# ECONOMIC ASSESSMENT OF POTENTIAL HAZARDOUS WASTE CONTROL GUIDELINES FOR THE INORGANIC CHEMICALS INDUSTRY

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15. Supplementary Notes
E.P.A. Project Officer - Michael Shannon

16. Abstracts An analysis of the economic impact of potential hazardous waste management regulations upon inorganic chemicals was performed based on hazardous waste management cost data supplied by the EPA. The inorganic chemicals included chlorine and caustic soda, hydrofluoric acid, elemental phosphorus, sodium dichromate, titanium dioxide, aluminum fluoride, chrome pigments, nickel sulfate, phosphorus pentasulfide, phosphorus trichloride, and sodium silicofluoride. A methodology was developed to systematically judge the broader economic effects on these chemicals, resulting from applications of hazardous waste management control, first by assessing the likelihood that management costs would be defrayed through price increases, and secondly, if price increases were not likely, the likelihood that plant closures would occur. Based on this approach, it was concluded that only hydrofluoric acid appears to be susceptible to plant shutdowns as a result of hazardous waste management control costs.

17. Key Words and Document Analysis. 17a. Descriptors

Hazardous Waste Management Control Guidelines

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17c. COSATI Field/Group

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# FOREWORD

Work for this report was conducted by Arthur D. Little, Inc., from July 1975 to October 1976. Since the completion of this study, the Resource Conservation and Recovery Act of 1976 (RCRA) was enacted into law on October 21, 1976. EPA is required to promulgate hazardous waste management standards within eighteen months of enactment of RCRA.

The study was conducted using information that would realistically reflect economic impacts if there were regulatory authority. The information and data contained in the report is still valid and will be of significant value to EPA in the process of developing regulations.

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ECONOMIC ASSESSMENT OF POTENTIAL HAZARDOUS WASTE CONTROL GUIDELINES FOR THE INORGANIC CHEMICALS INDUSTRY

by

Arthur D. Little, Inc.

# I. INTRODUCTION

## Purpose and Scope

This report was prepared for the U.S. Environmental Protection Agency (EPA), Office of Solid Waste Management Programs, Hazardous Waste Management Division, to assess the economic impact of potential hazardous waste control guidelines for the inorganic chemicals industry. The report provides EPA with: (1) a preliminary assessment of the likely economic consequences of promulgating certain hazardous waste control guidelines, (2) a data base for further economic analysis of selected industry sectors, (3) a background for guideline development work pursuant to Section 209 of the Solid Waste Disposal Act, as amended. The potential hazardous waste management guidelines evaluated here have not been promulgated and no regulatory authority exists for their promulgation. The economic impact conclusions are those of the Contractor and not of the EPA.

The term "hazardous waste", as applied to specific constituents of waste or by-product streams, is used in a tentative sense. Final judgements about the hazardous nature of certain of the chemicals termed "hazardous" in this report have not been made. Additional information will be required as to the actual fate of such material in a given disposal site or situation before a final decision regarding their inclusion in the definition of "hazardous waste" can be made by EPA.

Hazardous waste management costs have been developed for 11 chemicals: aluminum fluoride, chlorine (including diaphragm, mercury and Downs cell processes), chrome pigments, hydrofluoric acid, nickel sulfate, phosphorus, phosphorus pentasulfide, phosphorus trichloride, sodium dichromate, sodium silicofluoride and titanium dioxide (chloride process).

The economic impact analysis included defining the industry structure, evaluating the supply and demand relationships for each of the 11 chemicals, reviewing proposed control technologies and management costs (these costs have been updated to 1975 values), and estimating the likely economic impacts of the regulations. The product of the study is an economic characterization of the industry and an outline of how key economic impact indicators such as cost changes, demand loss, plant closures, and job losses would be affected if the guidelines were promulgated.

The costs of compliance with designated hazardous waste management guidelines were developed by the Versar Corporation under contract with EPA's Office of Solid Waste Management Programs.[a] The cost estimates of the Assessment Report have been reviewed with firms in the industry and inflated to 1975. However, no rigorous attempt has been made to verify the costs. The Report stated that the accuracy range of the cost estimates was $\pm$ 20 percent for the Alkalies and Chlorine Industry, and $\pm$ 40-50 percent for the Inorganic Pigments and Industrial Inorganic Chemical Industry. While many of the important economic impacts result from incremental and relative costs rather than total costs, the overall accuracy of the economic analysis is limited by the accuracy of the cost information.

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a. "Assessment of Industrial Hazardous Waste Practices, Inorganic Chemicals Industry," March, 1975 contract number 68-01-2246.

# II. EXECUTIVE SUMMARY

## A. Major Findings

1. Segmentation of the Industry. The Assessment Report developed costs of waste management for 13 chemicals and chemical processes included in the Standard Industrial Classification (SIC) 281 - Industrial Inorganic Chemicals. The economic impact analysis has been focused on five primary chemicals likely to experience the greatest impact. Eight secondary chemicals and chemical processes likely to experience a lower level of impact have been treated in less detail.

The chemicals were segmented (Figure II-1) on the basis of hazardous waste management costs as a percent of selling price and by market size. The primary chemicals examined were chlorine made by the mercury cell process, titanium dioxide made by the chloride process, elemental phosphorus, sodium dichromate, and hydrofluoric acid.

2. Summary of Impacts on Chemical Production. The impact of the hazardous waste management costs on the total demand for the primary chemicals has been estimated using econometrically-derived demand elasticities. Table II-1 summarizes the effect on demand and production of the complete passthrough of incremental compliance costs. For example, hydrofluoric acid could experience a 1.6 percent drop in demand due to the higher prices, which represents a $2.9 million drop in sales. The incremental compliance cost and relative impacts on the secondary chemicals are summarized in Table II-1.

Using a model plant cost structure for each primary chemical, a discounted cash flow analysis was performed to test whether manufacturers are likely to close plants rather than install the required capital facilities and continue to operate with the higher operating costs. After a sensitivity analysis

| 1975 Market Size (Production) | Small (Under 0.5 Percent) | Medium (0.5 to 1.0 Percent) | Large (Over 1.0 Percent) |
|---|---|---|---|
| Large (Over 1 Million Short Tons) | Diaphragm Cell Chlorine | | (HIGHEST PRIORITY) Mercury Cell Chlorine |
| Medium (Over 100,000 Short Tons) | Downs Cell Chlorine<br>Aluminum Fluoride | Titanium Dioxide (Chloride Process) | Phosphorus<br>Sodium Dichromate<br>Hydrofluoric Acid |
| Small (Under 100,000 Short Tons) | (LOWEST PRIORITY) Sodium Silicofluoride<br>Phosphorus Pentasulfide<br>Phosphorus Trichloride | Chrome Colors<br>Nickel Sulfate | |

Treatment Costs As Percent of Selling Price

**Source:** Contractor's Estimates.

FIGURE II-1 ECONOMIC IMPACT PRIORITIES OF INORGANIC CHEMICALS

TABLE II-1

SUMMARY OF IMPACT FINDINGS*

| Primary affected chemicals | Demand elasticity[e] | Expected demand impacts: Change in demand (percent) | Expected demand impacts: Value of demand change[a] ($ MM) |
|---|---|---|---|
| Chlorine (mercury cell process) | -0.36 | none[f] | none[f] |
| Hydrofluoric acid | -1.91 | 0-1.6 | 0-2.9 |
| Phosphorus | -2.18 | -1.5 | -6.2 |
| Sodium dichromate | -0.50 | -0.4 | -0.4 |
| Titanium dioxide (chloride process) | -0.42 | -0.2 | -1 |

| Secondary affected chemicals | Market size[b] | Treatment cost[c] | Impact[d] |
|---|---|---|---|
| Aluminum fluoride | Medium | Small | Limited |
| Chlorine (diaphragm, Downs cells) | Large | Small | Moderate |
| Chrome pigments | Small | Medium | Limited |
| Nickel sulfate | Small | Medium | Limited |
| Phosphorus pentasulfide | Small | Small | Negligible |
| Phosphorus trichloride | Small | Small | Negligible |
| Sodium silicofluoride | Small | Small | Negligible |

*Source: Contractor's estimates.

a. Calculated by multiplying drop in demand (metric tons) by average 1975 shipment value ($/ton).

b. Large: over 1 MM tons/year; medium: over 100 M tons/year; small: under 100 M tons/year.

c. As a percent of selling price; medium: over 0.5 percent; small: under 0.5 percent.

d. Terms indicate relative rank as well as order of magnitude of impacts.

e. The percent change in demand given a 1 percent increase in price.

f. The economic impact on mercury cell chlorine, in terms of demand changes, is expected to be negligible based on the assumption that manufacturers will be unable to raise prices to recover hazardous waste management costs. See Section VIII. A. 1.

to test higher waste management costs, it was concluded that only in the case of hydrofluoric acid was there a possibility of plant closures. These results are summarized in Table II-2.

With the exception of hydrofluoric acid, the economic impact of the proposed hazardous waste management regulations on the production of inorganic chemicals appears to be fairly modest. However, there are two factors working contrary to this conclusion which have not been quantitatively evaluated. The first is that there is strong evidence of significant differences among the costs of compliance of plants producing the same product. These differences can allow one producer to come into compliance at a lower cost level than another and gain a competitive advantage. Proximity to an approved landfill is a good example of one of these differences.

The second factor is the coincidence of air and water pollution control costs at the same time as the hazardous waste management costs. In many cases, the air and water costs are much greater (generally in the ratios of 1:7:10, hazardous waste: air: water).[a] The addition of hazardous waste management requirements can be more important at a time of other significant pollution control costs than at a time when the firms can deal with the hazardous waste costs alone.

3. Summary of Industry Economic Impacts. The primary affected chemicals accounted for about 32 percent of the $8 billion of inorganic chemicals shipped in 1975.[b] The estimated value of shipments which would

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a. Manufacturing Chemists Association Survey, reported in the Oil and Gas Journal, September 22, 1975.

b. Only $1.3 billion (16%) of the primary chemicals were made in production processes with high hazardous waste costs and whose production was evaluated by the primary economic impact analysis. See Table VIII-22.

TABLE II-2

POSSIBLE PLANT CLOSURES RESULTING FROM HAZARDOUS WASTE TREATMENT COSTS*

| Chemicals | Number of existing plants | Number of possible plant closures | Percent |
|---|---|---|---|
| Chlorine-mercury cell | 27 | - | - |
| Titanium dioxide -chloride | 8 | - | - |
| Elemental phosphorus | 10 | - | - |
| Sodium dichromate | 3 | - | - |
| Hydrofluoric acid | 12 | 1 - 2 | 8 - 16 |
| Total | 60 | 1 - 2 | 2 - 3 |

*Source: Contractor's estimates.

have been lost in 1975 as a result of the passthrough of hazardous waste management costs to consumers (due to demand elasticity effects) is $8 to $11 million, or about 0.1 percent of total industry shipments. This is equivalent to about 0.4 percent of the 1975 primary affected chemical shipment value.

Incremental industry investment required for Level III control of hazardous wastes from the primary affected chemicals is estimated at $20.1 million, as shown on Table II-3. This is an investment which would be required over a period of several years. While the $20.1 million is low compared to an estimated $6.3 billion of total capital spending and $684 million spent on pollution control by the chemical industry as a whole in 1975,[a] it is high compared to the apparent level of capital expenditures related to the primary chemicals. An estimated $120 million was invested by the chemical industry in 1975 related to the primary chemicals of which $13 million of capital expenditures were made for pollution control. About $1 million was spent for solid waste including hazardous waste.

The inorganic chemical industry has experienced long-term growth of 5 to 6 percent per annum. Annual growth from 1975 to 1985 is expected to average between 4 and 5 percent. The growth of the inorganic chemicals industry is not likely to be significantly affected by the cost of hazardous waste management. Some small reduction in demand growth is likely to occur as real prices rise; however, hazardous waste management costs are relatively small when compared to other increasing cost elements.

## B. Chapter Summaries

A more detailed review of the major findings of this study is presented here in the form of brief synopses of Chapters III to VIII. The reader should understand that in preparing chapter summaries, generalizations

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a. Survey of Current Business, Department of Commerce, July 1976, p. 14.

TABLE II-3

INCREMENTAL INDUSTRY INVESTMENT REQUIRED FOR HAZARDOUS WASTE CONTROL*

| Chemicals | Product capacity (1,000's of metric tons) | Incremental capital investment required to achieve level III treatment ($/ton of capacity) | Incremental capital investment required for total industry (000 $) |
|---|---|---|---|
| Chlorine-mercury cell | 2,800 | -[a] | - |
| Titanium dioxide- chloride | 514 | -[a] | - |
| Elemental phosphorus | 560 | 16.48 | 9,200 |
| Sodium dichromate | 154 | 9.68 | 1,500 |
| Hydorfluoric acid | 327 | 28.72 | 9,400 |
| Total | | | 20,100 |

*Source: Contractor's estimates.

a. Level III hazardous waste disposal is specified as contract disposal.

have been made in the interest of greater ease of understanding; thus, statements in the summaries may not fully reflect the complexities of the issues treated in the individual chapters.

1. Industry Characterization. (Chapter III) The inorganic chemicals industry had shipments of nearly $8 billion in 1975 and has shown long-term real growth of about 5 to 6 percent per annum. Growth between 1975 and 1985 is expected to average between 4 and 5 percent per annum. The primary affected chemicals accounted for about 32 percent of industry shipments in 1975, while the secondary chemicals accounted for about 2 percent of industry shipments.

The structure of the industry markets tends towards oligopoly, i.e., a relatively small number of large, diversified companies account for a majority of inorganic chemical production. The leading firms have enjoyed relatively stable market positions over a period of 15 years or longer. Among the reasons for this dominance by a relatively few companies are economies of scale, growth by acquisition, and the trend toward greater horizontal and vertical integration.

A financial profile of the inorganic chemicals industry is difficult to construct because of the diversity of activities in which the large chemical producers are engaged. In general, the profitability of this capital-intensive industry has averaged 6.5 percent of sales over the past ten years. Return on equity has averaged 11.5 percent over the same period. This is slightly lower than the ten-year record achieved on sales of all chemicals because of the commodity nature of many inorganic chemicals.

In 1975, new investment in the industrial chemical industry was over $6 billion. In general, the industry has been unable to finance most of its capital requirements internally and has relied on outside sources for both debt and equity funding. This dependence on outside funds will continue in the future.

Employment and wages in the industry totalled approximately 100,000 and $1.35 billion respectively in 1974. The primary affected chemicals accounted for about 32 percent of wages and employment, the secondary affected chemicals about 2 percent.

The primary affected chemicals are produced by 29 companies. The principal companies are Allied Chemical (three primary chemicals), DuPont (three), Stauffer (three), FMC (two), Monsanto (two), and Dow (one). DuPont is the largest single producer of the five primary affected chemicals, producing an estimated 14 percent of the total. Dow and Monsanto are second and third in importance, with approximately 11 percent of primary affected chemical production each.

2. Characterization of Primary Affected Chemicals. (Chapter IV) The economic and competitive environment for each of the primary chemicals has been defined using published material and interviews with knowledgeable persons in the industry. Table II-4 lists some of the parameters generally characterizing the primary chemicals. Chlorine and titanium dioxide are growing at rates above the average rate of growth in U.S. GNP, while the growth of the remaining products is at a significantly lower rate. Capacity utilization

TABLE II-4

CHARACTERIZATION OF PRIMARY CHEMICALS*

| Chemical | 1975 production 1,000's metric tons | Number of producers | Number of plants | Demand growth %/year | Product substitution | Import competition | Capacity utilization % |
|---|---|---|---|---|---|---|---|
| Chlorine | | | | | | | |
| • total | 8,260 | 35 | 67 | 6 | low | low | 85 |
| • mercury cell | 2,060 | 15 | 27 | 6 | low | low | 75 |
| Hydrofluoric acid | 284 | 8 | 12 | 0-2 | moderate | high | 87 |
| Phosphorus | 408 | 10 | 10 | 0-2 | high | low | 73 |
| Sodium dichromate | 112 | 3 | 3 | 1-3 | low | none | 90 |
| Titanium dioxide | | | | | | | |
| • total | 547 | 9 | 15 | 4-5 | low | low | 65 |
| • chloride process | 330 | 5 | 8 | 4-5 | low | low | 65 |

*Source: Current Industrial Reports (M28A(75)), "Directory of Chemical Producers," Contractor's estimates.

is generally high and expected to remain so, with the possible exception of hydrofluoric acid, which is facing increased competition from imports and which faces the possibility of reduced demand for fluorocarbons.

Sodium dichromate has only three producers and three plants, with the two largest of comparable size. Each of the producers will have a significant influence on price changes resulting from the compliance costs. For the other products, there are enough plants and producers so that price changes will be a closer reflection of average industry costs.

Counting only the mercury cell chlorine, there were approximately 5,500 thousand metric tons of the primary chemicals produced in 1975 with an estimated value of $1.3 billion ($2.4 billion including all chlorine). The mercury cell chlorine accounted for 38 percent of the product tonnage and titanium dioxide accounted for another 10 percent.

3. Characterization of Secondary Chemicals. (Chapter V) The competitive environment and industry economics of the six secondary chemicals were characterized in less detail than the primary chemicals. Table II-5 displays parameters generally characterizing the chemicals. The total production of the secondary chemicals in 1975 was approximately 344,000 metric tons. Aluminum fluoride was the largest volume at 118,000 tons, 34 percent of the total, followed by phosphorus trichloride at 75,000 tons. Phosphorus pentasulfide and phosphorus trichloride are projected to have strong demand growth, while the remaining chemicals will have low or negative growth.

Most of the producers of the secondary chemicals are also primary chemical producers. The reverse is also true among the larger producers.

TABLE II-5

CHARACTERIZATION OF SECONDARY CHEMICALS *

| Chemical | 1975 production 1,000's metric tons | Number of producers | Number of plants | Demand growth %/year | Capacity utilization % | Product substitution |
|---|---|---|---|---|---|---|
| Aluminum fluoride | 118 | 4 | 5 | 3.3 | 80 | low |
| Chrome pigments [a] | 41 | 11 | 15 | 1-2 | 85 | moderate |
| Nickel sulfate [b] | 9 | 4 | 4 | decline | 60 | low |
| Phosphorus pentasulfide | 56 | 3 | 3 | 6 | 70 | low |
| Phosphorus trichloride | 75 | 5 | 6 | 7-9 | 85 | low |
| Sodium silicofluoride | 45 | 3 | 3 | decline | 70 | high |

*Source: Current Industrial Reports (M28A(75)), "Directory of Chemical Producers", and Contractor's estimates.

a. Chrome pigments: chrome green; chrome oxide green; chrome yellow and orange; zinc yellow; and iron blue.

b. 1974 production.

4. Proposed Regulations and Treatment Costs. (Chapter VI) The treatment costs used in the assessment of economic impact were developed in a separate Assessment Report for the EPA. Because EPA does not currently have a Congressional mandate to promulgate guidelines for the control of hazardous wastes in the inorganic chemicals industry, the cost data and the impact assessments derived from them are hypothetical.

The Assessment Report identified three levels of control technology for each chemical corresponding to current practices (I), best currently used practices (II), and environmentally acceptable practices (III). For the calculations of price and demand impacts, the incremental cost to the average plant moving from Level I to Level III was used. For the worst case plant closure analysis, the total Level III costs were used. Higher costs developed through industry interviews were used in the sensitivity analysis. Table II-6 lists the model plant incremental control costs for the five primary chemicals.

5. Economic Impact Methodology. (Chapter VII) The economic impact analysis evaluated the economic implications of hazardous waste management control costs in terms of plant closures, cost increases, demand reduction, and associated effects on industry size, growth, employment, wages, local economies and foreign trade. The analysis did not include consideration of secondary effect^ on consumers, long-range changes in demand or capital limitations.

The study methodology involved a segmentation of the eleven chemicals under study into two categories: primary affected chemicals and secondary affected chemicals. In general, the primary affected chemicals are those with larger production volumes and larger incremental treatment costs as a percent of selling price. The segmentation allowed a greater concentration of effort on the five chemicals likely to experience the greatest impact.

TABLE II-6

INCREMENTAL COSTS FOR ACHIEVING LEVEL III HAZARDOUS WASTE TREATMENT TECHNOLOGY (1975) *

| | Chlorine and caustic (diaphragm cell process) | Chlorine and caustic (mercury cell process) | Titanium dioxide (chloride process) | Hydro-fluoric Acid | Phosphorus | Sodium dichromate |
|---|---|---|---|---|---|---|
| Investment costs | | | | | | |
| Land | - | - | - | (5,000/yr) | 0 | 0 |
| Other | - | - | - | 660,450 | 824,000 | 629,000 |
| Total | - | - | - | 660,450 | 824,000 | 629,000 |
| Annual costs | | | | | | |
| Capital | - | - | (5,000) | 172,340 | 215,000 | 101,900 |
| Operating | - | (46,800) | (38,400) | 18,000 | 3,600 | 80,400 |
| Energy & power | - | (175) | - | - | 2,700 | (8,100) |
| Contractor | 51,000 | 367,200 | 157,200 | - | - | 60,000 |
| Total | 51,000 | 320,230 | 113,800 | 190,340 | 221,300 | 234,200 |
| Model plant annual production | 162,000 | 90,000 | 36,000 | 23,000 | 50,000 | 65,000 |
| Cost per metric ton of product | $0.31/ton | $3.56/ton | $3.16/ton | $8.28/ton | $4.43/ton | $3.60/ton |
| Cost per metric ton of waste (wet) | $25.50/ton | $72.78/ton | $2.85/ton | $1.73/ton | $6.08/ton | $3.25/ton |

*Source: "Assessment of Industrial Hazardous Waste Practices, Inorganic Chemicals Industry," Versar, Inc.

For the primary chemicals, the demand functions were econometrically estimated using historical sales and product transaction price values. The supply functions were not estimated due to insufficient data, and thus, equilibrium prices could not be derived. However, engineering estimates were made of production costs at the plant level for use in the plant closure analysis.

Through published sources and industry interviews, the competitive environment of the products was characterized. These factors were considered when outlining how producers would probably respond when faced with the new hazardous waste control costs.

Having specified pricing strategies, changes in total demand were estimated using the demand elasticity values. The plant closure analysis used updated control costs in a discounted cash flow analysis of the decision to make the necessary capital investment in control facilities. For the cases where Level III was contract disposal, plant cash flow had to remain positive for the plant to stay open. Since plant closures are more likely for plants with higher production and disposal costs, a sensitivity analysis was performed with higher costs to test the range of potential plant closures.

6. Assessment of Economic Impact. (Chapter VII) Of the five primary chemicals, only hydrofluoric acid appears to be susceptible to plant shutdowns as a result of hazardous waste management control costs. The other primary chemicals would experience a low level of demand reduction because of the additional cost of hazardous waste control, but no plant shutdowns would be expected as a direct result of these costs.

The estimated plant level manufacturing costs for the five primary chemicals are shown on Table II-7, along with the total and incremental hazardous waste treatment costs. The table also shows the incremental costs as a percentage of plant level pre-tax income. If corporate overhead costs are added to the manufacturing costs, the compliance costs become a higher percentage of income than that shown. For chlorine and caustic, the incremental costs are 2.8 percent of plant level manufacturing costs and 6.8 percent of income. The incremental treatment costs for elemental phosphorus are $4.43 per ton of phosphorus, which is 1.4 percent of pre-tax income.

For each of the five primary chemicals, the total product demand reduction resulting from price increases has been estimated for a range of price increases. Table II-8 lists the demand reductions assuming that all of the incremental compliance costs are recovered in price increases. In some instances, competition is not expected to allow price increases in the short run sufficient to fully recover the costs. The expected demand losses when the price constraints are taken into account are also shown on Table II-8.

The possible early closure of one or two small hydrofluoric acid plants were the only potential plant closures identified. An estimated 45 to 90 jobs would be lost if the closures occurred. If a high production-cost plant does close because of the hazardous waste costs, the severest impact will be seen in the community where the plant is located. Some of the plant's production would be taken over by the remaining plants, whose employment would increase.

TABLE II-7

RELATIVE MACNITUDE OF HAZARDOUS WASTE TREATMENT COSTS*

| Chemical | Manufacturing cost per product ton | Total treatment cost per product ton | Incremental treatment cost per product ton | Incremental treatment cost as a % of pre-tax income |
|---|---|---|---|---|
| Chlorine and caustic (mercury cell) | $126 | $4.08 | $3.56 | 6.8 |
| Titanium dixoide (chloride process) | 744 | 4.32 | 3.16 | 8.8 |
| Phosphorus | 679 | 7.00 | 4.43 | 1.4 |
| Sodium dichromate | 452 | 8.92 | 3.60 | 2.4 |
| Hydrofluoric acid | 485 | 18.90 | 8.28 | 7.2 |

*Source: Contractor's estimates.

Notes: 1. The manufacturing costs and the pre-tax income are for model plants at the plant level and do not include corporate overhead costs.

2. Chlorine and caustic are joint products. The manufacturing and treatment costs include both chemicals.

TABLE II-8

DEMAND IMPACTS ON PRIMARY CHEMICALS*

| Chemical | 1975 demand ($MM) | Demand loss with 100% cost passthrough[a] ($MM) | Expected demand loss[a] ($MM) |
|---|---|---|---|
| Chlorine[b,e] | 861 | 8.4 (1%) | none |
| Hydrofluoric acid | 170 | 5.8 (3.4%) | 0 - 2.9 (1.7%) |
| Phosphorus | 403 | 6.2 (1.5%) | 6.2 (1.5%) |
| Sodium dichromate[c] | 87 | 0.4 (0.4%) | 0.4 (0.4%) |
| Titanium dioxide[d] | 426 | 0.8 (0.2%) | 0.8 (0.2%) |
| Total | 1,947 | 21.6 (1%) | 7.6 - 10.5 (0.4% - 0.5%) |

*Source: Contractor's estimates.

a. Assumes full cost recovery pricing strategy and lost demand valued at 1975 prices.

b. Total chlorine production is included because a price change for mercury cell chlorine would have to be matched by increases in other chlorine prices in order for the change to stick.

c. The value of sodium dichromate production in 1975 was actually about $68 MM (112,000 metric tons). The demand impact calculation assumed 144,000 tons as more representative than the actual 1975 value.

d. The total titanium dioxide production is included rather than only the chloride process production for the same reason all chlorine is included. About 60% is chloride process production.

e. Price increases for caustic soda would result in a demand reduction, however its magnitude has not been estimated. Expected demand loss is zero because little or no cost passthrough is anticipated.

In addition to the jobs affected by plant closures, a small number of jobs would be affected by the drop in product demand due to price increases. Table II-9 summarizes the job impacts. The 55-65 jobs affected by demand reduction may not result in any current employees losing their jobs. In most cases the effects are so small that they would more likely be seen in slower employment growth than would have occurred in the absence of the hazardous waste management costs.

TABLE II- 9

POTENTIAL IMPACT OF HAZARDOUS WASTE TREATMENT COSTS ON EMPLOYMENT*

| Chemicals | Number of employees | Employment loss due to Plant closure | Demand loss |
|---|---|---|---|
| Chlorine-mercury | 2165 | - | - |
| Titanium dioxide | 6165 | - | 10 |
| Elemental phosphorus | 2890 | - | 40 |
| Sodium dichromate | 850 | - | 3 |
| Hydrofluoric acid | 540 | 45 - 90 | 0 - 10 |
| Total | 12,610 | 45 - 90 | 55 - 65 |

*Source: Contractor's estimates.

# III. INDUSTRY CHARACTERIZATION

Although this study deals with eleven inorganic chemical products, a discussion of the individual organization of markets for these products must be placed in a broader context. For example, it would not be appropriate to assume that firms buying and selling chlorine constitute an industry, separate and distinct from the chemical industry as a whole. Chlorine is simply a sub-category or finer classification of the entire chemical industry.

Economic conditions, especially in terms of a common set of supply technologies, in this larger market certainly affect the supply and demand for individual product groups. In order to judge what type of analytic methods are most appropriate for the estimation of price, output, and other economic effects of hazardous waste regulation, it is necessary to characterize both the general nature of the industry as well as the specific nature of each product. To this end, this chapter will describe the inorganic chemicals industry in terms of size and growth, structure, financial traits, employment and wages, dependence on affected chemicals and characteristics of production facilities.

## A. Size and Growth

As shown in Table III-1, the inorganic chemicals industry accounted for shipments of nearly $8 billion in 1975. Industry growth is mixed, with the largest sectors exhibiting the slowest growth, and vice versa. The typical inorganic chemical has a growth rate in the range of four to eight percent per year or 1.5 to 2 times the growth of U.S. GNP.

TABLE III-1

SIZE AND GROWTH OF INDUSTRIAL INORGANIC CHEMICALS INDUSTRY*

| Industry sector | 1975 value of shipments ($ billions) | Growth rate (%/yr.) 1974-75 | 1975-85 |
|---|---|---|---|
| Chlor alkali | 1.15 | 12 | 5.7 |
| Industrial gases | 0.99 | 10 | 8.3 |
| Inorganic pigments | 1.04 | 5 | 6.2 |
| Industrial inorganic chemicals | 4.73 | 2 | 3.9 |
| Total | 7.91 | | |

*Source: U.S. Industrial Outlook, 1976, U.S. Department of Commerce.

## B. Structure

1. Development of the Chemical Industry.[a] Markets for individual chemical products tend towards oligopoly, or a fewness of sellers. It is generally true that in most chemical product "sub-industries", over half of all shipments are accounted for by the largest four sellers. In all of these markets, a relatively small number of very large, diversified companies account for a majority of the output. Table III-2 shows the assets of the seven leading chemical companies in 1958 and 1973 and the sales of the seven leading chemical companies in 1975. From 1958 to 1973, many of the firms have more than doubled their size, and the distinctions between the large firms have narrowed somewhat. Thus, leadership among the "Big Seven" has come to be even more evenly shared than was true in the late 1950's. However, the most remarkable characteristic of the leading firms has been the relative stability of each firm's position over a period of 15 years.

In addition to these market leaders, there are a number of other large firms that typically specialize in individual product groups; e.g., Diamond Shamrock, Hooker, and BASF Wyandotte are all large chlorine producers. There are also several large manufacturing corporations and conglomerates which do not participate primarily in the chemical industry but which do maintain large chemical divisions. Again, this point can be demonstrated by referring to chlorine: PPG Industries and Occidental Petroleum are among the largest producers of chlorine (2nd and 4th largest respectively), although they are not

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a. A significant part of the material in this section is drawn from A.E. Kahn, "The Chemical Industry," in Walter Adams, ed., The Structure of American Industry, 3rd edition, 1961.

TABLE III-2

LEADING CHEMICAL COMPANIES*

I. Assets Basis

| Rank in 1973 | | Rank in 1958 | Assets ($, MM) 1958 | Assets ($, MM) 1973 |
|---|---|---|---|---|
| 1. | E.I. DuPont de Nemours | 1. | 2,649 | 4,832 |
| 2. | Union Carbide | 2. | 1,530 | 4,162 |
| 3. | Dow Chemical | 3. | 875 | 3,896 |
| 4. | Monsanto | 6. | 664 | 2,545 |
| 5. | Allied Chemical | 5. | 748 | 1,763 |
| 6. | American Cyanamid | 7. | 584 | 1,442 |
| 7. | Olin | 4. | 787 | 1,188 |

II. Chemical Sales Basis

| Rank in 1975 | | Chemical sales ($,MM) | Total sales ($,MM) |
|---|---|---|---|
| 1. | E.I. DuPont de Nemours | 5,500 | 7,222 |
| 2. | Union Carbide | 3,425 | 5,665 |
| 3. | Dow Chemical | 3,360 | 4,888 |
| 4. | Monsanto | 3,054 | 3,625 |
| 5. | Exxon | 2,594 | 44,864 |
| 6. | W.R. Grace | 1,800 | 3,529 |
| 7. | Celanese | 1,716 | 1,900 |

*Sources: Moody's Industrials, and Chemical and Engineering News.

normally thought of as major competitors in the chemical industry. Over time, this trend toward "outsiders" taking significant market positions in certain products has been increasing.

There are a number of reasons for the domination of chemical markets by a handful of large companies. One industry observer suggests that the distinctive conditioning influence has been technology, "....the enormous potentialities of applying chemical science to industry, exploited with increasing intensity during the last 60 years, have provided favorable conditions for growth in the scale of enterprise."[a] In many instances, it appears that there are substantial economies of scale in the production of chemicals. It is a simple fact of nature that many chemical production facilities exhibit declining unit costs over large ranges of total output. At some point, however, it is also true that average unit costs probably begin to increase as the very large size of plants causes some diseconomies of scale to set in.

In addition to technology, several other reasons for the existence of large firm size in the chemical industry may be cited. First, chemical companies tend to be vertically integrated from basic raw materials into numerous product categories that use an essential resource. As an example, it is often said that DuPont went from nitrocellulose explosives backward into synthetic ammonia, forward and sideways into nitrocellulose lacquers, artifical leather, plastics, film, rayon, and cellophane. Second, large firm size stems from the historical cumulation of numerous horizontal mergers of

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a. Kahn, ibid, p. 241.

competing producers. This merger movement, the effects of which are still felt today, was primarily motivated by a simple desire for market control. Third, the methods of expansion and entry in the industry have usually been characterized by one firm joining with, or buying out, other firms already in the industry or which are planning to enter. Such methods clearly benefit the firms involved by avoiding duplication of facilities, patent restrictions, and most importantly, competition.

Aside from all of these reasons, chemical companies have grown larger simply by virtue of their size, i.e., "size breeds size." There is empirical support for this point of view. Several studies have found that large companies appear to earn rates of return on equity that are significantly higher than those earned by smaller firms.[a] One argument that would explain this phenomenon is that larger firms may have better access to capital markets or may be more able to finance growth out of retained earnings.

2. Market Conduct and Performance. An oligopolistic market is characterized by a certain dependence between the business decisions of each market participant. Because there are only a few sellers in the market, in determining what price to set, a given firm will include in its decision analysis the expected reactions of its rivals. Such is not the case in a competitive market where firms have no influence over price and are free to sell all the output they care to at the prevailing market price. This aspect of interdependency between firms in the chemical industry clearly has profound effects on the conduct and resulting performance of all firms

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a. Hall and Weiss, "Firm Size and Profitability," Review of Economics and Statistics, 1967, pp. 319-331.

within the industry. Market conduct is generally conservative and statesmanlike with no firm investing in "too" much capacity nor shaving prices much below the prevailing market price. Each firm has a vested interest in maintaining a certain degree of stability in its market(s).

It has been noted that chemical companies have employed the following methods to ensure stable market conditions:[a]

- firms form joint ventures in fields of common interest;
- companies use established firms in a given field to market their products;
- patents are often pooled among companies with an understanding that a firm's markets or product areas are to be recognized; and
- chemical raw materials are bought and sold between a small number of firms with preferential discounts often involved.

These means offer a company the opportunity to reduce its exposure to uncertain events in its various markets.

Price policy is a second aspect of chemical firms' conduct that conditions performance. For the most part, a method of full cost pricing is used. This technique involves a percentage markup over unit costs. One industry observer argues that this price policy tends to reduce competition in the industry for the following two reasons.[b]

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a. Kahn, ibid, pp. 249-252.

b. Kahn, ibid, pp. 252-253.

First, there are numerous indirect and discretionary costs like research and development expense which all lead to a confused determination of standard costs. Many of the chemical production processes lead to joint products with attendant cost allocation difficulties. As a result, costs often seem to bear little relation to prices.

Second, most producers believe that demand for their products is inelastic, i.e., a given increase in price leads to less than a proportionate decrease in revenue. Yet it is rarely the case that a single producer would unilaterally change his price. It has been observed that something like a kinked demand curve is operable in many chemical product markets. This construct refers to the condition whereby any price cut in a market will be matched by competitors, but price increases are not followed, thus conferring market share losses on the would-be price leader. Although the abstraction of a kinked demand curve is appealing in a descriptive sense, it tells us little about how prices are actually determined.

Most sales of chemicals are by long-term contract. This fact seems to cause buyers to pay more attention to safety of supply and quality rather than to price differences. It is not well known whether chemical prices change very often since there is no equivalent of a "futures market" for chemical products. Bureau of Labor Statistics (BLS) price indexes show a tremendous amount of price inflexibility, but these data may be suspect. One study has shown that BLS sampling procedures are severely biased towards price change infrequency.[a] To find the true level of price and the rate of

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a. G. Stigler and Kindahl, The Behavior of Industrial Prices (New York: NBER, 1970).

price change, an independent study would have to poll actual producers for their long-term contract prices over a number of years. Without these types of data, it is extremely difficult to conclude anything about the level of price and the responsiveness of price to changes in market demand.

It has been argued that chemical prices are another example of administered prices.[a] By this it is meant that prices slide upward, tending to remain relatively constant during market contractions and rise slowly during expansions. Such behavior is often associated with the presence of market power.

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a. Gardiner C. Means introduced this concept in the 1930's.

## C. Financial Profile

A financial profile of the "inorganic" chemical industry has limited meaning because of the diversity of chemical activities in which inorganic chemical producers are engaged. Most companies, in their financial reporting, do not break down financial information by product line; this is considered proprietary information. In addition, where financial data are broken into product groups, the data may include a broad range of chemicals other than simply inorganic chemicals.

A financial profile of the "inorganic" chemical industry has been developed based on financial data reported by the Federal Trade Commission (FTC) which covers the three-digit SIC group 281. It must be recognized that the financial data are not completely representative of the inorganic chemical industry because most companies do not report financial data based strictly on SIC classification. Also, in the classification of companies for reporting purposes by the FTC, a company can be included in the industrial chemical industry, although it may be involved in diversified activities including non-chemical businesses.

1. Profitability. The industrial inorganic chemical industry is a cyclical, capital intensive business. These influences have an important impact on the profitability of the industry. Table III-3 summarizes the earnings pattern of the industrial chemical industry over the 1965-74 period. The earnings trend indicates that the level of profitability closely follows the economy, with profitability declining in 1967 and 1970, recent recession years. Industry profitability is also expected to decline in 1975.

The profitability of the industrial inorganic chemical industry has averaged 6.5 percent of sales and 11.5 percent return on equity over the past 10 years. This compares to a profitability of 7.0 percent of sales and 12.0 percent return on equity over the 10-year period for all chemicals. In general,

TABLE III-3

INDUSTRIAL INORGANIC CHEMICALS (SIC 281)

FINANCIAL PROFILE *

| | 10-Yr. Ave. | 1974 [a] | 1973 | 1972 | 1971 | 1970 | 1969 | 1968 | 1967 | 1966 | 1965 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Net income after taxes/net sales | 6.5% | 8.2% | 6.5% | 5.4% | 5.0% | 5.0% | 6.0% | 6.3% | 6.5% | 8.1% | 8.3% |
| Net income after taxes/total assets | 6.4 | 8.9 | 6.7 | 5.3 | 4.6 | 4.6 | 5.7 | 6.2 | 6.1 | 7.7 | 7.9 |
| Net income after taxes/net worth | 11.5 | 16.6 | 12.6 | 9.8 | 8.4 | 8.4 | 10.4 | 11.1 | 10.7 | 13.6 | 13.8 |
| Dividends/net income after taxes | 53.1 | 32.6 | 40.3 | 53.6 | 62.5 | 68.6 | 57.9 | 57.8 | 58.1 | 49.3 | 49.9 |

*Source: "Quarterly Financial Report for Manufacturing Corporations", Federal Trade Commission.

a. 1974 figures reflect change in accounting procedures and are not directly comparable to previous years.

the profitability of the chemical industry is higher than for all manufacturing corporations. The lower profitability reflects the commodity-oriented nature of a portion of the inorganic chemical business. Commodity chemicals are large volume chemicals with limited product differentiation between producers. As a result, a primary competitive tool is pricing which results in a lower level of profitability for commodity chemicals.

The industrial inorganic chemical industry is a cyclical industry as reflected by the cyclical trends in the earnings pattern of the industry. The profitability of the industry declined from 8.3 percent of sales in 1965 to 5.0 percent of sales in 1971. During this period, overcapacity was built in the industry and industry profitability subsequently suffered. Since the industrial inorganic chemical industry is capital intensive, a high operating rate in a chemical plant is necessary to maintain reasonable levels of profitability.

The overcapacity also caused greater price competition. Producers strove to achieve higher operating rates and sales levels through reduced profit margins which further impacted industry profitability.

During the early 1970's, operating rates in the industrial chemical industry improved significantly. Also, with stronger demand, producers were able to raise prices and achieve a level of profitability which had not been reached in the industry since the early 1960's.

2. Investment and Capital Structure. The investment in the industrial chemical industry was over $25 billion (in current dollars) in 1974, including investment in net fixed assets and working capital requirements. Table III-4 summarizes investment in the industry over the 1965-74 period.

TABLE III-4

INDUSTRIAL INORGANIC CHEMICALS (SIC 281)

FINANCIAL PROFILE*

| Industry investment | 1974 [a] | 1973 | 1972 | 1971 | 1970 | 1969 | 1968 | 1967 | 1966 | 1965 |
|---|---|---|---|---|---|---|---|---|---|---|
| Net fixed assets ($MM) | 16,961 | 17,899 | 16,705 | 16,321 | 15,438 | 14,564 | 13,727 | 13,696 | 12,663 | 11,196 |
| Working capital ($MM) | 8,181 | 9,178 | 8,046 | 7,299 | 6,555 | 6,456 | 6,315 | 6,090 | 5,758 | 5,464 |
| Total investment ($MM) | 25,142 | 27,077 | 24,751 | 23,620 | 21,993 | 21,020 | 20,042 | 19,786 | 18,421 | 16,660 |
| Working capital/ net sales | 19.0% | 23.2% | 24.3% | 24.8% | 23.9% | 23.8% | 24.1% | 25.0% | 24.4% | 26.2% |
| Net sales/net fixed assets | 2.55 | 2.21 | 1.98 | 1.80 | 1.78 | 1.86 | 1.91 | 1.78 | 1.86 | 1.86 |

* Source: "Quarterly Financial Report for Manufacturing Corporation", Federal Trade Commission.

a. 1974 figures reflect change in accounting procedures and are not directly comparable to previous years.

The industrial chemical industry is capital intensive with significant investment requirements for both working capital and fixed assets. Working capital needs have averaged 23.9 percent of sales over the 10-year period ranging from 19.0 percent of sales in 1973 to 26.2 percent of sales in 1965. For all manufacturing working capital was 17.2 percent of sales in 1974 and indicates a slightly higher working capital requirement in the industrial chemical industry. Also, investment in fixed assets (property, plant, and equipment) as a function of sales is higher than all manufacturing corporations. For the industrial chemical industry over the 10-year period, 1965-74, there were $1.96 of sales for every dollar of net fixed investment in plant and equipment. This compares to all manufacturing corporations which had a significantly higher level of sales per dollar of investment, $3.47 of sales per dollar of net fixed investment over the 1965-74 period.

The capital intensity of the industrial chemical industry places large capital needs on the industry. In general, the industry has been unable to generate internally its own capital needs through retained earnings, and it has relied heavily on outside sources of financing, including debt and equity capital. Table III-5 summarizes the net cash position of the industrial chemical industry over the past 10 years. The analysis compares internally generated sources of cash to annual cash needs, including dividends and capital expenditures, in order to determine annual external capital requirements. Over the 1965-74 period, the industry has had a net cash deficit of close to $900 million, which had to be raised from external sources. In view of high capital needs of the industry to increase future plant capacity, it is expected that the industry will continue to require significant amounts of capital from external sources.

TABLE III-5

INDUSTRIAL INORGANIC CHEMICALS (SIC 281)

FINANCIAL PROFILE*

($MM)

| Cash flow | 1974[b] | 1973 | 1972 | 1971 | 1970 | 1969 | 1968 | 1967 | 1966 | 1965 |
|---|---|---|---|---|---|---|---|---|---|---|
| Net income after taxes | $3,542 | $2,553 | $1,809 | $1,463 | $1,365 | $1,621 | $1,654 | $1,595 | $1,897 | $1,741 |
| Depreciation[c] | 2,122 | 2,282 | 2,146 | 2,013 | 1,892 | 1,795 | 1,762 | 1,648 | 1,515 | 1,366 |
| Cash inflow | 5,664 | 4,835 | 3,955 | 3,476 | 3,257 | 3,416 | 3,416 | 3,243 | 3,412 | 3,107 |
| Dividends | $1,155 | $1,030 | $ 970 | $ 915 | $ 937 | $ 939 | $ 956 | $ 927 | $ 937 | $ 868 |
| Capital expenditures[a] | 4,487 | 3,476 | 2,536 | 2,896 | 2,766 | 2,632 | 1,793 | 2,681 | 2,982 | 2,916 |
| Cash outflow | $5,642 | $5,506 | $3,506 | $3,811 | $3,703 | $3,571 | $2,749 | $3,608 | $3,919 | $3,784 |
| Net cash flow | 22 | 329 | 449 | (205) | (446) | (155) | 667 | (365) | (507) | (677) |
| Debt/equity ratio | 0.38 | 0.39 | 0.41 | 0.44 | 0.43 | 0.41 | 0.41 | 0.41 | 0.39 | 0.38 |

*Source: "Quarterly Financial Report for Manufacturing Corporations", Federal Trade Commission.

a. Capital expenditures ($year_n$) = net fixed investment ($year_n$ - $year_{n-1}$) + depreciation ($year_n$).

b. 1974 figures reflect change in accounting procedures and are not directly comparable to previous years.

c. Depreciation must be added to net income after taxes to determine cash flow because in determining net income, depreciation was a non-cash charge to operating income.

The primary sources of raising additional financing for the industry include long-term debt and equity financing. The industrial chemical industry currently has a high level of debt in its capital structure with a debt/equity ratio of 0.38 in 1974. This compares to a debt/equity ratio of 0.32 in 1974 for all manufacturing corporations. The debt/equity ratio for the industrial chemical industry reached a peak of 0.44 in 1971 because of continuing capital needs in view of declining profitability and cash flow in the industry. As a result, the industrial chemical producers relied more heavily on debt capital during this period to finance capital requirements. In recent years the debt/equity ratio of the industry has improved because of improved cash flow. This has allowed the industrial chemical industry to bring its reliance on debt in its capital structure more in line with the level for all manufacturing corporations.

The industrial chemical industry also has reduced its dividend payout significantly in recent years in order to reduce the industry's reliance on long-term debt, improve liquidity, and provide for additional capital expenditure requirements. As shown in Table III-3, the dividend payout has declined in recent years to 32.6 percent of net income in 1974, which compares to 53.1 percent of net income over the 1965-74 period.

Since the industry has historically relied heavily on long-term debt for external financing and in recent years has reduced dividend payout levels, the industrial chemical industry in the future must have an improved level of profitability in order to have access to equity financing to provide a portion of external capital needs. Access to equity financing will be to a large extent dependent on the industry achieving profitability above historical levels in order to attract equity capital. Factors which reduce the level of profitability in the industry or divert investment needs could limit its ability to meet plant expansion requirements. If the industry is prevented from expanding at necessary levels to meet demand for their products, the situation may have long-term economic impacts.

3. Cost Structure. The cost structure of the industry is heavily weighted to operating costs. Table III-6 summarizes the distribution of the sales dollar for the industrial chemical industry over the 1965-74 period. Operating costs have increased over the 10-year period from 79.0 percent of sales in 1965 to 82.5 percent of sales in 1974. Even with the improved level of profitability in the industry in 1973-74, operating costs have not returned to levels achieved in the 1960's. (The data is not completely comparable because of changes in reporting procedures in 1974.) The improved levels of profitability have come, to a large extent, from lower depreciation levels and a reduced tax rate. The depreciation level has declined from 6.5 percent of sales in 1965 to 4.9 percent of sales in 1974, and the tax rate has declined from 42.0 percent to 39.3 percent in 1965 and 1974 respectively. As a result, the level of profitability in the industrial chemical industry in 1974 is comparable to the level of profitability in 1965, although operating costs as a percent of sales in 1974 are substantially higher.

TABLE III-6

INDUSTRIAL INORGANIC CHEMICALS (SIC 281)

COST PROFILE*

| | 1974[a] | 1973 | 1972 | 1971 | 1970 | 1969 | 1968 | 1967 | 1966 | 1965 |
|---|---|---|---|---|---|---|---|---|---|---|
| Net sales | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| Operating costs | 82.5 | 82.1 | 83.2 | 83.8 | 83.9 | 82.2 | 81.6 | 82.1 | 79.7 | 79.0 |
| Depreciation | 4.9 | 5.8 | 6.5 | 6.8 | 6.9 | 6.6 | 6.7 | 6.8 | 6.4 | 6.5 |
| Income from operations | 12.3% | 12.1% | 10.3% | 9.4% | 9.2% | 11.2% | 11.7% | 11.1% | 13.9% | 14.5% |
| Non-operating income and expenses | 1.2 | (0.8) | (1.0) | (0.8) | (0.7) | (0.4) | (0.6) | (0.2) | (0.2) | (0.2) |
| Net income before taxes | 13.5% | 11.3% | 9.3% | 8.6% | 8.5% | 10.8% | 11.2% | 10.9% | 13.7% | 14.3% |
| Taxes | 5.3% | 4.8% | 3.9% | 3.6% | 3.5% | 4.8% | 4.9% | 4.4% | 5.6% | 6.0% |
| Net income after taxes | 8.2% | 6.5% | 5.4% | 5.0% | 5.0% | 6.0% | 6.3% | 6.5% | 8.1% | 8.3% |
| Tax rate | 39.3% | 40.7% | 41.9% | 41.9% | 41.2% | 44.4% | 43.8% | 40.4% | 40.9% | 42.0% |

*Source: "Quarterly Financial Report for Manufacturing Corporations", Federal Trade Commission.

a. 1974 figures reflect change in accounting procedures and are not directly comparable to previous year.

## D. Employment and Wages

The inorganic chemical industry is a major sector of the U.S. economy in terms of employment and industry wages.

Employment in the industrial inorganic chemical industry (SIC 281) totaled 99,700 employees in 1974, and wages were an estimated $1.4 billion in 1974. A summary of wages and employment in the inorganic chemical industry is provided in Table III-7.

The primary affected chemicals represent a significant portion of the value of shipments of the inorganic chemical industry, which was 15.6 percent of the total value of industry shipments in 1974.[a] Wages and employment related to the manufacture of the primary chemicals were an estimated $0.21 billion and 15,500 employees. Since 1972 the primary affected chemicals have become an increasingly important sector of the inorganic chemical industry. The secondary affected chemicals comprised only 2.2 percent of total inorganic chemical shipments in 1974. Total wages were $30 million and employment was an estimated 2,200 employees.

In total, the primary and secondary affected chemicals are an important part of the total inorganic chemical industry. The primary and secondary affected chemicals represented 17.8 percent of 1974 industry shipments. Wages related to the manufacture of these chemicals were an estimated $0.24 billion, and there were an estimated 17,700 employees.

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a. Excludes non-mercury cell chlorine production.

TABLE III-7

SUMMARY OF WAGES AND EMPLOYMENT IN THE INDUSTRIAL INORGANIC CHEMICALS INDUSTRY (SIC 281)*

| | 1972 | 1974 |
|---|---|---|
| SIC 281 | | |
| Total wages ($ MM) | 1078.4 | 1350e |
| Employees (000) | 99.4 | 99.7 |
| Value of shipments ($ MM) | 6126.8 | 7675 |
| Primary chemicals | | |
| Total wages[a] ($ MM) | 147.7 | 210e |
| Employees (000) | 13.6 | 15.5 |
| Value of shipments ($ MM) | 841.1 | 1195.3 |
| % of total | 13.7 | 15.6 |
| Secondary chemicals | | |
| Total wages[a] ($ MM) | 22.6 | 30e |
| Employees (000) | 2.1 | 2.2e |
| Value of shipments ($ MM) | 125.5 | 167.4 |
| % of total | 2.1 | 2.2 |
| Primary and secondary | | |
| Total wages[a] ($ MM) | 170.3 | 240e |
| Employees (000) | 15.7 | 17.7e |
| Value of shipments ($ MM) | 966.6 | 1362.7 |
| % of total | 15.8 | 17.8 |

*Source: Census of Manufacturing, Current Industrial Reports M28A, Department of Commerce, U.S. Industrial Outlook, 1976, County Bus. Patterns, Contractor's estimates.

a. 1974 employees and wages prorated based on value of shipments.

Note: The primary affected chemicals are chlorine, hydrofluoric acid, elemental phosphorus, sodium dichromate and titanium dioxide. The secondary affected chemicals are aluminum fluoride, chrome pigments, nickel sulfate phosphorus pentasulfide, phosphorus trichloride, and sodium silicofluoride.

## E. Company Reliance on Primary Affected Chemicals

There are 29 companies engaged in the production of the primary affected inorganic chemicals. The principal producers of the primary affected chemicals, with over $100 million of estimated 1975 production value, are Allied Chemical (three primary chemicals), Dow Chemical (one), DuPont (three), FMC (two), Monsanto (two), and Stauffer (three). DuPont is the largest producer of the primary affected chemicals, with 1975 estimated produced value of $241 million.

A summary of the producers of the primary affected chemicals and the producers' dependence on the five chemicals is in Table III-8. For the five largest producers the dependence on the primary affected chemicals is high in relation to each company's industrial chemical sales. The production value of the primary chemicals ranges from 18 percent to 46 percent of Monsanto's and DuPont's 1975 industrial chemical sales. However, the dependence of total company sales on the primary affected chemicals is 4.9 percent and 3.3 percent of Monsanto's and DuPont's total 1975 corporate sales. For Stauffer Chemical the primary affected chemicals production value equals 35 percent of industrial chemical sales and 12 percent of total company sales. This represents a large portion of the company's sales.

The estimated production value understates each company's dependence on the five primary affected chemicals. A large portion of these products is used captively by these producers for the production of other products. If the sales value of the end products manufactured from the primary affected chemicals were considered, the companies' sales dependency on the five primary affected chemicals could be significantly higher than the sales dependency on the primary affected chemicals alone. The primary affected chemicals may be purchased on the merchant market, which would reduce the dependence of end products. However, the volume and price of

## TABLE III-8

### COMPANY DEPENDENCE ON PRIMARY AFFECTED CHEMICALS (1975)

| Producer | Primary chemicals: Chlorine — Estimated production value ($MM) | Chlorine — % of industrial chemical sales | Elemental phosphorus — Estimated production value ($MM) | Elemental phosphorus — % of industrial chemical sales | Hydrofluoric acid — Estimated production value ($MM) | Hydrofluoric acid — % of industrial chemical sales | Sodium dichromate — Estimated production value ($MM) | Sodium dichromate — % of industrial chemical sales | Titanium dioxide — Estimated production value ($MM) | Titanium dioxide — % of industrial chemical sales | Total — Estimated production value ($MM) | Total — % of industrial chemical sales | % of total sales |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alcoa | 7.9 | 1.7 | | | 24.0 | 5.3 | | | | | 31.9 | 7.0 | 1.3 |
| Allied Chemical | 27.9 | 5.6 | | | 47.0 | 9.5 | 26.6 | 5.4 | | | 101.5 | 20.4 | 4.4 |
| American Cyanamid | | | | | | | | | 58.8 | 11.0 | 58.8 | 11.0 | 3.3 |
| BASF Wyandotte | 26.2 | NA | | | | | | | | | 26.2 | NA | 4.4 |
| Diamond Shamrock | 54.1 | 15.3 | | | | | 24.8 | 7.0 | | | 78.9 | 22.3 | 7.0 |
| Dow Chemical | 186.0 | 11.3 | | | | | | | | | 186.0 | 11.3 | 3.8 |
| Dupont | 15.9 | 3.0 | | | 32.6 | 6.2 | | | 192.4 | 36.4 | 240.9 | 45.6 | 3.3 |
| Electro-Phos. Corp. | | | 11.7 | NA | | | | | | | 11.7 | NA | NA |
| Essex Chemical | | | | | 4.8 | 20.2 | | | | | 4.8 | 20.2 | 10.1 |
| Ethyl Corp. | 10.8 | 3.2 | | | | | | | | | 10.8 | 3.2 | 1.1 |
| FMC | 13.4 | 2.7 | 102.5 | 20.5 | | | | | | | 115.9 | 23.2 | 5.1 |
| Glidden-Durkee | | | | | | | | | 57.0 | NA | 57.0 | NA | NA |
| B.F. Goodrich | 5.1 | 2.3 | | | 7.8 | 4.8 | | | | | 12.9 | 5.9 | 0.7 |
| Hooker Chemical | 45.3 | 2.8 | 40.4 | 2.5 | | | | | | | 85.6 | 5.4 | 1.6 |
| Kaiser | 9.1 | 9.8 | | | 21.8 | 23.4 | | | | | 30.9 | 33.2 | 2.0 |
| Kerr-McGee | | | | | | | | | 25.9 | 6.3 | 25.9 | 6.3 | 1.4 |
| Linden Chlorine | 7.8 | NA | | | | | | | | | 7.8 | NA | NA |
| Mobay | 3.4 | NA | | | | | | | | | 3.4 | NA | NA |
| Mobil | | | 3.1 | 0.3 | | | | | | | 3.1 | 0.3 | * |
| Monsanto | 4.2 | 0.4 | 172.5 | 17.2 | | | | | | | 176.7 | 17.6 | 4.9 |
| N.L. Industries | | | | | | | | | 121.0 | 33.7 | 121.0 | 33.7 | 9.5 |
| N.J. Zinc | | | | | | | | | 38.0 | NA | 38.0 | NA | NA |
| Olin | 27.5 | 4.4 | | | | | | | | | 27.5 | 4.4 | 2.2 |
| Pennwalt | 16.1 | 4.4 | | | 10.9 | 3.0 | | | | | 27.0 | 7.4 | 3.8 |
| PPG | 56.3 | 8.0 | | | | | 10.6 | 1.5 | | | 66.9 | 9.5 | 3.6 |
| Shell | 6.3 | 0.5 | | | | | | | | | 6.3 | 0.5 | * |
| Sobin Chemical | 5.2 | NA | | | | | | | | | 5.2 | NA | NA |
| Stauffer Chemical | 16.6 | 5.6 | 79.3 | 26.6 | 7.8 | 2.6 | | | | | 103.7 | 34.8 | 12.1 |
| Vulcan | 6.3 | 19.2 | | | | | | | | | 6.3 | 19.2 | 1.8 |

Source: Annual Reports, U.S. Department of Commerce - Current Industrial Reports - Series M28A and Contractor's estimates.

* less than 0.1%.

merchant material available would limit this alternative. The total sales dependency of a producer on the primary affected chemicals would have to be determined on a case-by-case basis depending on the chemical, the availability of merchant supplies, and the cost of chemicals purchased on the merchant market.

Other producers for whom the production value of the primary affected chemicals represents an important portion of total industrial chemical sales include Allied Chemical, Diamond Shamrock, Essex Chemical, FMC, Hooker Chemical, and NL Industries. The production value of the primary affected chemicals ranges from 20 percent of industrial chemical sales for Allied Chemical and Essex Chemical to 33 percent of industrial chemical sales for NL Industries and Kaiser. In terms of dependence on total company sales, the production value of the primary affected chemicals is 4.4 percent, 10.1 percent, 9.5 percent, and 2.0 percent of total company sales for Allied, Essex, NL Industries and Kaiser, respectively.

In general, the production value of the primary affected chemicals represents a small portion of total company sales. There are only five companies which have production values of the primary affected chemicals greater than 5 percent of total company sales. The companies with the highest dependence are Stauffer Chemical and Essex Chemical with production values of the five primary affected chemicals equaling 12.1 percent and 10.1 percent of total company sales. Other companies, for which financial data are not available, may have a high level of dependence on the primary chemicals. These companies are Electro-Phos Corporation (47.5 percent owned by Mitsubishi Corporation, Ltd.), Linden Chlorine, and Sobin Chemical (a subsidiary of International Minerals and Chemicals). These are small companies in terms of total sales level and, therefore, their sales of the primary affected chemicals may represent a major portion of each company's total sales.

## F. Characterization of Production Facilities

Inorganic chemical production facilities are generally capital-intensive, skilled labor operations, located in the East Coast (Delaware, New Jersey), Gulf Coast (Texas, Louisiana) or West Coast (California). The ages of the plants in the industry are five to thirty years old. The production process is typically continuous, rather than batch, and operating levels of 70 to 85 percent of capacity must generally be achieved in order to assure efficiency and profitability.

Since major technological developments tend to take place infrequently, new facilities are built only when market demand justifies capacity expansions. In sectors of the industry where demand growth is low, virtually all of the plants in the sector may have been built prior to 1970, with a significant number built before 1940. Accordingly, many existing production facilities were built with little regard (by today's standards) for engineering and siting considerations relating to pollution control.

Because of the relative maturity of this industry, many of the production facilities are nearly, or fully, depreciated. A plant owner's willingness to make an additional investment in pollution control facilities will depend on a variety of quantitative and qualitative factors. For example, the plant may be approaching technological obsolescence and the owners may decide to close the facility rather than commit fresh capital to the control of hazardous wastes. On the other hand, if few substitutes for a given product are available and a producer is able to pass the added costs on to consumers--thus maintaining an acceptable rate of return on capital--the incremental cost of hazardous waste control may simply serve as an inducement to speed the reinvestment of capital in newer, larger and more efficient production facilities.

## IV. CHARACTERIZATION OF PRIMARY AFFECTED CHEMICALS

### A. Chlorine and Caustic Soda

#### 1. Industry Structure.

a. Producers. Producers of chlorine and caustic may be segmented on the basis of production process. Approximately 70 percent of U.S. chlorine and caustic production is via the diaphragm cell; approximately 25 percent via the mercury cell and 5 percent via the Downs cell or as a by-product in the manufacture of magnesium, potassium hydroxide and potassium nitrate. The technology for both mercury and diaphragm cells was developed in the United States in the 1880's and, although many refinements have been made to increase efficiency and reduce pollution, the technology has remained basically the same. Both cells produced comparable grades of chlorine, but the mercury cell produces a more concentrated caustic solution of higher purity than that obtained from the diaphragm cell. A listing of the ten largest U.S. chlorine producers, including capacity and process information, is presented in Table IV-1. A similar listing for twenty-five additional producers is shown in Table IV-2.

b. Integration and Captive Requirements. The U.S. chlor-alkali industry exhibits characteristics of both vertical and horizontal integration to varying degrees--generally in proportion to the overall size of the producing companies. Although the degree of integration varies widely from company to company, in terms of vertical integration, the average captive consumption is approximately 60 percent. In terms of horizontal integration, the average company depends on chlor-alkali products for approximately

TABLE IV-1
TOP TEN 1975 CHLORINE PRODUCERS*
(PLANTS, CAPACITIES, AND PROCESSES)

| Company/plant | Capacity (1,000 metric tons/yr) | Process |
|---|---|---|
| Allied Chemical Corp. | | |
| Acme, North Carolina | | Mercury |
| Baton Rouge, Louisiana | 538.8 | Diaph. |
| Brunswick, Georgia | | Mercury |
| Moundsville, W. Virginia | | Mercury |
| Syracuse, New York | | 2 Merc/2 Diaph. |
| BASF Wyandotte Corp. | | |
| Geismar, Louisiana | | 2 Diaph/1 Merc. |
| Port Edwards, Wisconsin | 506.1 | Mercury |
| Wyandotte, Michigan | | Diaph. |
| Diamond Shamrock Corp. | | |
| Deer Park, Texas | | 1 Diaph/1 Merc. |
| Delaware City, Delaware | 1044.9 | Mercury |
| Mobile, Alabama | | Mercury |
| Muscle Shoals, Alabama | | Mercury |
| Painesville, Ohio | | Diaph. |
| Dow Chemical - U.S.A. | | |
| Freeport, Texas [a] | 1868.4 | Diaph/Magnesium |
| Midland, Michigan | | Diaph. |
| Oyster Creek, Texas [a] | 1429.4 | |
| Pittsburg, California | | Diaph. |
| Plaquemine, Louisiana | | Diaph. |
| E.I. duPont | | |
| Memphis, Tennessee | | Downs |
| Niagara Falls, New York | 306.9 | Downs |
| Corpus Christi, Texas | | Kelchlor |
| Hooker Chemical Corp. (Subsidiary Occidental Petroleum) | | |
| Montague, Michigan | | Diaph. |
| Niagara Falls, New York | 843.5 | Diaph. |
| Tacoma, Washington | | Diaph. |
| Taft, Louisiana | | Hooker HC-4B, C-60, HC-80 |
| Olin Corp. | | |
| Charleston, Tennessee | | Mercury |
| Augusta, Georgia | 530.6 | Mercury |
| McIntosh, Alabama | | Mercury |
| Niagara Falls, New York | | Mercury |

TABLE IV-1 (continued)

| Company/plant | Capacity (1,000 metric tons/yr) | Process |
|---|---|---|
| Pennwalt Corp. | | |
| Calvert City, Kentucky | | Mercury |
| Portland, Oregon | 310.2 | Diaph. |
| Tacoma, Washington | | Diaph. |
| Wyandotte, Michigan | | Diaph. |
| PPG Industries, Inc. | | |
| Barberton, Ohio | | Diaph. |
| Corpus Christi, Texas | 1087.3 | Diaph. |
| Lake Charles, Louisiana | | Diaph/Mercury |
| Natrium, W. Virginia | | Diaph/Mercury |
| Stauffer Chemical Co. | | |
| Henderson, Nevada | | Diaph. |
| Le Moyne, Alabama | 320.0 | Mercury |
| St. Gabriel, Louisiana | | |
| Total | 8786.1 = 78.3% total capacity | |
| All Companies = | 11,223.4 | |

* Source: 1975 Directory of Chemical Producers.

TABLE IV-2
OTHER 1975 CHLORINE PRODUCERS
(PLANTS, CAPACITIES AND PROCESSES)

| Company/plant | Capacity (1,000 metric tons/yr) | Process |
|---|---|---|
| Alcoa | | |
| Pt. Comfort, Texas | 153.5 | Mercury |
| American Magnesium Co. | | |
| Snyder, Texas | 23.6 | Magnesium |
| Brunswick Pulp & Paper | | |
| Brunswick, Georgia | 27.2 | Diaph. |
| Champion Int'l. Corp. | | |
| Canton, North Carolina | 16.3 | Diaph. |
| Pasadena, Texas | 12.7 | Diaph. |
| Ethyl Corp. | | |
| Baton Rouge, Louisiana | 209.0 | Downs/Diaph. |
| Pasadena, Texas | | Downs |
| FMC | | |
| S.Charleston, W.Virginia | 258.0 | 2 Diaph. |
| Georgia-Pacific | | |
| Bellingham, Washington | 43.5 | Mercury |
| Plaquemine, Louisiana | 261.3 | NA |
| B.F. Goodrich | | |
| Calvert City, Kentucky | 261.2 | Mercury |
| Hercules Inc. | | |
| Hopewell, Virginia | 16.3 | Diaph. |
| Inland Chem. Corp. | | |
| Newark, New Jersey | 39.2 | Diaph. |
| Kaiser | | |
| Grammercy, Louisiana | 174.7 | Diaph. |
| Linden Chlorine Products | | |
| Linden, New Jersey | 150.2 | 2 Mercury |
| Mobay Chem. Corp. | | |
| Cedar Bayou, Texas | 65.3 | (HCl) |
| Monsanto | | |
| Sauger, Illinois | 82.1 | Mercury |

TABLE IV-2 (continued)

| Company/plant | Capacity (1,000 metric tons/yr) | Process |
|---|---|---|
| NL Indust. Inc. | | |
| Rowley, Utah | 144.4 | NA |
| Velsicol Chem. Corp. | | |
| Memphis, Tennessee | 22.5 | Diaph. |
| RMI | | |
| Ashtabula, Ohio | NA | Downs |
| Shell Chem. Co. | | |
| Deer Park, Texas | 122.4 | Diaph. |
| Sobin Chemicals | | |
| Ashtabula, Ohio | 32.7 | Mercury |
| Orrington, Maine | 68.6 | Mercury |
| Jefferson Chem. Co. | | |
| Port Neches, Texas | 49.0 | Diaph. |
| Vicksburg Chem. Co. | | |
| Vicksburg, Mississippi | 29.9 | NA |
| Vulcan Materials | | |
| Wichita, Kansas | 83.3 | Diaph. |
| Weyerhaeuser Co. | | |
| Longview, Washington | 86.2 | Mercury |
| Hooker Sobin Chemical | | |
| Niagara Falls, New York | NA | Mercury |
| Fort Howard Paper Co. | | |
| Green Bay, Wisconsin | NA | Diaph. |

*Source: 1975 Directory of Chemical Producers.

10-15 percent of its sales. These average figures may be misleading, because captive consumption may reach 100 percent in some cases and horizontal integration may be nonexistent in other cases.

c. Other. Competition in the chlor-alkali industry is generally on a price basis since most chlorine is consumed as an intermediate in the production of other chemicals.

As with many industries, chlorine producers have been hit by a sharp increase in energy prices. Dependence has been high on cheap sources of energy for all of the chlorine production processes; thus, with higher energy costs, manufacturing costs have risen significantly in recent years. The increased energy costs have had an adverse impact on chlorine capacity expansion and product prices. In the future, the availability of energy and access to relatively low cost supplies will continue to influence capacity expansion and the competitive position of producers in the industry. [a]

2. Supply Characteristics.

a. Manufacturing Routes. The diaphragm cell process represents over two-thirds of U.S. chlorine capacity and, even though conversion to the use of dimensionally stable anodes is rapidly taking place, the graphite anode version of the process is still a basis for industry comparison. The major raw material for the diaphragm cell process is a nearly saturated solution of sodium chloride made up by dissolving purchased solid salt in water or brine or by injecting water into an underground salt structure. The crude brine must be purified before it is introduced to the electrolytic cells.

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a. The Conference Board, "Energy Consumption in Manufacturing," 1974, p. 184.

In the cells the brine is electrolyzed to produce chlorine, caustic soda and hydrogen according to the equation:

$$NaCl + H_2O \rightarrow 1/2\ Cl_2 + NaOH + 1/2\ H_2.$$

Chlorine is formed at the graphite anode, bubbles to the top of the cell and is removed by the chlorine header. The sodium ion migrates to the cathode where hydroxyl ion and hydrogen are formed, generating a solution containing 10-11 percent sodium hydroxide (NaOH).

The cell liquor withdrawn from the cathode still contains about 13-15 percent salt because only 50 percent of the salt is decomposed under optimum cell operating conditions. This liquor is concentrated in steam-heated multi-effect evaporators to produce a 50 percent caustic soda product which contains about 1 percent salt. The remaining salt crystallizes out during concentration and is centrifuged from the caustic and recycled for brine saturation.

In the mercury cell process, the cathode is a thin layer of mercury rather than a series of hollow plates supporting an asbestos diaphragm. A saturated, purified brine is fed to the cell where it is electrolyzed to chlorine and a sodium-mercury amalgam. The amalgam is decomposed to form a 50 percent sodium hydroxide solution and regenerated mercury.

The Downs cell process involves electrolyzing fused sodium chloride to produce sodium metal and chlorine. Because of the relatively higher value of sodium, the chlorine which is generated is generally thought of as a by-product.

Of the three primary technologies, the mercury cell process typically generates a proportionately greater amount of hazardous wastes per unit of output. For this reason, shifts at the margin have been occurring from the mercury cell to the diaphragm process, and this trend is expected to continue. Through 1978, shutdowns of marginal mercury cell plants may occur as new diaphragm cell capacity comes on-stream. Some industry observers believe that between 1971 and 1983 mercury cell production in several states will be completely abandoned.

b. Manufacturing Costs. Estimated 1975 model plant manufacturing costs for chlorine and caustic from a diaphragm cell and from a mercury cell plant are presented in Tables IV-3 and IV-4 . These manufacturing costs are based on a large modern plant with a capacity of 453.6 metric tons of chlorine per stream day for the diaphragm cell plant and 453.6 metric tons per day for the mercury cell plant. Coproduced with this chlorine would be 1.1 ton of caustic soda per ton of chlorine. As is normal in the industry, in this estimate all costs are placed on chlorine, or as it is often expressed, the costs are on an electro-chemical unit (ECU) basis. The ECU is one ton of chlorine plus the coproduced caustic. This estimate is based on 360 stream days per year, normal for the industry, and current costs for labor and materials.

c. Capacity Utilization. Historically, industry capacity utilization has remained high for chlorine and caustic soda--often at a level of 90 percent or higher. However, the economic downturn of 1975 led to operating rates averaging approximately half of this level in some periods.

TABLE IV-3

ESTIMATED 1975 COST OF PRODUCING
CHLORINE AND CAUSTIC SODA (DIAPHRAGM)*
(METRIC TONS)

| | |
|---|---|
| Process | Brine electrolysis in graphite anode diaphragm cells |
| Plant capacity | 453.6 T $Cl_2$/SD |
| Annual production | 163,300 T chlorine |
| | 172,400 T caustic soda (100% basis) |
| Fixed | Original (1968) $24,700,000 |
| | Replacement (1975) $40,000,000 |

| Variable costs | Quantity | $/Unit | $/T $Cl_2$ |
|---|---|---|---|
| Salt (100%, as brine) | 1.78 T | 2.20 | 3.92 |
| Power, total AC | 3785 kwh | 0.012 | 45.42 |
| Fuel, net | 9.4 MMBtu | 0.70 | 6.56 |
| Water makeup | 4.4 Mgal | 0.02 | 0.09 |
| Chemicals & operating supplies | | | 2.15 |
| Cell rebuilding materials | | | 0.99 |
| Cell license | | | 0.53 |
| Graphite | 7.7 lb | 0.80 | 6.17 |
| | | | 65.83 |
| Semi-variable costs | | | |
| Operating labor | 52 men | 12,000/yr | 3.82 |
| Supervision | 8 foremen | 18,000/yr | 0.88 |
| | 1 superintendent | 25,000/yr | 0.15 |
| Labor overhead | 35% of Labor & supervision | | 1.70 |
| Maintenance | 5% of $40,000,000/yr | | 12.24 |
| | | | 18.79 |
| Fixed costs | | | |
| Plant overhead | 70% of Labor & supervision | | 3.41 |
| Depreciation | 9.1% of $28,000,000/yr [a] | | 15.60 |
| Local taxes & insurance | 1.5% of $40,000,000/yr | | 3.67 |
| | | | 22.68 |
| Total cost of manufacture | | | 107.30 |

*Source: Contractor's estimates.

a. Estimate of original cost plus capital replacements.

## TABLE IV-4

### ESTIMATED 1975 COST OF PRODUCING CHLORINE AND CAUSTIC SODA (MERCURY)*
### (METRIC TONS)

| | |
|---|---|
| Process | Brine electrolysis in graphite anode mercury cells |
| Plant capacity | 453.6 T Chlorine/SD |
| Annual production | 163,300 T Chlorine<br>172,400 T Caustic soda (100% Basis) |
| Fixed investment | Original (1968) $25,400,000<br>Replacement (1975) 43,200,000<br>Mercury inventory 2,000,000 |

| Variable costs | Quantity | $/Unit | $/T $Cl_2$ |
|---|---|---|---|
| Salt, solid | 1.70 T | 12.22 | 22.48 |
| Power, total AC | 4290 kwh | 0.012 | 51.44 |
| Fuel, net | 0.88 MMBtu | 0.70 | 0.62 |
| Water makeup | 2.42 Mgal | 0.02 | 0.05 |
| Mercury | 0.28 lb | 4.08 | 1.12 |
| Chemicals & operating supplies | | | 3.14 |
| Graphite | 6.0 lb | 0.80 | 5.29 |
| | | | 84.14 |
| **Semi-variable costs** | | | |
| Operating labor | 41 men | 12,000/yr | 3.01 |
| Supervision | 8 foremen | 18,000/yr | 0.88 |
| | 1 superintendent | 25,000/yr | 0.15 |
| Labor overhead | 35% of Labor & supervision | | 1.41 |
| Maintenance | 5% of $43,200,000/yr | | 13.22 |
| | | | 18.67 |
| **Fixed costs** | | | |
| Plant overhead | 70% of Labor & supervision | | 2.83 |
| Depreciation | 9.1% of $30,000,000/yr | | 16.72 |
| Local taxes & insurance | 1.5% of $43,200,000/yr | | 3.97 |
| | | | 23.52 |
| Total cost of manufacture | | | 126.33 |

*Source: Contractor's estimates.

3. Demand Characteristics.

a. Market Size. U.S. apparent consumption[a] demand for chlorine has risen from approximately 2.3 million metric tons per annum in 1951 to approximately 9.7 million metric tons in 1974--a growth rate averaging 6.5 percent per annum during this period. The 1975 production level of 8.3 million metric tons represents a market value estimated at $870 million.

Historical levels of U.S. production and commercial shipments of chlorine are presented in Tables IV-5 and IV-6. U.S. chlorine production volume has traditionally reflected the performance of the U.S. economy. On the basis of a healthy economy between 1955 and 1968, apparent U.S. consumption of chlorine grew at an average annual rate of 6.3 percent during the period. However, since 1968, because of the economic slowdown of 1970-71 and recent capacity constraints, annual chlorine consumption increases have averaged only 4.3 percent.

b. Growth. Despite the existence of uncertainties in several important end uses for chlorine such as fluorocarbons and solvents, market growth is expected to continue at an average annual rate of approximately 5-6 percent through 1980. Over the next several years, the rate of additions to capacity is expected to exceed demand growth. Assuming no supply constraints, the 1980 level of U.S. chlorine demand is forecast at about 12 million metric tons.

c. Uses. Approximately 75 percent of U.S. chlorine production is used in the manufacture of other chemical products, the most important of which are vinyl chloride plastics, chlorinated solvents and fluorocarbons. That portion of chlorine not used as a raw material is used chiefly in the pulp and paper industries and in water treatment. Details of this use

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a. Apparent consumption equals production and imports minus exports.

TABLE IV-5
U.S. CHLORINE PRODUCTION 1960-1975
(THOUSANDS OF METRIC TONS)*

| | Diaphragm cells | Mercury cells | Downs cells | Total |
|---|---|---|---|---|
| 1960 | NA | NA | NA | 4209.4 |
| 1961 | NA | NA | NA | 4176.6 |
| 1962 | 3557.6 | 863.7 | 247.5 | 4668.7 |
| 1963 | 3675.6 | 1031.7 | 253.0 | 4960.3 |
| 1964 | 4187.6 | 1334.0 | 278.4 | 5799.9 |
| 1965 | 4415.5 | 1500.8 | 285.2 | 6201.5 |
| 1966 | 4806.3 | 1827.4 | 262.1 | 6895.7 |
| 1967 | 5321.3 | 2035.5 | 266.8 | 7623.6 |
| 1968 | 5482.1 | 2302.4 | 265.6 | 8050.1 |
| 1969 | 5889.9 | 2374.7 | 246.8 | 8511.4 |
| 1970 | 6169.0 | 2410.8 | 283.6 | 8863.5 |
| 1971 | 5926.1 | 2309.4 | 254.7 | 8409.1 |
| 1972 | 6476.7 | 2164.8 | 304.1 | 8945.7 |
| 1973 | 6780.3 | 2323.1 | 340.0 | 9443.2 |
| 1974 | 6738.1 | 2390.7 | 510.9 | 9639.7 |
| 1975 | NA | NA | NA | 8297.0 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A and notes based on Chlorine Institute data on installed capacity.

TABLE IV-6
U.S. CHLORINE COMMERCIAL SHIPMENT VALUES
(THOUSANDS OF METRIC TONS)*

| | Commercial shipments (1,000 metric tons) | Total value ($MM) | Value per metric ton | List price ($/metric ton) |
|---|---|---|---|---|
| 1960 | 1718.4 | 112.2 | 65 | 72 |
| 1961 | 1790.5 | 116.9 | 65 | 72 |
| 1962 | 1992.7 | 127.4 | 64 | 71 |
| 1963 | 1970.1 | 124.0 | 63 | 69 |
| 1964 | 2200.1 | 135.6 | 62 | 68 |
| 1965 | 2552.5 | 146.5 | 57 | 63 |
| 1966 | 2774.8 | 157.6 | 57 | 63 |
| 1967 | 2748.8 | 134.2 | 49 | 54 |
| 1968 | 3023.5 | 157.8 | 52 | 57 |
| 1969 | 2937.0 | 154.8 | 53 | 58 |
| 1970 | 3028.8 | 155.1 | 51 | 56 |
| 1971 | 3065.2 | 154.8 | 51 | 56 |
| 1972 | 3444.9 | 162.2 | 47 | 52 |
| 1973 | 3689.8 | 190.1 | 52 | 57 |
| 1974 | 3678.2 | 261.5 | 71 | 125 |
| 1975 | 3034.5 | 318.3 | 105 | 135 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A, and Chemical Marketing Reporter.

pattern are presented in Table IV-7. In theory, the use pattern for mercury cell chlorine is the same as that for diaphragm cell chlorine since the two processes produce an equivalent product. However, locational factors and other market parameters undoubtedly lead to different use patterns for chlorine produced by these routes. Further research on the differences in use patterns is required.

d. Substitute Products. No direct substitutes for chlorine are available in most of its uses. The exceptions, which account for less than 20 percent of estimated chlorine demand, are use of chlorine as a bleach or sanitizing agent in the pulp and paper industry and in water treatment. Even in these uses the substitutes are not readily available but are in varying stages of development. Substitution for chlorine in its major uses can occur on a secondary or tertiary level. For example, in the case of polyvinyl chloride (PVC) derived from chlorine, other plastics or materials may be substituted for PVC in certain applications and thus affect demand for chlorine. Similar examples can be given for fluorocarbons and for chlorinated solvents.

e. Prices. As indicated in Table IV-6, chlorine prices have been relatively stable over the past decade with a slight decline apparent until 1973. Since this time the price trend has been upwards. Current spot prices for chlorine are about $150/metric ton. Because of the large volume of chlorine being sold at much lower prices under long-term contracts, the average value per ton is much closer to about $100/ton. Import and export prices are presented in Table IV-8.

TABLE IV-7
U.S. END USES OF CHLORINE, 1974*

| | Percent |
|---|---|
| Organic chemicals (including solvents) | 47 |
| Vinyl chloride | 19 |
| Pulp and paper | 15 |
| Inorganic chemicals | 10 |
| Sanitation and water treatment | 5 |
| Miscellaneous | 4 |

*Source: Chemical Marketing Profiles

TABLE IV-8
CHLORINE IMPORT AND EXPORT PRICES 1960-1975
($PER METRIC TON) *

| | Import | Export |
|---|---|---|
| 1960 | 73 | 65 |
| 1961 | 80 | 62 |
| 1962 | 72 | 61 |
| 1963 | 72 | 65 |
| 1964 | 75 | 65 |
| 1965 | 68 | 54 |
| 1966 | 64 | 63 |
| 1967 | 68 | 64 |
| 1968 | 68 | 61 |
| 1969 | 66 | 64 |
| 1970 | 79 | 76 |
| 1971 | 63 | 70 |
| 1972 | 67 | 109 |
| 1973 | 73 | 119 |
| 1974 | 96 | 208 |
| 1975 | 132 | 265 |

*Source: U.S. Department of Commerce, FT 110, 135, 410.

f. Foreign Competition. Very little chlorine moves into or out of the U.S. The small amount of trade which does occur is chiefly between the U.S. and Canada and represents less than 1 percent of U.S. production. Table IV-9 presents data on foreign trade over the past 16 years.

TABLE IV-9
U.S. CHLORINE PRODUCTION AND TRADE 1960-1975*
(THOUSANDS OF METRIC TONS)

| | Production | Imports | Exports |
|---|---|---|---|
| 1960 | 4209.4 | 24.5 | 24.5 |
| 1961 | 4176.6 | 20.0 | 29.0 |
| 1962 | 4668.7 | 26.3 | 32.7 |
| 1963 | 4960.3 | 23.6 | 33.6 |
| 1964 | 5799.9 | 20.0 | 39.9 |
| 1965 | 6201.5 | 35.4 | 39.0 |
| 1966 | 6895.7 | 65.4 | 19.1 |
| 1967 | 7623.6 | 52.7 | 32.7 |
| 1968 | 8050.1 | 38.1 | 32.7 |
| 1969 | 8511.4 | 22.7 | 23.6 |
| 1970 | 8863.5 | 22.7 | 14.5 |
| 1971 | 8490.1 | 31.8 | 10.0 |
| 1972 | 8945.7 | 34.5 | 6.4 |
| 1973 | 9443.2 | 45.4 | 11.8 |
| 1974 | 9639.7 | 76.3 | 15.4 |
| 1975 | 8257.0 | 67.1 | 15.2 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A. U.S. Department of Commerce, FT 110, 135, 410.

## B. Hydrofluoric Acid

### 1. Industry Structure

a. Producers. Currently eight producers have a capacity of 349,300 metric tons,as shown in Table IV-10. The industry is highly concentrated with four producers having over 80 percent of domestic capacity. DuPont and Allied have over 50 percent of the total industry capacity,and they both have large captive requirements for hydrofluoric acid. The share of the total market would be greater if their manufacturing plants in Mexico and Canada were considered.

b. Captive Requirements. Since the two major end-use areas for hydrofluoric acid are as chemical intermediates, there is a high level of captive consumption of hydrofluoric acid production. Of the eight domestic producers of hydrofluoric acid, two are producers of both fluorocarbons and aluminum fluoride, three are producers of fluorocarbons, and two are also producers of aluminum fluoride. Only one producer is not forward integrated into the production of fluorocarbons or aluminum fluoride. Commercial shipments of hydrofluoric acid are not reported; however, based on producer capacities of fluorocarbons and aluminum fluoride, an estimated 60 percent of production is used captively.

### 2. Supply Characteristics

a. Manufacturing Routes. Hydrofluoric acid is produced by the reaction of fluorspar and sulfuric acid in a furnace. DuPont utilizes a proprietary process which reacts sulfur trioxide and steam with fluorspar. Hydrogen fluoride generators may be horizontal, stationary, or a rotary kiln or a combination of several reactor systems. The hydrogen fluoride gas which evolves in the reaction is recovered and condensed by the refrigeration. By-products of the reaction include calcium sulfate and unreacted calcium fluoride which creates the hazardous waste disposal problems. Large, continuous

TABLE IV-10

HYDROFLUORIC ACID CAPACITIES (1975)*

| Producer | Location | Annual capacity (1,000 metric tons) |
|---|---|---|
| Alcoa | Point Comfort, Texas | 49.9 |
| Allied Chemical | Baton Rouge, Louisiana<br>Geismar, Louisiana<br>Nitro, West Virginia<br>North Claymont, Delaware<br>Port Chicago, California | 98.0 |
| DuPont | Strang, Texas | 68.0 |
| Essex Chemical | Paulsboro, New Jersey | 10.0 |
| Harshaw Chemical (Division of Kewanee Oil) | Cleveland, Ohio | 16.3 |
| Kaiser | Gramercy, Louisiana | 45.4 |
| Pennwalt | Calvert City, Kentucky | 22.7 |
| Stauffer Chemical | Houston, Texas | 16.3 |
| Total | | 326.6 |

*Source: Contractor's estimates.

unit processes have been developed in recent years which provide economies of scale over the smaller volume batch process.

b. Manufacturing Costs. Estimated 1975 manufacturing costs for hydrofluoric acid are presented in Table IV-11. Capacity for this model plant is 23,000 tons per year with a fixed investment requirement of $7.0 million. Large-scale, continuous process plants are able to achieve economies of scale which allow them to have substantially lower production costs.

c. Capacity Utilization. Industry capacity has historically kept in line with demand, resulting in high industry operating levels (Table IV-12). In 1974, operating levels reached 96 percent of capacity. The demand for hydrofluoric acid is sensitive to the overall economy as reflected by the decline in production in 1970 and 1975, two recession years. In 1975, the controversy over the use of fluorocarbons may also have influenced production, although the degree to which this is the case is not ascertainable.

Domestic production is expected to rebound from the depressed levels in 1975, but historical operating rates will not be achieved in the next several years assuming static to low growth in demand. Increased imports will supply an increasing share of domestic consumption, and there will be overcapacity for domestic production. A ban on fluorocarbon propellants in aerosols will create additional overcapacity. As a result, with an imbalance in the supply/demand, the smaller, high-cost hydrofluoric acid plants will be faced with strong competitive pressures.

3. Demand Characteristics.

a. Market Size. U.S. production of hydrofluoric acid has grown from 15,000 metric tons in 1940 to 345,800 metric tons in 1974, and production declined to 284,300 metric tons in 1975. Production of anhydrous hydrofluoric acid accounts for about 70 percent of total production and aqueous

TABLE IV-11
ESTIMATED 1975 COST OF MANUFACTURING
HYDROFLUORIC ACID (99.95%)*
(METRIC TONS)

| | |
|---|---|
| Plant capacity | 63.5 T/SD |
| Annual production | 20,860 T/yr |
| Fixed investment (1975) | $7,000,000 |

| Variable | Quantity | $/Unit | $/Ton |
|---|---|---|---|
| Fluorspar | 2.2 T | 106.9 | 235.17 |
| Sulfuric acid (100% basis) | 1.6 T | 55.10 | 88.16 |
| Oleum (100% basis) | 1.12 T | 57.3 | 64.18 |
| Lime | 0.05 T | 33.1 | 1.65 |
| Power | 396.7 kwh | 0.02 | 7.93 |
| Fuel | 11.0 MMBTU | 0.70 | 7.71 |
| Water | 15.4 Mgal | 0.02 | 0.31 |
| | | | 405.11 |
| Semi-variable costs | | | |
| Operating labor | 12 men | 12,000/yr | 6.90 |
| Supervision | 4 men | 18,000/yr | 3.45 |
| | 1 superintendent | 25,000/yr | 1.20 |
| Maintenance | 6% of Investment/yr | | 20.12 |
| Labor | 35% of Labor & supervision | | 4.04 |
| | | | 35.71 |
| Fixed costs | | | |
| Plant overhead | 70% of Labor & supervision | | 8.09 |
| Depreciation | 9.1% of Investment/yr. | | 30.53 |
| Local taxes & insurance | 1.5% of Investment/yr. | | 5.04 |
| | | | 43.66 |
| Total cost of manufacture | | | 484.48 |

*Source: Contractor's estimates.

TABLE IV-12

INDUSTRY OPERATING CAPACITY - HYDROFLUORIC ACID*
(THOUSANDS OF METRIC TONS)

| Year | Capacity | Production | % capacity |
|---|---|---|---|
| 1965 | - | 205.2 | - |
| 1966 | - | 242.5 | - |
| 1967 | 259 | 247.6 | 96 |
| 1968 | - | 274.1 | - |
| 1969 | - | 297.1 | - |
| 1970 | 319 | 294.8 | 92 |
| 1971 | - | 303.2 | - |
| 1972 | - | 319.7 | - |
| 1973 | 361 | 331.8 | 92 |
| 1974 | 361 | 345.8 | 96 |
| 1975 | 327 | 284.3 | 87 |

*Source: U.S. Department of Commerce, Chemical Marketing Reporter, Contractor's estimates.

hydrofluoric acid accounts for about 5 percent of total production. The remaining 25 percent of hydrofluoric acid production is produced, but not withdrawn from the manufacturing process (see Table IV-13 ). Exports are negligible and imports have become important in recent years,as shown in Table IV-14. Imports are expected to become increasingly important as a result of expanded capacity for hydrofluoric acid in Mexico. Apparent consumption is defined as production plus imports, less exports, as summarized in Table IV-15.

b. Growth. U.S. production of hydrofluoric acid increased at an average annual rate of 6.7 percent between 1960 and 1970 and apparent consumption grew at a similar rate. However, from 1970 to 1974 production increased only 4.1 percent per year while consumption increased 6.2 percent per year, in line with the historical growth rate. The lower rate of growth in recent years for production of hydrofluoric acid reflects the significant level of imports of hydrofluoric acid which began in 1971. The future of the market for hydrofluoric acid is uncertain, particularly for the production of fluorocarbons, because of the controversy over the possible impact of fluorocarbons on the ozone layer. In addition, the increased use of fluosilicic acid versus hydrofluoric acid and the recovery of fluorine emissions because of pollution controls are having an adverse impact on demand for hydrofluoric acid in the aluminum market.

TABLE IV-13

U.S. HYDROFLUORIC ACID PRODUCTION 1960-1975*
(THOUSAND OF METRIC TONS)

| | Anhydrous | Aqueous | Produced but not withdrawn from system | Total |
|---|---|---|---|---|
| 1960 | 107.4 [a] | NA | 46.3 | 153.7 |
| 1961 | 94.9 | 11.9 | 65.8 | 172.6 |
| 1962 | 103.8 | 11.8 | 35.4 | 151.0 |
| 1963 | 106.1 | 10.5 | 54.2 | 170.8 |
| 1964 | 111.2 | 11.0 | 56.9 | 179.1 |
| 1965 | 123.9 | 12.4 | 68.9 | 205.2 |
| 1966 | 141.7 | 17.5 | 83.3 | 242.5 |
| 1967 | 146.4 | 20.2 | 81.0 | 247.6 |
| 1968 | 174.6 | 17.1 | 82.4 | 274.1 |
| 1969 | 201.1 | 15.6 | 80.4 | 297.1 |
| 1970 | 203.7 | 14.3 | 76.8 | 294.8 |
| 1971 | 199.3 | 13.8 | 90.1 | 303.2 |
| 1972 | 218.9 | 16.2 | 84.6 | 319.7 |
| 1973 | 226.3 | 18.1 | 87.4 | 331.8 |
| 1974 | 237.2 | 18.4 | 90.2 | 345.8 |
| 1975 | 193.4 [b] | 14.6 | 76.3 | 284.3 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A.

a. Includes aqueous

b. 1960-1963 production is estimated.

TABLE IV-14

IMPORTS AND EXPORTS OF HYDROFLUORIC ACID*
(THOUSANDS OF METRIC TONS)

| | Imports | Price per metric ton (imports) | Exports |
|---|---|---|---|
| 1960 | NA | NA | NA |
| 1961 | NA | NA | NA |
| 1962 | NA | NA | NA |
| 1963 | NA | NA | NA |
| 1964 | NA | NA | NA |
| 1965 | NA | NA | NA |
| 1966 | NA | NA | NA |
| 1967 | NA | NA | NA |
| 1968 | NA | NA | NA |
| 1969 | NA | NA | NA |
| 1970 | 1.0 | 339 | NA |
| 1971 | 19.4 | 335 | NA |
| 1972 | 12.9 | 381 | NA |
| 1973 | 28.7 | 342 | NA |
| 1974 | NA | NA | NA |
| 1975 | NA | NA | NA |

*Source: U.S. Department of Commerce, FT410, FT246.

TABLE IV-15

APPARENT CONSUMPTION OF HYDROFLUORIC ACID *
(THOUSANDS OF METRIC TONS)

| Years | Total production | Imports | Exports | Apparent consumption[a] |
|---|---|---|---|---|
| 1960 | 153.7 | NA | NA | 153.7 |
| 1961 | 172.6 | NA | NA | 172.6 |
| 1962 | 151.0 | NA | NA | 151.0 |
| 1963 | 170.8 | NA | NA | 170.8 |
| 1964 | 179.1 | NA | NA | 179.1 |
| 1965 | 205.2 | NA | NA | 205.2 |
| 1966 | 242.5 | NA | NA | 242.5 |
| 1967 | 247.6 | NA | NA | 247.6 |
| 1968 | 274.1 | NA | NA | 274.1 |
| 1969 | 297.1 | NA | NA | 297.1 |
| 1970 | 294.8 | 1.0 | NA | 295.8 |
| 1971 | 303.2 | 19.4 | NA | 322.6 |
| 1972 | 319.7 | 12.9 | NA | 332.6 |
| 1973 | 331.8 | 28.7 | NA | 360.5 |
| 1974 | 345.8 | NA | NA | 375.0[e] |
| 1975 | 284.3 | NA | NA | 300.0[e] |

*Source: U.S. Department of Commerce.

a. Includes changes in inventory stock.

e. Estimated.

Future growth for domestic hydrofluoric acid production over the 1974 to 1980 period is likely to be limited to static to low growth resulting from the impact of increased imports, static demand in the aluminum market, and the fluorocarbon controversy. This assumes that there will be no restrictions on the use of fluorocarbons which potentially could have a major impact on domestic productior for hydrofluoric acid. Above average growth is expected in such markets as petroleum alkylation, uranium processing and fluoride salts.

c. Uses. The major end uses for hydrofluoric acid are as an intermediate for the production of fluorocarbons and aluminum and synthetic cryolite which are used in aluminum smelting. The aluminum and fluorocarbon market each accounted for an estimated 42 percent of the apparent consumption of hydrofluoric acid in 1974 (see Table IV-16). The fluorocarbon market will experience continued growth, assuming there are no restrictions on fluorocarbon uses. Hydrofluoric acid consumption for the aluminum market is expected to be static or decline over the next several years because of the increased recovery of fluorine emissions as a result of pollution requirements. The remaining uses of hydrofluoric acid, which account for 18 percent of consumption, include petroleum alkylation, fluoride salts, stainless steel pickling, uranium processing and miscellaneous uses.

d. Substitute Products. There are no substitutes for hydrofluoric acid in the production of fluorocarbons. However, there is limited competition at secondary levels where fluorocarbons compete with other materials, particularly in the aerosol propellant market. Fluorocarbons dominate the market for propellants in aerosols in competition with hydrocarbons and carbon dioxide because of cost/performance advantages. There has been considerable effort to develop alternatives to fluorocarbon propellants because of their high cost and because of concern over the possible impact of fluorocarbons on the ozone levels in the upper atmosphere; however, to date, suitable alternatives to fluorocarbon propellants have not been developed.

TABLE IV-16

U.S. HYDROFLUORIC ACID END USES, 1974*

| | Percent |
|---|---|
| Fluorocarbons | 42 |
| Aluminum | 42 |
| Petroleum alkylation | 4 |
| Fluoride salts | 3 |
| Stainless steel pickling | 3 |
| Uranium processing | 2 |
| Miscellaneous | 4 |

*Source: Chemical Marketing Reporter.

In the refrigeration/air conditioning market for fluorocarbons, there are limited alternatives, and this market tends to be relatively price inelastic because the cost of fluorocarbons represents only a small portion of the total cost of a refrigeration or air conditioning system.

In the aluminum market, fluosilicic acid can be substituted for hydrofluoric acid, and it has experienced increased use at the expense of hydrofluoric acid. Fluosilicic acid is produced from the recovery of fluoride wastes in the production of fertilizer grade phosphoric acid. Currently, fluosilicic acid accounts for an estimated 20 percent of the fluorine requirements of the aluminum industry. At present, there are no major plans in the chemical or aluminum industry to increase the use of fluosilicic acid in place of hydrofluoric acid in the aluminum market. Increased production of fluosilicic acid has been considered, but because of the declining demand for hydrofluoric acid in the aluminum market, there has been a limited market for additional capacity. With the recent increase in prices for hydrofluoric acid and aluminum fluoride, the use of fluosilicic acid in the aluminum market has become increasingly economically attractive; however, with the demand outlook for the aluminum market, it is not expected that fluosilicic acid will increase its share of the fluorine requirements for the aluminum industry.

e. Prices. Actual prices for hydrofluoric acid declined from 1960 to 1966 from $369 per metric ton to $293 per metric ton (see Table IV-17). Since 1966 actual prices have increased gradually at approximately 5 percent annual rate with the major part of actual price increases occurring in 1973 and 1974. Higher prices in these years reflected the higher operating rates and raw material costs in the industry. Actual prices historically are below list prices which reflect the large portion of interplant transfers in the reported shipments of hydrofluoric acid. Also, merchant sales are generally made under long-term contracts.

TABLE IV-17

ACTUAL VERSUS LIST PRICES OF HYDROFLUORIC ACID*
(THOUSANDS OF METRIC TONS)

| | Shipment quantity (anhydrous) (1,000 metric tons) | Value ($MM) | Unit value ($/metric ton) | List price (anhydrous) ($/metric ton) |
|---|---|---|---|---|
| 1960 | 63.4 | 23.4 | 369 | 424 |
| 1961 | 55.8 | 19.0 | 341 | 380 |
| 1962 | 71.2 | 22.3 | 313 | 380 |
| 1963 | 67.4 | 20.7 | 307 | 380 |
| 1964 | 73.6 | 21.7 | 295 | 380 |
| 1965 | 88.7 | 26.7 | 301 | 424 |
| 1966 | 96.8 | 28.4 | 293 | 424 |
| 1967 | 107.5 | 32.3 | 300 | 424 |
| 1968 | 116.8 | 36.7 | 314 | 455 |
| 1969 | 133.2 | 42.8 | 321 | 486 |
| 1970 | 132.3 | 46.9 | 355 | 546 |
| 1971 | 123.7 | 46.1 | 373 | 600 |
| 1972 | 150.6 | 52.7 | 350 | 600 |
| 1973 | 145.7 | 59.6 | 409 | 600 |
| 1974 | 161.6 | 71.5 | 442 | 1003 |
| 1975 | 129.0 | 58.0 | 450 | 744 |

* Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A, and Chemical Marketing Reporter.

Notes: 1. Unit values reflect interplant transfers and understate average value of commercial shipments. In 1975, the average commercial shipment value is estimated to be $600/metric ton.

During periods of rapid price escalation as in recent years, the list price will rise more rapidly than contract prices, and the spread between list and actual shipment values will widen.

Prices are determined by the major producers in the industry which act as price leaders. Prices are established based on manufacturing costs as well as a desired rate of return. However, with the current competitive environment in the industry, full cost recovery through price increases is not likely for all producers.

f. Profitability. The actual producer's profitability from the production of hydrofluoric acid has not been determined. Based on model plant manufacturing costs, an approximate level of profitability has been estimated. Table IV-18 is an income statement for the model plant. Corporate overhead, GS&A burden, and other pollution control costs have not been included. Assuming the model plant is representative of the industry's cost structure, the after-tax profits are $57 per metric ton and the cash flow is $87 per metric ton based on a $600 per ton average selling price for 1975.

g. Foreign Competition. Foreign competition in hydrofluoric acid was historically insignificant up until 1971 when there were 19,400 metric tons imported. The major portion of imports is from Canada; however, with new production capacity for hydrofluoric acid on-stream in Mexico, installed to serve the U.S. market, imports should continue to increase. It is expected that imports will represent an increasing proportion of domestic consumption of hydrofluoric acid over the next several years because no new domestic capacity expansions are expected in the next several years.

TABLE IV-18

MODEL PLANT INCOME STATEMENT AND CASH FLOW - 1975
HYDROFLUORIC ACID*

| | |
|---|---|
| Plant capacity | 23,180 metric tons per year |
| Operating rate | 90% |
| Production | 20,860 metric tons per year |
| Average 1975 selling price | $600 per metric ton |
| Manufacturing cost | 485 |
| PBT | 115 |
| PAT (50% tax rate) | 57 |
| Plus: Depreciation | 30 |
| Net cash flow | $87 per metric ton |

*Source: Contractor's estimates.

## C. Elemental Phosphorus ($P_4$)

### 1. Industry Structure.

a. Producers. Currently 10 producers have a capacity of 560,000 metric tons, as shown in Table IV-19, although TVA is planning on closing down their manufacturing facility in 1976. Three producers account for 81 percent of industry capacity. Electro-Phos Corporation is currently expanding capacity to 20,000 metric tons, and therefore industry capacity will be 532,000 metric tons in 1977.

Producers of elemental phosphorus are primarily located in Tennessee, Florida and the Northwest near sources of raw materials. The major proportion of capacity is located in Tennessee and the Northwest because of the historically available low cost power. Florida accounts for only 8 percent of industry capacity. Electric power costs represent a significant portion of total manufacturing costs, and therefore low-cost power is critical in the production of cost-competitive products.

b. Captive Requirements. Since the two major end-use areas for elemental phosphorus are as chemical intermediates, it is not surprising that more than 80 percent of the 1974 production was used captively. Captive use has been above 90 percent in all but three of the last 10 years, as shown in Table IV-20. With the high captive use, there are only seven producers, one of which plans to shut down operations in 1976 and another is principally an exporter.

c. Other. Competition in the elemental phosphorus industry is on a price basis since most is consumed as an intermediate in other chemical production. For these uses quality is standard, although supply availability has been an increasing problem in the last several years because of shortages.

TABLE IV-19

ELEMENTAL PHOSPHORUS PRODUCERS*

| Producer | Location | Annual capacity (1,000 metric tons) |
|---|---|---|
| FMC | Pocatello, Idaho | 132 |
| Electro-Phos Corp. | Pierce, Florida | 15 |
| Hooker Chemical | Columbia, Tennessee | 52 |
| Mobil Oil | Nichols, Florida | 4 |
| Monsanto | Columbia, Tennessee | 122 |
| Monsanto | Soda Springs, Idaho | 100 |
| Stauffer | Mt. Pleasant, Tennessee | 41 |
| Stauffer | Silver Bow, Montana | 38 |
| Stauffer | Tarpon Springs, Florida | 23 |
| TVA | Muscle Shoals, Alabama | 33 |
| Total | | 560 |

*Source: Chemical Profile, July 1, 1975.

TABLE IV-20

PRODUCTION, SALES AND CAPTIVE USE FOR ELEMENTAL PHOSPHORUS*
(THOUSAND METRIC TONS)

| Year | Production | Sales | Captive use[a] | % captive |
|---|---|---|---|---|
| 1964 | 457 | 30 | 427 | 93 |
| 1965 | 504 | 41 | 463 | 92 |
| 1966 | 514 | 40 | 474 | 92 |
| 1967 | 533 | 59 | 474 | 89 |
| 1968 | 557 | 52 | 505 | 91 |
| 1969 | 566 | 40 | 526 | 93 |
| 1970 | 542 | 35 | 507 | 94 |
| 1971 | 495 | 38 | 457 | 92 |
| 1972 | 491 | 26 | 465 | 95 |
| 1973 | 477 | 80 | 397 | 83 |
| 1974 | 476 | 77 | 399 | 84 |
| 1975 | 408 | 50 | 358 | 88 |

*Source: U.S. Department of Commerce.

a. Includes stock changes.

Cost increases have been passed along through price increases in recent years. The recent shortages have allowed producers to obtain full recovery of cost increases. However, with static growth in demand and low capacity utilization expected over the next several years, the market will be increasingly competitive, and it will limit the producer's ability to obtain a full recovery of future cost increases.

2. Supply Characteristics.

a. Manufacturing Routes. The principal process for industrial production of elemental phosphorus is the furnace process which accounts for 100 percent of domestic production. Phosphate rock is smelted with coke and silica in an electric furnace to produce elemental phosphorus vapors. The phosphorus-laden vapors are collected in condensing towers where the phosphorus is separated and stored. The phosphate rock used by producers is generally captively produced, and it is often less than a commercial grade of rock so that its market value is limited. There are considerable by-products from the production of elemental phosphorus, including ferrophosphorus and slag. Ferrophosphorus has a commercial value, but slag does not have a commercial value and it is generally dumped.

Alternative manufacturing routes for the production of industry phosphoric acid are being carefully examined because of the increasing cost of producing elemental phosphorus for the use in manufacture of industrial-grade phosphoric acid. Energy requirements are very high for the production of elemental phosphorus, and manufacturing plants have been located near low-cost power sources. However, in recent years power costs have increased sharply resulting in higher production costs for elemental phosphorus. Since energy costs in areas where phosphorus production is located are expected to continue to escalate, the costs of production of elemental phosphorus will continue to increase. As a result, there is growing research effort in examining the potential for alternative manufacturing routes for industrial-grade phosphoric acid which would eliminate the need for the intermediate step of producing elemental phosphorus.

b. Manufacturing Costs. Estimated 1975 manufacturing costs for elemental phosphorus are presented in Table IV-21. The manufacturing costs are based on a 49,900 metric ton per year plant located in a western state where almost 50 percent of industry capacity is located. The total manufacturing costs may be higher for plants located in other areas of the country because of higher power costs or because of lower grades of phosphate rock available. Energy costs are expected to rise more rapidly over the next five years in Tennessee than in the western states. With significantly higher energy costs, manufacturers of elemental phosphorus located in Tennessee will be in a high-cost manufacturing position.

c. Capacity Utilization. During the 1960's industry operating levels were high with a 96 percent average industry operating rate in 1967. Because of the high fixed investment and the desirability to operate at high levels from a manufacturing viewpoint, high operating rates were maintained to allow economic production costs. In 1970, the industry operating level declined to 87 percent because of substantial overcapacity. With increasing government restrictions on phosphate levels in detergents and the resulting decline in demand, overcapacity developed which forced several producers to close down. Since 1972, operating rates have been improving in the face of declining demand because of continued reduction in capacity.

As shown in Table IV-22, in 1974 the industry operating rate was 85 percent, which was below historical levels. However, because of power shortages and other problems, industry operating capacity was below reported capacity which resulted in shortages of elemental phosphorus. In 1975, the industry operating rate declined to 73% of reported capacity.

TABLE IV-21

ESTIMATED COST OF MANUFACTURING*

ELEMENTAL PHOSPHORUS (1975)
(METRIC TONS)

| | |
|---|---|
| Plant capacity | 151.5 T/D |
| Annual production | 49,900 T/Yr |
| Fixed investment (1975) | $41,000,000 |
| (1968) | $26,000,000 |
| Location: Western States | |

| Variable costs | Quantity | $/Unit | $/Ton |
|---|---|---|---|
| Phosphate rock | 10.0 T | 22.0 | 220.00 |
| Silica | 1.25 T | 1.54 | 1.93 |
| Coke | 1.9 T | 4.41 | 83.75 |
| Electrodes | 58.4 Lbs | 0.24 | 14.02 |
| Electricity | 14,330 Kwh | .008 | 114.61 |
| Fuel | 12.1 MMBtu | 0.80 | 9.70 |
| Water | | | 2.20 |
| | | | 446.21 |
| **Semi-variable costs** | | | |
| Direct operating labor | 5.15 man hours | 6.00 | 34.05 |
| Direct supervisory wages | 15% of operating labor | | 5.11 |
| Maintenance labor | 3.0 man hours | 6.50 | 21.49 |
| Maintenance supervision | 15% of maintenance labor | | 3.23 |
| Maintenance material | 3% of investment/yr. | | 24.64 |
| Labor | 30% of wages | | 19.16 |
| Operating supplies | | | 5.51 |
| | | | 113.19 |
| **Fixed Costs** | | | |
| Plant overhead | 60% of wages | | 38.33 |
| Depreciation | 9% of investment/yr. | | 73.93 |
| Local taxes and insurance | 2.0% of investment/yr. | | 18.07 |
| | | | 130.33 |
| Total cost of manufacture | | | 689.73 |
| **Byproduct credits** | | | |
| Ferrophosphorus | 0.14 T | 51.8 | (7.25) |
| Slag | 7.2 T | 0.94 | (6.74) |
| Total cost including byproduct credits | | | $675.74 |

*Source: Contractor's estimates.

TABLE IV-22

INDUSTRY OPERATING CAPACITY - ELEMENTAL PHOSPHORUS*
(THOUSAND METRIC TONS)

| Year | Capacity | Production | % capacity |
|---|---|---|---|
| 1964 | - | 457.4 | - |
| 1965 | - | 504.2 | - |
| 1966 | - | 513.5 | - |
| 1967 | 552 | 532.9 | 96 |
| 1968 | - | 556.8 | - |
| 1969 | - | 565.6 | - |
| 1970 | 622 | 541.6 | 87 |
| 1971 | - | 494.8 | - |
| 1972 | 535 | 490.9 | 83 |
| 1973 | - | 477.1 | - |
| 1974 | 558 | 475.9 | 85 |
| 1975 | 558 | 407.7 | 73 |

*Source: U.S. Department of Commerce, Chemical Marketing Reporter.

3. Demand Characteristics.

a. Market Size. Since 1945, U.S. production of elemental phosphorus has grown from 73,000 metric tons to over 500,000 metric tons in 1969 when production peaked. Production has declined since 1969 and in 1975 was 415,800 metric tons, as shown in Table IV-23. Apparent consumption considers imports, exports, and changes in inventory levels and as a result, apparent consumption was 375,100 metric tons in 1975.

b. Growth. U.S. production of elemental phosphorus increased at an average annual rate of 3.8 percent between 1960 and 1970; however, since 1970 it has declined 3.2 percent per year through 1974. The decline in demand in recent years is because of limitations on the use of phosphate builders in laundry detergents, the major end-use sector for phosphorus. However, in 1974, phosphorus was in limited availability because of power shortages and other problems which limited the production capability of phosphorus producers. The future of phosphate detergents plus the availability of adequate power will affect the future growth of phosphorus most significantly and probably will limit it to static to low growth. Also, the TVA plans to discontinue production of $P_4$ and furnace acid for fertilizer use, which will have a negative impact on production growth.

c. Uses. The largest end-use area in 1974 was as an intermediate for the production of phosphoric acid for industrial and fertilizer applications. Industrial uses for phosphoric acid include phosphate detergents, food and beverage additives, fire control, and metal treating. Phosphoric acid production accounted for 75 percent of domestic production of phosphorus in 1974, as shown in Table IV-24. Growth in phosphoric acid production in all probability will be static over the next several years because of regulatory pressures on phosphate detergents, increasing competition from non-ionic detergents, and because TVA plans to shut down

TABLE IV-23

U.S. PRODUCTION AND TRADE OF ELEMENTAL PHOSPHORUS (1960-1975)
(THOUSANDS OF METRIC TONS)*

| | Production | Imports | Exports | Stocks at producing plants (Dec. 31) | Apparent consumption[a] |
|---|---|---|---|---|---|
| 1960 | 371.4 | 1.3 | NA | 13 | 367.7 |
| 1961 | 390.9 | 1.1 | NA | 10 | 395.0 |
| 1962 | 410.3 | 0.2 | NA | 14 | 406.5 |
| 1963 | 443.1 | 0.1 | NA | 8 | 449.2 |
| 1964 | 457.4 | 0.2 | NA | 7 | 458.6 |
| 1965 | 504.2 | 0.3 | NA | 5 | 506.5 |
| 1966 | 513.5 | 0.4 | NA | 8 | 510.9 |
| 1967 | 532.9 | 0.3 | NA | 10 | 531.2 |
| 1968 | 556.8 | 0.4 | NA | 9 | 558.2 |
| 1969 | 565.6 | 0.5 | NA | 7 | 568.1 |
| 1970 | 541.6 | 0.3 | NA | 9 | 539.9 |
| 1971 | 494.8 | 0.3 | NA | 8 | 496.1 |
| 1972 | 490.9 | 0.5 | 17.2 | 6 | 476.2 |
| 1973 | 477.1 | 0.6 | 24.2 | 8 | 451.5 |
| 1974 | 475.9 | NA | 30.5[b] | 7 | 446.4 |
| 1975 | 407.7 | NA | 32.6 | 7 | 375.1 |

*Source: U.S. Department of Commerce, Current Industrial Reports, M28A. U.S. Department of Commerce, FT 110, 246, 410.

a. Equals production and imports - exports $\pm$ $\Delta$stocks.

b. 11 months.

TABLE IV-24

U.S. END USES OF PHOSPHORUS, 1974*

| | Percent |
|---|---|
| Phosphoric acid (industrial and fertilizer use) | 75 |
| Non-acid chemicals and other | 21 |
| Exports | 4 |

*Source: Contractor's estimates.

their phosphorus capacity utilized for the production of fertilizers. Non-acid chemicals and exports account for 21 percent and 4 percent respectively of phosphorus end use. Non-acid chemicals include phosphorus pentasulfide, phosphorus trichloride and phosphorus pentoxide, which are used in insecticides, lube oil additives, and flame retardants. These areas should achieve a level of growth higher than phosphoric acid over the next several years, and as a result, will represent an increasing share of the market for phosphorus.

d. Substitute Products. There are no direct substitutes for elemental phosphorus in the major end-use categories, industrial phosphoric acid manufacture and other phosphorus chemicals. In addition, there are minimal substitute markets for these products because industrial phosphoric acid and other phosphorus chemicals ($P_2S_5$, $P_2O_5$, $PCl_3$) are also principally chemical intermediates. However, there is competition from wet-process phosphoric acid particularly in fertilizer production where high-grade phosphoric acid is not required. The TVA plans to shut down the only furnace acid facility for the production of fertilizers and use wet-process-based phosphoric acid instead.

Tertiary levels of competition exist such as for detergent builders and water treatment chemicals which are the major markets for furnace-based phosphoric acid. However, there has been widespread research looking for cost-effective and environmentally acceptable alternatives to phosphate-based builders because of regulatory pressures to reduce phosphate content in detergents. These efforts have had limited success, although the recent introduction of non-ionic detergents may become increasingly competitive with phosphate-based detergents and cleaners. There are also possible substitutes for metal treating, fire control, insecticides, lube oil additives, and flame retardant end uses for industrial phosphoric acid and non-acid chemicals. However, at this level of use, the cost of elemental phosphorus is a small portion of the total product cost and the treatment cost impact will be minimized.

e. Prices. Prices historically have been relatively stable for elemental phosphorus. As shown in Table IV-25, actual prices (defined by unit value) have been relatively stable and have ranged from $371 per metric ton to $398 per metric ton over the 1962 to 1970 period. Since 1972, actual prices have increased dramatically along with list prices because of increasing power and phosphate rock costs. The producers of elemental phosphorus have had the pricing flexibility to pass on these higher manufacturing costs in the face of declining demand. Although the capacity utilization in the industry has been below historic levels, the effective capacity utilization has been high because of power supply interruptions and other problems which reduced the actual industry capacity. The high effective capacity utilization resulted in shortages in 1974, and also contributed to the producer's ability to recover higher manufacturing costs. In the future, with static demand growth, the industry may have less pricing flexibility than in recent years.

Import and export prices are summarized in Table IV-26. In general, these prices are higher than domestic prices, reflecting transportation cost differentials as well as the premium value placed on elemental phosphorus in the import/export market.

f. Profitability. The actual producer's profitability from the production of elemental phosphorus has not been determined. Based on model plant manufacturing costs, an approximate level of profitability has been estimated. Table IV-27 is an income statement for the model plant. Corporate overhead, GS&A burden, and other pollution control costs have not been included. Assuming the model plant is representative of the industry's cost structure, the after-tax profits are $188 per metric ton and the cash flow is $249 per metric ton based on a $1,050 per ton average selling price for 1975.

g. Foreign Competition. Foreign competition in elemental phosphorus has historically been insignificant and is likely to remain so, at least for the next several years.

TABLE IV-25

ACTUAL VERSUS LIST PRICES FOR ELEMENTAL PHOSPHORUS*

| | Shipment quantity (1,000 metric tons) | Value ($MM) | Unit value ($/metric ton) | List price ($/metric ton) |
|---|---|---|---|---|
| 1960 | 374.2 | 120.5 | 322 | 419 |
| 1961 | 333.2 | 130.0 | 290 | 419 |
| 1962 | 346.6 | 135.1 | 390 | 419 |
| 1963 | 387.6 | 146.0 | 377 | 419 |
| 1964 | 410.6 | 152.8 | 372 | 419 |
| 1965 | 465.2 | 172.6 | 371 | 419 |
| 1966 | 465.3 | 173.1 | 372 | 419 |
| 1967 | 486.8 | 184.1 | 378 | 419 |
| 1968 | 515.2 | 191.2 | 371 | 419 |
| 1969 | 515.6 | 203.2 | 394 | 419 |
| 1970 | 499.2 | 198.5 | 398 | 419 |
| 1971 | 455.9 | 191.4 | 420 | 419 |
| 1972 | 464.9 | 190.2 | 409 | 419 |
| 1973 | 443.5 | 206.3 | 465 | 419 |
| 1974 | 451.7 | 273.4 | 605 | 485 |
| 1975 | 384.8 | 379.9 | 987 | 617 - 1168 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A, and Chemical Marketing Reporter.

TABLE IV-26

IMPORT AND EXPORT PRICES OF ELEMENTAL PHOSPHORUS *
($ PER METRIC TON)

| | Import | Export |
|---|---|---|
| 1960 | 337 | NA |
| 1961 | 335 | NA |
| 1962 | 701 | NA |
| 1963 | NA | NA |
| 1964 | 879 | NA |
| 1965 | 987 | NA |
| 1966 | 731 | NA |
| 1967 | 1070 | NA |
| 1968 | 916 | NA |
| 1969 | 979 | NA |
| 1970 | 1146 | NA |
| 1971 | 991 | NA |
| 1972 | 1072 | 442 |
| 1973 | 1183 | 508 |
| 1974 | NA | 658 |
| 1975 | NA | 1124 |

*Source: U.S. Department of Commerce, FT 110, 246, 410.

TABLE IV-27

MODEL PLANT INCOME STATEMENT AND CASH FLOW - 1975

ELEMENTAL PHOSPHORUS*

| | |
|---|---|
| Plant capacity | 55,300 metric tons per year |
| Operating rate | 90% |
| Production | 49,900 metric tons per year |
| Average 1975 price | $1,050 per metric ton |
| Manufacturing costs | 674 |
| PBT | $ 376 |
| Profit after tax (50% tax rate) | 188 |
| Plus: depreciation | 61 |
| Net cash flow | $ 249 per metric ton |

*Source: Contractor's estimates.

## D. Sodium Dichromate

### 1. Industry Structure.

a. Producers. There are currently three producers of sodium dichromate with a capacity of 154,000 metric tons per year, as shown in Table IV-28. The Allied Chemical and Diamond Shamrock plants are approximately the same size and together account for about 82 percent of total capacity. Mallinckrodt, Inc., produces small quantities of high grade sodium dichromate for laboratory and pharmaceutical markets.

b. Captive Requirements. There is significant forward and backward integration by the three producers. Over 50 percent of sodium dichromate production is consumed in the manufacture of chrome colors (pigments) and chromic acid. All U.S. chromic acid production is from Allied and Diamond Shamrock plants, as shown in Table IV-28. Of their dichromate production, 32 percent and 25 percent respectively is dedicated to their chromic acid production. PPG has only small captive outlets for its dichromate. None of the sodium dichromate producers are chrome color producers.

Soda ash and sulfuric acid are major raw materials for dichromate production and are made by each of the dichromate producers.

c. Competition. Sodium dichromate is sold primarily on the basis of price as a standard specification product interchangeable among the producers. There are few long-term contracts and the shorter-term contracts usually contain provisions allowing the producer to change prices by giving a short notice period. Between January and December 1975, prices changed from $550 to $660 per metric ton or about 20 percent as a result of higher materials costs.

TABLE IV-28

SODIUM DICHROMATE AND CHROMIC ACID
PLANTS AND CAPACITIES-1975*

| Company/plant | Capacity (1,000 metric tons/year) Sodium dichromate | Chromic acid |
|---|---|---|
| Allied Chemical Corp. | | |
| Baltimore, Maryland | 59 | 19 |
| Diamond Shamrock Corp. | | |
| Castle Hayne, North Carolina | 68 | 17 |
| Mallinckrodt, Inc. | | |
| St. Louis, Missouri | | |
| (high grade product for laboratory use) | small | |
| PPG Industries, Inc. | | |
| Corpus Christi, Texas | 27 | 0 |
| Total | 154 | 36 |

*Source: Contractor's estimates.

Most major buyers will split their purchases with several producers in order to maintain a relationship with alternative suppliers. Because there are only three suppliers, an incentive exists to be strongly influenced but not dominated by price considerations in purchases over a year.

There are some differences between the market profiles of the three producers. For example, PPG's sales are more heavily directed to chrome colors. Plant location gives a geographical price advantage to producers in some areas.

Since most of the dichromate production is consumed in secondary chemicals, many of the competition characteristics for the secondary chemicals are largely the same as for sodium dichromate.

2. Supply Characteristics.

a. Manufacturing Routes. Sodium chromate and dichromate are made by calcining chrome ore (chromite) with soda ash and lime. More specifically, sodium chromate is manufactured by calcining a mixture of chromite ore, lime and soda ash. The sodium chromate, if desired, can be recovered by leaching and crystallization. Sodium dichromate is produced by treating a sodium chromate solution with sulfuric acid. Sodium dichromate and the sodium sulfate by-product produced are separated and recovered by crystallization. Sodium dichromate is the principal commercial product. It is usually priced to cost less per unit of $CrO_3$ than sodium chromate.

Chromium chemicals are produced from chromite ore, the term chromite being a general one used to designate chromium-bearing spinel. The composition of chromite varies widely, usually with inclusions of magnesia, alumina and silica. Although distinctions are not clearcut, there are three broad grades of chromite: high-chromium chromite, a metallurgical grade; high-iron chromite, which is the chemical grade; and high-aluminum chromite, the refractory grade. Chromite has not been mined in the United States since 1961 when a small tonnage was produced under the government's Defense Production Act. With the exception of government stockpile releases, U.S. producers of chromium chemicals are therefore dependent on foreign sources. No commercially viable process for upgrading domestic chromite bearing materials to compete with foreign ones has been developed.

Most of the known world reserves are located in the Republic of South Africa and Southern Rhodesia. The embargo on chromite from Southern Rhodesia, brought about by United Nations action in 1966 and an Executive Order in 1967, resulted in the U.S. turning to the U.S.S.R. for some of its chromite requirements. Most of the chemical grade chromite, however, comes from the Republic of South Africa.

b. Manufacturing Costs. Estimated manufacturing costs for sodium dichromate are shown in Table IV-29. The manufacturing costs are based on a plant with 136 metric tons per day capacity and an investment (assuming the plant was built in 1960) of $5.7 million. The indicated manufacturing cost in 1975 is $451.7 per metric ton. Included in this total is the cost of producing by-product sodium sulfate, amounting to approximately $27 per ton of dichromate. Corporate overhead and G & A burdens are not included.

c. Capacity Utilization. Table IV-30 lists the yearly value of U.S. production, imports, exports, and apparent consumption of sodium dichromate. Judging from the industry capacity values in Table IV-28, the capacity utilization in the industry has varied considerably in the last few years. In 1975 about 75 percent of rated total capacity was used, while in 1974

## TABLE IV-29

## ESTIMATED 1975 COST OF MANUFACTURING SODIUM DICHROMATE*

| | |
|---|---|
| Plant capacity | 136 T/SD |
| Annual production | 45,300 metric tons |
| Fixed investment (1975) | $10,400,000 |

| Variable costs | Quantity | $/Unit | $/Ton |
|---|---|---|---|
| Chromite ore (48% $Cr_2O_3$) | 1.09 T | 176.00 | 212.00 |
| Soda ash | 0.77 T | 66.00 | 56.00 |
| Lime | 0.73 T | 33.00 | 26.00 |
| Sulfuric acid (66 Bé) | 0.45 T | 51.3 | 25.00 |
| Power | 500 kwh | 0.02 | 11.00 |
| Fuel | 40 MMBtu | 0.70 | 31.00 |
| Water | 14 Mgal | 0.02 | 0.31 |
| | | | 362.00 |
| Semi-variable costs | | | |
| Operating labor | 124 men | 12,000/yr | 32.9 |
| Supervision | 12 foremen | 18,000/yr | 4.8 |
| | 1 superintendent | 25,000/yr | 0.6 |
| Maintenance | 6% of Investment/yr | | 13.7 |
| Labor overhead | 35% of Labor & supervision | | 13.4 |
| | | | 65.4 |
| Fixed costs | | | |
| Plant overhead | 70% of labor & supervision | | 26.7 |
| Depreciation | 9.1% of Investment/yr | | 20.7 |
| Local taxes & insurance | 1.5% of Investment/yr | | 3.4 |
| | | | 50.8 |
| Total cost of manufacture | | | 478.20 |
| Byproduct credit - sodium sulfate | 0.73 | 33.1 | 26.5 |
| Net cost | | | 451.70 |

*Source: Contractor's estimates.

TABLE IV-30

U.S. PRODUCTION AND TRADE OF SODIUM DICHROMATE AND CHROMATE 1960-1975*
(THOUSANDS OF METRIC TONS)

| | Production | Imports | Exports | Apparent consumption |
|---|---|---|---|---|
| 1960 | 110.7 | 1.7 | 8.7 | 103.7 |
| 1961 | 109.8 | 1.5 | 6.5 | 104.8 |
| 1962 | 115.7 | 2.3 | 4.5 | 113.5 |
| 1963 | 121.6 | 3.2 | 4.6 | 120.2 |
| 1964 | 125.2 | 3.1 | 6.1 | 122.2 |
| 1965 | 128.0 | 16.3 | 3.6 | 140.7 |
| 1966 | 128.5 | 21.9 | 2.4 | 148.0 |
| 1967 | 122.8 | 7.4 | 3.0 | 127.2 |
| 1968 | 132.5 | 10.5 | 4.4 | 138.6 |
| 1969 | 138.5 | 5.9 | 4.6 | 139.8 |
| 1970 | 139.4 | 3.3 | 4.5 | 138.2 |
| 1971 | 125.5 | 5.8 | 2.8 | 128.5 |
| 1972 | 133.2 | 5.2 | 3.6 | 134.8 |
| 1973 | 144.1 | 0.9 | 11.6 | 133.4 |
| 1974 | 162.2 | 2.1 | 9.6 | 154.7 |
| 1975 | 112.1 | 0.4 | 9.6 | 102.9 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A. U.S. Department of Commerce FT 110, 135, 410.

production was in excess of rated capacity at 105 percent. Capacity utilization is expected to return to high values of at least 90 percent in 1976 and 1977, with the improved general economic conditions and particularly with improved automotive and appliance sales.

3. Demand Characteristics.

a. Market Size. Table IV-30 lists the apparent U.S. consumption of sodium chromate and dichromate for the period 1960 through 1975. For most of this period, U.S. production as reported by the Department of Commerce has varied between 120 and 150 thousand metric tons anually. As indicated, these data include both sodium chromate and sodium dichromate. While some of the sodium chromate produced in the initial phase of the manufacturing process is marketed as such (an estimated 15 thousand tons of dichromate equivalent), most of the sodium chromate filtrate is further processed to produce sodium dichromate.

On a long-range basis (in the post-World War II period), apparent consumption of sodium chromate and dichromate has increased at an average annual compound rate of 2.4 percent per year. Both production and apparent consumption declined in 1971, but increased 8.9 percent and 6.4 percent respectively annually through 1974. There was a sharp decline in 1975 to 112.1 thousand metric tons of production and 102.9 tons of consumption. This decline reflected the generally poor economic conditions and the state of the automobile and appliance industries in particular which use chrome products. Production in 1976 has recovered from 1975 levels as the economy has improved.

The demand elasticity for sodium dichromate was estimated using Department of Commerce production and unit values shown in Table IV-32 through 1974. The elasticity was -0.5, indicating that a 1 percent increase in product price would result in a 0.5 percent decline in sales.

b. Uses and Substitutes. Fifty-six percent of sodium dichromate production in 1974 is estimated to have been consumed in the manufacture of chrome colors (pigments) and chromic acid. Table IV-31 is a market profile reported in "Chemical Profiles". The largest market segment is chrome colors which accounted for 32 percent of production. None of the dichromate producers are chrome color producers. Therefore,all of the sodium dichromate used in chrome color production is sold on the commercial market.

The production of chromic acid is the second largest use of sodium dichromate at 24 percent of 1974 production. However, Allied Chemical and Diamond Shamrock produce all U.S. chromic acid and use their own dichromate as a raw material.

Chromic acid is used primarily in chrome plating processes as well as in copper stripping, aluminum anodizing and for general corrosion prevention. The automotive industry represents the major user for chrome plating, although other durable goods manufacturing such as appliances also have requirements.

The third most important outlet for sodium dichromate is leather tanning. With the exception of heavy cattle hides, where vegetable tanning is used, chrome tanning is the most important treatment for all hides. Chrome tannage is used in shoe uppers, glove leathers, garment leathers, and bag leather. In the tanning process, sodium dichromate is reduced with glucose to make the solutions of chromium salts employed in chrome leather tanning.

Five percent of sodium dichromate is used in various metal treating and finishing processes. For example, a solution of sodium dichromate and sulfuric acid is used in the bright dipping of brass and copper to remove oxide scale. Another important use in metal finishing is in the formation of chemical conversion coatings to provide corrision protection and decorative effects, as well as to provide a good base for painting metal surfaces.

TABLE IV-31

ESTIMATED 1974 USE PATTERN FOR SODIUM CHROMATE AND DICHROMATE*

| End Use | % |
|---|---|
| Pigments | 32 |
| Chromic acid | 24 |
| Leather tanning | 14 |
| Corrosion control | 8 |
| Metal treatment | 5 |
| Petroleum | 4 |
| Textiles & dyes | 4 |
| Exports | 3 |
| Miscellaneous | 6 |
| Total | 100 |

* Source: "Chemical Profiles" January 1, 1974, Schnell Publishing Co.

The textile industry consumes 4 percent of sodium dichromate in a variety of ways. Among its applications are mordanting of wool, dyeing nylon and wool, dyeing with chromate colors, as an aftertreatment on cotton to retard fading of dyes during washing and for stripdyed wool.

Substitutes are represented by alternate materials (or processes) for derivatives of sodium dichromate rather than for the dichromate. As an example, a high impact plastic can be substituted for chrome-plated trim on motor vehicles. Cadmium yellow can be used in place of chrome yellow pigments. Market growth for chrome leather is limited by lower cost substitutes, specifically, the poromeric materials. Tin-free steel cans coated with chromate compete with aluminum cans and seamless, deep-drawn steel cans coated with tin.

C. Growth. Sodium dichromate is a mature product whose immediate future will depend on the sales of the secondary products in which it is used. There is no significant threat either from imports or substitutes to sodium dichromate. Sales of chromic acid used in chrome plating will move generally with the economy and slow growth can be anticipated on the average. While some uses of chrome colors have fallen off because of environmental concerns, other uses,such as in road signs,have been rising and slow growth can be anticipated. The use of dichromate in leather tanning may continue to decline slowly. On the whole, sodium dichromate will experience a very modest annual growth in the range of 2 percent per year.

d. Prices. A comparison of list prices versus actual prices as calculated from the Commerce Department data on reported value and quantity of shipments is shown in Table IV-32. From 1960 to 1969 list prices increased very little, at an annual average rate of 0.9 percent. From 1969 to 1974 the list prices have increased 8.7 percent per annum. Actual prices varied

TABLE IV-32

ACTUAL VERSUS LIST PRICES FOR SODIUM DICHROMATE 1960-1975*

| | Shipments[a] (1,000 metric tons) | Value ($ MM) | Unit value ($/metric ton) | List price ($/metric ton) |
|---|---|---|---|---|
| 1960 | 80.9 | 22.7 | 281 | 287 |
| 1961 | 77.4 | 20.5 | 265 | 287 |
| 1962 | 88.1 | 24.8 | 281 | 287 |
| 1963 | 80.0 | 21.2 | 265 | 287 |
| 1964 | 90.4 | 22.9 | 253 | 287 |
| 1965 | 94.1 | 24.2 | 257 | 287 |
| 1966 | 85.5 | 23.9 | 280 | 309 |
| 1967 | 85.3 | 23.0 | 270 | 309 |
| 1968 | 90.7 | 23.9 | 264 | 309 |
| 1969 | 87.6 | 23.1 | 264 | 309 |
| 1970 | 93.6 | 24.8 | 265 | 331 |
| 1971 | 80.1 | 21.9 | 273 | 353 |
| 1972 | 87.1 | 24.5 | 281 | 353 |
| 1973 | 95.4 | 28.6 | 300 | 380 |
| 1974 | 104.8 | 40.9 | 390 | 469 |
| 1975 | 81.2 | 41.2 | 507 | 550 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A, and Chemical Marketing Reporter.

a. Including interplant transfers.

very little between 1960 and 1972 in the range of $250 and $280 per metric ton. In 1973 and 1974 the actual prices increased 17.8 percent per year then increased 30 percent in 1975.

The 1975 price rise was in spite of a sharp decline in production and demonstrated the ability of producers to maintain price levels in spite of falling demand.

e. Foreign Competition. Imports and exports of sodium dichromate have been a relatively insignficant part of the U.S. market. In the past few years exports have exceeded imports and accounted for about 5 percent of production. As discussed earlier all chrome ore (chromite) used in U.S. plants is imported principally from South Africa.

## E. Titanium Dioxide

### 1. Industry Structure.

a. Producers. In 1975 there were nine domestic $TiO_2$ producers operating 15 plants, all but one of which are in the eastern half of the U.S. Table IV-33 summarizes pertinent information regarding these facilities. Since 1956, chloride process facilities have accounted for all new $TiO_2$ pigment plant construction. However, two producers, PPG and NL Industries, have recently closed their chloride facilities, moves reportedly due to raw material supply and economic problems.

b. Captive Requirements. The major captive use of $TiO_2$ pigment is in the paint industry, where three of the top six $TiO_2$ consumers have their own pigment plants. Captive $TiO_2$ consumption as a percentage of apparent consumption rose from 8 percent in 1965 to 14 percent in 1971. DuPont, Glidden-Durkee, and NL Industries are the major captive users, and it is believed that these companies account for virtually all of the captively consumed $TiO_2$ pigment.

c. Other. Nearly all $TiO_2$ plants are isolated manufacturing facilities, although a few are part of larger, multi-product facilities. Most plants produce and sell titanate and other salts as by-products from the process.

Although $TiO_2$ is sold in volumes comparable to those of some commodities, it is marketed more as a specialty chemical than as a commodity. Producers' marketing efforts in recent years have been centered around grade improvement, quality control, and customer-oriented technical service. Depending on particular product characteristics, individual producers frequently are strong in one market segment, such as paper, but weak in another, such as paint.

TABLE IV-33

TITANIUM DIOXIDE PLANTS AND CAPACITIES - 1975*

| Company/plant | Capacity (1,000 Metric tons/yr) | Process |
|---|---|---|
| American Cyanamid Co. | 65.3 | |
| Savannah, Ga. | 36.3 | Sulfate |
| | | Chloride |
| Combustion Engineering, Inc. | n.a. | |
| Camden, N.J. | n.a. | |
| Wilmington, Del. | | |
| E.I. duPont | 27.2 | |
| Antioch, Ca. | 99.8 | Chloride |
| Edge Moor, Del. | 206.8 | Chloride |
| New Johnsonville, Tenn. | | Chloride |
| Kerr-McGee Corp. | 45.4 | |
| Hamilton, Miss. | | Chloride |
| Lonza Inc. | | |
| Mapleton, Ill. | n.a. | |
| NL Industries, Inc. | 98.0 | |
| St. Louis, Mo. | 112.5 | Sulfate |
| Sayreville, N.J. | | Sulfate |
| New Jersey Zinc. Co. (Subs Gulf and Western) | | |
| Ashtabula, Ohio | 26.3 | Chloride |
| Gloucester City, N.J. | 39.9 | Sulfate |
| SCM Corp. | | |
| Ashtabula, Ohio | 24.5 | Chloride |
| Baltimore, Md. | 26.3 | Chloride |
| | 48.1 | Sulfate |
| Transelco Inc. | | |
| Pennyan, N.Y. | n.a. | |
| Total | 856.4 | |

*Source: Contractor's estimates.

2. Supply Characteristics.

a. Manufacturing Routes. $TiO_2$ is manufactured by either of two processes-sulfate and chloride. Current domestic manufacturing capacity is about 856,000 tons, approximately 40 percent of which is sulfate. The sulfate process is older and employs sulfuric acid to separate and recover $TiO_2$ from ilmenite, the principal raw material used in this manufacturing route. The sulfate process has the disadvantage of producing a large amount of potential pollutants in the form of spent sulfuric acid and ferrous sulfate (copperas). Depending on processing steps employed, the two chemical forms of $TiO_2$, anatase and rutile, can be produced.

The alternate method of production, and the one employed in every $TiO_2$ plant built since 1956, is the chloride process. In this process, chlorine is reacted at high temperature with the raw ore, generally rutile, a high $TiO_2$-content material. $TiO_2$ is recovered later in the process through further chemical treatment, and approximately 90 percent of the chlorine is recovered for reuse. Due to higher quality ore and reactant recycling, the chloride process produces far less pollutant by-product than the sulfate process. Although rutile pigment has been the sole product from the chloride process in the past, DuPont began production of both anatase and rutile grades upon conversion of its Edgemoor, Delaware plant to 100 percent chloride production in 1974. Chloride pigment has more uniformly consistent particle size; hence, it offers greater hiding power and is used preferentially in certain critical applications such as automotive paint.

b. Manufacturing Costs. Table IV-34 summarizes estimated manufacturing costs for a 22,680 ton per year chloride plant. The costs for raw materials, utilities, direct labor, and overhead are based on current estimates for these items. Ore cost comprises over 50 percent of the cost of manufacture, and this item has been most responsible for the elimination of the chloride process's earlier cost advantage over the sulfate process. Chloride pigment producers are anxious to lower this cost through either more widespread use of ilmenite or through successful commercialization of synthetic rutile production. An important factor in economical chloride production is recovery and recycle of chlorine gas after the oxidation step.[a]

c. Capacity Utilization. Table IV-35 summarizes capacity and production figures for recent years and shows that capacity utilization has been in the 75 percent to 90 percent range. Capacity has been taken at announced, or nameplate, levels and is higher than effective capacity due to grade/product mix constraints. The industry is now facing a potential tight-supply situation in the next several years as demand rebounds from depressed 1975 levels.

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a. The chloride process for the manufacture of $TiO_2$ is the subject of this analysis, despite its more favorable pollution characteristics, for two reasons. First, this is the dominant route to $TiO_2$, and second, the manufacturing costs for $TiO_2$ for the chloride process have been estimated to be as much as 15 percent higher than for the sulfate process. This higher manufacturing cost, in combination with relative product price levels and hazardous waste treatment costs, makes the chloride process more susceptible to adverse economic impact from treatment and disposal of hazardous wastes.

TABLE IV-34

ESTIMATED COST OF MANUFACTURING
TITANIUM DIOXIDE BY THE CHLORIDE PROCESS (1975)*
(THOUSAND METRIC TONS)

| | |
|---|---|
| Plant capacity | 68 T/SD |
| Annual production | 22,680 Tons |
| Fixed investment (1975) | $28,000,000 |

| Variable cost | Quantity | $/Ton | $/Ton pigment |
|---|---|---|---|
| Rutile | 1.17 T | 303.0[a] | 354.51 |
| Coke | 0.35 T | 77.1 | 26.99 |
| Chlorine | 0.21 T | 132.2 | 27.77 |
| Chemical additions | | | 8.82 |
| Water makeup | 2.53 Mgal | 0.05 | 0.13 |
| Power | 898 kwh | 0.02 | 17.96 |
| Natural gas | 11 MMBtu | 0.70 | 7.71 |
| | | | 443.89 |
| Semi-variable costs | | | |
| Operating labor | 68 men | 12,000/yr | 35.97 |
| Supervision | 12 foremen | 18,000/yr | 9.52 |
| | 1 superintendent | 25,000/yr | 1.10 |
| Maintenance | 6% of Investment/yr | | 74.05 |
| Labor overhead | 35% of Labor & supervision | | 10.31 |
| | | | 136.95 |
| Fixed costs | | | |
| Plant overhead | 70% of labor & supervision | | 32.62 |
| Depreciation | 9.1% of Investment/yr | | 112.32 |
| Local taxes & insurance | 1.5% of Investment/yr | | 18.51 |
| | | | 163.45 |
| Total cost of manufacture | | | 744.29 |

*Source: Contractor's estimates.

a. Estimated contract price, spot price is $510/T.

TABLE IV-35

INDUSTRY OPERATING RATE - TITANIUM DIOXIDE*
(THOUSANDS OF METRIC TONS)

| Year | Capacity | Production | Capacity utilization (percent) |
|---|---|---|---|
| 1966 | 660 | 540 | 82 |
| 1967 | 695 | 535 | 77 |
| 1968 | 678 | 567 | 84 |
| 1969 | 705 | 604 | 86 |
| 1970 | 764 | 595 | 78 |
| 1971 | 740 | 616 | 83 |
| 1972 | 746 | 653 | 88 |
| 1973 | 792 | 710 | 90 |
| 1974 | 856 | 712 | 83 |
| 1975 | 856 | 547 | 64 |

*Source: U.S. Department of Commerce, Chemical Marketing Reporter.

3. Demand Characteristics.

a. Market Size. U.S. production of $TiO_2$ has grown from 414 thousand metric tons in 1960 to about 550 thousand metric tons in 1975, valued at about $428 million. Table IV-36 shows the history of $TiO_2$ production and foreign trade.

b. Growth. From 1960 to 1974, overall market growth has been at an annual rate of 3 percent to 4 percent although certain individual end-use segments, such as plastics, have grown considerably faster. Calculation of the growth rate from 1960 to the depressed level of demand in 1975 distorts the long-term growth rate to an average of 2 percent per annum.

c. Uses. Table IV-37 identified the major end uses for $TiO_2$ pigments. Paint and coatings applications, currently accounting for 52 percent of total consumption, constitute the major use for $TiO_2$. Two other end uses, paper and plastics, have grown rapidly in recent years, and in 1973, accounted for an additional 27 percent of $TiO_2$ consumption.

The remaining applications are: floor coverings, 3 percent; rubber, 3 percent; and miscellaneous, 15 percent.

d. Substitute Products. $TiO_2$ use is presently threatened by substitute products in only one market segment: paper. $TiO_2$ is an effective opacifier, but it is at a cost disadvantage to alumina and silica clays, some of which offer nearly equivalent brightness. In the paint industry, $TiO_2$ is by far the most effective white pigment in terms of hiding power, a key to the trend toward one-coat paint applications. While pigment research is extensive, no equally effective substitute has been found. In plastics and rubber, $TiO_2$ offers the best combination of white pigment cost, dispersion, and resistance to discoloration. In other product application areas, no substitute products represent serious threats to $TiO_2$'s present position.

TABLE IV-36

U.S. TITANIUM DIOXIDE PRODUCTION AND TRADE, 1960-1975*
(THOUSANDS OF METRIC TONS)

| | Production | Imports | Exports[a] |
|---|---|---|---|
| 1960 | 413.6 | NA | 18.2 |
| 1961 | 456.5 | NA | 17.2 |
| 1962 | 475.0 | NA | 17.2 |
| 1963 | 471.6 | NA | 16.3 |
| 1964 | 507.0 | 40.6 | 18.2 |
| 1965 | 523.5 | 45.0 | 15.4 |
| 1966 | 539.7 | 43.6 | 13.6 |
| 1967 | 535.1 | 42.5 | 12.7 |
| 1968 | 566.2 | 48.4 | 13.6 |
| 1969 | 584.9 | 48.3 | 12.7 |
| 1970 | 594.9 | 54.7 | 13.6 |
| 1971 | 615.3 | 38.9 | 12.7 |
| 1972 | 629.4 | 78.4 | 9.1 |
| 1973 | 712.6 | 54.8 | 19.1 |
| 1974 | 714.1 | 32.0 | 27.6 |
| 1975 | 547.2 | 23.9 | 14.2 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A. U.S. Department of Commerce FT 110, 135, 410.

a. Exports for 1960-1971 have been adjusted to a 100% $TiO_2$ basis by SRI.

TABLE IV-37

U.S. END USE OF TITANIUM DIOXIDE, 1973*

| | Percent |
|---|---|
| Paint, varnish and lacquer | 52 |
| Paper | 18 |
| Plastics | 9 |
| Floor coverings | 3 |
| Rubber | 3 |
| Miscellaneous | 15 |

*Source: Chemical Marketing Profiles.

e. Prices. Current list prices are 40.0 cents per pound for rutile grades, and 34.5 cents per pound for anatase. At these prices, $TiO_2$ frequently is one of the most expensive raw materials in its end-use applications. List prices have historically been stable or slowly rising, with the industry generally attempting to move as a whole to a given new price level. Due mostly to overcapacity problems, the industry has been plagued with substantial price discounts which forced several major producers to operate at a loss in the 1970-71 period. Price history is shown in Table IV-38.

f. Foreign Competition. As indicated in Table IV-39, exports of $TiO_2$ have remained quite small at less than 2 percent to 3 percent of domestic production. Imports, on the other hand, have ranged in recent years from 5 percent to 10 percent of total apparent consumption, although 1972 saw a large jump to 78,000 metric tons, or 11 percent of apparent consumption. Imports will probably continue at present percentage levels for the foreseeable future.

TABLE IV-38

TITANIUM DIOXIDE COMMERCIAL SHIPMENT VALUES*
(THOUSANDS OF METRIC TONS)

| | Commercial shipments (000 M tons) | Total value ($ MM) | Value per metric ton ($/M ton) | List prices/metric ton | |
|---|---|---|---|---|---|
| | | | | Anastase ($/M ton) | Rutile ($/M ton) |
| 1960 | 396.3 | 236.0 | 596 | 573 | 617 |
| 1961 | 415.1 | 244.4 | 589 | 573 | 617 |
| 1962 | 435.7 | 242.8 | 557 | 551 | 595 |
| 1963 | 441.6 | 257.5 | 583 | 551 | 595 |
| 1964 | 458.0 | 266.2 | 581 | 551 | 595 |
| 1965 | 476.1 | 274.7 | 577 | 551 | 595 |
| 1966 | 495.1 | 279.7 | 565 | 551 | 595 |
| 1967 | 492.6 | 277.2 | 563 | 551 | 595 |
| 1968 | 512.4 | 288.8 | 564 | 551 | 595 |
| 1969 | 535.7 | 301.1 | 562 | 573 | 617 |
| 1970 | 509.2 | 277.8 | 546 | 573 | 573 |
| 1971 | 527.6 | 262.4 | 497 | 573 | 529 |
| 1972 | 565.0 | 291.2 | 515 | 573 | 573 |
| 1973 | 633.4 | 353.8 | 556 | 617 | 595 |
| 1974 | 623.0 | 458.9 | 737 | 728 | 827 |
| 1975 | 475.8 | 370.3 | 778 | 761 | 882 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A and Chemical Marketing Reporter.

TABLE IV-39

TITANIUM DIOXIDE IMPORT AND EXPORT PRICES 1960-1975*
($ PER METRIC TON)

| | Imports | Exports [a] |
|---|---|---|
| 1960 | NA | 549 |
| 1961 | NA | 535 |
| 1962 | NA | 500 |
| 1963 | NA | 497 |
| 1964 | 369 | 456 |
| 1965 | 400 | 468 |
| 1966 | 394 | 559 |
| 1967 | 376 | 567 |
| 1968 | 386 | 603 |
| 1969 | 391 | 591 |
| 1970 | 406 | 544 |
| 1971 | 404 | 646 |
| 1972 | 426 | 462 |
| 1973 | 502 | 728 |
| 1974 | 772 | 891 |
| 1975 | 806 | 843 |

*Source: U.S. Department of Commerce, FT 110, 135, 410.

a. Exports for the years 1960-71 have been adjusted to a 100% $TiO_2$ basis.

## V. CHARACTERIZATION OF SECONDARY AFFECTED CHEMICALS

### A. Aluminum Fluoride

In 1975, U.S. production of aluminum fluoride totaled 108,900 metric tons, a 20 percent decline from 1974 production of 136,000 tons. U.S. output of aluminum fluoride, which is used almost entirely in the production of primary aluminum, has increased at an average annual compound rate of approximately 3.3 percent for the period 1963 through 1975, although production in recent years has been relatively constant. In its use as a fluxing agent for primary aluminum production, aluminum fluoride is to a minor extent interchangeable with another fluxing agent, cryolite. In general, however, there are no direct substitutes for aluminum fluoride in this major application. A very substantial part of aluminum fluoride consumption is captively supplied, viz. 70 percent in 1975.

There are currently four U.S. producers of aluminum fluoride, two of which--Aluminum Company of America (Alcoa) and Kaiser Aluminum & Chemical--are also major aluminum producers. The two remaining aluminum fluoride producers, not integrated forward to aluminum production, are Allied Chemical and Stauffer Chemical. Productive capacity for aluminum fluoride has been in excess of actual production in recent years. In 1975 the industry operating rate was approximately 68 percent.

#### 1. Industry Structure.

a. Producers. At the present time there are four manufacturers of aluminum fluoride operating five plants. Their plant locations and estimated capacities are shown in Table V-1. Two of the three major primary aluminum producers are included in the list. These two producers account for 69 percent of total industry capacity. Reynolds, the second largest aluminum producer (in terms of U.S. aluminum ingot capacity), has shut down its aluminum fluoride facility. In addition, Olin also had an aluminum fluoride plant in Joliet, Illinois, which has been shut down.

TABLE V-1

ALUMINUM FLUORIDE PRODUCERS*
(1975)

| Company | Location | Capacity (Thousand tons) | Capacity (% of total) |
|---|---|---|---|
| Allied Chemical Corp.<br>Industrial Chemicals Div.<br>Specialty Chemicals Div. | Geismar, Louisiana | 35.0 | 21.9 |
| Aluminum Corp. of America | Fort Meade, Florida<br>Point Comfort, Texas | 60.0 | 37.5 |
| Kaiser Aluminum & Chemical Corp. | Gramercy, Louisiana | 50.0 | 31.2 |
| Stauffer Chemical Co. | Greens Bayou, Texas | 15.0 | 9.4 |
| Total | | 160.0 | 100.0 |

* Source: Published estimates.

b. Captive Requirements. Commerce Department data for the period 1968 through 1973 broken down by captive/merchant shipments are shown in Table V-2. As indicated, in 1973 captive shipments of aluminum fluoride represented approximately 71 percent of total shipments. We have estimated that in 1974 and 1975 captive shipments were 55-60 percent of total shipments. Alcoa and Kaiser are the two major factors in captive consumption of aluminum fluoride. Reynolds has closed its aluminum fluoride plant at Bauxite, Arkansas, and is believed to be supplied primarily by Allied Chemical.

Both Alcoa and Kaiser, in addition to supplying their own captive requirements for aluminum fluoride, also supply the aluminum fluoride requirements of some of the smaller, non-integrated aluminum producers, such as Intalco, Ormet, Anaconda, and Harvey. Allied and Stauffer are primarily merchant suppliers of aluminum fluoride.

c. Producer Integration. All of the aluminum fluoride producers are substantially integrated to raw materials, and, in the case of Alcoa and Kaiser, to downstream products, i.e., primary aluminum. More specifically, Alcoa, Kaiser, and Allied produce both hydrofluoric acid and alumina hydrate in addition to aluminum fluoride. Stauffer produces hydrofluoric acid and aluminum fluoride, but not alumina hydrate.

2. Supply Characteristics.

a. Manufacturing Routes. Aluminum fluoride is manufactured from hydrofluoric acid and alumina hydrate. The alumina hydrate used is an intermediate product obtained in the processing of bauxite to alumina. It is necessary to use the hydrate for reaction because the alumina prepared for electrolysis and calcined at high temperatures is not reactive. Newer facilities use a fluid bed system for the reaction between hydrofluoric acid and the alumina hydrate.

TABLE V-2

CAPTIVE/MERCHANT SHIPMENTS FOR ALUMINUM FLUORIDE*
(THOUSANDS OF METRIC TONS)

| Year | Total shipments | Merchant shipments | Approximate captive shipments (% of total) |
|---|---|---|---|
| 1968 | 125.5 | 55.9 | 54.5 |
| 1969 | 129.8 | 48.8 | 62.4 |
| 1970 | 122.2 | 47.5 | 61.1 |
| 1971 | 141.3 | 59.1 | 58.2 |
| 1972 | 123.9 | 45.2 | 63.6 |
| 1973 | 127.1 | 37.2 | 70.6 |
| 1974 | 156.0 | 63.4 | 59.4 |
| 1975 | 114.9 | 51.7 | 55.0 |

*Source: U.S. Department of Commerce.

Alcoa has been operating a plant in Fort Mead, Florida, since late 1971 to produce aluminum fluoride from fluosilicic acid, a by-product of phosphoric acid manufacture. It is anticipated, however, that for the foreseeable future the fluosilicic acid route to aluminum fluoride will constitute a relatively constant part of total production, with most of the output continuing to be derived from hydrofluoric acid and hydrated alumina.

b. Manufacturing Economics. Estimated manufacturing costs for aluminum fluoride are shown in Table V-3. The cost estimates are based on a plant with an annual capacity of 29,940 metric tons and a 1975 fixed investment of $3.0 million.

The raw material costs account for an estimated 95 percent of the total manufacturing costs. We have assumed a cost for hydrofluoric acid of $485 per ton based on hydrofluoric acid manufacturing costs. If an aluminum fluoride producer were to purchase hydrofluoric acid on the open market, it would result in manufacturing costs for aluminum fluoride higher than the current market price because of the low profit margins for aluminum fluoride. The implication is that a producer of aluminum fluoride must be integrated to hydrofluoric acid to be profitable.

c. Supply/Demand Balance. U.S. alumina fluoride capacity is in excess of actual production and has been for the past several years, even with the closing of aluminum fluoride facilities by Reynolds and Olin. Presumably, Reynolds, because they were not integrated backward to the production of HF, found it more economic to purchase aluminum fluoride while low profitability and the small merchant market may have prompted Olin's decision to close its plant. For 1974 and 1975, production represented 84 percent and 69 percent of current capacity of 160,000 tons.

TABLE V-3

ESTIMATED COST OF MANUFACTURING (1975)
ALUMINUM FLUORIDE*
(THOUSANDS OF METRIC TONS)

| | |
|---|---|
| Plant capacity | 29,940 tons/year |
| fixed investment | $3,000,000 |

| Raw materials | Units | $/Unit | Unit/Ton | $/Ton |
|---|---|---|---|---|
| HF (cost) | Metric ton | 485 | .67 | 325.0 |
| $Al_2O_3$ | Metric ton | 163 | .61 | 99.4 |
| Utilities | Kwh | | 143.0 | |
| Fuel | MMBtu | | 2.25 | |
| Direct labor | | | | |
| Supervisors | | | | 5.73 |
| Operators | | | | |
| Overhead (100% of DL) | | | | 5.73 |
| Maintenance (50% of DL) | | | | 2.87 |
| Maintenance supplies (5% investment/year) | | | | 5.57 |
| Depreciation (2% investment/year) | | | | 2.23 |
| Taxes and insurance (1 1/2% investment/year) | | | | 1.68 |
| Total | | | | 448.21 |

*Source: Contractor's Estimates.

3. Demand Characteristics.

a. Market Size and Growth. Aluminum fluoride production for the period 1963 to 1975 is shown in Table V-4. During this time span, U.S. production of aluminum fluoride has increased at an average annual compound rate of approximately 3.3 percent. Aluminum fluoride imports are small, and exports are an estimated 10-15 percent of total production. The apparent U.S. market for the material in 1975 was less than 117,900 metric tons. (The exact quantity of aluminum fluoride imports and exports cannot be determined because the material is grouped with a number of other aluminum compounds in U.S. Tariff Commission import data.)

b. Uses. Aside from minor applications in secondary aluminum production and use as a metallurgical and ceramic flux, aluminum fluoride is used entirely by producers of primary aluminum. In primary aluminum production, aluminum fluoride functions as a major make-up ingredient in the fused electrolyte of the aluminum reduction cell. Although there is no actual consumption of the aluminum fluoride in the electrolysis reaction, there are mechanical losses, pyrohydrolysis and some carbon tetrafluoride formation. Consumption varies between companies and smelters but averages between 30 to 35 kilograms of aluminum fluoride per metric ton of aluminum produced. In addition to operating requirements (pot make-up), additional quantities of aluminum fluoride are needed for pot line startup. A 59,000 metric ton pot line, for example, would require approximately 544 metric tons of aluminum fluoride as an initial charge.

The consumption of aluminum fluoride per ton of primary aluminum produced has declined in recent years as a result of the industry's efforts to realize more efficient recovery of fluorine values from pot linings and flue gases. Table V-5 presents estimated consumption of aluminum fluoride in the United States.

TABLE V-4

PRODUCTION, FOREIGN TRADE, AND APPARENT CONSUMPTION
OF ALUMINUM FLUORIDE*
(THOUSANDS OF METRIC TONS)

| Year | Production | Imports | Exports | Apparent consumption |
|---|---|---|---|---|
| 1963 | 78.9 | NA | NA | NA |
| 1964 | 84.1 | NA | NA | NA |
| 1965 | 101.6 | NA | NA | NA |
| 1966 | 113.3 | NA | NA | NA |
| 1967 | 119.5 | NA | NA | NA |
| 1968 | 126.2 | NA | NA | NA |
| 1969 | 129.9 | NA | NA | NA |
| 1970 | 123.2 | NA | NA | NA |
| 1971 | 143.3 | NA | NA | NA |
| 1972 | 126.1 | NA | NA | NA |
| 1973 | 127.3 | NA | NA | NA |
| 1974 | 153.5 | NA | NA | NA |
| 1975 | 117.9 | NA | NA | NA |

*Source: U.S. Department of Commerce.

TABLE V-5

U.S. CONSUMPTION OF ALUMINUM FLUORIDE*
(THOUSANDS OF METRIC TONS)

| | Primary aluminum production | Aluminum fluoride consumption | | | Aluminum fluoride consumption (Kg) per ton of primary aluminum |
|---|---|---|---|---|---|
| | | Primary aluminum | Other[b] | Total[a] | |
| 1963 | 2,098 | 70 | 4 | 74 | 33 |
| 1965 | 2,499 | 97 | 4 | 101 | 39 |
| 1970 | 3,607 | 117 | 5 | 122 | 32 |
| 1972 | 3,739 | 118 | 6 | 124 | 32 |
| 1973 | 4,109 | 121 | 6 | 127 | 30 |
| 1974 | 4,448p | 128 | 6 | 134 | 29 |
| 1975 | 3,519p | 101 | 5 | 106 | 29 |

*Source: Contractor's estimates and Bureau of Mines, Minerals Industry surveys.

a. Based on total shipments less other uses.

b. Estimate.

As previously mentioned, aluminum fluoride is also used in the refining of secondary aluminum. The two accepted techniques for producing secondary aluminum are referred to as "wet fluxing" and "hot fluxing". Aluminum fluoride is used in both wet and hot fluxing techniques to remove magnesium from the molten scrap, the actual quantity depending on the magnesium content of the scrap. Aluminum fluoride is also used in brazing fluxes (for aluminum fabrication), fluxes for ceramic glazes and enamels, and for welding rod coatings.

c. Substitute Products. In addition to aluminum fluoride, cryolite is also used as the molten electrolyte in the electrolytic reduction of aluminum to aluminum metal. The two fluxes are to some degree interchangeable, depending upon operating practices and the sodium oxide content of the alumina used in the reduction plant. For start-up of a new pot line, considerably more cryolite is required (approximately 1,800 metric tons for a 59,000 metric ton pot line) than aluminum fluoride. During pot line operation, loss of fluorine values is greater than loss of sodium values. Consequently, during normal operation of a pot line, more aluminum fluoride than cryolite is used to maintain a constant composition of the melt. The effect of the industry's efforts to recover fluorine values from flue gases and pot linings will in general be more pronounced for cryolite than for aluminum fluoride.

d. Prices. In Table V-6, list versus actual prices (unit value) are shown for aluminum fluoride for the period 1963 through 1975. The "actual" prices are as calculated from Commerce Department data for total shipments and represent industry average plant prices. In 1972 plant prices returned very nearly to levels which prevailed during the early 1960's. Throughout the period illustrated, however, plant prices were considerably below list prices. Current merchant prices are $400 per metric ton, which are above current list prices.

TABLE V-6

ACTUAL VERSUS LIST PRICES FOR ALUMINUM FLUORIDE 1960-1975 *
(THOUSANDS OF METRIC TONS)

| | Shipments (1,000 metric tons) | Value ($MM) | Unit value ($/metric ton) | List price ($/metric ton) |
|---|---|---|---|---|
| 1960 | 60.4 | 17.9 | 296.4 | 358 |
| 1961 | 53.7 | 14.9 | 277.5 | 358 |
| 1962 | 65.5 | 19.2 | 293.1 | 358 |
| 1963 | 73.6 | 22.2 | 301.6 | 358 |
| 1964 | 85.0 | 25.3 | 297.6 | 358 |
| 1965 | 100.7 | 27.0 | 268.1 | 309 |
| 1966 | 113.9 | 29.7 | 260.8 | 298 |
| 1967 | 119.4 | 30.9 | 258.8 | 298 |
| 1968 | 125.5 | 26.8 | 213.5 | 298 |
| 1969 | 129.8 | 28.2 | 217.3 | 287 |
| 1970 | 122.2 | 27.0 | 220.9 | 287 |
| 1971 | 141.3 | 36.7 | 259.7 | 369 |
| 1972 | 123.9 | 36.1 | 291.4 | 386 |
| 1973 | 127.1 | 37.0 | 291.1 | 386 |
| 1974 | 156.0 | 45.7 | 292.9 | 386 |
| 1975 | 114.9 | 46.0 | 400.3 | 386 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A, and Chemical Marketing Reporter.

## B. Chrome Pigments

Total U.S. production in 1974 for the five chrome pigments (chrome green, chrome oxide green, chrome yellow and orange, molybdate chrome orange and zinc yellow) plus iron blue was an estimated 64,630 metric tons, more than half of which was represented by chrome yellow and orange. Imports have been increasing and in 1973 represented 17 percent of total U.S. output. Exports have declined since first reported in 1966 and are negligible. Apparent U.S. consumption in 1973 was 72,980 metric tons. The U.S. market for chrome pigments and iron blue has been expanding slowly with the largest growth shown in molybdate chrome orange, chrome yellow, and chrome oxide green.

The major uses for these inorganic pigments are in paint, printing ink, floor products and paper. Specialty applications are in ceramics, cement, and asphalt roofing. Captive requirements by the U.S. producers are minimal.

There are four major U.S. producers (with production of three or more of the individual products) and seven minor producers. In general, the producers are neither integrated back to raw materials (e.g., sodium bichromate) nor forward to end products.

Plant prices in 1974 varied between $900 and $1,700 per metric ton depending upon the specific product. The weighted average price in 1974 was an estimated $1,400 per metric ton.

1. Product Characteristics.

a. Market Size and Growth. U.S. production data for chrome pigments for the period 1960 through 1974 are shown in Table V-7. As indicated by these data, U.S. production has been increasing for chrome oxide green, chrome yellow and orange, and molybdate chrome orange. The most rapid growth, 6.1 percent per year on a compound basis, has been demonstrated by molybdate chrome orange followed by chrome yellow and orange at 4.2 percent per annum compounded and chrome oxide green with an average annual compound growth of 2.8 percent in the 15-year period. Production of iron blue has been essentially static at 4,000-5,000 metric tons per year. Production of chrome green and zinc yellow has shown a slight declining trend, although production figures for chrome green have been available since 1971.

b. Prices. In Table V-8, actual prices for the five chrome pigments plus iron blue as calculated using U.S. Department of Commerce data are compared with list prices taken from the Chemical Marketing Reporter. Actual prices remained slightly below list prices from 1960 to 1973. In 1974 a range of list prices is given due to the variation in price during the year.

Total 1974 shipments, including interplant transfers for the five reported chrome pigments, was 58,740 metric tons, as shown in Table V-9. (Chrome green has not been reported by the U.S. Department of Commerce since 1971.) The value of these shipments was $82.016 million. Thus, the average unit value in 1974 for the five products was $1,396 per metric ton. In 1973 the average unit value was $1,017 per metric ton. There was thus a 37 percent price increase in 1974.

TABLE V-7

U.S. PRODUCTION OF CHROME PIGMENTS, 1960-1975*
(THOUSANDS OF METRIC TONS)

| | Chrome green | Chrome oxide green | Chrome yellow | Molybdate chrome orange | Zinc yellow | Iron blues | Total |
|---|---|---|---|---|---|---|---|
| 1960 | 2.83 | 4.71 | 19.40 | 5.75 | 5.49 | 4.36 | 42.54 |
| 1961 | 2.93 | 4.78 | 20.62 | 6.34 | 5.17 | 4.25 | 44.09 |
| 1962 | 2.96 | 5.33 | 22.20 | 6.78 | 6.01 | 4.48 | 47.76 |
| 1963 | 2.61 | 4.74 | 22.47 | 7.66 | 6.23 | 4.57 | 48.28 |
| 1964 | 2.82 | 5.09 | 24.07 | 8.48 | 7.05 | 4.58 | 52.09 |
| 1965 | 2.78 | 5.81 | 26.55 | 8.58 | 7.22 | 4.97 | 55.91 |
| 1966 | 2.69 | 6.22 | 28.51 | 9.86 | 7.41 | 5.06 | 59.85 |
| 1967 | 2.49 | 4.71 | 27.86 | 9.40 | 7.09 | 5.24 | 56.79 |
| 1968 | 2.57 | 5.66 | 29.77 | 10.33 | 6.73 | 5.49 | 60.55 |
| 1969 | 2.38 | 5.32 | 29.05 | 10.32 | 6.62 | 5.30 | 58.99 |
| 1970 | 2.31 | 6.13 | 29.46 | 10.00 | 5.22 | 4.73 | 57.85 |
| 1971 | 2.46 | 5.97 | 26.35 | 10.33 | 5.06 | 4.89 | 55.06 |
| 1972 | NA | 5.59 | 30.66 | 11.27 | 5.14 | 4.71 | 57.37[a] |
| 1973 | NA | 6.50 | 33.70 | 12.76 | 4.82 | 4.58 | 62.36[a] |
| 1974 | NA | 6.97 | 34.44 | 13.24 | 5.23 | 4.75 | 64.63[a] |
| 1975 | NA | 5.09 | 23.51 | 8.67 | NA | 3.32 | 40.59[b] |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A.

a. Excludes chrome green.

b. Excludes chrome green and zinc yellow.

TABLE V-8

U.S. SHIPMENTS OF CHROME PIGMENTS, 1960-1975*
(THOUSANDS OF METRIC TONS)

| | Chrome green | Chrome oxide green | Chrome yellow & orange | Molybdate chrome orange | Zinc yellow | Iron blues | Total |
|---|---|---|---|---|---|---|---|
| 1960 | 2.93 | 4.49 | 18.73 | 5.53 | 5.04 | 4.12 | 40.84 |
| 1961 | 2.93 | 4.65 | 19.87 | 6.03 | 5.07 | 3.75 | 42.30 |
| 1962 | 2.92 | 5.49 | 21.61 | 6.76 | 5.71 | 4.00 | 46.49 |
| 1963 | 2.61 | 4.78 | 22.28 | 7.28 | 6.07 | 4.13 | 47.15 |
| 1964 | 2.71 | 4.97 | 23.94 | 8.10 | 6.91 | 4.51 | 51.14 |
| 1965 | 2.64 | 5.47 | 25.04 | 7.78 | 6.60 | 4.72 | 52.25 |
| 1966 | 2.63 | 6.11 | 28.21 | 9.53 | 7.55 | 4.76 | 58.79 |
| 1967 | 2.41 | 4.93 | 27.03 | 9.20 | 6.90 | 4.96 | 55.43 |
| 1968 | 2.50 | 5.67 | 29.07 | 9.97 | 6.84 | 5.11 | 59.16 |
| 1969 | 2.45 | 4.98 | 29.12 | 10.04 | 6.59 | 5.06 | 58.24 |
| 1970 | 2.29 | 5.51 | 28.79 | 10.34 | 5.34 | 4.96 | 57.23 |
| 1971 | 2.47 | 5.27 | 25.72 | 9.75 | 5.36 | 4.58 | 53.15 |
| 1972 | NA | 5.32 | 29.04 | 11.13 | 5.40 | 4.25 | 55.14[a] |
| 1973 | NA | 6.66 | 32.84 | 11.74 | 5.06 | 4.66 | 60.96[a] |
| 1974 | NA | 6.69 | 30.81 | 11.78 | 4.57 | 4.89 | 58.74[a] |
| 1975 | NA | 4.74 | 23.18 | 9.00 | NA | 3.44 | 40.36[b] |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A.

a. Excludes chrome green.

b. Excludes chrome green and zinc yellow.

TABLE V-9

LIST VERSUS ACTUAL PRICES FOR CHROME PIGMENTS 1960-1975*
(DOLLARS PER METRIC TON)

| | Chrome green | | Chrome oxide green | | Chrome yellow and orange | | Molybdate chrome orange | | Zinc yellow | | Iron blue | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | List | Actual | List | Actual | List | Actual | List | Actual | List | Actual | List | Actual |
| 1960 | 970 | 864 | 981 | 938 | 772 | 712 | 1080 | 1072 | NA | 598 | 1147 | 1079 |
| 1961 | 970 | 868 | 981 | 943 | 772 | 713 | 1080 | 1122 | NA | 600 | 1213 | 1145 |
| 1962 | 970 | 872 | 981 | 932 | 750 | 699 | 1080 | 1128 | NA | 580 | 1213 | 1166 |
| 1963 | 970 | 853 | 981 | 969 | 750 | 678 | 1058 | 1125 | NA | 533 | 1224 | 1182 |
| 1964 | 1014 | 926 | 1009 | 989 | 794 | 712 | 1103 | 992 | NA | 534 | 1224 | 1157 |
| 1965 | 1036 | 955 | 1009 | 981 | 838 | 747 | 1147 | 1067 | NA | 603 | 1224 | 1168 |
| 1966 | 1036 | 962 | 1009 | 1045 | 838 | 764 | 1147 | 1037 | NA | 590 | 1246 | 1224 |
| 1967 | 1080 | 999 | 1075 | 1052 | 838 | 760 | 1147 | 1037 | NA | 622 | 1246 | 1220 |
| 1968 | 1125 | 1047 | 1075 | 1054 | 882 | 776 | 1169 | 947 | NA | 676 | 1290 | 1233 |
| 1969 | 1125 | 1022 | 1091 | 1050 | 882 | 783 | 1202 | 1062 | NA | 722 | 1323 | 1207 |
| 1970 | 1191 | 948 | 1103 | 1052 | 937 | 830 | 1235 | 1100 | NA | 724 | 1356 | 1257 |
| 1971 | 1235 | 1064 | 1136 | 1079 | 970 | 860 | 1312 | 1150 | 816 | 772 | 1389 | 1366 |
| 1972 | 1235 | NA | 1136 | 1115 | 1036 | 842 | 1389 | 1236 | 860 | 845 | 1521 | 1442 |
| 1973 | 1411 | NA | 1323 | 1163 | 1103 | 831 | 1477 | 1288 | 915 | 970 | 1544 | 1484 |
| 1974 | 1455 | NA | 1323 | 1546 | 1147 | 1217 | 1654 | 1658 | 915 | 1298 | 1896 | 1792 |
| 1975 | 1962 | NA | 1323 | 1940 | 1510 | 1403 | 1654 | 1896 | 1675 | NA | 1896 | 1993 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A, and Chemical Marketing Reporter.

c. Foreign Trade. The data for the years 1963 through 1973 is shown in Table V-10. For the period covered, imports of chrome pigments have generally been increasing, with chrome yellow and orange and molybdate chrome orange representing the largest volume imports. Total imports have ranged from 16 percent to 17 percent of total production for the 11-year period. Japan has been a leading supplier of chrome yellow.

Exports of chrome pigments are negligible and have been declining since first reported in 1966, as shown in Table V-10.

d. Uses and Substitutes.

Chrome Green. The chrome greens find wide application in many kinds of paints such as house paints, sash and trim paints, enamels, both air-drying and baking, flat paints, and also in printing inks, lacquer, calcimines, oilcloth, paper, etc.

Chrome Oxide Green. Chromium oxide green comprises two different pigments. The principal product is the anhydrous oxide, $Cr_2O_3$, but a certain amount of hydrated chromic oxide, or Guinet's green, is also manufactured. Chrome oxide green's resistance to alkalies, acids and high temperatures, and its superlative fastness to light make it valuable for use as a colorant in Portland cement, ceramic-tile glazes, rubber, alkali-proof printing inks, limeproof paints, concrete and stucco paints, and bridge paints. It finds special use in coloring cement and in green granules for asphalt roofing. An interesting application is in camouflage paints, since the reflectance spectrum of chromic oxide resembles that of green foliage. Hydrated chromium oxide finds considerable use in automotive finishes.

TABLE V-10

IMPORTS AND EXPORTS OF CHROME PIGMENTS*

| | Imports | | Exports | |
|---|---|---|---|---|
| | Quantity (1,000 metric tons) | Value ($ MM) | Quantity (1,000 metric tons) | Value ($ MM) |
| 1963 | 0.79 | 0.4 | NA | NA |
| 1964 | 1.11 | 0.6 | NA | NA |
| 1965 | 1.33 | 0.7 | NA | NA |
| 1966 | 2.68 | NA | 0.79 | 0.482 |
| 1967 | 3.79 | NA | 0.71 | 0.392 |
| 1968 | 5.15[a] | NA | 0.14 | 0.153 |
| 1969 | 5.39[a] | 2.6 | 0.15 | 0.189 |
| 1970 | 7.44[a] | 3.9 | 0.16 | 0.227 |
| 1971 | 9.73[a] | 4.5 | 0.18 | 0.227 |
| 1972 | 10.58 | 6.3 | NA | NA |
| 1973 | 10.85[a] | 5.6 | 0.23 | 0.461 |
| 1974 | 6.55 | 8.2 | NA | NA |

*Source: U.S. Bureau of Mines - Minerals Yearbook.

a. Includes hydrated chromium oxide green.

Chrome Yellow and Orange. The chrome yellows are bright, clean colors with good hiding power and good resistance to fading in either mass colors or tints. They are soft, grind easily, and are not reactive with most paint vehicles. Their durability for exterior use is generally good, although they do darken on exposure and are susceptible to blackening in the presence of hydrogen sulfide. They have poor resistance to alkali and discolor when subjected to high temperature, as in baking. Their many good qualities and relatively low cost make them very useful pigments in many kinds of paints and lacquers, traffic line paints, printing inks, papers, linoleum, leather finishes, etc. They are also used in calcimines and water paints which are not alkaline. Large quantities of chrome yellows are used with iron blues in the manufacture of the chrome green pigments.

Chrome oranges are generally employed in the same manner as the chrome yellows. In addition, the darker shades are used in rust-inhibitive primers and paints for use on ferrous metals. A specific bright red-orange shade of basic lead chromate, known as International Airway Orange, is a standard color for airport markings.

Molybdate Chrome Orange. The molybdenum oranges are characterized by their strong and brilliant color, very high hiding power, and high tinting strength. Despite costing more than the chrome oranges, they are economical to use because of their high strength. They have poor resistance to alkali and, on exposure to light, darken more than do the basic chrome oranges. They are used in many kinds of paints, enamels, and lacquers, and are especially useful in mixtures with organic red toners to produce economical light-red colors of good brilliance. Use is made of them in floor coverings and printing inks.

Zinc Yellow. Due to its limited water solubility, zinc yellow is important as an inhibitive pigment for prime-coating metals. It is also used in decorative finishes but almost always in combination with other color pigments such as hydrated chromium oxide. In addition, it is employed to make zinc green pigment, a precipitated mixture with iron blue.

Iron Blues. The iron blues are very strong pigments which may appear almost black in the full color. They are used in all kinds of paints and enamels, such as sash and trim paints, automotive enamels, lacquers, and "metallic" finishes. They are also used extensively in inks and printing inks, carbon paper inks, crayons, linoleum, composition flooring, paper, laundry blues, etc. For use in making chrome greens, the green shades of the iron blues are preferred.

2. Production Characteristics.

a. Production Processes.

Chrome Green. To make chrome green, chrome yellow and iron blue are physically mixed prior to grinding or coprecipitated from solution and then dried, ground, and packaged.

Chrome Oxide Green. The currently favored method of preparing chromic oxide is by the calcining of sodium dichromate with sulfur or carbon in a reverbatory furnace.

$$Na_2Cr_2O_7 + S = Cr_2O_3\downarrow + Na_2SO_4$$

$$Na_2Cr_2O_7 + C = Cr_2O_3\downarrow + Na_2CO_3 + CO\downarrow$$

Sodium sulfate from the first reaction above or soda ash from the second is removed by washing, and the chromic oxide is filtered, dried and packaged. Chromic oxide for pigments is made with sulfur; that for aluminothermic chromium is made with charcoal or some other low-sulfur carbonaceous material.

Guignet's green (hydrated chromic oxide) results from the firing of a mixture of potassium dichromate and boric acid at about 550 C. The product is leached, filtered, washed, and dried. The pigment product is about 81 percent chromic oxide, 17 percent water, and about 2 percent boric acid (formerly considered necessary but now regarded as an impurity).

Chrome Yellow and Orange. Chrome yellow pigment is basically a mixture of lead chromate, lead sulfate, and zinc sulfate, whereas chrome orange pigment contains basic lead chromate and lead sulfate. The primary ingredient of chrome yellow pigment is lead chromate, which is produced by the reaction of sodium chromate or dichromate with lead nitrate or acetate. The lead nitrate is often obtained in-plant by reacting lead oxide (litharge) or pig lead with nitric acid. If zinc sulfate is to be in the pigment mixture, it is prepared by reacting zinc oxide with sulfuric acid. If lead sulfate is to be in the pigment mixture, it is formed by the addition of sodium sulfate to the reaction vessel in which lead chromate is formed. The precipitated and mixed pigment material is subsequently filtered out, treated for development of the specific pigment properties desired, and packaged.

The basic lead chromate (chrome orange), which may be described as a coprecipitate of lead hydroxide and lead chromate, is produced by the addition of lead hydroxide to the reaction vessel in which lead chromate is formed.

Molybdate Chrome Orange. The pigment known as molybdate chrome orange (or molybdenum orange) is a mixed crystal of lead sulfate, lead chromate, and lead molybdate. In the production process a mixture of sodium chromate and sodium molybdate is added to a solution of lead nitrate or acetate to produce the precipitate.

Zinc Yellow. Zinc yellow pigment is a complex mixture whose composition includes zinc, potassium, and chromium. Of the two types of zinc yellow, the low chloride-sulfate type is prepared by first reacting zinc oxide with potassium hydroxide, then adding the chromate as a solution of potassium tetrachromate. High chloride zinc yellow is made by reacting zinc oxide with hydrochloric acid and sodium dichromate to produce a zinc yellow slurry. The solids are removed by filtration, dried, milled, and packaged for sale.

Iron Blues. Iron blues include Prussian blue, Chinese blue, bronze blue, etc. The generalized production process, which varies somewhat from plant-to-plant, involves the precipitation of ferrous sulfate-ammonium sulfate solutions with sodium ferrocyanide to produce ferrous ferrocyanide, followed by oxidation of this product to ferric ferrocyanide by sodium chlorate. The precipitated pigment is filtered, washed, dried, surface-treated to enhance pigment properties, and packed.

b. Process Hazardous Waste. Treatment of wastewaters from the production of chrome yellows and oranges and molybdate chrome orange generates a hazardous waste containing lead salts and chromium hydroxide. The amounts and types of reactants and wastes will differ depending on the color produced.

Treatment of the waterborne wastes from the production of zinc yellow generates insoluble zinc salts, chromium hydroxide, and unrecovered zinc yellow, all of which require careful disposal.

The wash waters from chrome oxide green production require treatment which generates sludges of chromium compounds requiring careful disposal.

The waterborne wastes from iron blue production contain a considerable amount of suspended product which is settled out prior to discharge. This material is then recovered as a hazardous waste which should have special handling due to its cyanide content. Chrome green is produced by mixing a slurry of chrome yellow and iron blue and thus the waste problems are similar to those of the two constituent pigments.

## C. Nickel Sulfate

### 1. Product Characteristics.

a. Market Size and Growth. Department of Commerce data for nickel sulfate production for the period 1960 through 1974 are shown in Table V-11. Production volume increased at an average compound rate of 7.4 percent per annum for the period 1960 through 1970. According to these data, production has decreased 11 percent per year on an average compounded basis from 1970 to 1974. The Commerce Department, without disclosing the company name, explained that a nickel sulfate plant representing significant capacity ceased production in early 1974. Domestic production of nickel sulfate in 1974 was 9,100 metric tons.

b. Prices. In Table V-12 list prices versus actual prices for nickel sulfate are shown for the years 1960 through 1974. The "actual" prices are calculated from Commerce Department data for total shipments and represent industry average plant prices. "Actual" prices have been increasing since 1960 at an annual average of 5 percent. List prices peaked in 1970 when nickel sulfate was in short supply, dropped, and rose in 1973 to the 1970 level. The year 1974 was unusual and thus a range of prices is given. List prices are greater than "actual" prices by about 25 percent.

c. Foreign Trade. Foreign trade of nickel sulfate has never been reported and is estimated to be very small.

TABLE V-11

U.S. PRODUCTION OF NICKEL SULFATE *
(THOUSANDS OF METRIC TONS)

| Year | Amount |
|---|---|
| 1960 | 9.5 |
| 1961 | 9.6 |
| 1962 | 9.7 |
| 1963 | 9.3 |
| 1964 | 10.8 |
| 1965 | 14.2 |
| 1966 | 16.0 |
| 1967 | 13.4 |
| 1968 | 17.8 |
| 1969 | 18.5 |
| 1970 | 19.0 |
| 1971 | 15.3 |
| 1972 | 9.4 |
| 1973 | 9.9 |
| 1974 | 9.1 |
| 1975 | NA |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A.

TABLE V-12

ACTUAL VERSUS LIST PRICES FOR NICKEL SULFATE 1960- 1975*

| | Shipment quantity (1,000 metric ton) | Value ($MM) | Unit value ($/metric ton) | List price ($/metric ton) |
|---|---|---|---|---|
| 1960 | 7.5 | 3.9 | 520 | 617 |
| 1961 | 9.0 | 4.8 | 533 | 617 |
| 1962 | 7.3 | 4.0 | 548 | 662 |
| 1963 | 7.8 | 4.3 | 551 | 662 |
| 1964 | 9.4 | 5.0 | 532 | 662 |
| 1965 | 11.3 | 5.2 | 460 | 662 |
| 1966 | 14.9 | 6.9 | 463 | 662 |
| 1967 | 13.6 | 7.2 | 529 | 706 |
| 1968 | 17.7 | 9.9 | 559 | 750 |
| 1969 | 17.3 | 11.4 | 659 | 827 |
| 1970 | 16.6 | 12.0 | 723 | 1114 |
| 1971 | 14.0 | 10.5 | 750 | 992 |
| 1972 | 8.5 | 6.9 | 821 | 1014 |
| 1973 | 9.4 | 9.0 | 957 | 1114 |
| 1974 | 8.4 | 9.0 | 1071 | 1180-1433 |
| 1975 | 5.8 | 7.8 | 1345 | 1566 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A, and Chemical Marketing Reporter.

d. Uses and Substitutes. It is estimated that 90 percent of total consumption is represented by metal plating and the remainder as a hydrogenation catalyst. Consumption of nickel sulfate by the plating industry has plateaued and is now expected to decline. As a result of disposal restrictions and the high price of nickel salts, the plating industry is beginning to recycle nickel sulfate. The extent of the expected decline in consumption is not yet clear. Some producers believe that after platers install closed loop systems to avoid wastewater disposal, the total demand for nickel sulfate will be reduced by 50 percent. Other producers believe that the impact on demand will not be so dramatic. Some platers may find it economically feasible to sell the spent solution and purchase "fresh" nickel sulfate. Processors may then recover nickel from the solution according to market demand. In this event, demand for nickel sulfate might not be drastically reduced. In any event, sales are expected to decline within the next five to ten year period, although the degree of the decline and its impact on the industry are not yet clear.

Nickel sulfate has no chemical substitutes in the plating industry. However, auto manufacturers have been replacing metal plated parts by stainless steel and plastic parts.

2. Production Characteristics.

a. Production Processes. Nickel sulfate is produced from two types of raw materials: (1) pure nickel or nickel oxide; or (2) impure nickel.

In the first case, the metal or oxide is digested in sulfuric acid and the solution is then filtered and either packaged for sale or further processed to recover a solid material, the hexahydrate. The sludges recovered by filtration can be sent to the second process to produce more nickel sulfate.

b. Concentration and Location of Markets. Approximately 90 percent of nickel sulfate production goes into metal plating. The metal plating industry is diversified, with a large number of small establishments. A large part of the metal plating industry is found in the Northeast and North Central regions.

c. Process Hazardous Wastes. The manufacture of nickel sulfates generates relatively small amounts of nickel-containing hazardous wastes for land disposal. They result from the treatment of wastewaters by raising the pH to precipitate metallic salts.

d. Capacity and Capacity Utilization. Capacity data are not publicly available. There is currently a balance between supply and demand and the industry is producing at capacity. Capacity expansions are not anticipated since overall demand is expected to decline as metal platers recycle the nickel sulfate to comply with water pollution regulations that require the reduction of nickel salts in waste water effluent.

3. Industry Structure.

a. Number of Firms and Degree of Concentration/Integration. The four most important nickel sulfate producers and their plant locations are shown in Table V-13. It is estimated that Harshaw Chemical Company is the largest manufacturer with close to 50 percent of total capacity. Chemetron may be the second largest manufacturer, followed by CP Chemicals and M&T Chemicals, Inc. The first three produce both liquid and dry product, while M&T Chemicals manufacturers liquid and resells dry material. In addition to these companies, Federated Metal/ASARCO produces crystal nickel sulfate from copper refining and a number of other companies produce small volumes at different times. Nickel sulfate is produced in diversified plants where the operation is a relatively small part of the total.

TABLE V-13

NICKEL SULFATE PRODUCERS*
(1975)

| Company | Location |
|---|---|
| Harshaw Chemical Co. | Cleveland, Ohio |
| Chemetron Corporation | Cleveland, Ohio |
| C.P. Chemicals | Sewaren, New Jersey |
| M&T Chemicals, Inc. | Matawan, New Jersey |

*Source: Contractor's estimates.

In the second case, the raw materials are also digested in sulfuric acid. However, the resulting solutions have to be treated in series with oxidizers, lime and sulfides to precipitate impurities. These solutions are filtered and marketed as such or further processed to recover a solid product. The recovered sludges from filtration are treated as hazardous waste.

To recover solid product, the nickel sulfate solutions are first concentrated, then filtered and fed to a crystallizer. The resultant suspensions are fed to a clarifier where solid product is recovered. This material is then dried, cooled, screened and packaged for sale. The recovered solids from the filtration step and other liquor from the classifiers are recycled to an earlier part of the process.

b. Production Costs. The manufacturing cost of nickel sulfate is heavily dependent on the price of nickel metal. For example, in 1972 when the producer's price for nickel was $1.33 per pound, the list price for nickel sulfate was $0.46 per pound. In 1974, the producer's price for nickel was $1.85 per pound and the list price for nickel sulfate was $0.65 per pound. That is, a 39 percent increase in the price of nickel resulted in a 41 percent increase in the list price of nickel sulfate.

Although detailed manufacturing costs for nickel sulfate are not shown, industry sources estimated that the replacement cost for a 5,000 ton-per-day plant in 1972 was $2.5 to $3.0 million. On the basis of the industry average 1972 plate price of $744 per ton, after-tax profits were estimated at $37.20 per ton.

## D. Phosphorus Pentasulfide

### 1. Industry Structure

a. Producers. Currently there are only three producers with a capacity of 79,900 metric tons, as shown in Table V-14. These capacities may be somewhat overstated in that they include debottlenecking and expansion plans which will not be completed until 1976 or 1977. Monsanto is the largest producer with 48 percent of total capacity. Stauffer is the second largest producer with 27 percent of total capacity, and Hooker has the remaining 25 percent of industry capacity. Monsanto and Stauffer both have important captive requirements while Hooker is primarily a merchant supplier of phosphorus pentasulfide.

b. Captive Requirements. Commercial shipments of phosphorus pentasulfide are not reported by the Department of Commerce; however, captive use is estimated to be only 25 percent of total production. Both Monsanto and Stauffer, the major producers of phosphorus pentasulfide, are forward integrated into the production of organophosphorus pesticides. There is little captive use of phosphorus pentasulfide for the production of lube oil additives, the major end-use market.

### 2. Supply Characteristics

a. Manufacturing Routes. The phosphorus sulfides are manufactured commercially by direct union of elemental phosphorus and sulfur. Usually molten white phosphorus is run into molten sulfur in a reaction vessel. The sulfur is stirred continuously and the rate of addition of the phosphorus is controlled to maintain reaction temperature. Phosphorus pentasulfide is purified by washing it with carbon disulfide, which removes small percentages of the sesquisulfide and free sulfur.

TABLE V-14

PHOSPHORUS PENTASULFIDE PRODUCERS - 1975*

| Producer | Location | Annual capacity (metric tons) |
|---|---|---|
| Hooker Chemical | Columbus, Mississippi | 6,400 |
| Hooker Chemical | Niagara Falls, New York | 13,600 |
| Monsanto | Anniston, Alabama | 10,900 |
| Monsanto | Sauget, Illinois | 27,200 |
| Stauffer | Morrisville, Pennsylvania | 8,200 |
| Stauffer | Mt. Pleasant, Tennessee | 9,100 |
| Stauffer | Nashville, Tennessee | 4,500 |
| Total | | 79,900 |

* Source: Chemical Marketing Reporter.

Direct production of organophosphorus insecticides is under evaluation without going through the intermediate, phosphorus pentasulfide. If an alternative manufacturing route is employed, it would have a major impact on the demand for phosphorus pentasulfide.

b. Supply/Demand Balance. As shown in Table V-15, industry capacity has historically kept ahead of demand. As a result, operating levels in the industry reflect the overcapacity which has occurred. In 1973, operating levels increased as production increased significantly and resulted in shortages of phosphorus pentasulfide. Because of raw material shortages rather than reduced demand, the industry operating level declined in 1974. The industry is currently undergoing additional expansion of capacity in order to meet the increased forecasted demand over the next several years.

3. Demand Characteristics.

a. Market Size. U.S. production of phosphorus pentasulfide has grown from 31,050 metric tons in 1960 to 61,460 metric tons in 1974. Production declined 14 percent in 1975 to 53,200 metric tons versus 49,600 metric tons in 1974. Data for imports and exports are not reported separately; however, imports are believed to be negligible and exports were an estimated 2,000-4,000 metric tons in 1974 (see Table V-16).

b. Growth. U.S. production of phosphorus pentasulfide increased at an average annual rate of 5.0 percent between 1960 and 1974; however, in recent years production has grown more rapidly with a 5.6 percent annual average growth from 1970 to 1974. The higher growth reflects the increased demand for organophosphorus pesticides and the increased use of phosphorus-based lube oil additives. Future growth should be at least at historical levels because of expected continued growth in the major end-use sectors. The availability of elemental phosphorus should not have a limiting impact on production growth.

TABLE V-15

INDUSTRY OPERATING CAPACITY - PHOSPHORUS PENTASULFIDE*
(THOUSANDS OF METRIC TONS)

| Year | Capacity | Production | % capacity |
|---|---|---|---|
| 1965 | 54 | 44.8 | 83 |
| 1966 | - | 48.8 | - |
| 1967 | - | 44.2 | - |
| 1968 | - | 43.0 | - |
| 1969 | 63 | 56.0 | 89 |
| 1970 | - | 49.5 | - |
| 1971 | - | 53.4 | - |
| 1972 | 69 | 55.6 | 81 |
| 1973 | - | 68.9 | - |
| 1974 | - | 61.5 | - |
| 1975 | 80 | 55.7 | 70 |

* Source: Chemical Marketing Reporter, Contractor's estimate.

TABLE V-16

U.S. PRODUCTION OF PHOSPHORUS PENTASULFIDE, 1960-1975*
(THOUSANDS OF METRIC TONS)

| Year | Production | Exports | Apparent consumption |
|---|---|---|---|
| 1960 | 31.05 | NA | NA |
| 1961 | 32.05 | NA | NA |
| 1962 | 30.87 | NA | NA |
| 1963 | 30.87 | NA | NA |
| 1964 | 37.76 | NA | NA |
| 1965 | 44.75 | NA | NA |
| 1966 | 48.84 | NA | NA |
| 1967 | 44.21 | NA | NA |
| 1968 | 43.03 | NA | NA |
| 1969 | 56.01 | NA | NA |
| 1970 | 49.48 | NA | NA |
| 1971 | 53.38 | NA | NA |
| 1972 | 55.56 | NA | NA |
| 1973 | 68.90 | NA | NA |
| 1974 | 61.46 | 2 | 59 |
| 1975 | 55.70 | NA | NA |

* Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A.

c. Uses. The largest and potentially fastest growing end-use area is as a precursor for lube oil additives, principally zinc dithiophosphate. The trend to fewer lube oil changes, and hotter operating engines for pollution control will result in increased demand for phosphorus-based additives which are antiwear and corrosion inhibitors. Industry forecasts range between 5 and 15 percent per year growth through 1980 for this end-use sector. Oil additives accounted for an estimated 50 percent of consumption of phosphorus pentasulfide in 1975, as shown in Table V-17.

The other major end-use area is for organophosphorus insecticides, including the parathions and malathion, which accounted for an estimated 40 percent of phosphorus pentasulfide consumption in 1975. This end-use sector has grown rapidly in recent years as organophosphorus insecticides have been a replacement for DDT and because of increased crop acreage. Future growth will be more limited, and demand will more closely follow crop trends and severity of pest control problems. The remaining 10 percent of consumption includes flotation agents, exports and miscellaneous uses.

d. Prices. Prices historically have been depressed for phosphorus pentasulfide. As shown in Table V-18, actual prices declined from $261 per metric ton in 1961 to $224 per metric ton in 1969. In the past several years prices have increased significantly due to increasing raw material costs as well as increased demand and tight supply for phosphorus pentasulfide. List prices were historically above actual prices, and to some extent, reflect the lower transfer price of the captive producer. Also, since competition in the industry is generally based on price, the historical overcapacity in the industry has resulted in depressed prices.

TABLE V-17

PHOSPHORUS PENTASULFIDE CONSUMPTION BY END USE - 1974*

| End use | % of total |
|---|---|
| Oil additives | 50 |
| Organophosphorus pesticides | 40 |
| Flotation agents | 6 |
| Exports | 3 |
| Miscellaneous | 1 |
| | 100 |

* Source: Chemical Marketing Reporter, Contractor's estimates.

TABLE V-18

ACTUAL VERSUS LIST PRICES FOR PHOSPHORUS PENTASULFIDE 1960-1975*

| | Shipments (1,000 metric tons) | Value ($MM) | Unit value ($/metric ton) | List price[a] ($/metric ton) |
|---|---|---|---|---|
| 1960 | NA | NA | NA | 254 |
| 1961 | 29.5 | 7.7 | 261 | 254 |
| 1962 | 28.5 | 7.5 | 263 | 303 |
| 1963 | 27.3 | 7.1 | 260 | 303 |
| 1964 | 34.2 | 8.3 | 243 | 303 |
| 1965 | 36.5 | 8.2 | 225 | 254 |
| 1966 | 38.9 | 8.9 | 229 | 259 |
| 1967 | 25.5 | 6.1 | 239 | 303 |
| 1968 | 30.2 | 7.3 | 242 | 314 |
| 1969 | 42.9 | 9.6 | 224 | 322 |
| 1970 | 40.3 | 9.5 | 236 | 322 |
| 1971 | 45.5 | 10.3 | 226 | 322 |
| 1972 | 44.9 | 10.9 | 243 | 322 |
| 1973 | 59.5 | 12.8 | 215 | 313 |
| 1974 | 49.3 | 18.0 | 365 | 313 - 661 |
| 1975 | 42.8 | 28.6 | 668 | 661 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A, and Chemical Marketing Reporter.

a. Powder, drums, carlot, works.

e. Foreign Competition. Foreign competition in phosphorus pentasulfide has historically been insignificant and is likely to remain so for the next several years.

f. Substitute Products. There are no substitutes for phosphorus pentasulfide as intermediates in the production of pesticides or lube oil additives. There are secondary levels of competition particularly with organophosphorus insecticides which compete with a number of alternative pesticide products. Also, phosphorus pentasulfide-based lube oil additives compete with alternative additives to a limited degree.

## E. Phosphorus Trichloride

### 1. Industry Structure.

a. Producers. Currently there are only five producers of phosphorus trichloride (see Table V-19) with a total capacity of 88,000 metric tons. Monsanto and Stauffer have 57 percent of total capacity, with the remaining three producers sharing 43 percent of the total capacity. Several producers are expanding or planning to expand capacity in the next several years.

b. Captive Requirements. Captive consumption of phosphorus trichloride is believed to be significant, although commercial shipments are not reported by the Department of Commerce. The four producers of phosphorus oxychloride are also producers of phosphorus trichloride, which implies that at least 43 percent of production is used captively. Captive consumption is likely to be greater than 50 percent since the producers of phosphorus trichloride are also producers of pesticides, phosphite esters, and other important end-use markets.

### 2. Supply Characteristics.

a. Manufacturing Routes. Phosphorus trichloride is produced by the reaction of phosphorus and chlorine. The raw materials are combined with phosphorus trichloride which moderates the heat of reaction. Liquid phosphorus and chlorine gas are continuously fed to a reaction vessel, and phosphorus trichloride is refluxed to remove the heat of reaction. The phosphorus trichloride is distilled and treated with additional chlorine to remove traces of unreacted phosphorus. The product is further distilled to remove organic chloride compounds and phosphorus oxychloride.

b. Supply/Demand Balance. As shown in Table V-20, in 1966 and 1968 the industry operated at a high level of capacity utilization. The reported capacities may be understated since phosphorus oxychloride is often produced

TABLE V-19

PHOSPHORUS TRICHLORIDE CAPACITIES - 1975*

| Producer | Location | Annual capacity (metric tons) |
|---|---|---|
| FMC | Nitro, West Virginia | 18,100 |
| Hooker | Niagara Falls, New York | 9,100 |
| Mobil | Charleston, South Carolina | 10,900 |
| Monsanto | Sauget, Illinois | 27,200 |
| Stauffer | Cold Creek, Alabama | 10,900 |
| Stauffer | Morrisville, Pennsylvania | 11,800 |
| Total | | 88,000 |

* Source: Chemical Marketing Reporter.

TABLE V-20

INDUSTRY OPERATING RATE - PHOSPHORUS TRICHLORIDE*
(THOUSANDS OF METRIC TONS)

| Year | Capacity | Production | % capacity |
|---|---|---|---|
| 1964 | - | 27.2 | - |
| 1965 | - | 34.8 | - |
| 1966 | 36 | 40.0 | 111 |
| 1967 | - | 46.4 | - |
| 1968 | 48 | 49.4 | 103 |
| 1969 | 48 | 52.0 | 108 |
| 1970 | - | 46.8 | - |
| 1971 | - | 50.1 | - |
| 1972 | 76 | 57.7 | 76 |
| 1973 | - | 72.8 | - |
| 1974 | 88 | 67.7 | 77 |
| 1975 | 88 | 74.6 | 85 |

* Source: U.S. Department of Commerce, Chemical Marketing Reporter.

in the same plant. If $PCl_3$ capacity used to produce $POCl_2$ is not reported, it would explain the estimated operating levels greater than 100 percent. A high level of capacity utilization was also achieved in 1973 because of significantly increased production. In 1974, the operating rate declined, but this was more likely due to raw material shortages as opposed to reduced demand. The higher prices which producers received reflect the continued market demand in the face of a lower operating level for the industry.

3. Demand Characteristics.

a. Market Size. Large-scale U.S. production of phosphorus trichloride began after World War II principally for use as plasticizers. Since 1951, production has grown from 10,900 metric tons to over 74,000 metric tons in 1975 (Table V-21). Since imports and exports are negligible, apparent consumption, including inventory changes, is taken equal to production.

b. Growth. U.S. production of phosphorus trichloride increased at an average annual rate of 7.4 percent between 1960 and 1975. However, since 1970 growth has averaged 9.8 percent per year. The future growth for phosphorus trichloride will be affected by the regulatory status of leaded gasolines which utilize phosphorus-based additives. This potential impact on demand will be offset by increased growth for flame retardants, pesticides, and other markets, and as a result, future growth should be moderate.

TABLE V-21

U.S. PRODUCTION OF PHOSPHORUS TRICHLORIDE, 1960-1975*
(THOUSANDS OF METRIC TONS)

| Year | Volume |
|---|---|
| 1960 | 20.88 |
| 1961 | 21.51 |
| 1962 | 22.97 |
| 1963 | 24.33 |
| 1964 | 27.23 |
| 1965 | 34.77 |
| 1966 | 40.03 |
| 1967 | 46.39 |
| 1968 | 49.40 |
| 1969 | 52.02 |
| 1970 | 46.75 |
| 1971 | 50.11 |
| 1972 | 57.74 |
| 1973 | 72.81 |
| 1974 | 67.72 |
| 1975 | 74.56 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A.

c. Uses. The largest end-use area for phosphorus trichloride was as an intermediate for the production of phosphorus oxychloride. This area accounted for an estimated 43 percent of domestic consumption in 1975, as shown in Table V-22. Phosphorus oxychloride is an intermediate for phosphate esters, which are used as gasoline additives, plasticizers and fire retardants. Use of phosphorus trichloride as a pesticide intermediate has been growing in recent years, and the end-use area has become the second largest market with an estimated 27 percent of domestic consumption.

Other end uses include phosphate esters, surfactants and stabilizers, and miscellaneous uses which account for the remaining 20 percent of consumption.

d. Prices. Prices for phosphorus trichloride declined from $275 per metric ton in 1960 to $188 per metric ton in 1970. Actual prices in the 1960's were close to list prices and reflected the high capacity utilization. In the early 1970's, actual prices were depressed, and the spread between list and actual prices widened reflecting reduced demand and overcapacity. In 1974, list prices more than doubled and actual prices increased more than 70 percent. The higher prices reflected higher raw material costs for phosphorus and chlorine as well as increased demand for phosphorus trichloride.

Actual versus list prices for phosphorus trichloride are shown in Table V-23.

e. Foreign Competition. Foreign competition in phosphorus trichloride has historically been insignificant and is likely to remain so at least for the next several years.

f. Substitute Products. There are limited substitutes for phosphorus trichloride because of its principal use as a chemical intermediate. There are secondary levels of competition such as other plasticizers, flame retardants, and pesticide products but direct competition is minimal. Also, alternative

TABLE V-22

CONSUMPTION OF PHOSPHORUS TRICHLORIDE BY END-USE*

| End use | % of 1975 total |
|---|---|
| Phosphorus oxychloride intermediate | 43 |
| Pesticide intermediates | 27 |
| Phosphite esters | 15 |
| Surfactants and stabilizers | 5 |
| Miscellaneous | 10 |
| Total | 100 |

* Source: Chemical Marketing Reporter

TABLE V-23

ACTUAL VERSUS LIST PRICES FOR PHOSPHORUS TRICHLORIDE 1960-1975*

| | Shipments (1,000 metric tons) | Value ($MM) | Unit value ($/M ton) | List price[a] ($/metric ton) |
|---|---|---|---|---|
| 1960 | 8.0 | 2.2 | 275 | 276 |
| 1961 | 7.4 | 2.0 | 270 | 276 |
| 1962 | 9.1 | 2.2 | 242 | 276 |
| 1963 | 8.7 | 2.1 | 241 | 276 |
| 1964 | 9.3 | 2.2 | 237 | 221 |
| 1965 | 11.7 | 2.5 | 214 | 221 |
| 1966 | 15.8 | 3.3 | 209 | 221 |
| 1967 | 15.3 | 3.4 | 222 | 232 |
| 1968 | 17.5 | 3.8 | 217 | 243 |
| 1969 | 19.1 | 4.3 | 225 | 243 |
| 1970 | 18.6 | 3.5 | 188 | 243 |
| 1971 | 22.6 | 4.6 | 204 | 292 |
| 1972 | 29.6 | 6.1 | 206 | 292 |
| 1973 | 36.7 | 8.1 | 221 | 292 |
| 1974 | 40.4 | 15.3 | 379 | 292 - 772 |
| 1975 | 38.9 | 23.1 | 594 | 816 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A, and Chemical Marketing Reporter.

a. Drums, carlot, works.

processes for producing phosphorus trichloride end products are under evaluation. If such processes were utilized on a large scale, they could have a major impact on phosphorus trichloride demand.

## F. Sodium Silicofluoride

### 1. Product Characteristics.

a. Market Size and Growth. U.S. production of sodium silicofluoride has increased 3.5 percent per annum during the 15-year period from 1960 to 1974. Production, as shown in Table V-24, reached a high of 54,800 metric tons in 1971 and has declined 5 percent per annum in the three years since then. Imports were not reported separately in 1974 and have been declining since 1969. Imported sodium silicofluoride appears to have little impact on the overall U.S. market except to make up shortages when U.S. production is low. Exports have never been reported. There appear to be three U.S. producers at three plants.

b. Prices. Price data, as shown in Table V-25, show a gradual decrease of 1.1 percent per annum from 1960 to 1974 for "actual" prices. "Actual" prices are calculated from Department of Commerce data for total shipments and represent industry average plant prices. However, 1972-4 prices show a decline from prices in the 1965-71 period. List prices were taken directly from the weekly data compiled by the Chemical Marketing Reporter and represent open market prices. List prices are substantially higher than plant unit values.

c. Uses and Substitutes. Water fluoridation and the production of synthetic cryolite are the two largest single uses for sodium silicofluoride. Other market areas provide a substantially smaller annual demand for this material. (Table V-26.)

TABLE V-24

U.S. PRODUCTION AND TRADE OF SODIUM SILICOFLUORIDE 1960-1975*
(THOUSANDS OF METRIC TONS)

| | Production | Imports | Exports |
|---|---|---|---|
| 1960 | 28.8 | 2.5 | NA |
| 1961 | 30.5 | 2.8 | NA |
| 1962 | 35.0 | 3.1 | NA |
| 1963 | 36.4 | 1.8 | NA |
| 1964 | 36.0 | 3.3 | NA |
| 1965 | 42.2 | 4.3 | NA |
| 1966 | 43.6 | 3.5 | NA |
| 1967 | 47.5 | 7.1 | NA |
| 1968 | 42.0 | 11.0 | NA |
| 1969 | 44.5 | 16.0 | NA |
| 1970 | 53.4 | 6.6 | NA |
| 1971 | 54.8 | 5.6 | NA |
| 1972 | 52.1 | 6.0 | NA |
| 1973 | 49.0 | 4.3 | NA |
| 1974 | 46.8 | NA | NA |
| 1975 | 44.2 | NA | NA |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A. U.S. Department of Commerce, FT 110, 246, 410.

TABLE V-25

ACTUAL VERSUS LIST PRICES OF SODIUM SILICOFLUORIDE 1960-1975*

| | Shipments (1,000 metric tons) | Value ($ MM) | Unit value ($/metric ton) | List price ($/metric ton) |
|---|---|---|---|---|
| 1960 | 26.0 | 3.0 | 115 | 143 |
| 1961 | 29.0 | 3.2 | 110 | 143 |
| 1962 | 30.8 | 3.5 | 114 | 165 |
| 1963 | 32.0 | 4.0 | 125 | 154 |
| 1964 | 34.2 | 4.6 | 135 | 165 |
| 1965 | 37.2 | 5.4 | 145 | 165 |
| 1966 | 41.4 | 6.1 | 147 | 165 |
| 1967 | 44.3 | 6.8 | 154 | 176 |
| 1968 | 40.8 | 6.2 | 152 | 176 |
| 1969 | 42.7 | 6.3 | 148 | 176 |
| 1970 | 50.9 | 7.4 | 145 | 176 |
| 1971 | 52.1 | 7.9 | 152 | 198 |
| 1972 | 49.2 | 6.3 | 128 | 198 |
| 1973 | 50.5 | 6.2 | 123 | 198 |
| 1974 | 45.4 | 6.1 | 134 | 198 |
| 1975 | 42.2 | 5.9 | 140 | 198 |

*Source: U.S. Department of Commerce, Current Industrial Reports, Series M28A, and Chemical Marketing Reporter.

TABLE V-26

SODIUM SILICOFLUORIDE END USE*

| | 1966 (%) | 1972 (%) |
|---|---|---|
| Water fluoridation | 24 | 27 |
| Synthetic cryolite | NA | 47 |
| Glass | 5 | 4 |
| Metallurgy of beryllium | 4 | 4 |
| Vitreous enamel frits | 3 | 2 |
| Other: | NA | 16 |
| preservative | | |
| glue | | |
| laundry sour | | |
| insecticide | | |
| latex | | |
| intermediate chemical (production of sodium fluoride) | | |

*Source: Contractor's estimates.

Although the number of public water systems fluoridating supplies is continually increasing, sodium silicofluoride is enjoying less popularity in this application. Difficulty in handling, poor applicator reliability and lifetime, and often poor relative economics have prompted the use of substitute fluoride compounds, especially in the largest and the smallest water systems. Fluoridation equipment manufacturers have confirmed such a trend toward more easily metered liquids (fluosilicic acid) and solids with a more constant solubility (sodium fluoride, which has essentially a uniform 4 percent solubility and can therefore be metered on a volumetric basis rather than on a dry weight basis).

In primary aluminum production, cryolite ($Na_3AlF_6$) is used with aluminum fluoride as a molten electrolyte in the electrolytic reduction of alumina to aluminum metal. A large proportion of cryolite is now synthetic due to an acute shortage of the natural material. Kaiser Aluminum and Chemical Corporation is the only producer of synthetic cryolite using sodium silicofluoride as a starting material. The silicofluoride is manufactured from fluosilicic acid at Kaiser's plant in Mulberry, Florida, and shipped to Kaiser's plant in Chalmette, Louisiana, for processing to cryolite. Other synthetic cryolite routes do not involve the manufacture of sodium silicofluoride. Kaiser's current cryolite capacity is 30,000 tons per year, which requires a minimum silicofluoride input of 26,800 tons per year.

This demand for cryolite, and therefore for sodium silicofluoride, is intimately tied in with primary aluminum production. The industry-wide operating factor for aluminum dropped from 95 percent of capacity in 1970 to 85 percent in 1971. Although this is expected to increase throughout the decade, no great increase in sodium silicofluoride usage is anticipated.

Other minor uses for sodium silicofluoride include:

1. leather and wood preservatives;
2. glue;
3. opacification of vitreous enamel frits;
4. opalescent glass;
5. laundry sours;
6. insecticides and rodenticides;
7. coagulating agent for latex;
8. extraction of beryllium from its ores; and
9. manufacture of sodium fluoride.

Water fluoridation may be accomplished by other fluoride-containing substances in place of sodium silicofluoride. Although sodium silicofluoride is the least costly (f.o.b. point of manufacture) on a per pound of available fluorine basis when compared to sodium fluoride and fluosilicic acid (agents most commonly used), shipping expenses and fluoridation equipment cost and operating expenses ultimately bring all three to nearly a competitive position. Fluosilicic acid, an acid in liquid form, provides a readily shipped, easily metered and controlled (on a volumetric basis) fluoridating agent. Larger communities have shown preference for the acid over other choices. Smaller communities have favored sodium fluoride due to its higher and constant 4 percent solubility level over most application temperatures. This allows controlled dissolution of the granular solid and subsequent volumetric metering. Sodium silicofluoride is typically metered into water systems as a dry powder or as a temperature-controlled solution.

In addition to cryolite, aluminum fluoride is used as a molten electrolyte in the electrolytic reduction of alumina to aluminum metal. The two fluxes are to some degree interchangeable, depending upon operating practices and the sodium oxide content of the alumina used in the reduction plant. Moreover, synthetic cryolite may be manufactured directly from hydrofluoric acid without an intermediate production of sodium silicofluoride. Kaiser is the only cryolite producer following the sodium silicofluoride route.

Potassium silicofluoride is a viable substitute for sodium silicofluoride in production of vitreous enamels. The current laundry sour market has become oriented toward materials more voluble than sodium silicofluoride.

2. Production Characteristics.

a. Production Processes. Sodium silicofluoride is a by-product of the fertilizer industry's wet process phosphoric acid production. Fluosilicic acid, the primary raw material for silicofluorides, is present as an impurity in the product phosphoric acid. Two primary schemes are in current use for producing silicofluorides. In the first, the recovered fluosilicic acid is reacted with sodium chloride in water. Sodium silicofluoride is collected as a precipitate, washed, dried and packaged. In the second, fluosilicic acid is not recovered as a separate stream but rather remains mixed in an impure phosphoric acid stream. Soda ash is mixed with the acid to form and precipitate the sodium silicofluoride. Again, the salt is separated, washed, and dried for packaging. These two process routes account for all of the annual domestic production of sodium silicofluoride.

b. Process Hazardous Wastes. In the process where the recovered fluosilicic acid is reacted in solution with sodium chloride, all of the wastes are waterborne. Treatment of this effluent does generate a small amount of some calcium fluoride-containing wastes. This treatment consists, in general, of precipitation with lime and settling or filtering of solids. In the second process where soda ash is mixed in the impure phosphoric acid stream, all wastes are waterborne. Their treatment generates a hazardous waste containing calcium fluoride as above. This second process is used in only one facility and the amount of waste material is small.

c. Capacity and Capacity Utilization. U.S. sodium silicofluoride capacity appears to be in excess of actual production. The 1972 data indicate that only 91 percent of the estimated 57,135 metric ton capacity was utilized.

Indications are that demand for sodium silicofluoride will not change substantially in the near future. Kaiser has stated that demand for synthetic cryolite is slipping; the popularity once enjoyed by silicofluoride in water fluoridation is also waning.

# VI. PROPOSED REGULATIONS AND MANAGEMENT COSTS

## A. Proposed Regulations

At this time (August 1976) EPA does not have a Congressional mandate to promulgate regulations for the control of hazardous wastes in the inorganic chemicals industry. In anticipation of such a mandate, a report was prepared for the EPA entitled "Assessment of Industrial Hazardous Waste Practices, Inorganic Chemicals Industry" by Versar, Inc. under contract #68-01-2246. The Assessment Report was prepared for information purposes and was not concerned with the modification of production processes or treatment technology, but only with the secure transfer of hazardous wastes to approved storage, treatment or disposal facilities. Three levels of technology were identified and considered for each chemical:

Level I: Technology currently employed by typical facilities; i.e., broad average present treatment and disposal practice. For most large volume wastes, two or three options are required to cover the different technologies utilized.

Level II: Best technology currently employed. The technology identified at this level must represent an acceptable process from an environmental and health standpoint currently in use in at least one location. Installations must be on a commercial scale. For the inorganic chemicals land-destined hazardous wastes this level may be similar to Level I in a number of instances.

Level III: Technology necessary to provide adequate health and environmental protection. Level III may be more or less sophisticated or may be identical with Level I or II technology. At this level, identified technology may include pilot or bench scale processes providing the exact stage of development is identified. One pertinent difference between Level III technology and Levels I and II is that it is not necessary that at least one location be using this technology. Technology transfers from other industries are also included.

The incremental cost of complying with a potential regulation that all producers must achieve at least Level III waste management practices was used in an economic impact analysis for each chemical. In some cases the incremental cost of compliance would be the difference between Level I and Level III and in other cases the total Level III costs represent the incremental costs.

## B. Hazardous Waste Management Costs

The hazardous waste management costs contained in the Assessment Report have been used in two different ways in the economic impact analysis. In order to approximate the average cost impact likely to be experienced by firms producing a primary chemical, the incremental costs of moving from Level I to Level III were calculated for each chemical. These incremental costs were then used to estimate average product price changes and losses in total product demand for the industry.

The Assessment Report costs were also used in the plant closure analysis and the sensitivity analysis. The average incremental cost of compliance is probably not a good approximation of the compliance costs faced by an individual plant in danger of closing. Either because of unique locational factors or an absence of even the Level I practices, the plant will probably be facing higher compliance costs than indicated by the average incremental costs. The Assessment Report did not estimate the costs to be used for a closure analysis. The assumption has been made in this economic impact analysis that the total Level III costs can be used in the worst case closure analysis. While it is not known what the actual costs are, this level of costs is believed to be correct within an order of magnitude, and should serve to at least identify situations needing closer examination.

The Assessment Report developed treatment and disposal costs for 1973 for the identified "potentially hazardous" wastes. For the impact analysis, these costs were updated to the base year, 1975, in order to be consistent with other cost data presented in the study. Except for this update, the cost figures used in the impact analysis which follows are precisely those developed for 1973. The updated total Level III treatment costs for the primary chemicals are shown in Table VI-1. The costs represent the treatment technology which most producers will be able to employ, in the opinion of the Assessment Report contractor. The following is a description of each option shown in the table.

Chlorine - Diaphragm Cell: secured landfill (off-site) for asbestos, lead sludges and chlorinated hydrocarbons.

Chlorine - Mercurcy Cell: off-site secured landfill (50 miles).

Titanium Dioxide: on-site approved land storage.

Phosphorus: recovery of phosphorus wastes by distillation. Precipitator dust recycled. Calciner and furnace fume scrubber wastes put in approved landfill.

Hydrofluoric Acid: secured landfill, rainwater diversion and leachate monitoring.

Sodium Dichromate: chemical treatment plus filtration and approved contract landfill.

The treatment and disposal costs were updated using the inflation factors shown on Table VI-2. The actual treatment costs can vary substantially.

The plant shutdown impact analysis is a worst case analysis based on the highest treatment costs for each model plant. The plants most likely to be impacted by the solid waste treatment requirements are those plants for which (1) there is no current control, (2) present controls are not appropriate for achieving Level III technology, or (3) locational factors make control techniques appropriate to other plants inappropriate to the impacted plant. A significant percentage of plants have some level of waste treatment control. As indicated in Table VI-3, the percent of plants with Level I control technology range from

TABLE VI-1

1975 TREATMENT COSTS*

**Chlorine-Diaphragm Cell**

**Level II & III - Option 3**

| | | |
|---|---|---|
| Investment costs: | | |
| land | 0 | |
| other | 0 | |
| total | 0 | |
| Annual costs: | | |
| capital | 0 | |
| operating | 0 | |
| energy/power | 0 | |
| contractor | 60,000 | |
| total | 60,000 | |
| Cost/m ton chlorine (excl. capital cost) | | 0.37 |
| Cost/m ton chlorine | | 0.37 |
| Cost/m ton haz.waste (wet) | | 28.84 |

**Chlorine-Mercury Cell**

**Level II & III - Option 5**

| | | |
|---|---|---|
| Investment costs: | | |
| land | 0 | |
| other | 0 | |
| total | 0 | |
| Annual costs: | | |
| capital | 0 | |
| operating | 0 | |
| energy/power | 0 | |
| contractor | 367,200 | |
| total | 367,200 | |
| Cost/m ton chlorine (excl. capital cost) | | 4.08 |
| Cost/m ton chlorine | | 4.08 |
| Cost/m ton haz.waste (wet) | | 83.84 |

**Titanium Dioxide**

**Level III - Option 5**

| | | |
|---|---|---|
| Investment costs: | | |
| land | 0 | |
| other | 0 | |
| total | 0 | |
| Annual Costs: | | |
| capital | 0 | |
| operating | 0 | |
| energy/power | 0 | |
| contractor | 157,200 | |
| total | 157,200 | |
| Cost/m ton $TiO_2$ (excl. capital cost) | | $4.32 |
| Cost/m ton $TiO_2$ | | 4.32 |
| Cost/m ton haz.waste (wet) | | 3.96 |

**Phosphorus**

**Level II & III - Option 3**

| | | |
|---|---|---|
| Investment costs: | | |
| land | (annualized) | |
| other | 1,012,690 | |
| total | 1,012,690 | |
| Annual costs: | | |
| capital | 264,180 | |
| operating | 78,000 | |
| energy/power | 5,400 | |
| contractor | 0 | |
| total | 347,580 | |
| Cost/m ton phosphorus (excl. capital cost) | | 1.67 |
| Cost/m ton phosphorus | | 7.00 |
| Cost/m ton haz.waste (wet) | | 9.52 |

TABLE VI-1 (Con't)

1975 TREATMENT COSTS* (continued)

| Hydrofluoric Acid | | | Sodium Dichromate | | |
|---|---|---|---|---|---|
| Level III - Option 4 | | | Level II & III - Option 5 | | |
| Investment costs: | | | Investment costs: | | |
| land | (10,000/yr.) | | land | 0 | |
| other | 1,037,850 | | other | 629,000 | |
| total | 1,037,850 | | total | 629,000 | |
| Annual costs: | | | Annual costs: | | |
| capital | 274,200 | | capital | 101,898 | |
| operating | 127,200 | | operating | 189,600 | |
| energy/power | 40,500 | | energy/power | 1,350 | |
| contractor | 0 | | contractor | 300,000 | |
| total | 441,900 | | total | 592,848 | |
| Cost/m ton HF (excl. capital cost) | | 7.29 | Cost/m ton chromate (excl. capital cost) | | 7.55 |
| Cost/m ton HF | | 18.90 | Cost/m ton chromate | | 8.92 |
| Cost/m ton haz.waste (wet) | | 4.03 | Cost/m ton haz.waste (wet) | | 8.12 |

*Source: "Assessment of Industrial Hazardous Waste Practices, Inorganic Chemicals Industry", Versar, Inc., updated to 1975.

TABLE VI-2

METHOD USED FOR UPDATING THE VERSAR TREATMENT COSTS TO 1975 COSTS*

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Investment

Other - update to 1975 using the CE* Plant Index.

$$\frac{\text{CE Plant Index (June 1975)}}{\text{CE Plant Index (June 1973)}} = \frac{181.8}{144.5} = 1.258$$

1.258 x June 1973 cost = June 1975 cost.

Land - assume constant land costs

Annual Costs

Capital - Use the same percentage as that used by previous contractor in each individual example. This is necessary because it appears that various combinations of factors have been used.

Operating - Operating costs are labor and supplies. An approximation of the updated cost can be made by using approximately a 20 percent increase. This 20 percent was developed using labor cost data published in Chemical Week.

Energy and Power - The previous contractor suggests that each of their examples used specific energy costs. A factor of 1.35 is reasonable to update the energy and power costs.

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*Source: "Chemical Engineering" (CE), and Contractor's estimates.

TABLE VI-3

BASELINE AND PROJECTED TREATMENT/DISPOSAL TECHNOLOGIES*

| Chemical process | Treatment/disposal | % of plants at Level I | Treatment at other plants | Treatment/disposal | % of plants at Level III |
|---|---|---|---|---|---|
| Chlorine (diaphragm cell) | Option 2<br>Off-site sludge land-fill, contractor burning of chlorinated hydro-carbons | 50 | Level III | Option 3<br>Secured, off-site landfill | none |
| Chlorine (mercury cell) | Option 2<br>On-site pond storage | 71 | Level II & III | Option 5<br>Off-site secured landfill | 14 |
| Titanium dioxide (chloride process) (rutile ore) | Option 1<br>Neutralization, precipi-tation and on-site storage | 50 | Higher cost level I & II | Option 5<br>Neutralization, precipi-tation and approved off-site storage | 12 |
| Hydrofluoric acid | Option 1<br>On-site landfill | 75 | Level II | Option 4<br>Secured on-site landfill | none |
| Phosphorus | Option 1<br>On-site landfill | 100 | N.A. | Option 3<br>Distillation and approved on-site landfill | none |
| Sodium dichromate | Option 3<br>Unlined pond storage, on- sitelandfill | 33 | Higher cost level I & II | Option 5<br>Chemical treatment, filtration and approved contract landfill | none |

*Source: "Assessment of Industrial Hazardous Waste Practices, Inorganic Chemicals Industry", Versar, Inc.

33 percent for sodium dichromate to 100 percent for phosphorus. Although some plants have treatment technology at Level II or III, a number of plants have limited or no controls, and therefore, an examination of the impact of total Level III treatment costs is necessary to reflect the potential plant shutdown impact. Also, if present control technology is not suitable for upgrading to Level III technology, total Level III treatment costs will be incurred by a producer who could not utilize existing controls. For example, Table VI-3 points out that 100 percent of the phosphorus plants have Level I control technology which potentially could reduce the cost impact of achieving Level III technology. However, the geographic location of a plant or some other site-specific problem may prevent a producer from utilizing a lower cost Level III approach. If, as a result, an alternative technology were required, the producer would not benefit from existing controls, and would be impacted by higher total Level III technology treatment cost. Therefore, in order to more realistically assess potential plant shutdowns, the total treatment costs required to achieve Level III technology have been considered.

The incremental cost impacts of achieving Level III for the average plants are shown on Table VI-4. Tables VI-3 and VI-4 were developed in cooperation with the Assessment Report contractor and represent a best judgement as to the current status of plants producing the primary chemicals and their ability to move to the specified Level III technology. The status of current control for the primary chemicals and the projected treatment/disposal options for the model plant are summarized in Table VI-3. Since the treatment and disposal costs presented in the "Assessment Report" represent the total costs required. to achieve the various technology levels, these costs have been adjusted to

TABLE VI-4

INCREMENTAL COSTS FOR ACHIEVING LEVEL III HAZARDOUS WASTE TREATMENT TECHNOLOGY (1975) *

| | Chlorine and caustic (diaphragm cell process) | Chlorine and caustic (mercury cell process) | Titanium dioxide (chloride process) | Hydro-fluoric acid | Phosphorus | Sodium dichromate |
|---|---|---|---|---|---|---|
| Investment costs | | | | | | |
| Land | - | - | - | (5,000/yr) | 0 | 0 |
| Other | - | - | - | 660,450 | 824,000 | 629,000 |
| Total | - | - | - | 660,450 | 824,000 | 629,000 |
| Annual costs | | | | | | |
| Capital | - | - | (5,000) | 172,340 | 215,000 | 101,900 |
| Operating | - | (46,800) | (38,400) | 18,000 | 3,600 | 80,400 |
| Energy & power | - | (175) | - | - | 2,700 | (8,100) |
| Contractor | 51,000 | 367,200 | 157,200 | - | - | 60,000 |
| Total | 51,000 | 320,230 | 113,800 | 190,340 | 221,300 | 234,200 |
| Model plant annual production | 162,000 | 90,000 | 36,000 | 23,000 | 50,000 | 65,000 |
| Cost per metric ton of product | $0.31/ton | $3.56/ton | $3.16/ton | $8.28/ton | $4.43/ton | $3.60/ton |
| Cost per metric ton of waste (wet) | $25.50/ton | $72.78/ton | $2.85/ton | $1.73/ton | $6.08/ton | $3.25/ton |

*Source: "Assessment of Industrial Hazardous Waste Practices, Inorganic Chemicals Industry," Versar, Inc.

reflect the incremental costs of compliance for those plants at Level I moving to Level III. Table VI-4 summarizes the incremental treatment costs for the model plant for each primary chemical. These incremental costs are based on the difference in the baseline and projected treatment/disposal options. For example, for a chlorine producer with a diaphragm cell plant, the baseline technology is off-site landfill (Option 2). The projected Level III technology for the model plant is secured, off-site landfill (Option 3) and the incremental costs reflect the incremental disposal costs for the model plant switching from Option 2 to Option 3 control technology.

The incremental compliance costs for the model plant are the treatment costs utilized for determining short-run economic impacts on price and demand. The incremental costs of treatment/disposal in Table VI-4 are said to be the costs that producers on the average will attempt to pass along through price increases. This analysis assumes the incremental costs for the model plant are representative of the principal industry producers. The industry price leaders are assumed to be impacted by the incremental treatment costs, and they will, therefore, attempt to pass along these compliance costs through price increases. For a variety of reasons, it is possible that the actual costs to be experienced by the price leaders will be higher or lower than those assumed in this analysis. No new attempt has been made to verify the applicability of the Assessment Report costs to the product price leaders.

# VII. ECONOMIC IMPACT METHODOLOGY

## A. Analytic Framework and Overview

The methodology applied in this report has sought to analyze the following short- and long-run economic impacts of proposed Federal hazardous waste control regulations:

1. Short-Run Impacts (1977-78). Short-run impacts include consideration of marginal plant closures, increases in price due to: (1) potential shortages from plant closures in the next two to three years; (2) shifts in industry cost curves because of compliance with regulation; (3) decreases in quantity demanded as a result of any price increases. Short-run secondary impacts considered include employment, wages, foreign trade and community effects.

2. Long-Run Impacts (1980 and beyond). Long-run impacts include consideration of price increases of a different magnitude than those which occur in the short run. Long-range impacts are discussed in greater detail in Section C. 6. of this chapter.

3. Impacts Not Considered. The following economic impacts are beyond the scope of this analysis: (1) secondary effects on consumers and suppliers of affected products; (2) long-run changes in demand, industry structure, and aggregate capital requirements.

4. Analytical Disciplines. Four disciplines were used in the assessment of the impact upon the inorganic chemical industry of proposed hazardous waste regulations.

a. Microeconomics. Microeconomic theory offers a conceptual framework upon which to build the logic of the impact analysis. With econometric techniques, a demand function can be specified and estimated.

b. Engineering Process Economics. Engineering process economics offer an ability to estimate the supply-cost characteristics of the affected products. These characteristics may then be employed in an assessment of model plant profitability.

c. Business and Industry Analysis. Business and industry analysis provides a conceptual apparatus through which to view the effects of the proposed regulations by considering aspects of industry structure, conduct, and performance. Also, such methods are necessary for the development of the numerous judgmental and interview-based inputs that are required to complete the overall economic impact analysis.

d. Financial Analysis. Financial analysis is used to evaluate the cash flows and capital structure of typical plants subject to hazardous waste regulations. This quantitative input is a useful measure of financial considerations, but it must be rounded out by careful consideration of the qualitative issues discussed in the industry analysis.

## B. Segmentation of Industry

In order to focus analytical efforts on those chemicals for which greatest impacts on the inorganic chemical industry would be expected, the chemicals were segmented into two categories. These two categories are: primary affected chemicals and secondary affected chemicals. The first category contains five of the thirteen chemicals/processes studied and it was for these five chemicals that a detailed economic impact assessment was performed. For the remaining eight chemicals, it appears that no severe economic impact would occur because of the small level of hazardous waste treatment costs developed as a basis for this analysis.

The segmentation of chemicals was done on the basis of market importance of the chemical (on the basis of production volume) and on a comparison of treatment/disposal costs with product selling price. This segmentation approach is illustrated in Figure VII-1 . A more detailed segmentation of all of the chemicals is presented in Table VII-1.

## C. Detailed Methodology

1. Microeconomic Theory of Hazardous Waste Control. Demand and supply curves are the fundamental conceptual tools of economic analysis in that they depict the quantities of a particular good that customers are willing to buy and sell, at certain prices of the good. In the long run, producers have complete flexibility to adjust their supply decisions to changing demand conditions. However, in the short run, producers have certain fixed commitments which act as constraints and offer only partial freedom to adjust to given changes in demand. For this reason, the firm's short-run supply curve will generally be steeper than the long-run supply curve.

Microeconomic theory states that the perfectly competitive firm will employ the most efficient mix of inputs in order to achieve the least-cost level of output. Given a set of production plans, a firm's supply curve can be discussed in terms of its total, average, and marginal cost curves. Total cost (TC), in the short run, is the sum of variable cost and any fixed costs that must be incurred--regardless of the level of output. Average cost (AC) is the cost per unit of output and is defined as total cost divided by the given level of output. Marginal cost (MC) is the change in total cost associated with a unit change in output and is defined as the slope of the total cost curve.

| 1975 Market Size (Production) | Small (Under 0.5 Percent) | Medium (0.5 to 1.0 Percent) | Large (Over 1.0 Percent) |
|---|---|---|---|
| Large (Over 1 Million Short Tons) | Diaphragm Cell Chlorine | | **(HIGHEST PRIORITY)** Mercury Cell Chlorine |
| Medium (Over 100,000 Short Tons) | Downs Cell Chlorine<br>Aluminum Fluoride | Titanium Dioxide (Chloride Process) | Phosphorus<br>Sodium Dichromate<br>Hydrofluoric Acid |
| Small (Under 100,000 Short Tons) | **(LOWEST PRIORITY)** Sodium Silicofluoride<br>Phosphorus Pentasulfide<br>Phosphorus Trichloride | Chrome Colors<br>Nickel Sulfate | |

Treatment Costs As Percent of Selling Price

**Source:** Contractor's Estimates.

FIGURE VII-1 ECONOMIC IMPACT PRIORITIES OF INORGANIC CHEMICALS

TABLE VII-1

PRELIMINARY ECONOMIC IMPACT FACTORS FOR THE INORGANIC CHEMICAL INDUSTRY*

| Primary affected chemicals | Treatment cost | Market size | Market growth | Market concentration | Substitutability |
|---|---|---|---|---|---|
| Chlorine (mercury cell) | Large | Large | High | High | High |
| Hydrofluoric acid | Large | Medium | Low | Moderate | Moderate |
| Phosphorus | Large | Medium | Low | High | Moderate |
| Sodium dichromate | Large | Medium | Low | High | Moderate |
| Titanium dioxide (chloride proc.) | Medium | Medium | Medium | High | Low |
| **Secondary affected chemicals** | | | | | |
| Aluminum fluoride | Small | Medium | | | |
| Chlorine (diaphragm cell) | Small | Large | | | |
| Chlorine (Downs cell) | Small | Medium | | | |
| Chrome pigments | Medium | Small | | | |
| Nickel sulfate | Medium | Small | | | |
| Phosphorus pentasulfide | Small | Small | | | |
| Phosphorus trichloride | Small | Small | | | |
| Sodium silicofluoride | Small | Small | | | |

Key: large or high = in top third of normal range.
medium or moderate = in middle third of normal range.
low or small = in lower third of normal range

*Source: Contractor's estimates.

Two final important short-run concepts are average fixed cost (AFC) and average variable cost (AVC). These are total fixed and total variable cost divided by the relevant level of output. These relationships can be expressed somewhat more formally as follows:

$$TC(q) = VC(q) + FC \qquad (1)$$

$$AC = TC/q \qquad (2)$$

$$MC = \Delta TC = TC(q+1) - TC(q) = VC\ (q+1) - VC(q) \qquad (3)$$

$$AFC = FC/q \qquad (4)$$

$$AVC = VC/Q \qquad (5)$$

where

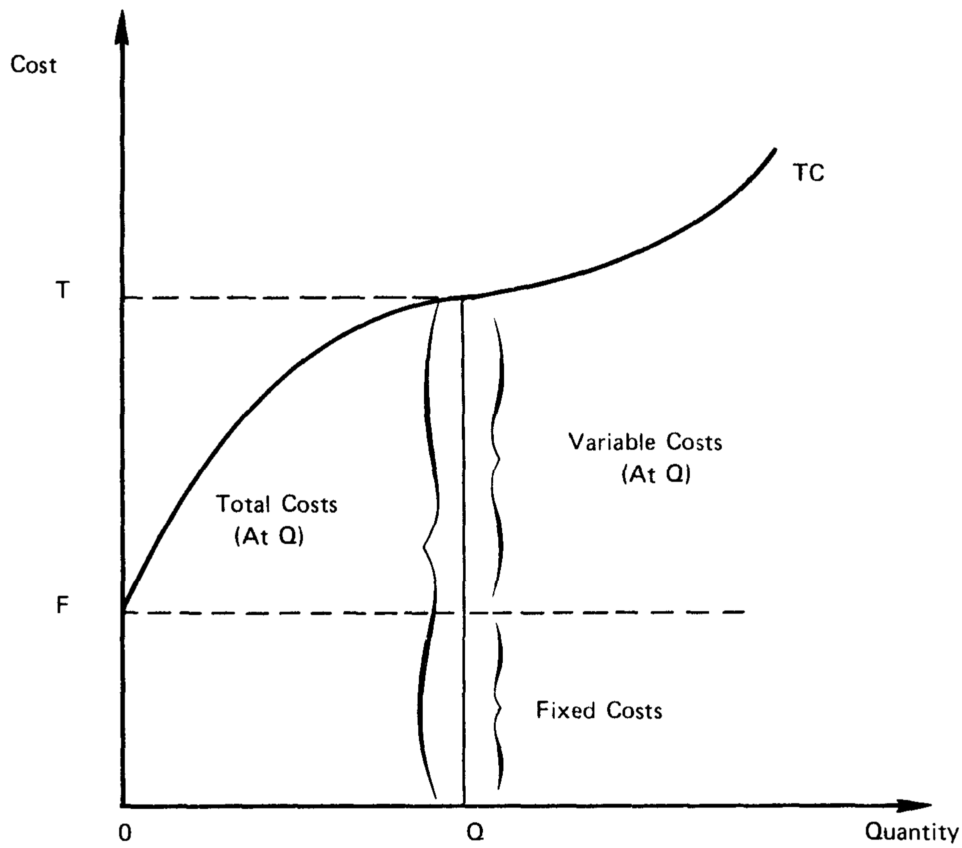
TC(q) = total cost of producing q units of output,

VC(q) = variable cost of producing q units of output,

FC = fixed cost of production required at all levels of output.

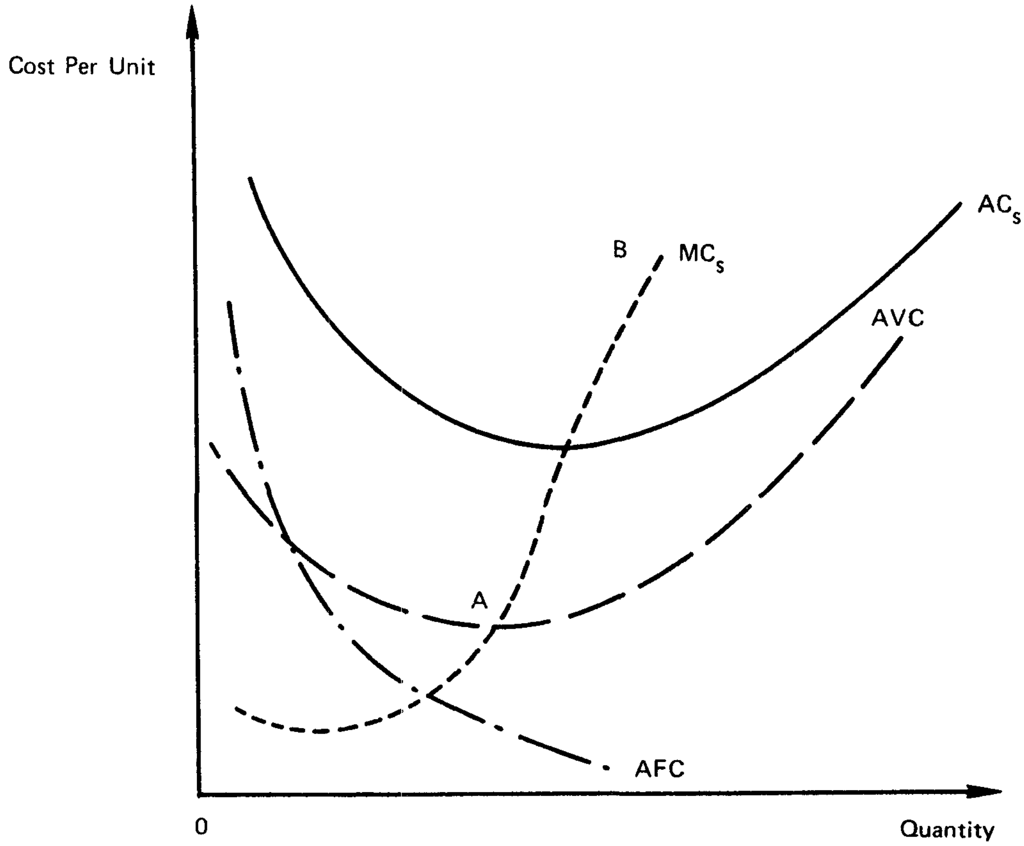
These relationships are shown graphically in the figures which follow. In Figure VII-2, TC is the short-run total cost curve. Fixed costs are the amount which must be incurred no matter what the level of production. Variable costs depend on the level of output and are equal to FT at an output of Q units. Thus, at the point Q, total costs can be measured on the vertical axis as OT.

Associated with any total cost curve is a set of average cost curves and a marginal cost curve. Figure VII-3 shows short-run average cost, $AC_s$, average variable cost, AVC, and average fixed cost, AFC. Also, short-run marginal cost is depicted as $MC_s$, which is the extra total cost per unit of extra output. It should be clear from equation 3 above, and from the verbal definitions, that $MC_s$ is totally independent of any fixed cost, depending only on variable cost. It should also be noted that $MC_s$ intersects both AVC and $AC_s$ at their minimum points. In the short-run, the firm's supply




**Source:** Contractor's Estimates.

**FIGURE VII–2 TOTAL COST CURVE**




**Source:** Contractor's Estimates.

**FIGURE VII–3 AVERAGE AND MARGINAL COST CURVES**

curve is defined as that portion of $MC_S$ which lies on or above AVC, i.e., the segment AB in Figure VII-3. Although not explicitly shown in the figure, in the long-run, when all costs are variable, the firm's supply curve is that portion of $MC_L$ which coincides with or lies above $AC_L$. To obtain a supply curve for an industry requires a summation of all the supply curves of the relevant, individual firms.

In a very real sense, a discussion of supply is only half of the equation because it is the interaction between demand and supply which determines the industry's and firm's equilibrium output and price. Generally, rational consumers of normal goods will demand more of a product as its price declines, i.e., the demand curve is negatively sloped. Profit is defined as the difference between total revenue and total cost. It can be proven that maximum revenue is achieved at the point where marginal revenue equals marginal cost.

In Figure VII-4, AR is a downward demand curve and MR is the associated marginal revenue curve. MR intersects MC at $Q_1$, thereby defining the industry's equilibrium output. Optimal price, $P_1$, is determined as the point on AR which is vertically above the point of equilibrium output.

An important aspect of microeconomic analysis is price elasticity. This is the degree to which consumers or producers will change their consumption or production decisions in response to a given change in price. If the demand for a particular product is of the form

$$Q_i = f(P_i, P_j, Y)$$

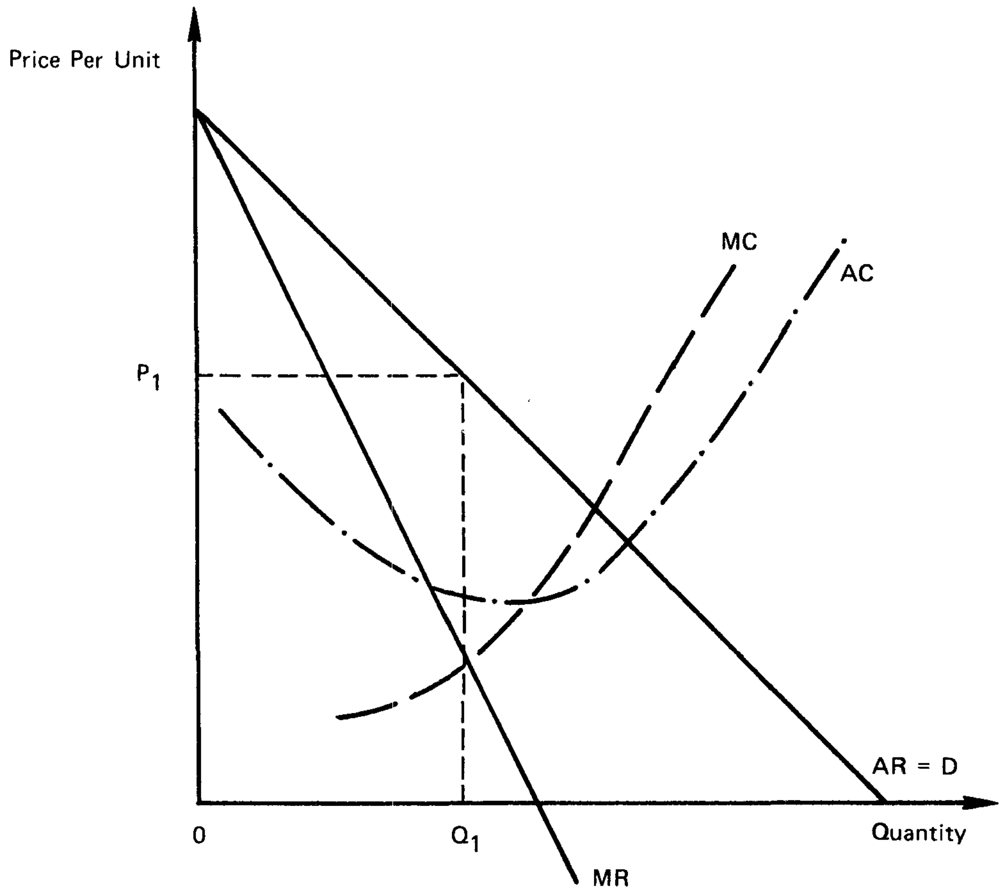
where

$Q_i$ = demand for product i,

$P_i$ = price per unit of product i,

$P_j$ = price per unit of product j, a substitute for product i,

Y = economic activity index,




**Source:** Contractor's Estimates.

**FIGURE VII–4 DETERMINATION OF EQUILIBRIUM PRICE AND QUANTITY**

then the price elasticity of demand is defined as

$$e = \left( \frac{\Delta Q_i}{\Delta P_i} \right) \frac{P_i}{Q_i} .$$

If $|e| < 1$ (=1, > 1), demand is said to be price inelastic (unitary elastic, elastic). Most chemical producers feel that demand for their products is relatively price inelastic. If this is so, then it has direct implications for the effect that pollution control regulations will have on both producers and consumers. Because e denotes the change in quantity demanded as a result of a given change in price, one would expect, ceteris paribus, that chemical firms with inelastic demand would be fairly successful in passing through to end users increases in cost due to pollution regulations that fall equally on all producers.

Conversely, in the elastic demand case, consumers will not be as willing to accept the price increases on the affected products, and the economic impacts upon the producers will be larger. Thus, all other things equal, profits and employment will fall and marginally profitable firms may be pushed into loss positions.

In the short run, the firm's decision to shut down or not will depend on whether it can cover its variable cost, i.e., AR > AVC. If the firm can't escape its fixed costs by shutting down, then it must try to maximize the excess of revenue over variable cost. In the long run, when all costs are variable, any firm that cannot cover its costs will go out of business rather than produce at a long-run loss.

In analyzing the effect of pollution control regulations on industry, one useful approach is to consider increased costs due to regulation as a tax. Increased costs have two components, one fixed (FT) and the other variable (VT). These pollution taxes alter the firm's cost functions in the following manner:

Recall that prior to any tax, the firm's total cost is defined as

$$TC(q) = VC(q) + FC$$

Now, if the two-part tax is imposed, total cost is

$$TC^*(q) = [1 + VT]\ VC(q) + [FC + FT]$$

Thus, the average and marginal costs inclusive of tax are

$$AC^* = TC^*/q$$

$$MC^* = \Delta TC^* = TC^*(q + 1) - TC^*(q)$$

$$= [1 + VT]\ VC\ (q + 1) - [1 + VT]\ VC\ (q)$$

$$= [1 + VT]\ [VC(q + 1) - VC\ (q)]$$

where

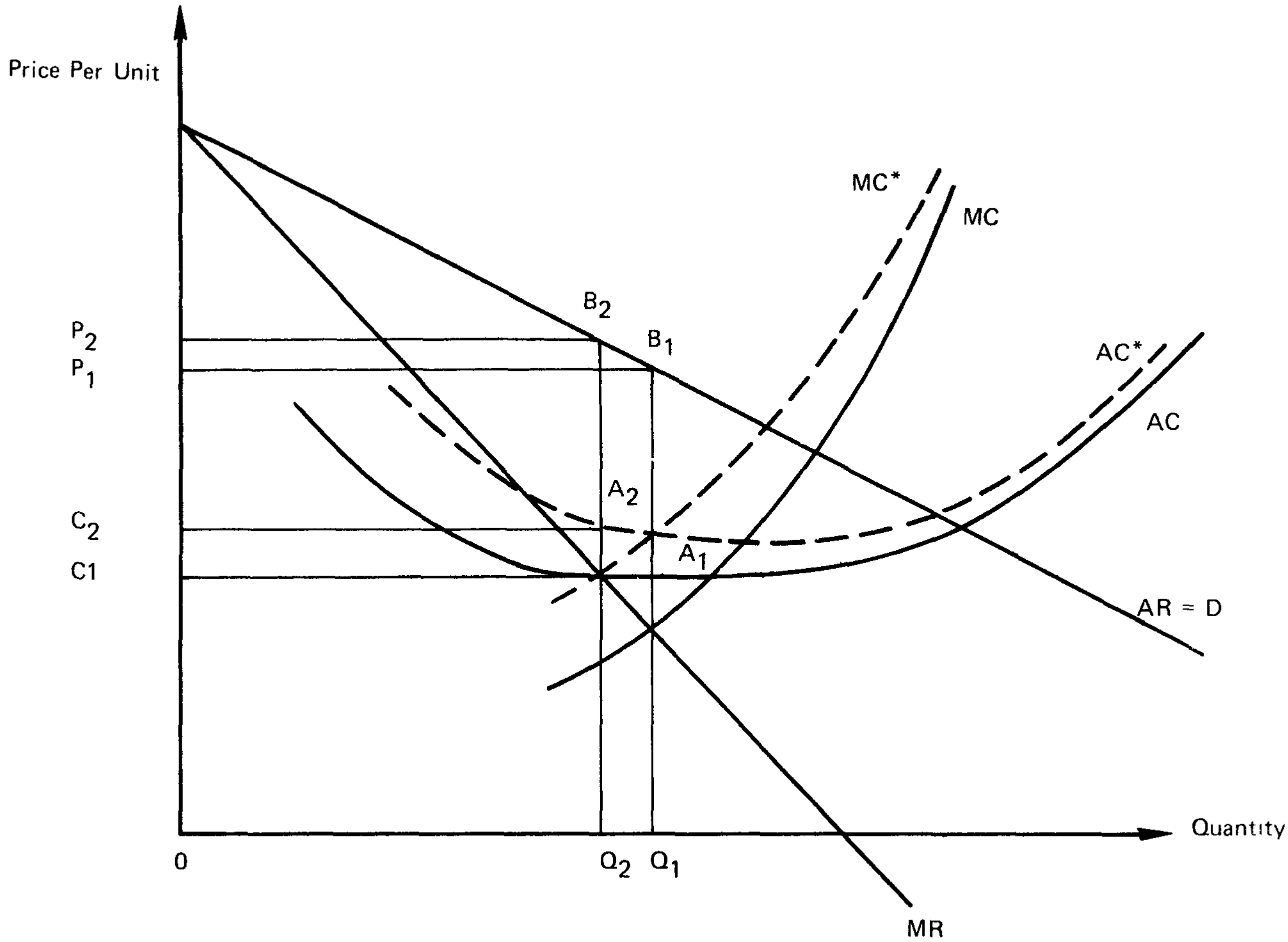
FT = fixed portion of pollution control requirement,

VT = variable portion of pollution control requirement,

and all asterisks denote costs inclusive of tax.

According to this framework, marginal cost would shift upward by the amount VT.

These effects can be demonstrated graphically, as well. In Figure VII-5, a situation similar to that shown in the previous figure is illustrated. Just as before, equilibrium output is determined by the intersection of MR and MC. Therefore, output would be $OQ_1$ and price per unit, $OP_1$. In this case, the industry incurs costs per unit of $OC_1$ and profits per unit of $C_1P_1$. Thus, total profits are the rectangle $C_1A_1B_1P_1$.




*Denotes Cost Inclusive of Tax.

**Source:** Contractor's Estimates

**FIGURE VII–5 EFFECT OF POLLUTION CONTROL-INDUCED COST CHANGES ON EQUILIBRIUM PRICE AND QUANTITY**

Now suppose that the industry's costs are increased as a result of the imposition of pollution control regulations. Upward shifts in average and marginal costs are shown by the dotted curves, $AC^*$ and $MC^*$, respectively. A new equilibrium is established at $(Q_2, P_2)$ with lower output and higher price. This shift in costs also has the effect of raising unit costs to $OC_2$ and reducing unit profits to $P_2C_2$. Therefore, total profits are reduced to the rectangle $C_2A_2B_2P_2$. It should be noted that the extent to which profits are reduced depends critically on the shape or slope of the relevant supply and demand functions.

2. Econometric Analysis. The demand was econometrically modelled for five chemicals -- chlorine, titanium dioxide, hydrofluoric acid, sodium dichromate, and elemental phosphorus. These products were chosen because they were expected to have the largest impacts and because there are fairly large markets for each of them.

In theory, the following demand function is to be estimated:

$$QP_t = a_o + b_1 \ POD_{t-i} + b_2 \ GNPD_t + b_3 \ PSD_{t-i}$$

where

$QP_t$ = quantity produced of given product in period t,

$POD_{t-i}$ = deflated price of given product in some period prior to period t,

$GNPD_t$ = gross national product in constant dollars in period t,

$PSD_{t-i}$ = deflated price of a substitute for the given product in some period prior to period t,

and $a_o$, $b_1$, $b_2$, and $b_3$ are coefficients to be estimated.

Production data were used in this function because there is a large amount of captive consumption for some of the chemicals. Thus, commercial shipments data would not indicate the extent to which production was responding to the demand for the chemical within the firm -- either as a feedstock to other processes or for other internal uses. GNP was included in the equation to capture shifts in demand or changes in the purchasing power of consumers.

Deflated price, POD, is expected to have a negative coefficient because the demand curve for any normal good is negatively sloped by definition. POD is lagged one or two periods because it is assumed that consumers respond to changes in price with a lag. The precise dimensions of this lagged response are not known, so several functional forms were experimented with. Generally, a lag of one or two years provided the most reasonable results.

The need to capture substitution effects calls for the inclusion of substitute price, PSD, in the demand function. However, there are a large variety of end uses for all the chemicals in this study. To complicate the matter, in each end use there is generally an entirely different product which could be substituted for the given chemical. In some cases, due to the unique structural properties of the chemical, there are virtually no direct substitutes for the product, although there may be indirect substitutes. For these reasons, data for PSD were not collected and not included in the demand estimation. Clearly, this omission leads to biased and inconsistent parameter estimates, with the extent of the bias related to the correlation between POD and PSD. This problem has not been analyzed in detail, but it should be noted that the demand relationships that have been econometrically estimated will be least reliable for those products which are subject to the strongest substitution possibilities from competing products.

Data for production and price on each of the five chemicals were collected for the period 1950-74. Macroeconomic data for GNP and a price deflator were also assembled. Using the contractor's version of an econometric software package (Time Series Processor or TSP), the demand equations were estimated by regression analysis, with the Cochrane-Orcutt correction for first order serially correlated errors. The results are shown in Table VII-2 . All of the estimated coefficients have the theoretically correct sign and are statistically significant from zero at the .05 confidence level or better. GNPD does not appear in many of the final equations because it was highly collinear with POD. Multicollinearity was determined to be a problem, because when GNPD was omitted from many of the equations, the standard errors for POD were observed to decline.

The Durbin-Watson (D.W.) statistic for the hydrofluoric acid and elemental phosphorus equations are below the cutoff value at the 5 percent level of significance, thereby indicating positive serial correlation. Attempts to correct this

TABLE VII-2

RESULTS OF REGRESSION ANALYSIS*

Chlorine

$$\log (QP_t) = \underset{(17.09)}{10.55} - \underset{(-2.01)}{.36} \log (POD_{t-1})$$

Period: 1962-74

$R^2$ = .98

F(1, 11) = 642.9

D.W. = 1.69

$\rho$ = .84
(5.63)

*The regression results include:

1. t-statistics which appear in parentheses below the estimated coefficients;

2. The period of fit is indicated and since estimation is with annual data the number of observations is implied;

3. $R^2$, R-squared, which refers to the raw or unadjusted coefficient of multiple determination;

4. F which is the F-statistic with k-1 and T-k degrees of freedom, where k=the number of right-hand side variables and T=the number of observations.

5. D.W. which is the Durbin-Watson statistic.

6. $\rho$ is rho or the first-order serial correlation coefficient.

TABLE VII-2 (Continued)

Hydrofluoric Acid[a]

$$\log(QP_t) = \underset{(17.6)}{23.5} - \underset{(-8.81)}{1.91} \log(POD_{t-2})$$

Period: 1952-73

$R^2$ = .80

$F(1, 20)$ = 77.65

D.W. = .28

Sodium Chromate and Dichromate

$$\log(QP_t) = \underset{(11.71)}{14.37} - \underset{(-1.97)}{.50} \log(POD_{t-1})$$

Period: 1972-74

$R^2$ = .59

$F(1, 11)$ = 15.90

D.W. = 1.28

$\rho$ = .45
(1.81)

a. Estimated by ordinary least squares with no correction for autocorrelation.

TABLE VII-2 (Continued)

Elemental Phosphorus[b]

$$\log (QP_t) = \underset{(14.27)}{26.37} - \underset{(-7.27)}{2.18} \log (POD_{t-1})$$

Period: 1950-74

$R^2 = .71$

$F(1, 22) = 53.28$

D.W. = .24

Titanium Dioxide

$$\log (QP_t) = \underset{(4.41)}{6.03} - \underset{(-4.18)}{.42} \log (POD_{t-2}) + \underset{(3.85)}{.46} \log (GNPD_t)$$

Period: 1963-74

$R^2 = .98$

$F(2, 10) = 180.7$

D.W. = 1.79

$\rho = \underset{(.54)}{-.15}$

b. Estimated by ordinary least squares with no correction for autocorrelation.

Source: Contractor's estimates.

problem with appropriate techniques did not meet with success. Therefore, the reported results are probably "less significant" than their t-statistics indicate, because the estimated standard errors are biased downward.

As stated earlier, the concept of elasticity is an extremely important one. The concept is particularly useful because it is dimensionless, being stated in terms of the percentage change in one variable with respect to the percentage change in another variable. As defined here, e is the price elasticity of demand evaluated at the means of price and quantity. It is meant to measure how quantity demanded changes in response to a percentage change in price. Usually e is described differently if it is greater than, equal to, or less than -1. When e is greater than -1, demand is said to be inelastic. Similarly, when e equals -1, demand is unit elastic, and when e is less than -1, demand is elastic. Thus, with an inelastic demand curve, a given price increase will be met by a less than proportionate decrease in quantity demand.

The demand price elasticities implied by the regression results are shown in Table VII-3 . (Because all of the equations are estimated in log-log form under the assumption of constant elasticity, the estimated coefficient for POD is the actual price elasticity.) It is important to note that each value is only a statistical estimate of the mean and is therefore subject to some error. Accordingly, the .05, or two standard error, confidence interval is also reported. In only 5 percent of the cases would the true value of e lie outside of this error band. Based on the estimates in Table VII-3, it would appear that demand is relatively price inelastic for chlorine, titanium dioxide, and sodium dichromate. On the other hand, demand is relatively elastic for hydrofluoric acid and elemental phosphorus. Depending on the extent of the product price increase caused by the imposition of hazardous waste management regulations, one would expect that the demand for inelastic groups of chemicals

TABLE VII-3

DEMAND ELASTICITIES OF PRIMARY AFFECTED CHEMICALS*

| Chemical | Price elasticity of demand | Confidence interval |
|---|---|---|
| Chlorine | -.36 | -.01, -.71 |
| Titanium dioxide | -.42 | -.22, -.62 |
| Hydrofluoric acid | -1.91 | -1.47, -2.34 |
| Sodium chromate & dichromate | -.50 | 0.0, -1.00 |
| Elemental phosphorus | -2.18 | -1.58, -2.78 |

*Source: Contractor's estimates.

would decrease less than proportionately. Conversely, product price changes will have a larger impact on the producers of the two price elastic chemicals.

The following data sources were used for the estimation of the demand equations.

QP - Total annual production. Census of Manufactures, U.S. Department of Commerce.

PO - Price per unit. Census of Manufactures, U.S. Department of Commerce.

GNP - Gross national product (current dollars). Survey of Current Business, U.S. Department of Commerce.

DEF - Implicit price deflator for GNP (1958 = 1.0). Survey of Current Business, U.S. Department of Commerce.

Also, the following data adjustments were made to deflate the independent variables:

POD - PO/DEF

GNPD - GNP/DEF

3. Process Economics. An important element of any quantitative assessment of economic impact is the determination of elements of, and total, production costs for a given chemical. Variable cost elements are used in an analysis of short-run economic consequences of regulations, while fixed and total production cost elements are used in a plant shutdown analysis.

The production cost estimates presented in this report are engineering estimates based on 1975 cost elements consistent with the process or technology believed to be in common use. The cost data which are developed are hypothetical in that they represent costs for a "model" or "representative" plant. It must be clearly understood that the particular circumstances surrounding the operation of each individual plant may significantly affect the accuracy of these cost estimates.

4. Short-Run Economic Impact Analysis. For the short-run analysis one would like to know the degree of price increase and associated quantity decrease that could be brought about by the imposition of hazardous waste control regulations. The required inputs to this analysis are: (1) incremental costs of compliance with potential hazardous waste guidelines; (2) costs of manufacture for affected products and processes; (3) elasticity of demand for affected products; (4) pricing strategy of producers in response to regulated cost increases.

The costs of compliance are provided by the Waste Practice Assessment Report. These costs have been adjusted to 1975 cost conditions so that they are in a comparable time frame with the manufacturing cost estimates. Aside from these effects, no additional changes were made in the Assessment Report cost data.

Under ideal conditions an econometric estimate of the industry supply function for each chemical would be an appropriate vehicle for analyzing the effect of changing manufacturing costs. However, due to a major problem with the data available for such an analysis, it was not possible to construct an econometric model of the supply side of the markets for the affected products. The essence of the data problem is that the only widely available time series of cost data is the Commerce Department's Current Industrial Reports.

In the case of chlorine, data on both "cost of materials, fuels, etc." and "production worker manhours and wages" are reported for the 4-digit SIC code, which is 2812, "Alkalies and Chlorine." SIC 2812 includes the following categories: compressed or liquified chlorine, sodium carbonate (soda ash), sodium hydroxide (caustic soda), potassium hydroxide (caustic potash), and other alkalies. Also, the cost data reported for SIC 2812 only apply to approximately two-thirds of total production. For a number of reasons, it was found that it would be extremely difficult to cull out of the total cost data that proportion which was attributable to the production of chlorine. Several approaches were tried but none led to reasonable estimates of unit cost when they were compared to independently derived, static estimates of production cost. The SIC 2812 data is primarily unusable because of this aggregation problem, which offers no objective basis for identifying the costs associated with an individual product. Other complicating factors are: (1) chlorine is a joint product with caustic soda, thus further muddying the cost allocation process; (2) chlorine is produced by at least three major production processes, and the pollution impact upon each process is fundamentally different. Even if one were able to isolate the costs of producing chlorine from the SIC 2812 data, there would be further aggregation problems with the varying mixes of production processes. Although the data problems were not quite as severe with titanium dioxide, there was still no reliable means for separating out the individual costs.

The alternative methodology employed for estimating the supply relationships for these different chemical products was the engineering cost estimation that is described in Section VII. C. 3. (These cost estimates were made for model plants.) A major problem associated with the use of these cost estimates is that they do not reflect the entire spectrum of plant cost conditions as they now exist within the industry; rather these estimates are for state-of-the-art technology. Any amount of economic impact detected here will have to be adjusted by the extent to which current industry manufacturing costs diverge from these estimates for a model plant. The engineering cost estimates were used in conjunction with the treatment and disposal cost data to provide a basis for estimating the degree to which the industry supply curve would shift upward in response to the waste regulations. In effect this type of analysis indicates the change in the level of average variable cost.

Another element required for the short-run impact analysis is the price elasticity of demand for each affected product. As stated in Section VII. C. 2., the price elasticity is a quantification of the expected change in quantity demanded that would result from a change in price.

In order to analyze what the price and quantity effects will be, it is necessary to understand how producers set their prices given certain cost conditions. In actuality a producer has a number of pricing alternatives available to him in determining the price response to a given change in costs due to increased expenditures or pollution control equipment. Due to his particular supply and market characteristics a producer may do nothing in terms of price and simply absorb the cost increases as reduction in profitability. In the long run this strategy would result in a continuing operation only if discounted revenues exceeded total costs. Microeconomic theory supports the view that the producer's short-run pricing policy would be dictated by the shape of the marginal cost curve, the average variable cost curve and the demand curve for the product. If the firm can't escape its fixed costs by shutting down in the short run, then it must be content with maximizing the difference between total revenue and total variable cost. Thus, the relevent economic concept for considering short-run pricing decisions is the firm's short-run marginal cost curve which is dependent only upon variable cost. So long as average variable costs are covered in the short run, the firm will stay in business even if it finds it must produce at a short-run loss.

Most firms are not so constrained by competition that they are only attempting to recover variable cost. Rather, they employ what is known as the full cost pricing method. This involves a constant percentage markup over total unit cost, i.e., average variable plus average fixed cost. Clearly if the demand for a firm's product is such that it could recover the full change in its average total costs in the short run, then it would find this to be the most effective pricing strategy. Yet depending on the firm's competitive environment, it may not be possible to achieve a total cost passthrough quickly and the firm will only cover average variable cost. It is difficult to specify precisely how a firm will change its prices in the face of increasing production costs. One can parameterize the range of price changes by assuming different pricing strategies and calculating the percentage price changes based on percentage changes in both average variable cost and average total cost.

In order to make clear this point on pricing policy, it must be underscored that the economic impacts discussed in the final chapter depend critically on the assumed price strategy, whether it be based on changes in variable cost, on changes in total cost, or on some variant thereof. In the case of some chemicals, it is more likely that a given industry structure would yield a pricing policy closer to one of the extremes of pricing to cover variable cost or total cost. Nonetheless, the full range of possible outcomes is tabulated by showing both total and variable cost changes, associated price changes, and the resulting impacts on demand.

These results are generally discussed for the industry as a whole and as if they were "once and for all" changes. In fact, individual producers may have quite different responses to pollution control induced expenditures. Some producers may elect to recover their increased costs by a gradual set of price increases which test customer reaction. Conversely, other producers may choose to recover cost changes in one, complete price change.

This approach is supported more by the standard microeconomic theory and provides for a more conservative estimate of future plant profitability. It should be clear, however, that the short-run price effect and the total cost recovery price effect provide a range of possible price effects due to near-term waste standards. What the actual price impact will be depends upon the pricing behavior of the industry. In other words, different models may apply to different chemicals.

The short-run effect on price of compliance with proposed regulations is based upon the assumption that the firms are profit maximizers and the supply function would shift upward by the change in marginal cost. The new equilibrium price would then be determined by the intersection of supply and demand. As an alternative to the standard competitive model, a price could also be calculated which reflected the total change in cost (fixed and variable) by including annual capital cost along with operating cost changes. The present example of the short-run analysis assumes that the degree of price change is dictated by the change in variable cost.

Having discussed the four different inputs to the short-run impact analysis, the entire procedure can be described with an example in terms of product X. The following notation is used:

$\Delta D_x$ = change in demand for product x due to a change in price,

$e_x$ = price elasticity of demand for product x,

$\Delta VC_x$ = change in variable cost due to compliance with hazardous waste control regulations. (This example could also have been done in terms of $\Delta TC_x$ = .)

The change in quantity demanded is the product of the econometric estimate of $e_x$, and $\Delta VC_x$ which can be computed from a comparison of the cost of compliance data with engineering estimates of total variable cost,

$$\Delta D_x = e_x \; ( \Delta VC_x)$$

This calculation can be clarified by a numerical example. Suppose that the incremental total annual variable cost associated with treating and disposing of hazardous waste for product "x" in order to achieve Level III technology is $500,000 for a model plant in 1975. The total annual variable cost (exclusive of hazardous waste treatment and disposal costs) of producing "x" is $15,000,000 at a model plant in 1975. Dividing each of these cost estimates by the assumed level of annual production puts them on a unit variable cost basis. If the quantity produced is assumed to be 100,000 units, then $\Delta VC_x$ would be

$$\Delta VC_x = \frac{(500{,}000)/100{,}000}{(15{,}000{,}000)/100{,}000} = \frac{5}{150}$$

$$= 3.3\%$$

Then, if the price elasticity of demand for product "x" were estimated to be 0.9, the percent change in demand would be

$$\Delta D_x = .9(3.3\%)$$

$$= 3.0\%$$

A knowledge of the industry and its business practices would then be required to interpret whether this 3 percent reduction in quantity demanded would be a severe and immediate impact, and whether it would fall more heavily on a certain segment of the industry.

It should be noted that, other things being equal, products with relatively more elastic demands will experience greater demand reduction for a given change in price than will those products with less elastic demands. This is so because in response to a given change in price, demand declines by more than a proportionate amount.

This type of short-run analysis implies the following assumptions:

- producers apply the same percentage mark-up to costs whether they be normal production, costs of production or increased operating costs due to pollution control. Therefore, the percentage change in prices will be the same as the percentage change in costs ;
- producers operate on a full-year basis at, or near, capacity;
- the typical plant is an accurate depiction of the industry; and
- there is no significant scale difference in unit cost estimates between treatment cost data and variable manufacturing cost data, although such estimates are sometimes based on different plant capacities.

These assumptions can be relaxed and different values of $\Delta VC$ and e can be used in order to test the sensitivity of the results. Chapter VIII includes a discussion of some of these sensitivity analyses.

The following section outlines how a firm's decision to close a plant can be analyzed. By using discounted cash flow analysis, it is possible to identify the effect that probable shifts in demand will have on marginal plants. These plants would be expected to be most severely impacted by the cost of hazardous waste regulations.

5. Plant Shutdown Analysis Methodology.

a. Introduction. The plant shutdown decision on the part of the producer is complex, involving both economic and non-economic considerations. If treatment costs cannot be passed on as price increases, a producer absorbs these costs or shuts down his plant. Considerations which will affect the shutdown decision are:

Profitability: The after-tax cost of waste treatment per ton of product produced compared with the unit after-tax net income measures the producer's ability to absorb the added cost.

Cash Flow: Plants probably will continue operating temporarily at zero profitability (if necessary) if the plant is producing a positive cash flow, particularly if it is in a stable or growing market.

Ratio of Investment in Treatment Facilities and Net Fixed Investment: If the new investment in hazardous waste management is large in comparison with existing plant investment (and other factors are marginal), there will be a greater inclination for the producer to shut down plant facilities rather than make the investment in effluent treatment. In some instances the availability of capital to the producer may influence the shutdown decision.

Integration: The degree of backward or forward integration is a factor in the shutdown decision. The producer with a significant raw material position or one using the product for downstream manufacture is less likely to curtail production than the non-integrated producer.

Chemical Complex: The existence of plants in complexes may tend to [illegible] of plant shutdown because of the effect on other elements of the complex.

Other Environmental Problems: If a company faces a substantial water and air pollution abatement (and/or unusual OSHA costs), the magnitude of the environmental cost taken together may prompt plant closing whereas any one taken alone would not.

Emotional Commitment: The emotional commitment of a company to that particular product under consideration (taking into account protection of competitive position, prestige, history of the product in the company's development and importance of the product in the company's long-range strategy) may be a factor in the shutdown decision.

Ownership: Other things being equal, multi-industry companies are more likely to shut down marginal plants than less diversified producers. The premise is that the multi-industry company has other (and better) investment opportunities than the single-product company, particularly a privately-held family business.

In reaching decisions concerning probable future plant closures, qualitative judgment must take into account the factors specified above. In many cases, one or two factors may assume overwhelming importance and this can change from situation to situation.

b. Financial Analysis. A quantitative investment analysis was performed in addition to an evaluation of the qualitative factors which affect the plant shutdown decision. The investment analysis was based on model plant manufacturing and treatment costs which are representative of typical plants for the primary affected chemicals. They should not be viewed as being representative of an individual plant situation. Utilizing these model plants, a discounted cash flow analysis (DCF) was performed in order to assess the investment implications of hazardous waste treatment investment requirements as a factor in determining the potential for plant shutdown.

A ten-year scenario from the date hazardous waste treatment would be required was tested via DCF analysis for the model plants. If the Net Present Value (NPV) of expected cash flows under this scenario is negative, it is reasonable to assume that plant shutdown from the effects of hazardous waste treatment investment can be expected.

Estimates of economic parameters for plant models (e.g.,operating costs, waste treatment and disposal costs, salvage value, working capital) are based on process economic analysis of the model plant. The model plant's cost estimates are included in Chapter IV, Characterization of Primary Affected Chemicals. Prices are based on current average market prices (1975) for the primary affected chemicals.

The financial ratios were based on the model plant manufacturing and total treatment costs, although these factors, in particular, vary from plant to plant. Based on industry interviews, an attempt was made to determine the variability of these costs. A sensitivity analysis was performed where it was felt that the variability from the model plant costs would have a different economic impact.

Future prices will depend on manufacturing cost changes as well as pollution control costs. Since manufacturing cost changes have not been forecasted, a constant profit margin has been assumed over the period of the investment analysis. The profit margin will vary from year to year, although over the long-term the profit margin should, on average, approximate a producer's desired profit margin. The impact of waste treatment costs on future prices depends on the producer's ability to pass on treatment and disposal costs through price increases (see Section C. 4.). The plant shutdown impact analysis considers the marginal producer who may be unable to recover waste treatment costs and in the DCF analysis, profit margins have been reduced based on estimated waste treatment costs. The investment analysis is done in 1975 constant dollars.

c. Discounted Cash Flow. A discounted cash flow (DCF) analysis was used to determine if producers would close their plants rather than invest in the required hazardous waste management facilities. The DCF analysis determined whether the net present value of the future cash flows of the model plant was greater than the required capital investment in waste treatment facilities.

The basic equation underlying the DCF analysis is:

$$NPV = \sum_{t=1}^{N} \frac{CF_t}{(1+r)^t}$$

where: NPV = net present value

$CF_t$ = net cash flow in period t

r = discounted rate

The cash flow in the DCF analysis is summarized as follows:

$$CF_t = P_t R_t C - COE_t - INV_t - TAX_t - SALV_o + SALV_t$$

where:

$P_t$ = product price in period t

$R_t$ = operating rate in period t

C = plant capacity in physical units in period t

$SALV_t$ = salvage value of project in last year of analysis

$COE_t$ = cash operating costs in period t, exclusive of interest and federal taxes

$INV_t$ = investment cash outlay in period t (including working capital)

$TAX_t$ = federal income tax paid in period t

The recovery value ($SALV_o$) of the plant in year 0 is included in the analysis because this is an opportunity cost as a result of not closing the plant.

A shortcoming to the approach is that it is based on a model plant economics and major uncertainties about future market prices, volume, costs etc. As a result, in certain instances, sensitivity to these factors were considered. Based on the DCF analysis as well as qualitative judgements about the primary affected chemicals, the liklihood of plant shutdowns was assessed.

6. Long-Run Economic Impact Analysis. In the long run, capital expansion takes place based upon the prevailing conditions of supply and demand in the industry. To make a complete determination of the long-run effects of pollution control expenditures it would be necessary to know the industry cost of capital, other aspects of industry cost, and the rate of demand growth. The critical element to such an analysis would be an estimate of the cost of capital or required rate of return that would apply to the industry, both with and without pollution controls. This cost of capital would then be used to calculate the long-run price that would be required to attract and maintain capital in the industry.

For a number of reasons it was not possible to develop econometric estimates of the long-run industry supply curve. This makes it more difficult to quantify a precise long-run economic impact. However, the short-run analysis provides a sound analytic basis from which to judge what the most likely long-run effects might be. Also it is clear that in the long-run all producers must fully recover any changes in their average total costs which are due to compliance with hazardous waste management regulations. Given the short-run impacts and several data and time constraints, estimates of the long-run changes in price that will most likely result from full compliance with the proposed regulations have been developed. These estimates are of necessity less precise than the short-run impacts.

## D. Limitations of Analysis

The methodology adopted and developed in this report has the following general drawbacks:

1. Segmentation of Industry. Early in the study, it was determined that five chemical products (chlorine, titanium dioxide, elemental phosphorus, hydrofluoric acid, and sodium dichromate) would be the primary focus of attention. This decision was based on the size of the markets for these chemicals and the magnitude of the ratio of estimated treatment costs to product list price. The remaining chemicals have by no means been excluded from the analysis, but simply were looked at in less depth. This partitioning process has, in effect, been the result of an assumption that any economic impacts in the second category of chemicals will be of such a minimal nature as to have little bearing on the broad level of domestic economic activity.

2. Sources of Error. By necessity, all of the estimates made as part of the study are subject to varying degrees of error. Sources of error can be from the lack of required data, the statistical properties of estimation based on sampling from a population, or simple human fallibility. Places where error will occur are, first, in the cost estimates contained in the Assessment Report. The Assessment Report Contractor estimated the following percent error in their hazardous waste treatment and disposal cost estimates:

| SIC Code | Classification | Major Products | % Error |
|---|---|---|---|
| 2812 | Chlor-Alkalis | Chlorine | ± 20% |
| 2816 | Inorganic Pigments | Titanium Dioxide<br>Chrome Pigments<br>Iron Blues | ± 40-50% |
| 2819 | Industrial Inorganic Chemicals, n.e.c. | Hydrofluoric Acid<br>Phosphorus | ± 40-50% |

A second area which is subject to measurable error is the econometric model. Each estimated coefficient has a standard error associated with it. These errors are reflected in the price elasticities of demand.

Finally, engineering estimates of manufacturing costs are subject to some identifiable error which is indicated by those making the actual estimates. Taken together, it will be necessary to qualify any final judgments on economic impact by noting that all of the inputs to this estimate were less than perfectly precise.

3. Other Regulations and Costs. The analysis deals only with the impacts of compliance with probable hazardous waste management control guidelines. Possible effects of effluent, air, or OSHA regulations are not considered.

4. Microeconomic Model. The conceptual microeconomic model used in this study is primarily one of pure competition. In this case, it is assumed that there are many sellers of a homogeneous product, with no barriers to entering the market and with perfect information on the part of all sellers. Thus, no seller has any control over price (i.e., all market participants are price takers). For many of the chemical products in this study, the assumptions of numerous sellers and no barriers to entry may be violated. Whether or not the performance of the industry is different from what would obtain under pure competition is quite a different matter. There is not enough evidence to refute an hypothesis that the industry is workably competitive. For this reason, the purely competitive model has been retained for the most part even though some of its assumptions have been violated. It may be that in some cases profit levels are resulting in rates of return greater than the cost of capital earned within the industry. If this is true, then the price rises (or quantity reductions) may be greater (or less) than we have estimated.

5. Single Industry. This study is in the tradition of a partial equilibrium analysis in that it considers only the economic impacts of pollution abatement regulations within a single industry. The necessary resources were not available for a full general equilibrium analysis which would trace through the inter-industry effects of compliance.

6. Forecasting. As with any study which attempts to forecast future events, these estimates are subject to increasing inaccuracy as they extend forward in time.

## VIII. ASSESSMENT OF ECONOMIC IMPACT

### A. Primary Affected Chemicals

1. Chlorine.

a. Treatment and Disposal Costs. The total cost for Level III control of hazardous waste from mercury cell chlorine is $4.08 per metric ton of product in 1975 dollars, according to the Assessment Report. These model plant costs are for off-site secured landfill within a 50-mile radius. Actual treatment costs to be experienced by specific plants can be highly site specific. For this reason, the model plant costs are used as generally indicative of actual costs and may not be applicable to any particular plant. For example, industry contacts have indicated that the Assessment Report treatment costs substantially understate treatment costs because adequate landfill sites may be several hundred miles from the plant site.

b. Short-Term Impact.

(1) Prices. Producers of mercury cell chlorine will have limited ability to recover full waste treatment costs through price increases. Mercury cell treatment costs are more than ten times greater than for diaphragm cell plants, which are also lower-cost producers in the absence of the hazardous waste costs. In view of the competitive nature of the industry, with more than 35 producers, the producers with higher treatment costs will be prevented from full recovery of treatment costs. The industry has experienced relatively high capacity utilization, moderate demand growth, and low foreign trade. The high level of captive usage of chlorine and the limited number of substitute products are factors which mitigate the price increase constraints and should allow full cost recovery by the diaphragm producers (see Table VIII-1). Some producers may be

TABLE VIII-1

PRICE INCREASE CONSTRAINT FACTORS - CHLORINE

| | Chlorine Mercury Cell |
|---|---|
| All Processes: | |
| 1975 Production (Thousand Metric Tons) | 3,257 |
| 1975 Unit Value ($/ Metric Ton Chlorine) | 105 |
| 1975 Production Value ($MM) | 867 |
| Number of Plants (Current) | 67 all chlorine<br>27 mercury cell |

| PRICE INCREASE CONSTRAINTS | | | |
|---|---|---|---|
| Factor | Condition for Constraint | Treatment | |
| Ratio of Incremental Before-Tax Treatment Cost to Selling Price per ECU (%) | High | Level III | 1.8 |
| Substitute Products | High Occurrence | | Low |
| Capacity Utilization | Low | | 95% |
| Captive Usage | Low | | 62% |
| Demand Growth | Low | | 6%/yr. |
| Foreign Competition | High | | Low |
| Abatement Cost Differences | Unequal | | Unequal |
| Price Elasticity of Demand | High | | Low to Moderate |
| Basis for Competition | Price | | Price |
| Market Share Distribution | Fragmented | | Concentrated |
| Number of Producers | Many | | 30 |
| Substitute Process | Many | | Few |

able to recover part of the treatment costs because of location or contract provisions, but full recovery of solid waste treatment costs by mercury cell producers is unlikely.

(2) Demand. Chlorine has had an historically low price elasticity of demand of -0.36 ($\Delta D/\Delta P$). Price increases because of hazardous waste treatment costs therefore have a limited impact on the demand for chlorine. Table VIII-2 lists the potential demand changes resulting from a range of price changes under two pricing strategies. The demand values are for the entire industry, not an individual plant, and the prices are industry-wide values.

The producer can either be pursuing a full cost recovery pricing strategy or in some highly competitive situations he may be pricing so as to only recover his variable costs. Faced with the treatment costs, the producer represented by the model plant could either attempt to recover the incremental total manufacturing costs of the plant, 2.8 percent, or the incremental variable costs, 3.5 percent, depending on which pricing strategy his current prices represent. On a longer-term basis the operator will always attempt to recover the incremental total treatment costs. Independent of what the operator's cost recovery objectives are, competitive demand may only allow a partial recovery in the short term. Table VIII-2 lists the demand changes, assuming different levels of passthrough of treatment costs under the two pricing strategies.

If the model plant producer were to attempt to recover the total hazardous waste treatment costs of 2.8 percent of total manufacturing costs and is allowed 100 percent passthrough, demand would drop one percent to 8.12 million tons. A 50 percent cost passthrough would result in 0.5 percent demand reduction to 8.16 million tons. As mentioned above, the cost advantage of diaphragm producers

TABLE VIII-2

IMPACT OF HAZARDOUS WASTE COSTS ON PRICE AND DEMAND
(CHLORINE MERCURY CELL)*

| Cost change ($/metric ton) | Percent cost change | Percent passthrough | Price ($/metric ton) | Demand (1,000's metric ton) |
|---|---|---|---|---|
| Change in total cost | | | | |
| 3.56/126.33 | 2.8% | 100 | 107.94 | 8120 |
| | | 50 | 106.47 | 8160 |
| | | 0 | 105.00 | 8200 |
| Change in variable cost | | | | |
| 3.56/102.81 | 3.5% | 100 | 108.68 | 8100 |
| | | 50 | 106.84 | 8150 |
| | | 0 | 105.00 | 8200 |

*Source: Contractor's estimates.

Notes:
1. The total manufacturing plant costs of the Arthur D. Little model are $126.33 per metric ton of product; variable costs are $102.81 per ton.
2. A percentage change in cost (total or variable) is assumed to be reflected in an equal percentage change in price at 100 percent cost passthrough.
3. The demand is for all chlorine, not just mercury cell production.
4. The manufacturing and control costs are for chlorine and caustic together. The percent allocation of manufacturing costs to each product is assumed to apply for the hazardous waste costs.
5. The $105 price is for chlorine. The commercial price per ECU of chlorine and caustic soda together (which corresponds to the total manufacturing cost) was $178 in 1975.

suggests the mercury cell producers will be able to change prices only to the limit of changes at diaphragm plants. If demand cannot be met by diaphragm plants, the mercury cell producers will have more price flexibility. As a conservative estimate, one can say that chlorine from mercury cells is being priced at full cost recovery but that competitive constraints will not allow price increases in the short run to recover the hazardous waste management costs.

(3) Profitability. The after-tax total treatment cost for the model plant is 7.8 percent of the estimated plant level net income (see Table VIII-3). The profitability levels have been determined from current market prices and estimated model plant manufacturing costs. The impact on profitability of treatment costs will vary for individual producers depending on their actual manufacturing costs and revenues. If producers of mercury cell chlorine are unable to recover treatment costs, the impact on profitability for the model plant would be moderate and not enough to result in a negative cash flow position for the plant.

c. Plant Shutdown Impact. No plant shutdowns are expected as a result of hazardous waste management costs. Even if the model plant were required to absorb the total hazardous waste treatment costs of $4.08/ton, the net present value of the investment in waste treatment is $25 million, based on a 15 percent cost of capital (see Table VIII-4). The investment in waste treatment would provide a positive return for the model plant, and, therefore, most producers are expected to take the necessary steps to meet hazardous waste requirements. Even under Case II assumptions, a positive return is obtained. It would require a combination of adverse circumstances, including a lower operating rate, higher manufacturing costs, and higher treatment costs because of an excessive distance to a secured landfill, for a plant shutdown to occur.

TABLE VIII-3

PLANT SHUTDOWN DECISION FACTORS - CHLORINE

| PLANT SHUTDOWN DECISION | | | |
|---|---|---|---|
| Factor | Condition for Shutdown | Treatment Level | Chlorine Mercury Cell |
| Ratio of AT Total Treatment Cost to AT Net Income (%) | High | III | 7.8% |
| Cash Flow (Including Treatment Costs) | Negative | | Positive |
| Ratio of Investment in Treatment Facilities to Net Fixed Investment (%) | High | III | 0 |
| Integration | Low | | High |
| Chemical Complex | Isolated Plant | | Complex |
| Other Environmental Problems (Including OSHA) | Multiple | | Nominal |
| Emotional Commitment | Indifference | | Low to High |
| Ownership | Multi-Industry Companies | | Multi-Industry |

TABLE VIII-4

SUMMARY OF SOLID WASTE TREATMENT INVESTMENT ANALYSIS FOR MERCURY CELL CHLORINE MANUFACTURE*
(1975)

| | Case I (model plant) | Case II |
|---|---|---|
| Commercial price per ECU (1975) | $178 /metric ton [c] | $178 /metric ton |
| Manufacturing costs | $126/metric ton | $135/metric ton |
| Total treatment costs (level III technology) | $4.08/metric ton (no capital investment) | $15/metric ton (no capital investment) |
| Average annual operating rate | 90% | 80% |
| Average annual production | 163,300 metric tons | 145,200 metric tons |
| After-tax cash flow | $40.5/ton | $35/ton |
| Net present value[a] (15% cost of capital)[b] | $24.9 MM | $17.4 MM |

*Source: Contractor's estimates.

a. Based on 10-year investment.

b. Weighted average cost of capital projected at 14.6% over the 1976-1980 period for the chemical industry, unpublished paper, "Cost of Capital Study", Professor Gerald A. Pogue, June 1975.

c. The $178 price of chlorine and caustic (1 to 1.1 tonnage ratio) is the composite of 1975 chlorine and caustic soda commercial shipment prices of $105 and $66 per ton respectively.

2. Hydrofluoric Acid.

a. Treatment and Disposal Costs. Assuming the solid waste from hydrofluoric acid manufacture is determined to be hazardous and must be treated accordingly, the total treatment costs in 1975 to achieve Level III technology for the model plant are $18.90 per metric ton for Option 4. The total required capital investment would be 19.6 percent of gross fixed investment.

The hazardous waste treatment costs are highly site-specific, and, therefore, the application of the model plant treatment costs to the entire industry would not be appropriate in all cases. For example, plants on the Gulf Coast, where there is a high water table, may find it impossible to find a suitable site where a secured landfill can be established at the costs developed for the model plant. Treatment costs could be 100-200 percent higher than the estimated Level III costs for the model plant.

b. Short-Term Impact.

(1) Prices. Smaller domestic producers of hydrofluoric acid will have difficulty fully recovering waste treatment costs through price increases. The treatment costs are expected to be higher for small plants, and in view of the competitive situation in the industry, they will be prevented from full recovery of treatment costs. Price increases will be based on the treatment costs at the larger plants which determine industry pricing. The industry is faced with low capacity utilization in relation to historical levels, limited demand growth, and high foreign imports (see Table VIII-5). Assuming a model plant producer could recover his full incremental treatment costs and was pricing at full cost recovery, price increases would be 1.7 percent (see Table VIII-6).

TABLE VIII-5

PRICE INCREASE CONSTRAINT FACTORS - HYDROFLUORIC ACID

| | | | Hydrofluoric acid |
|---|---|---|---|
| All Processes: | | | |
| 1975 Production (Metric Tons) | | | 284,000 |
| 1975 Unit Value ($/Metric Ton) | | | 600 |
| 1975 Production Value ($MM) | | | 170 |
| Number of Plants (Current) | | | 12 |
| PRICE INCREASE CONSTRAINTS | | | |
| Factor | Condition for Constraint | Treatment Level III | |
| Ratio of Incremental Solid Waste Disposal Cost to Selling Price (%) | High | | 1.4% |
| Substitute Products | High Occurrence | | Direct - Moderate<br>Secondary - Moderate |
| Capacity Utilization | Low | | 96% - 1974 (high)<br>80% - 1975 (low) |
| Captive Usage | Low | | About 60% |
| Demand Growth | Low | | (0-2%) - low<br>(1974-1980) |
| Foreign Competition | High | | High |
| Abatement Cost Differences | Unequal | | Unequal |
| Price Elasticity of Demand | High | | High (-1.91) |
| Basis for Competition | Price | | Price |
| Market Share Distribution | Fragmented | | Conc: 4 with 80% |
| Number of Producers | Many | | 8 |
| Substitute Process | Many | | None |

TABLE VIII-6

IMPACT OF HAZARDOUS WASTE COSTS ON PRICE AND DEMAND
(HYDROFLUORIC ACID)*

| Cost change ($/metric ton) | Percent cost change | Percent passthrough | Price ($/metric ton) | Demand (1,000's metric ton) |
|---|---|---|---|---|
| Change in total cost | | | | |
| 8.28/484.48 | 1.7% | 100 | 610.20 | 290.2 |
| | | 50 | 605.10 | 295.1 |
| | | 0 | 600.00 | 300.0 |
| Change in variable cost | | | | |
| 0.78/440.82 | 0.2% | 100 | 601.20 | 298.8 |
| | | 50 | 600.60 | 299.6 |
| | | 0 | 600.00 | 300.0 |

*Source: Contractor's estimates.

Notes:
1. The total manufacturing plant costs of the Arthur D. Little model are $484.48 per metric ton of product. The model plant variable costs are $440.82 per ton.
2. A percentage change in cost (total or variable) is assumed to be reflected in an equal percentage change in price at 100 percent cost passthrough.

The high level of captive usage of hydrofluoric acid and the limited number of substitute products are factors which mitigate the price increase constraints. Some producers may be able to recover a part of the treatment costs through other end products.

(2) Demand. Hydrofluoric acid has had an historically high price elasticity of demand of -1.91 ($\Delta D/\Delta P$). Price increases because of hazardous waste treatment costs, therefore, have a significant impact on the demand for hydrofluoric acid. Table VIII-6 lists the potential demand changes resulting from a range of price changes. The demand values are for the entire industry, not an individual plant, and the prices are industry-wide values. Table VIII-6 lists the demand changes assuming different levels of passthrough of treatment costs and different pricing strategies, as discussed for chlorine.

The incremental variable cost from hazardous waste treatment (Option 1 to Option 4) is estimated at 0.2 percent for the model plant. With 100 percent passthrough, demand would drop 0.38 percent while with only a 50 percent passthrough, demand would drop 0.19 percent. Depending on the producers' ability to raise prices to recover variable cost increases, it will have a varying impact on demand.

If a producer attempts to recover total treatment costs (fixed and variable) associated with hazardous waste treatment, the impact on demand will be higher. The incremental total treatment cost is estimated at 1.7 percent for the model plant. With a 100 percent passthrough, demand would be reduced 3.2 percent and with only 50 percent passthrough, demand would be reduced 1.6 percent. Producers historically appear to have been pricing at full cost recovery during a period of high demand growth and high capacity utilization. In the short run, the price leaders will probably not be able to raise prices to fully recover incremental costs. Price increases covering 0 to 50 percent of the hazardous waste costs would probably be seen.

(3) Profitability. The after-tax total treatment costs for the model plant are 16.4 percent of the estimated net income at the plant level (see Table VIII-7). The profitability levels have been determined from current market prices and estimated model plant manufacturing costs. The impact on profitability of treatment costs will vary for individual producers depending on their actual manufacturing costs and revenues. For producers with higher than expected treatment costs, the impact on profitability could be severe because of their inability to fully recover higher treatment costs. The treatment costs for certain producers could result in a reduction of after-tax profits of 100 percent based on having to bear full treatment costs at triple the level estimated in the Assessment Report and lower operating rates (see Table VIII-8).

c. Plant Shutdown Impact. The anticipated closing of at least one to two hydrofluoric acid plants over the next five years is expected to be accelerated by hazardous waste management costs. With the low growth outlook and increasing foreign competition, the domestic industry is faced with over-capacity through 1980. Although industry cash flow is expected to remain positive, integration is high and the impact on profitability or investment is not excessive for the model plant, the market uncertainty and the competitive environment, combined with the hazardous waste costs, may result in the closure of a few small plants earlier than otherwise anticipated. Some smaller producers may be able to meet Level III treatment requirements at a small incremental cost. However, if a small plant with high manufacturing costs is also faced with total waste treatment costs, the plant shutdown potential is increased.

TABLE VIII-7

PLANT SHUTDOWN DECISION FACTORS - HYDROFLUORIC ACID

| PLANT SHUTDOWN DECISION | | | Hydrofluoric acid |
|---|---|---|---|
| Factor | Condition for Shutdown | Treatment Level III | |
| Ratio of AT Total Treatment Cost to AT Net Income (%) | High | | 16.4% |
| Cash Flow (Including Treatment Costs) | Negative | | Positive |
| Ratio of Investment in Treatment Facilities to Net Fixed Investment (%) | High | Option 3<br>Option 4 | 9.0%<br>14.8% |
| Integration | Low | | High |
| Chemical Complex | Isolated Plant | | Isolated and complex |
| Other Environmental Problems (Including OSHA) | Multiple | | Water pollution |
| Emotional Commitment | Indifference | | None |
| Ownership | Multi-Industry Companies | | Multi-industry |

TABLE VIII-8

SUMMARY OF SOLID WASTE TREATMENT INVESTMENT ANALYSIS FOR HYDROFLUORIC ACID MANUFACTURE-1975*

| | Case I (model plant) | Case II |
|---|---|---|
| Commercial price (1975) | $600/metric ton | $600/metric ton |
| Manufacturing costs | $485/metric ton | $530/metric ton |
| Total treatment costs[a] (level III technology) | $18.90/metric ton | $57.2/metric ton |
| (capital investment) | ($1.04 MM) | ($3.11 MM) |
| Average annual operating rate | 90% | 80% |
| Average annual production | 20,860 metric tons | 18,500 metric tons |
| After-tax cash flow | $81.2/ton | $49.8/ton |
| Net present value[b] (15% cost of capital) | $6.4 MM | $0.10 MM |

*Source: Contractor's estimates.

a. Treatment costs are stated as per ton of capacity.

b. Based on 10-year investment.

The net present value of the hazardous waste treatment investment for a model plant faced with total treatment costs is $6.4 MM, based on a 15 percent cost of capital (see Table VIII-8). Based on this analysis, the producer with a model plant would obtain a reasonable return on the required investment for hazardous waste treatment. Case II examines the situation where a producer is faced with high manufacture costs, high or total treatment costs and an operating rate comparable to current industry operating levels. The NPV of the waste treatment investment for this plant based on a 15 percent cost of capital is marginally positive at $0.1 MM. The return is marginal because under other less favorable operating and economic conditions the net present value is potentially negative. Faced with a marginal return on investment, and considering (1) the competitive environment in the industry, and (2) the producer's own captive requirements, a producer may consider a plant shutdown.

3. Elemental Phosphorus.

a. Treatment Costs. Assuming the solid waste from elemental phosphorus manufacture is determined to be hazardous and must be treated accordingly, the 1975 treatment costs for a model phosphorus plant are $6.9/metric ton of phosphorus to achieve Level III technology, according to the Assessment Report. These treatment costs are 0.7 percent of 1975 estimated selling price. Incremental treatment costs are 0.4 percent of the selling price. In addition, the investment requirements are 2.5 percent of gross plant investment for the model plant.

The treatment costs for hazardous waste disposal are site-specific so that the model plant treatment costs cannot be assumed to represent the actual cost for each producer. The treatment costs depend on plant size, land availability and cost, local soil conditions, and waste loads. The last two factors have particular importance in elemental phosphorus manufacture. The plants located in western states have a lower waste load to treat because of higher grade ore which is processed. In addition, soil conditions are such that the installation of a secured landfill necessary for Level III technology could be achieved in line with the model plant treatment costs. Elemental phosphorus plants located in other areas of the country, because of higher waste loads and permeable soil conditions, could require significantly higher treatment costs in order to achieve Level III technology. Industry contacts have indicated that the Level III hazardous waste treatment costs may be 100-200 percent higher than the model plant treatment costs in some cases.

b. Short-Term Impact.

(1) Prices. Producers of elemental phosphorus have had pricing flexibility in recent years to pass on increased costs through price increases. The producer's ability to pass on cost increases in the future will be more limited. The low capacity utilization in the industry (see Table VIII-9), low demand growth, and high price elasticity of demand are factors which will limit elemental phosphorus producers' pricing flexibility in the future. The concentration and high captive usage in the industry offset these factors and will probably allow some recovery of treatment costs.

However, with the unequal treatment costs expected between plants located in different areas of the country, price increases will probably be limited to treatment costs incurred by western plants. The reduced pricing flexibility in the future will prevent producers with higher treatment costs from fully recovering increased costs through price increases.

TABLE VIII-9

PRICE INCREASE CONSTRAINT FACTORS - PHOSPHORUS

| | | | Phosphorus |
|---|---|---|---|
| All Processes:<br>1975 Production (metric tons)<br>1975 Unit Value ($/metric tons)<br>1975 Production Value ($MM)<br>Number of Plants (Current) | | | <br>408,000<br>987<br>408<br>10 |
| PRICE INCREASE CONSTRAINTS | | | |
| Factor | Condition for Constraint | Treatment Level III | |
| Ratio of total incremental solid waste disposal cost to selling price | High | | 0.4% |
| Substitute Products | High Occurrence | | Direct - Low<br>Secondary - Low<br>Tertiary - High |
| Capacity Utilization | Low | | Low (75%) |
| Captive Usage | Low | | High |
| Demand Growth | Low | | Low (0-2%) |
| Foreign Competition | High | | Low |
| Abatement Cost Differences | Unequal | | Unequal |
| Price Elasticity of Demand | High | | High (-2.18) |
| Basis for Competition | Price | | price; (commodity product) |
| Market Share Distribution | Fragmented | | Concentrated (3 producers with 81%) |
| Number of Producers | Many | | 10 |
| Substitute Process | Many | | None |

Assuming the model plant treatment costs would be applicable to a western plant, the price increases resulting from full recovery of model plant incremental treatment costs would be 0.4 percent of the 1975 estimated selling price.

(2) Demand. Elemental phosphorus has historically had a high price elasticity of demand. This is significant in view of the fact that phosphorus is primarily an intermediate for other end products. Environmental restrictions on the use of phosphate-based detergents in recent years bias the price elasticity analysis, but with an adjustment for the impact of regulatory restrictions, the price elasticity of demand for phosphorus is still high at -2.18.

Depending on his current pricing strategy, the producer represented by the model plant will either change prices in proportion to the percentage change in total manufacturing costs of the plant, or the variable costs as a result of the hazardous waste management costs. Independent of what the operator's cost recovery objectives are, competitive demand may only allow a partial recovery in the short term. Table VIII-10 lists the demand changes, assuming different levels of passthrough of treatment costs, as well as the different pricing strategies.

The treatment costs for the model plant are modest, and the change in total costs resulting from hazardous waste treatment costs (Option 1 to Option 3) are only 0.7 percent. The short-term impact on demand will vary depending on the producers' ability to fully recover costs through price increases. With 100 percent passthrough, demand would decline 1.5 percent, while a 50 percent passthrough would result in a 0.8 percent decline in demand.

Since price increases are expected to be limited to the cost impact on the model plant because of the competitive situation in the industry, the impact on demand will be minimized. If all producers were able to pass on their total treatment cost increases, the reduction in demand based on the price elasticity

TABLE VIII-10

IMPACT OF HAZARDOUS WASTE COSTS ON PRICE AND DEMAND
(ELEMENTAL PHOSPHORUS) *

| Cost change ($/metric ton) | Percent cost change | Percent passthrough | Price ($/metric ton) | Demand (1,000's metric ton) |
|---|---|---|---|---|
| Change in total cost | | | | |
| 4.33/675.74 | 0.7% | 100 | 983.07 | 403.7 |
| | | 50 | 986.54 | 406.9 |
| | | 0 | 990.00 | 410.0 |
| Change in variable cost | | | | |
| 0.13/545.41 | 0.02% | 100 | 984.80 | 409.8 |
| | | 50 | 984.90 | 409.9 |
| | | 0 | 990.00 | 410.0 |

*Source: Contractor's estimates.

Notes: 1. The total manufacturing plant costs of the Arthur D. Little model are $675.74 per metric ton of product. The model plant variable costs are $545.41 per ton.

2. A percentage change in cost (total or variable) is assumed to be reflected in an equal percentage change in price at 100 percent cost passthrough.

of demand could be more significant because of the expected higher treatment costs faced by certain plants.

At present, producers appear to be pricing at full cost recovery. If the compliance costs are as small as the model plant incremental costs (0.4 percent of price), the price leaders would be able to increase prices to recover most of the costs.

(3) Profitability. The after-tax treatment costs for the model plant are 2.2 percent of estimated after-tax net income at plant level. If elemental phosphorus producers are unable to recover treatment cost increases, the impact on profitability for the model plant will be small. For producers with higher expected treatment costs, the impact on profitability will be more significant because of their inability to raise prices to fully recover their costs. The treatment costs for certain producers could result in a reduction of after-tax plant profits of 4-6 percent based on total treatment costs 100-200 percent higher than the estimated model plant costs.

c. Plant Shutdown Impact. No plant shutdowns are expected because of hazardous waste treatment costs. Although not all producers will be able to fully recover treatment costs, the level of profitability in the industry will allow the producers to absorb these cost increases in their profit margins. In addition, cash flow is expected to continue to be positive, the investment requirements are a modest percent of gross fixed investment, and with the level of integration in the industry (see Table VIII-11), these factors will mitigate any plant shutdown decisions. Producers with higher treatment costs than the model plant treatment costs are not expected to shut down, although their level of profitability will be more adversely impacted.

TABLE VIII-11

PLANT SHUTDOWN DECISION FACTORS - PHOSPHORUS

| PLANT SHUTDOWN DECISION | | | Phosphorus |
|---|---|---|---|
| Factor | Condition for Shutdown | Treatment Level III | |
| Ratio of Total AT Treatment Cost to AT Net Income (%) | High | | 1.9% |
| Cash Flow (Including Treatment Costs) | Negative | | Positive |
| Ratio of Investment in Treatment Facilities to Net Fixed Investment (%) | High | | 2.5% |
| Integration | Low | | High |
| Chemical Complex | Isolated Plant | | Isolated |
| Other Environmental Problems (Including OSHA) | Multiple | | Air and water pollution, OSHA |
| Emotional Commitment | Indifference | | Low |
| Ownership | Multi-Industry Companies | | Multi-industry |

Elemental phosphorus producers also have other environmental requirements, particularly water pollution regulations. Hazardous waste limitations will not result in a plant shutdown, although, depending on the level of other environmental requirements, the combination of all environmental regulations may have an impact on the industry which is beyond the scope of this study.

The net present value of the investment in treatment facilities for the model plant faced with total treatment costs is $44.6 million based on a 15 percent cost of capital (see Table VIII-12). Based on this analysis, the producer with a model plant would obtain a reasonable return on the required total investment for hazardous waste treatment. Case II examines the situation where a producer is faced with high manufacturing costs, high treatment costs, and an operating rate comparable to current industry operating levels. The NPV of the waste treatment investment for this plant is still high at $26.1 million. Even under the Case II assumptions, there is a reasonable level of return for the hazardous waste treatment investment.

The plant shutdown impact could change over the next several years if the market scenario is different from the basic assumptions. The industry is faced with rapidly escalating power costs which, because of the competitive environment in the future, producers may not be able to fully recover. Also, further environmental restrictions on the use of phosphate detergents or a more rapid substitution of phosphate builders by the detergent industry could result in a decline in demand for elemental phosphorus. If faced with deteriorating profit margins and a decline in demand, the impact of hazardous waste treatment costs could have a more adverse impact on the industry.

TABLE VIII-12

SUMMARY OF HAZARDOUS WASTE TREATMENT INVESTMENT

ANALYSIS FOR ELEMENTAL PHOSPHORUS MANUFACTURE-(1975)*

| | Case I | Case II |
|---|---|---|
| Commercial price (1975) | $990/metric ton | $990/metric ton |
| Manufacturing costs | $675/metric ton | $775/metric ton |
| Total treatment costs[a] (Level III technology) | $7.00/metric ton | $19.20/metric ton |
| (capital investment) | ($1.15 MM) | ($3.04 MM) |
| Average annual operating rate | 90% | 80% |
| Average annual production | 49,900 metric tons | 44,350 metric tons |
| After-tax cash flow | $217/metric ton | $171/metric ton |
| Net present value[b] (15% cost of capital) | $44.6 MM | $26.1 MM |

*Source: Contractor's estimates.

a. Treatment costs are stated as per ton of capacity.

b. Based on 10-year investment.

4. Sodium Dichromate.

a. Treatment Costs. The generalized hazardous waste management costs presented in the Assessment Report are particularly difficult to use in the case of sodium dichromate because there are only three plants. Each of the plants has a unique set of process and locational factors which influence the actual disposal costs. In addition, the argument is made that chromium hydroxide ($Cr^{+3}$) is not toxic and as such should not be covered by the hazardous waste regulations. The model plant treatment costs should be viewed as indicative rather than definitive for the dichromate plants.

The model plant in the Assessment Report and the contractor model plant were somewhat different in size. The costs have therefore been converted to costs per metric ton of product. The incremental costs of compliance for the sodium dichromate producers is represented by moving from the Report Option 3 to Option 5. Plants coming into compliance would require a capital investment of approximately $9.68 per ton of annual production, or about 3 percent of net fixed assets. The total incremental treatment and disposal costs are $3.60 per metric ton of product, which was 0.6 percent of 1975 average selling price.

b. Short-Term Impact.

(1) Prices. As a whole, producers have shown considerable flexibility to increase prices to cover higher costs. Table VIII-13 was constructed to display the factors bearing on the ability of the producers to change prices and recover higher costs. Their ability to individually recover the costs of hazardous waste management will depend on how different the per unit costs are among the three producers. If their costs are approximately equal, they may

TABLE VIII-13

PRICE INCREASE CONSTRAINT FACTORS - SODIUM DICHROMATE

| | Sodium Dichromate |
|---|---|
| All Processes: | |
| 1975 Production (Thousand Metric Tons) | 112.1 |
| 1975 Unit Value ($/Metric Ton) | 606.0 |
| 1975 Production Value ($MM) | 44.2 |
| Number of Plants (Current) | 3 |

| PRICE INCREASE CONSTRAINTS | | | |
|---|---|---|---|
| Factor | Condition for Constraint | Treatment Level III | |
| Ratio of Incremental Before-Tax Treatment cost to Selling Price (%) | High | | 0.6% |
| Substitute Products | High Occurrence | | Few (for derivatives) |
| Capacity Utilization | Low | | 90% - High |
| Captive Usage | Low | | 25% - Moderate |
| Demand Growth | Low | | Low |
| Foreign Competition | High | | Negligible |
| Abatement Cost Differences | Unequal | | Unequal |
| Price Elasticity of Demand | High | | -0.5 - Low |
| Basis for Competition | Price | | Price & Service |
| Market Share Distribution | Fragmented | | Concentrated |
| Number of Producers | Many | | 3 |
| Substitute Process | Many | | none |

be able to recover the costs uniformly. If one producer has much lower costs than the other producers, they may be able to restrain price increases by their competitors. In a low capacity utilization year, such as 1975, this would be particularly true.

Current prospects are that over the next few years sodium dichromate producers will experience little change from historic patterns of low growth but fairly high capacity utilization. Price rises in 1975, in spite of sharp production declines, suggest an ability to hold prices at necessary levels. It is not possible given currently available information to say what the cost of compliance differential will be among the producers. As an approximation, one can say that the costs estimated by the Assessment Report could be matched by price changes if they are generally applicable to the three producers. Since none of the plants are currently at Level III (Option 5) and significant incremental expenditures would have to be made by each plant, price changes adequate to cover most of, if not all of, the hazardous waste costs can be expected.

(2) Demand. Through 1974, sodium dichromate has had a low to moderate elasticity of demand. The elasticity was estimated earlier at -0.5. Table VIII-14 lists the potential demand changes resulting from price changes under a range of pricing strategies. The competitive environment in the industry will determine whether firms are setting prices so as to cover variable costs or total costs. This price objective is assumed to remain unchanged. Therefore, the percent price change would equal either the percent change in variable costs or total costs. The demand values are for the entire industry, not an individual plant, and the prices are industry-wide values.

TABLE VIII-14

IMPACT OF HAZARDOUS WASTE COSTS ON PRICE AND DEMAND (SODIUM DICHROMATE) *

| Cost change ($/metric ton) | Percent cost change | Percent passthrough | Price ($/metric ton) | Demand (1,000's metric ton) |
|---|---|---|---|---|
| Incremental total cost | | | | |
| 3.60 /451.70 | 0.8 | 100 | 604.8 | 144.4 |
| | | 50 | 602.4 | 144.7 |
| | | 0 | 600.0 | 145.0 |
| Incremental variable cost | | | | |
| 2.04/400.90 | 0.5 | 100 | 603.0 | 144.6 |
| | | 50 | 601.5 | 144.8 |
| | | 0 | 600.0 | 145.0 |

*Source: Contractor's estimates.

Notes:

1. The total manufacturing plant costs of the Contractor's model are $451.70 per metric ton of product. The model plant variable costs are $400.90 per ton (including by-product credit).

2. A percentage change in cost (total or variable) is assumed to be reflected in an equal percentage change in price at 100 percent cost passthrough.

3. Total yearly demand at $600 per ton is assumed to be 145,000 metric tons, reflecting historic levels rather than the actual 1975 level.

If the producer represented by the contractor model plant is attempting to recover the total manufacturing costs of the plant, his objective in increasing prices would be 0.8 percent. If the current price strategy is to recover variable costs, his objective would be to raise prices 0.5 percent.

Table VIII-14 lists 1975 prices as $600 per ton of sodium dichromate and total plant manufacturing costs (excluding corporate overhead) as $452 per ton. The price level suggests that the producer is probably pricing so as to recover his total costs plus a return on investment. The 0.8 percent price increase objective is probably closer to actual operator behavior. Independent of what the operator's cost recovery objectives are, competitive demands may allow a partial recovery. Table VIII-14 lists the demand changes assuming different levels of passthrough as well as different pricing objectives.

Demand was assumed to be 145 thousand metric tons at $600 per ton. In 1975, demand was actually lower. The 145 thousand tons is more representative of future levels. If the producer attempts to recover the change in total costs of 0.8 percent and is allowed a 100 percent cost passthrough, demand would drop by 0.4 percent to 144.4 thousand tons. A 50 percent cost passthrough would result in a 0.2 percent demand reduction to 144.7 thousand tons.

The actual price change achievable will depend on the hazardous waste management costs per ton of product for the three producers. If their incremental costs of compliance are similar, they will be able to raise prices to recover most of the costs without competitive price constraints from another producer. It appears that each of the sodium dichromate producers will have to make substantial incremental hazardous waste expenditures, and the actual price changes would be in the range of 50 percent to 100 percent passthrough of hazardous waste treatment costs.

(3) Profitability. The actual profitability of sodium dichromate sales has not been determined. The contractor model plant has been used to indicate an approximate profitability at the plant level. Table VIII-15 is an income statement for the model plant. Corporate overhead and G&A burdens have not been included. Assuming the model approximately represents the current plant's cost structure, the after-tax profits are $74.15 per metric ton on sales of $600 per ton. The cash flow is $97.95 per ton.

A producer will attempt to increase price so there is no profit reduction as a result of the hazardous waste management costs. If prices cannot be increased, the producer would have to absorb the new costs. Table VIII-16 lists the effect on profitability of the producer's having to absorb the total Level II and III costs of $8.92 per ton. A sensitivity analysis using a cost level of $15 per ton was also examined. These costs are intended to represent a worst case analysis. In the first case, after-tax profits would be reduced to $69.7 per ton (a 6 percent reduction). In the higher cost case, the reduction would be to $66.67 per ton (a 10.1 percent reduction).

c. Plant Shutdown Impact. The plant shutdown decision in the short run is based on whether the net present value of the required capital investment in hazardous waste management facilities is positive. Table VIII-16 lists such a computation. The Assessment Report estimates the capital costs at, for Level II and III (Option 5), $630,000. In the worst case when prices cannot be increased, the net present value of the investment is $17.2 MM, assuming the $8.92 per ton cost and $16.3 MM, assuming the $15 per ton cost.

Based on these values, none of the three sodium dichromate plants are expected to close as a result of the hazardous waste management costs. Table VIII-17 displays the factors contributing to the plant closure decision.

TABLE VIII-15

MODEL PLANT INCOME STATEMENT - 1975
SODIUM DICHROMATE*

| | |
|---|---|
| Production | 39,735 metric tons |
| Revenue | $600/ton |
| Manufacturing cost | 451.70 |
| Gross profit | 148.30 |
| Profit after tax | 74.15 |
| Depreciation | 23.80 |
| After-tax cash flow | 97.95 |

*Source: Contractor's estimates.

TABLE VIII-16

SUMMARY OF HAZARDOUS WASTE TREATMENT
INVESTMENT ANALYSIS FOR SODIUM DICHROMATE (1975)*

| | Case I (model plant) | Case II |
|---|---|---|
| Commercial price ($/metric ton) | $600 | $600 |
| Manufacturing cost ($/metric ton) | 451.7 | 451.7 |
| Total treatment costs[a] ($/ton) | $8.92 | $15.00 |
| (capital investment) | ($0.63 MM) | ($1.0 MM) |
| Average annual operating rate | 80% | 80% |
| Average annual production (metric tons) | 39,735 | 39,735 |
| Net present value[b] (15% cost of capital) | $17.2 MM | $16.3 MM |

*Source: Contractor's estimates.

a. Treatment costs are stated as per ton of capacity.

b. Based on 10-year investment.

TABLE VIII-17

PLANT SHUTDOWN DECISION FACTORS - SODIUM DICHROMATE

| PLANT SHUTDOWN DECISION | | | Sodium dichromate |
|---|---|---|---|
| Factor | Condition for Shutdown | Treatment Level | |
| Ratio of AT Treatment Cost to AT Net Income (%) | High | III | 6.0% (low) |
| Cash Flow (Including Treatment Costs) | Negative | | Positive |
| Ratio of Investment in Treatment Facilities to Net Fixed Investment (%) | High | | 3.0% (low) |
| Integration | Low | | Moderate |
| Chemical Complex | Isolated Plant | | Isolated |
| Other Environmental Problems (Including OSHA) | Multiple | | Multiple |
| Emotional Commitment | Indifference | | High |
| Ownership | Multi-Industry Companies | | Multi-Industry |

5. Titanium Dioxide (chloride process).

a. Treatment Costs. The Assessment Report estimated the costs associated with the treatment of hazardous waste from the manufacture of titanium dioxide. The total 1975 treatment costs for the model plant are $4.3 per metric ton. These treatment costs are 0.6 percent of 1975 estimated selling price. Incremental treatment costs are $3.2 per metric ton, or 0.4 percent of 1975 estimated selling price. There are no investment requirements in order to achieve Level III control of hazardous waste treatment. Compliance costs for the sulfate process are higher, but the manufacturing costs are correspondingly lower.

The treatment costs for hazardous waste disposal are site-specific so that the model plant treatment costs cannot be assumed to represent the impact on each producer. The treatment costs depend on plant size, land availability and cost, local soil conditions, and waste loads.

b. Short-Term Impact.

(1) Prices. Producers of titanium dioxide should be able to recover a large part of waste treatment costs through price increases. With the competitive environment in the industry, generally high capacity utilization, and moderate demand growth, producers will be able to recover a significant portion of treatment costs (see Table VIII-18, which summarizes price increase constraints).

(2) Demand. Titanium dioxide has a low price elasticity of demand of -0.42 ($\Delta D/\Delta P$). Price increases because of hazardous waste treatment costs will therefore have a limited impact on the demand for titanium dioxide. The incremental total costs from hazardous waste treatment (Option 1 to 5) is estimated at 0.4 percent for the model plant. Depending on the producer's ability

TABLE VIII-18

PRICE INCREASE CONSTRAINT FACTORS - TITANIUM DIOXIDE

| | $TiO_2$, Chloride Proc. |
|---|---|
| All Processes: | |
| 1975 Production (Thousand Metric Tons) | 549 all $TiO_2$<br>330 chloride process |
| 1975 Unit Value ($/Metric Ton) | 778 |
| 1975 Production Value ($MM) | 427 |
| Number of Plants (Current) | 15 all $TiO_2$<br>8 chloride process |

| PRICE INCREASE CONSTRAINTS | | | |
|---|---|---|---|
| Factor | Condition for Constraint | Treatment | |
| Ratio of Total Before-Tax Treatment cost to Selling Price (%) | High | Level III | 0.6 |
| Substitute Products | High Occurrence | | Low |
| Capacity Utilization | Low | | 85% |
| Captive Usage | Low | | 14% |
| Demand Growth | Low | | 4-5% yr. |
| Foreign Competition | High | | Low |
| Abatement Cost Differences | Unequal | | Unequal |
| Price Elasticity of Demand | High | | Low |
| Basis for Competition | Price | | Technology & Service |
| Market Share Distribution | Fragmented | | Concentrated |
| Number of Producers | Many | | 9 |
| Substitute Process | Many | | Few |

to raise prices over the short term to recover total cost increases, it will have a varying impact of demand. Based on a 100 percent cost passthrough, demand will decline 0.17 percent while a 50 percent cost passthrough will result in a 0.08 percent decline in demand. Titanium dioxide producers appear to price on a total cost basis, but from a short-term perspective, the operators should be able to recover most or all of the compliance cost if they are of the magnitude shown for the model plant. Table VIII-19 lists the demand changes assuming different levels of passthrough of treatment costs as well as different cost change assumptions.

If the model plant producer were to attempt to recover incremental variable treatment costs of 0.5 percent, and 100 percent passthrough is feasible, demand would drop 0.2 percent, while a 50 percent cost passthrough would result in a 0.1 percent demand reduction (see Table VIII-19).

(3) Profitability. The total after-tax treatment cost for the model plant is 12 percent of the estimated after-tax income at the plant level for Option 5 (see Table VIII-20). The profitability levels have been determined from current market prices and estimated model plant manufacturing costs. The impact on profitability of treatment costs will vary for individual producers depending on their actual manufacturing costs and revenues.

c. Plant Shutdown Impact. No plant shutdowns are expected because of hazardous waste treatment costs. Although not all producers will be able to fully recover treatment costs, the level of profitability in the industry will allow the producers to absorb these cost increases in their profit margins. In addition, cash flow is expected to continue to be positive, the investment requirement for treatment facilities is zero, and the level of integration in the industry is low to moderate. These factors will

TABLE VIII- 19

IMPACT OF HAZARDOUS WASTE COSTS ON PRICE AND DEMAND
(TITANIUM DIOXIDE CHLORIDE PROCESS)*

| Cost change ($/metric ton) | Percent cost change | Percent passthrough | Price ($/metric ton) | Demand (1,000's metric ton) |
|---|---|---|---|---|
| Change in total cost | | | | |
| 3.16/744.29 | 0.4% | 100 | 776.88 | 549.0 |
| | | 50 | 778.44 | 549.5 |
| | | 0 | 780.00 | 550.0 |
| Change in variable cost | | | | |
| 3.16/580.84 | 0.5% | 100 | 776.10 | 548.7 |
| | | 50 | 778.05 | 549.4 |
| | | 0 | 780.00 | 550.0 |

*Source: Contractor's estimates.

Notes: 1. The total manufacturing plant costs of the Arthur D. Little model are $744.29 per metric ton of product. The model plant variable costs are $580.84 per ton.

2. A percentage change in cost (total or variable) is assumed to be reflected in an equal percentage change in price at 100 percent cost passthrough.

TABLE VIII-20

PLANT SHUTDOWN DECISION FACTORS - TITANIUM DIOXIDE

| PLANT SHUTDOWN DECISION | | | $TiO_2$ , Chloride Proc. |
|---|---|---|---|
| Factor | Condition for Shutdown | Treatment Level | |
| Ratio of Total AT Treatment Cost to AT Net Income (%) | High | III | 12% |
| Cash Flow (Including Treatment Costs) | Negative | | Positive |
| Ratio of Investment in Treatment Facilities to Net Fixed Investment (%) | High | III | 0 |
| Integration | Low | | Low to Moderate Forward<br>Low to Moderate Backward |
| Chemical Complex | Isolated Plant | | Isolated |
| Other Environmental Problems (Including OSHA) | Multiple | | Solid Waste<br>Air (Chloride) |
| Emotional Commitment | Indifference | | High |
| Ownership | Multi-Industry Companies | | Multi-Industry |

mitigate any plant shutdown decisions. Producers with higher treatment costs than the model plant treatment costs are not expected to shut down, although their level of profitability will be more adversely impacted. The net present value of the investment in treatment facilities for high cost producers is estimated to be positive, based on a 15 percent cost of capital (see Table VIII-21).

TABLE VIII-21

SUMMARY OF HAZARDOUS WASTE TREATMENT INVESTMENT ANALYSIS FOR TITANIUM DIOXIDE MANUFACTURE* (1975) (CHLORIDE PROCESS)

| | Case I (model plant) | Case II |
|---|---|---|
| Commercial price (1975) | $780/metric ton | $780/metric ton |
| Manufacturing costs | $744/metric ton | $744/metric ton |
| After-tax treatment costs (Level III technology) | $4.3/metric ton[a] | $8.6/metric ton[a] |
| Average annual operating rate | 90% | 90% |
| Average annual production | 22,680 metric tons | 22,680 metric tons |
| After-tax cash flow | $128.0/ton | $125.8/ton |
| Net present value[b] (15% cost of capital) | $9.7 MM | $8.2 MM |

*Source: Contractor's estimates.

a. Based on average annual production of 22,680 metric tons.

b. Based on 10-year investment.

## B. Secondary Affected Chemicals

### 1. Aluminum Fluoride.

a. Treatment Costs. There are limited hazardous waste problems associated with the production of aluminum fluoride. Therefore, the estimated hazardous waste treatment costs developed by the Assessment Report for 1975 are only $0.7 per metric ton for Level III technology. The investment costs for Level III hazardous waste treatment technology are also low at $0.15 million, or 5.0 percent of gross fixed investment for the model plant.

Several producers of aluminum fluoride do not isolate hydrofluoric acid, a principal raw material, in the manufacturing process. Since the production of hydrofluoric acid does generate significant hazardous waste, the waste loads for these producers of aluminum fluoride would result in higher hazardous waste treatment costs. Assuming the waste treatment costs for hydrofluoric acid and aluminum fluoride are additive, the total hazardous waste treatment costs for the model plant are $13.1 and $16.1 per metric ton of aluminum fluoride based on Options 3 and 4 for hazardous waste control from the production of hydrofluoric acid.

The hazardous waste treatment costs are site-specific, and as a result, the applicability of the model plant treatment costs to all producers would not be appropriate. Some firms have said that their estimated costs are more than twice the levels of the model plant costs, or $25 to $30 per metric ton of aluminum fluoride, including costs for the treatment of hazardous waste from the production of hydrofluoric acid.

b. Short-Term Impact. Domestic producers of aluminum fluoride should be able to recover waste treatment costs through price increases. Since there is high captive usage, no substitute products, limited foreign competition, and a limited number of producers, the industry should be able to raise prices to recover treatment costs. With the possibility of unequal treatment cost differences, full treatment cost recovery may be limited for some producers because of the competitive situation. The fact that there are only two merchant suppliers of aluminum fluoride, the aluminum producers without captive production of aluminum fluoride, in spite of the competitive situation in the industry, should allow aluminum fluoride producers to raise prices to recover treatment costs. If the merchant producers of aluminum fluoride were to shut down, certain aluminum producers would be dependent on their competitors for an important raw material.

Another factor which should allow hazardous waste treatment cost passthrough is the limited number of plants in the industry. If one large producer were to close down, the supply/demand balance would change dramatically and could create short-term shortages of aluminum fluoride. With a better supply/demand balance and possible shortages, price increases may occur which would be greater than price increases resulting from the passthrough of hazardous waste treatment costs.

The after-tax treatment costs, including HF treatment costs for the model plant, are 23 percent and 29 percent of after-tax profits for Options 3 and 4 respectively. If producers of aluminum fluoride are unable to recover treatment costs, the impact on the profitability of the model plant would be high. For producers with treatment costs higher than model plant costs, the impact on profitability would be a reduction in after-tax profits of 54 percent and 66 percent for Options 3 and 4, respectively, based on treatment costs double the model plant costs.

c. Plant Shutdown Impact. It is not expected that any producers of aluminum fluoride will shut down because of hazardous waste treatment costs. If cost passthrough were to occur, there would also be no impact on profitability.

The high level of integration in the industry will also mitigate the plant shutdown impact. The captive users of aluminum fluoride, even if unable to recover treatment costs, will be forced to absorb the treatment costs in order to maintain supplies of an important raw material. Also, if a captive user were to close down, the available market price of aluminum fluoride would be higher than the production costs including hazardous waste treatment costs. The problem of the captive users making the necessary investment for hazardous waste treatment is impacted by capital availability for aluminum producers and the competitive position of aluminum. These issues are beyond the scope of this study but can have important implications on the captive user's decision to absorb, if necessary, hazardous waste treatment costs.

If cost passthrough is not allowed, or waste treatment costs are higher than estimated by industry, a plant shutdown could occur. Since there are only five domestic plants for the production of aluminum fluoride, one plant shutdown would improve the supply/demand balance in the industry. Therefore, under worst case assumptions, only one plant is susceptible to shutdown.

2. Chrome Pigments.

a. Treatment Costs. There are significant hazardous waste problems associated with the production of pigments in the chrome colors group. Treatment of process wastewater generates a solid waste containing various lead and chromium salts. The estimated hazardous waste treatment and disposal cost presented in the Assessment Report is $7.50 per metric ton for Level III technology. Level III control involves contractor chemical fixation and land disposal and. therefore, no additional investment is required.

b. Short-Term Impact. The short-term impact of hazardous waste treatment and disposal costs for chrome pigments is expected to be minimal, although some producers could have difficulty in recovering full treatment costs through price increases. The Level III treatment costs represent about 0.5% of product selling price. This is a relatively small incremental cost compared to increasing energy and raw material costs. On the other hand, the industry is facing increasing pressure from imports as well as relatively low domestic market growth. A much more significant issue facing the industry is the possible carcinogenic nature of chromates.

c. Plant Shutdown Impact. Although the chrome pigments industry may experience plant shutdowns during the next five years, no shutdowns are expected as a direct result of hazardous waste treatment and disposal costs. These costs are expected to be of relatively less significance in this regard than the other factors discussed above. In the current buyer's market situation, and in view of the abatement cost differences facing the industry, it is unlikely that there will be complete passthrough of hazardous waste treatment costs to consumers. Therefore, a potential exists for a small impact on industry profitability.

3. Nickel Sulfate.

a. Treatment Costs. Production of nickel sulfate results in the formation of nickel-containing hazardous wastes for land disposal. The Assessment Report estimated Level III hazardous waste treatment and disposal costs at $8.30 per metric ton for off-site secured landfill in lined drums, and $3.80 per metric ton for contractor chemical fixation. These costs were estimated for a plant producing 9 metric tons of nickel sulfate per day.

b. Short-Term Impact. The Level III treatment costs represent approximately 0.5 percent of the product selling price. Despite this relatively small size, some producers of nickel sulfate could experience difficulty in passing this cost on to consumers. Production of nickel sulfate has dropped in recent years and the demand outlook is limited by the fact that pollution control regulations are forcing consumers to more efficiently recycle product which was formerly discarded. In addition, the industry is threatened by various indirect substitutes. At present, industry capacity is in excess of demand. In the current buyer's market, price increases will be difficult to sustain.

c. Plant Shutdown Impact. In the last several years at least one plant has been closed as the result of slackening demand for nickel sulfate. Additional plant shutdowns may occur over the next five years, however, it is unlikely that any shutdowns will occur as a direct result of hazardous waste treatment and disposal costs. Other adverse factors, outlined above, would play a more significant role. On the other hand, to the extent that hazardous waste management costs cannot be passed on to consumers, the industry will be forced to absorb these additional costs and industry profitability will be reduced accordingly.

4. Phosphorus Pentasulfide.

a. Treatment Costs. The hazardous waste treatment costs for the model plant are $.07 per metric ton. Industry contacts have indicated that these costs substantially understate their actual costs. In fact, the model plant disposal costs for phosphorus trichloride are substantially higher although similar waste disposal techniques are employed. Assuming disposal techniques for phosphorus pentasulfide are equivalent to phosphorus trichloride, disposal costs would be $0.4 per metric ton of phosphorus pentasulfide.

b. Short-Term Impact. Producers of phosphorus pentasulfide should be able to pass along treatment costs through price increases. The industry is experiencing high demand growth, high capacity utilization, and low foreign competition. Also, the limited number of substitute products, high captive usage, equal abatement costs, and the limited number of producers are conditions which should allow the producers to recover disposal costs. Since the treatment costs ($0.4 per ton) are only 0.1 percent of the 1974 selling price, the impact on prices will be limited. The impact on demand for phosphorus pentasulfide because of higher prices will be small. With the small price increase and an assumed moderate price elasticity of demand, the reduction in demand because of hazardous waste treatment costs will be limited. Also, there will be no impact on the profitability of phosphorus pentasulfide because the producers will be able to raise prices to recover treatment costs.

c. Plant Shutdown Impact. There should be no plant shutdown because of hazardous waste treatment costs. With full treatment cost recovery, phosphorus pentasulfide producers will not be faced with a plant shutdown decision.

5. Phosphorus Trichloride.

a. Treatment costs. The costs to achieve Level III technology for the disposal for hazardous waste from the production of phosphorus trichloride is $0.4 per metric ton. These costs are based on a model plant of 58,000 metric tons, although the largest plant in the industry is 27,200 metric tons. However, the treatment costs would be similar for smaller plants.

b. Short-Term Impact. Producers of phosphorus trichloride should be able to pass along treatment costs through price increases. The conditions in the industry including moderate demand growth, high captive usage, low foreign competition, limited substitutes, and a high level of industry concentration suggest that price increase constraints in order to recover treatment costs will be limited. Since the model plant treatment costs are only 0.1 percent of the 1974 selling price, the impact on prices will be small.

The impact on the demand for phosphorus trichloride will also be limited. With the small price impact expected and an assumed moderate price elasticity, the reduction in demand because of hazardous waste treatment costs will be small. Also, there will be no impact on the profitability of phosphorus trichloride because the producers will be able to raise prices to recover treatment costs.

c. Plant Shutdown Impact. There should be no plant shutdown because of hazardous waste treatment costs. With full treatment cost recovery, phosphorus trichloride producers will not be faced with a plant shutdown decision.

6. Sodium Silicofluoride.

a. Treatment Costs. In either of the two processes by which sodium silicofluoride is manufactured, treatment of waterborne wastes generates a small amount of hazardous waste material containing calcium fluoride. According to the Assessment Report, the concentration of calcium fluoride in the solid waste is such that some protection of ground and surface waters is required. A more complete discussion of the potentially hazardous nature of these wastes is presented in the Assessment Report. Hazardous waste management costs for a 45 metric ton per day plant have been estimated in the Assessment Report at $0.80 per metric ton for Level III technology. This compares to a cost of $8.50 per metric ton for deep welling of hazardous wastes which is now being done by at least one plant.

b. Short-Term Impact. At $0.80 per metric ton, hazardous waste management costs for Level III amount to less than 0.5 percent of product selling price. Some producers of sodium silicofluoride could experience difficulty in recovering the full waste management costs through price increases. This is because of the generally low level of demand growth in the industry and because of significant abatement cost differences. Each of the three U.S. sodium silicofluoride plants uses a different hazardous waste treatment/disposal process and hazardous waste management costs and water treatment costs are often difficult to separate. To the extent that full cost passthrough is not achieved, industry profitability will suffer.

c. Plant Shutdown Impact. No plant shutdowns are expected for sodium silicofluoride producers as a direct result of hazardous waste treatment and disposal costs. Other factors in the industry are likely to be more significant in arriving at a shutdown decision. On the other hand, the additional cost of hazardous waste management, to the extent that this cost must be absorbed, can only serve to decrease the attractiveness of an investment in the production of this chemical.

## C. Inorganic Chemical Industry Impact

As is apparent from the discussion of expected economic impacts on the primary and secondary affected chemicals presented above, hazardous waste management costs are not, in themselves, likely to lead to severe economic consequences for most producers of these chemicals. In particular, the effect of these costs on producers of the secondary affected chemicals is judged to be small in every case.

This section summarizes the expected impact of hazardous waste management costs on the producers of the five primary affected chemicals from the overall perspective of the inorganic chemicals industry.

1. Size and Growth. The primary affected chemicals accounted for about 32 percent of the $8 billion of inorganic chemicals shipped in 1975, though only 16 percent were made by processes with high hazardous waste costs (Table VIII-22). Chlorine/caustic accounted for 79 percent of the production tonnage and 29 percent of the production value of primary product/processes.

Table VIII-23 summarizes the estimated impacts on product demand of producer price increases in the face of hazardous waste management costs. The estimated value of shipments which would have been lost as a result of 100 percent passthrough of hazardous waste management costs to consumers (due to price elasticity effects) is $21.6 million, or about 0.27 percent of total industry shipments. This is equivalent to about 1 percent of the 1975 primary affected chemical shipment value. Actual demand losses are expected to be lower at $8 to $11 million due to competitive constraints on price increases in some cases.

This study indicates that only one of the studied chemicals, hydrofluoric acid, could experience plant shutdowns as a result of imposing the estimated hazardous waste treatment costs for Level III control of these wastes. As

TABLE VIII-22

PRODUCTION AND VALUE OF PRIMARY CHEMICALS - 1975*

| Chemical | Production (1'000's metric tons) | | Price[a] $/ton | Value ($MM) | |
|---|---|---|---|---|---|
| Chlorine | | | | | |
| • mercury cell | 2 ,060 | | 105 | 216 | |
| • non-mercury cell[b] | | 6,200 | 105 | | 651 |
| Caustic soda | | | | | |
| • mercury cell | 2,270 | | 67 | 152 | |
| • non-mercury cell[b] | | 6,830 | 67 | | 458 |
| Hydrofluoric acid | 284 | | 600 | 170 | |
| Phosphorus | 408 | | 987 | 403 | |
| Sodium dichromate | 112 | | 600 | 67 | |
| Titanium dioxide | | | | | |
| • chloride process | 330 | | 778 | 257 | |
| • non-chloride process[b] | | 220 | 778 | | 171 |
| Total | 5,464 | 13,250 | | 1,265 | 1,280 |

*Source: Current Industrial Reports, Inorganic Chemicals - 1975 (M28A(75)), Contractor's estimates.

a. Prices are the unit commercial shipment values, except for HF, which is a contractor estimate.

b. Production of primary chemicals by processes with lower hazardous waste treatment costs and not evaluated during the primary economic impact analysis.

TABLE VIII-23

DEMAND IMPACTS ON PRIMARY CHEMICALS*

| Chemical | 1975 demand ($MM) | Demand loss with 100% cost passthrough[a] ($MM) | Expected demand loss[a] ($MM) |
|---|---|---|---|
| Chlorine[b,e] | 861 | 8.4 (1%) | none |
| Hydrofluoric acid | 170 | 5.8 (3.4%) | 0 - 2.9 (1.7%) |
| Phosphorus | 403 | 6.2 (1.5%) | 6.2 (1.5%) |
| Sodium dichromate[c] | 87 | 0.4 (0.4%) | 0.4 (0.4%) |
| Titanium dioxide[d] | 426 | 0.8 (0.2%) | 0.8 (0.2%) |
| Total | 1,947 | 21.6 (1%) | 7.6 - 10.5 (0.4% - 0.5%) |

*Source: Contractor's estimates.

a. Assumes full cost recovery pricing strategy and lost demand valued at 1975 prices.

b. Total chlorine production is included because a price change for mercury cell chlorine would have to be matched by increases in other chlorine prices in order for the change to stick.

c. The value of sodium dichromate production in 1975 was actually about $68 MM (112,000 metric tons). The demand impact calculation assumed 144,000 tons as more representative than the actual 1975 value.

d. The total titanium dioxide production is included rather than only the chloride process production for the same reason all chlorine is included. About 60% is chloride process production.

e. Price increases for caustic soda would result in a demand reduction, however its magnitude has not been estimated.

indicated in Table VIII-24, one to two small hydrofluoric acid plants may close earlier as a result of these added costs. These plants represent 2 to 3 percent of the plants producing the primary affected chemicals.

The ratio of incremental hazardous waste treatment costs to model plant net income is shown in Table VIII-25. Although these costs are on a model plant basis, the percentage of net income is roughly the same as would be calculated for the entire industry sector. Assuming a producer is unable to recover treatment costs, these ratios reflect the potential impact on the net income from a model plant. For example, hydrofluoric acid producers would experience a 7.2 percent loss in net income which is an important contribution to the plant shutdown scenario indicated by the analysis for this sector.

The incremental capital investment required for producers of the primary chemicals to move from Level I to Level III controls is estimated to be $20.1 million, Table VIII-26. The estimate is based on extrapolating the model plant capital investment to the total production capacity of the three chemicals requiring new capital investments to come into compliance with a Level III requirement.

An expenditure of $20.1 million is small relative to total chemical industry capital spending of $6.3 billion in 1975, of which $684 was spent on pollution control facilities. However, the required investment is large relative to current investment related to the primary chemicals. Table VIII-27 was constructed to give a rough estimate of current capital expenditures relating to the primary chemicals. Total capital expenditures for the production of all the primary chemicals were $120 million in 1975, of which $13 million was for pollution control. Less than $1 million of the $13 million was for solid waste control, of which hazardous waste is part. Chlorine/caustic and titanium dioxide require no new investment. When they are excluded from the primary chemicals, the total 1975 pollution control capital expenditures were about

TABLE VIII-24

POSSIBLE PLANT CLOSURES RESULTING FROM HAZARDOUS WASTE TREATMENT COSTS*

| Chemicals | Number of existing plants | Number of possible plant closures | Percent |
|---|---|---|---|
| Chlorine-mercury | 27 | - | - |
| Titanium dioxide - chloride process | 8 | - | - |
| Elemental phosphorus | 10 | - | - |
| Sodium dichromate | 3 | - | - |
| Hydrofluoric acid | 12 | 1 - 2 | 8 - 16 |
| Total | 60 | 1 - 2 | 2 - 3 |

*Source: Contractor's estimates.

TABLE VIII-25

RATIO OF INCREMENTAL HAZARDOUS WASTE TREATMENT COSTS TO MODEL PLANT PRE-TAX INCOME*

| Chemicals | Pre-tax plant level income per ton [a] | Increment treatment cost per ton | Percent of pre-tax income |
|---|---|---|---|
| Chlorine and caustic - mercury cell | 52 | 3.56 | 6.8 |
| Titanium dioxide - chloride process | 36 | 3.16 | 8.8 |
| Elemental phosphorus | 315 | 4.43 | 1.4 |
| Sodium dichromate | 148 | 3.60 | 2.4 |
| Hydrofluoric acid | 115 | 8.28 | 7.2 |

*Source: Contractor's estimates.

a. These values are at the plant level and do not include corporate overhead costs.

TABLE VIII- 26

INCREMENTAL INDUSTRY INVESTMENT REQUIRED FOR HAZARDOUS WASTE CONTROL*

| Chemicals | Incremental capital investment required to achieve Level III treatment ($/ton of capacity) | Total industry capacity (000 metric tons) | Incremental capital investment required for total industry ($ 000) |
|---|---|---|---|
| Chlorine-mercury cell | - [a] | 2,800 | - |
| Titanium dioxide | - [a] | 514 | - |
| Elemental phosphorus | 16.48 | 560 | 9,200 |
| Sodium dichromate | 9.68 | 154 | 1,500 |
| Hydrofluoric acid | 28.72 | 327 | 9,400 |
| Total | | | 20,100 |

*Source: Contractor's estimates.

a. Level III hazardous waste disposal is specified as contract disposal.

TABLE VIII-27

ESTIMATED CAPITAL EXPENDITURES ON POLLUTION CONTROL - 1975*

($ million)

| | | Capital expenditures | | |
|---|---|---|---|---|
| Product group | Shipments | Total | Total pollution control | Solid waste |
| Chemicals and allied products (SIC 28) | 85,000 | 6,300 | 684 | 40 |
| Industrial inorganic chemicals (SIC 281) | 8,000 | 740 e | 80 e | 4.7 e |
| Primary chemicals | 1,270 | 120 e | 13 e | 0.7 e |
| • excluding chlorine/caustic and $TiO_2$ | 640 | 59 e | 6.4 e | 0.4 e |
| e = estimate | | | | |

*Source: Survey of Current Business, July 1976; U.S. Industrial Outlook, 1976; Contractor's estimates.

Notes: 1. Expenditures of SIC 281 were estimated to be in same ratio with SIC 28 in 1975, as were total capital expenditures in 1973 (373/3186). The ratio may understate Solid Waste expenditures for Inorganic Chemicals.

2. Expenditures for the Primary Chemicals were estimated to be proportionate to shipments of SIC 281.

3. Only the model plants for hydrofluoric acid, phosphorus, and sodium dichromate required new capital investments to come into compliance with Level III from Level I.

$6.4 million. In this context, the new $20.1 million required for hazardous waste control becomes much more important, even though the expenditure would be made over several years.

The discounted cash flow analysis has shown that in almost all cases the producers would make the necessary investment to come into compliance with the Level III requirements. The $20.1 million would appear to impose a severe distortion on current capital expenditure patterns for these chemicals. However, one must realize that these chemicals have the most severe of the hazardous waste problems and the typical large diversified producer is also making other inorganic products which will not face the high hazardous waste capital costs.

The growth of the inorganic chemicals industry is not likely to be significantly affected by the cost of hazardous waste management. Some small reduction in demand growth is likely to occur as real prices rise; however, hazardous waste management costs are relatively small when compared to other elements of increasing cost. As is the case throughout much of this analysis, the additional costs resulting from hazardous waste management are relatively small in themselves; however, this is not to say that these costs do not work incrementally to increase overall production costs and contribute to a variety of economic phenomena.

2. Employment and Wages. The impact of hazardous waste management costs on employment in the inorganic chemicals industry is shown in Table VIII-28. As a result of the potential shutdown of one to two hydrofluoric acid plants, 45 to 90 related jobs could be lost. The production at these plants would be made up by increased production and employment at the remaining plants. About 60 jobs could be affected by demand reduction due to price increases. All of these jobs may not actually be lost because the demand changes are so small in most cases. The lost jobs may be subtracted from new ones which would otherwise be created by growth. The related effect on wages is shown in Table VIII-29. An estimated $0.6 to $1.2 million in wages would be lost if the HF plants are closed. The wage losses resulting from demand losses are $0.6 to $0.7 million.

3. Community Effects. Community effects may be expected in those instances where plant shutdown leads to a significant net decrease in the number of jobs available in a given community. In this study, hydrofluoric acid was identified as the one chemical, among eleven studied, where plant shutdowns may occur as a result of hazardous waste management costs. It was beyond the scope of this study to review prospects for individual chemical plants. Nonetheless, the majority of hydrofluoric acid plants are located in small communities and, therefore, hydrofluoric acid plant shutdowns are likely to cause significant community effects in terms of employment and wages.

4. Foreign Trade Effects. As indicated in Table VIII-30, foreign trade effects for the five primary affected chemicals range from small to negligible. This is because foreign trade represents such a small part of U.S. production and consumption in most cases. An exception is hydrofluoric acid, where imports represented about 16% of production in 1975. Hydrofluoric acid imports are

TABLE VIII-28

POTENTIAL IMPACT OF HAZARDOUS WASTE TREATMENT COSTS ON EMPLOYMENT*

| Chemicals | Number of employees | Plant closure | Demand loss |
|---|---|---|---|
| Chlorine-mercury | 2165 | - | - |
| Titanium dioxide | 6165 | - | 10 |
| Elemental phosphorus | 2890 | - | 40 |
| Sodium dichromate | 850 | - | 3 |
| Hydrofluoric acid | 540 | 45 - 90 | 0 - 10 |
| Total | 12,610 | 45 - 90 | 55 - 65 |

*Source: Contractor's estimates.

TABLE VIII-29

POTENTIAL IMPACT OF HAZARDOUS WASTE TREATMENT COSTS ON WAGES*

| Chemicals | Estimated wages ($MM) | Wages affected ($MM) | |
|---|---|---|---|
| | | Plant closure | Demand loss |
| Chlorine-mercury | 29 | - | - |
| Titanium dioxide | 82 | - | 0.1 |
| Elemental phosphorus | 38 | - | 0.5 |
| Sodium dichromate | 11 | - | - |
| Hydrofluoric acid | 7 | 0.6 - 1.2 | 0 - 0.1 |
| Total | 167 | 0.6 - 1.2 | 0.6 - 0.7 |

* Source: Contractor's estimates.

TABLE VIII-30

BALANCE OF PAYMENTS EFFECTS 1975*

| Chemical | U.S. production (000 metric tons) | Imports (000 metric tons) | Exports (000 metric tons) | Estimated hazardous waste treatment impact |
|---|---|---|---|---|
| Primary affected chemicals: | | | | |
| Chlorine | 8,260 | 67 | 15.2 | none |
| Hydrofluoric acid | 284 | 42.0 | n.a. | small |
| Phosphorus | 408 | negligible | 32.5 | small |
| Sodium dichromate | 112 | 0.4 | 9.6 | none |
| Titanium dioxide | 547 | 23.9 | 14.2 | small |

*Source: U.S. Exports, FT 410, U.S. General Imports, FT 135, U.S. Dept. of Commerce, 1975.

expected to represent an increasing portion of U.S. production based on previous capacity commitments. In the long term, if demand for hydrofluoric acid increases, environmental considerations may limit capacity expansion in the U.S., and the U.S. balance of payments would be adversely impacted.

## IX. ACKNOWLEDGEMENTS

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| | |
|---|---|
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| Alcoa | Monsanto |
| Diamond Shamrock | Olin |
| Dow | PPG Industries |
| DuPont | Stauffer |

# APPENDIX A

## DETAILS OF SHORT-RUN ECONOMIC IMPACT ANALYSIS CALCULATIONS FOR PRIMARY AFFECTED CHEMICALS

Appendix A summarizes the detailed calculations for determining short-run economic impacts on demand and price for the primary affected chemicals. The analyses are based on the model plant production and treatment costs and demand elasticities discussed in Chapter VII. The demand impact has been estimated for several levels of cost passthrough, ranging from 0 to 100 percent.

## TABLE A-1
## SHORT-RUN IMPACT ANALYSIS*

Chemical: Chlorine - Diaphragm Cell

| | | |
|---|---|---|
| Increment Treatment/Disposal Costs (1975) | | |
| (option 2 to option 3) | | |
| Annual Capital Costs | | - |
| Variable Costs | | |
| Operating | | - |
| Energy & Power | | - |
| Contractor | | $51,000 |
| Total Variable Costs | | $51,000 |
| Total Annual Costs | | $51,000 |
| Assumed Annual Production (metric tons) | | 162,000 |
| Variable Unit Cost of Disposal | | $ 0.31/ton |
| Total Unit Cost of Disposal | | $ 0.31/ton |
| Annual Production Costs - Model Plant | | |
| Annual Fixed Costs | | $ 22.68/metric tons |
| Variable Unit Costs | | 84.62 |
| Total Unit Annual Cost | | $107.30 |
| Short Run Demand Change | | |
| Price Elasticity of Demand (e): | -0.36 | |
| Change in Variable Costs: | $\frac{0.31}{84.62}$ = | 0.37% |
| Change in Total Costs: | $\frac{0.31}{107.30}$ = | 0.29% |

*Source: Contractor's estimates.

## TABLE A-2
## SHORT-RUN IMPACT ANALYSIS*

Chemical: Chlorine - Mercury Cell

| | | |
|---|---|---|
| Increment Treatment/Disposal Costs (1975) | | |
| (option 2 to option 5) | | |
| Annual Capital Costs | | |
| Variable Costs | | |
| Operating | | ($ 46,800) |
| Energy & Power | | ( 175) |
| Contractor | | 367,200 |
| Total Variable Costs | | $320,230 |
| Total Annual Costs | | $320,230 |
| Assumed Annual Production (metric tons) | | 90,000 |
| Variable Unit Cost of Disposal | | $ 3.56/metric ton |
| Total Unit Cost of Disposal | | $ 3.56/metric ton |
| Annual Production Costs | | |
| Annual Fixed Costs | | $ 23.52/metric ton |
| Variable Unit Costs | | 102.81 |
| Total Unit Annual Cost | | $126.33 |
| Short Run Demand Change | | |
| Price Elasticity of Demand (e): | - 0.36 | |
| Change in Variable Costs | $\frac{3.56}{102.81}$ = | 3.46% |
| Change in Total Costs: | $\frac{3.56}{126.33}$ = | 2.82% |

*Source: Contractor's estimates.

TABLE A-3

SHORT-RUN IMPACT ANALYSIS*

| | | |
|---|---|---|
| Chemical: Hydrofluoric Acid | | |
| Increment Treatment/Disposal Costs (1975) | | |
| (option 1 to option 4) | | |
| Annual Capital Costs | | $172,340 |
| Variable Costs | | |
| Operating | | $ 18,000 |
| Energy & Power | | - |
| Contractor | | - |
| Total Variable Costs | | $ 18,000 |
| Total Annual Costs | | $190,340 |
| Assumed Annual Production (metric tons) | | 23,000 |
| Variable Unit Cost of Disposal | | $ 0.78/metric ton |
| Total Unit Cost of Disposal | | $ 8.28/metric ton |
| Annual Production Costs - Model Plant | | |
| Annual Fixed Costs | | $ 43.66/metric ton |
| Variable Unit Costs | | 440.82 |
| Total Unit Annual Cost | | $ 484.48 |
| Short Run Demand Change | | |
| Price Elasticity of Demand (e): | - 1.91 | |
| Change in Variable Costs: | $\frac{0.78}{440.82}$ = | 0.18% |
| Change in Total Costs: | $\frac{8.28}{484.48}$ = | 1.7% |

*Source: Contractor's estimates.

TABLE A-4

SHORT-RUN IMPACT ANALYSIS*

| | | |
|---|---|---|
| Chemical: Elemental Phosphorus | | |
| Increment Treatment/Disposal Costs (1975) | | |
| (option 1 to option 3) | | |
| Annual Capital Costs | | $215,000 |
| Variable Costs | | |
| Operating | | $ 3,600 |
| Energy & Power | | 2,700 |
| Contractor | | - |
| Total Variable Costs | | $ 6,300 |
| Total Annual Costs | | $221,300 |
| Assumed Annual Production (metric tons) | | 50,000 |
| Variable Unit Cost of Disposal | | $ 0.13/metric ton |
| Total Unit Cost of Disposal | | $ 4.43/metric ton |
| Annual Production Costs | | |
| Annual Fixed Costs | | $ 130.33/metric ton |
| Variable Unit Costs (including by-product credit) | | 545.41 |
| Total Unit Annual Cost | | $ 675.74 |
| Short Run Demand Change | | |
| Price Elasticity of Demand (e): | - 2.18 | |
| Change in Variable Costs: | $\frac{0.13}{545.41}$ = | 0.02% |
| Change in Total Costs: | $\frac{4.43}{675.74}$ = | 0.66% |

*Source: Contractor's estimates.

TABLE A-5

SHORT-RUN IMPACT ANALYSIS*

| | | |
|---|---|---|
| Chemical: Sodium Dichromate | | |
| Increment Treatment/Disposal Costs (1975) | | |
| (option 3 to option 5) | | |
| Annual Capital Costs | | \$101,900 |
| Variable Costs | | |
| Operating | | \$ 80,400 |
| Energy & Power | | ( 8,100) |
| Contractor | | 60,000 |
| Total Variable Costs | | \$132,300 |
| Total Annual Costs | | \$234,200 |
| Assumed Annual Production (metric tons) | | 66,430 |
| Variable Unit Cost of Disposal | | \$ 1.99/ton |
| Total Unit Cost of Disposal | | \$ 3.53/ton |
| Annual Production Costs - Model Plant | | |
| Annual Fixed Costs | | \$ 50.80/metric ton |
| Variable Unit Costs (incl. $Na_2SO_4$ credit) | | 400.90 |
| Total Unit Annual Cost | | \$ 451.70 |
| Short Run Demand Change | | |
| Price Elasticity of Demand (e): | | -0.50 |
| Change in Variable Costs: | $\frac{1.99}{400.90}$ = | 0.51% |
| Change in Total Costs: | $\frac{3.53}{451.80}$ = | 0.78% |

*Source: Contractor's estimates.

TABLE A-6

SHORT-RUN IMPACT ANALYSIS*

Chemical: Titanium Dioxide - Chloride Process

| | | |
|---|---|---|
| <u>Increment Treatment/Disposal Costs</u> (1975) | | |
| (option 1 to option 5) | | |
| Annual Capital Costs | | - |
| Variable Costs | | |
| Operating | | ($ 38,400) |
| Energy & Power | | - |
| Contractor | | 157,200 |
| Total Variable Costs | | $114,300 |
| Total Annual Costs | | $114,300 |
| Assumed Annual Production (metric tons) | | 36,000 |
| Variable Unit Cost of Disposal | | $ 3.18/metric ton |
| Total Unit Cost of Disposal | | $ 3.18/metric ton |
| <u>Annual Production Costs</u> | | |
| Annual Fixed Costs | | $ 163.45/metric ton |
| Variable Unit Costs | | 580.84 |
| Total Unit Annual Cost | | $ 744.29 |
| <u>Short Run Demand Change</u> | | |
| Price Elasticity of Demand (e): | - 0.42 | |
| Change in Variable Costs: | $\frac{3.18}{580.84}$ = | 0.55% |
| Change in Total Costs: | $\frac{3.18}{744.29}$ = | 0.43% |

*Source: Contractor's estimates.

# APPENDIX B

## DETAILS OF PLANT SHUTDOWN INVESTMENT ANALYSIS FOR PRIMARY AFFECTED CHEMICALS

Appendix B summarizes the detailed plant shutdown analysis for the primary affected chemicals. The analysis is based on a discounted cash flow approach over a ten-year period. The cash flow determined is an average for the ten-year period. Two cases have been examined. The first case assumes the model plant will be faced with the total treatment costs for hazardous waste control. The second case is a sensitivity analysis which examines the impact of alternative, but possible, operating and treatment cost assumptions.

TABLE B-1

NET PRESENT VALUE OF HAZARDOUS WASTE CAPITAL INVESTMENT FOR CHLORINE/MERCURY CELL*

| | Case I | | Case II |
|---|---|---|---|
| Production | 163,300 metric tons/year | | 145,200 metric tons/year |
| Revenue (per ECU) | $178/metric ton | | $178/metric ton |
| Manufacturing costs | $126.4 | | $126.4 |
| Treatment costs | $ 4.1 | | $ 15.0 |
| | $ 47.5 | | $ 36.6 |
| PAT (50% tax rate) | $ 23.8 | | $ 18.3 |
| Plus depreciation: | | | |
| Plant | $16.7 | | $16.7 |
| Treatment investment | 0 | | 0 |
| Cash flow | $40.5/metric ton | | $35.0/metric ton |
| Case I | Year 0 | Year 1-10 | Year 10 |
| Investment | 0 | | |
| Working capital | | | |
| Operating | ($4.48 MM) | | $4.48 MM |
| Treatment | ($0.17 MM) | | $0.17 MM |
| Salvage value (10% plus mercury inventory) | ($6.32 MM) | | $6.32 MM |
| Cash flow | | $6.61 MM | |
| | ($10.97 MM) | $6.61 MM/year | $10.97 MM |

NPV (@ 15%) = $24.9 MM

TABLE B-1 (Continued)

NET PRESENT VALUE OF HAZARDOUS WASTE CAPITAL INVESTMENT FOR CHLORINE/MERCURY CELL*

| Case II | Year 0 | Year 1-10 | Year 10 |
|---|---|---|---|
| Investment | 0 | | |
| Working capital | | | |
| Operating | ( $3.98MM) | | $3.98 MM |
| Treatment | ( $0.54MM) | | $0.54 MM |
| Salvage value (10% plus mercury inventory) | ($6.32 MM) | | $6.32 MM |
| Cash flow | | $5.08 MM | |
| | ($ 10.84MM) | $5.08 MM/year | ($10.84 MM) |
| NPV (@15%) = $17.4 MM | | | |

*Source: Contractor's estimates.

TABLE B-2

NET PRESENT VALUE OF HAZARDOUS WASTE CAPITAL INVESTMENT FOR HYDROFLUORIC ACID *

| | Case I | Case II |
|---|---|---|
| Production | 20,860 metric tons/ year (90% operating rate) | 18,500 metric tons/ year (80% operating rate) |
| Revenue | $600/metric ton | $600/metric ton |
| Manufacturing costs | $ 484.5 | $530 |
| Treatment costs[a] (Option 4) | $ 21.1 | $ 71.5 |
| | $ 94.4 | $ -1.50 |
| PAT (50% tax rate) | $ 47.2 | $ -.75 |
| Plus depreciation: | | |
| Plant | $ 30.5 | $ 34.3 |
| Treatment investment | $ 5.0 | $ 16.8 |
| Cash flow | $82.7/ metric ton | $50.4/ metric ton |

| Case I | Year 0 | Year 1-10 | Year 10 |
|---|---|---|---|
| Investment | ($1.04 MM) | | |
| Working capital[b] | | | |
| Operating | ($2.37 MM) | | $2.37 MM |
| Treatment | ($0.04 MM) | | $ .04 MM |
| Salvage value (10%) | ($0.7 MM) | | $ 0.7 MM |
| Cash flow | | $1.73 MM | |
| | ($4.15 MM) | $1.69 MM /year | $3.11 MM |

NPV (@ 15%) = $6.6 MM

TABLE B-2 (Continued)

NET PRESENT VALUE OF HAZARDOUS WASTE CAPITAL INVESTMENT FOR HYDROFLUORIC ACID*

| Case II | Year 0 | Year 1-10 | Year 10 |
|---|---|---|---|
| Investment | ($3.11 MM) | | |
| Working capital | | | |
| Operating | ($2.3 MM) | | $2.3 MM |
| Treatment | ($0.12 MM) | | $.12 MM |
| Salvage value (10%) | ($0.7 MM) | | $ 0.7 MM |
| Cash flow | ______ | $0.93 MM | ______ |
| | ($6.23 MM) | $0.92 MM/year | $3.12 MM |

NPV (@ 15%) = $-0.09 MM

*Source: Contractor's estimates.

a. Based on treatment costs of $441,900/year and $1.3MM/year for Cases I and II respectively.

b. Working capital = (manufacturing costs - depreciation x $\frac{\text{annual production}}{4}$).

TABLE B-3

NET PRESENT VALUE OF HAZARDOUS WASTE CAPITAL INVESTMENT FOR ELEMENTAL PHOSPHORUS*

| | Case I | Case II |
|---|---|---|
| Production | 49,900 metric tons/ year (90% operating rate) | 44,350 metric tons/ year (80% operating rate) |
| Revenue | $990/metric ton | $990/metric ton |
| Manufacturing costs | $ 674 | $ 774 |
| Treatment costs[a] | $ 7.0 | $ 24 |
| | $ 309.0 | $ 192 |
| PAT (50% tax rate) | $ 154.5 | $ 96 |
| Plus depreciation: | | |
| Plant | $ 60.9 | $ 68.5 |
| Treatment investment | $ 2.0 | $ 6.8 |
| Cash flow | $217.4/metric ton | $171.3/metric ton |

| Case I | Year 0 | Year 1-10 | Year 10 |
|---|---|---|---|
| Investment | ($1.0 MM) | | |
| Working capital | | | |
| Operating | ($7.65 MM) | | $7.65 MM |
| Treatment | ($ .02 MM) | | $ .02 MM |
| Salvage value (10%) | ($4.1 MM) | | $4.1 MM |
| Cash flow | | $10.85 MM | |
| | ($12.77 MM) | $10.85 MM/year | $11.77 MM |

NPV (@ 15%) = $44.6 MM

TABLE B-3 (Continued)

NET PRESENT VALUE OF HAZARDOUS WASTE CAPITAL INVESTMENT FOR ELEMENTAL PHOSPHORUS*

| Case II[b] | Year 0 | Year 1-10 | Year 10 |
|---|---|---|---|
| Investment | ($3.04 MM) | | |
| Working capital | | | |
| Operating | ($7.82 MM) | | $7.82 MM |
| Treatment | ($ .06 MM) | | $ .06 MM |
| Salvage value (10%) | ($4.1 MM) | | $4.1 MM |
| Cash flow | | $7.60 MM | |
| | ($15.02 MM) | $7.60 MM/year | $11.98 MM |

NPV (@ 15%) = $26.1 MM

*Source: Contractor's estimates.

a. Based on treatment costs of $1.01 MM and $3.03 MM for Cases I and II respectively.

b. Based on electricity costs of $0.15 per KWH.

TABLE B-4

NET PRESENT VALUE OF HAZARDOUS WASTE CAPITAL INVESTMENT FOR SODIUM DICHROMATE*

| | Case I | Case II |
|---|---|---|
| Production (80% operating rate) | 39,735 metric tons/year | 39,735 metric tons/year |
| Revenue | $600/metric ton | $600/metric ton |
| Manufacturing costs | $451.8 | $451.8 |
| Treatment costs (Option 5) | $8.92 | $15.00 |
| | $139.28 | $133.20 |
| PAT (50% tax rate) | $69.64 | $66.60 |
| Plus depreciation: | | |
| Plant | $23.82 | $23.82 |
| Treatment investment | $ 1.58 | $ 2.60 |
| Cash flow | $95.04/metric ton | $93.02/metric ton |

| Case I | Year 0 | Year 1-10 | Year 10 |
|---|---|---|---|
| Investment | ($0.63 MM) | | |
| Working capital | | | |
| Operating costs | ($4.25 MM) | | $4.25 MM |
| Treatment costs | ($0.09 MM) | | $0.09 MM |
| Salvage value (10%) | ($1.04 MM) | | $1.04 MM |
| Cash flow | | $3.78 MM | |
| | ($6.01 MM) | $3.78 MM/year | $5.38 MM |

NPV (@15%) = $17.1 MM

TABLE B-4 (Continued)

NET PRESENT VALUE OF HAZARDOUS WASTE CAPITAL INVESTMENT FOR SODIUM DICHROMATE*

| Case II | Year 0 | Year 1-10 | Year 10 |
|---|---|---|---|
| Investment | ($0.63 MM) | | |
| Working capital | | | |
| Operating costs | ($4.25 MM) | | $4.25 MM |
| Treatment (est.) | ($0.15 MM) | | $0.15 MM |
| Salvage value (10%) | ($1.04 MM) | | $1.04 MM |
| Cash flow | | $3.70 MM | |
| | ($6.07 MM) | $3.70 MM/year | $5.44 MM |
| NPV (@ 15%) = $16.6 MM | | | |

*Source: Contractor's estimates.

TABLE B-5

NET PRESENT VALUE OF HAZARDOUS WASTE CAPITAL INVESTMENT FOR TITANIUM DIOXIDE*

| | Case I (chloride process) | Case II (chloride process) |
|---|---|---|
| Production (90% operating rate) | 22,680 metric tons/year | 22,680 metric tons/year |
| Revenue | $780/metric ton | $780/metric ton |
| Manufacturing costs | $744.6 | $744.6 |
| Treatment costs[a] | $ 4.3 | $ 8.6 |
| | $ 31.1 | $ 26.8 |
| PAT (50% tax rate) | $ 15.5 | $ 13.4 |
| Plus depreciation: | | |
| Plant | $ 112.4 | $ 112.4 |
| Treatment investment | 0 | 0 |
| Cash flow | $128.0/metric ton | $125.8/metric ton |

| Case I | Year 0 | Year 1-10 | Year 10 |
|---|---|---|---|
| Investment | 0 | | |
| Working capital | | | |
| Operating | ($3.58 MM) | | $3.58 MM |
| Treatment | ($ .02 MM) | | $ .02 MM |
| Salvage value (10%) | ($2.8 MM) | | $2.8 MM |
| Cash flow | | $2.90 MM | |
| | ($6.4 MM) | $2.90 MM/year | $6.40 MM |

NPV (@ 15%) = $9.7 MM

TABLE B-5 (Continued)

NET PRESENT VALUE OF HAZARDOUS WASTE
CAPITAL INVESTMENT FOR TITANIUM DIOXIDE*

| Case II | Year 0 | Year 1-10 | Year 10 |
|---|---|---|---|
| Investment | 0 | | |
| Working capital | | | |
| Operating | ($3.58 MM) | | $3.58 MM |
| Treatment | ($ .04 MM) | | $ .04 MM |
| Salvage value (10%) | ($2.8 MM) | | $2.8 MM |
| Cash flow | | $2.85 MM | |
| | ($6.42 MM) | $2.85 MM/year | $6.42 MM |

NPV (@ 15%) = $8.2 MM

*Source: Contractor's estimates.

a. Treatment costs based on $4.3/ton x 22,680 tons/year = $97,520/year, and $8.6/ton x 22,680 tons/year = $195,048/year.

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