE CONTROL COSTS

	Elasticity	
	-0.34	-0.67
%Δ Price (%/kg)	0.11%	0.11%
Δ Price ($/kg)	$.0014	$.0014
%Δ Output (%/kg)	(0.04%)	(0.07%)
Δ Output (10^6 kg)	(.025)	(.050)
%Δ Total Revenue	0.07%	0.04%
Δ Total Revenue (10^6 $)	$.065	$.033
Δ Employment (# of Employees)	0	0

[1] Based on Production Weighted Average Cost

DEFINITIONS:

Δ = Change In

Market Price = $1.33/kg

1995 Output = 68.57 x 10^6 kg (based on 1989 production at 2 percent annual compound growth)

1995 Total Revenue = $91,201,398.63 (market price x 1995 output)

1995 Employment = 249

17.2.5.1 Option One Control Costs

Option one control costs represent the estimated actual HON control cost that an industry will incur. The weighted average percentage price increase of .11 percent leads to a price increase $.0014 per kilogram. For the two elasticity levels of - .34 and -.67, the decrease in output is 25 thousand kilograms (.04%) and 50 thousand kilograms (.07%), respectively.

Facility 11A, which is both the highest cost and the smallest plant in the industry, accounts for 1.97 million kilograms of industry production. If this facility absorbs the entire output loss, it would lose from 1.3 percent to 2.5 percent of its production. No employment loss is projected. It is unlikely that HON controls would lead to closure given triethylene glycol costs alone, as it is a coproduct of the lower glycols, which account for a much larger share of plant production. The impact of option one controls on triethylene glycol facilities is negligible.

17.2.6 Conclusion

The range of control costs are from $.0011 per kilogram to $.0027 per kilogram. The differential is small, and the production-weighted average price increase is probably an accurate estimate of the actual price increase. Triethylene glycol is a small volume chemical, produced as a coproduct of the lower glycols. HON impacts on this chemical must be looked at in tandem with controls on the other glycols. Impacts for triethylene glycol alone are negligible.

17.2.7 References

1. U.S. International Trade Commission. <u>Synthetic Organic Chemicals -- United States Production and Sales, 1989</u>, Washington, DC, December 1990, p. 15-7.
2. "Chemical Profile -- Triethylene Glycol." <u>Chemical Marketing Reporter</u>, February 5, 1990.
3. Mannsville Chemical Products Corp. "Chemical Products Synopsis -- Triethylene Glycol." Asbury Park, NJ, January 1989.
4. Reference 3.
5. Reference 3.
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7. U.S. International Trade Commission. <u>Synthetic Organic Chemicals -- United States Production and Sales, 1988</u>, Washington, DC, September 1989, p. 15-8.

8. Reference 1.

9. <u>Chemical Marketing Reporter</u>, January 8, 1990, p. 34.

10. <u>Chemical Marketing Reporter</u>, December 31, 1990, p. 32.

11. <u>Chemical Marketing Reporter</u>, February 18, 1991, p. 40.

12. Reference 3.

13. Reference 3.

14. "Chemical Profile -- Triethylene Glycol." <u>Chemical Marketing Reporter</u>, March 30, 1987.

15. Reference 2.

16. U.S. Department of Commerce, International Trade Administration. <u>U.S. Industrial Outlook</u>, 1991, Washington, DC, pp. 3-1 to 3-4.

17. Phone conversation, February 28, 1991, between A.K. Jenkins (JACA Corp.) and National Energy Information Center, Energy Information Administration.

18. Standard & Poor's Corp. <u>Industry Surveys</u>. "Chemicals -- Basic Analysis." New York, NY, November 2, 1989, p. C30.

19. Reference 14.

20. Reference 2.

21. Reference 2.

22. Reference 3.

23. Reference 2.

24. Reference 3.

25. Reference 3.

26. Reference 3.

27. U.S. International Trade Commission, <u>Synthetic Organic Chemicals -- United States Production and Sales, 1986</u>, Washington, DC, September 1987, p. 212.

28. Reference 2.

29. <u>Chemical Marketing Reporter</u>, January 8, 1990, p. 29.

30. <u>Chemical Marketing Reporter</u>, February 25, 1991, p. 31.

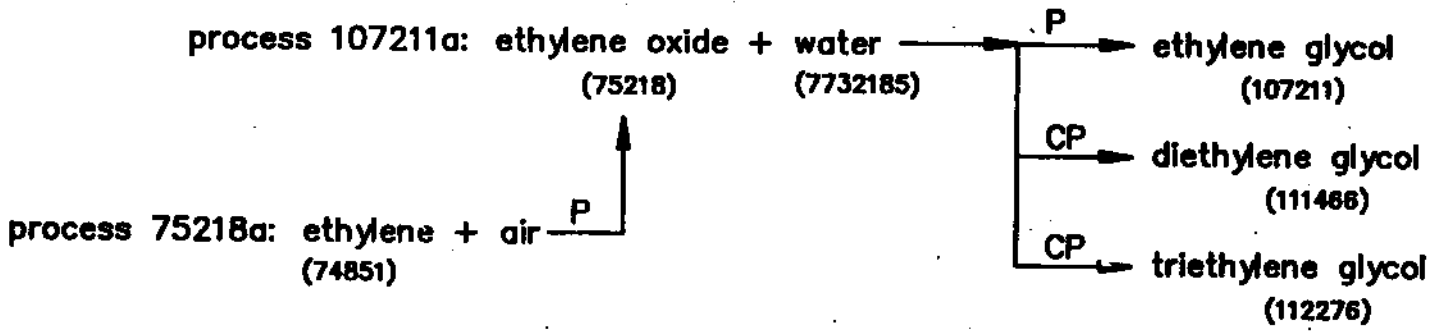
31. Reference 2.

32. "Chemical Profile -- Ethylene Glycol." <u>Chemical Marketing Reporter</u>, January 22, 1990.

33. Reference 2.

FIGURE 17-2
CHEMICAL TREE

TRIETHYLENE GLYCOL



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 18

BISPHENOL-A PRODUCTION

18.1 INDUSTRY PROFILE

Bisphenol-A (BPA), also referred to as 4',4'-isopropylidene-diphenol, is produced by the condensation of phenol and acetone. It is the primary raw material in the production of polycarbonate resins and epoxy resins. Only 32 percent of 1989 domestic production was sold on the merchant market.[1]

18.1.1 Brief Market Introduction

18.1.1.1 Historical Overview

Two commercial grades of bisphenol-A are sold, polycarbonate-grade and epoxy-grade. Most BPA sales are made at negotiated prices.[2] Because the majority of polycarbonate-grade BPA is consumed captively, it is difficult to determine its average realized price.[3]

Table 18-1 does list the historical average realized price for epoxy-grade BPA. From 1986 to 1989 price steadily increased to a ten-year high of $1.22 per kilogram in 1989. Epoxy-grade BPA prices were driven by increased epoxy resin consumption; during the time period, consumption grew at a 6 to 7 percent compounded rate.[4]

Though pricing data are unavailable for the polycarbonate-grade BPA, it is likely that average realized value also rose from 1986 to 1989. This is suggested by the fact that polycarbonate resin demand in the late 1980s experienced growth of 8 to 10 percent annually.[5]

Comparing the two BPA grades, producers consider the polycarbonate-grade to be more value-added.[6] The polycarbonate resin market is larger and less mature than the epoxy resin market.[7] In 1989, the list price for polycarbonate-grade BPA was nine cents per kilogram higher than the epoxy-grade BPA list price.[8]

18.1.1.2 Recent Developments

In January 1990, the list price of epoxy-grade BPA ranged from $1.92 to $2.07 per kilogram, while polycarbonate-grade BPA ranged from $2.00 to $2.16 per kilogram.[9,10] These same ranges applied in July and December 1990, and March 1991.[11,12,13]

TABLE 18-1. AVERAGE REALIZED PRICE OF BISPHENOL-A (EPOXY-GRADE), 1980-1989

	Price ($/kg)
1989	1.22
1988	1.21
1987	1.08
1986	0.95
1985	1.06
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	1.06

N.A. - Not available.

NOTE: Average realized price for polycarbonate-grade BPA is unavailable. Most polycarbonate-grade is consumed captively; thus, values are difficult to determine. However, according to Mannsville Chemical Products Corp., the list price for polycarbonate-grade in 1989 was almost 9 cents per kilogram higher than the list price for epoxy-grade BPA.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Bisphenol-A," August 1990; U.S. International Trade Commission, <u>Synthetic Organic Chemicals</u>, 1988, 1989.

18.1.2 Demand Conditions

18.1.2.1 Uses for Bisphenol-A

BPA derivatives are used in a variety of industries including automotive, housing, aircraft, appliances, and electronics. Table 18-2 lists the uses of BPA and their percentage of total consumption. Accounting for 61 percent of BPA consumption is the manufacture of polycarbonate (PC) resins. These resins are made by reacting BPA with phosgene. Besides being the largest volume BPA derivative, PC resins are the largest volume engineering plastic.[14] Engineering plastics are used, in part, as metal replacements in autos, appliances, and electronics. Polycarbonates are also used in high-performance moldings and shatterproof window glazing. PC resins are used heavily in the automotive and construction industries.[15] Also used heavily in the automotive and construction industries are epoxy resins.[16] These resins are produced by reacting BPA and epichlorohydrin. The biggest uses of epoxy resins are in protective coatings, adhesives, and plastics. The resins also are used in laminating printed circuit boards and for encapsulating electrical devices.

Miscellaneous derivatives of BPA include tetrabromobisphenol-A, bisphenol-A-formaldehyde resins, polysulfone resins, and polyarylate resins. Tetrabromobisphenol-A is a flame retardant. Bisphenol-A-formaldehyde resins are used in specialty applications, such as inks, coatings, varnishes, and abrasive binders.

18.1.2.2 Consumption

Table 18-3 lists domestic apparent consumption of BPA from 1980 to 1989. Consumption increased 308 million kilograms from 1980 to 1989. A significant part of this growth occurred from 1986 to 1988; consumption of BPA went from 398 million kilograms to a decade-high 563 million kilograms. Increased BPA consumption during this period was driven by increased demand for PC resins and epoxy resins. As previously mentioned, in the late 1980s PC resins experienced demand growth in the range of 8 to 10 percent annually. From 1986 to 1989 epoxy resin consumption grew 6 to 7 percent annually. BPA consumption dipped by 33 million kilograms in 1989; at the end of the year demand for BPA derivatives began to slump due in part to the slump in the automotive and construction industries.[17]

TABLE 18-2. USES OF BISPHENOL-A, 1990

	Percent of Total Consumption
Polycarbonate resins	61%
Epoxy resins	28%
Miscellaneous[a]	11%

[a] Includes tetrabromobiosphenol-A, polysulfone resins, polyarylate resins, and bisphenol-A-formaldehyde resins.

Source: Chemical Marketing Reporter, September 24, 1990, p. 54.

TABLE 18-3. APPARENT CONSUMPTION OF BISPHENOL-A IN THE U.S., 1980-1989

	Apparent Consumption[a] (10^6 kg)
1989	530
1988	563
1987	404
1986	398
1985	402
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	222

[a] Production plus imports, minus exports. Because inventory changes are ignored, this is a simplified estimate of consumption.

N.A. - Not available.

Sources: Chemical & Engineering News, June 18, 1990, p. 39; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Bisphenol-A," August 1990; U.S. International Trade Commission, Synthetic Organic Chemicals, 1989.

18.1.2.3 Exports

U.S. exports of BPA from 1980 to 1989 are listed in Table 18-4. Exports reached a high of 50.8 million kilograms in 1987, accounting for 11.2 percent of production. The steep increase in exports from 1986 to 1987 (+ 42%) resulted from a weakening U.S. dollar.[18]

18.1.2.4 Future Prospects

BPA demand growth is dependent on its two main derivatives (PC and epoxy resins) which account for 89 percent of BPA consumption.[19] In turn, polycarbonate resins and epoxy resins are partly dependent on the automobile and housing industries.[20] With the recent slump in these sectors, PC and epoxy resin growth has slowed.

In spite of this downturn, growth is expected to pick up. Chemical Marketing Reporter has characterized the BPA market as being "fundamentally strong."[21] After the 1990 downturn, PC resins are forecast to grow 5 to 8 percent annually through the 1990s.[22] Epoxy resins have limited future growth opportunities in protective coatings and adhesives, but good growth opportunites in electrical/electronic applications.[23] They are forecast to grow 3 to 5 percent annually through 1995.[24] Overall, BPA consumption is forecast to increase 5 percent annually over the next five years.[25]

Exports will decrease as more BPA capacity is installed overseas, especially in Japan and Europe.[26]

18.1.3 Supply Conditions

18.1.3.1 Production Processes

BPA is produced via the condensation of phenol and acetone. Phenol and acetone are used in approximately a two to one mole ratio.[27] Though BPA plants are relatively simple, the production process is delicate because a number of impurities are formed.[28] Epoxy resins can be manufactured despite these impurities. However, the crude BPA must be purified for use in PC resin production. In early batch processes, purification was achieved using a high-cost crystallization process. The cost of purification has been reduced with the advent of newer processes which use distillation and extractive crystallization under pressure.

18.1.3.2 Domestic Producers and Total Production

BPA is manufactured domestically by four producers. Table 18-5 details the four by plant location and capacity. Total industry capacity is 607 million kilograms. All four BPA producers also make phe-

TABLE 18-4. U.S. EXPORTS OF BISPHENOL-A, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1989	43.1	7.7%
1988	46.7	7.7%
1987	50.8	11.2%
1986	35.8	8.2%
1985	28.1	6.5%
1984	N.A.	N.A.
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	18.1 (est.)	7.5%

[a] See Table 18-6.

N.A. - Not available.

est. - Estimate.

Source: Mannsville Chemical Products Corp. "Chemical Products Synopsis -- Bisphenol-A." August 1990.

TABLE 18-5. U.S. PRODUCERS OF BISPHENOL-A, 1990

Company	Location	Capacity (10^6 kg/yr)
Aristech	Haverhill, OH	103
Dow	Freeport, TX	102
General Electric[a]	Burkeville, AL[b]	75
	Mt. Vernon, IN	168
Shell	Deer Park, TX	159
		607

[a] GE's entire production is captively consumed.

[b] This facility was not due to start producing until 1991.

Source: Chemical Marketing Reporter, September 24, 1990.

nol and acetone, the two BPA feedstocks.[29,30]

Total U.S. production for the decade is reported in Table 18-6. Production increased almost steadily from 1980 to 1988, then dropped in 1989 as BPA derivative demand dropped in the latter part of the year. The largest production total, 608 million kilograms, occurred in 1988.

According to Chemical Marketing Reporter, capacity utilization in 1989 was almost 100 percent.[31]

18.1.3.3 Costs of Production

BPA's primary sources of production costs are the two feedstocks, acetone and phenol.

Acetone's trade list price has gone from 64 cents per kilogram in January 1990 to 80 cents per kilogram in March 1991.[32,33] In 1990, acetone supplies were considered to be "very tight."[34] However, acetone demand should be supplied by imports, inventories, and on-purpose production. BPA accounts for 14 percent of acetone consumption.[35]

The price of phenol decreased from 95 cents per kilogram in January 1990 to 72 cents in March 1991.[36,37] Phenol is currently in oversupply. This is expected to correct itself when derivatives such as BPA experience increased growth.[38] BPA is the second leading derivative of phenol, accounting for 30 percent of phenol consumption.[39] Mannsville Chemical Products Corporation is of the opinion that U.S. producers of phenol would probably give preference to higher-value-added derivatives such as BPA in the event of a phenol shortage.[40]

18.1.3.4 Imports

Table 18-7 lists imports. Prior to 1987, imports were less than 227,000 kilograms (less than 1% of consumption) and considered negligible.[41] There was an 8.6 million kilogram increase in imports from 1988 to 1989. The reason for this increase is unknown.

18.1.3.5 Future Prospects

The U.S. BPA market is in a temporary state of overcapacity due to slumping demand in 1990. General Electric had already completed its Burkeville, AL plant in early 1990, but with the demand slump for

TABLE 18-6. U.S. PRODUCTION OF BISPHENOL-A, 1980-1989

	Quantity (10^6 kg)
1989	563
1988	608
1987	454
1986	434
1985	430
1984	346
1983	292
1982	218
1981	252
1980	240

Sources: Chemical & Engineering News, June 18, 1990, p. 39; U.S. International Trade Commission, Synthetic Organic Chemicals, 1989.

TABLE 18-7. U.S. IMPORTS OF BISPHENOL-A, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Consumption[a]
1989	10.4	2.0%
1988	1.8	0.3%
1987	0.9	0.2%
1986	Neg.	Neg.
1985	Neg.	Neg.
1984	Neg.	Neg.
1983	Neg.	Neg.
1982	Neg.	Neg.
1981	Neg.	Neg.
1980	Neg.	Neg.

[a] See Table 18-3.

Neg. - Negligible. According to Mannsville Chemical Products Corp., imports of BPA prior to 1987 were less than 227,000 kilograms (1% of consumption).

Source: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Bisphenol-A," August 1990.

PC resins, has not yet used the plant for production.[42] Shell was scheduled to expand capacity by 57 million kilograms in late 1990.[43] This overcapacity will be reduced once the growth for PC and epoxy resins picks up.

While acetone is in tight supply, phenol is in a temporary state of overcapacity. These two chemicals, especially phenol, depend on BPA growth. However, BPA must also compete against larger end uses of acetone and phenol (for example, acetone's derivative methyl methacrylate).

18.1.4 Future Market Prospects

BPA demand growth will continue to depend on the growth of its two primary derivatives, polycarbonate resins and epoxy resins. After a downturn in 1990, overall BPA consumption is forecast to increase 5 percent annually over the next five years.

Currently, the BPA market is experiencing overcapacity, the result of a 1990 demand slump and various capacity expansions. However, as BPA demand picks up this situation is expected to correct itself. BPA will continue to depend on the costs of its feedstocks, acetone and phenol. But due to its higher value-added, BPA will have priority over other phenol derivatives.[44]

18.2 ECONOMIC IMPACT ANALYSIS

18.2.1 HON Compliance Costs

A synopsis of annualized compliance costs and summary statistics for bisphenol-A is presented in Table 18-8. Costs are displayed for option one controls. Option one controls are the actual estimated costs that facilities are likely to incur. Figure 18-1 illustrates control costs graphically. Four facilities are displayed.

Bisphenol-A is currently being produced via condensation of phenol and acetone. Since this is the only commercial process, no analysis of separate process costs is necessary.

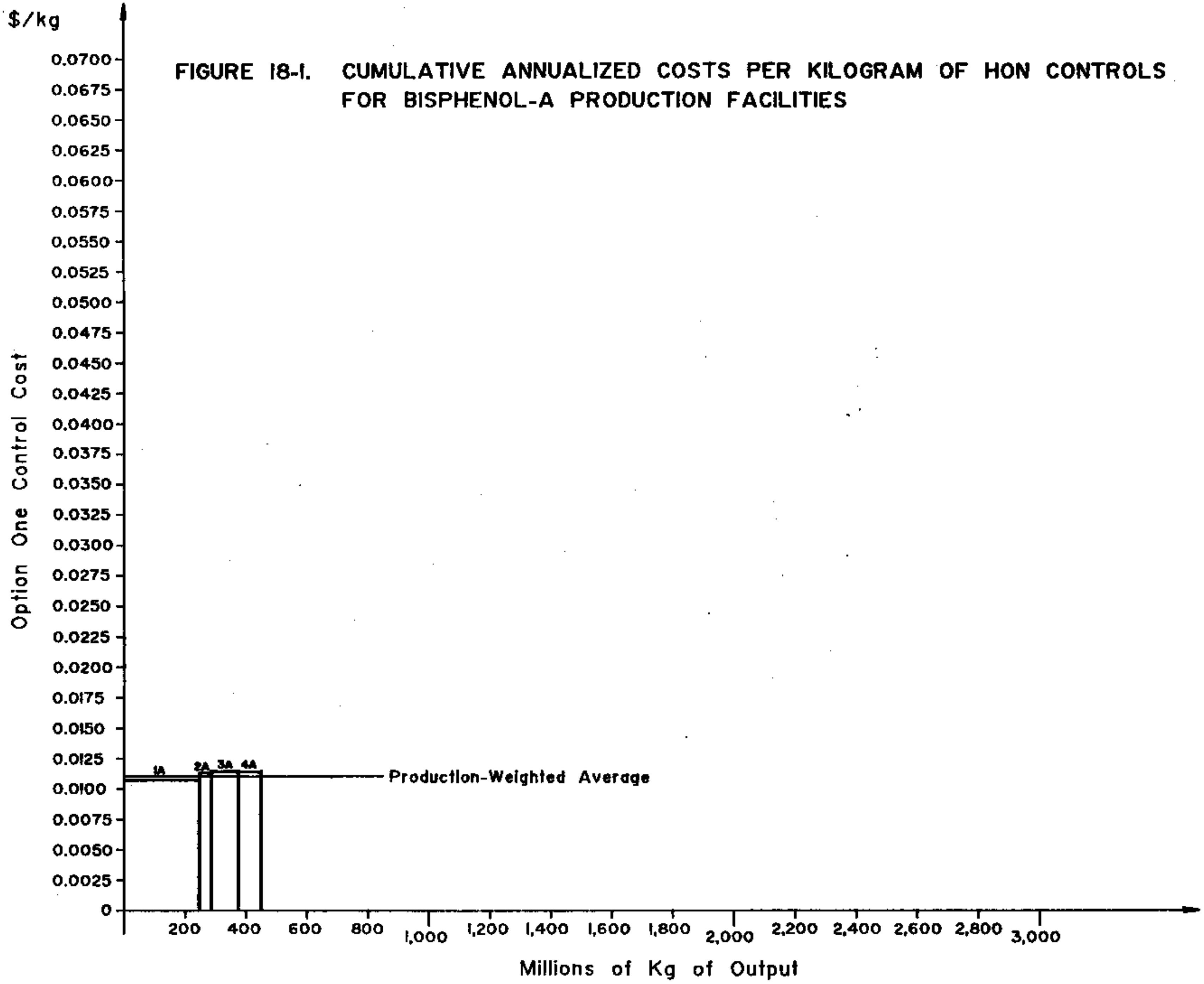
18.2.2 Pricing

Sixty-eight percent of bisphenol-A is consumed captively. Merchant-market sales of Bisphenol are large volume, and negotiated on a sale by sale basis. Phenol and acetone costs influence Bisphenol-A pricing. Phenol has been experiencing weak demand, effectively dragging down phenol prices. As, phenol softens, less is produced. Acetone, a coproduct of phenol, experiences tightened supply, and prices firm up. These pricing trends might counter each other.

TABLE 18-8. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR BISPHENOL-A PRODUCTION FACILITIES AND BISPHENOL-A PRODUCTION PROCESSES

Facility/ Process	Annual Production (10^6 kg)	Option One Controls ($/kg)
1A	147.8	$0.0107
2A	139.9	$0.0113
3A	89.8	$0.0114
4A	76.6	$0.0114
<u>Summary Statistics</u>		
Mean		$0.0112
Production Weighted Average		$0.0111

FIGURE 18-1. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR BISPHENOL-A PRODUCTION FACILITIES



End-use demand for Bisphenol-A, projected to grow at 5 to 8 percent annually, could put upward pressure on prices.

18.2.3 Elasticities

Demand elasticities for bisphenol-A will be estimated on the basis of available substitutes for bisphenol-A, as well as substitutes for end-uses. The potential for import substitution is also examined.

18.2.3.1 Demand Elasticities

18.2.3.1.1 Polycarbonate Resins

Polycarbonate resins make up 61 percent of Bisphenol-A demand. These engineering resins are currently produced with Bisphenol-A as a principle ingredient. Other methods have been explored, but the Bisphenol-A route is the only one which is commercially viable. Polycarbonates themselves have end-use substitutes, including methyl methacrylates, nylon resins, acetal resins, and others. In this sector, Bisphenol-A is considered moderately inelastic.

18.2.3.1.2 Epoxy Resins

Epoxy resins, which account for 28 percent of Bisphenol-A demand, are dependent on Bisphenol-A as an input. Epoxy resins themselves have quite a few substitutes, including a variety of other plastics, as well as glues. The derived demand for Bisphenol-A as used for epoxy resins is deemed slightly inelastic.

18.2.3.2 Imports

Recently, imports of bisphenol-A have been gaining in importance, growing from .3 percent of U.S. consumption in 1988, to 2.0 percent of U.S. consumption in 1989. While still a relatively small percentage, the trend could signify increases in the future. If this is the case, U.S. producers might have to consider import substitution as a factor when pricing Bisphenol-A.

18.2.3.3 Elasticity Estimate

The demand elasticity for Bisphenol-A within the two end-use sectors ranges from slightly inelastic to moderately inelastic. Given the importance of polycarbonates in end-uses, demand for Bisphenol-A is estimated to be in the moderately inelastic range of -.34 to -.67.

18.2.4 Market Structure

Table 18-9 summarizes the parameters for the market structure of bisphenol-A. Four firms are currently producing bisphenol-A. Thus, the level of verticle integration. On average, 8 chemical compounds are produced at bisphenol-A sites, suggesting a substantial level of horizontal intergration. Imports in the industry are slightly important, and will have minimal effect on bisphenol-A. In summary, the market structure pricing for bisphenol-A is highly oligopolistic, and firms will likely absorb a significant share of HON control costs.

18.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the bisphenol-A industry for option one control costs are presented in Table 18-10.

18.2.5.1 Option One Control Costs

Option one control costs represent the actual estimated cost that an industry will incur. The production weighted average percentage price increase of .56 percent leads to a price increase $.0111 per kilogram. For the two elasticity levels of -.34 and -.67, the output reduction is 1.2 million kilograms (0.19%) and 2.3 million kilograms (0.38%), respectively.

The maximum decline in output of 2.3 million kilograms makes up 1.3 percent of the output of the Facility 4A, which is both the smallest facility and the facility with the highest compliance cost. The loss in employment is estimated to be from 6 to 12 employees. Thus, HON controls will have a minimal impact on the bisphenol-A industry.

18.2.6 Conclusion

The range of costs in the total industry control scenario is $.0176 to $.0185. The differential is small, indicating that the production-weighted average cost is a reasonable estimate of the cost burden of each facility. Since, 68 perecnt of bisphenol-A is consumed captively, price changes are likely to be felt in end-use markets. The impact of HON controls in the bisphenol-A industry will be negligible.

TABLE 18-9. MARKET STRUCTURE CHARACTERISTICS FOR BISPHENOL-A

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced at Site (Horizontal Integration)	Imports
4	100%	5,515.0	68%	8	Slightly Important

[a] Herfindahl-Hirschman Index

TABLE 18-10. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE BISPHENOL-A INDUSTRY[1], OPTION ONE CONTROL COSTS

	Elasticity	
	-0.34	-0.67
%Δ Price (%/kg)	0.56%	0.56%
Δ Price ($/kg)	$.0111	$.0111
%Δ Output (%/kg)	(0.19%)	(0.38%)
Δ Output (10^6 kg)	(1.2)	(2.3)
%Δ Total Revenue	0.37%	0.19%
Δ Total Revenue (10^6 $)	$4.5	$2.2
Δ Employment (# of Employees)	(6)	(12)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

Δ = Change In

Market Price = $1.98/kg

1995 Output = 608.5 x 10^6 kg (based on 1989 production at 5% annual compound growth)

1995 Total Revenue = $1,204,851,044.42 (market price x 1995 output)

1995 Employment = 3,283

18.2.7 References

1. U.S. International Trade Commission. Synthetic Organic Chemicals -- United States Production and Sales, 1989, Washington, DC, December 1990, p. 3-2.
2. Mannsville Chemical Products Corp. "Chemical Products Synopsis -- Bisphenol-A." Asbury Park, NJ, August 1990.
3. Phone conversation, March 15, 1991, between A.K. Jenkins (JACA Corp.) and Doug Lumley, Representative, Mannsville Chemical Products Corp.
4. Reference 2.
5. Reference 2.
6. "BPA Producers See Capacity Loosening." Chemical Marketing Reporter, February 27, 1989, pp. 5, 11.
7. Reference 6.
8. Reference 2.
9. Chemical Marketing Reporter, January 8, 1990, p. 27.
10. Reference 9.
11. Chemical Marketing Reporter, July 9, 1990, p. 31.
12. Chemical Marketing Reporter, December 31, 1990, p. 25.
13. Chemical Marketing Reporter, March 11, 1991, p. 33.
14. Reference 2.
15. "Chemical Profile -- Bisphenol-A." Chemical Marketing Reporter, September 24, 1990.
16. Reference 15.
17. Reference 15.
18. Reference 2.
19. Reference 15.
20. Reference 15.
21. Reference 15.
22. Reference 2.
23. Reference 2.
24. Reference 2.
25. Reference 2.
26. Reference 2.
27. Reference 2.

28. Reference 2.

29. "Chemical Profile -- Phenol." Chemical Marketing Reporter, August 6, 1990.

30. "Chemical Profile -- Acetone." Chemical Marketing Reporter, July 30, 1990.

31. Reference 15.

32. Chemical Marketing Reporter, January 8, 1990, p. 26.

33. Chemical Marketing Reporter, March 11, 1991, p. 32.

34. Reference 30.

35. Reference 30.

36. Chemical Marketing Reporter, January 8, 1990, p. 32.

37. Chemical Marketing Reporter, March 11, 1991, p. 38.

38. Reference 29.

39. Reference 29.

40. Reference 2.

41. Reference 2.

42. Reference 15.

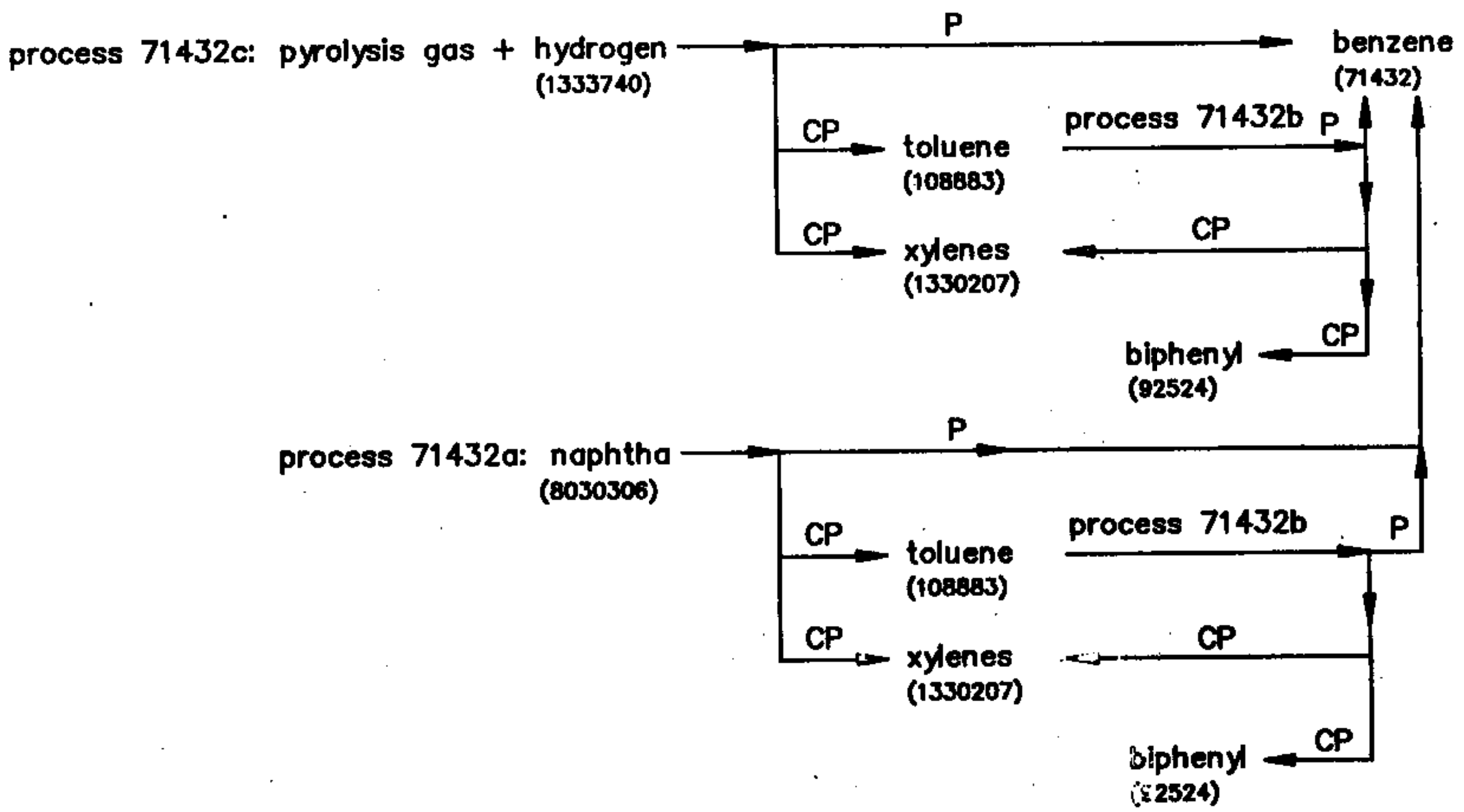
43. Reference 15.

44. Reference 2.

FIGURE 18-2

CHEMICAL TREE

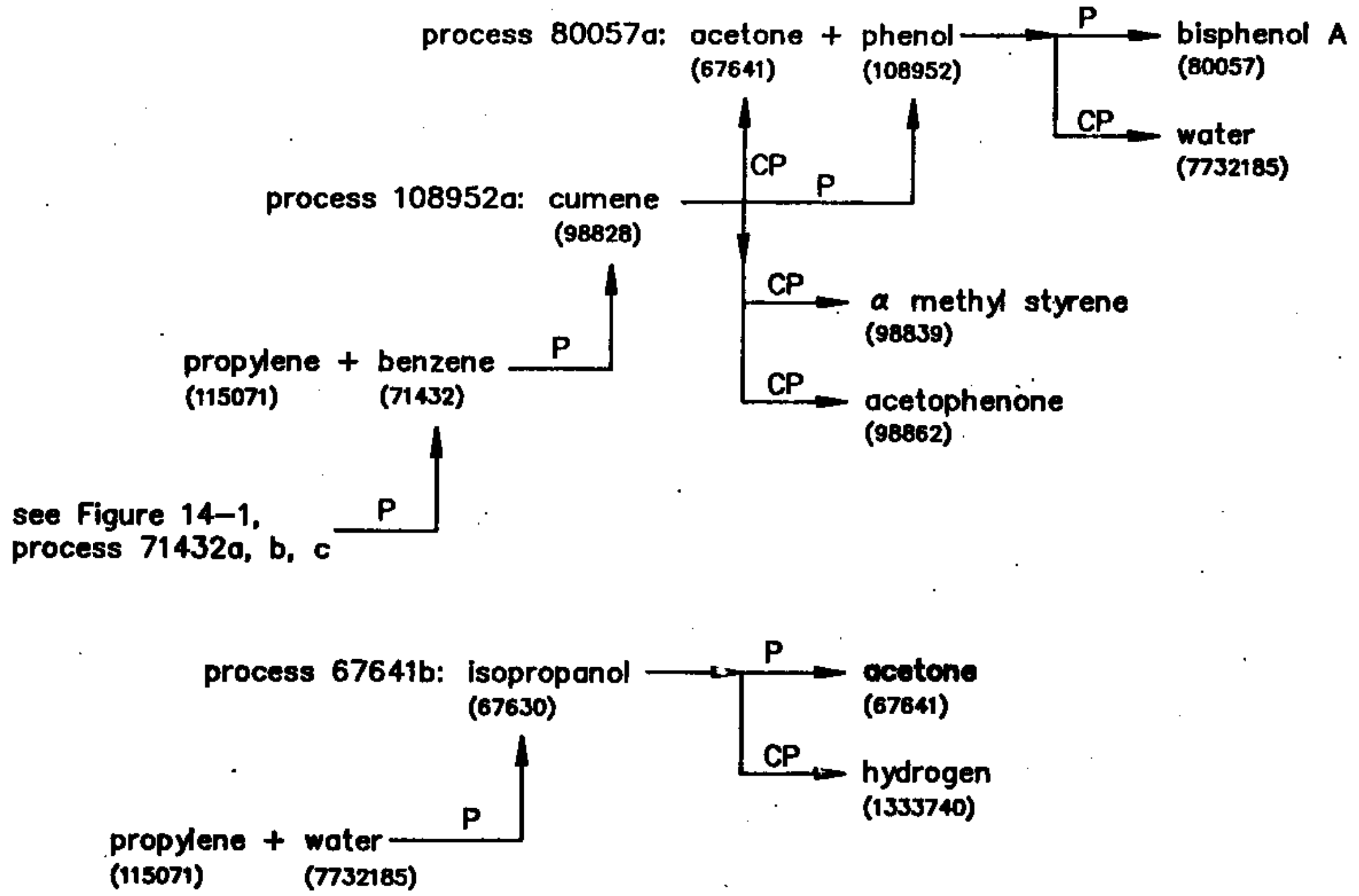
BENZENE



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

FIGURE 18-3
CHEMICAL TREE
BISPHENOL A



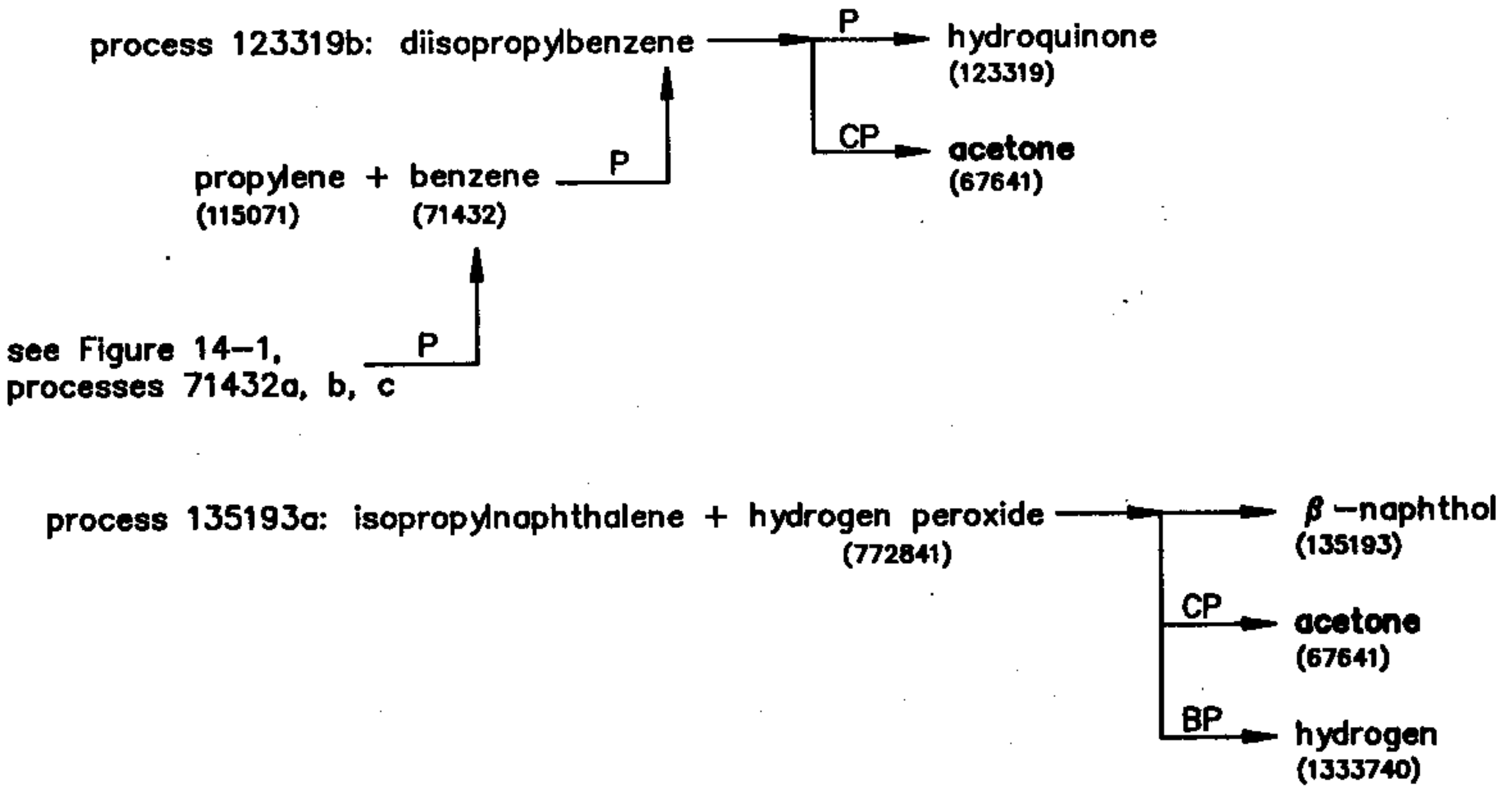
NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

FIGURE 18-3 (CONT.)

CHEMICAL TREE

BISPHENOL A



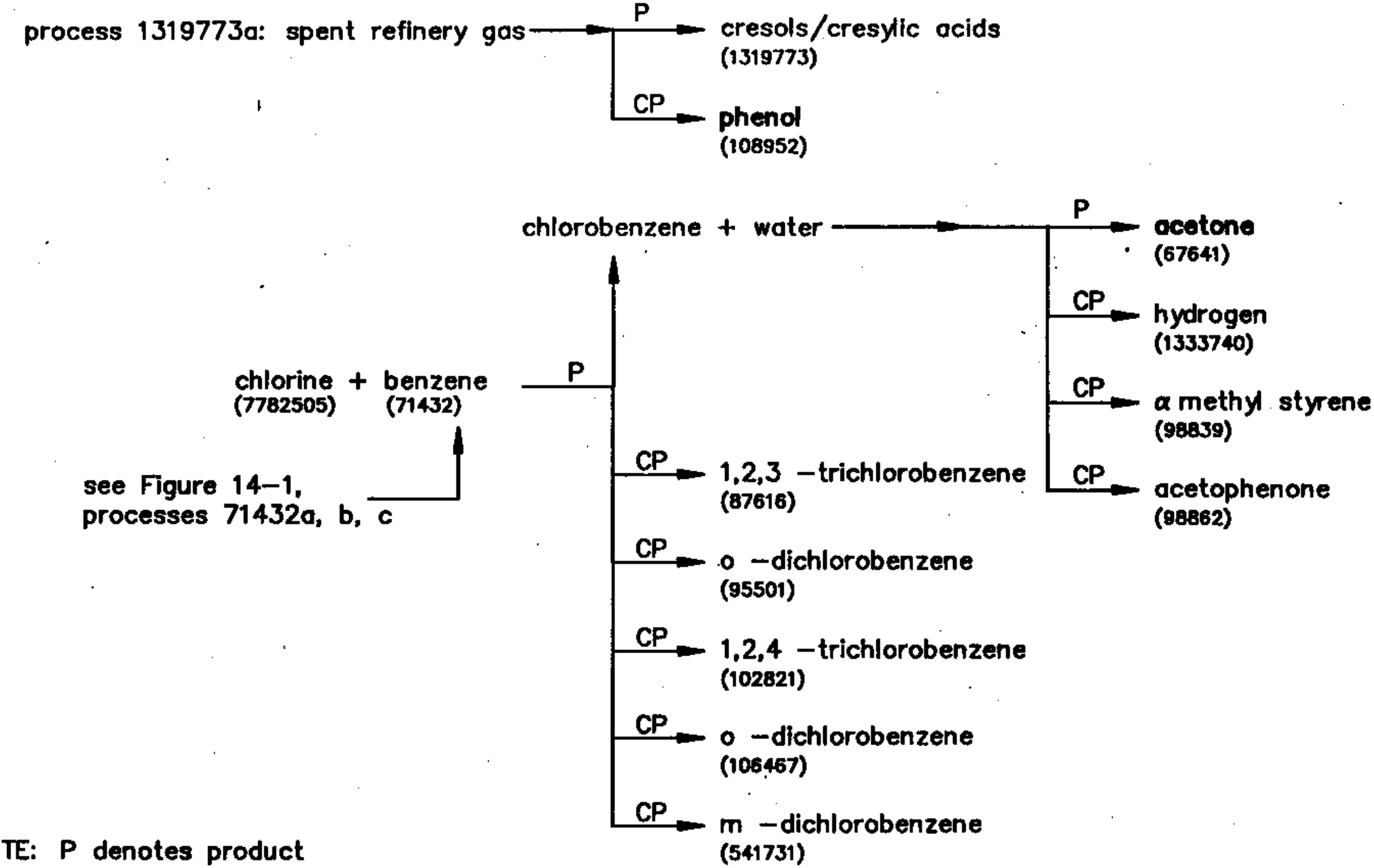
NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

FIGURE 18-4 (CONT.)

CHEMICAL TREE

BISPHENOL A



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 19

TEREPHTHALIC ACID/DIMETHYL TEREPHTHALATE PRODUCTION

19.1 INDUSTRY PROFILE

Terephthalic acid (TPA) is categorized as an aromatic acid. It is sold as a free acid or as an ester, dimethyl terephthalate (DMT). TPA and DMT are two separate chemicals, both of which are polyester's two major aromatic feedstocks.[1] The U.S. International Trade Commission, which reports domestic production and sales data for organic chemicals, groups TPA and DMT together. Consequently, every table, except Table 19-1, in this profile concerns both chemicals.

19.1.1 Brief Market Introduction

19.1.1.1 Historical Overview

TPA pricing is based on a formula developed by Amoco Chemical Company, the world leader in TPA capacity.[2] The formula calculates price based on paraxylene costs, labor costs, oil costs, and the wholesale price index.[3] The price of DMT, in turn, is stoichiometrically based on the price of TPA.[4] TPA trade list prices from 1980 to 1989 are listed in Table 19-1. The price rose from 1986 to 1988 as consumption of TPA and DMT increased. It is not known whether TPA or DMT are discounted.

19.1.1.2 Recent Developments

TPA was priced at 67 cents per kilogram and DMT at 61 cents per kilogram in the first quarter of 1990.[5] As a point of reference, paraxylene was 56 cents per kilogram.[6] In the second quarter, paraxylene fell from 56 cents to 51 cents per kilogram, pushing TPA down to 62 cents and DMT to 58 cents.[7]

19.1.2 Demand Conditions

19.1.2.1 Uses for Terephthalic Acid/Dimethyl Terephthalate

Table 19-2 details the various end uses of TPA and DMT. The manufacture of polyester fibers is the dominant end use accounting for 63 percent of TPA/DMT consumption. Either TPA or DMT can be used as a polyester raw material, though the two are not interchangeable in the same facility.[8] Apparel and home furnishings are the primary outlets of polyester fibers.[9] They are also used in tire cord and other industrial products. Polyester is the leading man-made fiber.[10]

TABLE 19-1. TRADE LIST PRICE OF TEREPHTHALIC ACID, 1980-1989

	Price (¢/kg)
1989	68 (est.)
1988	61
1987	59
1986	58
1985	67
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	79

N.A. - Not available.

est. - Estimate

Source: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Terephthalic Acid," June 1990.

TABLE 19-2. USES OF TEREPHTHALIC ACID AND DIMETHYL TEREPHTHALATE, 1990

	Percent of Total Consumption
Polyester fibers	63%
PET bottles and plastics	19%
PET tape and films	12%
Miscellaneous[a]	6%

[a] Includes terephthalate engineering resins.

Source: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Terephthalic Acid," June 1990.

TABLE 19-3. APPARENT CONSUMPTION OF TEREPHTHALIC ACID AND DIMETHYL TEREPHTHALATE IN THE U.S., 1980-1989

	Apparent Consumption[a] (10^6 kg)
1989	3,162
1988	3,968
1987	2,813
1986	2,248
1985	2,422
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	2,565

[a] Production plus imports, minus exports. Because inventory changes are ignored, this is a simplified estimate of consumption. Because imports for terephthalic acid and dimethyl terephthalate are not significant, they are also not factored into the calculation.

N.A. - Not available.

Sources: Chemical & Engineering News, June 18, 1990, p. 39; Chemical Marketing Reporter, March 19, 1990; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Terephthalic Acid," June 1990; U.S. International Trade Commission, Synthetic Organic Chemicals, 1989.

other industrial products. Polyester is the leading man-made fiber.[10]

In 1989 an estimated 907 million kilograms of PET (polyethylene terephthalate) resins were produced.[11] Of this total approximately 60 percent was used in PET bottles, while about 40 percent was used in PET tape and film.[12] Nineteen percent of TPA/DMT consumption is used to make PET bottles, microwaveable trays, and packaging. Another 12 percent is used in PET tapes and films. PET film applications include amateur and professional photographic film, x-ray film, and microfilm. For engineering drawings, polyester film is the standard material.[13] Magnetic recording film is slit into tape form for computerized disks, as well as audio and videocassettes.

Among the miscellaneous uses of TPA and DMT are terephthalate engineering resins, including polybutylene terephthalate (PBT). PBT has important applications in molding various plastic products and specialty bottles. Also, rigid alloys of PBT are used in molding automotive body parts.

19.1.2.2 Consumption

Historical apparent consumption in the U.S. is listed in Table 19-3. From 1987 to 1988, consumption of TPA and DMT increased by 1,155 million kilograms (+41%). The 3,968 million kilograms of TPA/DMT consumed in 1988 was a ten-year high. High demand for TPA by polyester producers drove this increase.[14] The 1989 total was 806 million kilograms lower than 1988. This resulted from reduced domestic polyester fiber demand; fiber demand decreased due to a high level of textile and clothing imports.[15]

19.1.2.3 Exports

Table 19-4 contains data on U.S. exports of TPA and DMT. The largest quantity shipped abroad was in 1988, when 673.6 million kilograms were exported. This was in response to a high level of TPA demand in Far Eastern markets, which was driven by high polyester fiber demand.[16] Exports dropped by 13.3 million kilograms in 1989 as new foreign TPA/DMT capacity came on line.

19.1.2.4 Future Prospects

TPA/DMT demand in the U.S. is expected to grow two to three percent annually in the near future.[17] Long-term polyester demand is expected to be flat.[18]

Since polyester fibers account for 63 percent of TPA/DMT consumption, the slide in their growth overshadows good prospects for

TABLE 19-4. U.S. EXPORTS OF TEREPHTHALIC ACID AND DIMETHYL TEREPHTHALATE, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1989	660.3	17.3%
1988	673.6	14.5%
1987	635.0	18.4%
1986	589.7	20.8%
1985	521.6	17.7%
1984	N.A.	N.A.
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	181.4	6.6%

[a] See Table 19-6.

N.A. - Not available.

Sources: <u>Chemical Marketing Reporter</u>, March 19, 1990; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Terephthalic Acid," June 1990.

PET applications. PET bottles and plastics will experience annual growth of eight to ten percent for the next several years.[19] A more moderate rate of growth, three to four percent annually, is forecast for PET tapes and films, which are more mature.[20]

However, there are two important footnotes with respect to PET applications. First of all, PET bottles can be substituted with glass and aluminum. Soda makers, for example, have the ability to switch easily between the three.[21] If paraxylene costs rise markedly, PET bottles will ultimately become less competitive. Secondly, PET film is currently in oversupply, and is being hurt by imports from the Far East.[22]

The best growth prospects may be for terephthalate engineering resins. Though growth rates have not been forecast, these resins have been experiencing growth of six to ten percent annually.[23]

World demand for TPA is forecast to grow eight percent annually.[24] This is much greater than the U.S. growth forecast. Cumulative growth over the period is 71 percent.[25] However, world TPA capacity is expected to double in this period.[26] Because of looming worldwide overcapacity, U.S. exports are likely to decrease. Traditional importers of PET plastics, TPA/DMT, and paraxylene are building their own plants and, in many cases, integrating backward.[27]

19.1.3 Supply Conditions

19.1.3.1 Production Processes

The majority of TPA is produced by the Amoco process.[28] The process produces fiber-grade TPA by the liquid phase air oxidation of paraxylene. TPA can also be produced via hydrolysis of DMT.

The most widely used process to produce DMT involves a number of steps. Paraxylene is oxidized to p-toluic acid, which is esterified to p-methyl toluate. Subsequently, the toluate is oxidized to monomethyl TPA, which is then esterified to DMT.

19.1.3.2 Domestic Producers and Total Production

Total domestic TPA/DMT capacity in 1990 was 3,425 million kilograms (refer to Table 19-5). Producers have been increasing their emphasis on TPA over DMT.[29] Early polyester fiber plants were based on DMT because it was easier to purify.[30] However, newer processes yield purified TPA of suitable quality. Also, newer TPA processes yield more polyester than the DMT process.[31] The DMT process also produces methanol, which has to be recycled, as opposed to the TPA process which only produces water as a byproduct. These explain the

TABLE 19-5. U.S. PRODUCERS OF TEREPHTHALIC ACID AND DIMETHYL TEREPHTHALATE, 1990

Company	Location	Capacity (10^6 kg/yr)
Amoco	Decatur, AL	953
	Charleston, SC	499
Cape Industries[a]	Wilmington, NC	590
DuPont[b]	Cape Fear, NC	544
	Old Hickory, TN	227
Eastman Kodak[c]	Columbia, SC	408
	Kingsport, TN	204
		3,425

[a] Hoechst Celanese owns 74 percent of Cape Industries.

[b] DuPont is converting from DMT to TPA production for its fiber operation.

[c] Eastman is converting from DMT to TPA production.

NOTE: Only two firms supply DMT to the merchant market, Cape Industries and DuPont.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Terephthalic Acid," June 1990; Chemical Marketing Reporter, March 12, 1990, p. 11.

current conversions by DuPont and Eastman Kodak from DMT production to TPA production. Only two firms now supply DMT to the merchant market, Cape Industries and DuPont.[32] Cape Industries considered switching to TPA production but will not since its majority owner, Hoechst Celanese, is the largest DMT buyer.[33]

Table 19-6 details historical production in the U.S. The ten-year high in 1988 of 4,642 million kilograms was in response to high domestic TPA consumption by polyester fiber producers and high exports. In 1989 production dropped in response to decreased domestic demand.

19.1.3.3 Costs of Production

Paraxylene is the TPA/DMT feedstock. TPA and DMT are the only commercial outlet for paraxylene, accounting for 100 percent of consumption.[34] Compared to most petrochemicals, paraxylene prices are set infrequently, on a quarterly basis.[35] This results in less feedstock variation for TPA/DMT producers. In turn, paraxylene is dependent on the crude oil prices which affect its feedstock of mixed xylenes.[36] Between January 1990 and March 1991 the price of paraxylene decreased from 56 cents per kilogram to 49 cents per kilogram.[37,38]

19.1.3.4 Imports

According to Mannsville Chemical Products Corporation, imports of TPA and DMT are not significant.[39] However, apparel and textile imports have affected domestic polyester fiber production by promoting decreased consumption of domestically produced apparel and textiles.

19.1.3.5 Future Prospects

DMT is increasingly being phased out as new production processes make TPA more attractive. Two major producers, DuPont and Eastman Kodak, are in the midst of switching to TPA production.

Overseas, capacity additions are forecast to occur at double the TPA growth rate.[40]

A major change in paraxylene contract pricing may change TPA/DMT pricing. Paraxylene producers want to begin pricing on a monthly basis, as opposed to a quarterly basis.[41] This is because the cost of mixed xylenes, the paraxylene feedstock, rose with the increase in oil prices after the Iraqi invasion of Kuwait.[42] TPA/DMT producers are countering that this short period of volatility does not warrant a change in the way paraxylene is priced. A change in the paraxylene

TABLE 19-6. U.S. PRODUCTION OF TEREPHTHALIC ACID AND DIMETHYL TEREPHTHALATE, 1980-1989

	Quantity (10^6 kg)
1989	3,822
1988	4,642
1987	3,448
1986	2,838
1985	2,944
1984	2,682
1983	2,552
1982	2,197
1981	2,828
1980	2,746

Sources: Chemical & Engineering News, June 18, 1990, p. 39; U.S. International Trade Commission, Synthetic Organic Chemicals, 1989.

contract pricing mechanism would increase cost variability to TPA/DMT producers, but would not necessarily change the average level of feedstock costs.

Over the next several years <u>Mannsville Chemical Products Corporation</u> forecasts modest escalation in TPA/DMT prices as paraxylene costs escalate in line with crude oil prices.[43]

The future level of textile imports will affect the demand for TPA/DMT by domestic polyester fiber producers.

19.1.4 <u>Future Market Prospects</u>

TPA/DMT demand is expected to grow at a moderate rate of two to three percent due to decreased domestic polyester fiber demand. PET applications, especially PET bottles and plastics, will have good growth. Exports will decrease as new foreign capacity comes on line and precipitates worldwide overcapacity.

The predominant trend on the supply side is a switch among domestic producers from DMT production to TPA production. Emphasis is being placed on TPA due to a more efficient production process. Costs of production could fluctuate to a greater degree if paraxylene producers switch from quarterly pricing to monthly pricing.

19.2 ECONOMIC IMPACT ANALYSIS

19.2.1 <u>HON Compliance Costs</u>

A synopsis of annualized compliance costs and summary statistics for TPA is presented in Table 19-7. Costs are presented for option one controls. Option one controls are actual estimates of control costs that facilities are likely to incur. Figure 19-1 illustrates the same information graphically. Nine facilities are displayed.

In analyzing HON control costs for this industry, TPA and DMT are viewed as separate processes for producing the same chemical. While this is not completely accurate, all of the literature concerning this industry, as well as the U.S. International Trade Commission, groups the two together when reporting data. Therefore, discussion of TPA impacts include DMT, and production of DMT is referred to as process C. Two other processes are currently used to produce TPA: acid oxidation of paraxylene (process A), and by hydrolysis of dimethyl terephthalate (DMT) (process B). The compliance cost differential between processes is less than one cent per kilogram, and between facilities is less than one-half cent per

TABLE 19-7. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR TPA/DMT PRODUCTION FACILITIES AND TPA/DMT PRODUCTION PROCESSES

Facility/ Process	Annual Production (10^6 kg)	Option One Controls ($/kg)
1C	588.0	$0.0086
2C	194.6	$0.0087
3A	506.8	$0.0088
4A	635.0	$0.0092
5C	739.4	$0.0093
6A	166.6	$0.0093
7A	181.4	$0.0096
8A	433.8	$0.0097
9A&B	619.4	$0.0103
<u>Control Costs by Process</u>		
Process A (acid oxidation of paraxylene)	2,659.5	$0.0094
Process B (hydrolysis of dimethyl terephthalate)	116.1	$0.0138
Process C (production of DMT)	1,289.4	$0.0087
<u>Summary Statistics</u>		
Mean		$0.0093
Production Weighted Average		$0.0093

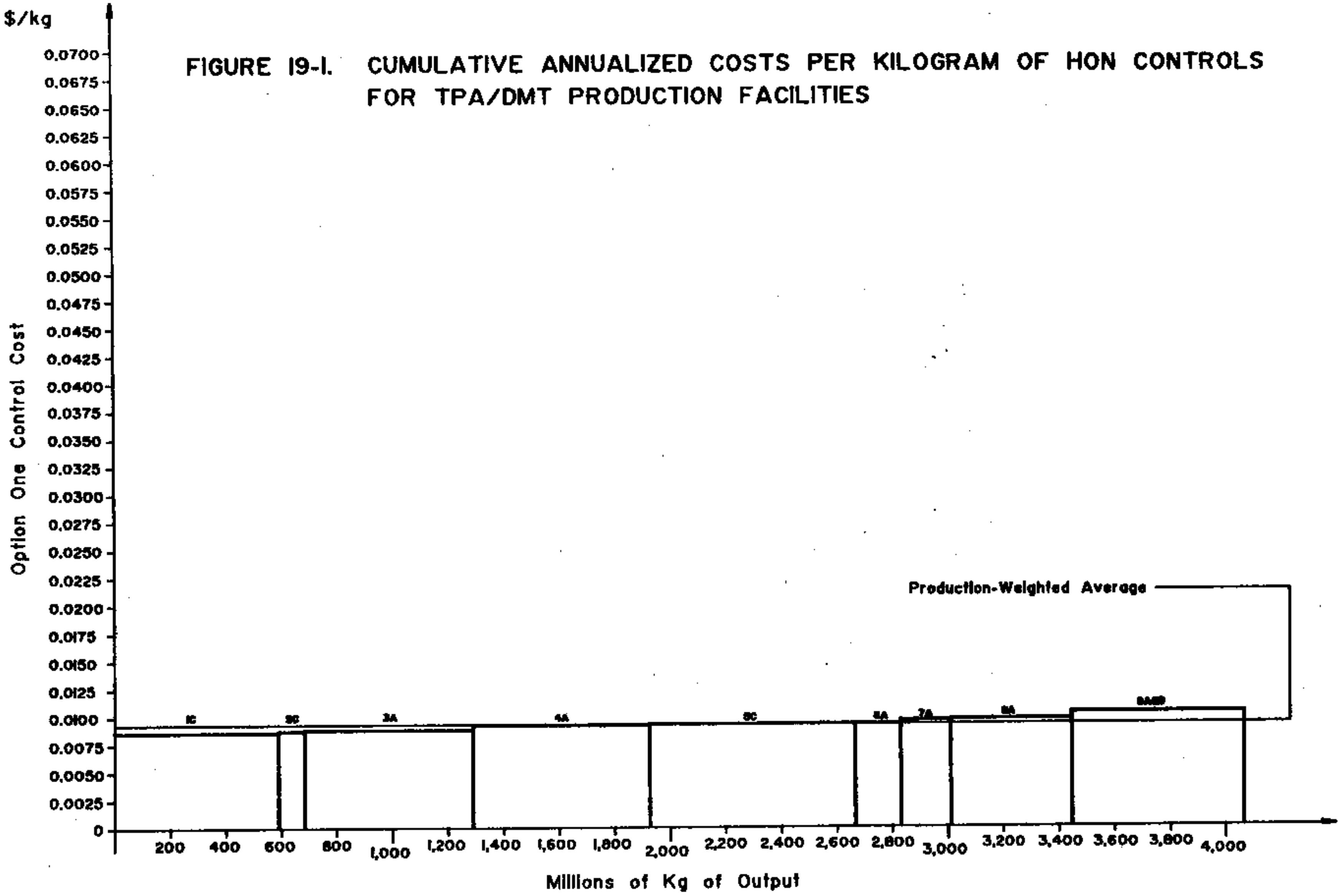


FIGURE 19-1. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR TPA/DMT PRODUCTION FACILITIES

kilogram, so the production-weighted average cost is probably an accurate measure of the actual price change in the industry.

19.2.2 Pricing

TPA and DMT prices differ slightly. The TPA price of $.72 per kilogram is used in this analysis, because it is lower than the DMT price of $.77 per kilogram, and so will not understate the impacts. Pricing is tied primarily to paraxylene costs, which are the principle feedstock, but are also based on fuel oil prices and the wholesale price index as well. End-use demand for TPA is projected to grow two to three percent annually in the near future, and probably won't increase beyond this as the polyester market is mature. Hence, prices are apt to be stable.

19.2.3 Elasticities

Demand elasticities for TPA will be estimated on the basis of available substitutes for TPA, as well as substitutes for end uses. The potential for import substitution will also be examined. Tendency for process substitution is negligible, and will not be analyzed.

19.2.3.1 Demand Elasticities

19.2.3.1.1 Polyester Fibers

Polyester fibers, accounting for 63 percent of TPA demand, appear to be highly dependent on TPA as an input. Polyester is the synthetic material used in the largest quantity by the textile industry. Moreover, the character of polyester fiber (i.e. texture, washability, durability, etc.) stems from its TPA component, in combination with the other principle input, namely ethylene glycol or a higher glycol. However, polyester fibers themselves do have substitutes, including other synthetic fibers, and natural fibers like cotton and wool. In many cases, blends of polyester and natural fibers are the textiles of choice for consumers. The demand for TPA is judged to be to moderately inelastic in this end-use sector.

19.2.3.1.2 Polyethylene Terephthalate

Polyethylene Terephthalate accounts for 31 percent of TPA demand, 19 percent allocated to bottles and plastics, and 12 percent to film and tape. Both nylon and acetal resins are possible substitutes for PET in bottle and plastic applications, but PET appears to combine the low-cost and performance attributes which make it an attractive choice. In tape and film applications, substitutes also exist, including cellophane, vinyl, and teflon. However, these substitutes also tend to have cost or performance disadvantages. The demand for TPA is regarded to be to moderately inelastic in this end-use sector.

19.2.3.2 Imports

Imports are thought to be insignificant in the TPA market, so domestic producers will not be hindered by the prospect of import substitution.

19.2.3.3 Elasticity Estimate

The demand elasticity in each sector is clearly inelastic, with imports having minimal effect, and market structure leaning towards oligopoly. Demand elasticity for TPA is estimated to be in the moderately inelastic range of -.34 to -.67.

19.2.4 Market Structure

Table 19-8 summarizes the parameters for the market structure of TPA/DMT. Four firms are currently producing TPA/DMT. Thus, the four-firm concentration ratio is 100%, signifying substantial market power. The HHI is 2,920, which falls in the range of substantial market power. On average, 2 chemical compounds are produced at TPA/DMT sites, suggesting a slight level of horizontal intergration. Imports in the industry are insignificant, and will not affect domestic pricing decisions. In summary, the TPA/DMT market is highly oligopolistic, and firms will likely absorb a significant portion of HON compliance costs.

19.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the TPA/DMT industry for option control costs are presented in Table 19-9.

19.2.5.1 Option One Control Cost

Option control cost represents the actual estimated control cost that an industry will incur. The production weighted average percentage price increase of 1.29 percent leads to a price increase $.0093 per kilogram. For the two elasticity levels of -.34 and -.67, the output reduction is 20.5 million kilograms (0.44%) and 40.4 million kilograms (.86%), respectively.

The maximum decline in output of 40.3 million kilograms makes up 24 percent of the output of the Facility 6A, which, with annual production of 166.6 million kilograms, is the smallest facility. This

TABLE 19-8. MARKET STRUCTURE CHARACTERISTICS FOR TPA/DMT

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced at Site (Horizontal Integration)	Imports
4	100%	2,920	N.A.	2	Insignificant

N.A. - Not available

[a] Herfindahl-Hirschman Index

TABLE 19-9. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE TPA/DMT INDUSTRY,[1] OPTION ONE CONTROL COSTS

	Elasticity	
	-0.34	-0.67
z%Δ Price (%/kg)	1.29%	1.29%
Δ Price ($/kg)	$0.0093	$.0093
%Δ Output (%/kg)	(0.44%)	(.86%)
Δ Output (10^6 kg)	(20.5)	(40.4)
%Δ Total Revenue	.85%	0.42%
Δ Total Revenue (10^6 $)	$28.9	$14.4
Δ Employment (# of Employees)	(41)	(80)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

Δ = Change In

Market Price = $0.72/kg

1995 Output = 4,714.1 x 10^6 kg (based on 1989 production at 2% annual compound growth)

1995 Total Revenue = $3,394,157,297.26 (market price x 1995 output)

1995 Employment = 9,248

is significant, and could lead to closure in the most extreme case where this facility absorbs the entire decline in output. Facility 9A&B is the highest cost facility, accounting for 619.4. million kilograms of industry output, and would lose 6.5 percent of its output if it had to absorb the entire decline. In this case, closure is less likely. However, the variance in cost is quite small, and the decline in output could well be shared across the industry. Employment is estimated to decline from between 41 to 80 employees.

While three processes are in use for producing TPA, the cost differential is small, and HON controls are not likely to stimulate process change.

19.2.6 Conclusion

The range of costs is $.0086 to $.0103. The differential is very small, indicating that the production-weighted average price increase is probably an accurate measure of the actual price increase that will be experienced in the industry. The differential is not enough to significantly alter the competitive balance, either between facilities, or between processes. Closure cannot be forecasted with any certainty. While DMT producers have been dwindling in numbers, HON controls will have little impact on this trend. The maximum impact could be closure of the smallest facility.

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34. Reference 27.

35. Reference 21.

36. Reference 5.

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39. Reference 5.

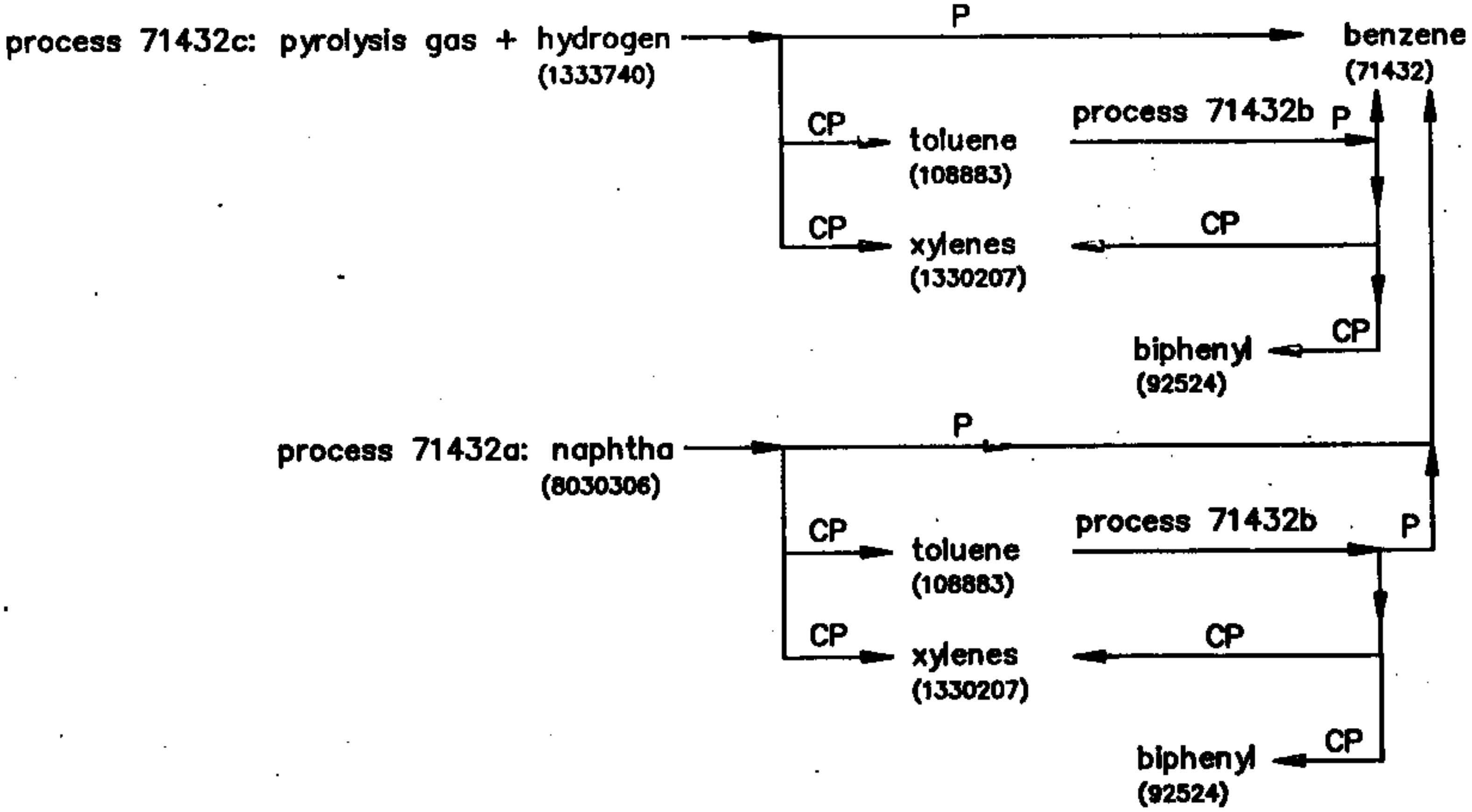
40. Reference 1.

41. **Reference 21.**

42. **Reference 21.**

43. **Reference 5.**

FIGURE 19-2
CHEMICAL TREE
BENZENE



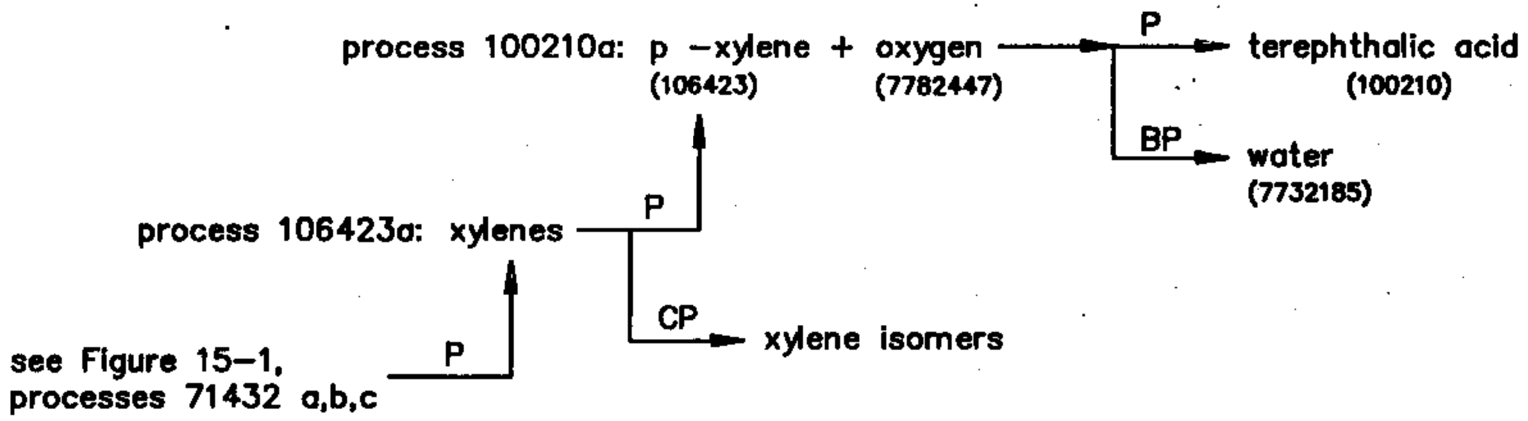
NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

FIGURE 19-3

CHEMICAL TREE

TEREPHTHALIC ACID



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 20

PROPYLENE GLYCOL PRODUCTION

20.1 INDUSTRY PROFILE

Propylene glycol (PG) is produced by the hydrolysis of propylene oxide. Almost sixty percent of domestic PG production is consumed in the manufacture of unsaturated polyester resins (UPRs).[1] In 1989, 80 percent of PG production was sold on the merchant market.[2]

20.1.1 Brief Market Introduction

20.1.1.1 Historical Overview

Two grades of PG are sold on the merchant market, industrial-grade and USP (or pharmaceutical) -grade.[3] Trade list prices are discounted.[4]

Table 20-1 lists the average realized price of industrial-grade PG from 1980 to 1989. The price of PG decreased from 1986 to 1987 despite a large increase in demand.[5] The implication is that the rightward shift of demand was offset by larger rightward shift of supply. Evidence supporting this argument is a 30 percent increase in industry output over the same time period stemming from a 13 percent increase in capacity.[6]

Average realized price rose 2 cents per kilogram from 1987 to 1988, then jumped 24 cents (39%) to a decade-high of 86 cents per kilogram in 1989. The latter increase resulted from increasing propylene oxide costs.[7]

Data for the USP-grade average realized prices are unavailable. However, in 1988 Mannsville Chemical Products Corporation reported that the grade is usually 7 to 9 cents per kilogram more than industrial-grade PG.[8]

20.1.1.2 Recent Developments

The trade list price of industrial-grade PG held steady at $1.23 per kilogram throughout 1990.[9,10] As of April 1991, the price

TABLE 20-1. AVERAGE REALIZED PRICE OF PROPYLENE GLYCOL (INDUSTRIAL-GRADE), 1980-1989

	Price (¢/kg)
1989	86
1988	62
1987	60
1986	66
1985	71
1984	77
1983	N.A.
1982	N.A.
1981	N.A.
1980	82

N.A. - Not available.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Propylene Glycol," April 1988; U.S. International Trade Commission, Synthetic Organic Chemicals, 1987, 1988, 1989.

was the same.[11] USP-grade PG rose in 1990 from $1.30 per kilogram in January to $1.43 in December.[12,13] In April 1991 USP-grade PG was still $1.43 per kilogram.[14] This price increase resulted from increased propylene oxide costs.[15] The increased feedstock costs did not affect the list price of the industrial-grade.

20.1.2 Demand Conditions

20.1.2.1 Uses of Propylene Glycol

Table 20-2 details the various end uses of PG. Its use as a raw material in the manufacture of UPRs consumed 58 percent of 1989 production. UPRs are used in a variety of applications: for bathtubs and showers in the construction industry, for boat hulls and swimming pools in the marine industry, and for truck cabs and engine hoods in the automobile industry. Electronics, furniture, and other consumer items also use UPRs.

Because it is an excellent humectant, PG is used as such in foods, pharmaceuticals, and cosmetics as well as in semi-moist pet foods and tobacco.[16] PG is also used as an emollient in cosmetics and pharmaceuticals because it is non-irritating to the skin.[17] Foods, pharmaceuticals, cosmetics, semi-moist pet foods, and tobacco together consume 31 percent of PG output.

In industry, PG is used as a lubricant and as a heat-transfer fluid. Six percent of PG output is used for various functional fluids.

One of PG's miscellaneous uses is as raw material for plasticizers. PG can also be substituted for ethylene glycol in various antifreeze-type applications.

20.1.2.2 Consumption

Domestic apparent consumption of PG from 1980 to 1989 is listed in Table 20-3. Two large jumps in consumption occurred in the latter half of the decade. From 1986 to 1987 consumption grew by 44 million kilograms (20%). This increase was driven by growing demand for UPRs.[18] Consumption rose again from 1987 to 1988, increasing by 32 million kilograms (12%). Ethylene shortages drove up ethylene glycol prices causing many producers of antifreeze-type applications to use PG instead.[19] It has been estimated that between 36.3 and 63.5 million kilograms of PG were substituted for ethylene glycol in 1988.[20]

TABLE 20-2. USES OF PROPYLENE GLYCOL, 1990

	Percent of Total Consumption
Unsaturated polyester resins (UPRs)	58%
Food, pharmaceuticals, cosmetics	15%
Semi-moist pet food	10%
Humectant for tobacco	6%
Functional fluids	6%
Miscellaneous[a]	5%

[a] Includes plasticizers.

Source: Chemical Marketing Reporter, January 1, 1990; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Propylene Glycol," April 1988.

TABLE 20-3. APPARENT CONSUMPTION OF PROPYLENE GLYCOL IN THE U.S., 1980-1989

	Apparent Consumption (10^6 kg)
1989	244
1988	293
1987	261
1986	217
1985	209
1984	214
1983	N.A.
1982	N.A.
1981	N.A.
1980	199

[a] Production plus imports, minus exports. Because inventory changes are ignored, this is a simplified estimate of consumption.

Sources: Chemical & Engineering News, June 18, 1990, p. 39; Chemical Marketing Reporter, March 5, 1990, p. 15; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Propylene Glycol." April 1988; U.S. Department of Commerce, International Trade Administration, Trade Data Services, Phone Conversation, April 19, 1991.

In 1989 domestic apparent consumption fell by 49 million kilograms (17%). A downturn in the automobile industry contributed to decreased demand for UPRs.[21] This decreased demand was reflected in 2.7 percent decrease in production of UPRs.[22] Also contributing to the lower consumption was the fact that substitution of PG for ethylene glycol did not continue.[23] Increasing feedstock (propylene oxide) costs eliminated any price advantage PG had over ethylene glycol during the 1988 ethylene shortage. PG's average realized price of 86 cents per kilogram was almost the same as ethylene glycol's price of 88 cents per kilogram.[24]

20.1.2.3 Exports

Table 20-4 lists PG exports from 1980 to 1989. Since 1984, exports have grown. This growth was driven in part by a weakening U.S. dollar.[25] Strong demand from Europe in 1989 pushed U.S. PG exports up 34 percent to a decade-high of 121.2 million kilograms.[26]

20.1.2.4 Future Prospects

Demand growth for PG will be driven by the growth of its applications. The demand growth of UPRs was flat in early 1990 but was expected to pick up in the latter part of the year.[27] Food, pharmaceutical, and functional fluid applications are experiencing strong growth and will continue to do so.[28] Functional fluids are expected to benefit from a shift away from ethylene glycol-based products.[29] This is due to the fact that ethylene glycol is considered more toxic than PG.[30]

PG's more favorable safety profile also will help producers in developing a new market, PG-based aircraft deicing products.[31] In terms of performance the PG-based products are superior to the currently used ethylene glycol-based products.[32] Some airports have already started recommending PG-based deicers to their client airlines.[33]

Overall, domestically produced PG is forecast to experience slow growth (about 2.5% or less) in 1991 and then grow more rapidly.[34] The forecast of growth through 1994 is 3 percent annually.[35]

U.S. exports will face increasing competition in Europe from Japanese PG exports.[36]

TABLE 20-4. U.S. EXPORTS OF PROPYLENE GLYCOL, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1989	121.2	33.2%
1988	90.7	23.8%
1987	79.8	23.5%
1986	49.4	19.0%
1985	37.2	16.4%
1984	21.8	10.4%
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	24.0	10.9%

[a] See Table 20-6.

Sources: Chemical Marketing Reporter, March 5, 1990, p. 15; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Propylene Glycol." April 1988.

20.1.3 Supply Conditions

20.1.3.1 Production Processes

The hydrolysis of propylene oxide produces PG. Process equipment and procedures are similar to those used in ethylene glycol production via the hydrolysis of ethylene oxide.[37]

20.1.3.2 Domestic Producers and Total Production

There are three domestic producers of PG with a total capacity of 409 million kilograms. Table 20-5 lists the U.S. producers along with plant location and capacity data. Additionally, Texaco has a swing unit (this facility can produce either ethylene glycol or PG) which has the ability to produce up to 56 million kilograms of PG. At some PG facilities capacity can be supplemented by using equipment normally used for ethylene glycol production. Arco's Bayport, TX facility controls 36 percent of industry capacity while Dow controls 44 percent and Olin 8 percent. Both Arco and Dow also produce propylene oxide.[38]

Total domestic production of PG from 1980 to 1989 is listed in Table 20-6. Production rose 30 percent (79 million kilograms) from 1986 to 1987 in response to strong demand for UPRs. From 1987 to 1988 production rose 12 percent (42 million kilograms) in response to increased PG demand. However, in 1989 production fell 4 percent (16 million kilograms) due to falling UPR demand and falling demand for PG as an ethylene glycol substitute.

Domestic output in 1989 represented 86 percent of PG capacity.[39]

20.1.3.3 Costs of Production

The primary source of costs is the propylene oxide feedstock. PG consumed about 23 percent of propylene oxide output in 1989.[40] Propylene oxide has risen from $1.20 per kilogram in January 1990 to $1.27 in April 1991.[41,42]

TABLE 20-5. U.S. PRODUCERS OF PROPYLENE GLYCOL, 1990

Company	Location	Capacity (10^6 kg/yr)
Arco	Bayport, TX	147
	South Charleston, WV[a]	49
Dow	Freeport, TX	113
	Plaquemine, LA[b]	68
Olin	Brandenburg, KY	32
		409

[a] Eastman Chemical Company has agreed to purchase this facility.

[b] Dow is currently adding 13.6 to 18.1 million kilograms of capacity.

NOTE: At some facilities additional PG can be produced by using equipment dedicated to ethylene glycol production. Texaco has a facility in Port Neches, TX which can produce ethylene glycol or propylene glycol. This facility can produce 56 million kilograms of PG when solely dedicated to that purpose. It is currently producing ethylene glycol. Texaco also sells PG produced by Arco.

Sources: Chemical Marketing Reporter, January 1, 1990, p. 46; Chemical Marketing Reporter, April 22, 1991, pp. 3,15; Chemicalweek, June 13, 1990, p. 33; Chemicalweek, October 24, 1990, p. 18.

TABLE 20-6. U.S. PRODUCTION OF PROPYLENE GLYCOL, 1980-1989

	Quantity (10^6 kg)
1989	365
1988	381
1987	339
1986	260
1985	227
1984	210
1983	220
1982	181
1981	215
1980	221

Sources: Chemical & Engineering News, June 18, 1990, p. 39; U.S. International Trade Commission, Synthetic Organic Chemicals, 1989, 1988.

20.1.3.4 Imports

After a high of 25.4 million kilograms in 1984, imports decreased throughout the rest of the decade to the point of being negligible (Table 20-7). This trend has paralleled the decreasing value of the dollar over the same time period, which made imports less competitive on price relative to domestically produced PG.[43]

20.1.3.5 Future Prospects

Dow is considering greatly increasing capacity at its Freeport, TX facility.[44] Arco has just reached an agreement to sell its South Charleston, WV facility (49 million kilograms of capacity) to Eastman Chemical Company. Eastman will control 12 percent of PG capacity.

With respect to the feedstock, demand for domestically produced propylene oxide is forecast to grow at 3 percent annually through 1994.[45] There were supposed to be propylene oxide capacity expansions in 1990 totalling 25 percent of 1989 year-end capacity.46 This seems to indicate no foreseeable propylene oxide shortages in the near future.

20.1.4 Future Market Prospects

Demand for domestically produced PG is forecast to initially face slow growth in 1990 and 1991, then grow more rapidly. Average annual growth is forecast at 3 percent.

In response, one of the three PG producers, Dow, is expanding capacity at both of its facilities. It remains to be seen what effect Eastman's entry will have on other PG producers. There is no foreseeable feedstock shortage on the horizon (up to 1994).

20.2 ECONOMIC IMPACT ANALYSIS

20.2.1 HON Compliance Costs

A synopsis of annualized cumulative control costs and summary statistics for propylene glycol facilities is presented in Table 20-8. Costs are displayed for option one controls. Option one controls are the estimated costs that facilities are likely to incur. Figure 20-1 illustrates the total industry control scenario graphically. Five facilities are displayed.

Propylene Glycol is currently produced via the hydrolysis of propylene oxide. Since this is the only commercial process, no analysis of separate process costs is necessary.

TABLE 20-7. U.S. IMPORTS OF PROPYLENE GLYCOL, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Consumption[a]
1989	0.2	0.1%
1988	2.2	1.0%
1987	1.8	1.0%
1986	6.4	3.0%
1985	19.5	9.0%
1984	25.4	12.0%
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	1.8	1.0%

[a] See Table 20-3.

N.A. - Not available.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Propylene Glycol." April 1988; U.S. Department of Commerce, International Trade Administration, Trade Data Services, Phone Conversation, April 19, 1991.

TABLE 20-8. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR PROPYLENE GLYCOL PRODUCTION FACILITIES AND PROPYLENE GLYCOL PRODUCTION PROCESSES

Facility/ Process	Annual Production (10^6 kg)	Option One Controls ($/kg)
1A	62	$0.0016
2A	103	$0.0020
3A	149	$0.0021
4A	41	$0.0024
5A	29	$0.0031
<u>Summary Statistics</u>		
Mean		$0.0022
Production Weighted Average		$0.0021

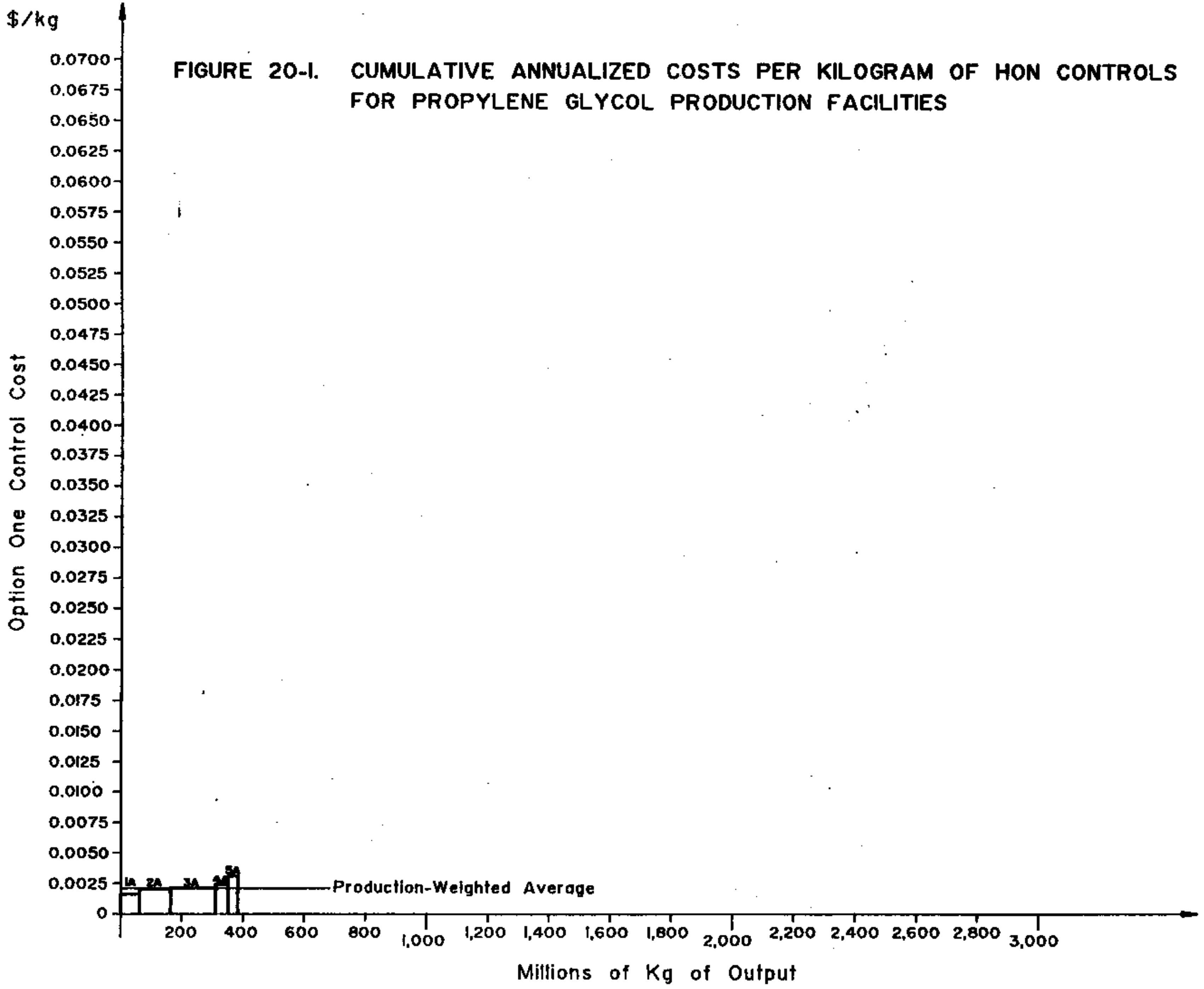


FIGURE 20-I. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR PROPYLENE GLYCOL PRODUCTION FACILITIES

20.2.2 Pricing

PG prices are determined by a combination of feedstock costs and end-use demand. The cost of propylene oxide (PO), the primary feedstock in PG, is tied closely to growth of the general economy, as well as to crude oil prices. With demand growth for PO estimated to mirror GNP growth, this feedstock probably won't inflate dramatically. PG end uses are mature, also making them sensitive to overall economic activity. New markets are being explored to exploit PG's favorable safety profile as a substitute for ethylene glycol. Success will enhance PG growth, keeping prices firm. The 1989 average realized price was $.86 per kilogram. The most recent spot price available at the time of this writing was $1.24 per kilogram.

20.2.3 Elasticities

The demand elasticity for propylene glycol is estimated on the basis of available substitutes for propylene glycol, as well as substitutes for end-uses. The potential for import substitution is also examined.

20.2.4.2 Demand Elasticities

20.2.4.2.1 Unsaturated Polyester Resins (UPRs). The largest end use for PG are UPRs, accounting for 58 percent of PA demand. UPRs are used to make a variety of consumer and engineering plastics. A wide variety of other glycols, including ethylene glycols, are available for producing UPRs, and these glycols can be combined to achieve the desired properties. By manipulating the relative proportion of various glycols, the need for any particular glycol can be minimized or eliminated. The demand for PG in this sector is estimated to be slightly inelastic.

20.2.4.2.1 Food, Pharmaceuticals, and Cosmetics, Semi-Moist Pet Food, Humectant for Tobacco. Food, pharmaceuticals, cosmetics, semi-moist pet food, and humectants account for 31 percent of PG demand. Other glycols can be used for most of these applications. PG, however, is particularly well suited for use in this area, since it doesn't have the adverse health effects sometimes observed when using other compounds, for example ethylene glycol. When an end-use product is ingested, PG is often the compound of choice. PG demand is deemed moderately inelastic in this sector.

20.2.4.2.1 Functional Fluids. Functional fluids, such as solvents and antifreeze, make up 6 percent of PG end-use demand. While this is a small share of overall PG demand, this sector is important because it is one in which PG producers hope to make inroads during the decade. Since PG is more environmentally benign than EG, producers are marketing PG as a more desirable substitute. PG also appears to exhibit superior performance in areas such as airplane deicing. PG is also becoming more price competitive with EG. demand for PG in this sector is regarded as moderately inelastic.

20.2.4.2.2 Imports Imports of propylene glycol are insignificant. Therefore, pricing decisions will be made based on domestic considerations, with little fear of import substitution.

20.2.4.2.4 Elasticity Estimate. The demand elasticity varies somewhat from sector to sector, but doesn't appear to extend into the elastic range. Given the importance of unsaturated polyester resins, which dominate propylene glycol end uses, the demand elasticity for PG is estimated to be in the slightly inelastic range of -.67 to -1.

20.2.4 Market Structure

Table 20-9 summarizes the parameters for the market structure of propylene glycol. Three firms are currently producing propylene glycol. Thus, four-firm concentration ratio is 100 percent, signifying substantial market power. The HHI is 4,316.1, which falls in the substantial range of market power. Captive consumption is only 20 percent, indicating slight vertical integration. On average, 10 chemical compounds are produced at propylene glycol sites, suggesting a substantial degree of horizontal integration. Imports in the industry are insignificant. In summary, the market structure of the propylene glycol industry is moderately to highly oligopolistic, and firms will likely absorb a significant portion of HON compliance costs.

20.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the ethylene glycol industry for option one costs are presented in Table 20-10.

TABLE 20-9. MARKET STRUCTURE CHARACTERISTICS FOR PROPYLENE GLYCOL

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Vertical Integration	Horizontal Integration	Imports
3	100%	4,316.1	20%	10	Insignificant

[a] Herfindahl-Hirschman Index

TABLE 20-10. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE PROPYLENE GLYCOL INDUSTRY[1], OPTION ONE CONTROL COSTS

	Elasticity	
	-0.67	-1.00
%Δ Price (%/kg)	0.25%	0.25%
Δ Price ($/kg)	$.0021	$.0021
%Δ Output (%/kg)	(0.16%)	(0.25%)
Δ Output (10^6 kg)	(.755)	(1.1)
%Δ Total Revenue	0.08%	0.00%
Δ Total Revenue (10^6 $)	$.320	$0.00
Δ Employment (# of Employees)	(2)	(3)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

Δ = Change In

Market Price = $0.86/kg

1995 Output = 459 x 10^6 kg (based on 1989 production at 3% annual compound growth)

1995 Total Revenue = $394,437,814.64 (market price x 1995 output)

1995 Employment = 1,075

20.2.5.1 Option One Control Costs

Option one control costs represent the actual estimated cost that an industry will incur. The production weighted average percentage price increase of 0.25 percent leads to a price increase $.0021 per kilogram. For the two elasticity levels of -.67 and -1.00, the output reduction is 755 thousand kilograms (.16%) and 1.1 million kilograms (.25%), respectively.

Facility 5A, which is both the highest cost and the smallest plant in the industry, accounts for 28.9 million kilograms of industry production. If this facility absorbs the entire output loss, it's decline in output would range from 2.6 percent to 4.2 percent. The loss in employment is from two to three employees. Closure would be unlikely given these control costs.

20.2.6 Conclusion

Propylene glycol is a commodity chemical with mature end-uses. The range of costs is $.0016 to $.0031 per kilogram. Price increases associated with HON controls should be easily achievable, so impacts are apt to be small. Thus, closure is unlikely, especially when considering the strong oligopolistic position of propylene glycol producers, most notably the high level of horizontal integration.

20.2.7 References

1. "Chemical Profile -- Propylene Glycol." Chemical Marketing Reporter, January 1, 1990, p. 46.
2. U.S. International Trade Commission. Synthetic Organic Chemicals -- United States Production and Sales, 1989, Washington, DC, December 1990, p. 15-6.
3. Mannsville Chemical Products Corp. "Chemical Products Synopsis -- Propylene Glycol." Asbury Park, NJ, April 1988.
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5. Reference 3.
6. Reference 3.
7. "PO Markets Seen Marking Time In '90." Chemical Marketing Reporter, January 8, 1990, pp. 3, 12.
8. Reference 3.
9. Chemical Marketing Reporter, January 8, 1990 p. 32.
10. Chemical Marketing Reporter, December 31, 1990, p. 30.
11. Chemical Marketing Reporter, April 8, 1991, p. 38.

12. Reference 9.

13. Reference 10.

14. Reference 11.

15. Reference 7.

16. Reference 3.

17. Reference 3.

18. Reference 3.

19. "PO/PG Improves Stand In EO/EG Market Sectors." Chemical Marketing Reporter, July 17, 1989, pp. 14-15.

20. Reference 19.

21. Reference 7.

22. Reference 7.

23. Reference 1.

24. Reference 2.

25. Reference 3.

26. Reference 1.

27. Reference 1.

28. Reference 1.

29. Reference 1.

30. Reference 7.

31. Reference 1.

32. Reference 19.

33. Reference 7.

34. Reference 1.

35. Reference 1.

36. "Producers Push For Higher Propylene Glycol Prices." Chemicalweek, June 13, 1990, p. 33.

37. Reference 3.

38. "Chemical Profile -- Propylene Oxide." Chemical Marketing Reporter, January 8, 1990, p. 42.

39. SRI International, "1989 Directory of Chemical Producers, United States."

40. Reference 38.

41. Reference 9.

42. Reference 11.

43. Reference 3.

44. Reference 36.

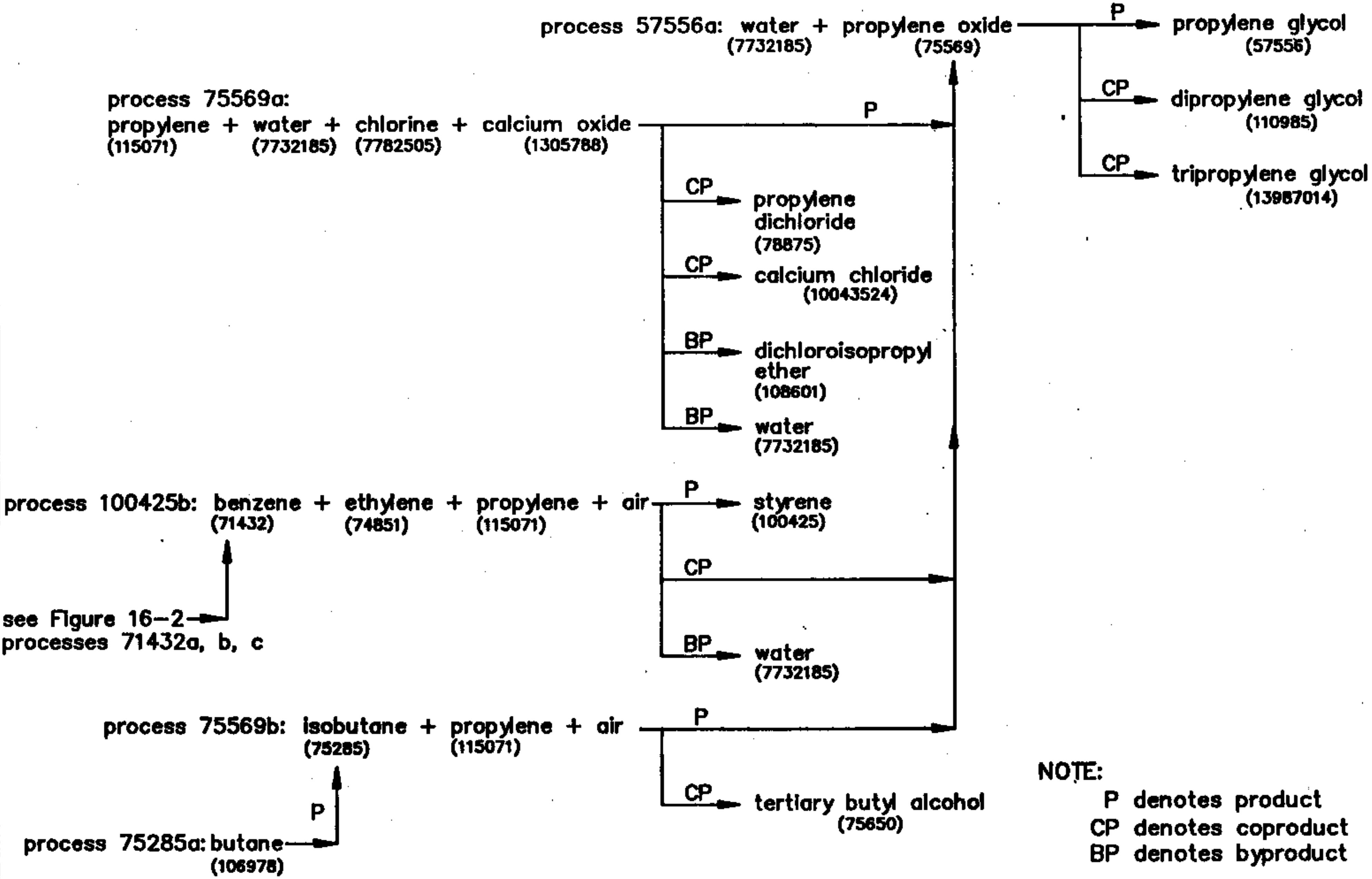
45. Reference 38.

46. Reference 7.

FIGURE 20-2

CHEMICAL TREE

PROPYLENE GLYCOL



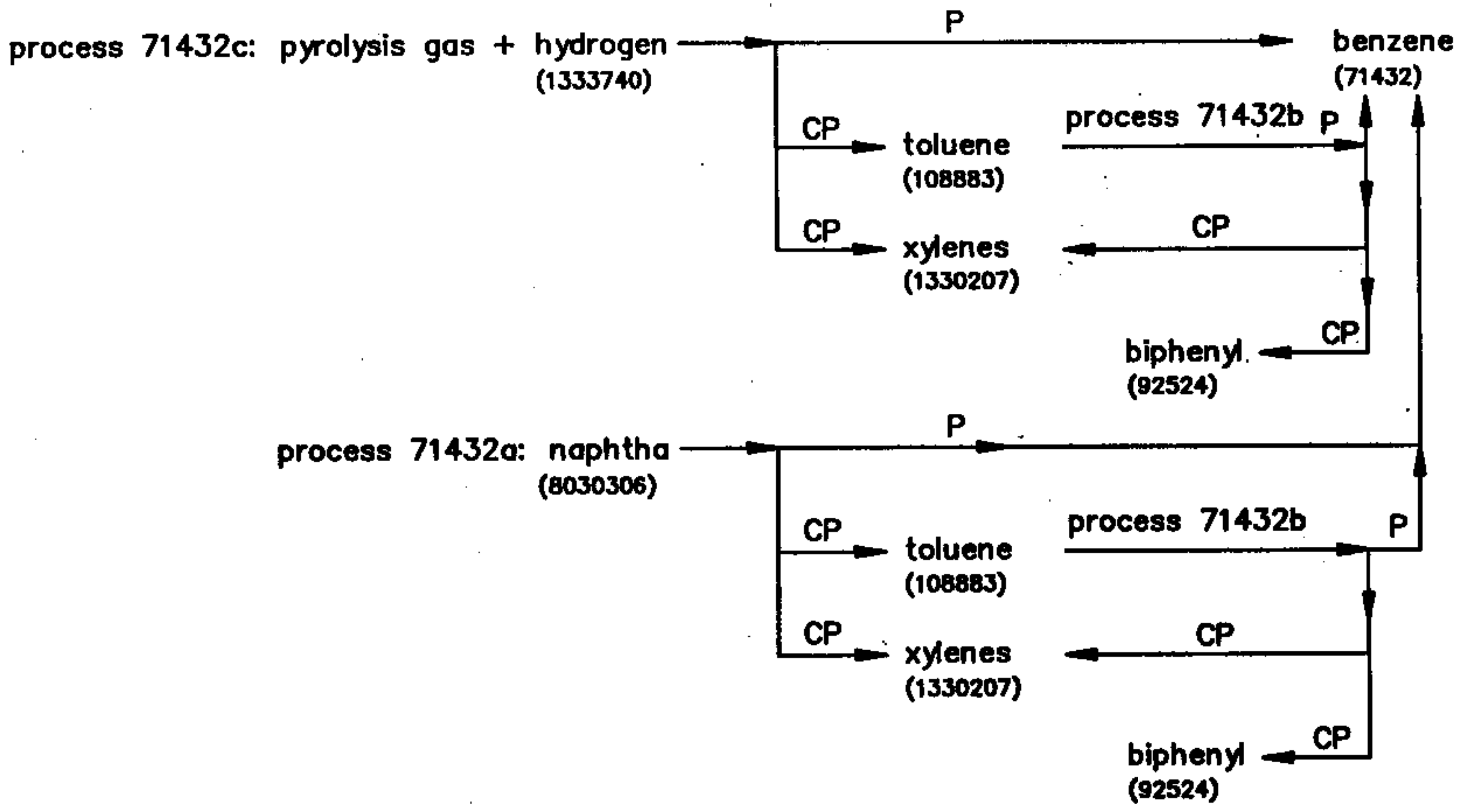
NOTE:
P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

FIGURE 20-3

CHEMICAL TREE

BENZENE



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 21

METHYL TERTIARY BUTYL ETHER

21.1 INDUSTRY PROFILE

Methyl tertiary butyl ether (MTBE) is an oxygenated compound derived from methanol and isobutylene.[1] MTBE was introduced in 1979.[2] Used exclusively as a gasoline additive to increase oxygen content and boost octane, MTBE is a clear, low-viscosity flammable liquid, characterized as an organic ether.[3] In 1989, 34 percent of MTBE was sold on the merchant market.[4]

21.1.1 Brief Market Introduction

21.1.1.1 Historical Overview

Table 21-1 lists average realized price of MTBE from 1980 to 1989. Prices declined slowly through 1986, but experienced a jump from 1987 to 1988. The decrease prior to 1986 was accompanied by steady growth in output, suggesting a downward shift of the industry supply curve, tied to declining crude oil and gasoline prices. The subsequent increase of 21 cents per kilogram from 1987 to 1988 is due to strengthening petroleum prices and escalating demand. The surge in demand stems from United States Environmental Protection Agency (EPA) lead phasedown rules in 1985, and several state mandates for increasing the oxygenate content of gasoline.[5,6]

21.1.1.2 Recent Developments

Data on MTBE prices since 1989 is sparse. In August 1990, contract prices peaked at 55 cents per kilogram, and then declined to 41 cents per kilogram by November, despite uncertainty in the Middle East. This is just 2 cents above the 1980 average realized price.

21.1.2 Demand Conditions

21.1.2.1 Uses for Methyl Tertiary Butyl Ether

Table 21-2 lists the end use for MTBE. MTBE's only end use is as a gasoline additive. As a small-volume intermediate, MTBE is decomposed captively to regenerate isobutylene for making butyl rubber.[7]

As a gasoline additive, MTBE serves two functions. First, as an oxygenate, it lowers the amount of exhaust emissions -- both of

TABLE 21-1. AVERAGE REALIZED PRICE OF METHYL TERTIARY BUTYL ETHER, 1980-1989

	Price (¢/kg)
1989	49
1988	46
1987	25
1986	24
1985	35
1984	35
1983	36
1982	42
1981	N.A.
1980	39

N.A. - Not available.

Sources: U.S. International Trade Commission, Synthetic Organic Chemicals, 1980 - 1989. Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Methyl t-Butyl Ether," September, 1990.

TABLE 21-2. USES OF METHYL TERTIARY BUTYL ETHER, 1989

	Percent of total consumption
Gasoline additive	100%

Source: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Methyl t-Butyl Ether," September, 1990.

hydrocarbons and carbon monoxide.[9] Prior to the 1990 Clean Air Act, oxygenates were not as important in gasoline formulation, but now the required total oxygen content in fuel is set at 2.0 percent in ozone nonattainment areas, and 2.7 percent in carbon monoxide nonattainment areas. Several states have also mandated oxygenate increases over the past few years. Second, MTBE is useful as an octane enhancer in unleaded gasoline.[10] Previously, lead alkyls were used as octane boosters. Aromatic additives, such as benzene and toluene, also increase octane levels.

21.1.2.2 Consumption

Export and import data are not available for MTBE, so apparent consumption in the U.S. (production plus imports, minus exports) cannot be calculated. Nevertheless, it is clear that demand for MTBE has grown substantially since 1986, due primarily to federal and state regulations.

21.1.2.3 Exports

Exports of all organic ethers in 1989 were 55.1 million kilograms. MTBE is a subset of this, and exports of MTBE appear to be insignificant.

21.1.2.4 Future Prospects

Future end-use growth of MTBE hinges on the form that EPA regulations will take over the next several years. Gasoline use itself is a mature market which ebbs and flows with motor-vehicle demand, and hence, the business cycle. Two separate EPA standards directly affect demand conditions in the MTBE market. The first is the lead phasedown which must be accomplished in full by December 31, 1995.[11] Lead alkyls were used traditionally as octane enhancers, but are being eliminated because of the detrimental health effects of lead. Aromatic compounds, such as benzene and toluene, have also been used as octane boosters, but these too are being controlled, as they generate hydrocarbon emissions. MTBE has emerged as the most viable substitute for lead and aromatics in the role of octane additive. Second is the requirement for increased amounts of oxygen in gasoline, with the goal of reducing carbon monoxide (CO) emissions. This trend started at the state level in the mid-1980s, and has been strengthened at the federal level by the 1990 Clean Air Act. Actual oxygen content standards in reformulated gasoline are still being determined. The

2.0 percent to 2.7 percent mentioned above translates into about 11 percent to 15 percent MTBE content.[12] So the ability of MTBE to both increase octane in unleaded gasoline and boost oxygen content, supplemented by EPA regulations, will account for the bulk of increased demand over the next decade. Growth in domestic demand is projected to range from 12 percent to 15 percent annually into the mid-1990s.[13]

Indirectly affecting MTBE demand are proposed ethanol subsidies. Ethanol is a feedstock for Ethyl tertiary butyl ether (ETBE), which also serves as an octane enhancer and oxygenate in unleaded gasoline. As a potential substitute for MTBE, ETBE can compete only if the higher cost of ethanol feedstock is offset by federal assistance.[14] A proposed fuel tax credit of sixty cents per gallon would greatly enhance ETBE use in place of MTBE, dampening MTBE growth. Federal tax credits and research and development incentives are being encouraged by the National Corn Growers Association, since ethanol can be produced from corn.[15]

Finally, a variety of potential substitutes, such as tertiary amyl methyl ether (TAME), fuel alcohols, alkylates, and several other ethers, could impact MTBE demand conditions.[16] None of these substitutes, including ETBE, are currently being manufactured commercially in the U.S.[17]

21.1.3 Supply Conditions

21.1.3.1 Production Processes

MTBE is produced by reacting isobutylene and methanol across a catalyst bed, in the liquid phase under mild temperature and pressure.[18] While this reaction is common to all MTBE producers, three different routes can be distinguished by the way in which isobutylene is produced.

Process A produces MTBE via the etherification of isobutylene. In this route isobutylene is formed by cracking C4 streams, either in steam crackers or cat crackers. Almost any C4 stream can be used as an isobutylene source, with isobutylene concentrations ranging from 15 percent to 50 percent. This variability is actually a constraint to developing MTBE processes based on C4 cracking, as isobutylene feedstocks are difficult to standardize.[19]

Alternatively, MTBE is produced via dehydration of tertiary butyl alcohol, in which isobutylene is made as a coproduct. This is the chosen process of ARCO Chemical, the industry leader in MTBE production with 43.9 percent share of capacity.[20]

Finally, MTBE is produced via isomerization of butane (process C), in which isobutylene is derived from isobutane. Only 13.9 percent of industry capacity is currently geared for this process.

21.1.3.2 Domestic Producers and Total Production

Table 21-3 lists domestic producers of MTBE. Nineteen firms are in the market, operating 21 plants, with a total industry capacity of 4,132 million kg. annually. Figures for 1990 production are not available, but capacity utilization based on 1989 output is 90 percent, suggesting pressure on available capacity. Arco Chemical has a capacity of 1,696 million kilograms, accounting for 43.9 percent of the industry total. The next closest manufacturer, Texas Petrochemicals Corp., has 15.6 percent of industry capacity.

Table 21-4 lists total domestic production from 1980 to 1989. Output rose throughout the decade, from 320 million kilograms in 1980 to 3732 kilograms in 1989, on the heels of strong demand. This is not typical of the synthetic organic chemical industry as a whole, as many chemical producers reduced output in the mid-1980s.

21.1.3.3 Costs of Production

Production of MTBE, like most synthetic organic chemicals, is capital intensive, with raw materials accounting for the lion's share of variable costs. Raw materials for MTBE are methanol and isobutylene. Methanol capacity utilization is approaching 90 percent, suggesting tight supplies.[21] Isobutylene also appears to be in short supply, as the easily recoverable amounts from C4 streams are already consumed by other chemical manufacturers.[22] Because of this, isobutylene requirements must come from isomerization of butane. This too, is problematic, as butane is volatile and therefore difficult to ship. Since MTBE producers in the U.S. by and large don't have local access to butane, isobutylene scarcity is exacerbated.

21.1.3.4 Imports

Imports of all organic ethers in 1989 were 39.8 million kilograms. MTBE is a subset of this, and MTBE imports appear to be insignificant.

TABLE 21-3. U.S. PRODUCERS OF METHYL TERTIARY BUTYL ETHER, 1990

Company	Location	Capacity (10^6 kg/yr)
Amoco	Whiting, IN	129
	Yorktown, VA	23
		152
ARCO Petroleum	Carson, CA	109
ARCO Chemical	Channelview, TX	1,179
	Corpus Christi, TX	517
		1,696
Ashland Oil	Catlettsburg, KY	120
Citgo	Lake Charles, LA	116
Champlin Refining Co.	Corpus Christi, TX	75
Conoco, Inc.	Ponca City, OK	52
Diamond Shamrock	Sunray, TX	91
Exxon Chemical	Baytown, TX	129
Fina Oil & Chemical	Big Spring, TX	22
Hill Petroleum	Houston, TX	59
Lyondell Petrochemical	Channelview, TX	95
Marathon Oil (USX)	Detroit, MI	48
Mobil	Beaumont, TX	109
Phillips	Sweeney, TX	129
Sun Refining & Marketing Co.	Marcus Hook, PA	108
Texaco	Port Neches, TX	345
Texas Petrochemicals Corporation	Houston, TX	603
Valero Refining	Corpus Christi, TX	73
	TOTAL	3,859

Source: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Methyl t-Butyl Ether," September, 1990.

TABLE 21-4. U.S. PRODUCTION OF MTBE, 1980 - 1989

	Quantity (10^6 kg)
1989	3732
1988	2576
1987	1594
1986	1531
1985	858
1984	624
1983	380
1982	374
1981	345
1980	320

Source: U.S. International Trade Commission, Synthetic Organic Chemicals, 1980 - 1989.

21.1.3.5 Future Prospects

In response to surging demand, the MTBE market is likely to expand rapidly. Currently, new plants and plant expansions are being undertaken by seven U.S. firms. Globally, plants are being built in Canada, Malaysia, Norway, Qatar, Algeria, and Saudi Arabia. U.S. capacity is expected to grow from approximately 5,706 million kilograms in 1991 to 12,777 million kilograms by 1995 -- an annual compound growth rate of 22.3 percent.[23] Global capacity is expected to grow from approximately 10,201 million kilograms in 1991 to 22,603 million kilograms in 1995 -- an annual growth rate of 22.0 percent.[24] U.S. supplies of MTBE are not expected to keep pace with domestic demand, suggesting a significant rise in import demand.[25]

Methanol capacity is also important, as it is projected that MTBE will eventually surpass formaldehyde and become the number one methanol derivative.[26] Due to the low profitability of methanol sales, methanol capacity increases have not been forthcoming.[27] A methanol shortage is projected by the mid-1990s unless significant expansion begins.[28] This could limit MTBE output and put upward pressure on MTBE prices.

Isobutylene will also influence MTBE supplies. In the short run, isobutylene availability will be in tight supply. The process most likely to fill this gap is isobutylene from butanes.[29] There are several projects that are planned or under way which will alleviate this constraint by the mid-1990s.[30]

A new development in MTBE production is the manufacture of tertiary amyl methyl ether (TAME) on the same site as MTBE.[31] TAME is considered "substantially similar" by the EPA, and therefore can be used as an oxygenate in place of MTBE.[32] Building a TAME plant on the same sight as an MTBE plant will allow producers to choose between whichever is more economical at the time. This would depend in part on the relative feedstock costs of isobutylene and isoamylene (isoamylene is a TAME feedstock). Marathon Petroleum Company recently announced an MTBE/TAME project to be built in Robinson, Ill.[33]

21.1.4 Future Market Prospects

The ability of MTBE to add oxygen to gasoline and boost octane insure its fast growth throughout the 1990s. One source projects that MTBE will be the fastest growing chemical in the decade.[34]

On the demand side, growth prospects are enhanced by state and federal regulations. On the supply side, the principle constraint to growth is raw materials availability. Production of raw materials should respond to MTBE consumption requirements, and increase as needed.

21.2 ECONOMIC IMPACT ANALYSIS

21.2.1 Compliance Costs

A synopsis of annualized cumulative control costs and summary statistics for MTBE production is presented in Table 21-5. Costs are presented for option one controls. Option one controls are the actual estimates of costs that facilities will incur. Figure 21-1 illustrates control costs graphically. Eighteen facilities are displayed*.

MTBE is currently produced by three processes. Process A is the etherification of isobutylene. Process C uses an isobutylene route in a slightly different way, and has been merged into process A for this analysis. Process B employs the isomerization of butane. The compliance cost differential between processes is very small. However, the cost differential between facilities is as great as one cent, and so the production-weighted average could understate the actual price increase.

21.2.2 Pricing

MTBE prices tend to mirror those of its historical gasoline blending competitor, toluene. These prices closely follow crude oil prices, as toluene is a crude oil derivative. Future trends in prices will be determined by the interplay of rapidly increasing demand and the scramble to build new plants to satisfy this demand. Raw materials constraints could pose an obstacle to increasing capacity, putting upward pressure on price. If prices increase, impacts of HON controls will be overstated.

21.2.3 Elasticities

Demand elasticities for MTBE will be estimated on the basis of available substitutes for MTBE, as well as substitutes for end-users. The potential for import substitution is also examined.

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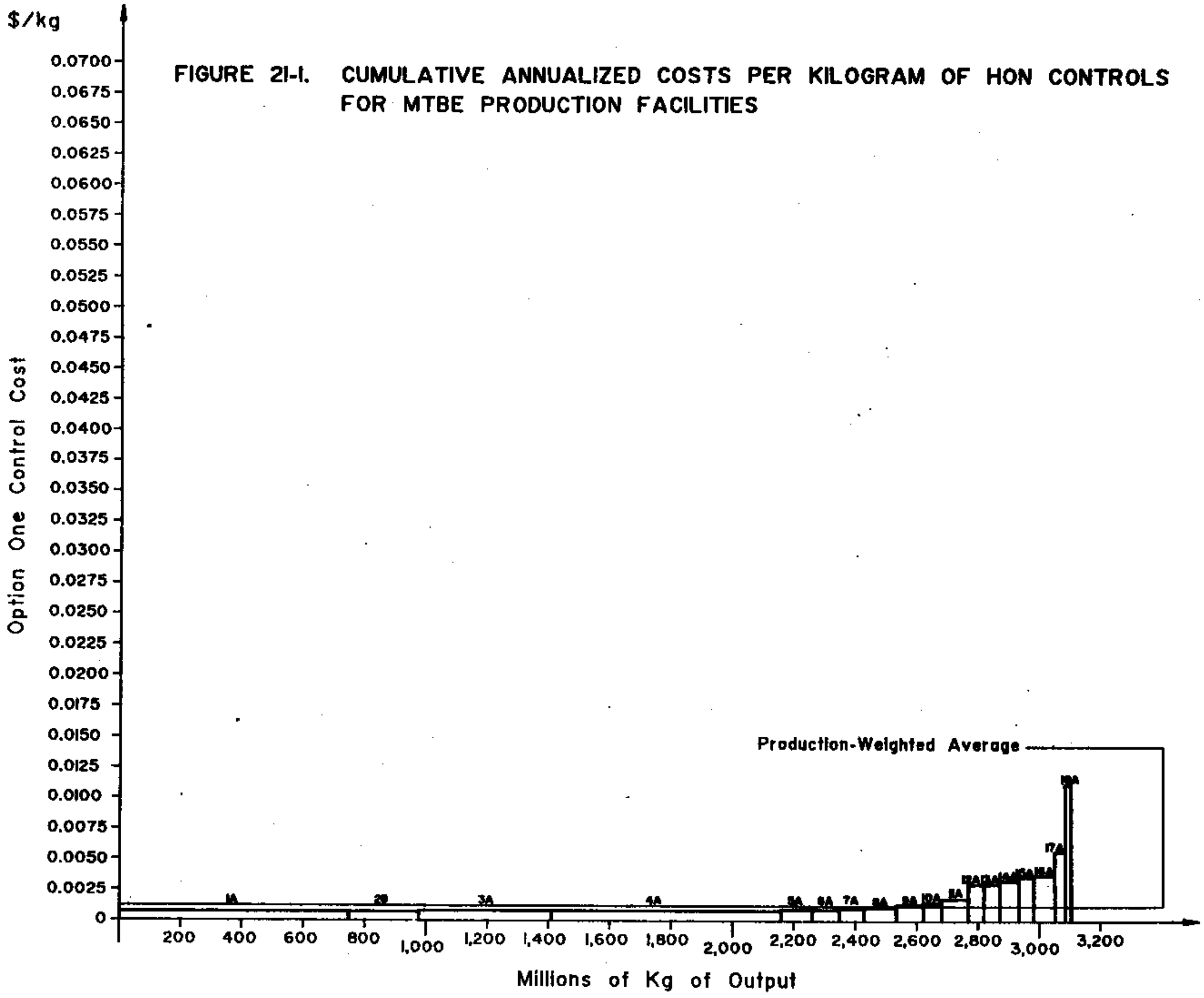
*The number of facilities analyzed is smaller than the number presented in section 21.1.3.2, due to the rapid expansion of the MTBE industry.

TABLE 21-5. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR MTBE PRODUCTION FACILITIES AND MTBE PRODUCTION PROCESSES

Facility/ Process	Annual Production (10^6 kg)	Option One Controls ($/kg)
1A	748.7	$0.0007
2B	228.4	$0.0007
3A	433.2	$0.0008
4A	748.7	$0.0008
5A	101.2	$0.0009
6A	89.5	$0.0009
7A	80.1	$0.0010
8A	103.6	$0.0011
9A	87.1	$0.0013
10A	61.2	$0.0015
11A	87.1	$0.0018
12A	51.8	$0.0030
13A	51.8	$0.0030
14A	61.2	$0.0033
15A	49.5	$0.0036
16A	68.3	$0.0037
17A	35.3	$0.0056
18A	18.8	$0.0111
<u>Control Costs by Process</u>		
Process A (Etherification of Isobutylene)		$0.0013
Process B (Isomerization of Butane)		$0.0008
<u>Summary Statistics</u>		
Mean		$0.0025
Production Weighted Average		$0.0012

FIGURE 21-1. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR MTBE PRODUCTION FACILITIES



21.2.3.1 Gasoline Additive

Use as a gasoline additive accounts for 100 percent of MTBE demand. EPA regulations for gasoline reformulation have assured MTBE a major role in this market. Previously used substitutes have been sanctioned, to some extent, in the 1990 Clean Air Act. (See section 21.1.2.4) Potential substitutes include ethyl tertiary butyl ether (ETBE), tertiary amyl methyl ether, fuel alcohols, alkylates, and other ethers. ETBE will require federal subsidies to be competitive. None of these substitutes are in commercial use in the U.S. for gasoline additives.

21.2.3.2 Imports

Imports of MTBE are insignificant, and will not hinder pricing discretion of domestic producers.

21.2.3.4 Elasticity Estimate

The demand for MTBE is estimated to be in the highly inelastic range of -.1 to -.34.

21.2.4 Market Structure

Table 21-6 summarizes the parameters for the market structure of MTBE. Nineteen firms are currently producing MTBE. The four-firm concentration ratio is 75.3 percent, signifying substantial market power. The HHI is 2,609.3, which falls the range of substantial market power. Captive consumption is 66 percent, indicating a moderate level of vertical integration. On average, two chemical compounds are produced at MTBE sites, suggesting a slight level of horizontal integration. Imports in the industry are not important. In summary, the MTBE industry is moderately oligopolistic, and firms will likely absorb a portion of HON compliance costs.

21.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the MTBE industry for option one control costs are presented in Table 21-7.

21.2.5.1 Option One Control Costs

Option one control costs represent the estimated actual HON control cost that an industry will incur. The production weighted average percentage price increase of .24 percent leads to a price

TABLE 21-6. MARKET STRUCTURE CHARACTERISTICS FOR MTBE

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced at Site (Horizontal Integration)	Imports
19	75.3%	2,609.3	66%	2	Insignificant

[a] Herfindahl-Hirschman Index

TABLE 21-7. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE MTBE INDUSTRY[1], OPTION ONE CONTROL COSTS

	Elasticity	
	-0.1	-0.34
%Δ Price (%/kg)	0.24%	0.24%
Δ Price ($/kg)	$.0012	$.0012
%Δ Output (%/kg)	(0.02%)	(0.08%)
Δ Output (10^6 kg)	(1.5)	(5.1)
%Δ Total Revenue	0.22%	0.16%
Δ Total Revenue (10^6 $)	(6.6)	(4.8)
Δ Employment (# of Employees)	(2)	(7)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

Δ = Change In

Market Price = $0.49/kg

1995 Output = 6.1 x 10^6 kg (based on 1989 production at 12% annual compound growth)

1995 Total Revenue = $3,003,349,909.62 (market price x 1995 output)

1995 Employment = 8,184

increase $.0012 per kilogram. For the two elasticity levels of -.1 and -.34, the output reduction is 1.5 million kilograms (.02%) and 5.1 million kilograms (.08%), respectively.

Facility 18A, which accounts for 18.8 million kilograms of industry production, is both the smallest size and highest cost plant in the industry. If this plant absorbs the entire reduction in output, it would lose from 8 to 27 percent of its production, which could put it on the borderline of closure. However, the industry is expanding rapidly, which would mitigate against its closure, unless its production costs are high relative to new entrants. There is no indication that lower-cost technologies are being used in new plants. The loss in employment is estimated to be from 2 to 7 employees.

21.2.5 Conclusion

Prospects for MTBE are very strong. This large-volume chemical is expanding rapidly. Closure of the smallest size firm is possible in the extreme case, but cannot be predicted with any certainty. If closure of this plant ensues, the small reduction in employment will be more than offset by industry expansion. The range of compliance costs is from $.0007 per kilogram to $.0056 per kilogram, with one outlier cost of $.0111. The cost differential is small, and the production-weighted average price increase is probably an accurate estimate of the actual price increase.

21.2.6 References

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2. Reference 1.
3. Reference 1.
4. United States International Trade Commission. Synthetic Organic Chemicals -- United States Production and Sales, 1989. Washington, DC, December 1990, p. 14-2.
5. "Chemical Profile -- MTBE." Chemical Marketing Reporter, March 24, 1986, p. 50.
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7. Reference 1.
8. "Auto Emission Gains Seen From Oxygenates." Chemical Marketing Reporter, December 24, 1990.

9. "Refiners Have Options To Deal With Reformulated Gasoline." <u>Oil & Gas Journal</u>, April 8, 1991, pp. 68-71.

10. Reference 1.

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12. Reference 9.

13. Reference 1.

14. Reference 1.

15. "Corn Belt Pushes Ethanol," <u>Chemical Marketing Reporter</u>, March 25, 1991, p. 7.

16. "U.S. Clean Air Act Expands Role For Oxygenates." <u>Oil & Gas Journal</u>, April 15, 1991, p. 44-45.

17. Reference 16.

18. Reference 1.

19. Reference 1.

20. Reference 1.

21. "Methanol 'Chaos' Seen As MTBE Goes Ahead," <u>Chemical Marketing Reporter</u>, March 21, 1991, p. 19.

22. Reference 1.

23. Reference 21.

24. Reference 21.

25. "MTBE Will Require A Significant Rise In Imports," <u>Chemical Marketing Reporter</u>, April 8, 1991, p. 9.

26. Reference 21.

27. "Growth in Methanol Supply Lags Demand," <u>Chemical and Engineering News</u>, September 3, 1990, p. 17.

28. Reference 21.

29. "Report From Houston -- Oxygenates," <u>Chemical Marketing Reporter</u>, February 4, 1991, p. 46.

30. Reference 25.

31. "Oxygenates Opportunities Are Seen As Improving." <u>Chemical Marketing Reporter</u>, March 4, 1991, p. 15.

32. Reference 29.

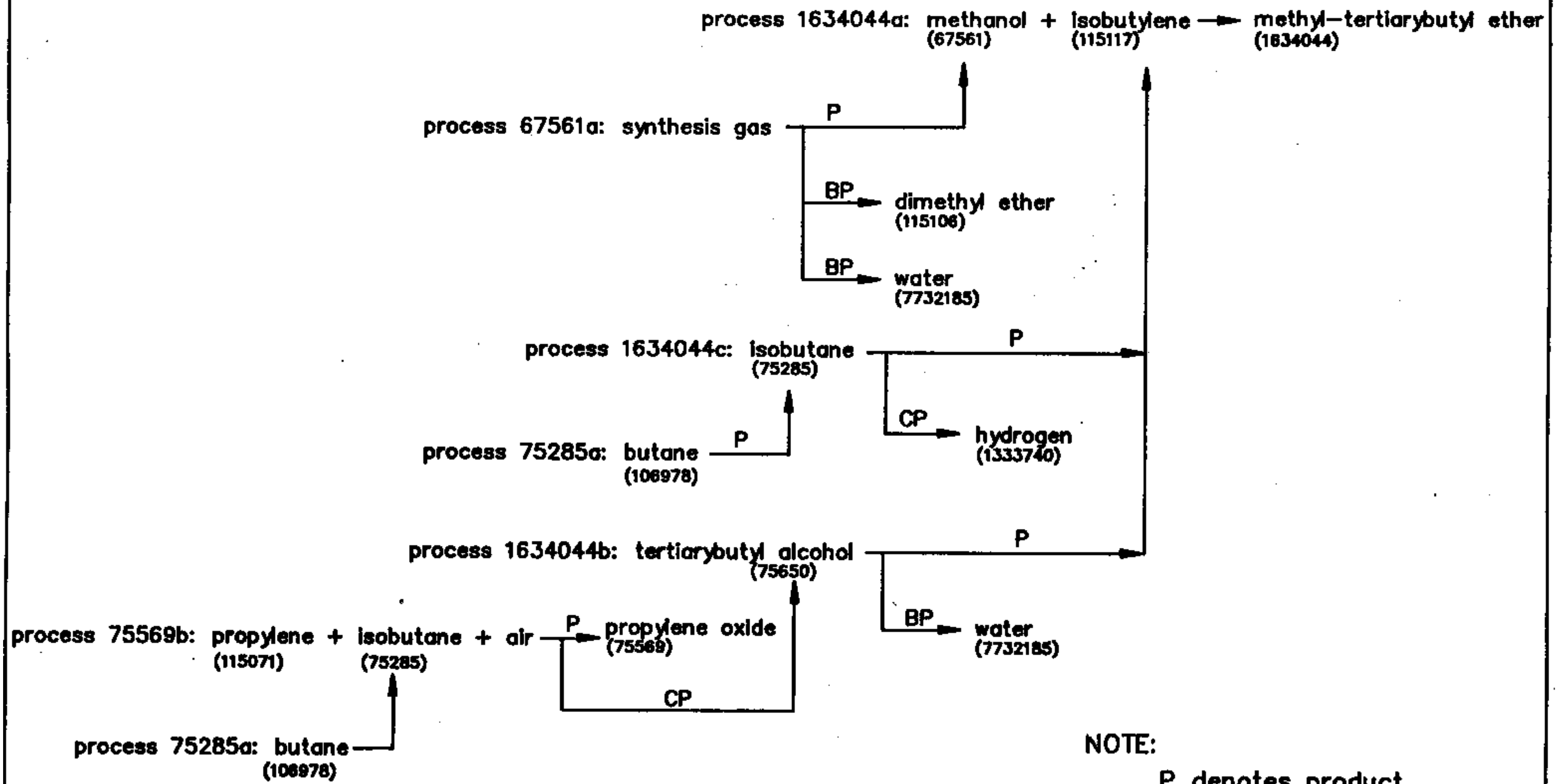
33. Reference 29.

34. Reference 21.

FIGURE 21-2

CHEMICAL TREE

METHYL–TERTIARYBUTYL ETHER



NOTE:

P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 22
PHTHALIC ANHYDRIDE PRODUCTION

22.1 INDUSTRY PROFILE

Phthalic anhydride (PA) is a chemical intermediate categorized as an aromatic acid anhydride.[1] It is produced by either the oxidation of naphthalene or the oxidation of o-xylene.[2] Its three primary applications, phthalate plasticizers, unsaturated polyester resins, and alkyd resins, are primarily consumed by the transportation (automotive), construction, and marine products industries.[3] In 1989, 47 percent of domestic PA output was sold on the merchant market.[4]

22.1.1 Brief Market Introduction

22.1.1.1 Historical Overview

PA is sold in two forms, as white, free-flowing flakes or as colorless molten material.[5] The molten form accounted for about 90 percent of shipments in 1989.[6] In 1990, Mannsville Chemical Products Corporation reported that the flake form generally sells for 7 to 9 cents more per kilogram than the molten.[7]

From 1980 to 1986 the average realized price of PA declined (Table 22-1). Reduced o-xylene costs were responsible for this decline; the decrease in o-xylene costs stemmed from a sharp decline in petroleum prices.[8] In 1987 the average realized price rose 4 cents as demand for phthalate plasticizers grew.[9] The average realized price continued to rise in 1988 and 1989 due to a leftward shift in supply. Rising o-xylene costs, resulting from resurgent petroleum prices, were responsible for the supply shift.[10]

22.1.1.2 Recent Developments

The trade list price of PA in flake form ranged from 80 cents per kilogram to 88 cents in January 1990.[11] It subsequently rose to $1.10 in December 1990 and was unchanged as of April 1991.[12,13] Molten PA rose from a range of 73 cents to 82 cents per kilogram in January 1990 to $1.01 in December.[14,15] This price was the same in April 1991.[16] There was a leftward shift of supply due to higher o-xylene prices and the closing of a 79 million kilogram BASF PA facility in South Kearny, NJ in October 1990.[17] Higher o-xylene prices were caused by rising petroleum prices during the Gulf conflict.

TABLE 22-1. AVERAGE REALIZED PRICE OF PHTHALIC ANHYDRIDE, 1980-1989

	Price (¢/kg)
1989	67
1988	64
1987	55
1986	51
1985	57
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	75

N.A. - Not available.

Source: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Phthalic Anhydride," October 1990; U.S. International Trade Commission, Synthetic Organic Chemicals, 1988, 1989.

22.1.2 Demand Conditions

22.1.2.1 Uses for Phthalic Anhydride

The automotive, construction, and marine products industries together currently consume 93 percent of PA output in the form of phthalate plasticizers, unsaturated polyester resins (UPRs), and alkyd resins. Table 22-2 lists the various applications of PA.

Phthalate plasticizers account for 53 percent of output. They are used to make flexible polyvinyl chloride (PVC). Some examples of these plasticizers are the widely-used dioctyl phthalates (DOPs) and the more specialized diundecyl dodecyl phthalates and undecyl dodecyl phthalates.[18]

Twenty-four percent of PA output is consumed in the manufacture of UPRs. Fiberglass-reinforced plastics based on UPRs are used in products such as shower stalls, translucent construction panels, boats, and recreational vehicles.

Alkyd resins are used as additives in protective coatings. These resins account for 16 percent of output.

22.1.2.2 Consumption

Apparent consumption of PA in the U.S. is listed in Table 22-3. Though data were unavailable for the years 1982 to 1984, it is known that demand for PA declined sharply during the 1982 recession.[19]

Between 1985 and 1987 consumption grew, reaching a ten-year high of 448 million kilograms in 1987. The 17 percent increase from 1986 to 1987 was driven by increased demand for phthalate plasticizers.

Consumption of PA subsequently declined for the rest of the decade. There was a 4 percent (18 million kilogram) decrease in 1988 followed by a 5 percent (23 million kilogram) decrease in 1989. Although no date was given, Mannsville Chemical Products Corporation reported that many PA-based alkyd resins lost market share to waterborne materials based on different raw materials such as acrylics, vinyls, epoxies, and urethanes.[20] This trend may have been behind the decrease in consumption in 1988. The decrease in consumption in 1989 resulted from decreased demand for PA by the slumping automotive and construction industries.[21]

22.1.2.3 Exports

U.S. exports of PA reached a decade-high of 38.1 million kilograms (8.4% of production) in 1988 (Table 22-4). Exports

TABLE 22-2. USES OF PHTHALIC ANHYDRIDE, 1990

	Percent of Total Consumption
Phthalate plasticizers	53%
Unsaturated polyester resins (UPRs)	24%
Alkyd resins	16%
Miscellaneous[a]	7%

[a] Includes polyols, pigments, dyes, perfumes, pharmaceuticals, tanning and curing agents, solvents, insect repellants, fire retardants, and a variety of chemical intermediates.

Source: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Phthalic Anhydride," October 1990.

TABLE 22-3. APPARENT CONSUMPTION OF PHTHALIC ANHYDRIDE IN THE U.S., 1980-1989

	Apparent Consumption[a] (10^6 kg)
1989	407
1988	430
1987	448
1986	384
1985	372
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	364

[a] Production plus imports, minus exports. Because inventory changes are ignored, this is a simplified estimate of consumption.

N.A. - Not available.

Sources: <u>Chemical & Engineering News</u>, June 18, 1989, p. 39; <u>Chemical Marketing Reporter</u>, March 15, 1990, p. 15; <u>Chemical Marketing Reporter</u>, March 26, 1990, p. 12; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Phthalic Anhydride," October 1990; U.S. International Trade Commission, <u>Synthetic Organic Chemicals</u>, 1989.

TABLE 22-4. U.S. EXPORTS OF PHTHALIC ANHYDRIDE, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1989	20.3	4.9%
1988	38.1	8.4%
1987	28.1	6.0%
1986	13.6	3.5%
1985	5.9	1.6%
1984	N.A.	N.A.
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	7.3	2.0%

[a] See Table 22-6.

N.A. - Not available.

Sources: Chemical Marketing Reporter, March 15, 1990, p. 15; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Phthalic Anhydride," October 1990.

benefitted from strong demand for PA in the Far East.[22] In 1989 there was a subsequent 47 percent decrease in exports, as new capacity overseas helped decrease demand for domestically-produced PA.[23]

22.1.2.4 Future Prospects

With the exception of UPRs, PA applications are relatively mature.[24] For this reason, and because 93 percent of PA applications are directly tied to the automotive and construction sectors, demand growth for PA will be close to GNP level.

Demand growth for phthalate plasticizers will be static.[25] Increasing plasticizer efficiency (meaning that less PA is needed) and slow PVC growth are two reasons why.[26] Also, dioctyl phthalates, the leading primary plasticizers, will probably face declining demand of 4 percent annually as enforcement of environmental regulations concerning the use, handling, and disposal of these plasticizers toughens.[27] Another problem is that all of the major plasticizer producers are also selling non-phthalate plasticizers.[28] Overall growth for phthalate plasticizers is expected to be about one percent less than GNP.[29]

The static demand growth for plasticizers may be mitigated somewhat by growth in demand for UPRs. They may experience 3 to 5 percent growth in demand.[30] If the transportation and construction sectors recover, there will be increased demand for reinforced plastics which use UPRs.

Though alkyd resins have lost market share, they will continue to be a major resin.[31]

Overall demand for PA was expected to decline in mid-1990 and 1991.[32] Assuming a recovery sometime in 1991, annual growth is forecast at two to three percent.[33]

Exports are expected to decline, as new PA capacity comes on line overseas.[34]

22.1.3 Supply Conditions

22.1.3.1 Production Processes

There are two ways to produce PA, either by the oxidation of o-xylene or by the oxidation of naphthalene. About 0.93 kilograms of o-xylene are needed per kilogram of PA produced in the o-xylene process; in the naphthalene process 1.05 kilograms of naphthalene are needed per kilogram of PA produced.[35] In terms of capital costs the processes are comparable.[36] In the last couple of decades o-xylene has become the dominant feedstock, supplanting petroleum naphthalene in particular.[37]

22.1.3.2 Domestic Producers and Total Production

Table 22-5 lists the domestic PA producers. There are five firms with one facility each. Total industry capacity is 432 million kilograms, of which Exxon controls the largest percentage (26%). Koppers Industries is the only firm that uses the naphthalene feedstock. Thirty-three percent of its capacity is naphthalene-based while the remaining 67 percent is standby capacity based on o-xylene. Whereas Koppers Industries is backward-integrated (it is the leading producer of coal-tar naphthalene), most of the other producers are not back-integrated into o-xylene production.[38]

Domestic production of PA decreased after a ten-year high in 1987 (Table 22-6). PA output reached this high of 469 million kilograms on the strength of demand for phthalate plasticizers. Output fell 3 percent (16 million kilograms) in 1988. In 1989, output fell another 8 percent (37 million kilograms) as slumps in the automotive and construction sectors resulted in lower demand for PA.

Output in 1989 represented 82 percent of total PA capacity.[39]

22.1.3.3 Costs of Production

As previously mentioned, in terms of capital costs the two production processes are comparable. Thus, raw material costs to a large extent determine the costs of production.

In the last couple of decades o-xylene became the primary PA feedstock. Throughout most of the 1980s, falling petroleum prices helped keep o-xylene costs down. However, petroleum prices began to rise in 1988, increasing o-xylene costs. Koppers Industries gained a significant competitive advantage because it primarily uses the naphthalene process.[40] Producers reliant on o-xylene were wary of hastily instituting price hikes to recover margins, according to Chemical Marketing Reporter.[41]

PA-grade naphthalene has sold in the range of 40 to 44 cents per kilogram from January 1990 to April 1991.[42,43] On the other hand, o-xylene price rose 22 cents in 1990 to 55 cents per kilogram.[44,45] The price fell back to 43 cents by April 1991.[46] The net increase in o-xylene costs has again put o-xylene-based PA producers at a disadvantage with respect to Koppers Industries.

TABLE 22-5. U.S. PRODUCERS OF PHTHALIC ANHYDRIDE, 1990

Company	Location	Capacity (10^6 kg/yr)
Aristech[a]	Pasadena, TX	95
Exxon Chemical	Baton Rouge, LA	113
Koppers Industries	Cicero, IL	68[b]
Stepan Chemical	Millsdale, IL	77
Sterling Chemical	Texas City, TX	79
		432

[a] Mitsubishi owns a controlling interest in Aristech.

[b] This figure includes 45.4 million kilograms of standby capacity based on o-xylene. The rest of capacity is naphthalene-based.

Source: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Phthalic Anhydride," October 1990.

TABLE 22-6. U.S. PRODUCTION OF PHTHALIC ANHYDRIDE, 1980-1989

	Quantity (10^6 kg)
1989	416
1988	453
1987	469
1986	391
1985	372
1984	395
1983	380
1982	310
1981	395
1980	371

Sources: Chemical & Engineering News, June 18, 1989, p. 39; U.S. International Trade Commission, Synthetic Organic Chemicals, 1989.

Besides the feedstock costs, environmental controls have contributed to increased production costs, according to Chemical Marketing Reporter.[47] It is not known, however, when this trend began.

22.1.3.4 Imports

Table 22-7 lists U.S. imports of PA from 1980 to 1989. The ten-year high occurred in 1988 when 15 million kilograms were imported. While imports have never accounted for more than 3.5 percent of domestic consumption, they have been responsible, in part, for discounting from list price in the domestic market.[48] Foreign PA producers are subsidized by their governments, allowing them to manufacture PA at lower cost than domestic producers.[49] Domestic producers have had to discount to match the lower prices of imports because PA is a chemical that competes on price.[50]

22.1.3.5 Future Prospects

Because the economic downturn that began in 1989 has depressed PA demand, supplies should be sufficient for the next few years.[51] Declining exports will also contribute to supply because more PA will be available domestically.

In October 1990 BASF closed a 79 million kilogram PA facility in Kearny, NJ. This closure is expected to help increase capacity utilization rates.[52]

The majority of domestic PA producers are evaluating the feasibility of the dual-feed system, incorporating flexibility between o-xylene and naphthalene.[53] This system would give PA producers the advantage of avoiding increasing feedstock costs during o-xylene or naphthalene price run-ups. However, it is not known whether there is enough naphthalene available to supply increased demand by PA producers.[54] Fifty-eight percent of naphthalene output is currently consumed by PA; 48 percent is accounted for by Koppers Industries, which uses its naphthalene mainly for PA production.[55]

22.1.4 Future Market Prospects

Demand for PA will mirror GNP growth due to the fact that production is primarily consumed by the automotive and construction industries. The forecast growth rate is 2 to 3 percent annually after a downturn in 1990 and 1991.

TABLE 22-7. U.S. IMPORTS OF PHTHALIC ANHYDRIDE, 1980-1989

	Quantity (10^6 Kg)	Percent of U.S. Consumption[a]
1989	11.4	2.8%
1988	15.0	3.5%
1987	6.8	1.5%
1986	6.8	1.8%
1985	5.4	1.5%
1984	N.A.	N.A.
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	0.5	0.1%

[a] See Table 22-3.

N.A. - Not available.

Sources: Chemical Marketing Reporter, March 26, 1990, p. 12; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Phthalic Anhydride," October 1990.

Supplies should be more than adequate to meet demand. A plant closure by BASF will help relieve industry overcapacity and push up capacity utilization rates.

Due to rising o-xylene costs, many producers are considering a dual-feed system. This would give them the flexibility of using either o-xylene or naphthalene as a feedstock.

22.2 ECONOMIC IMPACT ANALYSIS

22.2.1 HON Compliance Costs

A synopsis of annualized compliance costs and summary statistics for phthalic anhydride is presented in Table 22-8. Process A costs are considerably higher than Process B costs: $.0312 per kilogram versus $.0033 per kilogram. Figure 22-1 illustrates control costs graphically. Six facilities are displayed.

Two processes are currently in use for PA production. Process A produces PA via oxidation of o-xylene. In process B, PA is produced via oxidation of naphthalene. Costs are displayed for option one controls. Option one controls are the estimated actual costs that facilities are likely to incur. These differences are masked by the production-weighted average.

22.2.2 Pricing

PA prices are determined by a combination of feedstock costs and end-use demand. Approximately 90 percent of PA capacity is geared for using o-xylene as its feedstock. O-xylene prices, in turn, are tied closely to petroleum prices. Hence, PA prices inflated considerably during the gulf war, in tandem with crude prices. Stabilizing crude prices and overseas competition are likely to depress prices, which are currently at an all-time high of $1.01 per kilogram. It should be noted that this is the list price, which can be 20 percent to 30 percent higher than contract prices. Growth in demand for PA will tend to mirror GNP growth, and is not apt to put considerable upward pressure on price.

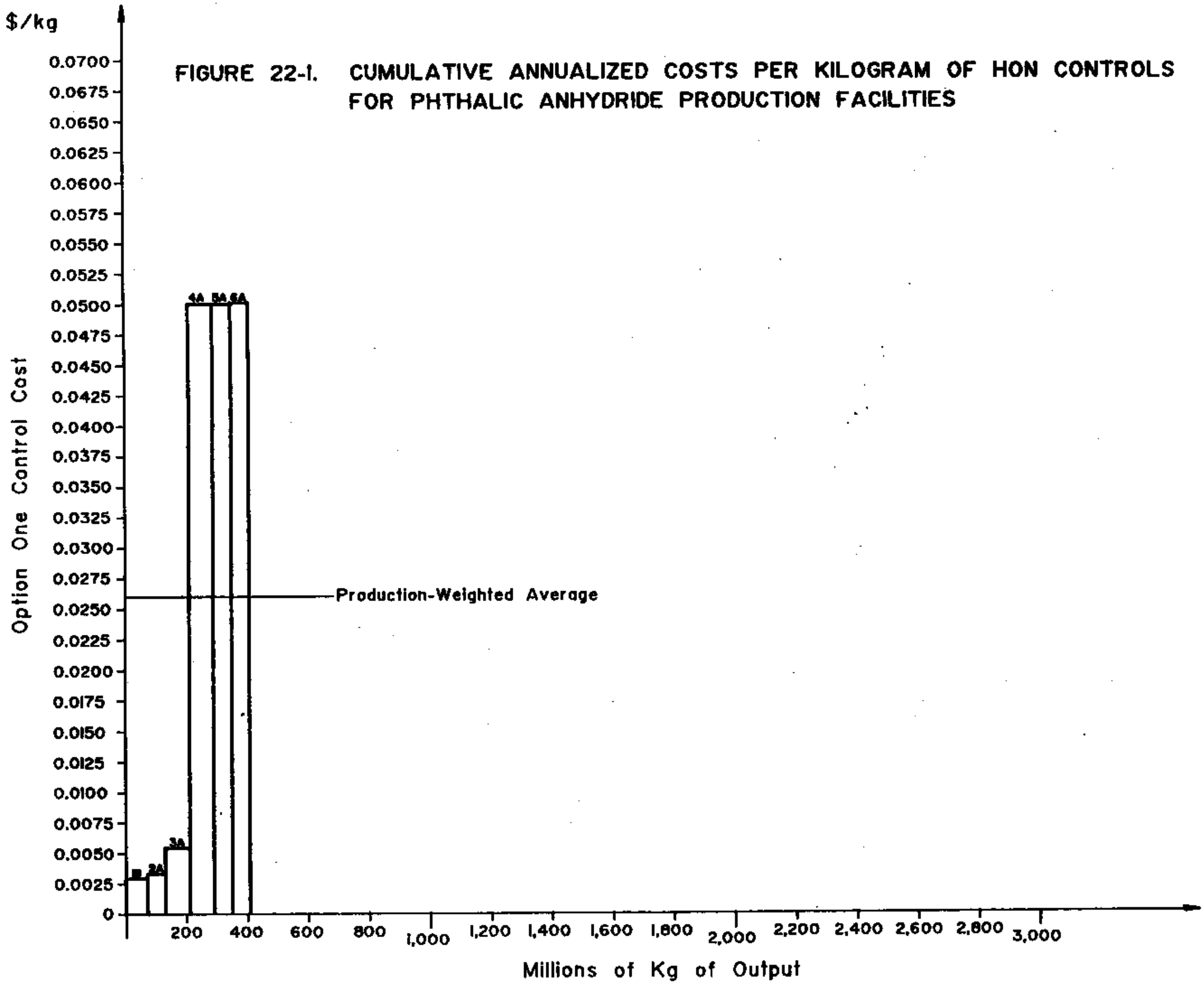
22.2.3 Elasticities

Demand elasticities for phthalic anhydride will be estimated on the basis of available substitutes for phthalic anhydride, as well as substitutes for end-uses. The potential for import substitution is also examined.

TABLE 22-8. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR PHTHALIC ANHYDRIDE PRODUCTION FACILITIES AND PHTHALIC ANHYDRIDE PRODUCTION PROCESSES

Facility/ Process	Annual Production (10^6 kg)	Option One Controls ($/kg)
1B	74.1	$0.0029
2A	79.6	$0.0033
3A	61.6	$0.0054
4A	78.0	$0.0500
5A	60.1	$0.0500
6A	58.5	$0.0501
<u>Control Costs By Process</u>		
Process A (oxidation of o-xylene)	332.3	$0.0312
Process B (oxidation of napthalene)	79.6	$0.0033
<u>Summary Statistics</u>		
Mean		$0.0269
Production Weighted Average		$0.0258

FIGURE 22-1. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR PHTHALIC ANHYDRIDE PRODUCTION FACILITIES



22.2.3.1 Demand Elasticities

22.2.3.1.1 Phthalate Plasticizers

Fifty-three percent of PA production is used to make phthalate plasticizers. These compounds are combined with PVC to enhance flexibility. There are many plasticizers that can be used for this purpose, depending on the specific properties desired in the end product. Phthalate plasticizers tend to have an edge over other plasticizers in that their chemical makeup can be varied to achieve PVC compounds with a variety of different performance characteristics. Demand for PA in this sector is regarded as moderately inelastic.

22.2.3.1.2 Unsaturated Polyester Resins (UPRs)

The second largest end use for PA are UPRs, accounting for 24 percent of PA demand. UPRs are used to make a variety of consumer and engineering plastics. Close substitutes are many, including isophthalic acid, maleic anhydride, fumaric acid, and acrylic resins. Demand for PA in this sector is judged as slightly inelastic.

22.2.3.1.3 Alkyd Resins

Alkyd resins account for 16 percent of PA demand. As with UPRs, maleic anhydride and fumaric acid are available as substitutes. Demand for PA in this sector is deemed to be slightly inelastic.

22.2.3.2 Imports

Imports in the phthalic anhydride market reached a ten-year high in 1988, when they accounted for 3.5 percent of domestic consumption. While this is a small percentage, it is thought that U.S. producers offer discounts partly in response to competition from imports (see section 22.1.3.4). Thus, the ability to recover HON control costs through price increases could be hindered by competition from imported phthalic anhydride.

22.2.3.3 Elasticity Estimate

The demand elasticity of phthalic anhydride varies from sector to sector, ranging between moderately inelastic and slightly inelastic. Given the importance of phthalate plasticizers in end-uses, the demand for phthalic anhydride is estimated to be in the moderately inelastic range of -.34 to -.67.

22.2.4 Market Structure

Table 22-9 summarizes the parameters for the market structure of phthalic anhydride. Six firms are currently producing phthalic anhydride. The four-firm concentration ratio is 84.3 percent, signifying substantial market power. The HHI is 2,067.7, which falls in the range of substantial market power. Captive consumption is 53 percent, indicating a moderate level of vertical integration. On average, two chemical compounds are produced at phthalic anhydride sites, suggesting a slight level of horizontal integration. Imports in the industry are moderately important, hindering pricing discretion of domestic producers. In summary, the market structure of phthalic anhydride is moderately to highly oligopolistic, and firms will likely absorb a significant portion of HON compliance costs.

22.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the phthalic anhydride industry for option one control costs are presented in Table 22-10.

22.2.5.1 Option One Control Cost

Option one control cost represents the actual estimated cost that an industry will incur. The production weighted average percentage price increase of 3.86 percent leads to a price increase $.0258 per kilogram. For the two elasticity levels of -.34 and -.67, the output reduction if 6.1 million kilograms (1.28%) and 12.0 million kilograms (2.50%), respectively.

The maximum decline in output of 12.0 million kilograms makes up 21 percent of the output of the Facility 6A, which is both the smallest facility and the highest cost facility. This is significant, and could lead to closure in the most extreme case where this facility absorbs the entire decline in output. Process B compliance costs are almost three cents per kilogram lower than process A compliance costs. Facility 1B is the only facility using process B. This facility, which has the capability to produce using either process, is backward-integrated into its naphthalene feedstock. If feedstock costs are significantly lower, which they currently appear to be, the process B user maintains a cost-advantage, and does not appear to be the marginal plant. HON control cost differentials serve to reinforce this advantage. In addition, process A costs range from $.0033 per kilogram to $.0501 per kilogram. This cost differential could indicate already existing differences in engineering parameters. The high cost process A users appear to be at a competitive disadvantage. Employment loss ranges from 11 to 22 employees.

TABLE 22-9. MARKET STRUCTURE CHARACTERISTICS FOR PHTHALIC ANHYDRIDE

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced at Site (Horizontal Integration)	Imports
6	84.3%	2,067.7	53%	2	Moderately Important

N.A. - Not Available

[a] Herfindahl-Hirschman Index

TABLE 22-10. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE PHTHALIC ANHYDRIDE INDUSTRY[1], OPTION ONE

	Elasticity	
	-0.34	-0.67
%▲ Price (%/kg)	3.86%	3.86%
▲ Price ($/kg)	$.0258	$.0258
%▲ Output (%/kg)	(1.28%)	(2.50%)
▲ Output (10^6 kg)	(6.1)	(12.0)
%▲ Total Revenue	2.53%	1.26%
▲ Total Revenue (10^6 $)	$8.1	$4.0
▲ Employment (# of Employees)	(11)	(22)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

▲ = Change In

Market Price = $0.67/kg

1995 Output = 477.6 x 10^6 kg (based on 1989 production at 2.5% annual compound growth)

1995 Total Revenue = $319,997,452.03 (market price x 1995 output)

1995 Employment = 872

22.2.6 Conclusion

The range of costs in the option one control scenario is \$.0029 to \$.0501. The differential is significant, indicating that the production-weighted average cost might mask actual price changes in the industry, which could be higher than predicted in this analysis. Since process A users are not backward-integrated into their feedstock, they could be at a disadvantage. The three high-cost process A users will probably share the output reduction, with the possibility of closure for one firm. Since firms are already considering adopting dual-process plants, HON controls could accelerate this consideration.

22.2.7 References

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38. "Naphthalene Robust in 1989 As Phthalic Outlet Performs." Chemical Marketing Reporter, April 10, 1989, pp. 12, 14.

39. "Chemical Profile -- Phthalic Anhydride." Chemical Marketing Reporter, July 24, 1989.

40. "Phthalic Prices Hiked; On Rising Feed Costs." Chemical Marketing Reporter, October 1, 1990, p. 13.

41. "Phthalic Producers Up Prices As Production Expenses Rise." Chemical Marketing Reporter, April 30, 1990, pp. 14-15.

42. Chemical Marketing Reporter, January 8, 1990, p. 31.

43. Chemical Marketing Reporter, April 8, 1991, p. 37.

44. Chemical Marketing Reporter, January 8, 1990, p. 34.

45. Chemical Marketing Reporter, December 31, 1990, p. 32.

46. Chemical Marketing Reporter, April 8, 1991, p. 40.

47. Reference 41.

48. Reference 1.

49. Reference 10.

50. Reference 22.

51. Reference 1.

52. Reference 40.

53. Reference 38.

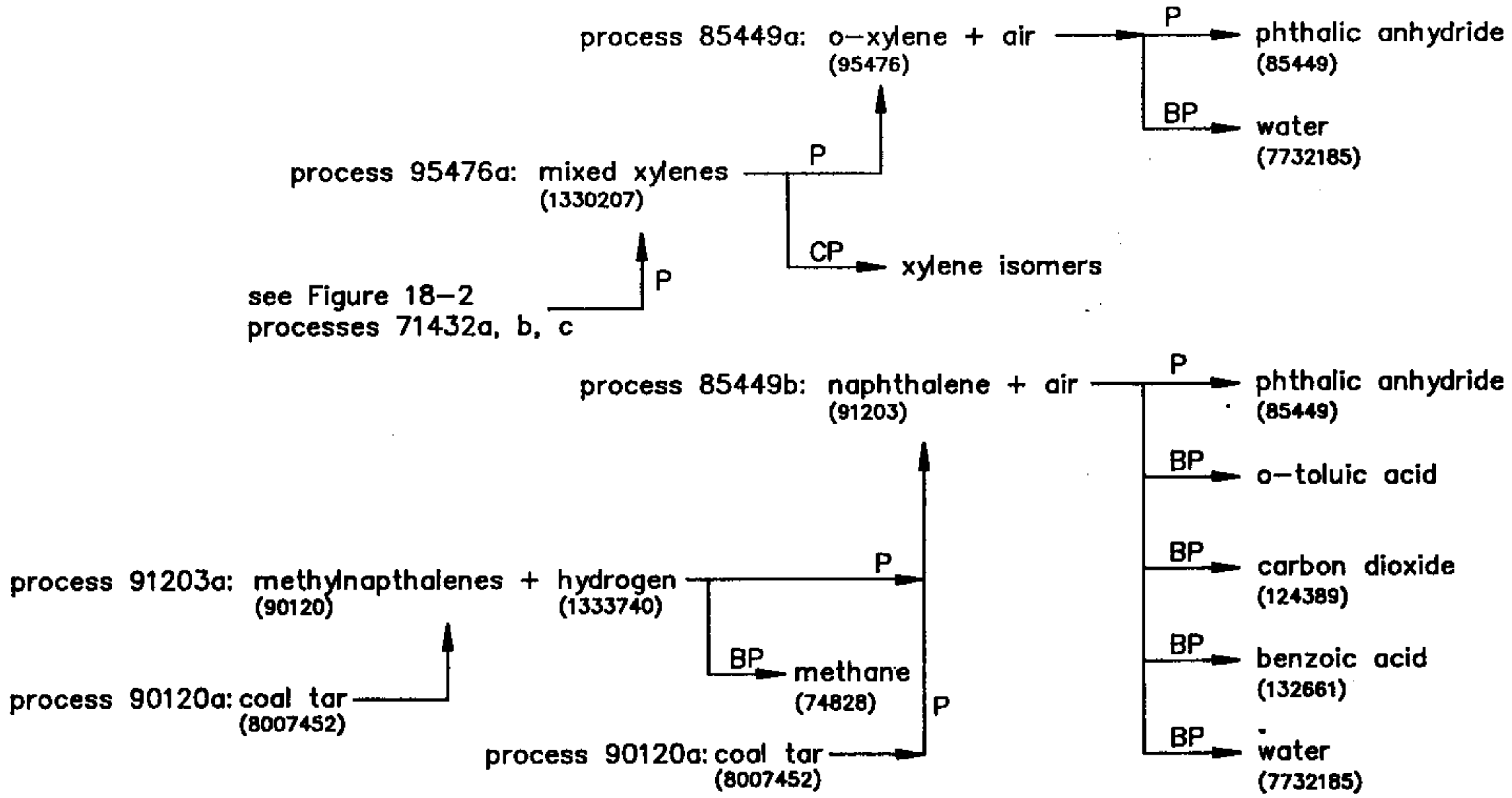
54. Reference 38.

55. "Chemical Profile -- Naphthalene." Chemical Marketing Reporter, November 5, 1990, p. 50.

FIGURE 22-2

CHEMICAL TREE

PHTHALIC ANHYDRIDE



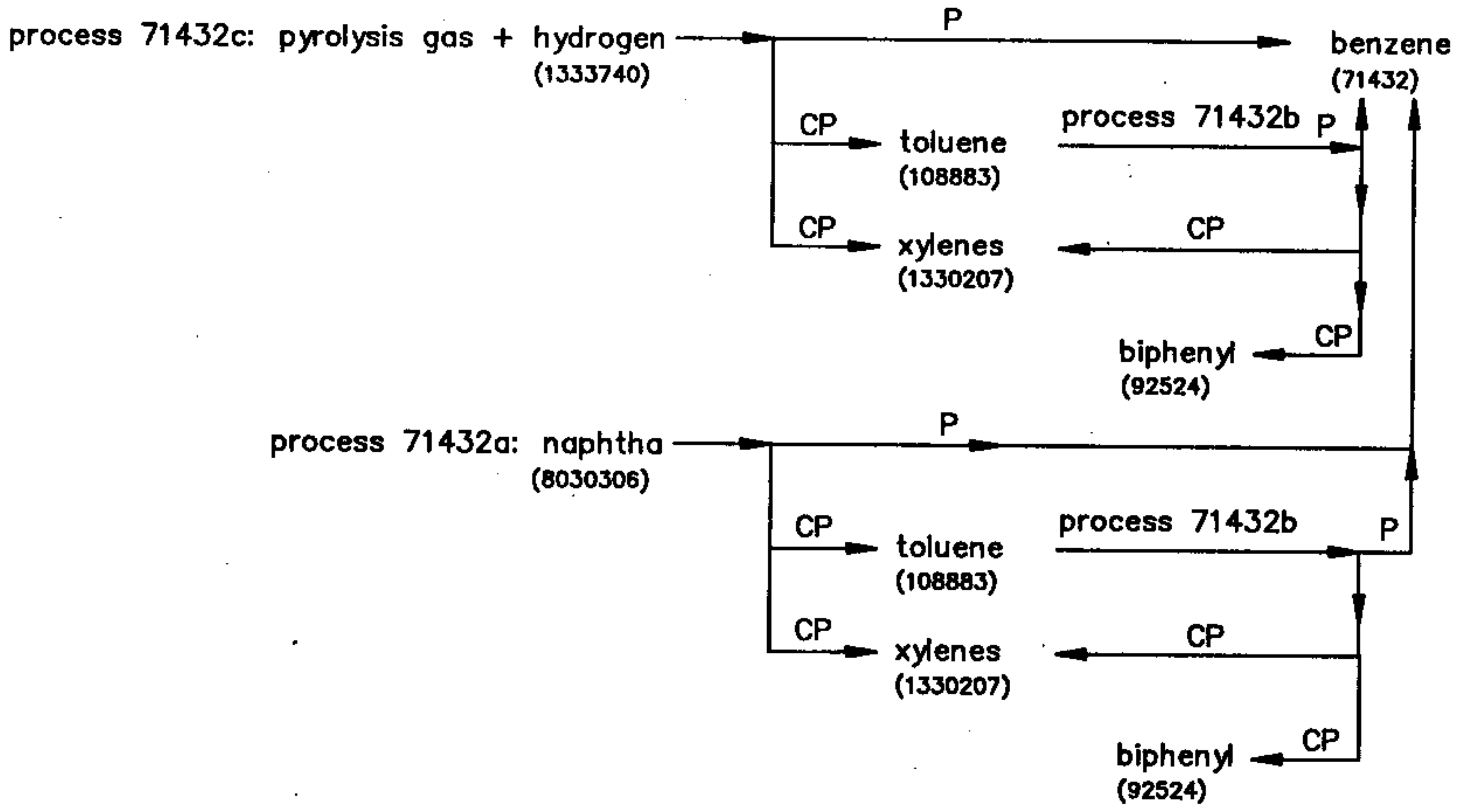
NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

FIGURE 22-3

CHEMICAL TREE

BENZENE



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 23

BENZOIC ACID PRODUCTION

23.1 INDUSTRY PROFILE

Benzoic acid, also referred to as benzenecarboxylic acid or phenylformic acid, is produced by the oxidation of toluene.[1] It has a variety of applications such as the manufacture of phenol, benzoate plasticizers, and sodium and potassium benzoates.[2] The domestic producers used the majority of benzoic acid output captively in 1990.[3]

23.1.1 Brief Market Introduction

23.1.1.1 Historical Overview

Two grades of benzoic acid are available commercially, technical and USP (pharmaceutical).[4] Trade list prices are often discounted.[5]

Data for the average realized price of benzoic acid from 1980 to 1989 are unavailable. Table 23-1 instead contains information concerning the trade list price over the same time period.

After increasing from 1980 to 1981, the trade list prices of the technical-grade and USP-grade remained almost constant throughout the decade. Prices remained constant despite steady growth of domestic demand. The most likely explanation is that declining petroleum costs helped lower toluene costs. Lower feedstock costs resulted in a rightward shift of the supply curve that offset the rightward shift of the demand curve.

In 1989 prices for both grades edged slightly upward due to increased toluene costs.[6]

23.1.1.2 Recent Developments

The trade list price for each benzoic acid grade was in the same range throughout 1990 as in 1989.[7,8] As of April 1991, prices were still unchanged.[9]

TABLE 23-1. TRADE LIST PRICE OF BENZOIC ACID, 1980-1989

	Price ($/kg)	
	Technical-grade	USP (pharmaceutical) - grade
1989	1.21-1.28[a]	3.81-3.86[a]
1988	1.21	3.81
1987	1.21	3.81
1986	1.21	3.81
1985	1.21	3.81
1984	1.15	3.81
1983	1.15	3.81
1982	1.21	3.81
1981	1.21	3.26
1980	1.04	2.20

[a] Price as of December 29, 1989.

NOTE: There is widespread discounting.

Sources: Chemical Marketing Reporter, January 1, 1990, p. 33; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Benzoic Acid," March 1990; SRI International, Chemical Economics Handbook, "Benzoic Acid -- United States," June 1989.

23.1.2 Demand Conditions

23.1.2.1 Uses for Benzoic Acid

Benzoic acid is used in a variety of applications. Table 23-2 lists these applications.

More than half of 1989 production was converted to phenol. To manufacture phenol, benzoic acid is oxidized.[10] Phenol demand is tied to the construction and automotive industries.[11] Both consume many of phenol's derivatives such as phenolic resins, used in plywood and insulation, and bisphenol-A, used in epoxy and polycarbonate resins. Other phenol derivatives include caprolactam, aniline, and xylenols.

Twenty percent of benzoic acid production was consumed in the manufacture of benzoate plasticizers. These plasticizers include diethylene glycol dibenzoate and dipropylene glycol dibenzoate. Specialty polyvinyl chloride compounds, polyvinyl acetate formulations, and elastomers all use benzoate plasticizers.

Sodium benzoate and potassium benzoate are also referred to as the salts of benzoic acid.[12] Together, they accounted for 12 percent of benzoic acid consumption. Both are used in the U.S. mainly as food and beverage preservatives.[13] Sodium benzoate is also used in Japan and Europe as a corrosion inhibitor in antifreeze.[14]

Use in the manufacture of benzoyl chloride accounted for 6 percent of consumption. Benzoyl chloride is used to make catalyst initiators such as tert-butyl perbenzoate and benzoyl peroxide. Used to cure polyesters, benzoyl peroxide is the most widely used organic peroxide.[15]

Benzoic acid is used as a chain terminator in some alkyd resins. It is also used to make butyl benzoate which is used to accelerate and increase the extent of dyeing. Miscellaneous uses include oil and gas well completion fluids and isodecyl benzoate, a paint additive.

23.1.2.2 Consumption

Domestic apparent consumption of benzoic acid from 1980 to 1989 is listed in Table 23-3.

Over the decade consumption has grown, on average, 2.8 percent annually. Though data are unavailable from 1981 to 1984, it is known that both domestically-produced phenol consumption and domestically-produced benzoate plasticizer consumption grew 20 percent between 1982 and 1984.[16]

TABLE 23-2. USES OF BENZOIC ACID, 1989

	Percent of Total Consumption
Phenol	52%
Benzoate plasticizers	20%
Sodium and potassium benzoate	12%
Benzoyl chloride	6%
Alkyd resins	3%
Butyl benzoate	2%
Miscellaneous[a]	5%

[a] Includes oil and gas well completion fluids and isodecyl benzoate.

Source: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Benzoic Acid," March 1990.

TABLE 23-3. APPARENT CONSUMPTION OF BENZOIC ACID IN THE U.S., 1980-1989

	Apparent Consumption[a] (10^6 kg)
1989	87
1988	84
1987	84
1986	76
1985	74
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	68

[a] Production plus imports, minus exports. Because inventory changes are ignored, this is a simplified estimate of consumption. It should also be noted that the production figures and export figures from which apparent consumption is derived are themselves estimates.

N.A. - Not available.

Sources: Chemical Marketing Reporter, March 19, 1990, p. 15; Chemical Marketing Reporter, March 26, 1990, p. 12; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Benzoic Acid," March 1990; SRI International, Chemical Economics Handbook, "Benzoic Acid -- United States," June 1989.

In more recent years increased demand for benzoate plasticizers has driven benzoic acid consumption.[17] Sodium benzoate and potassium benzoate have also grown 3 to 4 percent annually.[18] Demand for benzoylchloride has been steady.[19] Only the smaller-volume end uses have shown little or no growth in demand.[20] The use of benzoic acid in alkyd resins has declined as the resins have lost market share to water-based coatings.[21]

The largest annual increase in consumption occurred in 1987. Consumption increased 11 percent (8 million kilograms) due to strong demand for benzoate plasticizers, the benzoic acid salts, and for phenol.[22]

23.1.2.3 Exports

Data concerning U.S. exports of benzoic acid from 1980 to 1989 are contained in Table 23-4. The ten-year high in terms of quantity and in terms of percentage of production occurred in 1989 when 9.3 million kilograms (10% of production) were exported. This figure may be slightly inflated, however, because it includes both exports of benzoic acid and exports of its salts, sodium benzoate and potassium benzoate. Major destinations for exports include Europe and Japan where sodium benzoate is used as a corrosion inhibitor in antifreeze. Kalama Chemical was the largest exporter of benzoic acid in 1988.[23]

23.1.2.4 Future Prospects

The demand growth for benzoic acid will be influenced to a large extent by future demand for phenol because it accounts for over half of consumption. In the short-run, demand growth for phenol is expected to flatten or decline slightly as the automotive and construction sectors slump.[24] Demand growth will pick up in the long-run as the economy in general recovers from the downturn in 1990.[25] Phenol is expected to grow 2 to 3 percent annually after 1990.[26]

Demand for non-phenol applications is forecast to grow 4 percent annually in the short-run.[27] Benzoate plasticizers will experience growing demand at a rate higher than GNP.[28] The benzoic acid salts will have more moderate demand growth of approximately 3 percent annually.[29] This is despite growing competition from imports.[30] Smaller-volume applications will experience flat growth in demand.[31]

TABLE 23-4. U.S. EXPORTS OF BENZOIC ACID, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1989	9.3b	10.0%
1988	5.9	6.7%
1987	5.0	5.7%
1986	3.2	4.1%
1985	1.8	2.4%
1984	0.8	N.A.
1983	0.9	N.A.
1982	0.7	N.A.
1981	1.0	N.A.
1980	0.9	1.3%

[a] See Table 23-6.

[b] Census Bureau's figure including benzoic acid and its salts.

N.A. - Not available.

NOTE: Export figures from 1980 to 1988 are estimates.

Sources: Chemical Marketing Reporter, March 19, 1990, p. 15; SRI International, Chemical Economics Handbook, "Benzoic Acid -- United States," June 1989.

Overall, demand for domestically-produced benzoic acid will grow 2 percent annually through 1994.[32]

23.1.3 Supply Conditions

23.1.3.1 Production Processes

The liquid phase oxidation of toluene, employing various cobalt catalysts, is the process used to manufacture benzoic acid. Benzaldehyde is produced as a coproduct.[33] Information concerning each producer's process is proprietary.[34] However, it is safe to assume that to treat their vent gases most producers are using adsorption or activated carbon rather than scrubbers.[35]

23.1.3.2 Domestic Producers and Total Production

There are three domestic producers of benzoic acid, each having one facility (Table 23-5). Total industry capacity in 1990 was 111 million kilograms.

Kalama Chemical controls 69 percent of total capacity. It is the only producer to use crude benzoic acid as a raw material for phenol production. In 1990, Kalama had 1.7 percent (32 million kilograms) of total phenol capacity.[36] Kalama also sells benzoic acid to the merchant market.[37]

Pfizer and Velsicol produce only refined benzoic acid.[38] Pfizer controls 5 percent of benzoic acid capacity and dedicates its capacity to the production of sodium benzoate and potassium benzoate. Velsicol concentrates on the production of benzoic acid esters (benzoate plasticizers and butyl benzoate) and benzoyl chloride. The company controls 26 percent of benzoic acid capacity.

Table 23-6 contains production data from 1980 to 1989. Total benzoic acid production rose throughout the decade and peaked in 1989 at 92 million kilograms. Production in terms of material used for phenol and material used for non-phenol derivatives also rose throughout the decade and peaked in 1989. The largest increase in total production occurred in 1987. The 10 million kilogram increase resulted from strong demand for benzoate plasticizers, benzoic acid salts, and crude benzoic acid used in phenol production.

23.1.3.3 Costs of Production

The costs of production for benzoic acid are determined by toluene costs and, in turn, petroleum costs. Declining petroleum

TABLE 23-5. U.S. PRODUCERS OF BENZOIC ACID, 1990

Company	Location	Capacity (10^6 kg/yr)
Kalama[a]	Kalama, WA	77[b,c]
Pfizer	Terre Haute, IN	5[d]
Velsicol	Chattanooga, TN	29[e]
		111

[a] Kalama is a subsidiary of the BC Sugar Group, a Canadian sugar refinery. It has a sister company, Chatterton Petrochemical of Vancouver, BC.

[b] Kalama is in the midst of a 23 million kilogram joint increase in capacity with Chatterton Petrochemical.

[c] Over half of Kalama's output is converted to phenol.

[d] Pfizer's capacity is dedicated to sodium benzoate and potassium benzoate production.

[e] Velsicol emphasizes production of benzoate plasticizers, butyl benzoate, and benzoyl chloride.

Source: Chemical Marketing Reporter, October 8, 1990, p. 50; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Benzoic Acid," March 1990.

TABLE 23-6. U.S. PRODUCTION OF BENZOIC ACID, 1980-1989

	Quantity (10^6 Kg)		
	Total[a]	For Phenol[b]	For Other Uses
1989	92	48	44 (est.)
1988	88	45	43 (est.)
1987	88	45	43
1986	78	45	33
1985	75	43	32
1984	N.A.	N.A.	30
1983	N.A.	N.A.	29
1982	N.A.	N.A.	28
1981	N.A.	N.A.	36
1980	69	36	33

[a,b] Total production figures for benzoic acid and production figures for benzoic acid converted to phenol are estimates.

N.A. - Not available.

est. - Estimate.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Benzoic Acid," March 1990; SRI International, Chemical Economics Handbook, "Benzoic Acid -- United Sates," June 1989.

costs kept toluene costs down throughout most of the 1980s. In 1988, toluene costs began to rise in response to rising petroleum prices.[39]

In 1990, toluene costs were in the range of $0.96 to $1.03 per gallon as of January; they ended the year in the range of $0.87 to $0.92 per gallon.[40,41] As of April 1991, toluene was selling from $0.88 to $0.89 per gallon.[42]

23.1.3.4 Imports

Imports reached a ten-year high in 1989 of 3.9 million kilograms, or 4.5 percent of domestic consumption (Table 23-7). Of this total, imports from Canada accounted for over 50 percent.[43] Chatterton Petrochemical (Vancouver, BC) exports large amounts of sodium benzoate to the U.S. where most North American beverage production occurs.[44] The firm DSM of The Netherlands is also a major exporter of benzoic acid to the U.S. market.[45]

23.1.3.5 Future Prospects

The supply of benzoic acid will be more than sufficient to meet expected domestic demand, according to Mannsville Chemical Products Corporation.[46]

Total industry capacity will increase as Kalama and its sister facility, Chatterton Petrochemical, undertake a joint 23 million kilogram capacity expansion, Kalama is making this move in an effort to decrease its reliance on phenol, and in order to increase production of non-phenol applications.[47] Competition in non-phenol markets may increase as a result.

The costs of production for benzoic acid will continue to be reliant on toluene costs and, in turn, petroleum costs.

23.1.4 Future Market Prospects

Domestically-produced benzoic acid will face growing demand of only 2 percent annually through 1994. The best prospects are for non-phenol applications, forecast to have demand growth of 4 percent annually in the short run. The short-run demand for phenol is expected to flatten or decline due to the slumping housing and auto sectors.

In an effort to take advantage of higher growth rates, Kalama Chemical is expanding capacity with an emphasis on non-phenol applications, primarily benzoate plasticizers and sodium benzoate.

TABLE 23-7. U.S. IMPORTS OF BENZOIC ACID, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Consumption[a]
1989	3.9[b]	4.5%
1988	2.2	2.6%
1987	1.1	1.3%
1986	0.9	1.2%
1985	0.5	0.7%
1984	0.3	N.A.
1983	0.4	N.A.
1982	0.2	N.A.
1981	0.1	N.A.
1980	Neg.	Neg.

[a] See Table 23-3.

[b] Census Bureau's figure for benzoic acid and other salts.

N.A. - Not available.

Sources: Chemical Marketing Reporter, March 26, 1990, p. 12; SRI International, Chemical Economics Handbook, "Benzoic Acid -- United States," June 1989.

This move may result in increased competition between the three domestic producers, particularly in non-phenol markets.

23.2 ECONOMIC IMPACT ANALYSIS

23.2.1 HON Compliance Costs

A synopsis of annualized cumulative control costs and summary statistics for benzoic acid production facilities presented in Table 23-8. Costs are presented for option one control costs. Option one control costs are estimates of the actual costs that facilities are likely to occur. Figure 23-1 illustrates control costs graphically. Three facilities are displayed.

Benzoic Acid is currently produced via oxidation toluene. Since this is the only commercial process, no analysis of separate process costs is necessary.

23.2.2 Pricing

Benzoic acid prices are determined by a combination of feedstock costs and end-use demand. Toluene, the primary feedstock in benzoic acid, is expected to grow slowly. Its principle use is as a blendstock in the gasoline pool, and legislation reducing the aromatic content of gasoline is hindering toluene growth. Phenol is the driving end-use, and is projected to grow slowly as it's demand is tied closely to growth of the general economy. Demand for non-phenol end-uses will grow at about 4 percent annually, providing for the bulk of benzoic acid growth in demand, and should keep prices firm.

23.2.3 Elasticities

The demand elasticity for benzoic acid is estimated on the basis of available substitutes for benzoic acid, as well as substitutes for end-uses. The potential for import substitution is also examined.

23.2.3.1 Demand Elasticities

23.2.3.1.1 Phenol

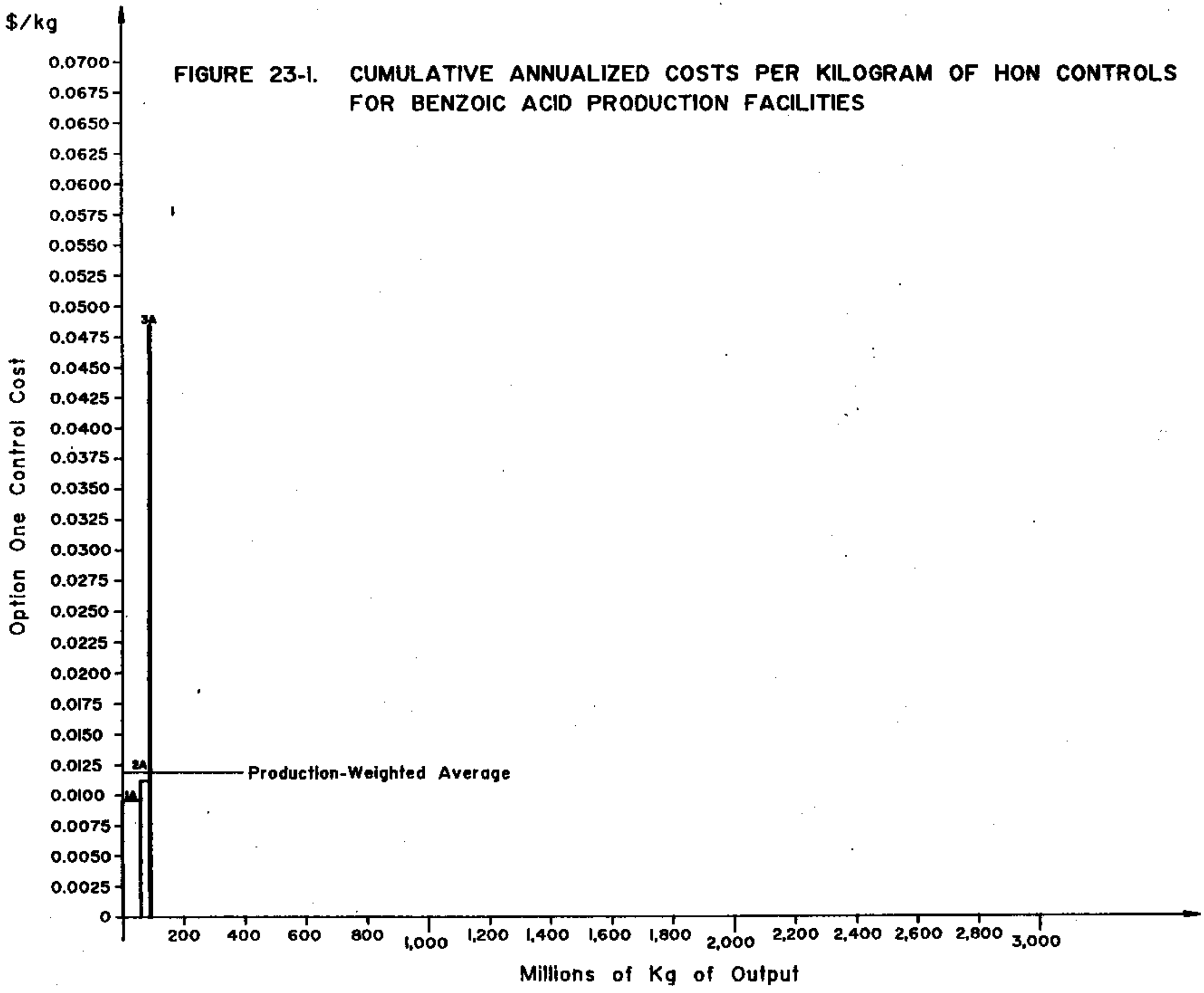
The largest end use for benzoic acid is phenol, accounting for 52 percent in 1989. Over 97 percent of phenol is produced with cumene as a feedstock, with less than three percent produced via toluene and benzoic acid. Substituting cumene for toluene and benzoic acid can be done fairly easily.

Phenolic resins are the primary phenol derivative, making up 38 percent of its end-uses. There are many alternatives to these resins,

TABLE 23-8. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR BENZOIC ACID PRODUCTION

Facility/ Process	Annual Production (10^6 kg)	Option One Controls ($/kg)
1A	59.6	$0.0096
2A	27.7	$0.0112
3A	4.3	$0.0484
<u>Summary Statistics</u>		
Mean		$0.0231
Production Weighted Average		$0.0119

FIGURE 23-1. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR BENZOIC ACID PRODUCTION FACILITIES



but they remain attractive owing to their low cost. Drawbacks are difficulty in re-use/recycling, and deficiency in impact resistance. As such, some more expensive thermosets such as alkyds and diallyl phthalate-based products are sometimes employed. Demand elasticity is estimated to be slightly inelastic in this sector.

23.2.3.1.2 Benzoate Plasticizers

Benzoate plasticizers make up 20 percent of benzoic acid demand. These plasticizers are commonly used to produce polyvinyl chloride and polyvinyl alcohol. A variety of substitutes with similar properties exist, including epoxidized soybean oil and phosphoric acid derivatives, such as isopropyl phenyl diphenyl phosphate and t-butyl phenyl diphenyl phosphate. Demand for benzoic acid in this sector is regarded as slightly inelastic.

23.2.3.1.3 Sodium and Potassium Benzoate

Sodium and potassium benzoate make up 12 percent of benzoic acid demand. These compounds are used as food and beverage preservatives, as well as a corrosion inhibitor in antifreeze. As food preservatives, a variety of substitutes exist, including sulfur dioxide and sulfites, nitrates and nitrites, and sorbic acid. As a corrosion inhibitor, substitutes are benzene sulfonic acid, butylamines, and some inorganics, to name a few. Demand for benzoic acid in this sector is deemed slightly inelastic.

23.2.3.2 Imports

Imports of benzoic acid have been growing steadily, and in 1989 made up 4.5 percent of domestic consumption. The majority of these imports come from Canada. Although not very high in absolute terms, the trend in growth of imports suggests that U.S. producers must consider the possibility of import substitution due to price increases.

23.2.3.3 Elasticity Estimate

In all cases, the demand elasticity is in the slightly inelastic range, hovering near unity. The demand elasticity is estimated to be between -.67 and -1.00.

23.2.4 Market Structure

In the U.S., 3 firms are currently producing benzoic acid. Importantly, these three firms don't appear to be in direct competition with each other. Each firm is vertically integrated into a different end-use, to the exclusion of other end-uses, and are therefore operating in different markets (see Section 23.1.4).

The market leader is reliant on conversion of benzoic acid to phenol. Since it manufacturers less than 3 percent of the domestically produced phenol, it appears to be a price taker. This firm also sells benzoic acid on the merchant market, and is considering entering non-phenol applications as the phenol market is weak.

The second largest producer devotes its benzoic acid share to the production of benzoate plasticizers. It is not known how many other firms produce benzoate plasticizers. However, it is likely that this firm is the industry leader. No other benzoic acid producers manufacture benzoate plasticizers, and the merchant market for benzoic acid is very small. If this firm is facing a less than perfectly elastic firm level demand curve, the price increase will be less than in the perfectly competitive case.

The smallest producer dominates the sodium benzoate and potassium benzoate market. These firms currently produce these salts. (The largest benzoic acid firm produces small amounts of these salts, as does one other.) Again, if this firm is facing a less than perfectly elastic firm level demand curve, the price increase will be less than in the perfectly competitive case.

23.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the benzoic acid industry are presented in Tables 23-9, 1A-3A, for option one control costs. Benzoic acid producers each cater to a different end-use market, and will therefore be impacted according to their individual compliance costs. In this case, the production-weighted average cost is irrelevant, and the three firms are analyzed separately.

23.2.5.1 Facility 1A

23.2.5.1.1 Option One Control Costs

Option one control costs represent the maximum HON control cost that an industry will incur. The weighted average percentage price increase of .75 percent leads to a price increase $.0096 per kilogram. For the two elasticity levels of -.67 and -1.00, the output reduction is 334 thousand kilograms and 498 thousand

TABLE 23-9(1A). IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE BENZOIC ACID INDUSTRY FOR FACILITY 1A[1], OPTION ONE CONTROL COSTS

	Elasticity	
	-0.67	-1.00
%Δ Price (%/kg)	0.75%	0.75%
Δ Price ($/kg)	$.0096	$.0096
%Δ Output (%/kg)	(0.50%)	(0.74%)
Δ Output (10^6 kg)	(.334)	(.498)
%Δ Total Revenue	0.25%	0.00%
Δ Total Revenue (10^6 $)	$.211	$0.00
Δ Employment (# of Employees)	(1)	(2)

[1] Vertically integrated into phenol production.

DEFINITIONS:

Δ = Change In

Market Price = $1.28/kg

1995 Output = 59.6 x 10^6 kg (based on 1989 production at 2% annual compound growth)

1995 Total Revenue = $85,934,012.66 (market price x 1995 output)

1995 Employment = 234

TABLE 23-9(2A). IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE BENZOIC ACID INDUSTRY FOR FACILITY 2A[1], OPTION ONE CONTROL COSTS

	Elasticity	
	-0.67	-1.00
%Δ Price (%/kg)	0.88%	0.88%
Δ Price ($/kg)	$.0112	$.0112
%Δ Output (%/kg)	(0.58%)	(0.87%)
Δ Output (10^6 kg)	(.204)	(.304)
%Δ Total Revenue	.29%	0.00%
Δ Total Revenue (10^6 $)	$.129	$0.00
Δ Employment (# of Employees)	(1)	(1)

[1] Vertically integrated into benzoate plasticizer production.

DEFINITIONS:

Δ = Change In

Market Price = $1.28/kg

1995 Output = 27.7 x 10^6 kg (based on 1989 production at 4% annual compound growth)

1995 Total Revenue = $44,835,617.78 (market price x 1995 output)

1995 Employment = 122

TABLE 23-9(3A). IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE BENZOIC ACID INDUSTRY FOR FACILITY 3A[1], OPTION ONE CONTROL COSTS

	Elasticity	
	-0.67	-1.00
%Δ Price (%/kg)	3.78%	3.78%
Δ Price ($/kg)	$.0484	$.0484
%Δ Output (%/kg)	(2.46%)	(3.64%)
Δ Output (10^6 kg)	(.125)	(.185)
%Δ Total Revenue	1.23	0.00%
Δ Total Revenue (10^6 $)	$.080	$0.00
Δ Employment (# of Employees)	0	0

[1] Vertically integrated into sodium benzoate and potassium benzoate.

DEFINITIONS:

Δ = Change In

Market Price = $1.28/kg

1995 Output = 4.3 x 10^6 kg (based on 1989 production at 3% annual compound growth)

1995 Total Revenue = $6,508,177.27 (market price x 1995 output)

1995 Employment = 18

kilograms, respectively. This facility accounts for 59.6 million kilograms of industry production. Its decline in output due to HON controls is from .56 percent to .84 percent of its production, which will not lead to closure. Employment loss is estimated to be from one to two employees.

23.2.5.2 Facility 2A

23.2.5.2.1 Option One Control Costs

The weighted average percentage price increase of .88 percent leads to a price increase $.0112 per kilogram. For the two elasticity levels of -.67 and -1.00, the output reduction is 204 thousand kilograms and 305 thousand kilograms, respectively. This facility accounts for 27.7 million kilograms of industry production. Its decline in output due to HON controls is from .74 percent to 1.1 percent of its production, which will not lead to closure. Employment loss is estimated to be one employee.

23.2.5.3 Facility 3A

23.2.5.3.1 Option One Control Costs

The weighted average percentage price increase of 3.78 percent leads to a price increase $.0484 per kilogram. For the two elasticity levels of -.67 and -1.00, the decrease in output is 125 thousand kilograms and 185 thousand kilograms, respectively. This facility accounts for 4.3 million kilograms of industry production. Its decline in output due to HON controls is from 2.9 percent to 4.3 percent of its production, which will not lead to closure. Employment loss is estimated to be 0 employees.

23.2.6 Conclusion

Three benzoic acid manufacturers produced about 91.6 million kilograms of product in 1989. However, since each of the three firms operates in a different market, impacts must be assessed on each firm, given firm-level HON controls. In each case, the impact of HON controls is small. The price increases in non-phenol applications could well accelerate the entrance of the largest firm (which produces phenol) into these markets.

23.2.7 References

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3. "Chemical Profile -- Benzoic Acid." Chemical Marketing Reporter, October 8, 1990.

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33. Reference 1.

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35. Reference 1.

36. Reference 11.

37. Reference 1.

38. Reference 1.

39. Mannsville Chemical Products Corp. "Chemical Products Synopsis -- Toluene." Asbury Park, NJ, March 1990.

40. Chemical Marketing Reporter, January 8, 1990, p. 34.

41. Chemical Marketing Reporter, December 31, 1990, p. 32.

42. Chemical Marketing Reporter, April 8, 1991, p. 40.

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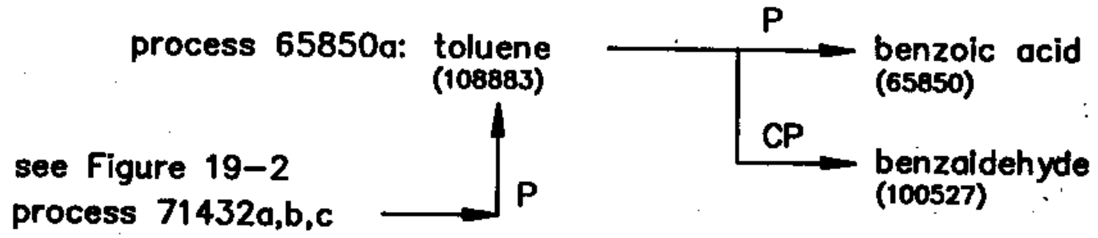
46. Reference 1.

47. "Benzoic Acid Expansion: Market Cool in Response." Chemical Marketing Reporter, January 15, 1990, pp. 5,12.

FIGURE 23-2

CHEMICAL TREE

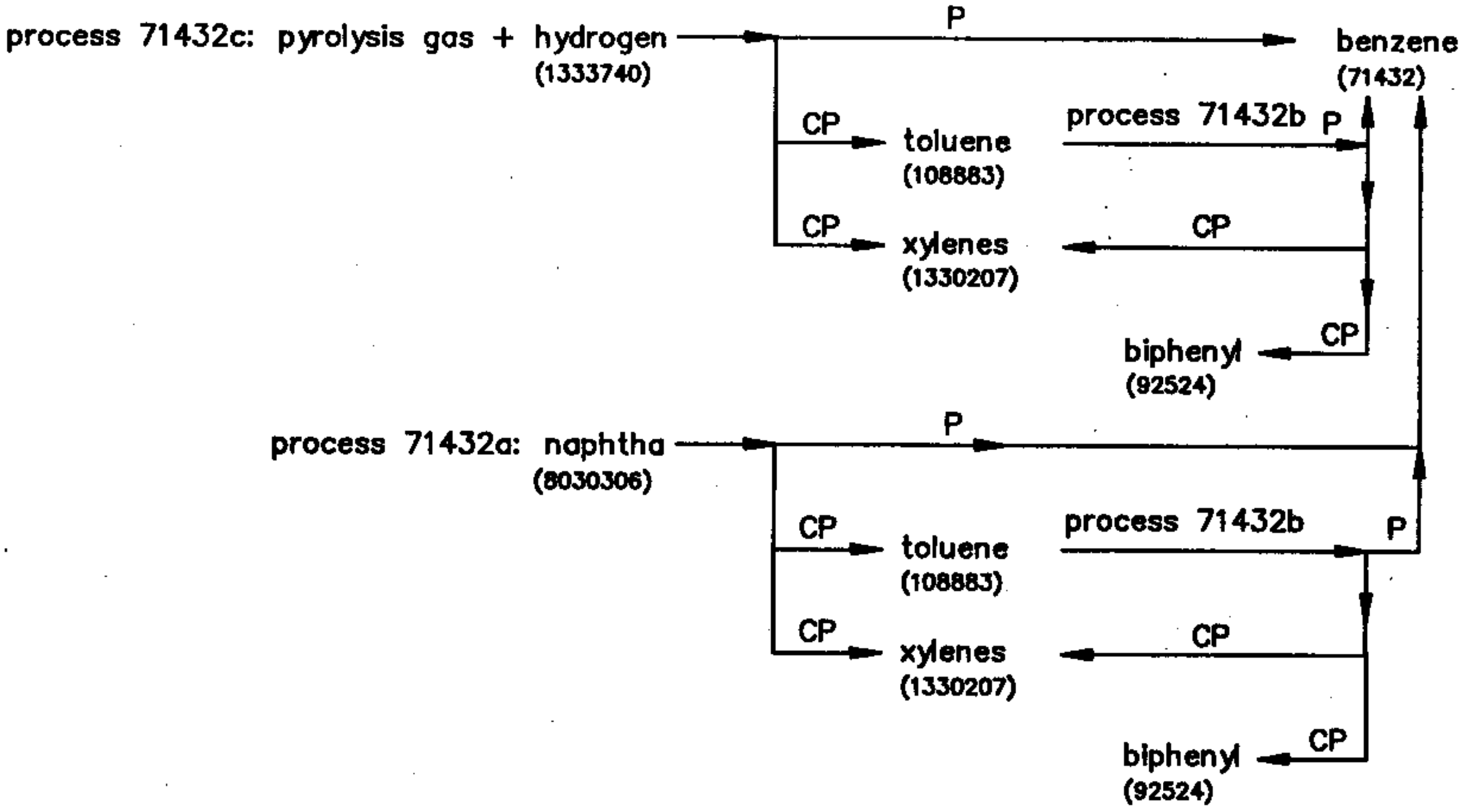
BENZOIC ACID



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

FIGURE 23-3
CHEMICAL TREE
BENZENE



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 24

ACRYLONITRILE PRODUCTION

24.1 INDUSTRY PROFILE

Acrylonitrile is a chemical intermediate categorized as an organic nitrile.[1] It is used in a variety of applications including acrylic fibers, high-impact resins, and adiponitrile. To manufacture acrylonitrile, most producers use the "Sohio process" which involves the oxidation of propylene and anhydrous, fertilizer-grade ammonia.[2] Fifty-seven percent of domestic production in 1989 was consumed captively.[3]

24.1.1 Brief Market Introduction

24.1.1.1 Historical Overview

Table 24-1 lists the average realized price of acrylonitrile from 1980 to 1989. From 1986 to 1988 price rose in response to increasing demand.[4,5] Increased propylene costs in 1988 also put upward pressure on price.[6] The 1988 price of 82 cents per kilogram was the ten-year high.

After reaching this ten-year high, the price of acrylonitrile fell 9 percent in 1989 to 75 cents per kilogram. There was downward pressure on price due to lower domestic demand as well as lower foreign demand.[7]

Discounting is common; therefore, trade list prices are higher than actual selling prices.[8]

24.1.1.2 Recent Developments

The trade list price of acrylonitrile in January 1990 ranged from 93 to 99 cents per kilogram.[9] By July it had fallen to 77 cents, despite a slight rise in propylene costs.[10] The price rose back to 85 cents by December, however, as both propylene costs and ammonia costs rose.[11] As of April 1991, acrylonitrile's price was still 85 cents.[12]

Domestic producers have had trouble raising price in response to increased feedstock costs.[13] This has been because of depressed acrylonitrile demand. As a result, profit margins have been so low that producers are claiming that they lose money by producing acrylonitrile.[14]

TABLE 24-1. AVERAGE REALIZED PRICE OF ACRYLONITRILE, 1980-1989

	Price (¢/kg)
1989	75
1988	82
1987	64
1986	57
1985	68
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	62

N.A. - Not available

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Acrylonitrile," May 1990; U.S. International Trade Commission, Synthetic Organic Chemicals, 1988, 1989.

24.1.2 Demand Conditions

24.1.2.1 Uses for Benzoic Acid

Acrylic and modacrylic fibers consumed 46 percent of 1989 acrylonitrile production (Table 24-2). Sixty-five to seventy percent of these fibers were used in apparel applications, thirty percent in home furnishings, and the remainder in industrial applications.[15]

Twenty-seven percent of acrylonitrile output was used to manufacture acrylonitrile-butadiene-stryrene (ABS) resins and styrene-acrylonitrile (SAN) resins. These high-impact resins compete with engineering resins and commodity-type resins.[16] ABS resins are used in appliances, business machines, telephones, transportation equipment, recreation equipment, luggage, and construction equipment. SAN resin applications include appliances, automobiles, housewares, and packaging. Acrylonitrile makes up about 25 percent of an ABS resin and about 30 percent of a SAN resin.[17]

Adiponitile (14 percent) is an intermediate used to manufacture nylon 6,6 fibers and plastic resins.

The catalytic hydrolysis of acrylonitrile produces acrylamide.[18] Acrylamide accounted for 6 percent of 1989 consumption of acrylonitrile. The chemical is used in various applications including water treatment, oil drilling, pulp and paper production, and mineral processing.

Miscellaneous acrylonitrile applications include use in the production of nitrile elastomers and polyacrylonitrile. Nitrile elastomers find use in fuel-line-type applications, latex coatings for oil-resistant papers, leather, and textiles. Polyacrylonitrile is a precursor for carbon-fiber used in high-strength applications. Examples of these applications are aircraft parts and golf-club shafts.

24.1.2.2 Consumption

Table 24-3 lists the domestic apparent consumption of acrylonitrile from 1980 to 1989.

After falling 12 percent (76 million kilograms) from 1985 to 1986, apparent consumption increased through 1988. This growth occurred despite lackluster demand for acrylic fibers over the last several years.[19] Consumption grew due in part to strong demand for ABS resins; in response to this demand, production of ABS resins grew at least 7 percent annually from 1986 to 1988.[20] Polyacrylonitrile applications, though low-volume, also grew substantially in the last

TABLE 24-2. USES OF ACRYLONITRILE, 1989

	Percent of Total Consumption
Acrylic and modacrylic fibers	46%
High-impact resins: Acrylonitrile-butadiene-styrene (ABS) resins - 22% Styrene-acrylonitrile (SAN) resins - 5%	27%
Adiponitrile	14%
Acrylamide	6%
Miscellaneous[a]	7%

[a] Includes nitrile elastomers, polyacrylonitrile.

Source: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Acrylonitrile," May 1990.

TABLE 24-3. APPARENT CONSUMPTION OF ACRYLONITRILE IN THE U.S., 1980-1989

	Apparent Consumption[a] (10^6 kg)
1989	643[b]
1988	674
1987	591
1986	561
1985	637
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	653

[a] Production plus imports, minus exports. Because inventory changes are ignored, this is a simplified estimate of consumption. Imports of acrylonitrile were not significant during the period, thus were not factored into the calculation.

[b] This figure may be overstated due to substantial inventory buildup.

Sources: Chemical & Engineering News, June 18, 1990, p. 39; Chemical Marketing Reporter, March 5, 1990, p. 15; Mannsville Chemical Products Corp., "Chemical Product Synopsis -- Acrylonitrile," May 1990; U.S. International Trade Commission, Synthetic Organic Chemicals, 1989.

several years.[21] The demand for acrylic fibers, as well as for other acrylonitrile applications, was strong in 1988.[22] As a result, apparent consumption grew 14 percent (83 million kilograms) to reach a ten-year high of 674 million kilograms.

The quantity demanded subsequently dropped 5 percent (31 million kilograms) in 1989 as domestic demand dropped. It should be noted that the figure for 1989 may be overstated. A decrease in exports led to substantial inventory buildup.[23] As stated in the table, inventory changes are ignored in estimating apparent consumption.

24.1.2.3 Exports

As can be seen in Table 24-4, there was significant worldwide demand in the 1980s for domestically-produced acrylonitrile. From 1985 to 1989 exports accounted for at least 40 percent of production. The ten-year high occurred in 1987 when 521.2 million kilograms of acrylonitrile were shipped abroad. By 1989 exports were down to 428.4 kilograms as worldwide demand fell. This led to substantial inventory buildup in the U.S.[24]

U.S. exports continued to suffer in 1990 due to lower worldwide demand and increasing worldwide capacity.[25,26] Nevertheless, the U.S., according to Chemicalweek, was the world's largest supplier of acrylonitrile.[27]

U.S. exports helped to keep capacity utilization rates near the 100 percent mark during the 1980s, especially in the latter years.[28]

24.1.2.4 Future Prospects

There are a variety of demand growth forecasts for acrylonitrile, despite the fact that most of its applications are mature.[29]

The Mannsville Chemical Products Corporation has forecast demand growth to be in the vicinity of GNP.[30] Acrylic fibers will face continued competition from synthetic and natural fibers such as nylon, polyester, and cotton. The ABS and SAN resins will have decent growth. ABS resins in particular are becoming more of a specialty product, eliminating some of the competition from engineering resins and commodity-type resins. Acrylamide will also experience good long-term growth in demand.

Some trade sources are more optimistic in their forecast. The Freedonia Group expects demand growth for acrylonitrile of 4.3 percent annually through 1993.[31] Demand will reach 771 million kilograms. Over the same time period acrylic fibers will grow 3.1 percent

TABLE 24-4. U.S. EXPORTS OF ACRYLONITRILE, 1980-1989

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1989	428.4	40.0%
1988	509.4	43.1%
1987	521.2	46.9%
1986	428.6	43.3%
1985	428.2	40.2%
1984	N.A.	N.A.
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	176.9	21.3%

[a] See Table 24-6.

N.A. - Not available.

Sources: <u>Chemical Marketing Reporter</u>, March 5, 1990, p. 15; Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Acrylonitrile," May 1990.

annually while ABS resins will grow more slowly at an annual rate of 2.4 percent. SAN resins will expand more quickly, 4.6 percent annually. The fastest growth, however, will be in nitrile elastomers, whose demand is forecast to grow 6.6 percent annually through 1993.

The world demand for acrylonitrile is forecast to grow from 3.4 billion kilograms in 1990 to 4.2 billion kilograms in 1996, according to BP Chemicals.[32] The firm expects all end uses to grow, with adiponitrile and ABS and SAN resins growing 5 percent annually. Acrylamide will grow 4 percent annually, acrylic fibers 2.3 percent, and nitrile elastomers anywhere from 1 to 3 percent.

Exports will decline due to increased capacity overseas.[33]

24.1.3 Supply Conditions

24.1.3.1 Production Processes

Every domestic producer of acrylonitrile uses the Sohio process.[34] This process involves manufacturing acrylonitrile by the oxidation of propylene and anhydrous, fertilizer-grade ammonia. Hydrogen cyanide and acetonitrile are produced as coproducts. Worldwide, the Sohio process is employed by 90 percent of all facilities.[35]

24.1.3.2 Domestic Producers and Total Production

Information concerning domestic producers of acrylonitrile is contained in Table 24-5. Total industry capacity is 1,306 million kilograms. This capacity is divided among 5 companies and 6 facilities. BP Chemicals controls the largest share of capacity, approximately 35 percent.

Table 24-6 lists production data from 1980 to 1989. Except for a drop in 1986, the production of acrylonitrile rose steadily from 1980 to 1988, reaching a high of 1,183 million kilograms in 1988. In 1989, production fell 112 million kilograms (9 percent) in response to decreased demand for acrylonitrile worldwide.

From 1985 to 1988, capacity-utilization rates have, for the most part, been close to 100 percent. The production of acrylonitrile in 1989 represented 89 percent of industry capacity.[36]

24.1.3.3 Costs of Production

The production costs for acrylonitrile are mainly determined by propylene costs.[37] Acrylonitrile consumed 14 percent of propylene output in 1989.[38] Costs are also dependent on the cost of anhydrous, fertilizer-grade ammonia.

TABLE 24-5. U.S. PRODUCERS OF ACRYLONITRILE, 1990

Company	Location	Capacity (10^6 kg/yr)
American Cyanamid	Fortier, LA	145
BP Chemicals (Sohio Division)[a]	Greenlake, TX Lima, OH	272 181
DuPont	Beaumont, TX	172
Monsanto	Chocolate Bayou, TX	218
Sterling Chemicals	Texas City, TX	318
		1,306

[a] In 1990 BP Chemicals was in the process of adding 90.7 million kilograms of capacity through expansions at both of its facilities.

Sources: Mannsville Chemical Products Corp., "Chemical Products Synopsis -- Acrylonitrile," May 1990;

TABLE 24-6. U.S. PRODUCERS OF ACRYLONITRILE, 1980-1989

	Quantity (10^6kg)
1989	1,071
1988	1,183
1987	1,112
1986	990
1985	1,065
1984	1,007
1983	973
1982	923
1981	906
1980	830

Sources: Chemical & Engineering News, June 18, 1990, p. 39; U.S. International Trade Commission, Synthetic Organic Chemicals, 1989.

In January 1990, propylene costs were in a range of 30 to 34 cents per kilogram.[39] By December the range increased to 52 to 54 cents.[40] However, by April 1991 propylene costs had fallen to a 41 to 45 cent range.[41]

The cost of anhydrous, fertilizer-grade ammonia cost in January 1990 ranged from 12 to 13 cents per kilogram.[42] It subsequently rose to a range of 16 to 17 cents by December and was unchanged as of April 1991.[43,44]

24.1.3.4 Imports

Imports of acrylonitrile were negligible throughout the 1980s.[45] However, demand for domestically-produced acrylonitrile has recently been hurt by imports of acrylic-based textiles and apparel.[46]

24.1.3.5 Future Prospects

No significant capacity expansions are expected in the near future.

With respect to feedstocks, no long-term supply problems are expected for acrylonitrile's main feedstock, propylene.[47] In fact, the propylene industry may reach a state of overcapacity once planned capacity additions come on stream. Steady growth in other propylene derivatives will keep prices from lowering significantly, however.[48]

24.1.4 Future Market Prospects

There are varying forecasts for the demand growth of acrylonitrile.
One forecast calls for close to GNP growth, while a trade source expects 4.3 annual growth. World demand is expected to grow from 3.4 billion kilograms in 1990 to 4.2 billion by 1996. U.S. exports will decline nevertheless due to increased acrylonitrile capacity worldwide.

The costs of production will not rise significantly because propylene is expected to be in abundant supply.

24.2 ECONOMIC IMPACT ANALYSIS

24.2.1 HON Compliance Costs

A synopsis of annualized compliance costs and summary statistics for acrylonitrile is presented in Table 24-7. Costs are displayed for option one controls. Option one controls are estimates of the actual control costs that facilities are likely to incur. Figure 24-1 illustrates control costs graphically. Six facilities are displayed.

TABLE 24-7. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR ACRYLONITRILE PRODUCTION FACILITIES

Facility/ Process	Annual Production (10^6 kg)	Option One Controls ($/kg)
1A	159.0	$0.0019
2A	272.0	$0.0021
3A	159.0	$0.0024
4A	218.0	$0.0060
5A	222.0	$0.0060
6A	175.0	$0.0069
<u>Summary Statistics</u>		
Mean		$0.0042
Production Weighted Average		$0.0042

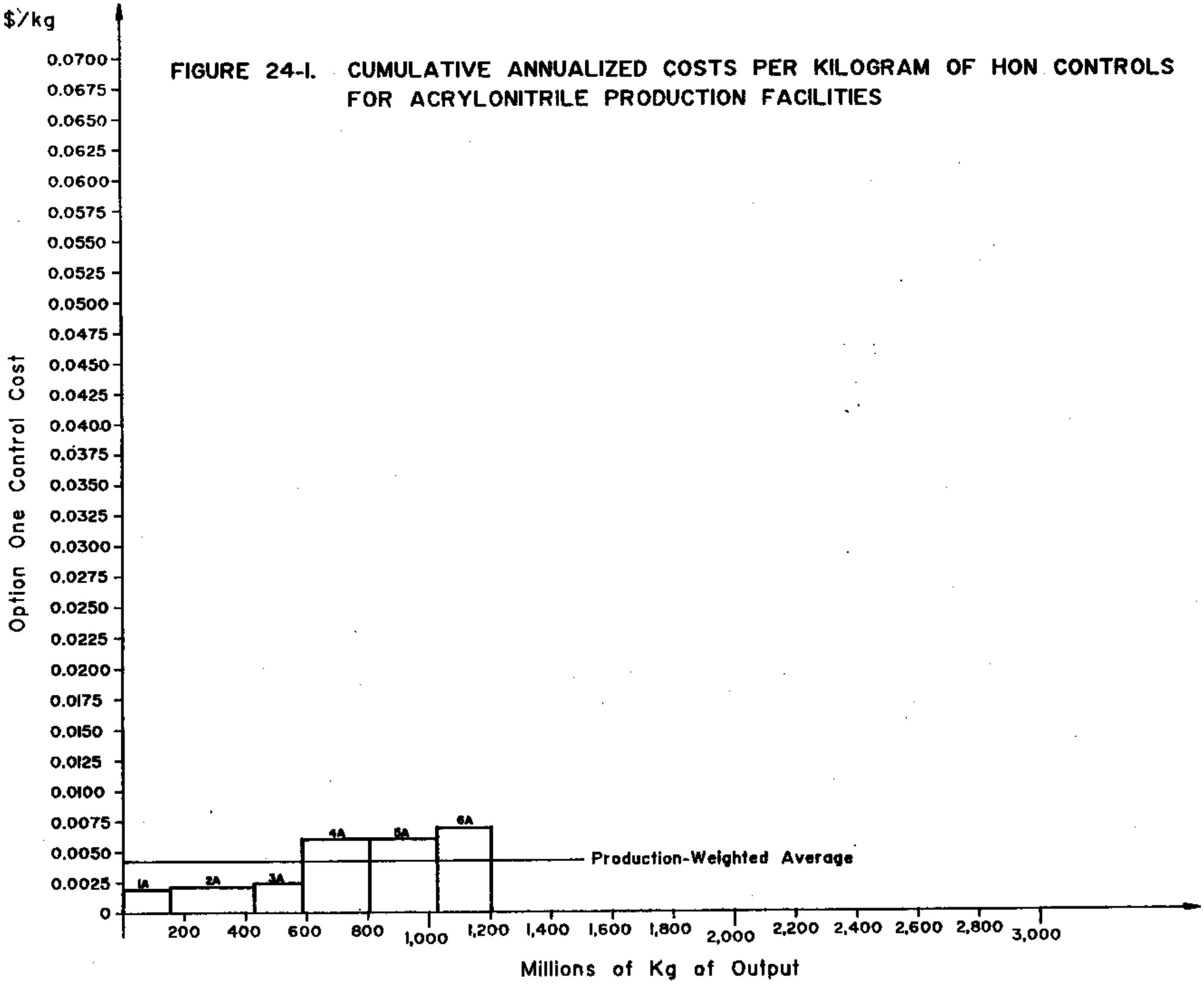


FIGURE 24-1. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR ACRYLONITRILE PRODUCTION FACILITIES

Acrylonitrile is currently produced via air oxidation of propylene. Since this is the only commercial process, no analysis of separate process costs is necessary.

24.2.2 Pricing

Acrylonitrile prices are determined by a combination of feedstock costs and end-use demand. Recently, list prices have been dropping due to declining export demand, and declining propylene prices, which is the primary feedstock. Worldwide overcapacity and slack demand for acrylic fibers could push prices lower still. Thus, the $.75 per kilogram price employed in this analysis might prove too high, and impacts could be understated.

24.2.3 Elasticities

Demand elasticities for acrylonitrile will be estimated on the basis of available substitutes for acrylonitrile, as well as substitutes for end-uses. The potential for import substitution is also examined.

24.2.3.1 Demand Elasticities

24.2.3.1.1 Acrylic and Modacrylic Fibers

Acrylic and Modacrylic Fibers make up 46 percent of acrylonitrile demand. Acrylonitrile is a particularly desirable synthetic fiber, owing to its characteristic of being "wool like." They have a soft touch, launder readily, dry rapidly, and keep their shape. For this reason, it has penetrated traditional consumer markets for wool. Wool itself, as well as cotton, are natural fiber substitutes. In the synthetic fibers, polyester, nylon, and rayon are competitors. The demand for acrylonitrile is estimated to be moderately inelastic in this sector.

24.2.3.1.2 High-Impact Resins

High-impact resins account for 27 percent of Acrylonitrile demand. Twenty-two percent of this is acrylonitrile-butadiene-styrene (ABS) resins, and the other five percent styrene-acrylonitrile (SAN) resins. These engineering resins are particularly well suited for consumer electric hand tools. Substitutes are nylon compounds, especially when hydrocarbon resistance is important, and polybutylene terephthalate. The demand for acrylonitrile in this sector is regarded as moderately inelastic.

24.2.3.1.2 Adiponitrile

Adiponitrile accounts for 14 percent of acrylonitrile demand. This synthetic elastomer finds use in engineering and process industries. Adiponitrile is useful for its ability to resist swelling when in contact with solvents, and also withstands chemical reactive attack. A variety of substitutes exist, including neoprene and fluorocarbon elastomers. The demand for acrylonitrile is deemed moderately inelastic in this sector.

24.2.3.2 Imports

Acrylonitrile imports themselves are thought to be insignificant. However, imports of acrylic-based textiles and apparel have dampened domestic demand for acrylonitrile. As such, domestic price increases which are felt in these end-use markets will be hindered by overseas competition.

24.2.3.3 Elasticity Estimate

The demand elasticity for Acrylonitrile in all end-use sectors is estimated to be in the moderately inelastic range of -.34 to -.67.

24.2.4 Market Structure

Table 24-8 summarizes the parameters for the market structure of acrylonitrile. Five firms are currently producing acrylonitile. The four-firm concentration ratio is 88.9%, signifying substantial market power. The HHI is 2,3713, which falls in the range of substantial market power. Captive consumption is 57%, indicating a moderate level of verticle integration. On average, 3 chemical compounds are produced at acrylonitrile sites, suggesting a slight level of horizontal integration. Imports in the industry are important, serving to undermine the pricing discretion of domestic producers. In summary, the acrylonitrile industry is moderately to highly oligopolistic, and producers are likely to absorb a significant portion of HON control costs.

24.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the acrylonitrile industry for option one control costs are presented in Table 24-9.

TABLE 24-8. MARKET STRUCTURE CHARACTERISTICS FOR ACRYLONITRILE

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced at Site (Horizontal Integration)	Imports
5	88.9%	2371.3	57%	3	Important

[a] Herfindahl-Hirschman Index

TABLE 24-9. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE ACRYLONITRILE INDUSTRY[1], OPTION ONE CONTROL COSTS

	Elasticity	
	-0.34	-0.67
%▲ Price (%/kg)	0.57%	0.57%
▲ Price ($/kg)	$.0042	$.0042
%▲ Output (%/kg)	(0.19%)	(0.38%)
▲ Output (10^6 kg)	(2.8)	(5.4)
%▲ Total Revenue	0.37%	0.19%
▲ Total Revenue (10^6 $)	$4.0	$2.0
▲ Employment (# of Employees)	(6)	(11)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

▲ = Change In

Market Price = $0.75/kg

1995 Output = 1,439 x 10^6 kg (based on 1989 production at 3 percent annual compound growth)

1995 Total Revenue = $1,079,124,762.99 (market price x 1995 output)

1995 Employment = 2,940

24.2.5.1 Option One Control Costs

Option one control costs represent the estimated actual HON control cost that an industry will incur. The production weighted average percentage price increase of 0.57 percent leads to a price increase $.0042 per kilogram. For the two elasticity levels of -.34 and -.67, the output reduction is 2.8 million kilograms (0.19%) and 5.4 million kilograms (0.38%), respectively.

The maximum decline in output of 5.4 million kilograms makes up 3.1 percent of the output of the Facility 6A, which, with annual production of 175 million kilograms, is the facility with the highest compliance cost. The loss in employment is estimated to range from 6 to 11 employees. Thus, in the most conservative option one scenario, HON controls will have a minimal impact on the acrylonitrile industry.

24.2.6 Conclusion

The range of HON control costs in the option one control scenario is $.0019 to $.0069. The differential is one-half cent, indicating that the production-weighted average cost is probably a good estimate of the industry price change. Fifty-seven percent of acrylonitrile is consumed captively, so the price increase will be achievable. Any price changes are likely to be felt in end-use markets. As noted in the pricing section, the price employed for this analysis might be too high. Nevertheless, the price is not so overstated as to alter the impacts substantially. Closure is unlikely, and the impact of HON controls in the acrylonitrile industry is estimated to be negligible.

24.2.7 References

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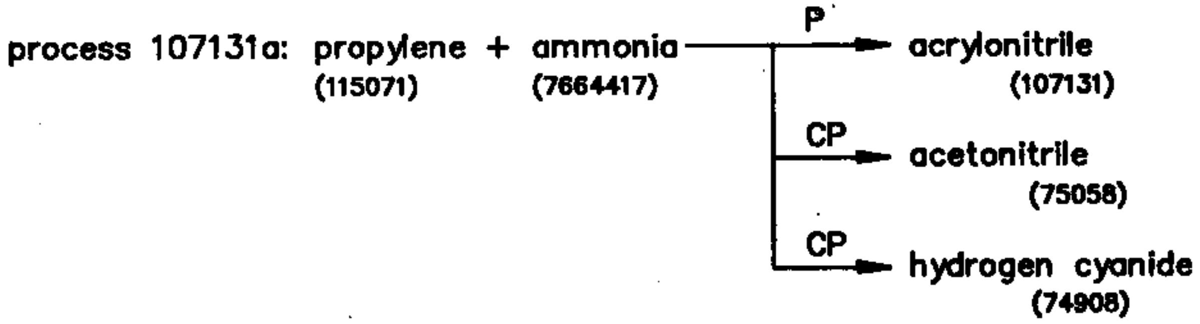
47. Reference 38.

48. Reference 38.

FIGURE 24-2

CHEMICAL TREE

ACRYLONITRILE



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 25

METHYL CHLORIDE PRODUCTION

25.1 INDUSTRY PROFILE

Methyl chloride, alternatively referred to as chloromethane, is a member of the chlorinated hydrocarbons family of chemicals. Seventy-nine percent of domestic consumption is accounted for by methyl chlorosilanes, used in the production of silicone fluids, resins, and elastomers. The dominant production process is direct chlorination of methane. In 1990, less than 40 percent of domestic methyl chloride production was sold on the merchant market.[1]

25.1.1 Brief Market Introduction

25.1.1.1 Historical Overview

Table 25-1 lists average realized price from 1980 to 1990. Prices increased slowly from 1980 to 1986, and then leveled off. Discounting off of list is common for large consumers. For example, while from 1985 to 1990 net price fluctuated between 42 and 46 cents per kilogram, the trade list price was between 53 and 57 cents per kilogram.[2] Average realized price declined from 1985 to 1989, but has been edging upwards since then.

In the early 1970s, tetramethyl lead accounted for nearly 40% of domestic methyl chloride consumption. Government regulations phased out the use of this lead alkyl anti-knock fuel additive for environmental reasons. Thus, tetramethyl lead ceased to be a methyl chloride end-use by 1986.[3]

25.1.1.2 Recent Developments

The price of methyl chloride has been edging up recently, with the most recent trade list price at nearly 62 cents per kilogram.[4] This increase could be attributable to increasing costs of raw material anhydrous hydrochloric acid. (See section 25.1.3.3 on costs of production.)

25.1.2 Demand Conditions

25.1.2.1 Uses for Methyl Chloride

Table 25-2 lists end uses for methyl chloride. Silicones account for 79 percent of methyl chloride applications, by far the largest consumer of the end-use markets.[5] Silcones themselves are widely used in sealant and adhesive applications, primarily in the

TABLE 25-1. AVERAGE REALIZED PRICE OF METHYL CHLORIDE, 1980-1990

	Price (¢/kg)
1990	.44
1989	.42
1988	.42
1987	.44
1986	.44
1985	.46
1984	.42
1983	.37
1982	.40
1981	.37
1980	.40

Sources: Mansville Chemical Products Corp., "Chemical Products Synopsis -- Methyl Chloride," November 1990; U.S. International Trade Commission, <u>Synthetic Organic Chemicals</u>, 1981-1984.

TABLE 25-2. USES OF METHYL CHLORIDE, 1990

	Percent of Total Consumption
Silicone fluids, resins, and elastomers	79%
Methylcellulose	7%
Quaternary Ammonium Compounds	5%
Agricultural Chemicals	5%
Butyl Rubber	2%
Miscellaneous	2%

Source: "Chemical Profile -- Methyl Chloride." Chemical Marketing Reporter, March 9, 1992.and surgical sectors.[6]

construction sector. Other outlets for silicones are the automotive, wire and cable, and medical and surgical sectors. Performance of these industries, especially construction and automotive, is closely tied to the national economy, and therefore so is the derived demand for methyl chloride in this application. Methyl chloride also has chemical intermediate applications, with sevenpercent of consumption going to agricultural uses, five percent to quarternary amines (used as surfactants and disinfectants), and five percent to butyl rubber.[7]

GE Plastics and Dow Corning consume all of their methyl chloride output captively in silicone production.[8]

25.1.2.2 Consumption

Apparent consumption of methyl chloride in the U.S. is listed in Table 25-3. Since export data is not available from 1981 through 1984, apparent consumption could not be calculated for these years.

As shown, apparent consumption increased gradually throughout the decade. This is due to increasing demand for methyl chloride in all of it's end uses -- especially for silicones -- during the 1980s.[9]

25.1.2.3 Exports

U.S. exports of methyl chloride are displayed in Table 25-4. Exports reached a decade-high of 10 million kilograms in 1989 (4.8% of U.S. production). In general, exports account for a relatively small percentage of U.S. production.

25.1.2.3 Future Prospects

The main area of market strength for methyl chloride is in it's application to silicones and methylcellulose. Other applications are considered mature.

Demand growth for methyl chloride in the production of silicones has been expanding at about two to three percent annually.[10] One source projects growth in this area to be five to seven percent over the next several years. However, a conflicting source is more cautious, as new markets for silicone products have not yet come to fruition.[11,12] Future demand for methyl chloride is highly dependent on the silicones market.

For use in methylcellulose, demand is expected to grow at two to three percent per year.[13] Agricultural and butyl rubber applications are considered mature, with growth no larger than one percent.[14]

Overall growth in demand for methyl chloride is projected to be one to two percent per year through 1996.[15] While other sources are

TABLE 25-3. APPARENT CONSUMPTION OF METHYL CHLORIDE IN THE U.S., 1980-1990

	Apparent Consumption[a] (10^6 kg)
1990	304
1989	308
1988	290
1987	265
1986	249
1985	236
1984	N.A.
1983	N.A.
1982	N.A.
1981	N.A.
1980	186

[a] Production plus imports, minus exports. Imports are negligible in the methyl chloride market, and are valued at zero. Because inventory changes are ignored, this is a simplified estimate of consumption.

Sources: Mansville Chemical Products Corp., "Chemical Products Synopsis -- Methyl Chloride," November 1990

Table 25-4. U.S. Exports of Methyl Chloride, 1980-1990

	Quantity (10^6 kg)	Percent of U.S. Production[a]
1990	9.5	3.0
1989	10.0	3.1
1988	7.7	2.6
1987	5.4	2.0
1986	6.4	2.5
1985	9.1	3.7
1984	N.A.	N.A.
1983	N.A.	N.A.
1982	N.A.	N.A.
1981	N.A.	N.A.
1980	5.0	3.0

[a] See Table 25-6.

Source: Mansville Chemical Products Corp., "Chemical Products Synopsis -- Methyl Chloride," November 1990.

more optimistic, this conservative scenario will assure that the economic impacts are not understated.

25.1.3 Supply Conditions

25.1.3.1 Production Processes

Methyl chloride is currently produced by three processes. The dominant process is hydrohalogenation of methanol. This process is more desirable due to its flexibility, since other chloromethanes, such as methylene chloride, chloroform, and carbon tetrachloride can also be produced, depending on demand conditions.[16] Other routes of production are the halogenation of methane to produce chloroform, yielding methyl chloride as a coproduct, and the esterification of methyl chloride to produce dimethyl sulfate, again generating methyl chloride as a coproduct.

25.1.3.2 Domestic Producers and Total Production

Table 25.5 list domestic producers of methyl chloride. There are currently five firms producing methyl chloride. Dow Chemical, Dow Corning, and Vulcan Materials all operate two facilities each. General Electric Plastics and Occidental operate one facility. Total industry capacity is 438 million kilograms, with Dow Corning controlling the largest percentage (41%).[17] Capacities are flexible as other chloromethanes can be produced in the same facility.

Table 25-6 lists U.S. production of of methyl chloride from 1980 to 1990. Production increased gradually throughout the decade, despite a considerable shakeup in the market. In the mid-1980s, Dupont, Ethyl Corporation, and Stauffer discontinued production, as tetramethyl lead was phased out.[18] In 1988, Vista exited the market by selling its Lake Charles, LA plant to Vulcan. In late 1990, Vulcan opened two of its own plants, and closed the old Vista plant permanently.[19]
Output in 1990 represented 80 percent of total methyl chloride capacity.

25.1.3.3 Costs of Production

Production costs of methyl chloride stem primarily from the cost of it's principle raw materials, methanol and hydrochloric acid (HCL). A future cost squeeze is possible as anhydrous HCL becomes less readily available.[20] This is due to environmental restrictions limiting the use of chloroflourocarbons made from chlorform. Chloroform production yields anhydrous HCL as a coproduct, which is less costly than on-purpose HCL.

TABLE 25-5. U.S. PRODUCERS OF METHYL CHLORIDE, 1991

Company	Location	Capacity (10^6 kg/yr)
Dow Chemical	Plaquemine, LA	79
	Freeport, TX	25
Dow Corning	Carrolton, KY	181
	Midland, MI	23
General Electric Plastics	Waterford, NY	41
Occidental Chemical	Belle, WV	44
Vulcan Materials	Geismar, LA	24
	Wichita, KS	21
		438

Sources: "Chemical Profile -- Methyl Chloride." Chemical Marketing Reporter, March 9, 1992.

TABLE 25-6. U.S. PRODUCTION OF METHYL CHLORIDE
1980-1990

	Quantity (10^6 kg)
1990	313
1989	318
1988	298
1987	271
1986	256
1985	245
1984	219
1983	186
1982	166
1981	184
1980	164

Source: Mansville Chemical Products Corp., "Chemical Products Synopsis -- Methyl Chloride," November 1990; U.S. International Trade Commission, Synthetic Organic Chemicals, 1981-1984.

25.1.3.4 Imports

Imports of methyl chloride are negligible, and no data is presented.

25.1.3.4 Future Prospects

Supplies of methyl chloride are thought to be adequate in the near term. Capacity expansions take six to nine months, and methyl chloride producers have information on end-use demand conditions for approximately five years.[21] No supply problems are predicted in the 1990s.

As the supply of anhydrous HCL becomes less readily available, producers might experience a cost squeeze over the next several years.

25.1.4 Future Market Prospects

The methyl chloride market is closely tied to the national economy, since applications in the construction and automotive sectors predominate. As such, prospects should brighten as the economy eases out of the current slowdown.

Future profitability and growth is highly dependent on growth in silicones applications. Increasing costs for anhydrous HCL could adversely affect profitability in the years to come.

25.2 ECONOMIC IMPACT ANALYSIS

25.2.1 Compliance Costs

A synopsis of annualized cumulative control costs and summary statistics for methyl chloride production is presented in Table 25-5. Eleven facilities are displayed. The same information is presented graphically on Figure 25-1. Costs are given for option one controls. Option one controls are estimates of the actual costs that facilities are likely to incur.

Methyl chloride is currently produced by three processes. Process A is the halogenation of methane to produce chloroform, yeilding methyl chloride as a coproduct. Process B, the dominant process in the industry, produces methyl chloride via hydrohalogenation of methanol. Process C employs the esterification of methyl chloride to produce dimethyl sulfate, again yeilding methyl chloride as a coproduct. It is noted that the cost differential between processes is masked by the production-weighted average cost.

TABLE 25-7. CUMULATIVE ANNUALIZED COSTS OF HON CONTROLS AND SUMMARY STATISTICS FOR METHYL CHLORIDE PRODUCTION FACILITIES AND METHYL CHLORIDE PRODUCTION PROCESSES

Facility/ Process	Annual Production (10^6 kg)	Option One Controls ($/kg)
1A	5.9	$0.0004
2C	5.4	$0.0034
3C	5.4	$0.0052
4B	10.3	$0.0114
5B	21.6	$0.0114
6B	63.9	$0.0143
7B	48.9	$0.0159
8B	85.5	$0.0160
9B	27.3	$0.0160
10B	38.5	$0.0209
11B	21.6	$0.0221
<u>Control Costs by Process</u>		
Process A		$0.0004
Process B		$0.0162
Process C		$0.0026
<u>Summary Statistics</u>		
Mean		$0.0125
Production Weighted Average		$0.0155

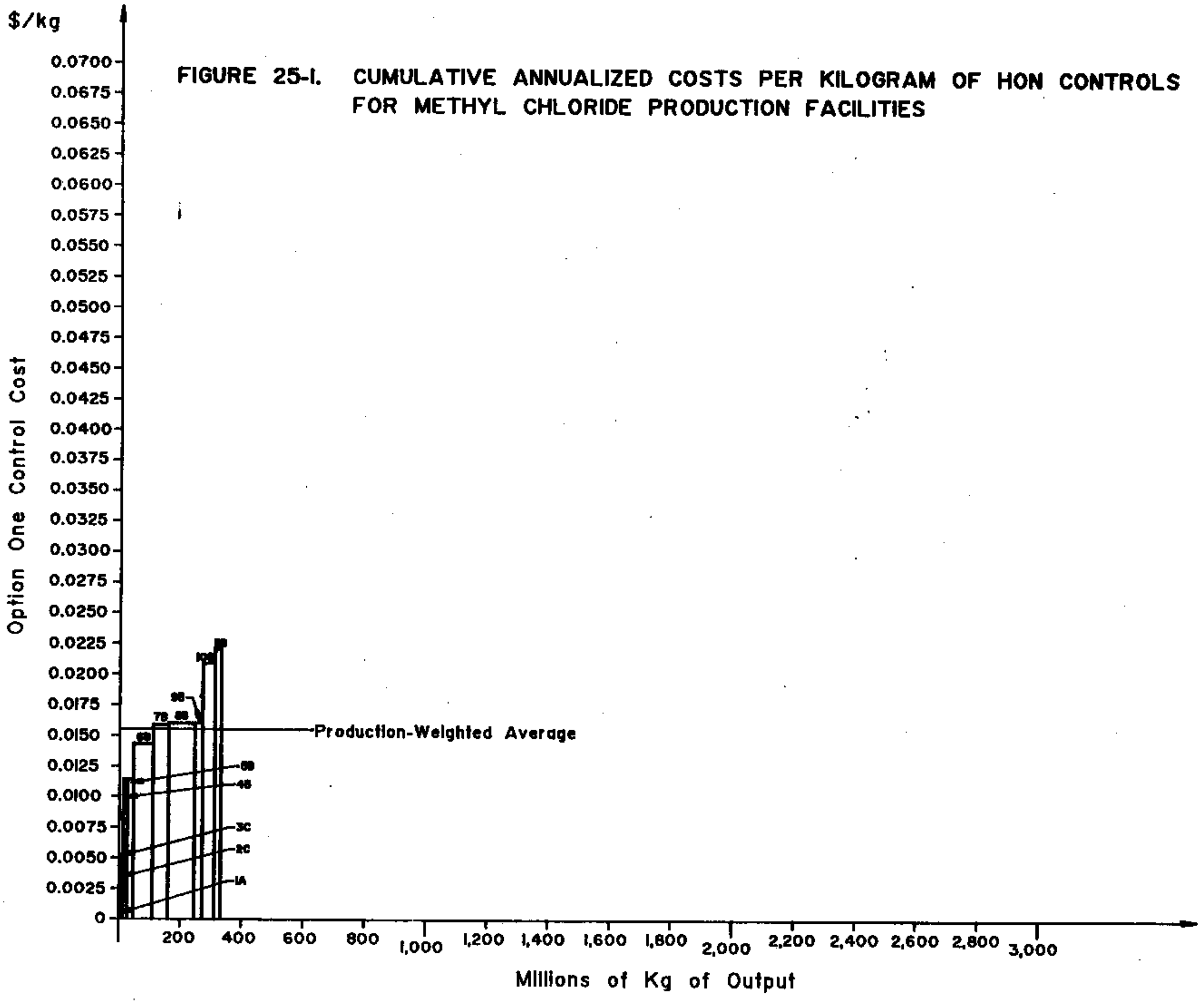


FIGURE 25-1. CUMULATIVE ANNUALIZED COSTS PER KILOGRAM OF HON CONTROLS FOR METHYL CHLORIDE PRODUCTION FACILITIES

25.2.2 Pricing

Methyl chloride prices generally follow that of its principle raw materials -- methanol and hydrochloric acid. Environmental restrictions limiting CFC's made from chloroform could put upward pressure on hydrochloric acid costs (see section 21.5.3.3). If methyl chloride producers respond with price increases, the economic impact of the HON might be overstated.

25.2.3 Elasticities

Demand elasticities for methyl chloride will be estimated on the basis of available substitutes for methyl chloride, as well as substitutes for end-users. The potential for import substitution is also examined.

25.2.3.1 Silicone Fluids, Elastomers, and Resins

Methyl chlroide production for use in silicones manufacturing accounts for 79 percent of methyl chloride demand.[*] Silcones themselves are widely used in sealant and adhesive applications, primarily in the construction sector. Other outlets for silicones are the automotive, wire and cable, and medical and surgical sectors. Over one thousand different silicone products are commercially available.[22]

Generally, silicone applications are based on their unique properties and cost-effectiveness. These properties include thermal stability, oxidative stability, resistence to weathering, good spreading power, and chemical and biological inertness.[23] Cost-effectiveness stems from assembly, installation, and maintenance labor costs, combined with longer service life than organic substitutes.[24]

A wide variety of organic fluids, resins, and elastomers are potential substitutes for silicone, but the above mentioned properties of silicones tend to make them preferable in end-use markets. Some applications require the uniqueness of silicones.

Given the unique properties of silicones, demand for methyl chloride in this sector is considered to be moderately inelastic.

25.2.3.2 Imports

Imports of methyl chloride are insignificant, and will not hinder pricing discretion of domestic producers.

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[*] Since this end use accounts for such a large share of total methyl chloride consumption, demand elasticities for other end uses are not analyzed.

25.2.3.4 Elasticity estimate

Other end-uses of methyl chloride are not examined in detail, since silicones account for 79 percent of methyl chloride applications. The demand for methyl chloride is estimated to be in the moderately highly inelastic range of -.34 to -.67.

25.2.4 Market Structure

Table 25-8 summarizes the parameters for the market structure of methyl chloride. Five firms are currently producing methyl chloride. The four-firm concentration ratio is 90.6 percent, signifying substantial market power. The HHI is 3027.7, which falls in the range of substantial market power. Captive consumption is just over 60 percent, indicating substantial market power. On average, seven chemical compounds are produced at methyl chloride sites, suggesting a substantial degree of horizontal integration. Imports in the industry are nsignificant. In summary, the market structure of the methyl chloride industry is highly oligopolistic, and firms will likely absorb a significant portion of HON compliance costs.

25.2.5 Impacts on Price, Output, Total Revenue, and Employment

Impacts on price, output, total revenue, and employment in the methyl chloride industry for option one controls are presented in Table 25-9.

25.2.5.1 Option One Control Costs

Option one control costs represent the actual control cost that an industry is likely to incur. The weighted average percentage price increase of 3.17 percent leads to a price increase $.0155 per kilogram. For the two elasticity levels of -.34 and -.67, the output reduction is 4.5 million kilograms (1.01%) and 8.7 million kilograms (2.07%), respectively.

Facility 11B, which accounts for 21.6 million kilograms of industry production, is highest cost plant in the industry. If this plant absorbs the entire reduction in output, it would lose from 21 to 40 percent of its production, which is unlikely to lead to closure. If either facility 1A, 2C, 3C, or 4B are marginal, then closure is again possible.

Three processes are used to produce methyl chloride. The cost differential favors process A and process C (where methyl chloride is produced as a coproduct). Process B incurs substantially higher control costs. At the same time, process B accounts for 89 percent of industry production. Plant flexibility and lower cost have led to the dominance

TABLE 25-8. MARKET STRUCTURE CHARACTERISTICS FOR METHYL CHLORIDE

Number of Firms	4-Firm Concentration Ratio	HHI[a]	Captive Consumption (Vertical Integration)	Other Chemicals Produced at Site (Horizontal Integration)	Imports
5	90.6%	3,027.7	60%	7	Insignificant

[a] Herfindahl-Hirschman Index

TABLE 25-9. IMPACTS ON PRICE, OUTPUT, TOTAL REVENUE AND EMPLOYMENT IN THE METHYL CHLORIDE INDUSTRY[1], OPTION ONE CONTROL COSTS

	Elasticity	
	-0.1	-0.34
%Δ Price (%/kg)	3.17%	3.17%
Δ Price ($/kg)	$.0155	$.0155
%Δ Output (%/kg)	(1.05%)	(2.07%)
Δ Output (10^6 kg)	(4.5)	(8.8)
%Δ Total Revenue	2.08%	1.03%
Δ Total Revenue (10^6 $)	(4.3)	(2.1)
Δ Employment (# of Employees)	(86)	(169)

[1] Based on Production Weighted Average Cost

DEFINITIONS:

Δ = Change In

Market Price = $0.49/kg

1995 Output = 6.1 x 10^6 kg (based on 1989 production at 12% annual compound growth)

1995 Total Revenue = $3,003,349,909.62 (market price x 1995 output)

1995 Employment = 8,184

of process B, and so a shift away from this process cannot be predicted with any certainty.[25] However, in the most conservative case, this would be a notable impact on methyl chloride producers.

25.2.5 Conclusion

Methyl chloride falls into the range of chemical compounds which will incur significant cost increases. Given these cost increases, closure of the highest cost plant is possible. Moreover, if one or more of the smaller sized facilities are marginal, closure could result. The range of price increases under the option one scenario is $.0004 per kilogram to $.0221 per kilogram. This is a considerable difference, and the production-weighted average price increase masks this difference. An additional impact that can be predicted from this analysis is the possibility of a shift away from process B production.

25.2.6 References

1. Mansville Chemical Products Corp., "Chemical Products Synopsis -- Methyl Chloride," November 1990.
2. Reference 1.
3. Reference 1.
4. "Chemical Marketing Reporter -- Chemical Prices." Chemical Marketing Reporter, March 2, 1992, p.31.
5. "Chemical Marketing Reporter Profile -- Methyl Chloride." Chemical Marketing Reporter, March 9, 1992, p. 42.
6. Reference 1.
7. References 1,5.
8. Reference 5.
9. "Methyl Chloride Up On Strong Growth In Silicones Market." Chemical Marketing Reporter, December 19, 1988, p.7.
10. Reference 5.
11. Reference 1.
12. Reference 5.
13. Reference 5.
14. Reference 5.
15. Reference 5.

16. Reference 1.

17. Reference 5.

18. Reference 1.

19. Reference 1.

20. Reference 1.

21. Reference 4.

22. Kirk-Othmer Encyclopedia of Chemical Technology, Third Edition, Volume 20, 1983, p.953.

23. Reference 22.

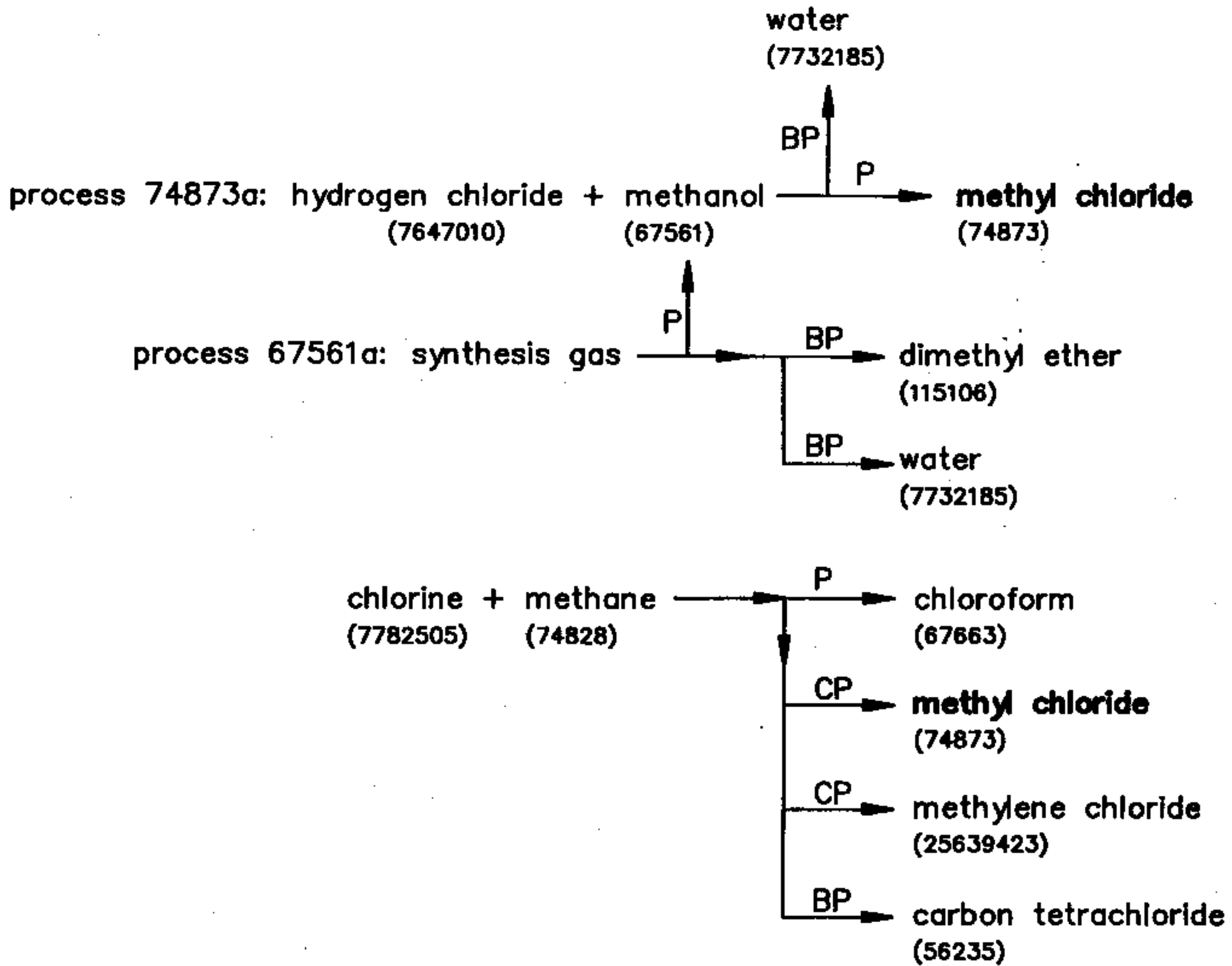
24. Reference 22.

25. Reference 1.

FIGURE 25-2

CHEMICAL TREE

METHYL CHLORIDE



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

CHAPTER 26

COMPOUNDS IN THE HIGH-COST RANGE

26.1 INTRODUCTION

Table 26-1 compares the distribution of the 490 chemical compounds with those 20 selected for detailed analysis, in terms of both annual production and control costs. As shown, the majority of compounds in both the population and the selection exhibit percentage cost-increases of less than one percent; 71.6 percent for the population and 66.7 percent for the selection. Chapters five through 25 of the economic impact analysis provide adequate coverage of this class of low-cost compounds. However, only four of the 21 compounds selected experiences control costs in excess of two percent per kilogram at the fiftieth percentile of industry output. Since 15.1 percent, or 74 of the compounds in the population do have control costs greater than two percent, and since these are the compounds that are likely to experience the most severe impacts, an accurate characterization of the impact of HON controls on the SOCMI must include an analysis of compounds in the high-cost increase range.

26.1.1 Selection of High-Cost Compounds

A literature search was performed on the initial list of 74 compounds with costs in excess of two percent, and it was found that inadequate data existed to compile detailed profiles on these compounds. Nevertheless, a certain amount of information was still needed to perform even a rudimentary analysis. At a minimum, information on prices, end-uses, annual production, and determinants of demand elasticity are necessary. In addition, emphasis was placed on choosing compounds with the highest control costs, since this would allow for the most extreme impacts. Given these needs, five compounds were selected for high-cost analysis. Table 26-2 lists these compounds, along with their CAS registry number.

The approach for assessing the impact of the HON on high-cost compounds is similar to the analysis of the population as a whole in that a group of compounds is selected and profiled, and the economic impacts on this group are extended to the population of compounds.

26.1.2 Characteristics of High-Cost Compounds

Based on analysis of the selected compounds, there are several features common to this group. High-cost compounds are characterized by low-volume production, residing considerably downstream from the basic

TABLE 26-1. DISTRIBUTION OF HON COMPOUNDS BY PERCENTAGE COST INCREASE AND ANNUAL PRODUCTION (10^6 kg): OPTION ONE COSTS

	All Regulated Compounds					
			Distribution By Annual Production (10^6 kg)			
% Change In Cost[a]	Number	% Of Total	<1	1-5	5-10	>10
Less than 1.00	351	71.6%	43	26	35	284
1.00 - 2.00	65	13.3%	0	2	18	28
2.00-3.00	17	3.5%	0	3	4	4
3.00-4.00	8	1.6%	0	2	0	2
4.00-5.00	6	1.2%	0	0	2	2
5.00-7.00	10	2.0%	1	3	2	4
7.00-10.00	2	0.4%	0	1	1	0
Greater than 10.00	31	6.3%	20	1	1	1
Total	490	99.9%[b]	64	38	63	325
% Of Total	100%		13.1%	6.7%	12.9%	67.3%

	Selected Compounds					
			Distribution By Annual Production (10^6 kg)			
% Change In Cost[a]	Number	% Of Total	<1	1-5	5-10	>10
Less than 1.00	14	66.7%	0	0	1	13
1.00 - 2.00	3	14.3%	0	0	0	3
2.00-3.00	1	4.8%	0	0	0	1
3.00-4.00	3	14.3%	0	0	0	3
4.00-5.00	0	0%	0	0	0	0
5.00-7.00	0	0%	0	0	0	0
7.00-10.00	0	0%	0	0	0	0
Greater than 10.00	0	0%	0	0	0	0
Total	21	100.1[b]	0	0	1	20
% Of Total	100%		0%	0%	5%	95%

[a] Cost increase based on control costs at the 50th percentile of industry output.

[b] Does not sum to 100 due to rounding.

Table 26-2. SELECTED COMPOUNDS IN THE HIGH-COST RANGE

Chemical Name	CAS Registry Number
Benzyl Benzoate	120514
Phthalimide	85416
Diphenyl Methane	101815
Gluteraldehyde	111308
Diisooctyl Phthalate	27554263

feedstocks, relatively specialized end-uses, and occupying a small share of expenditures in the producer's budget.

Low-volume production and high compliance costs can be explained in part by the presence of economies of scale in compliance costs in the SOCMI. As control costs are spread out over smaller and smaller levels of output, cost per unit increases. Using data from the RADIAN database, it was found that while only 9.6 percent of the compounds with annual production greater than 20 million kilograms experience cost increases greater than one percent, 28.7 percent of the compounds with annual production less than 20 million kilograms have costs increases greater than one percent. While the majority of HON controlled be subject to low compliance costs, low-volume compounds are more likely to be high-cost.

Another important feature of high-cost chemicals is that they tend to be produced fairly far downstream from the basic feedstock chemicals. Since control costs are accumulated at each link in a chemical tree, as compounds are further downstream from the basic feedstocks they tend to be higher cost, other things being equal. It is important to note that costs calculated in this way could well be overstated. By accumulating the total cost at each link in the chemical tree, the assumption is that manufacturers corresponding to each link are able to fully pass through control costs. The more likely scenario is that some control costs will be absorbed by each producer as they bargain with end-users, so that a lower amount is passed on to the next link.

In addition, high-cost compounds tend to have specialized end-uses. All of the compounds chosen for analysis are in the group of multipurpose additives. Multipurpose additives perform a particular function for a variety of end-use industries. As such, performance attributes of these chemicals are tailored specifically to the needs of end-use industries. Thus, these raw materials are to some extent necessities which are difficult to substitute for in the short run.

Finally, as multipurpose additives, high-cost compounds occupy a small share of expenditures in the producer's budget. Therefore, producers will be less likely to substitute for these compounds in the short run.

26.1.3 Profiles of High-Cost Compounds

Profiles of the five high-cost compounds include information on pricing, manufacturing, and end-uses.

26.1.3.1 Benzyl Benzoate

Benzyl benzoate, an ester of benzoic acid, is a colorless, oily liquid with a faint pleasant aromatic odor and a sharp burning taste. It occurs naturally in Peru and Tolu balsams, and is prepared commercially via esterification of benzyl alcohol.[1]

Benzyl benzoate is a multi-purpose additive with a variety of end-uses. The pleasant odor of benzyl benzoate, like other benzoic esters, has long been utilized in the perfume industry, where it is employed as a solvent for synthetic musks and as a fixative. It is also used in confectionery and chewing gum flavors. In addition, benzyl benzoate is used as an insect repellent and in formulations for repelling mosquitoes, chiggers, ticks, and fleas, as well as in the control of livestock insects. It was used in the Vietnam War to eradicate and repel certain ticks and mites. Finally, benzyl benzoate finds usage in medicine, cosmetics, and as a plasticizer.[2]

Annual production of benzyl benzoate in 1990 was 245 thousand kilograms.[3] Average realized price for the same year was $2.82 per kilogram.[4]

26.1.3.2 Phthalimide

Phthalimide is prepared in two grades: powder and flake. It is manufactured commercially by reacting phthalic acid with ammonia, or by reacting phthalic anhydride with ammonia.[5] Phthalimide is a chemical intermediate used in the production of potassium phthalimide and other compounds. In addition, it is used as a filler in industrial waxes.[6]

Data from conventional published sources is not available on annual production of phthalimide. However, according to the Radian database, annual production of phthalimide is 7.5 million kilograms. The price used for this analysis is $2.16 per kilogram.[7]

26.1.3.3 Diphenyl Methane

Diphenyl methane is a pharmaceutical intermediate, used for organic synthesis and as an additive in flavor and fragrance compounds.[8] It is manufactured from benzene and benzyl chloride.[9] Large discounts are given for quantity purchases.[10]

Data from conventional published sources is not available on annual production of diphenyl methane. However, according to the Radian database, annual production of diphenyl methane is 765 kilograms. Prices vary widely depending on the amount purchased, and the price used for this analysis $16.64 is per kilogram. This is the price offered for the largest quantity purchase, and is used so that the impacts are not understated. If only small volumes are desired, the price can be as high as $47.70 per kilogram.[11]

26.1.3.4 Gluteraldehyde

Gluteraldehyde is commercially available in three grades: technical, biological, and electron microscopy.[12] It is sold in liquid form, and is manufactured using acrolein.[13] Gluteraldehyde is used as an anti-corrosive for cooling towers, an anti-microbial, and as a fixing tissue for crosslinking proteins.[14]

Data from conventional published sources is not available on annual production of gluteraldehyde. However, according to the Radian database, annual production of gluteraldehyde is 1,190 kilograms. Prices vary depending on the purity. The price used for this analysis is $3.53 per kilogram. This is the price offered for the lowest technical, grade, a 25 percent reagent, and is used so that the impacts are not understated. The price for the 50 percent reagent technical grade is $5.60 per kilogram.[15]

26.1.3.5 Diisooctyl Phthalate

Diisooctyl phthalate is sold in liquid grade, and is manufactured via esterification of phthalic anhydride.[16] It is a commercially important polyvinyl chloride plasticizer with a long history for a variety of general purpose end-uses.[17] It is useful for its good compatibility with vinyl and its low rate of solvation.[18]

Data from conventional published sources is not available on annual production of diisoctyl phthalate. However, according to the Radian database, annual production of diisooctyl phthalate is 7 million kilograms. Small discounts are given for larger quantities. The price used for this analysis is $1.15 per kilogram. This is the price offered for the largest quantity purchase, and is used so that the impacts are not understated. Prices can be as high as $1.87 per kilogram.[19]

26.1.4 Market Trends of High Cost Compounds

Growth rates in demand for high-cost compounds are not available from conventional data sources. Since these chemicals tend to be multi-purpose additives with specialized end-uses, their growth in demand is likely to be derived from their end-uses. Even so, quantified growth rates are difficult to come by. So as not to understate the impacts, a growth rate of one percent will be assumed for this analysis.

26.2 ECONOMIC IMPACTS

26.2.1 HON Compliance Costs

Compliance costs based on option one are shown in Table 26-3 for the five selected high-cost compounds. Since very little information could be obtained concerning facility-level activities, compliance costs are not presented for each facility. Instead, production-weighted average costs are shown, as well as separate process costs if they are needed.

26.2.2 Prices

Prices used for assessing economic impacts are presented in Table 26-4. The pricing of high-cost chemicals is characterized by considerable discretion, as prices vary widely for different quantities of purchases. While in many cases, the cost increases resulting from compliance are extremely large, it would appear that these producers have some ability to pass on costs to end-users.

26.2.3 Price Elasticities of Demand for High Cost Compounds

Price elasticities of demand for high-cost compounds are considered highly inelastic, in some cases approaching the range of perfectly inelastic. This conclusion stems from three important characteristics of high-cost compounds. The first is that, like other chemical compounds, the high-cost compounds are factors of production, and are difficult to substitute for as producers, in the short run, tend to be "locked into" technological processes. Secondly, these compounds have relatively specialized end-uses, and so can be considered a necessity in the producer's technology. Thirdly, they account for a small share of expenditures in the producer's budget, also lending to there tendency for inelasticity.

The principle implication of perfectly inelastic demand is that firms can raise prices to cover HON control costs in full, without sacrificing output. An additional implication is that prices will increase at the expense of consumer's surplus, so that the cost of compliance will be borne by the consumer and not the manufacturer.

In the economic impact analysis below, two values are used for the price elasticity of demand; -0.01 and -0.34. Using the elasticity level of -.34 leads to a projection of impacts that is very extreme. In most cases, firms cannot sustain these impacts. This is considered an absolute upper bound. It is argued that attention should be focused on the impacts stemming from a price elasticity of demand equal to -0.01, or almost perfectly inelastic, for the reasons stated above.

Table 26-3. CUMULATIVE ANNUALIZED PRODUCTION-WEIGHTED AVERAGE COSTS AND PROCESS COSTS OF HON CONTROLS FOR HIGH-COST COMPOUNDS

Chemical Name/ Process	Control Costs Option One Controls ($/kg)
Benzil Benzoate	$2.55
Phthalimide	$11.89
Process A	$0.14
Process B	$35.17
Process C	$0.10
Diphenyl Methane	$312.65
Gluteraldehyde	$83.97
Diisooctyl Phthalate	$0.11

Table 26-4. PRICES OF HIGH-COST CHEMICALS

Chemical Name	Price
Benzil Benzoate	$2.82[a]
Phthalimide	$2.16[b]
Diphenyl Methane	$16.64[c]
Gluteraldehyde	$3.53[c]
Diisooctyl Phthalate	$1.15[c]

[a] United States International Trade Commission. Synthetic Organic Chemicals -- United States Production and Sales, 1990. Washington, DC, December, 1991, p. 7-2.

[b] RADIAN database, from Chemical Marketing Reporter, "Chemical Prices."

[c] Manufacturer's retail price.

26.2.4 Impacts on Price and Output

Table 26-5 presents price and output adjustments for the six high-cost compounds. Data are presented for two demand elasticities: -.01 and -.34. The sections following analyze the impacts for each of the compounds.

It should be noted that the impacts shown are likely to be overstated for several reasons. First, as noted above, the control cost estimates are probably too large (see Section 26.1.2). Second, these impacts are based on a full-cost passthrough scenario. The assumption is made that the size of the price increase is sufficient to fully recover control costs. Given the oligopolistic nature of the SOCMI (see Chapter 1, Section 1.3.2), the actual price increase that manufacturer's can achieve is likely to be lower than this. Thus, the impacts could be overstated. Third, impacts are based on the lowest available price estimate. As noted, however, prices for high-cost chemicals vary widely. Thus, the lower price estimates serve to understate the revenue basis, which in turn overstates the impacts. Fourth, even in cases where the impacts appear to be severe, closure cannot be predicted with any certainty, given the dynamic nature of the SOCMI (see Chapter 1, Section 1.3.3).

26.2.3.1 Benzyl Benzoate

Option one control costs represent the actual control cost that an industry is likely to incur under the HON. The production-weighted average percentage price increase for benzyl benzoate is 90.42 percent, which leads to a price increase of $2.55 per kilogram. For the two elasticity levels of -.01 and -.34, the reduction in output is 1,932 kilograms (.64%) and 59,197 kilograms (19.7%), respectively.

According to the Radian database, seven facilities, all with an annual production of 43,000 kilograms, produce benzyl benzoate. Focusing on the elasticity of -0.01, a facility of this size would lose just over four percent of it's annual output, which appears tenable. In the most extreme scenario, with an elasticity equal to -0.34, and if one plant were to absorb the entire decline in output, it would close. However, since each plant is of the same size, the more likely scenario is that the output adjustment would be shared by all the facilities in the industry, and the impacts would be minimized. Thus, the impacts are considered negligible for the producer, and closure is unlikely.

Table 26-5. SUMMARY OF PRICE AND OUTPUT ADJUSTMENTS FOR HIGH-COST COMPOUNDS

Chemical Name	Elasticity = -.01		Elasticity = -.34	
	% ▲ P	% ▲ Q[a]	% ▲ P	% ▲ Q
Benzil Benzoate	90.42	(0.64)	90.42	(19.7)
Phthalimide	530.9	(1.8)	530.9	(46.5)
Diphenyl Methane	1878.93	(2.58)	1878.93	(63.8)
Gluteraldehyde	2378.67	(2.75)	2378.67	(66.4)
Diisooctyl Phthalate	9.46	(.090)	9.46	(3.03)

[a] Percentage changes in quantity are calculated using a constant-elasticity demand function.

based on the lowest available price estimate. To this it is added that these producer's seem to have quite a degree of pricing discretion, which would allow them to alleviate the impact of compliance. Fourth, as with the SOCMI as a whole, it is assumed here that many products are produced at sites along with the high-cost compounds, and that the dynamic nature of the SOCMI makes it difficult to predict closure with any certainty.

26.2.5 References

1. Kirk-Other Encyclopedia of Chemical Technology, Third Edition, Volume 3, pp. 778-792, from Kirk-Other Online Dialog File.
2. Reference 1.
3. United States International Trade Commission. Synthetic Organic Chemicals -- United States Production and Sales, 1990. Washington, DC, December, 1991, p. 7-2.
4. Reference 3.
5. Database of HON Chemicals. Radian Corporation, Research Triangle Park, NC. This database, provided by RADIAN Corp., details the production processes for all HON chemicals. It also includes prices used for the analysis.
6. American Chemical Society. Chemcyclopedia 92, Washington, DC, 1991, p. 99.
7. Reference 5.
8. Reference 6, p. 273.
9. Reference 5.
10. Phone conversation, February 26, 1992, with Penta Manufacturing.
11. Reference 10.
12. Reference 6
13. Reference 5.
14. Reference 6, p. 77.
15. Phone conversation, February 26, 1992, with Union Carbide.
16. Reference 5.
17. Facsimile from Exxon Chemical, Product Information Rev. 1 (10/90), "Jayflex Diop Plasticizer", received February 27, 1992.

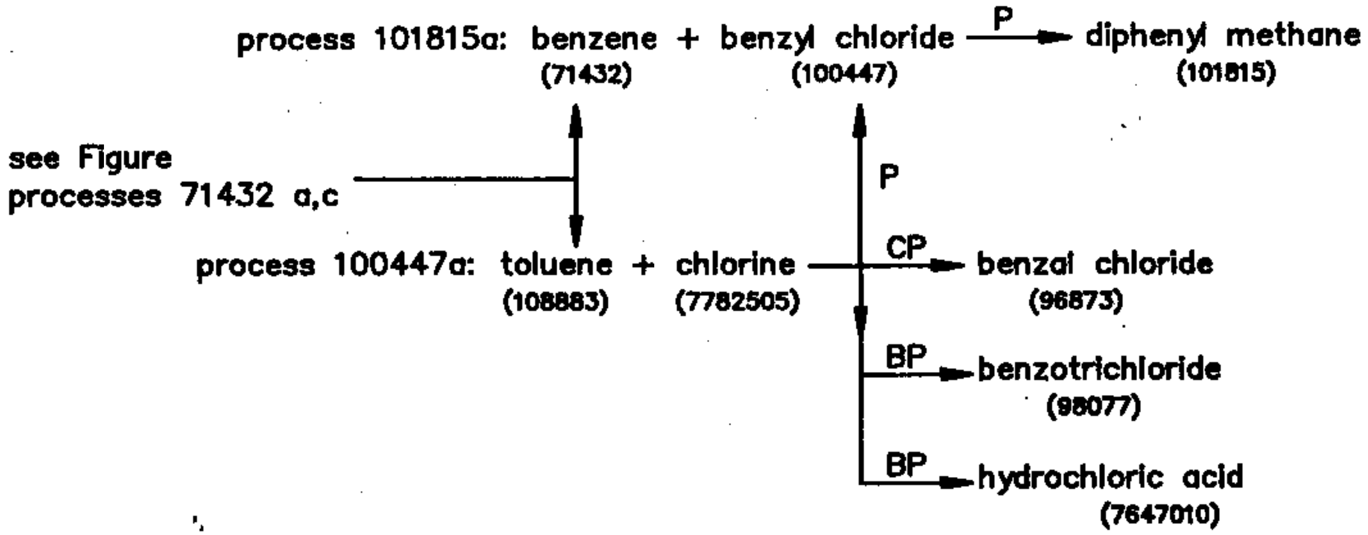
18. Reference 6, p. 63.

19. Phone conversation, February 26, 1992, with C.P. Hall Co.

FIGURE 26-3

CHEMICAL TREE

DIPHENYL METHANE



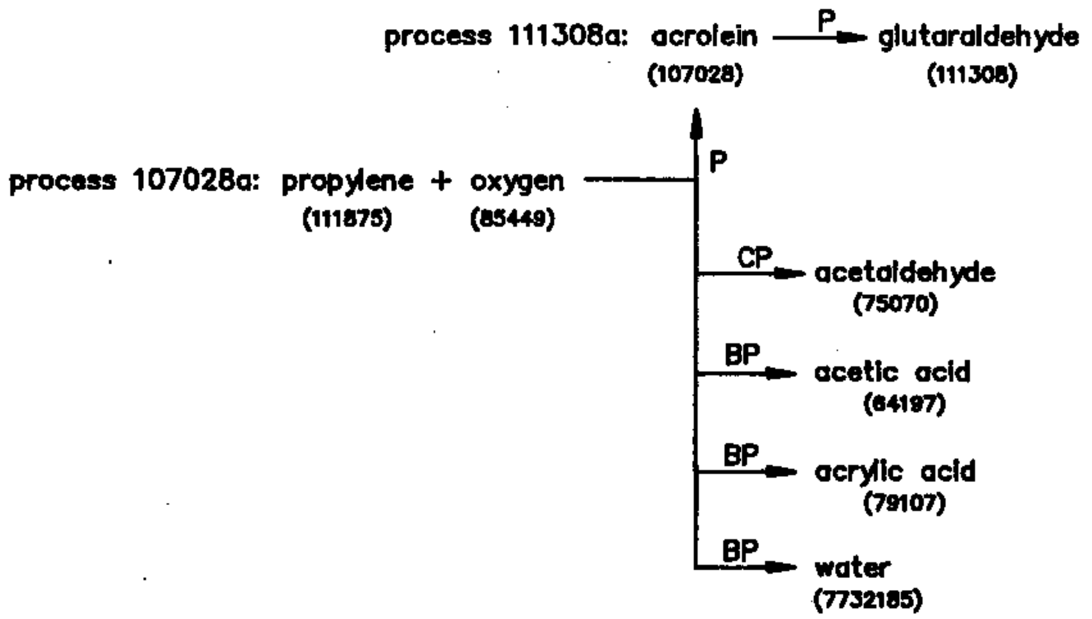
NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

FIGURE 26-4

CHEMICAL TREE

GLUTARALDEHYDE



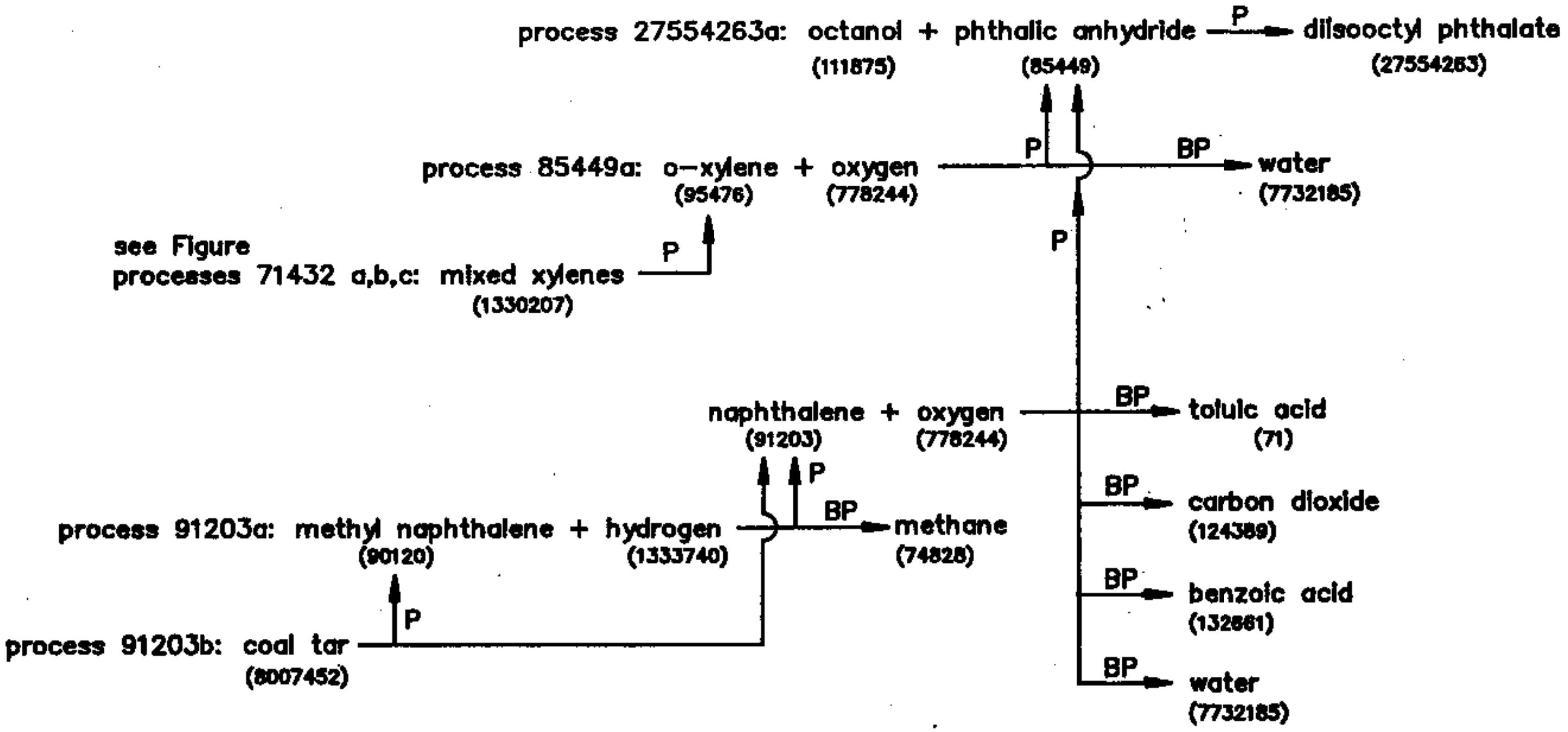
NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.

FIGURE 26-5

CHEMICAL TREE

DIISOOCTYL PHTHALATE



NOTE: P denotes product
CP denotes coproduct
BP denotes byproduct

Numbers in ( ) are CAS registry numbers.