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Volume I

COMPREHENSIVE STUDY OF SPECIFIED AIR POLLUTION SOURCES TO ASSESS THE ECONOMIC EFFECTS OF AIR QUALITY STANDARDS

by

D. A. LeSourd, M. E. Fogel, A. R. Schleicher, T. E. Bingham,
R. W. Gerstle, E. L. Hill, F. A. Ayer

Prepared for:
Division of Economic Effects Research
Air Pollution Control Office
Environmental Protection Agency

RESEARCH TRIANGLE PARK, NORTH CAROLINA 27709

ENVIRONMENTAL PROTECTION AGENCY

~~XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX~~

AIR POLLUTION CONTROL OFFICE
1033 Wade Avenue
Raleigh, North Carolina 27605

Date: February 8, 1971

Reply to Attn of:

Subject: Economics of Clean Air: Annual Report to Congress, Backup Document by the Research Triangle Institute

To: Addressees

1. The technical report from the Research Triangle Institute which serves as the backup document for chapters 3 and 4 of the third 305(a) report to Congress, "The ~~Economics~~ or Cost of of Clean Air" is enclosed. —"

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RESEARCH TRIANGLE INSTITUTE
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Finally, special appreciation is extended to the secretaries who typed and retyped the many drafts of this report: J. Stockton, project secretary; S. Evans, F. Heald, S. Powell, and T. Stone.

ABSTRACT

Estimates are made of the costs of controlling and reducing the emissions of selected pollutants from mobile sources within the Nation and pollutants from 23 stationary sources within 298 metropolitan areas. Under the assumed implementation plan, these estimated costs are those that will be incurred during the period of Fiscal Year 1971 through Fiscal Year 1976. In addition, an extended analysis is made to determine the economic impact of control costs on each industrial source or group of industrial sources studied. Also, the aggregate effects of the impact of individual industries upon buyer industries and consumer prices are determined.

The pollutants from mobile sources selected for analysis are hydrocarbons, carbon monoxide, nitrogen oxides and particulates. The six pollutants for which control cost estimates are made for stationary sources are particulates, sulfur oxides, carbon monoxide, hydrocarbons, fluorides, and lead. Emission standards applied are considered stringent in comparison with many currently in use throughout the Nation. Mobile sources include automobiles and light and heavy-duty trucks. Stationary sources studied include solid waste disposal, commercial and institutional heating plants, industrial boilers, residential heating plants, steam-electric power plants, asphalt batching, brick and tile, coal cleaning, cement, elemental phosphorus, grain handling and milling (animal feed), gray iron, iron and steel, kraft (sulfate) pulp, lime, petroleum products and storage, petroleum refineries, phosphate fertilizer, primary nonferrous metallurgy (aluminum, copper, lead and zinc), rubber (tires), secondary nonferrous metallurgy, sulfuric acid, and varnish. Data essential for defining metropolitan areas, emission control standards, and relevant process and air pollution control engineering characteristics required to support the cost analyses for each source and the cost impact on each industrial process are presented and analyzed in separate appendixes to this report.

Residential heating was examined but control cost estimates were not made. Also, the economic impact of emission controls on the sulfuric acid industry was not made.

Air pollution control costs for mobile sources are presented on a national basis and in terms of unit investment and annual operating and maintenance costs as well as total annual operating and maintenance costs. The analyses cover the estimated emissions and control costs for new cars for Model Year (Fiscal Year) 1967 through Model Year (Fiscal Year) 1976. Control costs for each stationary source, except for residential heating, are shown for 298 metropolitan areas by investment and annual expenditures by Fiscal Year 1976. The emissions and cost estimates developed reflect the control costs of each stationary source in operation as of Calendar Year 1967 and those sources assumed to be constructed during Calendar Year 1968 through Fiscal Year 1976. The impact of control on selected industries and the Nation are also determined. Finally, an extensive bibliography is included.

Published separately but developed as a part of this research study are computer programs that will facilitate future cost projections (Volume II), and a survey plan for obtaining plant and plant process information where such information is presently lacking (Volume III).

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Chapter 1

Introduction

I. PURPOSE OF RESEARCH

This report is submitted in fulfillment of the requirements of the Air Pollution Control Office (APCO) Contract No. CPA 70-60. The research results presented herein are in support of the air pollution control cost estimates and resulting economic analyses given by the Administrator of the Environmental Protection Agency in the Third Report to the Congress of the United States as provided for in Section 305(a) of Public Law 90-148, the Clean Air Act, as amended.

The purpose of the research reported in this document was to make estimates of the air pollution control costs and economic impact that will result from implementation of the Clean Air Act, as amended. The section of the act pertinent to this research reads:

> *Sec. 305. (a) In order to provide the basis for evaluating programs authorized by this Act and the development of new programs and to furnish the Congress with the information necessary for authorization of appropriations by fiscal years beginning after June 30, 1969, the Secretary, in cooperation with State, interstate, and local air pollution control agencies, shall make a detailed estimate of the cost of carrying out the provisions of this Act; a comprehensive study of the cost of program implementation by affected units of government; and a comprehensive study of the economic impact of air quality standards on the Nation's industries, communities, and other contributing sources of pollution, including an analysis of the national requirements for and the cost of controlling emissions to attain such standards of air quality as may be established pursuant to this Act or applicable State law. The secretary shall submit such detailed estimates and the results of such comprehensive study of cost for the five-year period beginning July 1, 1969, and the results of such other studies, to the Congress not later than January 10, 1969, and shall submit a reevaluation of such estimate and studies annually thereafter.*

II. SCOPE OF RESEARCH

Air pollution control costs are estimated for mobile sources on a national basis and for three major categories of stationary sources (solid waste disposal, stationary fuel combustion, and industrial processes) for 298 designated metropolitan areas (Appendix I). An extended analysis was also carried out to determine the economic impact of control costs on each industrial source or group of industrial sources studied. In addition, this analysis was carried one step further in order to determine the aggregate effects of the individual industry impacts of control costs upon buyer industries and consumer prices. Although published separately, computer programs that facilitate cost projections, and a survey plan for obtaining plant and plant process information were developed as a part of this research study.

Included under the mobile source category are gasoline powered automobiles, and light and heavy-duty trucks. Stationary sources include solid waste disposal, stationary fuel combustion, and industrial processes. The sources included under stationary fuel combustion are commercial and institutional heating plants, industrial boilers, residential heating plants, and conventional steam-electric heating plants. The industrial process sources studied are: asphalt batching, brick and tile, coal cleaning, cement, elemental phosphorus, grain handling and milling (animal feed), gray iron, iron and steel, kraft (sulfate) pulp, lime, petroleum products and storage, petroleum refineries, phosphate fertilizer, primary nonferrous metallurgy (aluminum, copper, lead, and zinc), rubber (tires), secondary nonferrous metallurgy, sulfuric acid, and varnish.

The four pollutants for which control costs estimates are made for mobile sources are hydrocarbons, carbon monoxide, oxides of nitrogen, and total particulates. The six pollutants for which control cost estimates are made, as appropriate, for each stationary source are particulates, oxides of sulfur, carbon monoxide, hydrocarbons, fluorides, and lead. The emission standards applied for each pollutant are presented in Appendix II.

For the mobile source category, air pollution control costs are estimated on a nationwide basis and reflect the additional initial purchase costs and annual operating and maintenance costs to purchasers of new automobiles beginning in Model Year (Fiscal Year) 1967 through Model Year (Fiscal Year) 1976.

For stationary sources, air pollution control costs are estimated for each stationary source except residential heating plants that operated during 1967 in 298 designated metropolitan areas of the Nation. These 298 metropolitan areas, which were selected and defined by APCO for this research study, are presented in Appendix I of this report. In 1967, these areas contained 85 percent of the Nation's population. Additionally, air pollution control costs that would be incurred by facilities built during the period 1968 through Fiscal Year 1976 were estimated. These estimates are limited to stationary sources and to the 298 metropolitan areas selected. Estimated costs for each source are aggregated for the metropolitan areas and are given in terms of total investment required as well as the total annual cost which can be expected by Fiscal Year 1976.

The scope of the extended analysis of the economic impact of air pollution control costs on each of the industrial processes is limited to the analysis of the relationship between the expected air pollution control costs and product price changes and profit positions of firms within each source or group of sources. Information is presented on market and industry structure in order to determine those factors which principally affect market prices and profits as well as the viability of individual plants and firms subjected to additional investment requirements and operating costs. The analysis carried out to study the aggregate effects of the individual industry impacts was limited to two major buyer industries--motor vehicle and construction. These two industries are foci of cumulative cost increases because they are major purchasers from many of the larger and more affected industrial sources studied. Finally, using the input-output analysis technique, the effect of air pollution control costs on the overall price level of the national economy was determined.

III. PRINCIPAL STUDY LIMITATIONS

The principal limitations of this study are described below. Limitations are discussed separately and in greater detail in Appendix III, Mobile Sources, and Appendix IV, Stationary Sources.

The principal limitation to the mobile source air pollution control cost and emission analyses is imposed by data inadequacies. Second, the analyses are limited to gasoline powered automobiles and light and heavy-duty trucks. Third, control costs are limited to newly purchased vehicles, although annual emissions are calculated for the total vehicular population excluding buses and diesel trucks.

The major data limitations experienced in the analysis include: present size of the vehicle population, mileage data, vehicle classification, emission factors and, probably most significant, control system costs. Vehicle registration data tend to include duplicate counting and are also somewhat inconsistent with respect to vehicle classification. This necessitated careful analysis of available data in order to reduce multiple vehicle counts to a minimum as well as to develop a reasonable distribution of vehicle classification. The development of emission factors for mobile sources involved assumptions concerning typical vehicular use patterns. For this study, government standard definitions were used where they existed. To obtain data on particulate emissions, which are not well defined and for which there is no standard measurement procedure, published literature and other industrial information were used. Finally, control system cost data are sketchy at best. Manufacturers of such devices cannot, or will not, give exact cost figures for motor vehicle controls. This report utilizes a combination of "off the record" interviews with manufacturers plus whatever published estimates were available. For items not yet in production, the same basic approach was used, but with much less confidence.

For the stationary source category, several general study limitations should be stressed. Air pollution control costs were estimated only for establishments located within the selected 298 metropolitan areas and only for the six pollutants presented above. For most sources, however, this represents the majority of plants in the United States and the most significant pollutants involved. In any case, the total costs presented in this report should not be considered as the total cost for achieving clean air--neither in the 298 areas nor in the Nation.

More specific limitations to the air pollution control cost and economic analyses are related to data insufficiency and the need to establish various working assumptions.

Ideally, estimation of air pollution control costs and related emission estimates require data on the size, details on all emission sources, and present level of emission controls at each establishment. Unfortunately, the required data are rarely obtainable from available sources. Primary sources of data utilized in this study were obtained from technical and trade journals, APCO surveys, reports from the Department of Commerce, the Bureau of the Census, other government agencies, and private communication with individual manufacturing firms and trade associations. Whenever detailed data were unavailable, assumptions were made in order to develop the required cost and emission estimates.

As far as limitations affecting the economic impact analyses, it is equally true that the principal difficulty hinges on data and information inadequacies. The inability to adequately define company and industry economic structure in terms of revenue, profit, operating levels, capital availability and other key factors, as well as the inability to take into account specific corporation accounting practices, are stringent limitations to the analyses. In addition, certain assumptions such as working with constant 1967 dollars, unvarying technology, unchanging patterns of product substitution and product and process mix for firms, and the use of simplified economic scale models must also be considered as limitations. The resultant product is a first level analysis, and within the limitations imposed, these results present a picture from which conclusions and decisions can be made with some level of assurance.

IV. PLAN OF THE REPORT

The results of this study are presented in the following four chapters. Chapter 2 discusses the overall study methodology employed to develop (1) the control cost and emission estimates for mobile and stationary sources, (2) the economic impact analysis for the industrial process sources, and (3) the resultant aggregate impact analysis. Chapter 3 presents a summary of emissions, controls and costs for mobile sources. Chapter 4 presents a summary of emissions, controls and costs for all categories of stationary sources. Chapter 5 presents a detailed discussion of the analytical framework employed in determining the economic impact of the costs of controlling stationary sources as well as summary statements of the results. Summary results include statements on an industry-by-industry basis in addition to a discussion of the aggregate effects of the control costs.

Included also in the report are seven appendixes. Appendix I defines the 298 metropolitan areas which serve as the geographic scope of the stationary sources analysis. Appendix II presents the emission control standards applied for the purposes of the study for both mobile and stationary sources. Appendix III presents a detailed technical discussion of the mobile source analysis. Appendix IV presents the details of the engineering analysis for each stationary source as well as the details of the economic analysis for each industrial process source. Appendix V presents a broad based discussion of the subject, problems and potential solutions of controlling stationary combustion sources. Appendix VI presents an analysis of the aggregate effects of industry changes upon buyer industries and consumer prices. Appendix VII is the report bibliography. Computer programs (Volume II) that facilitate cost projections, and a survey plan (Volume III) for obtaining plant and plant process information not now available are published as two separate reports.

Chapter 2

Study Methodology

I. INTRODUCTION

The purpose of this chapter is to describe the methodological framework which serves as the basis for estimating air pollution emissions and control costs carried out in this research. For simplicity, the discussion is separated under two general headings: "Mobile Sources Methodology" and "Stationary Sources Methodology."

II. MOBILE SOURCES METHODOLOGY

A. Overview

The control cost and emission analyses for the mobile source category focussed only on gasoline powered automobiles and light and heavy-duty trucks. Buses and diesel trucks were not explicitly considered in the analysis. The baseline year for the analysis was Model Year 1967. Basically the methodology involved: (1) estimating the characteristics of the vehicle population in terms of number, type of vehicle and distribution of vehicle by age for each year of the period 1967 through 1976, (2) estimating control costs to purchasers of new vehicles purchased during the period 1967 through Fiscal Year 1976, and (3) estimating annual emissions of each pollutant both with and without installation of control systems for the total vehicle population. By 1976, over 80 percent of all vehicles in service will be model years 1967 through 1976. Finally, only air pollution control systems of proven technical feasibility were considered.

B. Selection of Vehicle Types and Pollutants

Considering the accuracy of available data and the significantly large fraction of vehicles represented by gasoline powered automobiles and light and heavy-duty trucks, the rationale for limiting the analysis to these vehicles and the exclusion of buses and diesel trucks is that the latter vehicles would not appreciably modify the resulting cost and emission analysis. The pollutants selected for the analysis were hydrocarbons, oxides of nitrogen, carbon monoxide, and total particulates.

On a Nationwide basis, the contribution of each of these emissions from mobile sources is a significant fraction of the total emissions of each pollutant. In addition, emission factors have been estimated, control standards proposed, and control technology determined for each of these.

C. Engineering and Cost Analysis

The engineering and cost analysis presented in Appendix III are predicated upon meeting increasingly stringent emission standards (Appendix II) for each of the pollutants for each model vehicle from 1967 through 1976. To meet these standards, factory installed control systems or combination of control systems have been assumed. The control systems for which costs have been estimated are presented in Tables III-4 and III-5 of Appendix III. Costs were estimated in terms of increased purchase and annual operating and maintenance costs to purchasers of new vehicles. For those control systems which could result in reduced operating costs, calculations were made to estimate these offsetting benefits. Information on initial control costs and anticipated incremental operating and maintenance costs were based upon available published data as well as personal communications with the automobile companies and with control system manufacturers. Operating and maintenance costs were based upon average vehicle use patterns.

The emission analysis included calculation of potential annual emissions for each pollutant without control, annual emissions assuming adoption of control practices, and the percent reduction of emissions on a yearly and cumulative basis. Emission factors were utilized which incorporated standard government definitions of typical vehicle use patterns. Acknowledgement of a typical vehicle use pattern is necessary because emission factors are stated in terms of mass rate per typical mile driven.

A detailed technical description of the analysis as well as a presentation of the results can be found in Chapter 3 and Appendix III.

III. STATIONARY SOURCES METHODOLOGY

A. Overview

The methodology followed in estimating air pollution control costs and emissions was basically an extension of last year's effort.[1/] Minor changes were incorporated, when new and improved data and information warranted, to improve the accuracy of estimates for various sources or pollutant types. This year, however, the study went beyond simply developing air pollution control cost estimates. For most of the industrial process sources, economic analyses were performed to determine the impact of the investment and annual cost requirements on the individual industry as well as aggregate impact on selected sectors and the national economy.

The steps taken in the engineering and cost analyses were:

1) Identification of significant sources for each pollutant.
2) Estimation of 1967 baseline data showing levels of emissions and controls.
3) Calculation of pollutant removal efficiencies required to meet the standards assumed.
4) Determination of appropriate control technology to achieve the required removal efficiencies.
5) Estimation of investment and annual costs for each control technique used by sources in existence in 1967.
6) Projection of emission and cost estimates through Fiscal Year 1976 and without indicated controls.

The following steps were added to the engineering and cost analyses to determine the economic impact of control costs on the industrial process sources:

1) Description of the industry and market structure relevant to each pollutant source.

1/ A departure from the previous effort (see Appendix VII, Bibliography, for report listing), although not specifically a methodological change, is in the presentation of the estimates. In this report, the estimates are presented in an aggregate fashion for 298 metropolitan areas instead of individual estimates for each area of the 100 metropolitan areas designated last year. The accuracy of aggregate estimates is clearly superior to individual regional estimates due to the necessity of utilizing average values of certain key parameters in the cost and emission estimating relationships.

2) Estimation of investment and annual control costs for typical plants or firms in each industry, where feasible.

3) Calculation of annual cost per unit of product sold.

4) Estimation of degree of cost shifting through product price by end of Fiscal Year 1976.

5) Evaluation of economic impact on typical firms, industry structures, prices, and sales.

6) Estimation of aggregate economic impact on selected industries and the national economy.

B. Selection of Sources and Pollutants

Of the many pollutants for which control expenditures may eventually be required, only six were selected by APCO for this study. They are particulates, sulfur oxides, hydrocarbons, carbon monoxide, fluorides, and lead. Choice of these particular pollutants was based on two important considerations. First, and most important, these pollutants are significant because of their widespread and adverse effects on communities. Second, acceptable emission control techniques exist for these six pollutants. In fact, air quality criteria and control technology documents for particulates, sulfur oxides, hydrocarbons, and carbon monoxide have already been published by APCO; fluoride and lead documents will be published in the near future.

The sources selected for inclusion in this study are those estimated to emit significant quantities of one or more of the above pollutants. The sources selected by APCO include solid waste disposal, commercial-institutional heating plants, industrial boilers, residential heating plants, steam-electric generating plants, and the following industrial process sources: asphalt, brick and tile, coal cleaning, cement, elemental phosphorus, grain handling and milling (animal feed milling only), gray iron foundries, iron and steel, kraft (sulfate) pulp, lime, petroleum products storage, petroleum refineries, phosphate fertilizer, primary nonferrous metallurgy (copper, lead, zinc, and aluminum), rubber (tires), secondary nonferrous metallurgy (copper, brass, bronze, aluminum, lead, and zinc), sulfuric acid, and varnish.

C. Engineering and Cost Analysis

Before cost analysis could be performed, a thorough engineering analysis of the sources was necessary. This included an understanding of production processes and an appraisal of their emissions on existing levels of control. In addition, there were numerous process steps for which one or more unit processes could be employed, e.g., wet or dry calcining of cement.

For each unit process, emission factors were either obtained from published literature or derived. Discussions of the emission factors employed for specific sources are presented in Appendix IV. Uncontrolled emissions were estimated for the unit processes simply by multiplying emission factors by appropriate production estimates. Estimates for a given source were made on an hourly, daily, or yearly basis for a given plant, an area, or the entire Nation.

To ascertain whether the 1967 emissions from a given source were in compliance with the assumed standards (Appendix II), it was necessary to estimate the existing level of control. Ideally, the level of control should be determined for each source within each metropolitan area. However, it became apparent early in the project that area-specific information could not be obtained during the available time, if at all. Accordingly, estimates of 1967 control levels were based on the best obtainable secondary data.[2/] For some sources, average control levels for the Nation were applied to the sources in all 298 metropolitan areas.

In some cases where emissions were being controlled, the control system was actually part of the production process; such costs were not considered to be air pollution control expenses.

The next step in the analysis was the calculation of the pollutant removal efficiences required to satisfy the emission standards assumed. Given the allowable and the existing emissions, the required removal efficiency was calculated using the following equation:

$$R.E. = \frac{Qe - Qa}{Qe} \times 100\%$$

2/ For the gray iron industry, control data on a plant by plant basis were available from an APCO survey.

where: R.E. is the removal efficiency (in percentage) required;
Qe is the existing emission; and
Qa is the allowable emission.

The relationship holds for both concentration-based and mass-rate emission standards.

The final step of the engineering analysis was the identification of applicable air pollution control alternatives. In nearly all cases, the designation of an alternative on which to base cost estimates was made because of industrial experience with the control alternative. Occasionally, it became apparent that one alternative was clearly superior to all others, but this was the exception rather than the rule. In most cases, there were several alternatives which would meet requirements. For example, the control of particulates can be accomplished by use of cyclones, fabric filters, electrostatic precipitators or wet-type scrubbers and, in the case of combustion equipment, by fuel substitution. Sulfur oxide emissions can be reduced by fuel substitution, gas scrubbing, and sulfur compound recovery systems. In general, the designation of control alternatives for carbon monoxide and hydrocarbons was straightforward since the number of alternatives was more limited. The specific control alternatives on which cost estimates for the given source were based are presented in Appendix IV. In general, the size of air pollution control equipment is expressed in terms of gas throughput and process size--gas volume relationships were determined for each unit process. In addition, certain engineering factors related to equipment cost had to be established, e.g., required pressure drop for venturi scrubbers; construction material; type of fabric filter material, wet or dry-type electrostatic precipitator, etc. Once these factors were determined, reasonable estimates of purchase, installation, and operating costs could be made. An example of a production - control cost relationship is shown in Figure 2-1 for the control of gray iron cupolas.

In order to apply the findings of engineering analysis to control cost estimation, a variety of source statistics were required. These source statistics included regional data for plant location and number of plants, production, capacity, and value of shipments, as applicable.

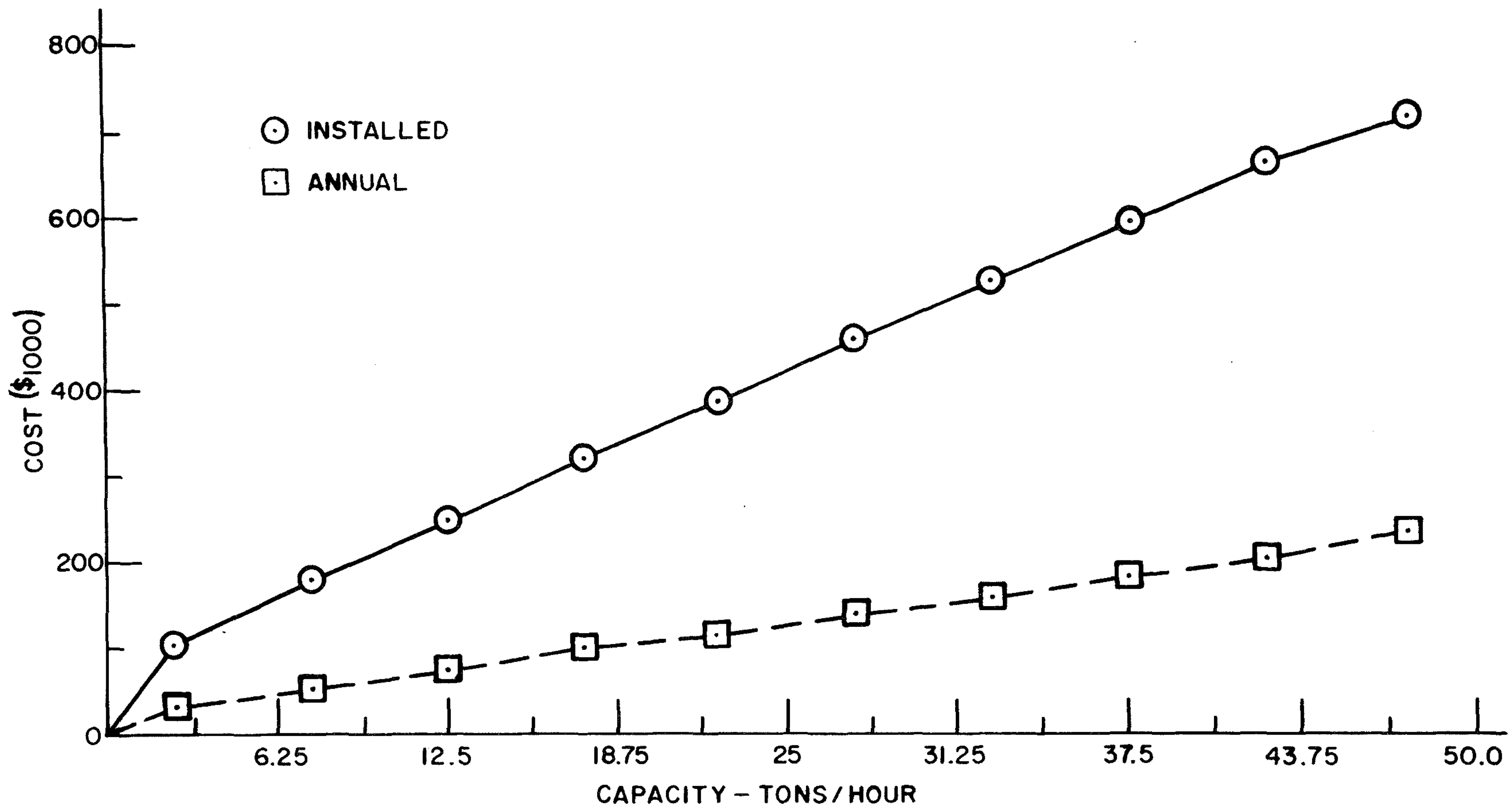

Fig. 2-1. Control Costs Versus Gray Iron Cupola Capacity.

Primary data on solid waste disposal were obtained from "The National Solid Wastes Survey" and the 1968 National Survey of Community Practices. For stationary combustion sources, the major sources of cost estimating data are given in Table 2-1. The principal sources of these data for industrial process sources are presented in Tables 2-2 through 2-4. Complete citations for most references may be found in the bibliography, Appendix VII.

A summary of statistics for industrial process sources is presented in Table 2-5.

Once a control alternative was designed and gas volume and other design specifications determined, control costs were calculated as a function of capacity and other production characteristics. The general array of tasks essential to the estimation of emission control costs is briefly described in this section.[3/] The initial task was that of gathering information about the number of plants or establishments in each of the 298 metropolitan areas. When available, detailed information about the number of plants or establishments in each of the 298 metropolitan areas and the size or capacity of individual processes within each plant was compiled. Most often, employment data were the best available indicators of plant size and production. The production estimate was then used to determine exhaust gas volume and emissions. In a few cases, the number of plants or the total capacity in an area had to be estimated because available records were incomplete. The amount of specific information that was obtained determined to a major extent the manner in which cost estimates were calculated.

Another task was to determine which plants needed emission controls, i.e., which plants emitted pollutants in excess of the assumed standards. Information inputs for this task were the 1967 level of control estimates and other factors provided by the engineering analysis described above.

Next, unit cost estimates for control alternatives or a combination of alternatives were computed. Data for these computations were obtained from a variety of sources: surveys, previous APCO studies, technical articles on specific control equipment, and articles dealing with specific industries. Unit cost estimates included all recognizable significant elements of costs; both initial investment and continuing annual costs

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3/ Minor but significant variations of the basic technique were necessary; the relevant sections of Appendix IV describes the method for each source category.

TABLE 2-1. - MAJOR SOURCES OF DATA FOR STATIONARY COMBUSTION COST ESTIMATING ANALYSES

Source	Major Document(s)
Steam-electric power generation plants	Steam-Electric Plant Construction Cost and Annual Production Expenses
Industrial boilers	1963 Census of Manufactures
Commercial-institutional heating plants	Supply and Demand for Energy in the U.S. by States and Regions, 1960 and 1967. Interstate Air Pollution Study: St. Louis, Phase II, Project Report, Air Pollution Emissions Inventory
Residential heating plants	1960 Census of Housing

TABLE 2-2. - PRINCIPAL SOURCES OF DATA ON INDUSTRIAL PROCESS SOURCE LOCATION, NUMBER, AND CAPACITIES

Data Class	
United States	298 Metropolitan Areas
American Bureau of Metal Statistics 1968 Yearbook Directory of Chemical Producers, Stanford Research Institute Directory of American Iron and Steel Works of the United States and Canada, 1967 Rubber Redbook, Directory of the Rubber Industry, 1968 (20th ed.) Waste Trade Directory 1963 Census of Business Rock Products, July 1967 and May 1969 Mimeographed lists, U.S. Bureau of Mines Tape from Dun and Bradstreet List prepared by Resources Research, Inc. N.E.S.S. Report, NAPCA Lists from state highway departments Lists from surveys by U.S. Department of Commerce and NAPCA Telephone contacts with firms	The sources used for the U.S. data on number of employees from 1963 Census of Manufactures and 1964-67 County Business Patterns

TABLE 2-3. - PRINCIPAL SOURCES OF DATA ON INDUSTRIAL PROCESS SOURCE PRODUCTION

Data Class	
United States	298 Metropolitan Areas
American Bureau of Metal Statistics 1968 Yearbook Bureau of Mines Minerals Yearbook, 1966 and 1967 Survey of Current Business, 1968 issues 1963 Census of Manufactures 1963 U.S. Census of Business U.S. Industrial Outlook, 1969 "Sulfuric Acid," Current Industrial Reports, 1967 Hot-Mix Asphalt Production and Use Facts for 1967 The Statistics of Paper, 1968 Supplement Feed Situation, ERS, USDA, May 1969	U.S. capacity in the industry was prorated to each of the 298 metropolitan areas on data from the Dun and Bradstreet tape, 1963 Census of Manufactures and 1964-67 County Business Patterns.

TABLE 2-4. - PRINCIPAL SOURCES OF DATA ON INDUSTRIAL PROCESS SOURCE VALUE OF SHIPMENTS

Data Class	
United States	298 Metropolitan Areas
Census of Manufactures, Preliminary Report 1963 Census of Manufactures 1963 U.S. Census of Business Bureau of Mines Minerals Yearbook, 1967 "Sulfuric Acid," Current Industrial Reports, 1967 U.S. Industrial Outlook 1969 Telephone contacts with firms Estimates of U.S. production Annual Report, International Paper Co., 1966	U.S. value of shipments by industry was prorated to each of the 298 metropolitan areas on the basis of the ratio of metropolitan area to U.S. production.

TABLE 2-5. - 1967 STATISTICS FOR INDUSTRIAL PROCESS SOURCES (NATIONALLY AND IN 298 METROPOLITAN AREAS)[1]

Source and Unit of Measurement		Total Number of Sources		Capacity[2] (Millions of Units per Year)		Production[2] (Millions of Units per Year)		Value of Shipments (Billions of Dollars per Year)	
		United States	298 Areas	United States	298 Areas	United States	298 Areas	United States	298 Areas
Asphalt Batching	tons of paving mixture[3]	1,284	1,064	658.0	549.0	216.0	180.0	1.50	1.30
Brick and Tile	brick equivalents	469	301	10,100.0	7,150.0	8,260.0	5,910.0	0.35	0.25
Coal Cleaning	tons	667	256	370.0	139.0	349.0	131.0	1.53	0.58
Cement	barrels	178	138	515.0	395.0	374.0	252.0	1.21	0.83
Elemental Phosphorus	tons	13	8	0.7	0.3	0.6	0.3	0.20	0.14
Grain: Handling	bushels[4]	11,124	4,098	6,430.0	3,480.0	18,000.0	9,760.0	N/A[5]	N/A[5]
Milling	tons	2,496	2,155	66.0	55.5	55.0	46.2	4.60	3.70
Gray Iron Foundries	tons of castings[3]	1,446	1,179	17.0	14.0	14.3	11.8	2.70	2.20
Iron and Steel	tons of raw steel	142	134	165.0	161.0	127.0	124.0	13.30	13.10
Kraft (Sulfate) Pulp	tons	116	81	32.1	22.5	23.9	16.8	3.60	2.50
Lime	tons	185	113	21.0	14.2	16.8	11.3	0.24	0.16
Petroleum Products and Storage	gallons[6]	29,664	14,998	182.0	129.0	1,820.0	1,290.0	22.50	15.80
Petroleum Refineries	barrels	256	199	4,210.0	3,620.0	3,580.0	2,720.0	20.29	15.41
Phosphate Fertilizer	tons P_2O_5	179	147	12.2	10.3	7.0	5.7	1.60	1.20
Primary Nonferrous Metallurgy: Aluminum	tons[7]	24	14	3.5	2.0	3.3	1.9	1.56	0.88
Copper	tons[7]	19	10	9.3	6.4	2.6	1.8	1.98	1.36
Lead	tons[7]	6	4	1.7	1.2	0.5	0.3	0.13	0.92
Zinc	tons[7]	15	9	1.3	0.6	0.9	0.4	0.33	0.15
Rubber (Tires)	tires[8]	60	54	1.1[8]	1.0[8]	213.0	196.0	3.70	3.40
Secondary Nonferrous Metallurgy	tons	627	583	2.6	1.9	2.3	1.7	1.59	1.17
Sulfuric Acid	tons	213	180	38.7	32.9	28.8	24.5	0.25	0.21
Varnish	gallons	220	216	23.0	22.0	10.0	9.6	0.03	0.03

1/ The 298 metropolitan areas are defined in Appendix I.

2/ Capacity and production are in millions of units (tons, etc.) unless otherwise footnoted.

3/ Capacity is calculated assuming 1,000 operating hours per year.

4/ Capacity is in million bushels of storage space; production, million bushels of throughput.

5/ Not applicable.

6/ Capacity is in billion gallons of gasoline storage space; production, billion gallons of gasoline handled.

7/ "Tons" applies to smelters; for copper and lead, capacity is given as input material and production is adjusted to remove effect of a labor strike.

8/ Capacity is in millions of tires per day.

information and estimates or assumptions were used only in the absence of specific data.

When installation of new control systems is involved, control costs are reported in terms of the initial investment required to implement controls and the continuing annual expenses related to that investment. The investment cost is the total expense of purchasing and installing control equipment. The annual cost is the sum of yearly charges for capital-related costs (interest on the investment funds, property taxes where applicable, insurance premiums, and depreciation charges) plus operating (fuel, labor, utilities, and supplies) and maintenance costs.

To account for the effect of upgrading existing control equipment, where possible, to meet increased control requirements, a set of cost-efficiency parameters called multipliers were derived. The multipliers were derived from the relationship that installed costs for 99 percent control would be double the cost for 90 percent control and that costs for 99.9 percent control would be three times the cost at 90 percent. The three points, (i.e., 90 percent equals 1.0, 99.0 equals 2.0, and 99.9 percent equals 3.0) were used to establish an exponential curve from which cost multipliers for other specific control efficiency levels could be read. With the multipliers taken from the curve, costs given in the literature for one level of efficiency can be adjusted for any other efficiency level. As an example, unit cost for a 95 percent efficiency control level can be adjusted for 98 percent efficiency as follows:

$$C_{98} = \frac{M_{98}}{M_{95}} \times C_{95}$$

where: C_{98} = cost for 98% control;

C_{95} = cost for 95% control;

M_{98} = multiplier for 98% control; and

M_{95} = multiplier for 95% control.

Hence, incremental investment costs can be calculated on the basis of $C_{98} - C_{95}$. Annual operating and maintenance costs in this situation are also reported on the basis of the increase required to move from a lower removal efficiency to the higher level.

For this study, the level of control which existed in an industry as of 1967 was used as a baseline; cost estimates were calculated only for providing controls in excess of the 1967 average level for a pollutant and a source. For example, the estimated 1967 average level of control in the asphalt industry was 80 percent; therefore, the estimated costs of control reflect only expenditures that must be made to comply with the assumed standard by the industry over and above the 1967 baseline of 80 percent. This working assumption follows from the premise that the level of control in effect when the Clean Air Act was amended in 1967 is not attributable to the Act. It was further assumed that the additional sources constructed after 1967 will be controlled at the 1967 control level and hence only the control required above this level would be attributable to the Act.

In order to project air pollution control cost and emission estimates through Fiscal Year 1976 for the industrial process sources, it was necessary to develop projections of the annual growth rates of production and capacity for each source. This was accomplished by projecting future production on the basis of a least square regression analysis with time (year) as the independent variable.[4/] The average annual rate of growth (or decline) in production could then be projected. The average annual rates of growth (or decline) in capacity were developed by relating the change in production projected to the change in capacity necessary in order to have the Fiscal Year 1976 operating rate equal to the average operating rate for the period 1958-1968. Table 2-6 presents the average annual growth rates for both production and capacity utilized in this study.

Except for the gray iron foundry industry and solid waste disposal, estimates of annual control costs were based on ten-year, straight-line (10 percent) depreciation of the indicated investment and 10 percent to cover capital-related charges such as interest, taxes, and insurance. In the gray iron foundry industry, depreciation and capital-related expenses were obtained from plant survey data. For estimates in solid

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4/ Except where such exogenous events as the apparent removal of tetraethyl lead from gasoline, and hence the predicted downward demand for lead, made it apparent that this technique was not valid.

TABLE 2-6.-AVERAGE ANNUAL GROWTH RATE FOR PRODUCTION AND CAPACITY

Industry	Average Annual Growth Rate for Production (Percent)	Average Annual Growth Rate for Capacity (Percent)
Steam-Electric (Fossil Fuel)	4.3	4.3
Asphalt Batching	3.1	3.1
Brick and Tile	1.5	1.5
Coal Cleaning	3.2	3.2
Cement	2.0	2.0
Elemental Phosphorus	4.6	4.9
Grain Handling and Milling	2.8	3.2
Gray Iron Foundries	6.2	6.6
Iron and Steel	3.9	4.2
Kraft (Sulfate) Pulp	6.0	6.0
Lime	4.7	4.7
Petroleum Products and Storage	2.7	2.7
Petroleum Refineries	2.7	2.8
Phosphate Fertilizer	5.1	5.3
Primary Nonferrous Metallurgy:		
Aluminum	5.8	4.4
Copper	1.3	0.2
Lead	4.1	4.1
Zinc	2.6	1.4
Rubber (Tires)	4.2	5.1
Secondary Nonferrous Metallurgy	6.1	6.6
Sulfuric Acid	4.9	5.1
Varnish	-2.4	-5.9

waste disposal, accounting conventions normally used by municipalities were employed. For all industries, maintenance and other operating expenses were estimated on the basis of the types of process and control equipment involved.

Finally, it should be noted that the cost and emission estimates were based on the best available data. Where data were scarce, engineering judgement had to be applied to fill in the analytical gaps. In all cases all assumptions were carefully reviewed.

D. Economic Analysis

The purpose of the economic analysis was to estimate the impact that would be felt by firms applying the designated controls to plants or operating units within the company structure, and thereby incurring the required investment and annualized cost. It was intended to answer, so far as possible, questions about the extent to which firms might shift the costs to customers in the form of higher prices, whether profits would be reduced, whether competitive market patterns would be disturbed, and whether some plants or companies would be forced to close.

The form of the analysis differed somewhat from industry to industry, depending upon the absolute magnitude of the costs involved, the structure of the industry and its market, and the kinds and amounts of data available. In general, the analysis followed the steps outlined in Paragraph A of this section and as described below:

1) Description of the industry and market. Basic data were assembled showing, within the data limitations, the number of firms, size distribution, operating characteristics, and similar measures of each industry. Product markets, major customers, sales practices, and distribution of sales were also defined for each industry. Estimates were made of price trends, demand, production, capacity, and capacity utilization. This stage of the analysis concluded with a qualitative

evaluation of the type and intensity of intra- and inter-industry competition for each industry studied.

2) Estimation of investment and annual control costs. The costs generated per control technique, per unit process or plant in the engineering and cost analysis, were translated into investment requirements and annual costs per firm, or per plant if that was the data availability limit. Where feasible, typical firms or plants were defined to represent the significant variations of size and process utilization within the industry and cost differentials resulting from these calculated variations. These costs were compared, where possible, with typical revenues and profits.

3) Calculation of annual cost per unit of production. The range of annual costs developed for typical firms or plants in the previous step were expressed as unit costs on the basis of the estimated production for those firms or plants, assuming a percentage utilization of capacity. Unit costs were then expressed as percentages of price.

4) Estimation of cost shifting. A qualitative evaluation was made of the price elasticity of demand over a price range equal to maximum annual cost per unit of product and the pricing practices of the industry, based on the industry and market data developed in Step 1. An estimate was then made of the probability that firms in each industry would raise prices to offset the increased costs resulting from installation of controls. The most probable change in price attributable to control costs by Fiscal Year 1976, exclusive of all other price influences, was estimated.

5) Evaluation of economic impact. Qualitative evaluation was made of the impact of nonshiftable control costs on the revenue and profit position of typical firms. Similarly, the impact of price changes on competitive markets was examined. Finally, the probability that some firms in each industry might be forced out of business or forced to change production and product patterns was estimated.

6) Estimation of aggregate impact. Using input-output analysis, the cumulative impact of price changes due to control costs was estimated for the automobile and construction industries. The aggregate effect of price changes induced by control costs on the national price level was also estimated, using the Gross National Product (GNP) deflator as the index of change.

Chapter 3

Summary of Mobile Sources

I. INTRODUCTION

The purpose of this chapter is to present the results of the mobile sources control cost and emission reduction analyses. The mobile sources included in the analyses were gasoline powered automobiles and light and heavy-duty trucks. Pollutants considered were hydrocarbons, carbon monoxide, oxides of nitrogen, and total particulates. The analyses cover the period 1967 through Fiscal Year 1976. A detailed discussion of the analyses and results are presented in Appendix III of this report.

II. EMISSION STANDARDS

Emission standards increasing in stringency through Fiscal Year 1976 were applied for each pollutant. These standards were considered to apply only to newly purchased vehicles. None of the emission standards used in this report apply to used vehicles. The control standards to be met by newly purchased vehicles in Fiscal Year 1976 are considered to be the limit of what can be expected with the present reciprocating internal combustion engine. It should be noted that the specific standards applied in this report were those promulgated or under consideration as of July 15, 1970. As will be reiterated in Appendix III, if the implementation of the standards adopted for this study is accelerated or if the standards are increased in stringency it can be expected that control costs will rise proportionally while annual emissions can be expected to decrease.

III. EMISSION CONTROL COSTS

Emission control costs were calculated on the basis of additional investment and operating and maintenance costs to purchasers and users of new vehicles beginning with vehicle model year 1968. For the purposes of analysis, vehicle model year and fiscal year were considered to be equivalent. Table 3-1 summarizes unit investment and annual operating and maintenance costs for automobiles, light-duty trucks and heavy-duty trucks, as well as total annual investment requirements and cumulative total annual operating and maintenance costs. As can be seen, unit investment costs per vehicle range from two dollars in 1968 to 240 dollars in 1976 for autos and light-duty trucks and from zero in 1968 to 46 dollars in 1976 for heavy-duty trucks. The resultant national investment requirement ranged from $13.9 million in 1968 to $3.03 billion in 1976. For autos and light-duty trucks, the control alternatives chosen for the years 1968 thru 1972 actually lead to reduced operating and maintenance costs. Starting with the control systems installed from 1973 on, however, increased operating and maintenance do occur. For heavy-duty trucks, operating and maintenance costs are either zero or positive. Cumulatively, national annual operating and maintenance costs reach $908 million by 1976.

IV. EMISSION REDUCTIONS

Table 3-2 summarizes the effect of the control costs expenditures on the annual emission of each of the pollutants. By Fiscal Year 1976, total national emissions of hydrocarbons, carbon monoxide, nitrogen oxides, and particulates from autos and trucks of all ages are reduced 71, 60, 23, and 16 percent, respectively. It is significant to note that before 1975, when nitrogen oxide standards become effective, increasing the control of hydrocarbons and carbon monoxide lead to increases in nitrogen oxide emissions. After 1975, the controlling of these emissions on a national level begins with the introduction of nitrogen oxide control systems. Also, the standards and hence reduction of particulate emissions do not begin until 1975. As time passes and with larger fractions of the vehicle population being under control by Fiscal Year 1976, the percent reduction of all pollutants from potential emissions will increase.

TABLE 3-1. - SUMMARY OF MOBILE SOURCES EMISSION CONTROL COSTS

Fiscal Year	Investment Cost per Vehicle [Autos and Light-Duty Trucks] (Dollars)	Additional Operating and Maintenance Cost per Vehicle [Autos and Light-Duty Trucks] (Dollars/Year)	Investment Cost per Vehicle [Heavy-Duty Trucks] (Dollars)	Additional Operating and Maintenance Cost per Vehicle [Heavy-Duty Trucks] (Dollars/Year)	Incremental Investment Cost to Purchasers of Model Year Vehicle (Millions of Dollars)	Cumulative Annual Operating and Maintenance Costs (Millions of Dollars)
1967	0	0	0	0	0	0
1968	2.00	-5.10[1]	0	0	13.9	- 35.4[1]
1969	2.00	-5.10[1]	0	0	20.7	- 88.2[1]
1970	7.00	-5.10[1]	9.00	0	56.1	-138.3[1]
1971	17.00	-2.70[1]	9.00	0	131.1	-175.3[1]
1972	17.00	-2.70[1]	9.00	0	136.6	-208.9[1]
1973	42.00	7.90	21.00	3.50	346.3	-154.4[1]
1974	42.00	7.90	21.00	3.50	498.5	- 50.3[1]
1975	240.00	20.70	46.00	13.50	2,068.7	743.5
1976	240.00	20.70	46.00	13.50	3,031.7	908.6

1/ Negative values indicate a savings in cost of operation.

TABLE 3-2. - SUMMARY OF MOBILE SOURCES NATIONAL ANNUAL EMISSION REDUCTION

Fiscal Year	Potential Emissions (millions of tons/year)				Controlled Emissions (millions of tons/year)			
	Hydrocarbons	Carbon Monoxide	Nitrogen Oxides	Particulates	Hydrocarbons	Carbon Monoxide	Nitrogen Oxides	Particulates
1967	21.1	126.0	5.70	0.33	21.1	126.0	5.70	.33
1968	24.2	130.0	5.91	0.35	20.7	125.6	6.07	0.35
1969	25.4	137.0	6.18	0.36	20.2	124.4	6.56	0.36
1970	26.1	140.0	6.35	0.37	19.0	118.4	6.91	0.37
1971	26.5	143.0	6.45	0.38	17.4	110.5	7.20	0.38
1972	27.3	146.0	6.64	0.29	15.7	102.0	7.58	.39
1973	28.0	151.0	6.82	0.40	14.1	94.0	7.44	.39
1974	28.8	155.0	7.00	0.41	12.4	86.0	7.13	0.41
1975	29.9	160.0	7.26	0.42	10.7	76.3	6.55	0.39
1976	30.8	166.0	7.50	0.44	9.1	66.4	5.78	0.37

Chapter 4

Summary of Stationary Sources

I. INTRODUCTION

The stationary sources covered in this chapter include solid waste disposal, stationary fuel consumption for heat and power, and industrial process sources. The engineering and technical analysis conducted for this study provides estimates of the levels of emissions of six pollutants: particulates, sulfur oxides, carbon monoxide, hydrocarbons, fluorides, and lead. The quantities of emissions of these pollutants from each source were estimated as of 1967. These provided a baseline from which to estimate the controls needed, their associated costs, and the control effectiveness that could be related to the passage of the Clean Air Act of 1967. Potential emissions were projected to fiscal year 1976 and the reduced emissions attainable in that year were calculated, along with estimates of the investment required to meet designated emission standards and the annual cost of control for fiscal year 1976. The results of this analysis are presented in this chapter. Detailed discussions of the analyses are presented in Appendix IV of this report.

II. EMISSION LEVELS

A. Solid Waste Disposal

It is estimated that solid waste was generated at the rate of 10.2 pounds per person per day in the United States in 1967. The 298 metropolitan areas had an estimated population of 166,882,000 in that year and therefore approximately 311 million tons of solid waste. Of this, 15 percent was incinerated, 42 percent was open burned, and 43 percent disposed of in landfills, ocean dumping, composting, and other ways. Incineration and open burning are sources of particulate, carbon monoxide, and hydrocarbon emissions. The initial 1967 estimated emissions and the 1976 levels of these emissions, as estimated with and without implementation of the Clean Air Act, are shown in Table 4-1.

TABLE 4-1. - SOLID WASTE DISPOSAL AND STATIONARY FUEL COMBUSTION
ESTIMATES OF POTENTIAL AND REDUCED EMISSION LEVELS AND ASSOCIATED COSTS

[298 Metropolitan Areas][1/]

Source	Year	Quantity of Emissions (Thousands of Tons per Year)[2/]						Associated Emission Control Level (Percent)						Control Costs (Millions of Dollars)	
		Part	SO_X	CO	HC	F	Pb	Part	SO_X	CO	HC	F	Pb	Investment	Annual
Solid Waste Disposal	1967	1,110.0	-	3,770.0	1,400.0	-	-	N/A [5/]	-	N/A [5/]	N/A [5/]	-	-		
	FY76 W/O[3/]	1,500.0	-	5,450.0	2,020.0	-	-	N/A [5/]	-	N/A [5/]	N/A [5/]	-	-		
	FY76 W[4/]	185.0	-	414.0	293.0	-	-	N/A [5/]	-	N/A [5/]	N/A [5/]	-	-	201.0	113.0
Commercial-Institutional Heating Plants	1967	127.0	940.0	-	-	-	-	0	0	-	-	-	-		
	FY76 W/O[3/]	152.0	1,440.0	-	-	-	-	0	0	-	-	-	-		
	FY76 W[4/]	135.0	1,400.0	-	-	-	-	11.2	2.8	-	-	-	-	41.7	25.1
Industrial Boilers	1967	1,360.0	2,330.0	-	-	-	-	61.5	0	-	-	-	-		
	FY76 W/O	1,410.0	2,310.0	-	-	-	-	62.0	0	-	-	-	-		
	FY76 W	142.0	1,100.0	-	-	-	-	99.0	50.5	-	-	-	-	1,050.0	555.0
Residential Heating Plants	1967	160.0	776.0	-	-	-	-	0	0	-	-	-	-		
	FY76 W/O	120.0	597.0	-	-	-	-	0	0	-	-	-	-		
	FY76 W	120.0	597.0	-	-	-	-	0	0	-	-	-	-	0	0
Steam-Electric Power Plants	1967	1,600.0	7,370.0	-	-	-	-	78.0	0	-	-	-	-		
	FY76 W/O	2,185.0	10,100.0	-	-	-	-	78.0	0	-	-	-	-		
	FY76 W	533.0	1,600.0	-	-	-	-	96.6	84.1	-	-	-	-	1,340.0	426.0

1/ The 298 metropolitan areas are defined in Appendix I.

2/ Emissions abbreviated are: particulates (Part), sulfur oxides (SO_X), carbon monoxide (CO), hydrocarbons (HC), fluorides (F), and lead (Pb). Blanks in the table indicate the emission levels meet the applicable regulation (Appendix II) or that emissions are negligible or do not exist.

3/ Estimates without implementation of the Clean Air Act are shown.

4/ Estimates with implementation of the Clean Air Act are shown.

5/ Not applicable.

B. Stationary Fuel Combustion

Combustion of fossil fuels for the production of heat and power is the source of substantial emissions of particulates and sulfur oxides. Coal and residual fuel oil are the fuels causing the most emissions, while distillate fuel oils and natural gas produce very small amounts of pollutants when burned in properly adjusted equipment.

For this analysis, the sources in this category have been divided into residential heating, commercial-institutional heating, industrial boilers (excluding fuel combustion that is part of the direct production process, as in a cement kiln, for instance), and steam-electric generation.

Included within the 298 metropolitan areas are 95.3 percent of the commercial-institutional heating plants, 83.4 percent of the industrial boilers, 81.0 percent of the residential heating plants, and 75.0 percent of the steam-electric power plants in the United States in 1967.

Table 4-1 shows the 1967 and 1976 emissions of particulates and sulfur oxides estimated for each of these sources and the associated emission control levels with and without controls. It is clear that industrial boilers and steam-electric power plants are the most important sources of emissions in this category, although commercial-institutional heating plants contribute substantial emissions of sulfur oxides as well. The control techniques adopted for this study can reduce particulate emissions from the major sources by more than 95 percent. Control of sulfur oxides is somewhat less effective, ranging from an estimated 50.5 percent to an estimated 80.1 percent for the two largest source categories.

C. Industrial Processes

Eighteen industries or industry groups were included for analysis as major sources of the six pollutants under study. Of these, 15 are sources of particulates, three of sulfur oxides, two of carbon monoxide, three of hydrocarbons, five of fluorides, and two of lead. Table 4-2 shows the estimated 1967 and 1976 emission levels and control effectiveness for each pollutant by source.

TABLE 4-2.- INDUSTRIAL PROCESS SOURCES - ESTIMATES OF POTENTIAL AND REDUCED EMISSION LEVELS AND ASSOCIATED COSTS

[298 Metropolitan Areas][1/]

Source	Year	Quantity of Emissions (Thousands of Tons per Year)[2/]						Associated Emission Control Level (Percent)						Control Costs (Millions of Dollars)	
		Part	SO_x	CO	HC	F	Pb	Part	SO_x	CO	HC	F	Pb	Investment	Annual
Asphalt Batching	1967	452.0	-	-	-	-	-	80	-	-	-	-	-		
	FY76 W/O[3/]	571.0	-	-	-	-	-	80	-	-	-	-	-		
	FY76 W[4/]	37.8	-	-	-	-	-	98	-	-	-	-	-	15.4	12.3
Brick and Tile	1967	-	-	-	-	15.6	-	-	-	-	-	0	-		
	FY76 W/O	-	-	-	-	20.8	-	-	-	-	-	0	-		
	FY76 W	-	-	-	-	1.0	-	-	-	-	-	95	-	40.8	11.6
Coal Cleaning	1967	64.7	-	-	-	-	-	58	-	-	-	-	-		
	FY76 W/O	92.3	-	-	-	-	-	58	-	-	-	-	-		
	FY76 W	14.1	-	-	-	-	-	93	-	-	-	-	-	13.1	5.3
Cement Plants	1967	239.0	-	-	-	-	-	96	-	-	-	-	-		
	FY76 W/O	280.0	-	-	-	-	-	96	-	-	-	-	-		
	FY76 W	16.1	-	-	-	-	-	99.7	-	-	-	-	-	110.0	29.6
Elemental Phosphorus	1967	2.4	-	-	-	2.4	-	80	-	-	-	85	-		
	FY76 W/O	3.3	-	-	-	3.3	-	80	-	-	-	85	-		
	FY76 W	0.2	-	-	-	0.2	-	99.0	-	-	-	98	-	6.6	3.1
Grain:															
Handling	1967	1,400.0	-	-	-	-	-	35	-	-	-	-	-		
	FY76 W/O	1,730.0	-	-	-	-	-	35	-	-	-	-	-		
	FY76 W	26.1	-	-	-	-	-	99.0	-	-	-	-	-	436.0	153.0
Milling	1967	274.0	-	-	-	-	-	35	-	-	-	-	-		
	FY76 W/O	347.0	-	-	-	-	-	35	-	-	-	-	-		
	FY76 W	5.4	-	-	-	-	-	99.0	-	-	-	-	-	27.4	11.0
Gray Iron Foundries	1967	166.0	-	2,220.0	-	-	-	12	-	18	-	-	-		
	FY76 W/O	255.0	-	3,420.0	-	-	-	12	-	18	-	-	-		
	FY76 W	29.1	-	209.0	-	-	-	90	-	95	-	-	-	317.3	108.2
Iron and Steel	1967	1,100.0	-	-	-	26.4	-	55	-	-	-	30	-		
	FY76 W/O	1,460.0	-	-	-	35.2	-	55	-	-	-	30	-		
	FY76 W	93.0	-	-	-	5.2	-	97	-	-	-	89	-	981.0	507.0
Kraft (Sulfate) Pulp	1967	561.0	-	-	-	-	-	81	-	-	-	-	-		
	FY76 W/O	847.0	-	-	-	-	-	81	-	-	-	-	-		
	FY76 W	120.0	-	-	-	-	-	98	-	-	-	-	-	73.0	30.3
Lime	1967	181.0	-	-	-	-	-	60	-	-	-	-	-		
	FY76 W/O	253.0	-	-	-	-	-	60	-	-	-	-	-		
	FY76 W	20.3	-	-	-	-	-	97	-	-	-	-	-	10.6	14.5
Petroleum Products and Storage	1967	-	-	-	600.0	-	-	-	-	-	63	-	-		
	FY76 W/O	-	-	-	738.0	-	-	-	-	-	63	-	-		
	FY76 W	-	-	-	320.0	-	-	-	-	-	86	-	-	1,080.0	0
Petroleum Refineries	1967	80.0	1,750.0	5,300.0	810.0	-	-	67	37	47	67	-	-		
	FY76 W/O	98.4	2,150.0	6,620.0	996.0	-	-	67	37	47	67	-	-		
	FY76 W	30.7	1,270.0	330.0	529.0	-	-	90	62	95	87	-	-	162.0	7.1
Phosphate Fertilizer	1967	-	-	-	-	0.6	-	-	-	-	-	98	-		
	FY76 W/O	-	-	-	-	1.5	-	-	-	-	-	98	-		
	FY76 W	-	-	-	-	0.2	-	-	-	-	-	99.8	-	32.1	10.0
Primary Nonferrous Metallurgy:															
Aluminum	1967	6.0	-	-	-	8.2	-	90	-	-	-	90	-		
	FY76 W/O	8.9	-	-	-	12.2	-	90	-	-	-	90	-		
	FY76 W	1.7	-	-	-	2.3	-	98	-	-	-	98	-	223.3	75.8
Copper	1967	-	2,140.0	-	-	-	-	-	25	-	-	-	-		
	FY76 W/O	-	2,380.0	-	-	-	-	-	25	-	-	-	-		
	FY76 W	-	227.0	-	-	-	-	-	94	-	-	-	-	87.0	42.0
Lead	1967	-	200	-	-	-	5.5	-	32	-	-	-	96		
	FY76 W/O	-	269.5	-	-	-	7.9	-	32	-	-	-	96		
	FY76 W	-	17.2	-	-	-	7.9	-	96	-	-	-	96	16.2	7.1
Zinc	1967	-	416.0	-	-	-	-	-	51	-	-	-	-		
	FY76 W/O	-	508.0	-	-	-	-	-	51	-	-	-	-		
	FY76 W	-	76.7	-	-	-	-	-	93	-	-	-	-	4.7	2.2
Rubber (Tires)	1967	1.2	-	-	n.a.[5/]	-	-	80	-	-	n.a.[5/]	-	-		
	FY76 W/O	1.7	-	-	n.a.[5/]	-	-	80	-	-	n.a.[5/]	-	-		
	FY76 W	-	-	-	n.a.[5/]	-	-	99.0	-	-	n.a.[5/]	-	-	1.9	1.3
Secondary Nonferrous Metallurgy	1967	9.8	-	-	-	-	14.5	48	-	-	-	-	48		
	FY76 W/O	14.8	-	-	-	-	22.0	48	-	-	-	-	48		
	FY76 W	2.9	-	-	-	-	2.2	96	-	-	-	-	96	61.9	21.8
Sulfuric Acid	1967	63.6	650.0	-	-	-	-	46	0	-	-	-	-		
	FY76 W/O	90.1	921.0	-	-	-	-	46	0	-	-	-	-		
	FY76 W	55.1	129.0	-	-	-	-	67	86	-	-	-	-	176.0	40.8
Varnish	1967	-	-	-	2.2	-	-	-	-	-	18	-	-		
	FY76 W/O	-	-	-	2.2	-	-	-	-	-	18	-	-		
	FY76 W	-	-	-	0.3	-	-	-	-	-	90	-	-	0.8	1.0

1/ The 298 metropolitan areas are defined in Appendix I.

2/ Emissions abbreviated are: particulates (Part), sulfur oxides (SO_x), carbon monoxide (CO), hydrocarbons (HC), fluorides (F), and lead (Pb). Blanks in the table indicate the emission levels meet the applicable regulation (Appendix II) or that emissions are negligible or do not exist.

3/ Estimates without implementation of the Clean Air Act are shown.

4/ Estimates with implementation of the Clean Air Act are shown.

5/ Not available.

III. COSTS

Control of emissions from stationary sources as indicated in this study and shown in Table 4-3 will require a total estimated investment by Fiscal Year 1976 of $6,510 million. By that year, the associated total annual control cost, including depreciation, operating and maintenance costs, will amount to an estimated $2,214 million.

As noted in Table 4-3, an investment of $201 million and annual costs of $113 million for control of solid waste disposal will reduce emissions of particulates by 87.7 percent, carbon monoxide by 92.4 percent, and hydrocarbons by 85.5 percent of the level of these emissions that would otherwise occur in Fiscal Year 1976. From the analyses reported in Appendix IV, it is estimated that approximately 54 percent of these costs will be borne by municipalities and the remaining 46 percent by private businesses and individuals.

Table 4-3 further shows that control of stationary fuel combustion sources will require a total investment of approximately $2,432 million by Fiscal Year 1976 and annual costs in that year will be approximately $1,006 million. As a result, it is estimated that particulate emissions will be reduced by 75.9 percent and sulfur oxide emissions will be reduced by 67.5 percent below the levels of emissions that would otherwise prevail as a result of fuel combustion in that year. By far the greatest share of these costs will be paid by manufacturers and electric utilities.

TABLE 4-3.- STATIONARY SOURCES - ESTIMATES OF POTENTIAL AND REDUCED EMISSION LEVELS AND ASSOCIATED COSTS

[298 Metropolitan Areas][1/]

Source	Year	Quantity of Emissions[2/] (Thousands of Tons per Year)						Control Costs (Millions of Dollars)	
		Part	SO_X	CO	HC	F	Pb	Investment	Annual
Solid Waste Disposal	1967	1,110	-	3,770	1,400	-	-		
	FY 76 W/O[3/]	1,500	-	5,450	2,020	-	-		
	FY 76 W[4/]	185	-	414	293	-	-	201	113
Stationary Fuel Combustion	1967	3,247	11,416	-	-	-	-		
	FY 76 W/O	3,867	14,447	-	-	-	-		
	FY 76 W	930	4,697	-	-	-	-	2,432	1,006
Industrial Processes	1967	4,601	5,156	7,520	1,412	53	20		
	FY 76 W/O	6,053	6,229	10,040	1,736	73	30		
	FY 76 W	453	1,720	539	849	9	10	3,877	1,095
Total	1967	8,958	16,572	11,290	2,812	53	20		
	FY 76 W/O	11,420	20,676	15,490	3,756	73	30		
	FY 76 W	1,568	6,417	953	1,142	9	10	6,510	2,214

1/ Metropolitan areas are defined in Appendix I.

2/ Emission abbreviations are: particulates (Part), sulfur oxides (SO_X), carbon monoxide (CO), hydrocarbons (HC), fluorides (F), and lead (Pb). Blanks in the table indicate the emission levels meet the applicable regulation (Appendix II) or that emissions are negligible or do not exist.

3/ Estimates without implementation of the Clean Air Act.

4/ Estimates with implementation of the Clean Air Act.

The group of manufacturing industries included under the industrial process category of sources will be required to invest $3,877 million and pay annual costs of $1,095 by Fiscal Year 1976 for control of emissions from their process sources (see Table 4-3). As a result, it is estimated that emissions from these sources will be reduced from the levels that would otherwise occur in that year by these percentages: particulates, 92.5 percent; sulfur oxides, 72.4 percent; carbon monoxide, 94.6 percent; hydrocarbons, 51.1 percent; fluoride, 87.7 percent; lead, 66.7 percent. The annual control costs relative to capacity, production, and shipments are shown in Table 4-4.

TABLE 4-4. - EXPECTED ANNUAL CONTROL COSTS RELATIVE TO CAPACITY, PRODUCTION, AND SHIPMENTS OF INDUSTRIAL PROCESS SOURCES[1]

[Fiscal Year 1976; 298 Metropolitan Areas]

Source and Unit of Measurement		Source Totals			Annual Control Cost (Millions of Dollars)	Cost Ratios		
		Capacity[2] (Millions of Units)	Production[2] (Millions of Units)	Value of Shipments (Billions of Dollars)		Cost per Unit of Annual Cap. (Dollars per Unit)	Cost per Unit of Annual Prod. (Dollars per Unit)	Cost per Dollar of Shipment (Percent)
Asphalt Batching	tons of paving mixture[3]	694.0	227.0	1.6	12.3	0.018	0.055	0.7
Brick and Tile	brick equivalents	8,060.0	6,660.0	0.2	11.6	0.001	0.002	5.8
Coal Cleaning	tons	177.0	167.0	0.8	5.3	0.030	0.032	0.8
Cement	barrels	462.0	295.0	0.9	29.6	0.064	0.100	3.3
Elemental Phosphorus	tons	0.4	0.4	0.1	3.1	7.750	7.750	3.1
Grain: Handling	bushels[4]	4,430.0	12,100.0	N/A[8]	153.0	0.345	0.013	N/A[8]
Milling	tons	70.6	58.8	4.8	11.0	0.156	0.187	0.2
Gray Iron Foundries	tons of castings[3]	22.0	18.0	3.5	108.2	4.947	6.039	3.1
Iron and Steel	tons of raw steel	219.0	165.0	17.4	507.0	2.315	3.073	2.9
Kraft (Sulfate) Pulp	tons	33.3	25.3	3.7	30.2	0.910	1.200	0.8
Lime	tons	19.9	15.8	0.3	14.5	0.729	0.918	4.8
Petroleum Products and Storage	gallons[5]	159.0	1,590.0	19.5	0	0	0	0
Petroleum Refineries	barrels	4,480.0	3,300.0	18.6	7.1	0.002	0.002	0.04
Phosphate Fertilizer	tons P_2O_5	15.6	8.5	1.8	10.0	0.641	1.176	0.6
Primary Nonferrous Metallurgy: Aluminum	tons[6]	2.7	2.4	1.1	75.8	28.100	31.500	6.9
Copper	tons[6]	6.5[9]	0.9	0.8	42.0[7]	6.450	46.600	5.3
Lead	tons[6]	1.6[9]	0.3	0.1	7.1[7]	4.438	23.600	7.1
Zinc	tons[6]	0.7	0.5	0.3	2.2[7]	3.143	4.400	0.7
Rubber (Tires)	tires	282.0	266.0	4.6	1.3	0.005	0.005	0.03
Secondary Nonferrous Metallurgy	tons	3.0	2.6	1.8	21.8	7.267	8.385	1.2
Sulfuric Acid	tons	47.2	34.7	0.3	40.8	0.864	1.176	13.6
Varnish	gallons	28.0	21.8	0.1	1.0	0.043	0.055	1.0

1/ Estimated costs for controlling particulate, sulfur oxide, carbon monoxide, hydrocarbon, fluoride and lead emissions from facilities expected to be operating in fiscal year 1976. The metropolitan areas are defined in Appendix I.

2/ Capacity and production are in millions of units (tons, etc.) per year unless otherwise noted in footnotes.

3/ Capacity is calculated assuming 1,000 operating hours per year.

4/ Capacity is in million bushels of storage space; production, million bushels of throughput.

5/ Capacity is in billion gallons of gasoline storage space; production, billion gallons of gasoline handled.

6/ "Tons" applies to smelters.

7/ Credit for increased sulfuric acid production is not included.

8/ Not applicable.

9/ Tons of ore concentrate are shown.

Chapter 5

Economic Impact of the Cost of Controlling Emissions from Stationary Sources

I. INTRODUCTION

Analysis of the economic impact of control costs on stationary sources starts with the required investment and annual costs required to control individual sources and the direct individual burden relative to the financial strength of each. It then considers the effect of these costs on the market for products and finally the aggregate impact on selected industrial sectors and the national economy.

The detailed cost analyses for industrial process sources, stationary combustion sources, and solid waste disposal are shown in Appendix IV. This chapter summarizes these analyses and discusses the general determinants of economic impact in these categories.

II. GENERAL PARAMETERS AFFECTING ECONOMIC IMPACT

A. Type of Source and Quantity of Emissions

Combustion of fossil fuels is a major source of particulate and sulfur oxide emissions, for which control costs will be substantial. It is difficult to estimate the economic impact of these costs on commercial and institutional establishments because of their great diversity. Commercial enterprises that rent their quarters may be very reluctant to pay increased rents to compensate property owners for control costs. Thus, the owners of older store and office buildings may have to absorb these costs in order to keep tenants. But, because it is older buildings that are most probably heated by coal-fired boilers, for which control costs will be highest, the effect may be to hasten the obsolescence of these structures and resultant changes in use patterns. Firms may move to newer quarters and property may change hands, rather than have the increased cost reflected in the prices charged by the firms due to an increase in rentals of the older facilities.

The impact on institutions such as schools and hospitals will tend to be borne by taxpayers for publicly owned institutions, while private owners may face reactions similar to the commercial patterns, but with less flexibility of response alternatives.

Industry uses substantial quantities of fossil fuels to product steam for heat and power, thereby contributing significantly to pollutant emissions. Fuel consumption in industrial boilers varies greatly from one industry to another so the significance of this source of pollution for any particular metropolitan area depends upon the mix of industrial plants present. For the firms involved, controlling emissions from this source will generally require switching to a low sulfur fuel. This may require an initial investment to convert the burner plus an increase in the annual cost of fuel. Typically, such costs should require a change in business operations for the firm and the costs will probably be passed on through the general pricing formula.

The impact of control costs on steam powered electric generating plants will be much more substantial than for other fuel consumers. They consume very large quantities resulting in large pollutant emissions concentrated in particular locations. Control problems and associated costs are much larger per plant, emission standards may be considerably more stringent, and, in most instances, control cannot be accomplished by fuel switching where supplies of low sulfur fuels are inadequate (see Appendix V).

At the other extreme, although residential heating plants are a significant source of pollution, zero control costs are shown for this source category because the trend of fuel use indicates that emissions in excess of applicable standards will soon be negligible. Coal furnaces are almost never installed in new single-family and very seldom in new multifamily dwellings. Coal furnaces are being replaced with oil, gas, or electric heating units as they wear out. In residential heating, oil and gas seldom produce significant emissions, since distillate oil and natural gas are very clean fuels. Air pollution controls will, therefore, have no effect on residential property owners.

For the industrial process sources covered in this report, control costs and the impact of these costs vary greatly depending upon the technological difficulty of controlling the source of pollution and the volumes of the pollutants involved. In some instances, adequate control can be achieved only through the use of equipment and materials that are still relatively unproven and expensive, as in primary aluminum smelting. In others, the controls are relatively simple and economical, such as the use of floating roofs for petroleum storage tanks.

B. Structure of Industry and Market

The economic impact of control costs on individual firms depends not only on the magnitude of the cost relative to the revenue and profit of the firm, but also on its competitive relationship with the other firms in its industry and competing industries and the nature of the market demand to which it sells. An industry characterized by a small number of very large firms selling under conditions of oligopolistic competition with price leadership, such as the steel industry, may be expected to shift increased costs into price without loss of sales and revenues in most instances. On the other hand, an industry such as gray iron foundries, in which there are many small firms engaging frequently in ruthless competition for custom orders from large customer firms, will find that price adjustments are very difficult to obtain. The smaller and less efficient firms that are least able to absorb increased costs may be those least able to increase prices; marginal firms will almost certainly be forced to close when required to introduce pollution controls that necessitate investment and operating costs but do not increase production.

Other industries include some older plants that are less efficient and profitable than their newer competitors, as is the case in cement production. The effect of control costs may then be to hasten closing or modernization of older plants to maintain the competitive position of the firm in a market that will accept a price increase covering only part of the increased cost.

The production of varnish using a cooked resin component, which is the source of pollutant emissions in that instance, illustrates another impact pattern. As one minor component of the larger industry complex encompassing all industrial and trade coatings, this type of varnish is already being gradually phased out by most producers. The impact of control costs may be expected to hasten the decline in production of this product as firms choose to discontinue the product rather than incur any control cost.

The buyer side of the product market also has an obvious influence on the ability of firms to shift control costs. For processes such as grain storage, the total cost is small relative to the user's ultimate product price. In addition, grain buyers have no effective alternative to the present system of elevator storage and must pay whatever price is charged. Therefore, control cost for grain storage appears fully shiftable.

One other important market pattern is that of regulated industries. Steam electric power producers will be able to recover control costs only to the extent that regulatory agencies include these costs in the rate base and approve rate increases. It may be assumed that regulatory agencies will do so, but there will almost certainly be time lags between the incurrance of added costs and the introduction of new rates during which producers will have to absorb the costs in the form of reduced profits.

III. SPECIFIC IMPACT ON FIRMS IN EIGHTEEN INDUSTRIAL PROCESS SOURCES

An analysis was made for this study of the impact of control costs on the eighteen industry sources discussed in Chapter 4. To the extent that data were available, the probable effects of control costs on the operation and structure of both firms and the industry were estimated, as well as the probability of price changes and the market reaction to them. These results are summarized in this section with a fuller statement provided in Appendix IV.

A. Asphalt Batching

Over 80 percent of this industry are within the 298 metropolitan areas. The total annual control cost for these firms is estimated to be $12.3 million, or about $15,357 per firm by FY 1976. Prices will rise in most areas by the full amount of the cost of control, increasing prices by $0.05 to $0.06 per ton at the plant. A few firms will find that most of their competitors are outside the control regions so that their prices cannot be increased significantly. Firms in this position could experience a 20-50 percent decrease in profits before taxes forcing them to probably discontinue operations or move to a new location. Some other firms, unable to finance the capital investment required for control, may also be forced to discontinue operations at their present locations.

B. Brick and Tile

The brick and tile industry faces very stiff competition from other building materials suppliers so that its share of the construction market has been declining. The projected FY 1976 annual control cost of $11.6 million for the firms in the 298 metropolitan areas equals approximately $1.76 per thousand brick or brick equivalents making it probable that a price increase of this magnitude would reduce sales significantly. It is estimated that prices will rise by no more than $1.00 to $1.10 per thousand, and that this will be accompanied by closing or merger of some marginal firms, a lower growth rate for the industry as a whole than would otherwise occur, and depressed earnings for most firms.

C. Coal Cleaning

The FY 1967 annual control cost for coal cleaning plants in the 298 metropolitan areas is estimated to be $5.3 million, or $0.03 per ton of coal. It is anticipated that this cost will be included in the price with no resultant burden on profits or sales for the firms involved.

D. Cement

Cement plants built since 1960 have been designed to provide effective control of pollutant emissions. Older plants, which account for 76 percent of the capacity of the industry, need additional control equipment to improve their existing control systems or to build entirely new systems. Thus, the impact of control costs on any firm will depend upon the number of its plants in the 24 percent of the industry that is now fully controlled, the 63 percent now partially controlled, or the 13 percent requiring new control systems. Annual control costs for typical plants in FY 1976 for the most expensive group needing new control systems are estimated to be in the range of $78,000 to $210,000 per plant, or $0.087 to $0.104 per barrel of cement produced. Because the costs are spread unevenly throughout the firms in the industry, and because it appears that the newer plants that are already controlled are the more efficient producers, it is probable that prices in most markets will increase little if at all. The current trend of large and highly efficient firms invading the market territories of older firms and the growing competition of substitute products strengthens this probability. As a result, the trend toward replacement of old plants may accelerate. Some reduction of the industry growth rate and lower profit margins are also anticipated.

E. Elemental Phosphorus and Phosphate Fertilizer

All of the firms producing elemental phosphorus have plants within the 298 metropolitan areas, but these account for less than half the phosphorus production in the U.S. Annual control costs for the plants involved will be approximately \$3.1 million, or \$7.80 per ton on the average. It is estimated that the price effect resulting from this cost increase will be a rise of less than one percent, or approximately \$3.90 per ton, reflecting the fact that only part of the production of each of the seven firms in the market would be affected under the proposed regulations. A price increase of this magnitude would probably not affect the sale of elemental phosphorus or phosphoric acid for industrial use significantly.

The firms producing elemental phosphorus are among those producing phosphate fertilizer and also selling phosphoric acid to other fertilizer manufacturers. It was not possible in this study to determine the impact of control costs applicable to the production of elemental phosphorus within the framework of revenues and profits from the multiple product operations of the firms. Control costs for fertilizer production were similarly blended into overall cost and revenue in such a way as to make analysis of the impact on profits impossible without more detailed data than were available at this time.

Annual control cost for all producers of phosphate fertilizer within the 298 metropolitan regions, estimated at \$6.91 million for Fiscal Year 1976, varies depending upon the type of fertilizer produced. The average cost amounts to approximately \$1.70 per ton of fertilizer produced, approximately the control cost per ton for production of normal superphosphate. Control cost for production of ammonium phosphate is estimated to be approximately half the average annual cost, the control cost for triple superphosphate being slightly above the average. It appears that these costs will be entirely incorporated into price, since demand has a very low price elasticity. The impact of these price increases can be evaluated in relation to the cost of nutrients delivered on the farm. Because of the control costs, the delivered price of the P_2O_5 equivalent in normal or triple superphosphate may be expected to increase in about the same proportion as the average fertilizer production costs. This would maintain the value advantage already established for triple superphosphate due to lower transportation cost in most locations. The projected price increase for ammonium phosphate is approximately half that of other phosphate fertilizers, giving it an added price advantage. If the average price of phosphate fertilizer increases by $0.70 to $1.00 per ton, it is expected that the trend toward reduction of production of normal superphosphate in favor of the two other fertilizer forms considered will be accelerated. As a result, some smaller producers making only normal superphosphate may be forced to discontinue production.

F. Grain Milling and Handling

This analysis was limited to grain elevators and grain mills producing animal feeds, since other types of milling were reported to be well controlled. Control of particulate emissions projected for storage, transfer, and milling of grain was found to require an annual cost by FY 1976 of $164 million, of which $153 million would be for controls on grain elevators and $11 million for controls on feed mills. The impact of these costs can only be approximated due to the complexity of the industry structure.

Of the 4,098 grain elevators in the 298 metropolitan areas, 71 percent have a capacity of less than 500,000 bushels; most of these are probably country elevators for temporary storage of grain. The remainder are primarily larger terminal elevators, many of them connected to mills of various types. There were also 2,155 feed mills covered in this study. Some of these are operated in conjunction with country elevators and some with terminal elevators. Further complexity is added by the fact that some feed mill operations are part of very large grain-processing firms making many products and also operating many grain elevators. Many smaller firms operate grain elevators with some of these also including feed mills in their operations.

Lacking detailed data on many of the firms and facilities involved, it was possible only to estimate the probable overall impact of control costs. This indicates that annual control costs for country elevators would be just under $10,000 per year on the average, with $78,000 per year for terminal elevators and $4,000 per year for feed mills. These costs will probably be shifted entirely into price amounting to an increase of $0.0127 per bushel of grain stored and $0.187 per ton of feed milled.

G. Gray Iron Foundries

The annual cost of control for the 1,115 foundries within the 298 metropolitan areas, representing 77 percent of the industry, is estimated to be $108.2 million for Fiscal Year 1976. Cost will vary substantially depending on the size of the plant, ranging from 0.7 percent of the cost of castings for large foundries to approximately 3 percent in small single cupola foundries. Net income before taxes for these firms averages 6.8 percent for the large foundries and 5.8 percent for small ones.

With low rates of return normal for the industry, it would appear that as much as possible of the added cost of controls would be shifted to the customers through price increases. Demand for castings is relatively insensitive to price increases since castings make only a small contribution to the cost of producing machinery and other products of the customer industries. Foundries find it very difficult to increase price, however, since this is a market in which many relatively small firms compete strongly for custom orders from a much smaller number of large customers. Ruthless competition among sellers plus the greater financial and market strength of buyers maintain strong pressures to hold prices down. As a result, prices are expected to rise only approximately two percent on the average, causing reduced profits for approximately one-third of the firms in the industry. The smaller and less efficient firms may therefore be expected to close or to merge with others to form more efficient larger production units.

H. Iron and Steel

The steel industry is usually described as an oligopoly characterized by administered prices and price leadership. In such an industry the added costs of air pollution control will probably be passed on to consumers through price increases whenever the industry decides to adjust its price structure in response to the overall cost and market pattern. Since general economic expansion, accompanied by some inflation, is anticipated through Fiscal Year 1976, and since the steel industry has reached agreement with foreign producers to limit imports of steel into this country to a significant degree, it is expected that steel prices will rise by the full amount of control costs, with the lowest control cost per ton of steel produced found in the use of electric arc furnaces, the highest for open hearth furnaces, and intermediate for basic oxygen furnaces. Examination of typical mixes of production equipment representative of the industry indicates that this range of cost will be from \$0.37 to \$1.91 per ton of finished steel produced.

I. Kraft (Sulfate) Pulp

The kraft paper industry has tended in recent years to follow a cycle of approximately five years duration during which prices, revenues, and profits have fluctuated in response to uneven investment. Demand growth has been anticipated by heavy investment, leading to temporary overcapacity, low prices, and low profits. As demand has caught up to productive capacity, prices and profits have risen, leading to improved expectations and repeated overinvestment. The industry is currently in the rising phase of this cycle which should persist into 1972. This period of expanding investment should include much of the required investment in control equipment. By FY 1976 it is expected that annual control cost will be \$30.3 million for the aggregate industry with nearly all of this being incorporated in the price structure.

By FY 1976, almost all pulp production will be by integrated firms rather than independent pulp producers. This is the direction in which the industry has been moving and it will probably be accelerated by the requirement of pollution controls that will make independent production less viable economically.

J. Lime

The cost of controlling emissions from lime kilns in the 298 metropolitan areas will be approximately \$14.5 million per year by FY 1976. Analysis of typical firms of various sizes indicates that cost will range from \$0.15 to \$0.60 per ton of lime produced, with costs being somewhat higher per ton of production for small firms than for large ones, and higher for operators of rotary kilns than for vertical kilns.

This is a highly competitive industry, complicated by the fact that a significant fraction of industrial customers have bought or constructed lime production facilities. Despite a steadily rising demand for open market lime, competition among producers, plus the fact that some plants will be outside control areas, is expected to prevent a general price rise for lime. Since the costs involved are relatively small, cost absorption by the producers is not expected to have serious adverse effects, although some very small plants may be closed.

K. Petroleum Refining and Storage

Bulk storage facilities for petroleum products are almost entirely owned by petroleum refining companies so that this analysis of the impact of control costs for both storage and refining is treated as one. The economic impact on these firms will be primarily from the required investment of $162 million for control of refinery processes and $1,082 million to control storage tanks. The recovery of products should completely offset the annual costs for storage facilities and partially offset annual costs for refineries, with the result that net annual control costs will amount to $7.1 million per year by Fiscal Year 1976. If this cost were applied entirely to gasoline production, it would be approximately $0.0021 per barrel, small enough to have no appreciable effect on the firms or the market. The indicated required investment, while large, appears to be within the capacity of the industry, but may require some firms to modify their investment plans.

L. Primary and Secondary Nonferrous Metallurgy

The company and market structures for production and sales of primary and secondary aluminum, copper, lead, and zinc are so closely interrelated that analysis of the impact of air pollution control costs has been made of the composite industrial complex. Until recently primary aluminum production was carried on by firms producing only that metal, but in the last few years a trend toward integration into a primary nonferrous metals production sector has appeared. The numerous substitution possibilities among these metals for various uses, and between primary and secondary production, make it necessary to consider the markets for all four simultaneously; price impacts are separately estimated as are the effects on firms to the extent possible.

Production of each of the four primary metals is dominated by three or four large firms, with a few smaller firms in competition. All of the firms involved are stable and generally profitable, resulting in considerable effective competition. The secondary industry, in contrast, is composed of many firms, more than half of which are small firms with fewer than 20 employees. Primary producers have substantial market power, generally well-balanced by the strength of large firms that make up most of the market demands. Secondary producers, however, have relatively much less ability to control the market; their prices and production are generally determined by the primary market.

Annual control costs for primary aluminum production varies according to the process employed. Average annual cost is estimated to be $0.013 per pound produced with the prebaked process, $0.016 per pound for the horizontal spike soderberg process, and $0.011 per pound for the vertical spike soderberg process. It is probable that considerable amounts of alumina and cryolite may be recovered by the required control equipment from prebaked and vertical spike soderberg operations, but not from horizontal spike soderberg operations. This could result in net annual costs for the first two of less than half that required for control of horizontal spike soderberg operations. Such a cost differential could significantly reduce the profits of a firm primarily dependent on use of the horizontal spike soderberg process. The competitive nature of this market is such that prices may be expected to rise in response to initiation of control expenses, but only sufficiently to cover the cost affecting a major share of the firms and output.

Producers of secondary aluminum will experience annual control costs of approximately $0.0032 per pound in the typical plant. It is probable that secondary aluminum producers will have to absorb much of this control cost if the primary price does not increase enough to allow the secondary price to rise. If this occurs, some of the marginal secondary producers may not be able to continue.

Analysis of primary and secondary producers of copper, lead, and zinc shows a somewhat similar pattern. Since the control method for primary smelters includes operation of contact acid plants to remove sulfur oxides, sulfuric acid is produced as a salable byproduct. Net annual control cost for primary smelters depends in part on the revenue realized from the sale of acid. Some firms already operate acid plants in conjunction with smelters, the acid from these sources being sold for approximately $14 per ton. To the extent that this is now being done, it presumably is a profitable operation. It may be presumed, however, that smelters now being operated without acid plants to utilize the available sulfur oxides do not do so because the firms involved have determined that acid could not be profitably produced. This may be either because the distance to a potential market is too great or because it is felt that market demand is not sufficient to absorb large additional quantities without sharp price reductions. Therefore, acid produced as a byproduct of air pollution control probably can be sold only at a price much below the present market and may not be marketable at all.

Annual control costs for a typical copper smelting plant already operating an acid plant would be approximately $1,370,000 or $0.0095 per pound of copper produced. If an acid plant is added where none is now in operation, and the acid sold at the present market price, annual costs would increase to $4,500,000 per year, less revenue of $2,500,000, and a net cost of $0.012 per pound of copper produced. Actual net annual costs will probably be somewhat higher.

Since an acid plant alone provides adequate control of emissions from a lead or zinc smelter, those firms now operating acid plants need incur no additional control cost. Addition of an acid plant to a lead or zinc smelter would result typically in an annual control cost of $2,500,000, with an equal amount of byproduct revenue if the acid were salable at $14 per ton.

Analysis of control of secondary copper, lead, and zinc plants indicates that annual control costs will be $0.0037 per pound for copper, $0.0019 per pound for lead, and $0.0031 per pound for zinc.

Despite the significant increased costs that may result from installations of air pollution controls, the current market for copper, lead, and zinc does not indicate an equivalent price increase over the next several years. Intense foreign competition, the uneven impact of controls on domestic producers, and probable overcapacity argue against a general rise in the price of any of these metals. Discontinuance of the use of lead as an additive for gasoline would appear likely to cause a price decline for that metal, in fact. It is probable, therefore, that, as in aluminum, some small and marginal secondary producers of copper, lead, and zinc may be adversely affected by control costs. Secondary lead producers may be particularly hard hit with little growth predicted after 1971 for primary lead producers.

M. Rubber

Air pollution controls to prevent emissions of carbon black during automobile tire manufacture are specified in this analysis. However, the value of carbon black recovered more than offsets the annual control cost, leaving no net annual cost for this process. A very small additional cost, equal to approximately $0.005 per tire, will be required for afterburners to control hydrocarbon emissions.

N. Sulfuric Acid

The impact of air pollution control costs and the supply of sulfur and sulfur products associated with them is the subject of a separate study now under way. This study should result in an analysis which covers the sulfuric acid industry, among others, in great detail; therefore, no impact analysis of this industry was made for this study.

O. Varnish

Control of emissions from varnish cookers, the only portion of the industry emitting significant amounts of pollutants, will require annual costs equal to approximately $0.10 per gallon of varnish produced. Analysis of the impact of this control cost on the market and on producing firms was hampered by the fact that virtually no data were available for varnish as a separate product distinguished from other industrial and trade coatings. It was determined, however, that production of varnish produced from cooked resins is rapidly declining. Synthetic varnishes apparently are taking over this market. It seems probable, therefore, that the primary effect of control costs will be to accelerate the decline in production of this product.

IV. CONTROL OF FOSSIL FUEL COMBUSTION

Special technical economic problems have been revealed by the analysis of stationary fuel combustion pollution sources. Superficially, the most obvious control technique would appear to be regulations requiring the use of low sulfur fuels to prevent the emission of sulfur oxides. It is increasingly apparent, however, that supplies of natural gas cannot be increased sufficiently to meet all the demands of fuel users who would prefer this fuel. Fuel oil supplies, also, are unlikely to be adequate for projected demands. Rapidly increasing demands for gasoline and jet fuel compete sharply with distillate fuel oil, pushing refineries to produce maximum quantities of these various light fractions of petroleum. As a result, production of residual fuel oil is not increasing as rapidly as otherwise would be expected. Yet, the very rapid growth in demand for electricity is resulting in increased generating capacity, much of which would be designed to consume residual fuel oil if this fuel were available in assured supply. Imports of residual fuel oil are restricted under the oil quota system making increased supply from this source, in amounts perhaps doubling present imports, unlikely. Even unlimited imports would ease the shortage only if low-sulfur oil were available whereas many foreign crude oils have very high sulfur content. A switch to low-sulfur fuels probably cannot, therefore, be accomplished by substituting natural gas and low-sulfur residual oil for current consumption of high-sulfur oil or coal. Finally, supplies of coal are potentially very large, but much of this has a sulfur content in excess of the one percent content generally applied as the standard acceptable for sulfur oxide emissions.

It appears, therefore, that controls must be based on some combination of consumption of low-sulfur fuels, desulfurization of fuels, and installation of mechanical devices to remove sulfur oxides from flue gases. An extended analysis of this problem is given in Appendix V.

V. AGGREGATE IMPACT ON THE ECONOMY

Two types of aggregate economic impact were examined in this study. The automobile and construction industries were identified as being industries purchasing many of the products of the industries to which air pollution controls will be applied. An analysis was made, therefore, of the cumulative effect of price increases resulting from control costs on the cost of producing automobiles and private construction. The other measure of aggregate impact used was the estimated change in the level of prices resulting from the specific price increases estimated for each subject industry. The change in the general price level was measured by the implicit GNP deflator since this appeared to be the most appropriate index for the purpose. Input-output analysis was used for both sets of estimates and a detailed explanation of the methodology and results of these studies is given in Appendix VI.

It is estimated that the cumulative impact of control costs affecting inputs to the construction industry will be approximately $600 million per year, resulting in a cost increase of 0.6 percent. The cumulative impact on the automobile industry, exclusive of direct cost increases resulting from controls on automobile exhaust emissions, is estimated at $225 million per year, or $22.50 per car produced if 10 million vehicles were manufactured.

The overall impact of price changes resulting from controls is estimated to increase the price level by 0.14 percent.

VI. CONCLUSIONS

A. General Economic Impact of Air Pollution Control

The foregoing analyses indicate that control of air pollution emissions from solid waste disposal, stationary fuel combustion, and industrial processes will require an investment of approximately $6.510 billion to control the capacity estimated to be in existence in the 298 metropolitan areas in Fiscal Year 1976. This estimate is based on projected industrial and population growth, which will substantially increase the sources of pollution and required investment in control equipment over that required for 1967. The total estimated annual cost of these controls, including depreciation, finance, and operating expenses, would then amount to approximately $2.214 billion per year by Fiscal Year 1976.

These figures are large in absolute amounts; however, their significance can be shown more clearly by comparing them with the related figures for the national economy. The $6.510 billion investment in air pollution control equipment is less than 5 percent of the $126 billion of gross private investment in the United States for the year 1968. Similarly, if the gross national product (GNP) of the United States in Fiscal Year 1976 is $1.2 trillion, the annual cost of $2.214 billion in that year will be less than 0.2 percent of the nation's gross output.

The investment requirements and annual costs estimated are for controls that would substantially reduce air pollution emissions in the United States. The effects of the controls on emissions are summarized in Table 5-1.

Analysis of the economic impact of projected requirements for air pollution control was concentrated on eighteen industrial process sources and only an analysis of direct costs and emission reductions was made for solid waste disposal and stationary fuel combustion. Some indication of the economic significance of the projected costs in the latter two sectors has become apparent, however.

TABLE 5-1. - ESTIMATED EMISSIONS FROM ALL STATIONARY SOURCES, FY1976
[298 Metropolitan Areas]

	Emissions					
	Part.	SO_x	CO	HC	F	Pb
Estimated Emissions with 1967 Control Levels (thousands of tons)	11,420	20,676	15,490	3.756	73	30
Emissions in Compliance with Assumed Standards (thousands of tons)	1,568	6,417	953	1,142	9	10
Reduction of Pollutants (thousands of tons)	9,852	14,259	14,537	2,614	64	20
Percentage Reduction	86.2	68.9	93.8	69.6	87.7	66.7

B. Solid Waste Disposal

Solid waste disposal in the 298 metropolitan areas will require an estimated total investment of $201 million by Fiscal Year 1976 and an annual cost that will amount to $113 million. Approximately 46 percent of these amounts will be borne by private individuals and businesses and 54 percent by municipal government. The costs borne by the municipal government may be passed on to the population within the 298 metropolitan areas or just to those people residing in an area where solid waste collection is being municipally provided. The range of possible per capita costs can be illustrated as follows:

- If the municipal costs were shared equally by the 186 million people estimated in the 298 metropolitan areas in Fiscal Year 1976, the per capita burden would be $0.58 for investment and $0.33 per year for annual costs. Both of these costs would presumably be financed out of local government taxes.
- Since only 39 percent of municipally collected waste is disposed of by methods requiring new or additional air pollution control, it might be postulated that only 39 percent of the population of these areas would have to pay the added costs. Using this assumption, the per capita costs would be $1.49 for investment and $0.84 per year for annual costs.

C. Stationary Fuel Combustion

The investment requirements and annual costs of air pollution control of heat and power production in commercial, institutional, and industrial establishments will be broadly spread throughout the economy. More than $1 billion of investment may be required of these firms and institutions by Fiscal Year 1976 and annual costs will be approximately $580 million by that year. These costs will be shared by approximately 1.2 million sources. The amount required of each establishment will depend upon its size and its need for steam for its operating processes. Without detailed knowledge of these factors, it is not possible to estimate the economic impact of the projected control requirements.

Steam-electric power plants will have investment requirements and annual costs almost equal to the other stationary combustion sources combined. When these costs are worked into the rate base structure of the industry, it is estimated that they will provide justification for an increase of approximately 2 percent in the average price of electricity. This cost will be diffused into the entire economy, making a small marginal contribution to many other cost patterns.

D. Industrial Processes

Analysis of the impact of annual control costs on the industries affected indicates that:

- Firms in seven of the 17 industries studied will be able to pass these added costs on to their customers in the form of higher prices. These are the asphalt batching, coal cleaning, elemental phosphorus, phosphate fertilizer, grain milling and handling, iron and steel, and kraft (sulfate) pulp industries.
- Firms in three industries are expected to recover sufficient quantities of valuable materials in controlling emissions to offset the entire annual cost of control. This is the case for petroleum refining, petroleum storage, and rubber (tires). Some primary aluminum producers also fall into this category although the rest of the nonferrous metallurgical industry does not.
- Firms in the other seven industries will probably have to absorb all or part of the control costs, which will reduce their revenue from sales, taxes paid, and net profits. In four of these industries--cement, secondary nonferrous metallurgy, varnish, and gray iron foundries--firms may find that less than half of their annual control costs can be recovered by increasing prices. The brick and tile, lime, and primary nonferrous metallurgical industries will recover a larger share of control cost, but probably not the entire amount.
- Those prices that are increased will not rise by more than approximately 2 1/2 percent as a result of air pollution control costs. Those increases which may exceed 2 percent are for brick and tile, elemental phosphorus, gray iron, and primary zinc.
- Increases in the cost of materials used by the automobile and construction industries, which use many of the products included in this study, may lead to an

increase in the price of an automobile of about $22.50 and in the cost of a new home of about $100, assuming 25 percent of the construction costs are for new housing units.

- The aggregate effect of price increases induced by air pollution control costs will increase the national price level by approximately 0.14 percent.
- A number of marginal firms may be forced to close or to enter different product lines. This effect will apparently be confined primarily to the secondary non-ferrous metallurgical, varnish, and gray iron industries. Some brick and tile and cement plants may become sub-marginal, also.
- No appreciable effect is predicted for the general level of employment or for employment in specific occupations.

APPENDIX I

Selection of 298 Metropolitan Areas

APPENDIX I

Selection of 298 Metropolitan Areas

The Clean Air Act, as amended, specified a plan for control of air pollution on a regional basis. In brief, after the U. S. Government has issued air quality criteria and a report on control techniques for a specific type of air pollutant, State governments are expected to adopt and implement air quality standards for that pollutant applicable to the air quality control regions (AQCR's) designated.

Estimates of cost are presented for stationary source controls in 298 metropolitan areas arbitrarily selected as regions. The 298 metropolitan areas reflect the anticipated number of AQCR's for the 5-year period covered by this report. All standard metropolitan statistical areas (SMSA's) are included as a part of a region. Two or more adjacent SMSA's appearing to have a mutual problem were combined into one region. Non-SMSA based regions were centered upon a community of 25,000 population, contiguous communities showing a common problem, communities containing known major point sources, or central communities within a large air shed. Selection and compilation of these regions does not necessarily imply intentions on the part of APCO to designate or not to designate them as AQCR's. Table I-1 was compiled on the basis of information available as of June 1, 1970. Information pertaining to the designation of AQCR's after that date has not been considered in this report.

TABLE I-1.- LIST OF 298 METROPOLITAN AREAS

1. Aberdeen (S. Dak.)
2. Aberdeen-Hoquiam (Wash.)
3. Abilene (Tex.)
4. Alamogordo (N. Mex.)
5. Alamosa (Colo.)
6. Albany (Ga.)
7. Albany-Schnectady-Troy-Amsterdam (N.Y.)
8. Albuquerque (N. Mex.)
9. Allentown-Easton-Phillipsburg (N. J., Penn.)
10. Amarillo (Tex.)
11. Anchorage (Alaska)
12. Ann Arbor-Jackson (Mich.)
13. Asheville (N. C.)
14. Astoria (Oreg.)
15. Athens (Ga.)
16. Atlanta (Ga.)
17. Atlantic City-Southeast New Jersey (N. J.)
18. Augusta-Aiken (Ga., S. C.)
19. Augusta-Waterville-Skowhegan (Maine)
20. Austin (Tex.)
21. Bakersfield (Calif.)
22. Baltimore (Md.)
23. Bangor (Maine)
24. Bay City-Saginaw-Midland (Mich.)
25. Bellingham (Wash.)
26. Berlin-Rumford (N.H., Maine)
27. Big Spring (Tex.)
28. Billings (Mont.)
29. Binghamton (N. Y., Penn.)
30. Birmingham (Ala.)
31. Bismark-Mandan (N. Dak.)
32. Bloomington (Ind.)
33. Bloomington (Ill.)

TABLE I-1. - LIST OF 298 METROPOLITAN AREAS (continued)

34.	Bluefield-Princeton (W. Va.)
35.	Blytheville (Ark., Mo., Tenn.)
36.	Boise (Idaho)
37.	Boston (Mass.)
38.	Bowling Green (Ky.)
39.	Bozeman (Mont.)
40.	Bristol-Johnson City-Kingsport (Tenn., W. Va.)
41.	Brunswick (Ga.)
42.	Bryan (Tex.)
43.	Butte-Anaconda (Mont.)
44.	Cape Girardeau-Caruthersville (Mo.)
45.	Carbondale-Marion-Harrisburg (Ill.)
46.	Casper (Wyo.)
47.	Cedar Rapids-Iowa City (Iowa)
48.	Champaign-Urban-Danville (Ill.)
49.	Champlain Valley (N. Y., Vt.)
50.	Charleston (S. C.)
51.	Charleston (W. Va.)
52.	Charleston-Matton (Ill.)
53.	Charlotte (N. C., S. C.)
54.	Charlottesville (Va.)
55.	Chattanooga (Ga., Tenn.)
56.	Cheyenne (Wyo.)
57.	Chicago (Ill., Ind.)
58.	Chico-Oroville (Calif.)
59.	Cincinnati (Ind., Ky., Ohio)
60.	Clarksburg-Fairmont-Morgantown (W. Va.)
61.	Cleveland (Ohio)
62.	Clovis (N. Mex.)
63.	Colorado Springs (Colo.)
64.	Columbia (S. C.)
65.	Columbia-Jefferson City (Mo.)
66.	Columbus-Newark (Ohio)
67.	Columbus-Phoenix City (Ala., Ga.)
68.	Corpus Christi (Tex.)

TABLE I-1. - LIST OF 298 METROPOLITAN AREAS (continued)

69. Cumberland-Keyser (Md., W. Va.)
70. Dallas-Fort Worth (Tex.)
71. Dayton (Ohio)
72. Davenport-Rock Island-Moline (Ill., Iowa)
73. Danville (N. C., Va.)
74. Decatur (Ill.)
75. Denver (Colo.)
76. Des Moines-Ames (Iowa)
77. Detroit-Port Huron (Mich.)
78. Dothan (Ala.)
79. Douglas-Lordsburg (Ariz., N. Mex.)
80. Dover (Del.)
81. Dubuque (Ill., Iowa, Wis.)
82. Duluth-Superior (Minn., Wis.)
83. Eau Claire (Wis.)
84. El Centro-Brawley (Calif.)
85. El Dorado (Ark., La.)
86. Elmira-Corning-Ithaca (N. Y.)
87. El Paso (N. Mex., Tex.)
88. Enid (Okla.)
89. Eureka (Calif.)
90. Evansville-Owensboro-Henderson (Ind., Ky.)
91. Fairbanks (Alaska)
92. Fargo-Moorhead (Minn., N. Dak.)
93. Fayetteville (N. C.)
94. Flagstaff (Ariz.)
95. Flint (Mich.)
96. Florence-Corinth (Ala., Miss., Tenn.)
97. Florence (S. C.)
98. Fort Collins (Colo.)
99. Fort Dodge (Iowa)
100. Fort Myers (Fla.)
101. Fort Pierce-Vero Beach (Fla.)

TABLE I-1. - LIST OF 298 METROPOLITAN AREAS (continued)

102.	Fort Smith-Muskogee (Ark., Okla.)
103.	Fort Wayne (Ind.)
104.	Four Corners (Ariz., Colo., N. Mex., Utah)
105.	Fresno (Calif.)
106.	Gadsden-Anniston (Ala.)
107.	Gainesville (Fla.)
108.	Gainesville (Ga.)
109.	Galesburg (Ill.)
110.	Grand Fork (Minn., N. Dak.)
111.	Grand Island (Nebr.)
112.	Grand Junction (colo.)
113.	Grand Rapids-Muskegon (Mich.)
114.	Grants Pass-Medford (Oreg.)
115.	Great Falls (Mont.)
116.	Green Bay-Fond du Lac (Wis.)
117.	Greenville (Miss.)
118.	Greenville-Spartanburg-Anderson (S. C.)
119.	Hagerstown (Md., Penn., W. Va.)
120.	Harrisburg-Lebanon (Penn.)
121.	Hartford-Springfield-New Haven (Conn., Mass.)
122.	All of Hawaii (Hawaii)
123.	Helena (Mont.)
124.	Hennepin-Ottawa (Ill.)
125.	Hot Springs (Ark.)
126.	Houlton-Caribou (Maine)
127.	Houston-Galveston (Tex.)
128.	Huntington-Ashland-Portsmouth (Ky., Ohio, W. Va.)
129.	Huntsville (Ala.)
130.	Hutchinson (Kans.)
131.	Indianapolis (Ind.)
132.	Jackson (Miss.)
133.	Jackson (Tenn.)
134.	Jacksonville (Fla.)
135.	Jamestown (N. Y.)
136.	Johnstown-Altoona (Penn.)

TABLE I-1. - LIST OF 298 METROPOLITAN AREAS (continued)

137. Joplin-N. E. Okla.-Fayetteville (Ark., Kans., Mo., Okla.)
138. Kalamazoo-Battle Creek (Mich.)
139. Kalispell-Flathead Lake (Mont.)
140. Kankakee (Ill.)
141. Kansas City (Kans., Mo.)
142. Keokuk (Ill., Iowa, Mo.)
143. Klamath Falls (Oreg.)
144. Kokomo-Marion (Ind.)
145. Knoxville (Tenn.)
146. La Crosse-Winona (Minn., Wisc.)
147. LaFayette (Ind.)
148. Lancaster (Penn.)
149. Lansing (Mich.)
150. Laredo-Eagle Pass (Tex.)
151. Las Vegas-Kingman (Ariz., Nev.)
152. Laurel-Hattiesburg (Miss.)
153. Lawrence-Lowell-Manchester (Mass., N. H.)
154. Lawton (Okla.)
155. Lewiston-Moscow-Clarkston (Idaho, Wash.)
156. Lexington (Ky.)
157. Lima-Findlay (Ohio)
158. Lincoln (Nebr.)
159. Little Rock (Ark.)
160. Logan (Utah)
161. Los Angeles (Calif.)
162. Louisville (Ind., Ky.)
163. Lower Rio Grande Valley (Tex.)
164. Lubbock (Tex.)
165. Lufkin-Nacogdoches (Tex.)
166. Lynchburg (Va.)
167. Macon (Ga.)
168. Madison (Wis.)
169. Mamitowoc-Sheboygan (Wis.)
170. Mankato-New Ulm (Minn.)

TABLE I-1 - LIST OF 298 METROPOLITAN AREAS (continued)

171. Mansfield (Ohio)
172. Marion (Ohio)
173. Mason City (Iowa)
174. Memphis (Ark., Miss., Tenn.)
175. Menominee-Escanaba-Marinette (Mich., Wis.)
176. Meridian (Miss.)
177. Miama (Fla.)
178. Midland-Odessa (Tex.)
179. Milwaukee (Wis.)
180. Minot (N. Dak.)
181. Minneapolis-St. Paul (Minn.)
182. Missoula (Mont.)
183. Mobile-Pennsacola-Biloxi-Gulfport (Ala., Fla., La., Miss.)
184. Modesto-Merced (Calif.)
185. Montgomery (Ala.)
186. Montpelier-Barre (Vt.)
187. Muncie-Anderson (Ind.)
188. Nashville (Tenn.)
189. Natchez (La., Miss.)
190. National Capital Area (D. C., Md., Va.)
191. Newburgh-Poughkeepsie-Kingston (N. Y.)
192. New London (Conn.)
193. New York-New Jersey-Connecticut (Conn., N. J., N. Y.)
194. Niagara Frontier (N. Y.)
195. Norfolk-Elizabeth City (N. C., Vir.)
196. Northeast Louisiana-Vicksburg (La., Miss.)
197. Oklahoma City (Okla.)
198. Omaha (Iowa, Nebr.)
199. Orlando (Fla.)
200. Ottumwa (Iowa)
201. Paducah-Metropolis-Cairo (Ill., Ky.)
202. Parkersburg-Marietta (Ohio, W. Va.)
203. Pendleton (Oreg.)

TABLE I-1 - LIST OF 298 METROPOLITAN AREAS (continued)

204.	Peoria (Ill.)
205.	Philadelphia (Penn.)
206.	Phoenix-Tucson (Ariz.)
207.	Pine Bluff (Ark.)
208.	Pittsburgh (Penn.)
209.	Pittsfield (Mass.)
210.	Pocatello-Idaho Falls (Idaho)
211.	Portland (Oreg.)
212.	Portland-Lewiston-Auburn (Maine)
213.	Prescott (Ariz.)
214.	Providence (Conn., R. I.)
215.	Pueblo (Colo.)
216.	Puerto Rico (Puerto Rico)
217.	Puget Sound (Wash.)
218.	Quincy (Ill., Mo.)
219.	Raleigh-Durham (N. C.)
220.	Rapid City (Iowa)
221.	Reading (Penn.)
222.	Redding-Red Bluff (Calif.)
223.	Reno-Carson City (Calif., Nev.)
224.	Richland-Kennewick-Pasco (Wash.)
225.	Richmond (Ind.)
226.	Richmond-Petersburg (Va.)
227.	Roanoke-Radford-Pulaski (Va.)
228.	Rochester (N. Y.)
229.	Rochester-Austin-Albert-Owato (Minn.)
230.	Rochester-Dover-Portsmouth (N. H.)
231.	Rockford-Janesville-Beloit (Ill., Wis.)
232.	Rocky Mount-Goldsboro-Kinston (N. C.)
233.	Rome (Ga.)
234.	Roswell-Carlsbad-Hobbs-Pecos (N. Mex.)
235.	Sacramento (Calif.)

TABLE I-1 - LIST OF 298 METROPOLITAN AREAS (continued)

236.	Salina (Kans.)
237.	Salinas-Monterey-Santa Cruz (Calif.)
238.	San Angelo (Tex.)
239.	San Antonio (Tex.)
240.	San Diego (Calif.)
241.	Sandusky (Ohio)
242.	Santa Fe (N. Mex.)
243.	San Francisco Bay Area (Calif.)
244.	San Luis Obispo (Calif.)
245.	Sarasota (Fla.)
246.	Sault Ste. Marie (Mich.)
247.	Savannah-Beaufort (Ga., S. C.)
248.	Scranton-Wilkes Barre-Hazelton (Penn.)
249.	Selma (Ala.)
250.	Sequatchie River Valley (Miss., Tenn.)
251.	Shenandoah Valley (W. Va.)
252.	Sherman-Denison (Tex.)
253.	Sioux City (Iowa, Nebr.)
254.	Sioux Falls (Iowa, S. Dak.)
255.	Southern Louisiana-Texas (La., Tex.)
256.	South Bend-Elkhart-Benton Harbor (Ind., Mich.)
257.	Spokane-Coeur d'Alene (Idaho, Wash.)
258.	Springfield (Ill.)
259.	Springfield (Mo.)
260.	St. Cloud (Minn.)
261.	St. Louis (Ill., Mo.)
262.	Sterling (Colo.)
263.	Steubenville-Weirton-Wheeling (Ohio, W. Va.)
264.	Stockton (Calif.)
265.	Syracuse-Auburn (N. Y.)
266.	Tallahassee (Fla.)
267.	Tampa-St. Petersburg-Lakeland (Fla.)

TABLE I-1 - LIST OF 298 METROPOLITAN AREAS (continued)

268. Terre Haute (Ind.)
269. Texarkana-Shreveport (Ark., La., Tex.)
270. Toledo (Mich., Ohio)
271. Topeka-Lawrence (Kans.)
272. Tulsa (Okla.)
273. Twin Falls (Idaho)
274. Tyler (Tex.)
275. Utica-Rome (N. Y.)
276. Valdosta (Ga.)
277. Victoria (Tex.)
278. Virgin Islands (Virgin Islands)
279. Visalia (Calif.)
280. Waco-Temple-Killeen (Tex.)
281. Walla Walla (Wash.)
282. Wasatch Front-Salt Lake City (Utah)
283. Waterbury-Torrington (Conn.)
284. Waterloo (Iowa)
285. Watertown (N. Y.)
286. Wausau (Wis.)
287. Wichita (Kans.)
288. Wichita Falls (Tex.)
289. Willimantic (Conn.)
290. Williamsport-Sanbury (Penn.)
291. Wilmington (N. C.)
292. Winston-Salem-Greensboro-High Point (N. C.)
293. Worchester-Fitchburg-Leominster (Mass.)
294. Yakima (Wash.)
295. York (Penn.)
296. Youngstown-Erie (Ohio, Penn.)
297. Yuma (Ariz.)
298. Zanesville-Cambridge (Ohio)

APPENDIX II

Assumed Emission Standards

Appendix II

Assumed Emission Standards

I. INTRODUCTION

Under the Clean Air Act, as amended, air quality standards will be adopted for Air Quality Control Regions (AQCR's), then plans for implementation of the standards will be adopted. Ordinarily, implementation plans must include emission standards intended to permit a region to attain and maintain its established air quality standards. For this report, emission standards were selected without going through the above steps, which would have required many assumptions about air quality standards and a massive computational effort to derive appropriate emission standards for all the 298 metropolitan areas. The emission standards selected for this report are representative of those now used throughout the Nation.

II. STANDARDS FOR PARTICULATES

For industrial process sources, the process weight rate regulation of the San Francisco Bay Area Pollution Control District (Table II-1) was used as the basis of control cost estimates. This regulation limits the weight of particulate emissions per hour as a function of the total weight of raw materials introduced into a process operation.

For incinerators, the New York State Incinerator Standard for new units was used. This standard limits total particulate emissions on the basis of mass rate (pounds/hour), rather than concentration. Several areas have adopted a variation of this; the New York State standard for new installations (Figure II-1) was used to determine the control efficiency of incinerators. For fuel-burning equipment, the combustion regulation of the State of Maryland was used (Figure II-2).

III. STANDARDS FOR SULFUR OXIDES

For fuel-burning equipment, a regulation based on mass emission rate per million B.t.u. input was used. It allows an emission rate of 1.46 pounds of sulfur dioxide per million B.t.u. input; this limit is based on an equivalent sulfur content of 1.0 percent by weight in coal (1.38 percent by weight in oil). For process sources, a concentration standard of 500 parts per million of sulfur dioxide was used.

IV. STANDARDS FOR HYDROCARBONS

For process sources, cost estimates were based on treatment of all exhaust gases to remove organic material by 90 percent (or more) by weight. For petroleum products storage, it was assumed that all stationary tanks, reservoirs, and containers with more than a 40,000-gallon capacity and a vapor pressure of 1.5 pounds per square inch absolute (or greater) must be equipped with floating roofs, vapor recovery systems, or other equally efficient devices. In addition, it was assumed that submerged filling inlets must be installed on all gasoline storage tanks with a capacity of 250 gallons or more.

V. STANDARD FOR CARBON MONOXIDE

Cost estimates were based on treatment of all exhaust gases to remove or reduce the weight of carbon monoxide emissions by at least 95 percent.

VI. STANDARDS FOR FLUORIDES

Three fluoride emission standards were utilized in this study. For the phosphate fertilizer and elemental phosphorus industries a standard of 0.2 pounds of total fluoride (gaseous and particulate) per ton of P_2O_5 was applied. For the aluminum industry a standard of 0.06 pounds of total fluoride per reduction cell per hour up to a maximum of 40 pounds per hour was applied. For the iron and steel and brick and tile industries emission standards were applied separately to the gaseous and particulate fluoride fractions. For the gaseous fraction a standard of 95 percent removal was assumed. The standard for fluoride particulates requires that the quantity of total particulate emissions, including fluoride, meet the "process weight rate" standard.

VII. STANDARD FOR LEAD PARTICULATES

The standard for lead particulates requires that the quantity of total particulate emission, including lead meet the "process weight rate" standard.

TABLE II-1. - ALLOWABLE RATE OF PARTICULATE EMISSION BASED ON PROCESS WEIGHT RATE*

Process Weight Rate		Rate of Emission	Process Weight Rate		Rate of Emission
Lbs/hr	Tons/hr	Lbs/hr	Lbs/hr	Tons/hr	Lbs/hr
100	0.05	0.551	16,000	8.00	16.5
200	0.10	0.877	18,000	9.00	17.9
400	0.20	1.40	20,000	10.00	19.2
600	0.30	1.83	30,000	15.00	25.2
800	0.40	2.22	40,000	20.00	30.5
1,000	0.50	2.58	50,000	25.00	35.4
1,500	0.75	3.38	60,000	30.00	40.0
2,000	1.00	4.10	70,000	35.00	41.3
2,500	1.25	4.76	80,000	40.00	42.5
3,000	1.50	5.38	90,000	45.00	43.6
3,500	1.75	5.96	100,000	50.00	44.6
4,000	2.00	6.52	120,000	60.00	46.3
5,000	2.50	7.58	140,000	70.00	47.8
6,000	3.00	8.56	160,000	80.00	49.0
7,000	3.50	9.49	200,000	100.00	51.2
8,000	4.00	10.4	1,000,000	500.00	69.0
9,000	4.50	11.2	2,000,000	1,000.00	77.6
10,000	5.00	12.0	6,000,000	3,000.00	92.7
12,000	6.00	13.6			

* Data in this table can be interpolated for process weight rates up to 60,000 lbs/hr by using equation $E=4.10\ P^{0.67}$ and can be interpolated and extrapolated for process weight rates in excess of 60,000 lbs/hr by using equation $E=55.0\ P^{0.11}-40$ (E = rate of emission in lbs/hr; P = process weight rate in tons/hr).

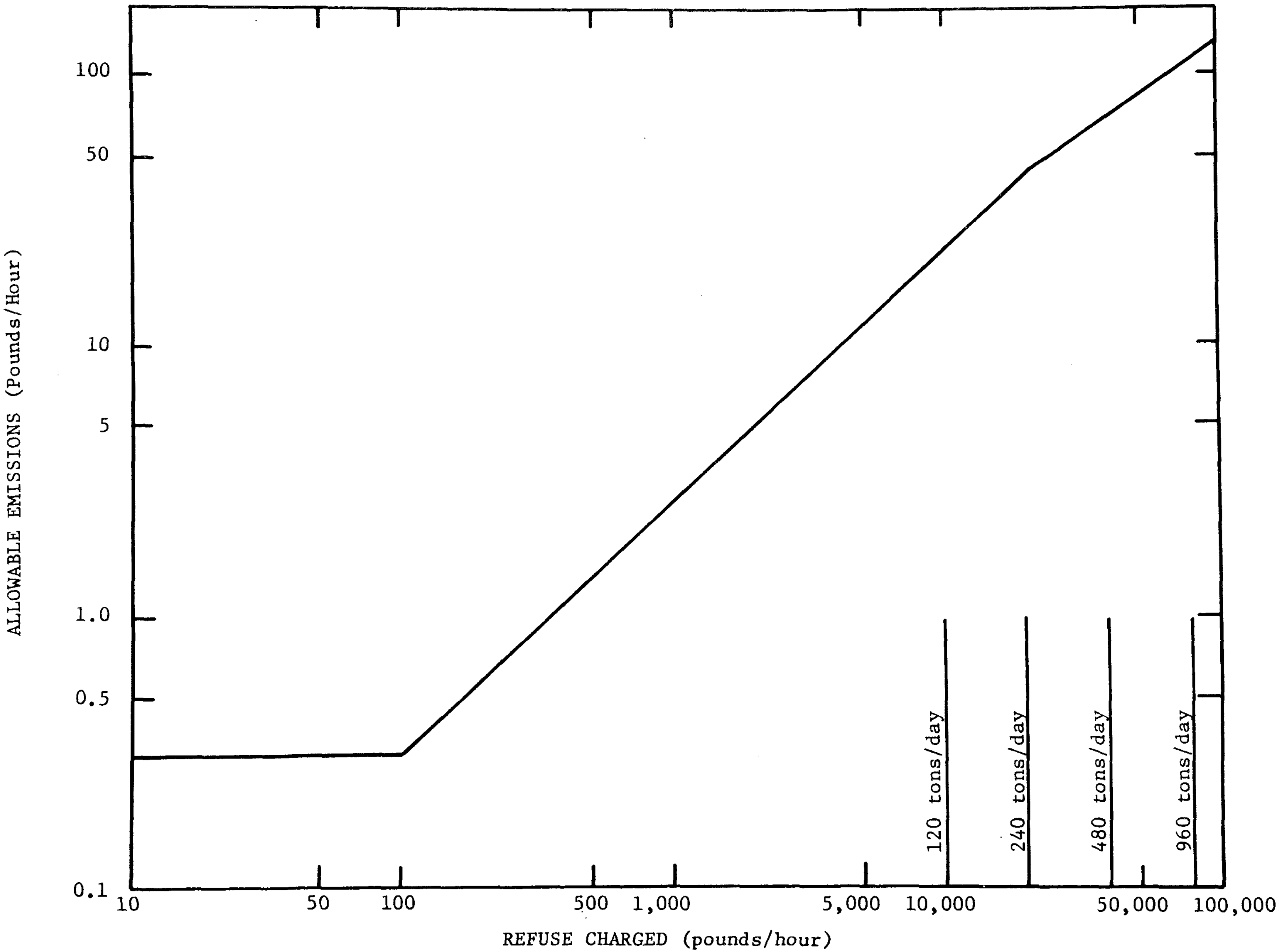

Fig. II-1.- New York State Particulate Emission Regulation for Refuse Burning Equipment.

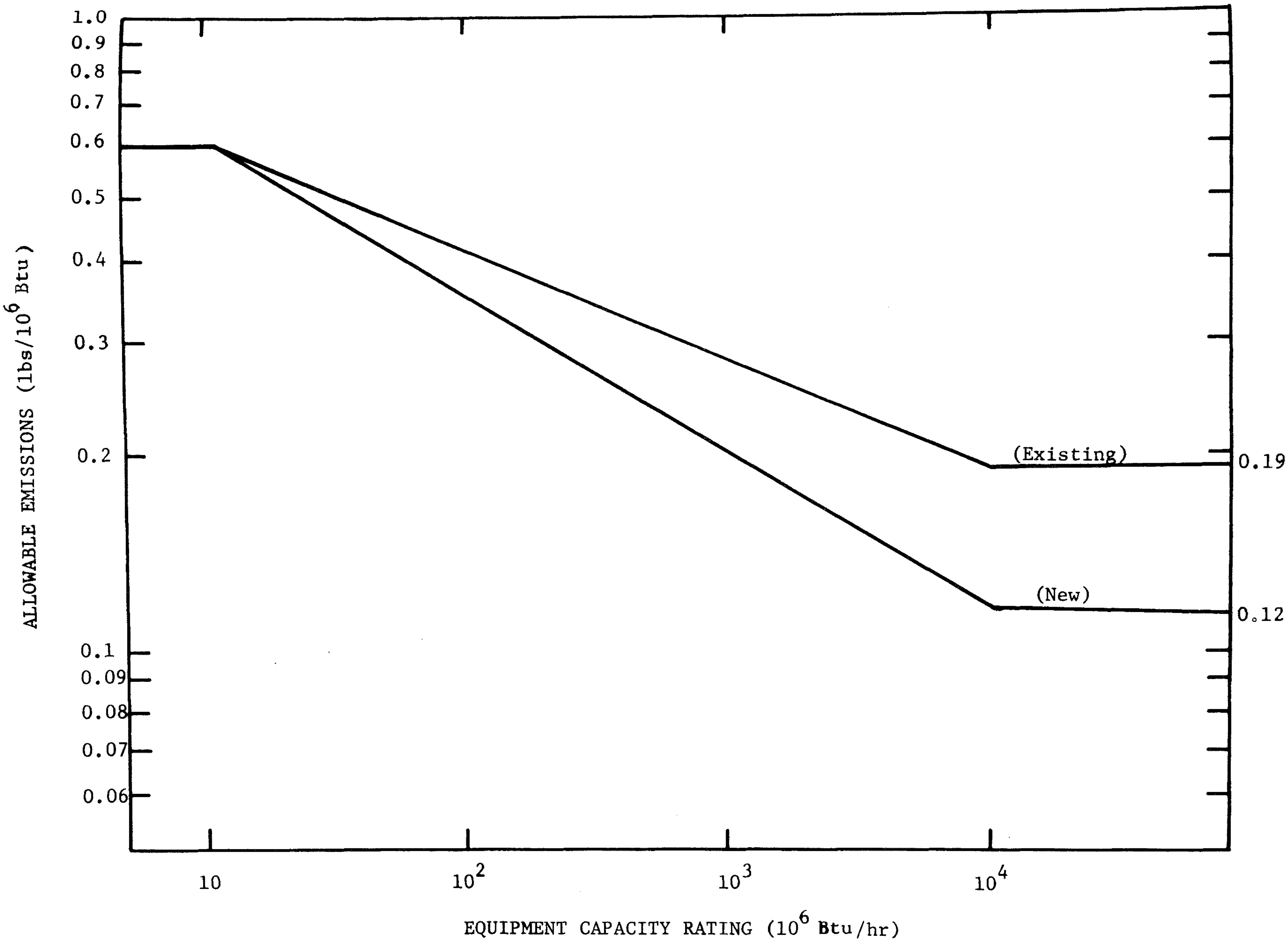

Fig. II-2.- Maryland Particulate Emission Standards for Fuel Burning Installations.

APPENDIX III

Mobile Sources

APPENDIX III

Mobile Sources

I. INTRODUCTION

This appendix concerns the costs of complying with current and projected Federal standards for motor vehicle air pollution emissions and presents estimates of the costs to purchasers and users of motor vehicles due to air pollution control for 1967 through Fiscal Year (Model Year) 1976. The estimates are based on current, anticipated standards and other available data as of July 1970. These standards cover or will cover emissions of hydrocarbons, carbon monoxide, nitrogen oxides, and particulate matters from motor vehicles. This appendix compares projected emissions under the anticipated standards with potential emissions which would be expected if no standards were in effect. The costs of meeting the standards are expressed in terms of additional initial costs to the consumer, increases in operating and maintenance costs, and an annualized combination of increased operating and maintenance costs. The effect of these expenditures on emissions is also indicated. Only costs associated with control of vehicular emissions are included. Costs or price increases from controls on supplier industries, such as steel making, are considered in Appendix VI. The cost of unleaded gasoline, where required, has been included in total costs presented in this appendix.

Only gasoline powered automobiles and light and heavy-duty trucks are covered in the emissions and cost data presented in this appendix. Within the accuracy of available data and estimating techniques, the inclusion of buses and diesel trucks would have little effect on the total emissions and cost figures.

The estimates and projections of emissions contained in this appendix are based on information available as of July 15, 1970 and are different from previously published estimates. Either the previous estimates of hydrocarbon and carbon monoxide emissions from motor vehicles were low or the methods for measuring these emissions gave lower readings than those obtained from vehicles under realistic operating conditions. This information was released by the Secretary of Health, Education, and Welfare on July 15, 1970 [Ref. 1].

The main text of this appendix first presents a synopsis of motor vehicle control technology through the 1976 models (Section II). Estimates of the growth of vehicle populations and the potential for emissions without control are discussed next (Section III). The costs to purchasers and users to have vehicles in compliance with standards are included in the section on costs (Section (IV). Some conclusions drawn from the analysis will be found in Section V.

II. EMISSIONS

A. Nature and Sources of Emissions

Motor vehicles are a major source of air pollution in the United States. The four major pollutants from motor vehicles are hydrocarbons, carbon monoxide, nitrogen oxides, and particulate matter. Motor vehicles account for approximately one-half of the hydrocarbon emissions and two-thirds of the carbon monoxide emissions to the atmosphere in the United States. Motor vehicles also contribute about one-third of the nitrogen oxides and nine-tenths of the lead-bearing particulate matter to the total national emissions of these pollutants.

Motor vehicle emissions occur in several ways. Hydrocarbon emissions come from evaporation from the fuel tanks and carburetors (gasoline powered vehicles), blowby and leakage from the engine crankcase, and incomplete combustion. Figure III-1 illustrates the sources and approximate relation of these emissions. Incomplete combustion also produces carbon monoxide in the exhaust gases. In the internal combustion engine, some of the atmospheric oxygen and nitrogen combine to form nitrogen oxides which are emitted in the exhaust. Unfortunately, conditions which favor more complete and efficient combustion, thereby reducing exhaust emissions of hydrocarbons and carbon monoxide, tend to increase the levels of nitrogen oxides formed.

For present consideration, the source of particulate matter emitted by motor vehicles is the exhaust. The particulate matter in exhaust gases from gasoline engines consists of carbonaceous material, salts and oxides of iron and lead, and droplets or particles of hydrocarbon materials. Lead compounds constitute about 80 percent of the particulate matter thus emitted.

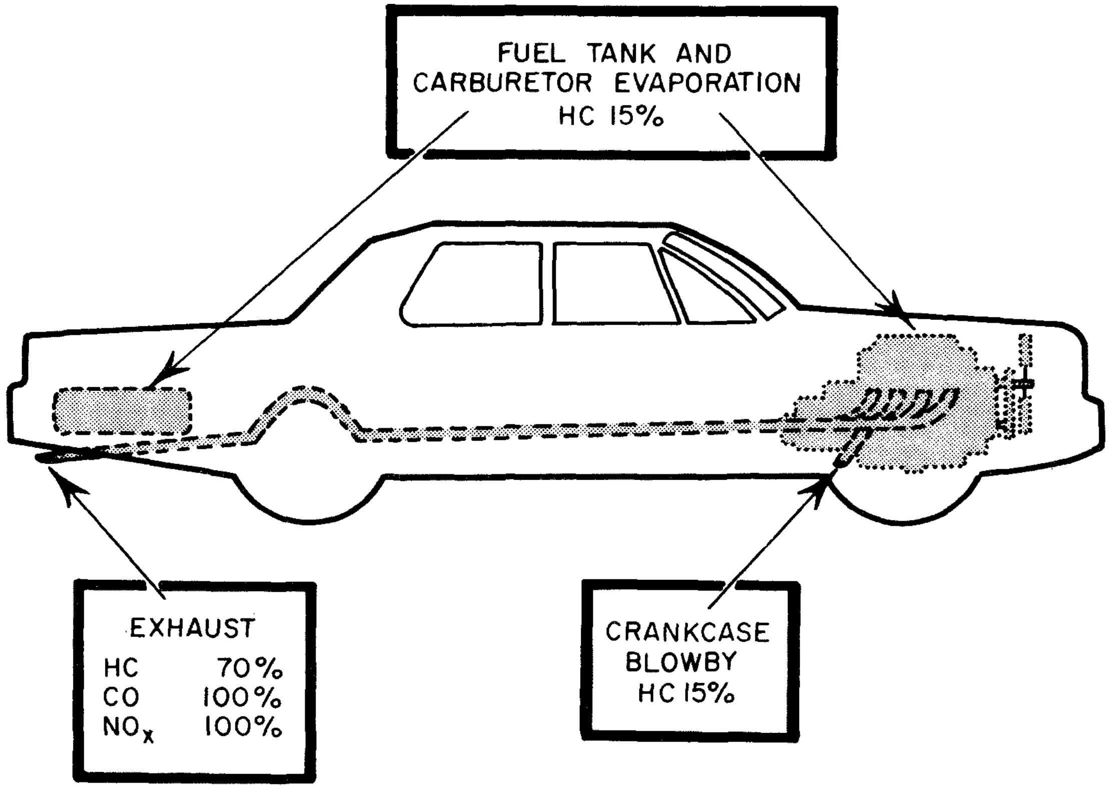

Fig. III-1. - Approximate Distribution of Emissions by Source for a Vehicle Not Equipped with Any Emission Control Systems.

Metallic lead is present to the extent of 50 to 60 percent of total particulate weight. Diesel engines have particulate emissions which consist almost entirely of small carbon particles. Based on present knowledge, both the total amount and the nature of the particulate matter from diesel engines represent much less of an environmental problem than that from gasoline engines.

B. Emission Levels and Effects of Standards

As has been previously noted, discrepancies have been found in the standards and measurement techniques in effect for the period FY 1968 through 1971. In the emission estimates reported herein, corrections have been made for the FY 1968 through 1971 period so that the data are on a comparable basis for the entire period of FY 1967 through 1976.

Crankcase emissions were already under control at the beginning of the time frame being considered here. The crankcase contributions of the older cars which are not equipped with blowby control devices have been included in the emission estimates presented here.

1. Potential for Emissions Without Control Under the Clean Air Act

Table III-1 gives the estimated growth of the number of automobiles and gasoline trucks in use for the period of Fiscal Years 1967 through 1976. This table also projects the potential emissions which could be expected if no control regulations were in effect. The total number of vehicles in use shows a growth of approximately 31 percent. The total potential annual emissions show an increase of approximately the same magnitude.

In making the projections shown in Table III-1, the vehicle populations have been projected on the basis of the best information on the numbers of vehicles actually in use rather than the number of vehicle registrations [Ref. 2]. The registration method is considered less accurate because it is basically a count of the number of registration transactions and results in multiple counting of some vehicles.

The vehicles shown in Table III-1 are divided into two categories; the first comprises automobiles and light-duty trucks. Light-duty trucks are six thousand pounds or less in gross vehicle weight (GVW). The other category, heavy-duty gasoline trucks, consists of trucks over six thousand pounds GVW. The vehicle data shown do not include either diesel trucks or buses of the gasoline or diesel variety. Based on the

TABLE III-1. - MOBILE SOURCE GROWTH AND POTENTIAL EMISSIONS, FY 1967-1976
[1967 Baseline]

Fiscal Year	Numbers of Vehicles in Use (Millions)			Potential Emissions Without Controls in Effect (Thousands of Tons)			
	Autos and Light-Duty Trucks	Heavy-Duty Gasoline Trucks	Total	Hydrocarbons	Carbon Monoxide	Nitrogen Oxides	Particulates
1967	81.8	5.3	87.1	21,100	126,000	5,700	333
1968	84.6	5.7	90.3	24,200	130,000	5,910	346
1969	88.3	5.9	94.2	25,400	137,000	6,180	361
1970	90.7	6.0	96.7	26,100	140,000	6,350	370
1971	92.2	6.1	98.3	26,500	143,000	6,450	377
1972	94.9	6.2	101.1	27,300	146,000	6,640	387
1973	97.5	6.4	103.9	28,000	151,000	6,820	396
1974	100.1	6.6	106.7	28,800	155,000	7,000	409
1975	103.9	6.8	110.7	29,900	160,000	7,260	423
1976	107.2	7.1	114.3	30,800	166,000	7,500	438
FY 1967-76 Total Potential Emissions				268,100	1,454,000	65,810	3,840

best data available, buses and diesel trucks constitute a small fraction of the total vehicle population [Ref. 3]. Also, for the time period considered in this appendix, the only anticipated Federal standards for diesels are for smoke density and cannot be directly related to the emissions of the other pollutants considered here. Additional Federal standards may be proposed later. The State of California, however, is proposing other exhaust emission standards for diesels.

Table III-1 also shows the potential emissions of the four major pollutants from motor vehicles. In addition to showing estimates for the individual pollutants and the total emissions, the table expresses total emissions as a percentage of 1967 levels. The estimated total potential emissions in 1976 are about one and one-third times those in 1967. Table III-1 further shows the projected total pollution potential over the entire span of FY 1967 through 1976.

2. Projected Standards and Emissions with Controls Under the Act

Table III-2 illustrates the effect of anticipated controls on the emissions for FY 1967 through 1976. In making the projections shown in Table III-2, current and anticipated standards detailed in Table III-3 were used. These standards either have been promulgated or are under consideration by the Air Pollution Control Office. The anticipated standards for heavy-duty trucks are still under study and development.

As shown in Table III-2, nearly 82 percent of the motor vehicles in use should be controlled by 1976. In projecting the percentage of vehicles under control, the age distribution of vehicles in use has been considered with older vehicles being removed from service and new vehicles being added with time. Age and use distribution within the vehicle population are based on 1969 data. It is assumed that a comparable distribution will hold through FY 1976.

It has been assumed in making projections that controlled vehicles will be maintained in such a manner that their average emissions will not exceed the level set by Federal standards. Tests have indicated that vehicles now on the road tend to increase their emission levels somewhat with age; however, the new Federal standards and methodologies for manufacturer qualification of vehicles are intended to insure that vehicles are capable of remaining below the standard levels through

TABLE III-2. - EFFECTS OF CONTROLS ON MOBILE SOURCE EMISSIONS, FY 1967-1976
[1967 Baseline]

Fiscal Year	Numbers of Vehicles						Total Number of Vehicles			Emissions with Controls in Effect							
	Autos and Light-Duty Trucks			Heavy-Duty Gasoline Trucks			Autos and Light and Heavy-Duty Gasoline Trucks			Hydrocarbons		Carbon Monoxide		Nitrogen Oxides		Particulates	
	Uncontrolled (Millions)	Controlled (Millions)	Percent Under Control	Uncontrolled (Millions)	Controlled (Millions)	Percent Under Control	Uncontrolled (Millions)	Controlled (Millions)	Percent Under Control	Level (Thousands of Tons)	Percent of Potential 1/	Level (Thousands of Tons)	Percent of Potential 1/	Level (Thousands of Tons)	Percent of Potential 1,2/	Level (Thousands of Tons)	Percent of Potential 1/
1967	81.8	0	0	5.32	0	0	87.1	0	0	21,070	100	126,100	100	5,700	100	330	100
1968	77.6	6.9	8.2	5.67	0	0	83.3	6.9	7.7	20,670	85	125,600	97	6,070	103	350	100
1969	71.0	17.3	19.6	5.89	0	0	76.9	17.3	18.4	20,160	79	124,400	91	6,560	106	360	100
1970	63.6	27.1	29.9	5.52	0.45	7.5	69.2	27.6	28.5	19,030	73	118,400	84	6,910	109	370	100
1971	54.3	37.9	41.1	5.04	1.04	17.1	59.3	38.9	39.6	17,430	65	110,500	77	7,200	112	380	100
1972	45.2	49.7	52.4	4.64	1.61	25.8	49.8	51.3	40.9	15,680	57	102,000	69	7,580	114	390	100
1973	37.0	60.5	62.0	4.19	2.23	34.7	41.2	62.7	60.3	14,080	50	94,000	62	7,440	109	390	100
1974	29.3	70.8	70.7	3.76	2.83	42.9	33.1	73.6	69.0	12,430	43	86,000	55	7,130	102	410	100
1975	22.7	81.1	78.1	3.41	3.43	50.2	26.1	84.5	76.4	10,710	35	76,300	48	6,550	90	390	92
1976	17.9	89.3	83.3	3.10	3.96	56.1	21.0	93.3	81.6	9,080	29	66,400	40	5,780	77	370	84
FY 1967-76 Emission and Percent Totals										160,300	60	1,030,000	71	66,900	102	3,740	97

1/ Potential emissions as shown in Table III-1.

2/ Implementation of hydrocarbon and carbon monoxide controls causes increase in nitrogen oxides emissions until countered by nitrogen oxides controls

TABLE III-3. - CURRENT AND ANTICIPATED STANDARDS FOR MOBILE SOURCES, 1967 - 1976

Vehicle Class	Year	Maximum Exhaust Pollutant Levels Permitted				Crankcase Vapors	Evaporative Losses
		Hydrocarbons	Carbon Monoxide	Nitrogen Oxides	Particulates		
Autos and Light-Duty Trucks (under 6,000 lbs. GVW)	1967	No Standard	No Standard	No Standard	No Standard	Under Control	No Standard
	1968	275ppm[1,2]	1.5%(vol.)[1,2]	"	"	NONE	"
	1969	275ppm[1,2]	1.5%(vol.)[1,2]	"	"	FOR	"
	1970	4.6gm/mi[2]	47gm/mi[2]	"	"		"
	1971	4.6gm/mi[2]	47gm/mi[2]	"	"	ALL	6gm/test
	1972	2.9gm/mi	37gm/mi	"	"	YEARS	2gm/test
	1973	2.9gm/mi	37gm/mi	3.0gm/mi	"		"
	1974	2.9gm/mi	37gm/mi	3.0gm/mi	"		"
	1975	0.5gm/mi	11gm/mi	0.9gm/mi	0.1gm/mi		"
	1976	0.5gm/mi	11gm/mi	0.9gm/mi	0.1gm/mi		"
Heavy-Duty Gasoline Trucks (over 6,000 lbs. GVW)	1967	No Standard	No Standard	No Standard	No Standard	Under Control	No Standard
	1968	"	"	"	"	NONE	"
	1969	"	"	"	"		"
	1970	275ppm[2]	1.5%(vol.)[2]	"	"	FOR	"
	1971	275ppm[2]	1.5%[2]	"	"	ALL	"
	1972	275ppm	1.5%	"	"		"
	1973	275ppm	1.5%	"	"	YEARS	2gm/test[3]
	1974	180ppm	1.0%	"	"		2gm/test[3]
	1975	180ppm	1.0%	785ppm	"		2gm/test[3]
	1976	180ppm	1.0%	785ppm	"		2gm/test[3]

1/ For engines over 140 cubic inch displacement.

2/ Measurement procedures originally specified in standards have been changed. As originally published (1970-71) standards were 2.2gm/mi for hydrocarbons and 23gms/mi for carbon monoxide. Under new procedures, the equivalent figures are those in this table. Revised measurement standards to be enforced beginning 1972. Federal Register Volume 35, No. 136, pt. II, July 15, 1970 and announcement from Office of Secretary of Health, Education, and Welfare, July 15, 1970. tion,

3/ Based on one control system per vehicle.

their useful life. Some method of enforcement or incentive may be required to assure that owners do maintain vehicles so that emissions are kept to specified levels.

The projected annual emissions with the anticipated controls in effect are expressed in weight quantities and as the percentage of the uncontrolled potential. By 1976 hydrocarbons should be reduced to about 29 percent of the uncontrolled potential, carbon monoxide to 40 percent, nitrogen oxides to 77 percent, and particulates to about 84 percent of potential.

The nitrogen oxides level with controls is expected to rise above the uncontrolled level for a portion of this time period. This is due to the fact that the controls for hydrocarbons and carbon monoxide, which are implemented earlier than those for nitrogen oxides, tend to produce an increase in nitrogen oxides with a reduction of the other pollutants. The first Federal standards for nitrogen oxides are expected to be effective in FY 1973. With these standards in effect, the levels of nitrogen oxides emitted will begin to show a decline. However, it is not until the last two years of the time period that these levels will actually fall below those expected if hydrocarbons and carbon monoxide were not being controlled.

In making the emission projections with controls as shown in Table III-2, consideration was given not only to the age distribution within the vehicle populations each year, but to the usage of various ages of vehicles. Based on total mileage estimates and the number of cars in use, the average mileage driven per year is about 10,600 miles; for heavy-duty trucks the average is about 12,000 miles. Based on Bureau of Public Roads surveys the trend is for annual mileage to decrease with the age of the vehicle. Thus, the newer vehicles contribute a significantly larger portion of the total mileage and fuel consumption than the older vehicles.

III. STATE-OF-THE-ART OF CONTROL TECHNOLOGY FOR MOBILE SOURCES

A. Vehicle Controls [Ref. 4].

The past year has not produced any major advances in either new technology for the control of the internal combustion engine or the development of power sources as alternatives. Some progress has been made in control techniques and more is anticipated in certain areas, such as the use of catalytic exhaust reactors. Such changes appear to be evolutionary rather than of the breakthrough variety.

Most of the progress to date in reducing hydrocarbon and carbon monoxide emissions has been made by increasing air-fuel ratios (AFR) in new engines. Many 1970 model cars are designed to operate at air-fuel ratios of 14 to 16 parts air to one part fuel, thus reducing the hydrocarbon and carbon monoxide emissions. It is an unfortunate fact that nitrogen oxides emissions reach a maximum in this range (approximately 15.5). Theoretically, an AFR in the range of 18 to 20 would be the optimum point for limiting emissions of all gaseous pollutants (hydrocarbons, carbon monoxide, and nitrogen oxides) in the exhaust. In practice, however, air-fuel ratios greater than about 17.5 produce rough engine operation which manufacturers feel would be unacceptable to most drivers. Automobile manufacturers and carburetor suppliers are continuing their efforts to develop satisfactory production models with leaner operating engines; i.e. using a higher air-to-fuel ratio.

Diesel engines always operate with an excess of air present in the combustion cylinders. This accounts for the diesel engine's low emissions of hydrocarbons and carbon monoxide as compared with the gasoline engine. The AFR is varied by the driver rather than being fixed by carburetor design as in a gasoline engine. Smoke from diesel engines is a function of the engine loading, speed, and the air-fuel ratio. Since these factors are under the control of the diesel operator, most diesel engines now on the road can meet smoke standards through FY 1976 if properly maintained and operated. Minor design changes, such as improved fuel injectors, are being incorporated into new diesel engines to further improve the performance in terms of smoke and odor emissions.

Exhaust emission standards for light-duty vehicles can be met through FY 1972 by minor modifications to current design engines. Such modifications include carburetion improvements, operation with leaner fuel mixtures, control of engine inlet-air temperature, and changes in the timing of valve and ignition operation.

The nitrogen oxides standards for exhaust emissions, which become effective in FY 1973, can be met through partial exhaust gas recirculation to the engine air inlet. Although recirculation reduces nitrogen oxides emissions, it has a slightly adverse effect on the levels of other emissions. However, it should be possible to meet standards by this means through FY 1974.

Anticipated standards for evaporative emissions from fuel tanks and engines of gasoline vehicles can be readily met through FY 1976. In fact, the ease with which the original standards were met has resulted in an advancement of the effective date of the more stringent evaporative standards. Automobile manufacturers report considerable progress during the last year in simplification and production engineering of evaporative control devices. These advances should result in reducing device complexity, maintenance requirements and initial price.

It should be possible for gasoline engines to achieve FY 1975 standard levels. However, in the opinion of the automobile manufacturers, this may be near the limit of what might be expected with reciprocating internal-combustion engines. In order to meet FY 1975 standards, some type of exhaust-gas reactor system appears necessary. Research and development efforts are continuing on both engine-exhaust manifold-type reactors and catalytic-muffler-type reactors. The current consensus of major U. S. manufacturers is toward the use of catalytic-muffler-type units in FY 1975 and FY 1976. Some limited production of single catalyst units may begin with the 1975 model year. This represents somewhat of a change in thinking during the last year. The change has been brought about because of a push toward the reduction or elimination of lead in gasoline. The presence of lead in gasoline has an undesirable effect on catalytic-reactor-type units and has been a major stumbling block in the development of such units. Although the automotive industry has sought the elimination of lead in gasoline because of adverse effects on the longevity of exhaust emission control systems such as catalytic and thermal reactors, reduction or elimination of lead will also greatly reduce the problem of particulate emissions in the exhaust.

In order to meet the FY 1975 standards, it is anticipated that the catalytic-reactor units will be used to reduce nitrogen oxides as well as carbon monoxide and hydrocarbons. To accomplish this, tandem catalytic units or dual-catalyst units will probably be required. In a two-catalyst system such as this, the engine is run fuel rich to produce the low-oxygen-content exhaust gases required for a reducing-type reactor. This results in an increase in fuel consumption. The dual-catalyst units will probably serve multiple functions in the exhaust system of 1975-76 model automobiles. The catalytic-reactor units may also serve as conventional mufflers and have provision for trapping particulate matter.

United States automobile manufacturers are working toward a lifetime of 50 to 100 thousand miles for the catalytic-muffler systems. In accord with this goal, manufacturers anticipated that so-called lifetime exhaust systems will be added to the vehicle. This means that the other portions of an exhaust system will be made of a durability comparable to or greater than the catalytic-reactor units. This is intended to avoid the possibility of damage or requirements for replacement of expensive catalytic units due to failure of other exhaust components. The increased life of such exhaust components will be of benefit to the consumer.

The foregoing discussion has been directed largely at automobiles. It is anticipated that the technology will be essentially identical for other light-duty gasoline vehicles. The same technology will probably be applied in general to the heavy-duty gasoline vehicles also, but there is a greater potential for the use of exhaust-manifold reactors on heavy-duty vehicles. During the period through FY 1976, however, it is probable that heavy-duty gasoline trucks will be able to meet the standards through engine modifications and the addition of some exhaust gas recirculation. It is not anticipated that particulate control will be required on heavy-duty vehicles through FY 1976. The technology of evaporative emission control for heavy-duty vehicles should be quite similar to that for light-duty vehicles. There may be some differences, however, due to the presence of multiple fuel tanks on many heavy-duty vehicles.

B. The Outlook for Unleaded Gasoline

Tetraethyl lead was once added only to premium grade gasoline. Regular grades were essentially of the same base, but without the lead addition. As a result, the public came to associate the name "ethyl" with premium quality. This association in the public mind continues despite the fact that both regular and premium gasolines today contain lead additives.

Average premium gasolines on the market contain about 2.8 grams of lead per gallon and have a research octane number (RON) of about 100; average regular grade gasoline has about 2.4 grams of lead per gallon and a RON of about 94. The range of octanes varies with time and sources of petroleum. Regular gasolines may range from 90 to 96 octane; premiums from 97 to 100. Some companies retail three grades of gasoline; others use blending pumps to offer virtually a continuous spectrum of octanes in the 92 to 100 range.

With current refining processes, the average RON of premium gas is slightly below 93 without lead added, satisfying the antiknock requirements of only about 55 percent of the automobiles currently in use. Removal of lead from regular gas would result in a research octane number slightly below 86, satisfying less than four percent of current automobiles. The combined regular and premium gasoline base stocks (before addition of lead) constitute the so-called "pool" for the nation. The "pool" octane thus obtained is about 91 RON.

1. Movement Toward Low Lead and Lead-Free Gasolines

Recent months have seen rapid changes in the prospects for low-lead or unleaded gasoline as the petroleum industry adjusts to the realities of potential restrictions. United States automobile manufacturers have decided to lower the octane requirements of new cars beginning with 1971 models. This removes some of the arguments against unleaded gasoline. If it is not necessary to maintain present high octane levels without using lead, refinery processes will not require extensive changes. This means that 91 RON unleaded gasoline can be offered at little or no change in price over present regular grades.

By the end of the 1971 model year, almost all U. S. automobile production will have engines suitable for operation on 91 research octane gasoline. This is an effort by the manufacturers to push the production of unleaded gasoline in anticipation of introducing catalytic exhaust reactor units. In the auto industry there is a general feeling that complete absence of lead in gasoline will increase the possibility of valve problems in current engine designs. Only very low levels of lead content are required to prevent these problems; however, present experience indicates that catalytic reactors may not tolerate even small concentrations of lead in gasoline. Gasoline or oil additives may be found to prevent valve problems without lead. Newer engines will be designed to avoid such problems.

2. Progress in Availability of Low-Lead and Lead-Free Gasolines

Major gasoline producers have recently announced the immediate or imminent availability of low-lead or unleaded gasolines. The products and prices being offered present a mixed picture. One producer has for a number of years offered an unleaded premium gasoline, with a price usually somewhat higher than leaded premiums in the same area. Another major producer has been offering an unleaded regular in some parts of the country, with a price above leaded premium. Yet another offers a low-lead regular (nominal 96 RON) as the middle level of a three-grade line. This middle grade is retailing for one cent per gallon above the leaded grade it has replaced. Other companies with three-grade or blending pump lines are offering their lowest octane product (92 to 94 nominal RON) at one cent below area prices for leaded regular. Other variations are in the offing as more suppliers announce their plans.

The variations in approach by producers reflect several influences. These influences include the company's ability to produce a given octane with lowered lead content (dependent on the nature of its crude supply and types of refining equipment) and judgments concerning financial and marketing strategies. Competitive effects will tend to produce a more uniform price and product balance as time passes.

Gasoline retailers report that initial consumer response to new low-lead and unleaded fuels has been disappointing. The concept that higher octane fuel is inherently better for an automobile is deeply imbedded in consumer psychology. The majority of U. S. automobile owners use gasoline with octane ratings (and hence lead content) in excess of their engine's requirements. This may result from years of exposure to gasoline advertisements, the association of the word "premium" with higher octane ratings, and ignorance. This situation will likely continue even though new cars will have lower octane requirements. Consumer apathy toward unleaded fuels may also reflect ignorance of the environmental concerns regarding lead.

A major educational campaign will be required to induce the consumer to accept the lowest octane gasoline which is actually required by his car. If this is not done, continued public demand for excessive quantities of high octane fuel could result in unnecessarily high prices for unleaded gasoline.

IV. COST ASPECTS OF COMPLIANCE WITH STANDARDS

Tables III-4 and III-5 detail the per-vehicle cost of complying with Federal standards for mobile sources for the 1967-76 model years. The uncontrolled 1967 model year is a baseline. Tables III-4 and III-5 show the emissions controlled for each vehicle model year, the anticipated control methods, and the control investment per vehicle [Ref. 5]. The control investment per vehicle represents an increase in price to the purchaser of new motor vehicles. Anticipated requirements for additional maintenance due to emission controls are also shown in the tables with the frequency and event cost of such additional maintenance indicated. It is assumed that legal or warranty requirements will insure that owners obtain the necessary maintenance. The anticipated additional maintenance costs are based on current labor costs for procedures comparable to those anticipated and for estimated costs of replacement items associated with emission controls. These anticipated periodic maintenance costs are also shown on an annualized basis. Additional operating costs incurred as a result of fuel penalties are also shown. The total additional annual costs per vehicle are the annualized maintenance cost plus the extra operating cost. All cost figures are based on 1970 dollars.

Since the motor vehicle industry provides products directly to the consumer public, costs have been expressed in terms of the owners and users of vehicles. In the automotive industry increased costs of manufacturers (including research and engineering) are passed directly to the final consumer by means of increased retail prices.

For the typical automobile owner and user, concepts of amortization, annualization, or percentage change in annual costs probably have little significance. The typical automobile owner will tend to view his costs largely in terms of the increased price at time of purchase and increased operating costs in terms of fuel usage. The depreciation characteristics of vehicles vary widely depending on the popularity of the individual model involved. For this reason it would add little to attempt to annualize investment costs according to actual vehicle depreciation curves.

The costs of additional maintenance requirements have been annualized on the basis of the time interval between the required maintenance events. Thus, a maintenance requirement that must be met on an average of once every five years has its costs annualized on a five-year basis.

TABLE III-4. - UNIT CONTROL METHODS AND COSTS, 1967 - 1976 MODEL YEARS

CARS AND LIGHT-DUTY TRUCKS

Model Year	Emissions Controlled[1/]	Control Method	Control Investment per Vehicle (Dollars)	Additional Maintenance Requirements: Type of Maintenance	Additional Maintenance Requirements: Average Frequency	Maintenance Event Cost (Dollars)	Additional Maintenance Annualized Cost (Dollars/Yr)	Additional Operating Cost (fuel penalty costs)[2,3/] (Dollars/Yr)	Additional Maintenance and Operating Cost (Dollars/Yr)[3/]
1967 and earlier	None	None	None	None	None	None	None	None	None
1968-69	HC,CO (exhaust)	Engine modifications	2.00	None (more care required in tuneup and adjustment procedures		None	None	-5.10	-5.10
1970	HC,CO (exhaust, some evaporative HC)	Engine modifications	7.00	None (more care required in tuneup and adjustment procedures)		None	None	-5.10	-5.10
1971	HC (exhaust and evaporative) CO	Engine modifications Evaporative traps	17.00	Repair and replacement of evaporative traps and parts	5 yrs. or 50,000 miles (once in 10 yrs.)	24.00	2.40	-5.10	-2.70
1972	"	"	17.00	"	"	24.00	2.40	-5.10	-2.70
1973-74	HC (exhaust and evaporative) CO,NO_x	Same as 1971 plus exhaust gas recirculation	42.00	Same as 1971 plus servicing of recirculation system	5 yr/ 50,000 miles for evaporative control 1 yr/ 10,000 miles for recirculation system	24.00 8.00	10.40	-2.50	7.90
1975-76	HC (exhaust and evaporative) CO,NO_x, particulates	Dual catalyst reactor-mufflers plus particulate traps (air injection required for reactors). Unleaded gasoline. Evaporative traps.	240.00	Servicing of air injection system. Replacement of catalytic units. Servicing evaporative traps. Maintenance adjustments and cleaning.	5 yr/ 50,000 miles for air injection, catalytic units and evaporative traps. Adjust and clean as needed. Credit for normal exhaust system maintenance.	98.00 24.00 -50.00	7.00	5% fuel penalty $13.70.	20.70

1/ HC = Hydrocarbons, CO = Carbon Monoxide, NO_x = Nitrogen Oxides.

2/ Based on 757 gal/yr @ 34¢/gal.

3/ Negative values indicate benefits rather than costs. Benefits due to slightly improved fuel mileage.

TABLE III-5. - UNIT CONTROL METHODS AND COSTS, 1967-1976 MODEL YEARS

HEAVY-DUTY GASOLINE TRUCKS

Model Year	Emissions Controlled[1/]	Control Method	Control Investment per Vehicle (Dollars)	Additional Maintenance Requirements		Maintenance Event Cost (Dollars)	Additional Maintenance Annualized Cost (Dollars/Yr)	Additional Operating Cost (fuel penalty costs) (Dollars/Yr)	Additional Maintenance and Operating Cost (Dollars/Yr)
				Type of Maintenance	Average Frequency				
Pre 1970	None	None	None	None	None	None	None	None	None
1970-71	HC,CO	Engine modifications (lean operation).	9.00	None	None	None	None	None	None
1972	HC,CO	"	9.00	None	None	None	None	None	None
1973	"	Same as 1970-71 plus evaporative traps.	21.00	Repair and replacement of evap. traps and parts.	5 yrs. (twice in 15 yrs.)	26.00	3.50	None	3.50
1974	"	Same as 1973	21.00	"	"	26.00	3.50	None	3.50
1975-76	HC,CO, NO_x particulates	Same as 1973 plus exhaust gas recirculation. Unleaded fuel.	46.00	Same as 1973 plus servicing or recirc. system.	5 yrs. evap. traps. 1 yr. recirc. system.	26.00 10.00	13.50	None	13.50

1/ HC = Hydrocarbons, CO = Carbon Monoxide, NO_x = Nitrogen Oxides.

In preparing the cost information shown in Tables III-4 and III-5, consideration has been given to offsetting benefits which may act to reduce the net cost to purchasers and users of motor vehicles; e.g., increased gas mileage due to leaner engine operation.

Crankcase emission devices (the PCV valve system) are not included in pre-1968 costs. These devices were required by law beginning with 1966 models, but have been standard on U. S. cars beginning with 1963 models.

Controls classified under the category of engine modifications include changes in compression ratios, valve and ignition timing, and carburetion and fuel-air inlet design changes. Changes of this type are commonly used by manufacturers to differentiate engines of one basic design in order to offer a product line of several horsepower options with varying fuel requirements. Such changes, which do not require the addition of any components to engines or involve any basic concepts not current in the 1967 designs, are here considered to be ordinary engineering options for the manufacturers with negligible effect on retail prices. Where additional items are added to the basic engine design, such as spark advance cut-out devices, evaporative traps, or equipment for exhaust gas recirculation, retail price estimates have been used in computing the control investment cost per vehicle. In the case of evaporative emission traps, consideration has been given to engineering advancements which have permitted reduction of the retail cost of such units from the $35 level for the prototypes as sold in California in 1970 to approximate $10 for the types that will be in general use throughout the U. S. in 1971 models. Possible costs for extensive emission compliance testing of assembly line vehicles have not been included.

For the 1975 and 1976 model years, the control investment costs per vehicle include the price of the catalytic-reactor-type muffler units with a long-life exhaust system, the equipment required for air injection to the oxidizing reactor, provision for trapping of particulates, and the evaporative emission traps. As has been previously stated, it is assumed that unleaded gasoline will be employed by the 1975 and 1976 model vehicles. For the 1975-76 models, a credit has been given under maintenance requirements for reduction in the exhaust system maintenance due to the use of long-life materials as compared to current exhaust system materials.

As may be seen from the Table III-4, the slightly improved fuel consumption with engines being operated under lean conditions produces an overall benefit or negative total annual cost per vehicle through the 1972 model year.

It has been estimated that the lean operation will produce approximately two percent improvement in gasoline mileage for 1968 through 1972 models. Theoretically, the use of evaporative traps to recover normally lost fuel should result in a fuel saving. However, in practice, the disturbances in carburetion and the balance of the air-fuel intake system produced by adding on such devices will probably tend to offset any gain due to fuel recovery.

Exhaust gas recirculation will probably produce a slight decrease in fuel economy, tending to offset the benefits of lean engine operation. Theoretically, recirculation should have little effect on engine efficiency, but again in practice, disturbances of carburetion and air-fuel distribution will produce a small loss in engine efficiency.

For FY 1975-76 fuel-cost penalties are incurred from two sources. Approximately a five percent fuel penalty is the minimum which can be expected for 1975-76 model automobiles using a reducing catalyst system to control nitrogen oxides. The government is seeking to have unleaded (and very low-lead) gasoline in general use by 1974 or 1975. Therefore, it is assumed that unleaded gasoline will be used by all automobiles and gasoline trucks in FY 1975-76. An additional two cents per gallon for unleaded gasoline is charged only against pre-1971 model vehicles for FY 1975-76. The increased cost for these cars to use unleaded fuel is based on an assumption of octane requirements similar to 1967 vehicles. It is assumed that there will be no extra cost for the low octane lead-free fuel used by 1971-76 model engines in FY 1975-76.

Cost estimates for producing unleaded gasoline of octane levels required by pre-1971 model automobiles have ranged from about one-half to two and one-half cents per gallon over comparable leaded fuels [Ref. 5-8]. The decision of automobile manufacturers to lower octane requirements beginning with 1971 models has greatly changed the fuel cost outlook from earlier projections. Fluctuations in costs of unleaded gasoline versus leaded are to be expected in the transition period. The price situation should be stabilized by the time vehicles appear with catalytic exhaust reactors.

Control costs for heavy-duty trucks are anticipated to be generally comparable to those for automobiles and light-duty trucks meeting the same standards. However, the differences in implementation of heavy-duty truck standards shifts the time frame of the costs. For the heavy-duty vehicles,

vehicles, higher fuel consumption rates increase the relative importance of fuel penalties and total annual cost.

A summary of the total national economic effects of mobile source controls through 1976 is given in Table III-6. The incremental capital investment given each year is for cost increases due to meeting the then-current emission standards for new vehicles sold that year. The incremental capital investment represents the sum-total of individual cost increases for all vehicles of a model year corresponding to the fiscal year shown (for practical purposes the automobile model sales season corresponds closely with a Federal fiscal year). The additional operating costs shown in Table III-6 are the total for all vehicles in use which are under any Federal emission standards. The age and use distributions within the vehicle populations have been considered. Reductions in the potential emission levels for each year are also shown in Table III-6.

Table III-6 also shows the totals of the capital investment and additional operating costs incurred over the entire period of 1967 through 1976, and the reduction from the potential emission level achieved. The total of the capital investment and additional operating costs projected for the period of FY 1967 through 1976 is approximately 7.1 billion dollars for the nation. It should be pointed out that the small dollar benefits (negative costs) per vehicle in the FY 1968 through 1974 period are very sensitive to variations in data on average vehicle useage and fuel consumption rates. For this reason, as far as the individual owner is concerned, costs and benefits will about offset each other in this period. For the individual private automobile owner, the purchase price differences will be the most obvious cost item, although these differences do not become major until the 1975 model year.

V. CONCLUSION

Based upon information available as of July 15, 1970, air pollution control costs to be borne by vehicle purchasers and users do not appear significant through Fiscal Year 1974. Control costs will climb sharply to meet the anticipated standards in succeeding years unless presently unforeseen technological advances occur. Meeting the projected standards

TABLE III-6. - COSTS OF CONTROLS AND EFFECTIVENESS IN REDUCING EMISSIONS, FY 1967-1976 ALL AUTOS AND GASOLINE TRUCKS

Fiscal Year	Incremental Investment Due to Increased Prices of New Vehicles[1] (Millions of Dollars)	Additional Costs for Operation and Maintenance [2] (Millions of Dollars)	Reductions in Emissions From Potential [3]							
			Hydrocarbons		Carbon Monoxide		Nitrogen Oxides		Particulates	
			(Thousands of Tons)	(Percent)	(Thousands of Tons)	(Percent)	(Thousands of Tons)	(Percent)	(Thousands of Tons)	(Percent)
1967	0	0	0	0	0	0	0	0	0	0
1968	13.9	-35.4[4]	3,500	15	4,300	3	-160[5]	- 3[5]	0	0
1969	20.7	-88.2[4]	5,200	21	12,400	9	-380[5]	- 6[5]	0	0
1970	56.1	-138.3[4]	7,100	27	22,000	16	-560[5]	- 9[5]	0	0
1971	131.1	-175.3[4]	9,100	35	32,200	23	-750[5]	-12[5]	0	0
1972	136.6	-208.9[4]	11,600	43	44,700	31	-940[5]	-14[5]	0	0
1973	346.3	-154.4[4]	13,900	50	56,800	38	-620[5]	- 9[5]	0	0
1974	498.5	- 50.3[4]	16,400	57	68,900	45	-130[5]	- 2[5]	0	0
1975	2,068.7	743.5[6]	19,200	65	84,400	52	710	10	31	7
1976	3,031.7	908.6[6]	21,700	71	99,500	60	1,720	23	68	16
FY 1967-76 Totals	6,303.6	803.3	107,700	40	425,200	29	-1,110	- 2	99	3

1/ Increased costs due to purchases of new vehicles during given year only.

2/ Total increased costs due to controls for all cars and gasoline trucks on road for given year.

3/ Based on potential emissions as shown in Table III-1.

4/ Direct economic benefits larger than direct costs to owners.

5/ Negative values indicate increases (which are results of controls on hydrocarbons and carbon monoxide).

6/ Total use of unleaded gasoline assumed beginning 1975. It is assumed that only pre-1971 model autos will be using extra cost high octane (greater than 91 RON) unleaded gasoline (2¢ per gallon extra).

through 1976 will, however, produce significant reductions in mobile source emissions. If implementation of the standards is accelerated or if the standards are increased in stringency, it can be expected that control costs will rise at an accelerated rate.

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3. Based on data from U.S. Department of Commerce, Bureau of Public Roads, as reported in 1968 Automotive Facts and Figures, published by Automobile Manufacturers Association, Detroit, Michigan, 1968.

4. Projected control techniques and prices based on surveys and interviews with industry representatives.

5. S. P. Lawson, J. F. Moore, and J. B. Rather, Jr., "Added Cost of Unleaded Gasoline," Hydrocarbon Processing. 46 No. 6, June 1967.

6. J. O. Logan, President Universal Oil Products Co., (Testimony to Assembly Committee on Transportation of the California Legislature), Los Angeles, California, December 4, 1969, 20 pp.

7. U. S. Motor Gasoline Economics, Bonner and Moore Association, Inc., for the American Petroleum Institute, Vol. I, June 1967, p. 2-32.

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APPENDIX IV

Stationary Sources

Appendix IV

Stationary Sources

I. INTRODUCTION

The purpose of this appendix is to present, on a source by source basis, the detailed analyses upon which the summaries presented in Chapters 4 and 5 are based. For the solid waste disposal and stationary combustion categories, the discussion is limited to the engineering analyses of the cost and emission estimations. Detailed economic discussion is not included because in-depth economic impact studies were not performed for these sources. For each of the industrial process sources, in addition to the engineering analyses provided, a discussion of the economic analyses performed to develop economic impact statements are also presented.* Sources that shared product markets or were in other ways related are discussed simultaneously. The industries grouped together for purposes of the analyses are petroleum refining and petroleum products and storage; phosphate fertilizer and elemental phosphorus; and primary and secondary metallurgy. Included in all of the discussions of the industrial process sources is a statement defining the scope and limitations of the economic analysis.

* Sulfuric acid is an exception because an economic impact analysis is being performed directly by APCO.

II. SOLID WASTE DISPOSAL

A. Effect of Air Pollution Control Alternatives

By 1976, the population of the 298 metropolitan areas should reach 186 million. It is also predicted that the per capita generation of solid waste will increase by approximately three percent per year. In 1967, the base year, the per capita per day generation of solid waste was estimated to be 10.2 pounds. Thus, it is estimated that 395 million tons of refuse will be generated in 1976.

For the purpose of estimating control costs, it is assumed that the following control alternatives would be used: (1) electrostatic precipitators to control particulate emissions in accordance with the New York State Particulate Emission Regulation for Refuse Burning Equipment (see Appendix II) on all municipal and 80 percent of the commercial incinerators onsite in 1967; (2) a sufficient number of new incinerators would be constructed to provide for incineration of 20 percent of all refuse; and (3) all open burning would be discontinued in favor of sanitary landfills.

By implementing this plan by Fiscal Year 1976, particulate emissions would be reduced from a potential of 1,500,000 tons to 185,000 tons, carbon monoxide from 5,450,000 tons to 414,000 tons, and hydrocarbons from 2,020,000 tons to 293,000 tons. The emissions are therefore reduced by 87.7 percent, 92.4 percent, and 85.5 percent, respectively.

B. Engineering Basis of the Analysis

1. Methodology

Air pollution control costs for solid waste were obtained by:

a) Determining the quantity and method of disposal of collected refuse.

The total collected refuse generated in any metropolitan area was computed on the basis of 5.5 pounds per capita per day [Ref. 1]. Specific data for a metropolitan area were used when available. The amount of refuse incinerated was obtained from incinerator listings obtained from previous studies [Ref. 2]. All incinerators were assumed to be operating at their stated capacity, and the balance of the refuse which was not incinerated was assumed to be disposed of by other methods: landfill, burning dumps, ocean dumping, composting, etc. When no detailed information on the method of disposal existed, it was assumed that 33 percent of this remaining amount was open burned [Ref. 3].

b) Determining the quantity and method of disposal of uncollected refuse.

Uncollected refuse was estimated using a rate of 4.7 pounds per capita per day [Ref. 1]. This refuse was assumed to be presently disposed of by 50 percent landfill, 25 percent open burning, and 25 percent domestic and commercial incineration.

c) Determining incinerator control costs.

All existing municipal incinerators must be upgraded to some extent to comply with regulations. The cost for this upgrading is presented in Table IV-1.

TABLE IV-1. - COST OF UPGRADING MUNICIPAL INCINERATORS

Year of Construction	Cost of Upgrading ($ per daily ton of capacity)	
	Investment	Annual
Before 1961	500	360
1961-1964	400	330
1965-1967	200	310

d) Determining open burning control costs for collected refuse.

All present open burning must be discontinued. It was assumed that 25 percent of this amount would go to new incinerators at a cost of $5,600 per daily ton for furnaces in the 300 ton per day or larger size, and $7,500 per daily ton for furnaces smaller than 300 tons per day [Refs. 3, 4, 5]. The annualized cost of operating an incinerator was based on $6 per daily ton and 300 days per year. The remaining 75 percent of open burning would go to sanitary landfills at an additional cost of $0.30 per ton. This is the only cost above that required to operate a burning dump. (See Reference 3.) No initial investment costs were included since land and personnel for the burning dump were already on hand. In metropolitan areas where there are no municipal incinerators, all open burning would be converted to sanitary landfill; that is, no new incinerators will be built in these areas.

e) Determining control costs for uncollected refuse.

Uncollected refuse control costs were based on all current open burning (25 percent of all solid waste) going to sanitary landfill at a cost of $0.40 per ton, and existing incineration (also 25 percent of the total) requiring upgrading at an investment cost of $1000 per daily ton of capacity with an annualized cost of $259 per daily ton. Presently, twenty percent of existing small incinerators were assumed to meet the New York State regulation, and 20 percent were assumed to convert to landfill at no additional cost.

f) Determining additional costs incurred by 1976.

These costs were based on the 1967 disposal practices, but were varied to accommodate population changes as well as a 3 percent yearly increase in the amount of solid waste generated per capita. These increases were then treated in the same manner as the 1967 values to arrive at a control cost.

g) Assuming that all California metropolitan areas were controlled through local efforts and any costs incurred were not due to Federal action.

The major single factor is the cost for new incinerators required to control 25 percent of the existing open burning. The high initial costs and the high yearly costs accounted for about

50 percent of the total annual costs for this metropolitan area.

The installation of electrostatic precipitators (ESP's) in place of scrubbers on existing municipal incinerators was also investigated. Annualized costs for ESP's are about 50 percent of scrubber costs. However, since no ESP's are currently used for controlling particulate emissions from incinerators, they were not considered in this analysis. Assuming some of the larger incinerators were to go to ESP's as a means of control, a typical metropolitan area's annualized cost would be reduced by about 10 percent.

Cost estimates for disposing of junked automobiles in controlled incinerators were based on an assumption that 50 percent of these automobiles were now being open burned. Based on data presented later in this section, the costs of controlling particulates from auto body incinerators would only add about 1 to 3 percent to the metropolitan area investment cost and even less to the annualized cost. Therefore, separate estimates of the cost of controlling junked auto disposals were not made because the percent contribution of these costs was less than the expected error of the major cost estimates.

2. <u>Control Costs</u>

The following air pollution control costs were utilized in estimating metropolitan area solid waste disposal expenditures.

a. <u>Municipal Incinerator Control Costs</u>

Table IV-2 presents the cost of controlling municipal incinerators with wet scrubbers.

Since installed costs did not vary by more than about 10 percent, an average cost of $500 per daily ton was used. For incinerators built between 1961 and 1964, 80 percent of the control costs were used. For units built after 1965, a control cost of $200 per daily ton was arbitrarily used since these units were assumed to have some type of acceptable control device already in place.

Annualized costs were based on a 13.3 percent capital charge and on the following operating cost equation [Ref. 6]:

$$G = S\ [0.745HK\ (Z + \frac{Qh}{1980}) + WHL + M] = 0.3985$$

where: S = acfm;
H = 7200 hours/year;
K = \$.01/kwh
Q = 0.01 gals/acfm;
Z = 0.006 hp/acfm;
W = 0.005 gals/hr acfm;
M = 0.03/acfm;
h = 30 feet;
l = $\$0.5 \times 10^{-3}$/gals.

Operating costs for a wide range of incinerator size were calculated and an average cost based on dollars per ton used for cost estimating purposes.

TABLE IV-2. - MUNICIPAL INCINERATOR CONTROL COSTS

Size (tons/day)	Flue Gas Volume (1000 acfm)1/	Collection Eff.(percent)	Installed Cost ($1000 total)2/	Installed Cost ($/daily ton)	Annualized Cost ($1000)	Annualized Cost ($/daily ton)
50	40	85	28	560	20	400
100	80	85	52	520	39	390
200	160	85	100	500	77	380
300	240	85	150	500	115	380
500	350	90	250	500	172	340
600	420	90	300	500	207	340
700	420	95	350	500	213	300
1000	600	95	480	480	302	300

1/ For sizes 50 - 300 tons per day, use 800 acfm/ton.
For sizes 500 - 600 tons per day, use 700 acfm/ton.
For sizes 700 tons per day and larger, use 600 acfm/ton.

2/ See Figure IV-1.

b. Control Costs for Smaller-Sized Incinerators

A one ton per day model size unit operating for 5 hours per day and 360 days per year (1800 hours per year) was used as a base for calculating control cost. Installed cost of a scrubber for this size unit (400 pounds per hour capacity) designed to meet the New York

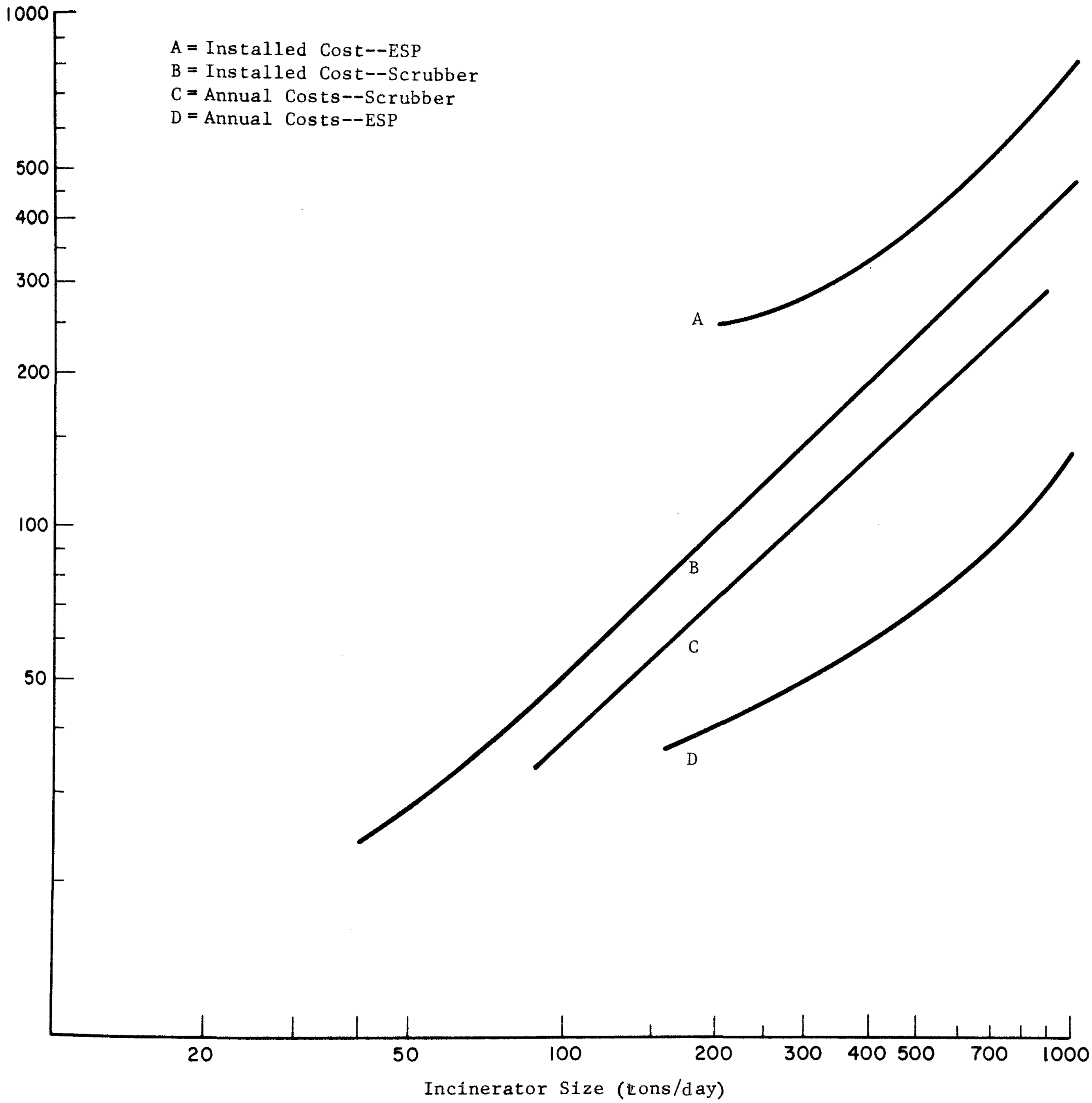


Fig. IV-1. Municipal Incinerator Particulate Control Costs.

State regulation is about $1000.[1/] Particulate control efficiencies on the order of 60 to 80 percent are required.

Annualized control costs were calculated as follows [Ref. 7]:

$$G = S\left[0.7457HK\ Z + \frac{Qh}{1980} + WHL + M\right] = 920\ (0.119)$$

$$= \$109/\text{year/daily ton}$$

where:

S = 920 acfm[2/];
H = 1800 hours/year;
K = $0.01/kwh;
Z = 0.006 hp/acfm;
Q = 0.01 gals/acfm;
h = 30 feet;
W = 0.005 gal/acfm;
L = $\$0.05 \times 10^{-3}$/gal;
M = $0.03/acfm.

Capital charges at 15%, (.15 x $1000) = $150/year/daily ton
TOTAL Annualized Cost = $259/daily ton

c. <u>Auto Body Disposal Costs</u>

Calculations to determine investment and annual costs of auto body disposal for a metropolitan area are presented below. A controlled incinerator handling 30 cars per day costs about $25,000 [Ref. 8].

1) Investment Cost:

$$\text{Investment Cost/Car} = \frac{\$25{,}000}{30\ \text{cars/day} \times 300\ \text{days/year}} = \$2.8/\text{car/year}.$$

$$\text{Metropolitan Area Investment Cost} = \frac{\text{metropolitan area population}}{1000} \times \frac{27\ \text{cars}}{1\ \text{year}}$$

$$\times\ 0.50^{3/} \times \$2.8/\text{car/year} = \$39/1000\ \text{population}.$$

2) Operating Cost, assuming $4/car:

$$\text{Metropolitan Area Operating Cost} = \frac{\text{metropolitan area population}}{1000} \times \frac{27\ \text{cars/1000 population}}{1\ \text{year}}$$

$$\times\ 0.50^{3/} \times \$4/\text{car} = \$56/1000\ \text{population/year}.$$

1/ An average value; control costs for small incinerators vary from $600 to $1300 per daily ton of refuse burned [Ref. 9].

2/ Based on 16,000 ft^3 of flue gas per 10^6 Btu of heat input, and 5000 Btu/lb of refuse.

$$5000\ \frac{\text{Btu}}{\text{lb.}} \times 4000\ \text{lb/hr} \times \frac{1}{60\ \text{min/hr}} \times \frac{16{,}000\ ft^3}{10^6\ \text{Btu}} = 535\ ft^3/\text{min at } 70°F,$$

or about 920 acfm at 450°F.

3/ Assuming 50 percent of all scrapped cars are presently being burned.

All uncontrolled emissions were based upon the emission rate shown in Table IV-3.

TABLE IV-3. - EMISSION RATES FOR VARIOUS SOLID WASTE DISPOSAL PRACTICES[1/]

Process	Particulate	Hydrocarbons[2/]	Carbon Monoxide
Open Burning	17	30	85
Municipal Incinerators	17	1.5	1.0
Domestic & Commercial Incinerators	12	7	15
Sanitary Landfill	0	0	0

1/ Pounds per ton of refuse.

2/ As Methane.

C. <u>Cost of Control</u>

The total investment requirement for implementing this plan would be $201 million and the annual cost, as of FY 1976, would be $113 million. These costs are in addition to expenditures for control before 1967.

III. STATIONARY FUEL COMBUSTION

A. Commercial-Institutional Heating Plants

1. Present and Projected Emissions

In 1967, there were approximately 952 thousand heating plants in commercial-institutional establishments (hotels, retail stores, schools, hospitals, etc.) located within the 298 metropolitan areas. These heating plants consumed 4.3 million tons of coal, 267 million barrels of oil, and 1.58 trillion cubic feet of gas in 1967. The combustion of these fuels resulted in emissions of 127 thousand tons of particulate matter and 940 thousand tons of sulfur oxides. Current emissions from these plants are under little or no control.

It is assumed that no additional coal-fired commercial-institutional heating plants were or will be built during the period from 1967 through Fiscal Year 1976. Consumption of oil and gas by such heating plants is expected to increase to 417 million barrels and 3.64 million cubic feet, respectively. The average value of the sulfur content of the fuel oil is assumed to be one percent by weight.

Given these fuel use patterns, it is estimated that annual emissions from commercial-institutional heating plants in the 298 metropolitan areas would reach 152 thousand tons of particulate matter and 1,440 thousand tons of sulfur oxides by Fiscal Year 1976.

2. Control of Emissions

It appears that control of sulfur oxides and particulate emissions from commercial-institutional heating plants in the 298 metropolitan areas can be accomplished by Fiscal Year 1976 by switching those plants currently using coal as a fuel to the use of oil.

Through such fuel switching, emissions would be reduced to 135 thousand tons of particulate matter and 1,400 thousand tons of sulfur oxides. The reductions are rather small because, even without fuel switching, it is expected, first, that little coal would be burned in such heating plants in Fiscal Year 1976 and, second, that all the oil utilized would meet the standards listed in Appendix II.

3. Engineering Basis of the Analysis

Particulate and SO_2 emissions were calculated for the 298 metropolitan areas using the uncontrolled emission rates shown in Table IV-4.

TABLE IV-4. - UNCONTROLLED EMISSION RATES FOR COMMERCIAL-INSTITUTIONAL SPACE HEATING

Fuel	Emission Rates	
	Particulate	SO_2
Coal	20 lbs./ton	38 (S)* lbs./ton
Oil	8 lbs./1000 gal.	157 (S)* lbs./1000 gal.
Gas	19 lbs./10^6 cf	1.4 lbs./10^6 cf

* (S) is sulfur content of fuel expressed as a percent.

The incremental fuel costs were based upon a factor of $3.93 per ton of coal replaced. This factor reflects both the increased cost of oil on a B.t.u. basis plus a low sulfur oil premium.

4. Estimated Control Costs

It is estimated that the investment required to change the estimated 21 thousand existing coal burning heating plants over to oil will be almost $41.7 million, a unit conversion cost of $2,000. The total annual cost, including both the incremental fuel costs (on a B.t.u. basis) and the annualized cost of the initial investment, will be $25.1 million per year.

B. Industrial Boilers

1. Present and Projected Emissions

In 1967, there were an estimated 307 thousand industrial boilers in the United States, with an estimated 256 thousand located within the 298 metropolitan areas. These boilers supply steam for material processing, space heating, and electric-power generation and annually consume 45 million tons of coal and 162 million barrels of oil, as well as a significant quantity of natural gas. Emissions from these boilers, assuming an estimated

61.5 percent control level for particulates and zero for sulfur oxides, amounted to 1,360 thousand tons of particulates and 2,330 thousand tons of sulfur oxides.

Of the oil consumed, approximately 81 percent is residual oil with an average sulfur content of 1.5 percent; the remaining 19 percent is distillate oils with a sulfur content averaging 0.5 percent. By Fiscal Year 1976, the annual consumption of coal is expected to drop to about 38 million tons, with the usage of oil increasing to 220 million barrels. It is expected that a significant percentage of the additional oil will be of an acceptable sulfur content of not more than 1.38 percent.

By Fiscal Year 1976, without implementation of the Clean Air Act, emissions from industrial boilers within the 298 metropolitan areas could be expected to reach 1,410 thousand tons of particulate matter and 2,310 thousand tons of sulfur oxides.

2. Control of Emissions

Control costs were estimated on the basis of switching existing coal burning boilers to oil as well as the additional fuel costs of switching from coal and high-sulfur fuel oil to oil with a sulfur content of not more than 1.38 percent. Under this plan emissions would be reduced to 142 thousand tons of particulate matter and 1,100 thousand tons of sulfur oxides, 99.0 percent and 50.5 percent reductions, respectively.

3. Engineering Basis of the Analysis

Emissions from industrial boilers within the 298 metropolitan areas were calculated on the basis of the emission rates shown in Table IV-5.

TABLE IV-5. - EMISSION FACTORS FOR INDUSTRIAL BOILERS

Fuel	Emission Rates	
	Particulate	SO_2
Coal	9(A)[1/] lbs/ton of coal	38 (S)[2/] lbs/ton of coal
Oil	19 lbs/1000 gals. of oil	157 (S) lbs/1000 gals. of oil
Gas	19 lbs /10^6 cf gas	1.4 lbs /10^6 cf gas

1/ Ash content expressed as a percent. An average value of 8 was used in this study.

2/ Sulfur content expressed as a percent.

The incremental annual fuel costs were based on a factor of $0.152 per million B.t.u. This value is based upon a $0.09 per million B.t.u. additional cost of burning oil of high-sulfur content instead of coal plus a $0.062 per million B.t.u. charge for oil desulfurization.

4. Estimated Control Costs

These controls are estimated to require an investment of $16,500 per boiler for a total investment of $1,050 million with a total annualized cost of $555 million.

C. Residential Heating Plants

1. Present and Projected Emissions

The population of the 298 metropolitan areas in 1967 was approximately 166,882,000. An estimated 47 million dwelling units housed this population. For the purposes of residential heating in 1967, 7.6 million tons of coal, 343 million barrels of distillate oil and 2.5 trillion cubic feet of natural gas were consumed. Combustion of these fuels resulted in annual emissions of 160 thousand tons of particulates and 776 thousand tons of sulfur oxides, with only coal burning exceeding the maximum limit of the selected regulations (see Appendix II).

Recent trends indicate that the use of coal as a home heating fuel is diminishing dramatically. In the United States in 1967, an estimated 22 million tons of coal were consumed for this purpose whereas it is projected that less than 9 million tons will be consumed in Fiscal Year 1976. There also is predicted diminishing utilization of distillate oil, although less dramatic than the reduction in coal usage. The increased use of natural gas and electrical heating is expected to supplant these fuels and meet the additional home heating requirements predicted by Fiscal Year 1976. By that time, emissions will be reduced to 120 thousand tons of particulates and 597 thousand tons of sulfur oxides.

2. Control of Emissions and Estimated Control Costs

Because the utilization of coal for residential heating is decreasing by "natural attrition" and because all the other modes of home heating fall well within the emission standards, no control costs are assigned to this source category.

By Fiscal Year 1976, the emission of particulates and sulfur oxides will be reduced to 120 thousand tons and 597 thousand tons, respectively. The source of about 75 percent of each of these emissions will be the combustion of low-sulfur content distillate oil which currently meets the most stringent combustion standards.

3. Engineering Basis of the Analysis

Emissions from residential heating plants within the 298 metropolitan areas were calculated on the basis of the emission rates in Table IV-6.

TABLE IV-6. - EMISSION RATES FOR RESIDENTIAL HEATING PLANTS

Fuel	Emission Rate	
	Particulate	SO_2
Coal	20 lbs/ton of coal	38 (S)* lbs/ton of coal
Oil	12 lbs/1000 gals. of oil	157 (S)* lbs/1000 gals. of oil
Gas	19 lbs/10^6 cf. of gas	0.4 lb /10^6 cf. of gas

*Sulfur content expressed as a percent.

D. Steam-Electric Power Plants

1. Present and Projected Emissions

In 1967, there were 516 investor and municipally owned (public) fossil fuel steam-electric power plants of 25 megawatts or greater capacity in the United States. These plants contained 2,984 steam boilers and consumed 270 million tons of coal and 6,753 million gallons of residual fuel oil. Within the 298 metropolitan areas, there were 387 power plants in which 2,060 boilers were located; this does not include the Tennessee Valley Authority power plants.

On an annual basis, it is estimated that 1967 particulate and sulfur oxide emissions from the power plants located in the 298 areas amounted to 1,600 thousand and 7,370 thousand tons, respectively. In spite of a particulate control level of 78 percent, these emissions accounted for 49.3 percent of all particulates and 64.6 percent of all sulfur oxides from fuel combustion sources in the 298 metropolitan areas in 1967.

Without the implementation of the Clean Air Act, emissions of particulate matter and sulfur oxides would reach 1,980 thousand tons and 10,100 thousand tons, respectively, by Fiscal Year 1976.

2. Control of Emissions

In power plants utilizing high sulfur coal and/or residual fuel oil, having a rated capacity in excess of 200 megawatts, and with an overall plant load factor in excess of 17 percent, it was assumed that wet limestone injection scrubbing systems would be installed to provide for the simultaneous control of particulate matter and sulfur oxides. Depending on the number and size of individual boilers within each plant, one or more wet limestone scrubbers would be required; control costs and emission reductions have been calculated accordingly. For high sulfur coal and residual oil burning power plants of less than 200 megawatts capacity or plants operating at less than a 17 percent load factor, it was assumed that it will be more economical to replace these fuels with low sulfur fuels. The premiums assigned to the use of low sulfur fuels were 90 cents per ton of coal and 80 cents per barrel of oil. Such a fuel switch is consistent with currently projected availability patterns for low sulfur fuels. With implementation of the Clean Air Act, the Fiscal Year 1976 emissions of particulates and sulfur oxides would be reduced to 533 thousand tons and 1,600 thousand tons, respectively.

3. Engineering Basis of the Analysis

The engineering analysis required to develop control costs for the steam-electric industry had three basic APCO guidelines: (1) be as effective as possible in reducing sulfur oxide emissions, (2) consider the latest technology, and (3) be realistic with regard to availability, cost, and fuel market impact. Preliminary consideration of an across-the-board switch for high-sulfur coal and oil and low-sulfur fuels was unfeasible in light of present supplies as well as other constraints.[4/] Consideration of hardware control of sulfur oxide indicated that among the dozen or more processes being studied, wet limestone injection scrubbing systems seem to be the most promising alternative.[5/] For the purposes of this report, therefore,

4/ See Appendix V for a full discussion of this subject.

5/ Supplied by APCO.

use of several control alternatives including some fuel switching and wet limestone scrubbers was assumed. Table IV-7 below indicates the control alternatives finally selected.

TABLE IV-7. - CONTROL ALTERNATIVES SELECTED FOR THE STEAM-ELECTRIC INDUSTRY

Industry Fuel Type	Sulfur Content (percent)	Plant Capacity (megawatts)	Plant Load Factor (percent)	Control Alternative
Coal	> 1*	>200	>17	Wet limestone scrubbing
Coal	> 1	>200	<17	Low-sulfur coal + Part. collection
Coal	> 1	<200	Any	Low-sulfur coal + Part. collection
Coal	< 1	Any	Any	Part. collection
Oil	> 1.38	>200	>17	Wet limestone scrubbing
Oil	> 1.38	>200	<17	Low-sulfur oil
Oil	> 1.38	<200	Any	Low-sulfur oil
Oil	< 1.38	Any	Any	No change
Natural Gas	N/A	Any	Any	No change

* > Greater than.

< Less than.

The choice of the 200 megawatt criterion was based upon the fact that in 1968 power plants rated at less than 200 megawatts consumed 33.3 million tons of coal. Based upon the National Academy of Engineers estimate that present pyrite washing techniques could add annually over 50 million tons of low-sulfur coal to the market, this criterion appears to be reasonable. The load factor of 17 percent was chosen as a threshold for economic reasons. The wet limestone scrubbing process appears more economical than fuel switching for plants with load factors in excess of 17 percent [Ref.10].

For the purpose of cost estimation, incremental costs for desulfurized coal and oil were required. An additional cost of 90 cents per tons of coal was utilized based upon a recent National Academy of Engineers Report [Ref. 11]. An additional cost of 80 cents per barrel of residual oil was utilized [Ref. 12]. Both figures represent the higher end of the ranges given by the sources but were considered the most realistic estimates available. Desulfurizing would reduce the sulfur content of both fuels to about one percent or less.

The cost estimating procedure for the dolomite-injection/ wet scrubbing process used cost equations developed by APCO. The equations, as shown below, are valid for capacities between 25 and 1,000 megawatts (MW) and for a load factor of 91 percent. They also assume stack gas reheat to 250° F by indirect liquid gas method and two stage scrubbing.

$$\text{Investment Cost (\$1000)} = 10{,}800(MW) - 4.58(MW)^2 + 934(S)(MW) - 0.396(S)(MW)^2, \text{ and}$$

$$\begin{aligned}\text{Annual Cost (\$1000)} = {} & L[112.7(MW)S - 8.33(MW)] + 1.3M \\ & [.018(MW) + .595(S + .0015(MW)S + 7.38] \\ & + 1.2W[.36S(MW)] + 1.2K[.0548(MW) \\ & - .00945S(MW) + .0020(MW)S^2] + T[11.799(MW) \\ & - .00536(MW)^2] + C[\text{Investment Cost}] \\ & + 1.2[322.57(MW) - .14376(MW)^2 + 29.46(MW)S \\ & - .01313S\ (MW)^2];\end{aligned}$$

where:

- MW = Megawatt rating;
- S = Sulfur content of fuel as a percent;
- L = Limestone cost, \$/ton;
- M = Cost of labor, \$/1000 man-hours;
- W = Cost of water, $\$/10^6$ gals.;
- K = Cost of electricity, $\$/10^6$ kwh;
- T = Cost of technical labor, \$/man-hour; and
- C = Annual capital charges as a percent of fixed investment, as a decimal.

The values assigned to these variables are as follows:

- MW - Plant data,[6/]
- S - Plant data,[6/]
- L - \$2.05,
- M - \$4000,
- W - \$100,
- K - \$4000,

6/ Supplied by APCO.

T - \$7.50, and

C - 14.5%.

The above relationships can be applied to oil burning installations with two modifications: the oil sulfur content must be divided by 1.35 and the megawatt rating must be multiplied by 0.95.

If the power plant load factor is different from 91 percent, corrections must be made to the annual cost as developed in the above equation. Correction factors were developed separately for three load factor ranges and for coal and oil boilers. The correction factors (C.F.) are stated as a function of load factor (L.F.) and uncorrected annual cost (X).

For coal boilers:

1. $64\% \leq L.F. \leq 100\%$

$$C.F. = [91\% - L.F.(.00855)(X) + X] \times \frac{\text{tons of coal/yr.}}{3000(MW)};$$

2. $33\% \leq L.F. \leq 63\%$

$$C.F. = [1.2300(X) + (63\% - L.F.).0256(X)] \times \frac{\text{tons of coal/yr.}}{3000(MW)};$$

3. $17\% \leq L.F. \leq 32$

$$C.F. = [2.0246(X) + (32\% - L.F.).0967(X)] \times \frac{\text{tons of coal/yr.}}{3000(MW)}.$$

For oil boilers:

1. $64\% \leq L.F. \leq 91\%$

$$C.F. = [(91\% - L.F.)(.00855(X) + X] \times \frac{\text{bbls. oil/yr.}}{12{,}808(MW)};$$

2. $33\% \leq L.F. \leq 63\%$

$$C.F. = [1.2309(X) + (63\% - L.F.)(.0256)(X)] \times \frac{\text{bbls. oil/yr.}}{12{,}808(MW)};$$

3. $17\% \leq L.F. \leq 32\%$

$$C.F. = [2.0246(X) + (32\% - L.F.)(.0967)(X)] \times \frac{\text{bbls. oil/yr.}}{12{,}808(MW)}.$$

4. Estimated Control Costs

Based upon the low sulfur fuel price premiums discussed above, as well as preliminary cost data for wet limestone scrubbing systems, control costs by Fiscal Year 1976 for all high-sulfur coal and oil burning plants within the 298 metropolitan areas were calculated. These are an investment requirement of \$1,340 million and a total annual cost of \$426 million. These costs would increase electric energy costs to the average consumer by 2 percent.

IV. INDUSTRIAL PROCESSES

A. Asphalt Batching

1. Introduction

The road paving material commonly called asphalt (more technically known as asphalt concrete, and often referred to as hot mix asphalt paving in the industry) is a heated mixture of crushed stone aggregate and asphalt. It is most commonly produced by a batch process with an estimated average production rate in the range of 150-200 tons per hour. Crushed stone or other aggregate is mixed and dried in a drying kiln and fed into a pugmill where it is mixed with asphalt. This hot mix is loaded into trucks for quick delivery to the work site where it is applied while still hot.

2. Emissions and Costs of Control

The asphalt batching process emits pollutant emissions in the form of dust particulates, emitted primarily by the aggregate drier and to a lesser extent by the conveying, screening, weighing, and mixing equipment. General industry practice is to combine the off gases from the drier and the emissions from other process points as collected in a ventline and send the combined gas stream through a cyclone dust collector [Ref. 13]. This results in approximately 80 percent removal of dust, reducing the estimated average 25 pounts of dust per ton of asphalt batched [Ref.14] to 5 pounds per ton remaining as uncontrolled emissions. The 1967 industry total of 452,000 tons of particulate would increase to 571,000 tons in Fiscal Year 1976 at the same level of controls.

To meet the process weight rate standards assumed for this study (see Appendix II), venturi scrubbers with a 10 inch water gauge pressure drop have been stipulated for all plants. The investment requirement estimated for these controls is $15.4 million and the annual costs are $12.3 million, beginning in Fiscal Year 1976.

3. Engineering Basis of the Analysis

The processes considered in this study include the major source of dust in the industry, the aggregate drier, as well as secondary sources, which include aggregate elevators, vibrating screens, hot aggregate bins, weigh hoppers and aggregate mixers. The trend in the industry is to combine the off gases from the drier and all the secondary sources (captured in a so-called vent-line) and send the resulting gas stream to a single collector.

Uncontrolled emissions amount to 25 pounds of dust per ton of asphalt size distribution of particulates batched [Ref. 14]. Presently, it is estimated that the industry as a whole controls to a level of 80 percent; therefore, present emissions which are considered herein as uncontrolled amount to 5 pounds per ton of asphalt produced. Required removal efficiencies were calculated on the basis of the process weight rate standard and an uncontrolled rate of 5 pounds per ton. These are shown in Table IV-8.

TABLE IV-8. - INCREMENTAL REMOVAL EFFICIENCIES REQUIRED

Process Size (tons/hour)	Incremental Efficiency Required (percent)
40	79
100	91
150	93
200	95

In order to meet these control requirements, it appears that the application of a 10-inch w.g. wet scrubber is cost effective. Table IV-9 summarizes control costs as a function of plant capacity and related gas volume.

Venturi scrubbers with a pressure drop of 10 inches, w.g., will achieve required removals [Ref. 13]. In all cases, an 80-percent efficient primary collector was considered as process equipment.

TABLE IV-9. - ASPHALT BATCHING EMISSION CONTROL COSTS

Kiln Gas Volume (10^3 acfm)	Equivalent Plant Capacity (tons of mix per hr.)	Costs ($1000)	
		Investment	Annual
6	30	4.0	2.7
12	60	5.9	4.0
18	90	7.3	5.3
20	120	8.8	7.0
30	150	9.6	8.2
36	180	10.5	9.6
42	210	11.6	11.0
48	240	12.6	12.1
54	270	13.6	13.3
60	300	14.7	14.1
66	330	15.6	15.3
72	360+	16.4	18.4

To relate process size to control system size, a factor of 19 thousand scfm (at an inlet temperature of 200° F) per 100 tons per hour were used [Ref. 15].

4. Scope and Limitations of Analysis

Data on the location of plants were incomplete. However, detailed data on plant capacities and production were incomplete; these data were estimated by applying the known distribution of plant sizes in 38 states to the known number of plants in the metropolitan areas. Financial data by plant or firm were even more fragmentary and similar estimating procedures were used. As a result, estimated industry costs may be somewhat in error, probably understated to a degree. The figures given are, however, felt to indicate the order of magnitude of industry cost impact and to reflect a reasonable approximation of the control cost per ton of product.

5. Industry Structure

The asphalt batching industry, which has 1,284 plants in the United States and 1,064 in the 298 metropolitan areas, is characterized by a large number of relatively small firms, many with only one plant and others with two or three plants. Most of the firms are small in comparison with the giant firms of some of the other industries in this study. Sales average close to $500,000 per year per plant. Most firms are closely held and the profits of a typical firm apparently support only one or a small number of owner-managers. Firms are widely dispersed across the country, mostly close to urban markets. Because of the necessity to deliver hot asphalt paving to the job site, plants can serve only a very limited geographic area. As a result, some plants have been designed to be mobile, moving from job to job. Most installations can be shut down and moved to new locations with relatively small cost. Resources used in the process (sand, crushed aggregate, and asphalt) are available almost anywhere.

6. Market

The market for asphalt paving mixtures is largely a function of road building and maintenance programs. Generally, such projects are contracted on a competitive bid basis. In the larger metropolitan areas, at least, this results in aggressive competitiion among firms and acts as a limiting force on profits. The degree of competition, size of the market, and growth in number and size of firms vary considerably across the country and from year to year, depending upon regional policies and spending programs.

The chief competitor to asphalt paving is concrete. Asphalt paving, however, is usually cheaper and simpler to install, although the concrete industry challenges asphalt on the basis of whole-life cost, including maintenance. In minor markets such as driveways, ready-mixed concrete firms are reported to have had some success in competing with asphalt when special promotional campaigns have been undertaken [Ref. 16].

7. Trends

It is expected that capacity and production in asphalt batching will grow at the rate of approximately 3.1 percent per year through Fiscal Year 1976, continuing the pattern of the 1960's. This would reflect a continued growth in government expenditures for highway building, although shifts in market location may be expected as construction of the interstate system slows and the emphasis shifts to secondary and urban roads and airports.

8. Economic Impact of Control Costs

This analysis indicates that by Fiscal Year 1976 total annual pollution control costs to the asphalt batching industry will run at the rate of $12.3 million per year. For an estimated Fiscal Year 1976 production of 227 million tons, this indicates an incremental cost of only $0.054 per ton. Assuming approximately 800 firms in the 298 metropolitan areas, the estimated annual cost for the average firm would be $15,375. If a typical firm has sales of $500,000 per year and profits before taxes of 12 percent of sales, or $60,000, absorption of the increased cost would reduce profit by one-third. These firms may be expected, therefore, to try to raise prices by the full amount of the added cost. In a small market, where sales are almost entirely based on competitive bidding, these price increases would be difficult to achieve unless almost all firms are subject to the same cost changes. This apparently would be true for most of the asphalt industry and prices may therefore rise $0.05 to $0.06 per ton. Although this is a small amount per ton of paving material, it does imply an increase of approximately $12.3 million for the nation as a whole as an equivalent increase in public expenditures.

It is to be expected that all producers in a region or market will tend to postpone installation of new equipment as long as possible so as to avoid incurring this cost before competitors. When regulatory orders force compliance, most firms will act at the same time. If this occurs, there is little reason to anticipate financial difficulties for the firms involved, except for those whose sources of credit make it difficult to raise the funds for an investment estimated to average approximately $19,000 per single plant firm.

B. Brick and Tile

1. Introduction

The brick and tile industry, represented by Standard Industrial Classification (SIC) Code 3251, includes those establishments primarily engaged in manufacturing brick and structural clay tile. The processes involved in manufacturing brick and related products include: grinding, screening, and blending of raw materials; forming; drying or curing; firing; and cutting. After the clay has been mined, it is transported to plant storage bins where the clays are blended to produce a more uniform raw material, control color, and allow raw material suitability for manufacturing a variety of units. Preparation of the raw material to produce brick and tile involves crushing the clay to remove large chunks, followed by grinding. The clay is then screened and the forming process begins. Water is added to the clay in a pugmill, a mixing chamber containing two or more revolving blades. The clay is then molded. Before the burning process begins, excess water is evaporated in drier kilns at temperatures ranging from 100° to 400° F for a period of 24 to 48 hours, depending on the type of clay. Heat may be generated primarily for drier kilns but it is commonly supplied as waste heat from burning kilns. Burning is one of the most specialized steps and requires 40 to 150 hours depending on kiln type and other variables. Several types of kilns are used, the chief types being tunnel and periodic. Natural gas, oil, or coal is used as fuel, and temperatures up to 2400° F are used in firing. Dried units are placed in periodic kilns permitting circulation of hot kiln gases. In tunnel kilns, units are loaded on special cars that pass through various temperature zones as they travel through the tunnel. Drying occurs in the forward section of the kiln, utilizing heat from the combustion gases to preheat and dry the formed clay as it moves toward the firing section. The heat required per ton of brick produced is $3\text{-}4 \times 10^6$ B.t.u.'s. The cooling period requires 48 to 72 hours.

2. Emissions and Costs of Control

Particulate emissions in the brick and tile industry are in the form of dust from the blending, storage, and grinding operations and off-gases from the tunnel kilns. Particulates from blending, storage and grinding are minimized by sufficient moisture and these emissions are well within the limits set by the particulate standards. Particulates from the kiln are mainly a combustion product and are a function of the fuel used.

Sulfur dioxide may be emitted if firing temperatures reach 2500° F or more or when using fuel containing sulfur [Ref. 28]. As stated previously, firing temperatures do not normally exceed 2500° F. In general, the fuel used is either oil or natural gas with acceptable sulfur content. Emissions of sulfur dioxide, therefore, were considered to be negligible.

Fluorides, emitted in a gaseous form, result from heating clay containing fluorides. Data on the fluoride content of clay are very sketchy. There is evidence that not all clay contains fluorides and where there is no fluoride content, fluoride emissions are no problem. This may occur on a region wide basis where a number of plants use clay of similar or the same geologic origin. In this analysis, in order to assess the impact expected, it is assumed that clay contains fluorides in proportion to the average fluoride content of all clays and that fluoride emissions of 1.23 pounds per ton of clay result [Ref. 28]. At present, it is believed that fluoride control is not practiced anywhere in the industry. On this basis, fluoride emissions estimated for the 298 metropolitan areas for 1967 were 15,600 tons with no controls. At the rate of growth estimated for the brick industry, these fluoride emissions would reach 20,800 tons in Fiscal Year 1976 without controls.

Fluoride emissions can be reduced to very low levels by scrubbing the kiln gases with water. This also serves as a particulate control method. For the purposes of this report a fluoride control standard requiring 95 percent removal efficiency is assumed. A single cyclone scrubber can remove fluorides at an efficiency in excess of 95 percent. This control level would reduce Fiscal Year 1976 fluoride emission to 1,000 tons and would require investment and annual costs of $40.8 million and $11.6 million, respectively.

3. Engineering Basis of the Analysis

Assuming that no coal is being used in the industry, particulate emissions are well within the limits set by this year's particulate standards. Therefore, particulates as such need not be considered. However, since some entrainment of fluorides by the combustion particulates can be expected, some form of particulate control should be implemented. As will be shown, the control device selected for the control of gaseous fluorides will also act as a particulate control device.

Costs have been developed for a fluoride emission control system composed of a single stage wet cyclone scrubber connected by ductwork to a typical tunnel kiln. These are shown in Figures IV-2 and IV-3 as a function of brick making capacity. This control system can remove gaseous fluorides with an efficiency in excess of 95 percent as well as removing particulates, in the case of coal combustion, to a level of 90 percent. Therefore, with the predominant fluoride emission being gaseous, the system can easily remove 95 percent of total fluoride emissions.

4. Scope and Limitations of Analysis

Detailed and accurate data on firms in this industry and their plant production and operations were not available during the preparation of this report. Therefore, some of the statistics used may not be absolutely accurate but it is believed that the analysis is sufficiently valid to determine the economic impact of air pollution controls. It was not possible, however, to relate projected costs directly to the operation of typical firms or to regional market and price variations.

The question of the fluoride content of the clay used in brick making in the United States (discussed briefly in the previous section) casts doubt on the control cost estimates made. It seems probable that the fluoride emission estimates and the corresponding estimates of control costs are exaggerated. The extent of the exaggeration will not be known until more data are available on the fluoride content of the various clays used by the industry.

5. Industry Structure

In 1967 there were 469 firms in the United States with 301 in the 298 metropolitan areas. United States production was 8,260 million brick and common brick equivalents having a value of $342.1 million. Production within the 298 areas was 5,910 million brick equivalents, 72 percent of the United States total. These firms average about 57 employees each and on the average produce 17.6 million brick and brick

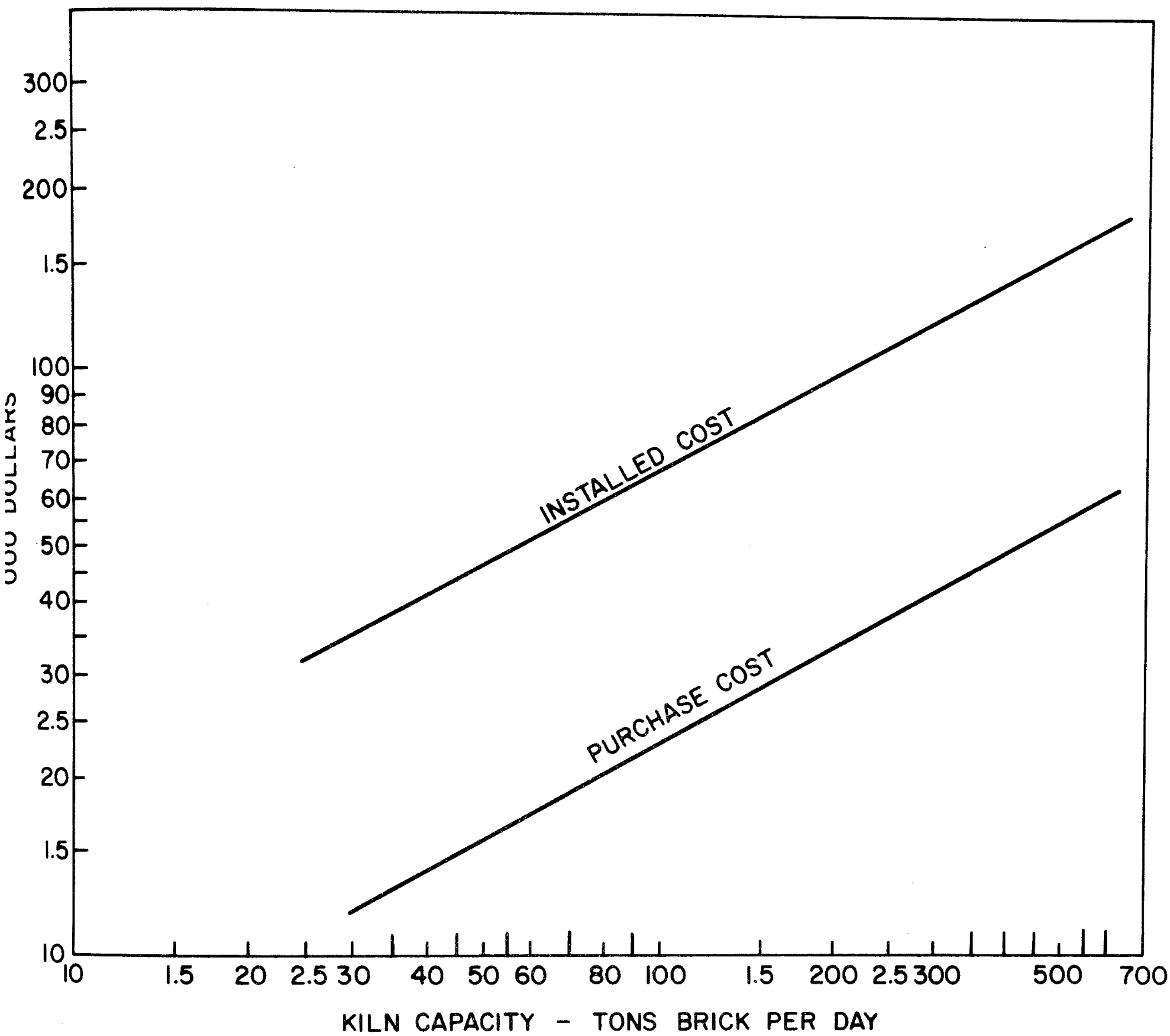


Fig. IV-2. Brick and Tile Installed and Purchase Costs of Control Systems [Ref. 28].

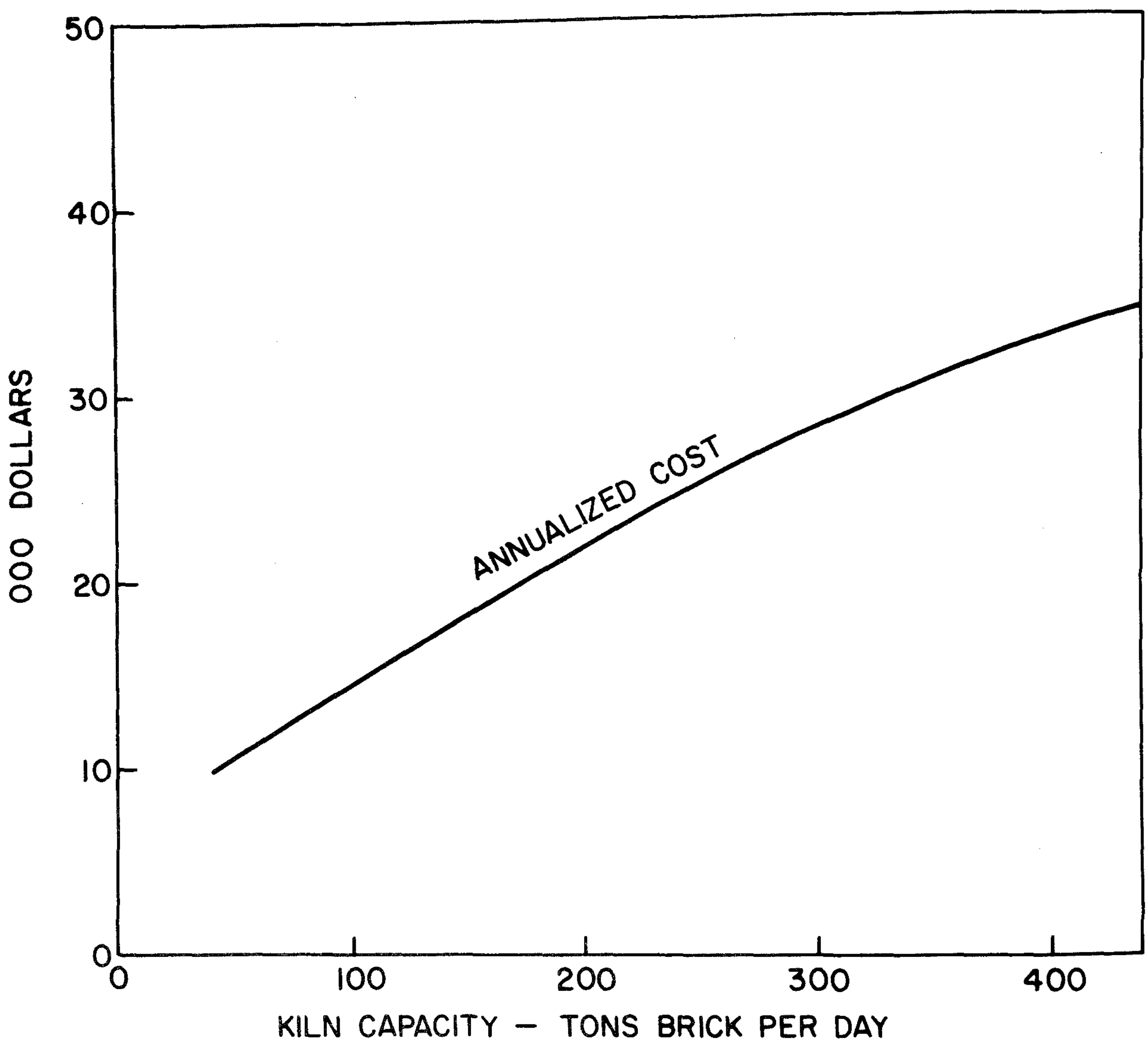


Fig. IV-3. Brick and Tile Annualized Cost of Control Systems [Ref. 28].

equivalents having a value of $729,400. However, 120 of these firms or about 25 percent had fewer than 20 employees indicating there are a number of marginal firms. Since 1958, 85 firms either have gone out of business or consolidated with other firms. Consolidation has been the trend in this industry as in other industries. Value of output in 1967 per production worker was $15,700, which is low compared to other industries. This has increased from $10,600 in 1958 and $13,200 in 1963.

Texas has more plants than any other state with 44 plants, followed by Ohio with 41 plants; Pennsylvania is third with 33 plants.

6. Market

The construction industry purchases about 97 percent of the output of the brick and tile industry. The performance of the brick and tile industry is therefore closely related to construction activity and more specifically to residential construction. Production increases and decreases as residential building increases or decreases. Even in residential construction these products are a rather negligible cost. Their use is influenced more by taste and the cost to install than by the cost of the item itself.

Because of the weight and bulk of brick and tile products, markets are regional in character rather than national. Intra-product competition is as much on specialty items, style, finishes, and color as on price. There are enough firms in most market areas to assure that prices cannot get out of line.

The major competitor to the industry is other building materials. Products such as concrete, wood, aluminum, asbestos, glass, steel and plastics compete in two ways. First, they compete directly on initial price. Second and more importantly, they compete on cost in place, a concept that includes both cost of material and cost of installation labor. Such competition limits the possibilities for brick and tile price increases.

7. Trends

Between 1958 and 1967, the value of new public and private building construction grew at an annual rate of 5.3 percent. During this same period, brick and tile shipments increased by only 2.8 percent per year. The disparity in these rates of growth primarily reflects the declining usage of brick.

The principal reason for the decline in the utilization of brick appears to be the cost of brick-in-place. Between 1959 and 1969, the cost of brick increased 22 percent compared with the 17 percent increase in the cost of all construction materials. Furthermore, in the same period, the average wage rate for union bricklayers increased at a rate over twice the rate of increase in brick prices. Assuming no increase in the productivity of bricklayers over the last decade (indeed, it is frequently alleged that union restrictions have reduced the number of bricks per day a bricklayer can lay), a cost index for brick-in-place shows about the same rate of growth as the average wage rate for bricklayers. This results because labor represents about 75 percent of the cost of brick-in-place.

Thus, it would appear that any increase in the cost of brick production which was passed on as a price increase of brick would aggravate the trend away from the use of brick in new construction and further limit brick production.

8. Economic Impact of Control Costs

The analysis indicates that by Fiscal Year 1976 total annual control cost to the brick and tile industry in the 298 metropolitan areas will run at the rate of $11.6 million per year. For an estimated 1976 production of 6.6 million brick and brick equivalents, an incremental cost of $1.76 per thousand brick is indicated. For the 301 firms in the 298 metropolitan areas, the estimated annual cost for the average firm would be $38,500. Few firms in this industry can afford a cost increase of this nature entirely from profits. At the same time because of the competitive position of brick among building materials and its declining market share, it is doubtful that a cost increase as small as this could be passed on in full to consumers as a price increase without further loss of markets. Thus, while prices may be expected to rise, due to the added cost of air pollution control, above the level they would otherwise achieve by 1976, the rise is expected to be in the range of $1.00 to $1.10 per thousand brick instead of the full $1.76 average annual cost.

As with other industries, all the producers in a region or market will avoid installation of pollution control equipment as long as possible so as to avoid incurring this cost before competitors. When regulatory orders force compliance, most firms will act at the same time. When this occurs there is little reason to anticipate financial difficulties for industry, except for those firms that are already marginal. These few marginal firms can be expected to merge with others or close.

D. Coal Cleaning

1. Introduction

Coal cleaning consists of removing some of the undesirable materials from raw mine run coal. These materials consist of sulfur compounds, dirt, clay, rock, shale, and other inorganic impurities. Both bituminous and anthracite coal are cleaned. Cleaning improves the quality of coal by increasing the B.t.u. output per pound and by reducing ash content. It is accomplished by washing the coal with air or water. Approximately 21 percent of wet washed coal is thermally dried. Air cleaning is accomplished by the use of pneumatic cleaners, while drying is accomplished predominantly with either flash driers or fluidized-bed driers.

2. Emissions and Costs of Control

The major air pollutant in the coal cleaning industry is particulates in the form of dust from either flash driers, fluidized-bed driers, or pneumatic cleaners.

Available data on the current level of control indicate that 87 percent of the flash and fluidized-bed driers and 16 percent of the pneumatic cleaners are controlled at an efficiency of 80 percent. The composite level of control is about 58 percent when the processes are weighted according to the quantity of coal handled. Thus, aggregate emissions of particulates in 1967 totaled 64,700 tons. By Fiscal Year 1976, aggregate emissions at 58 percent controls could be expected to total about 92,300 tons of particulates. To obtain a composite level of 93 percent control in Fiscal Year 1976, flash driers will have to be controlled to an average level of 93.2 percent efficiency, fluidized-bed driers to an average level of 97.8 percent efficiency and pneumatic cleaners to an average level of 94.5 percent. Aggregate annual emissions of particulates can then be expected to be reduced to approximately 14,100 tons in Fiscal Year 1976.

Because of the coal dust content of the off-gases from coal cleaning, a fire and explosion hazard exists. Because of this explosion hazard, wet scrubbers constructed of mild steel rather than baghouses are preferred as control devices [Refs. 17 and 18]. A 15 inch w.g. venturi scrubber was selected as the control device for the fluidized-bed drier and a 10 inch w.g. venturi was assumed for both the flash drier and the pneumatic cleaner. These pressure drops will provide the efficiencies required. The investment requirement would be $13.1 million and annual costs in Fiscal Year 1976 would be $5.3 million.

3. Engineering Basis of the Analysis

Coal is cleaned by both wet and dry methods. In this analysis only the three predominant processes within the coal cleaning industry were considered: flash and fluidized-bed thermal driers (for coal cleaned by wet methods), and pneumatic cleaners. These three processes are significant sources of particulate emissions mostly in the form of coal dust. Uncontrolled particulate emission rates from these three processes are shown in Table IV-10.

TABLE IV-10. - UNCONTROLLED PARTICULATE EMISSION RATES FROM COAL CLEANING PROCESSES*

Process	Uncontrolled Emissions (lb/ton coal feed)
Flash drier	12
Fluidized-bed drier	13
Pneumatic cleaner	3

* A cyclone is assumed part of process equipment, not air pollution control equipment.

Source: Reference 17 and calculated from data given in References 18 and 19.

Available data on the current level of control reveal that 87 percent of both types of thermal driers and 16 percent of pneumatic cleaners are controlled at an efficiency of 80 percent [Ref. 20]. The composite level of control was about 58 percent, when the processes were weighted according to the quantity of coal handled. To comply with the process weight rate standard assumed in this analysis, flash driers, fluidized-bed driers, and pneumatic cleaners will have to be controlled to efficiencies of 93.2, 97.8, and 94.5 percent, respectively.

To develop control costs for the various unit processes, unit gas volume estimates had to be made. Table IV-11 presents the estimates along with the control equipment selected for each unit process.

TABLE IV-11. - UNIT GAS VOLUMES AND CONTROL EQUIPMENT

Process	Gas Volume acfm/ton per hour	Selected Control Equipment
Flash Drier	540	10" w.g. venturi
Fluidized-bed Drier	480	15" w.g. venturi
Pneumatic Cleaner	357	10" w.g. venturi

Sources: References 21, 22, and 23.

The model processes considered in this analysis have the following sizes: flash drier, 50 tons of coal feed per hour; fluidized-bed drier, 208; and pneumatic cleaner, 70 [Refs. 18 and 21]. The gas volumes (control system sizes) are 27, 99.9, and 25 thousand actual cubic feet per minute for the flash drier, the fluidized-bed drier and the pneumatic cleaner, respectively [Refs. 18, 19, and 21]. The gas stream temperature assumed for this analysis was 159° F [Ref. 21]. The annual hours of operation were 3,750, assuming 2 shifts per day, 7.5 effective hours per shift, 5 days per week, and 50 weeks per year [Ref. 22].

Due to the considerable fire and explosion hazard associated with coal dust, wet scrubbers instead of baghouses are preferred as control devices [Refs. 21 and 23]. A 15" w.g. venturi scrubber was assumed as the control device for the fluidized-bed drier and a 10" w.g. venturi was assumed for both the flash drier and the pneumatic cleaner. These pressure drops correspond to the required control efficiencies stated above.

Cost estimates for controlling emissions from coal cleaning establishments were based on the types of processes and on the production [Ref. 24] in each plant. Output or production of total coal cleaned was prorated to the different processes as follows: 7.1 percent by pneumatic methods with the remainder to wet washing. Nationally, only 20.7 percent of cleaned coal is thermally dried and 43.5 percent of thermally dried coal is dried in fluidized-bed driers [Ref. 25]. The remaining 56.5 percent of thermally dried coal was assumed to be dried in flash driers. For each plant in the 298 metropolitan areas, it was assumed that coal was cleaned in the above proportions.

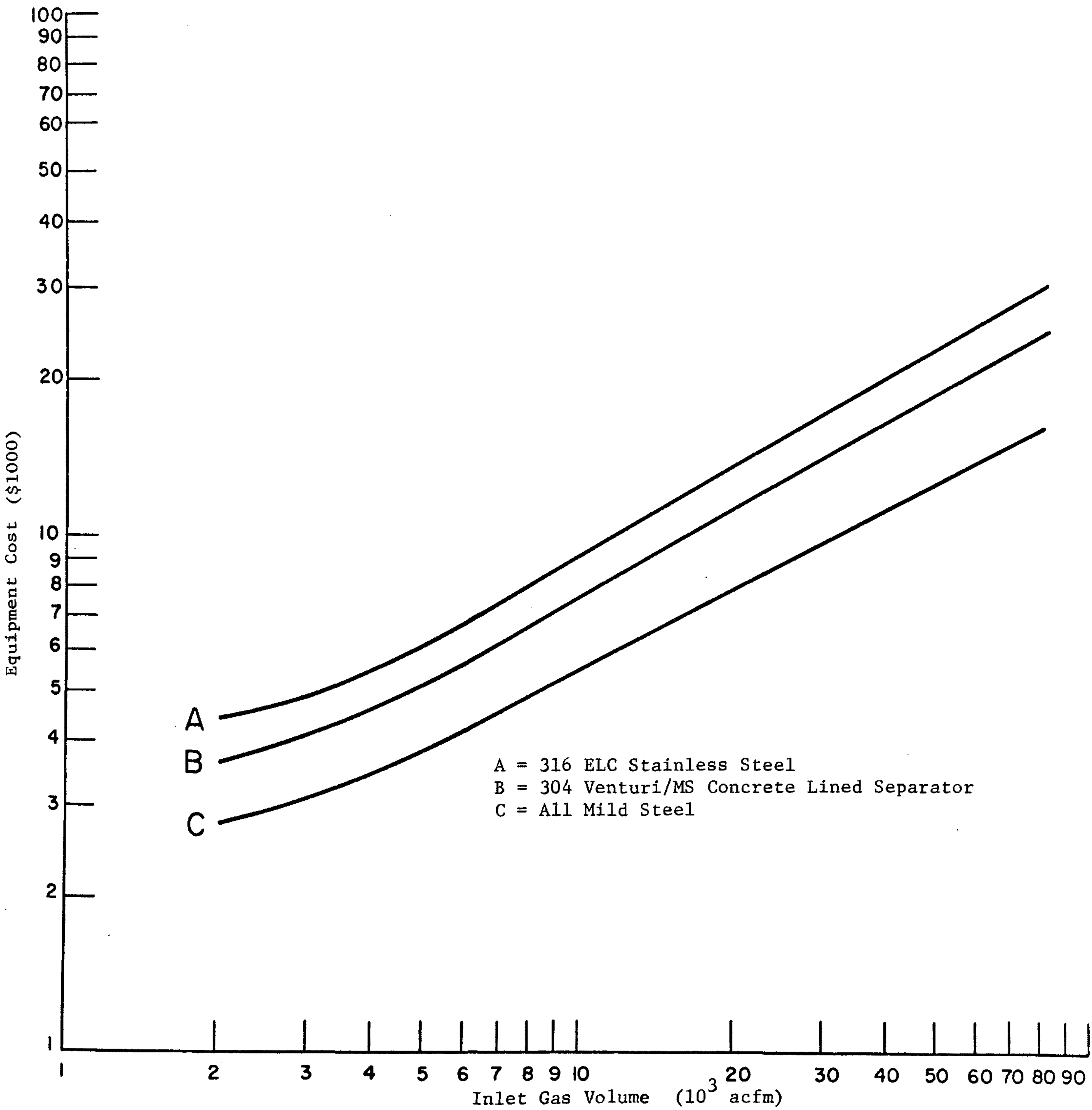
Cost estimating factors were calculated for each unit process based upon Figures IV-4 through IV-6. These factors are summarized in Table IV-12.

TABLE IV-12. - COAL CLEANING CONTROL COSTS

Equipment Type	Costs ($1000/ton/hour)	
	Investment	Annual
Pneumatic cleaners	0.316	0.148
Fluidized-bed driers	0.247	0.201
Flash Driers	0.463	0.219

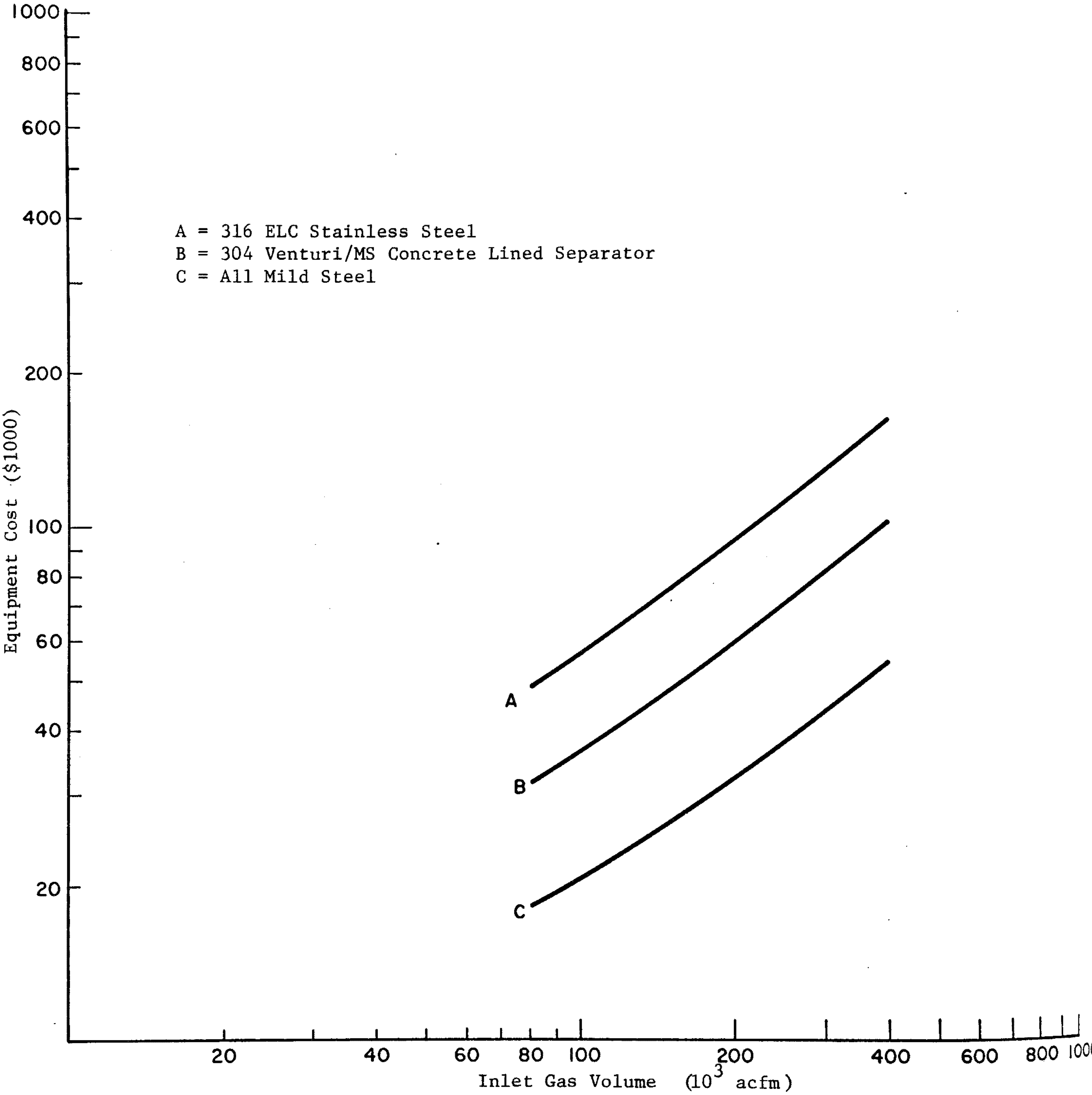
4. Scope and Limitations of Analysis

Although there is a relatively large number of coal cleaning plants in the United States, detailed data on plant locations, capacities, and production are available. Metropolitan area totals for capacities and production were obtained from these data. However, it was not possible to determine the coal cleaning process used in every case, so average values were applied to the regional production and capacities to obtain volumes of emissions. Growth estimates were made from past rates of increase in production. Cost of control was based on cost to control a model plant of average size. Financial data and market information for the industry are fairly complete.



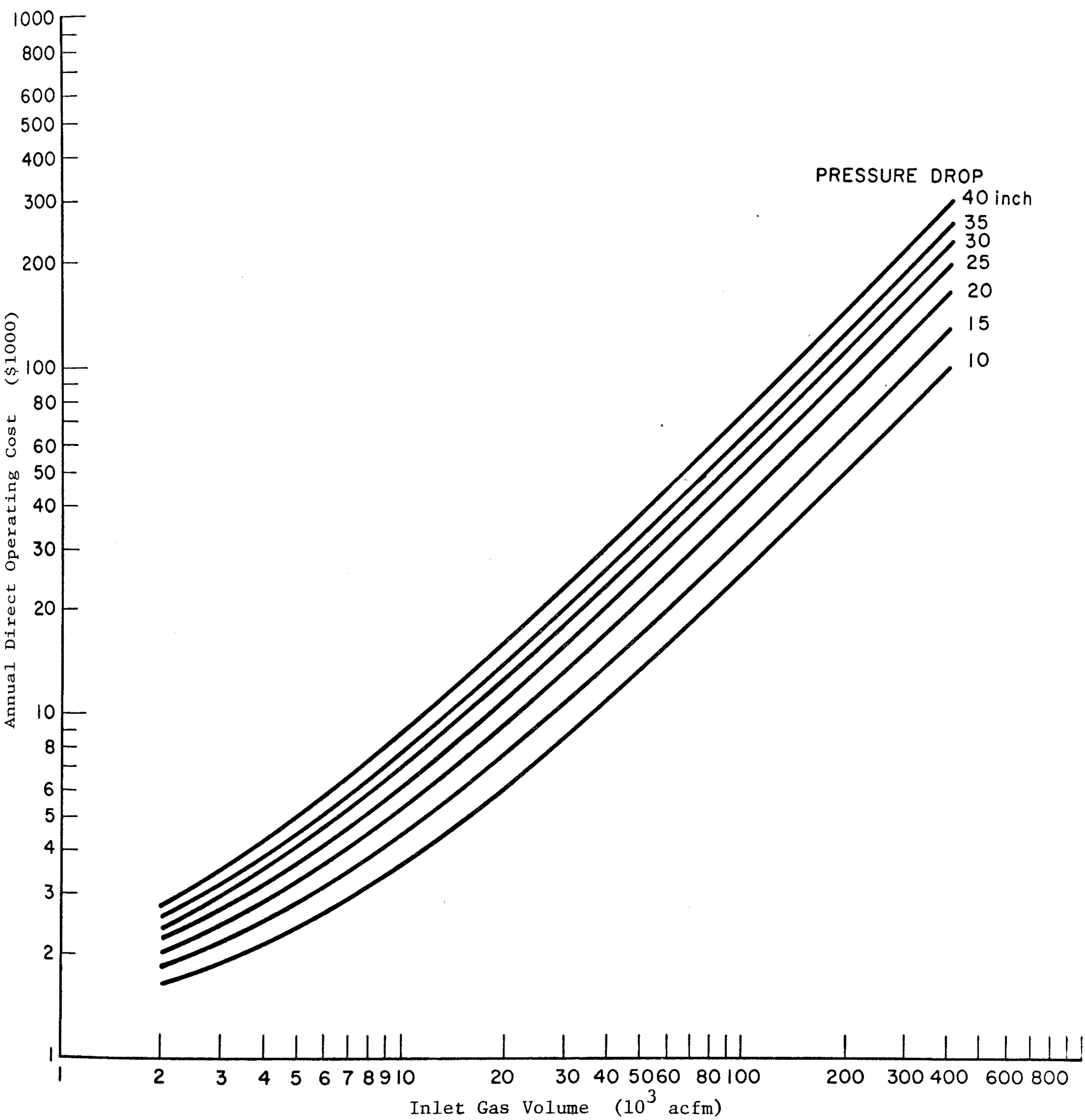
Source: Poly Con Corporation.

Fig. IV-4. Equipment Cost for Venturi Scrubbers.



Source: Poly Con Corporation.

Fig. IV-5. Equipment Cost for Venturi Scrubbers.



Source: Poly Con Corporation.

Fig. IV-6. Annual Direct Operating Cost for Venturi Scrubbers.

5. Industry Structure

Coal cleaning is a part of the process of improving the quality of raw coal for market. It is usually done by the producer, normally close to the mine to avoid transporting waste rock.

In 1967, the 667 coal cleaning plants in the United States had a capacity of 370 million tons. Production totaled 349.0 million tons and had a value of shipments of $1.5 billion. Cleaning plants are located in 20 states with over 90 percent located east of the Mississippi. Sixty-nine percent of the total plants are located (in order of importance) in West Virginia, Pennsylvania, and Kentucky. Virginia, Illinois, and Ohio have 35 or more plants each and with Alabama with 20 plants, make up more than 25 percent of the total number of plants.

Only 256 of the 667 plants are in the 298 metropolitan areas, and they account for only 37.6 percent, 37.5 percent, and 40 percent of total industry capacity, production, and value of shipments, respectively.

6. Market

The market for coal and thus the market for coal cleaning is largely a function of the production of electric power and the output of blast furnaces and basic steel. Almost 30 percent of the industry output is utilized for generating electricity. Blast furnaces and basic steel production utilize an additional 22 percent. Exports amount to approximately 2 percent of output, mostly of metallurgical coal. Besides coal mining, which purchases 19 percent of coal production, no other industry utilizes as much as four percent of the remaining 27 percent of industry output.

Even though the electric power industry and the steel industry utilize over half of coal production, coal makes up only about four percent of the value of inputs into the electric power industry and 2.3 percent of the inputs into steel production. These are exceeded, but only slightly, by one other industry -- the hydraulic cement industry -- where about 5.5 percent of the input is coal.

While coal does make up a rather small proportion of the inputs into these industries, it is a rather important input especially for steam-electric generation. For this reason many of these industries own coal companies to provide their supplies. Long term contracts, some as long as 20 years, are also used for this purpose.

Even though coal companies are owned by other industry or utilities, most sell at least some of their output in the open market. This practice, together with the number of independent coal companies, maintains competition among firms. In addition, coal is in competition with other fuels -- gas, oil, nuclear power, and electricity (which is often produced from coal). All this serves to limit profits.

In spite of its bulk, coal moves to a limited extent in the export market. The United States is a net exporter, but the extent of foreign trade is not great enough to have a major impact on domestic supply. However, it does tend to push prices up, since export prices may be as much as 30-50 percent above United States prices.

Coal, along with other fuels, is currently enjoying an expanding market. This is placing considerable pressure on production to meet the growing demand.

7. Trends

It is expected that capacity and production will grow through Fiscal Year 1976 at 4.8 percent per year. The proportion of coal cleaned has also been steadily increasing. In 1927, the percentage of total coal cleaned was 5.3 percent. By 1952, 49 percent of production was cleaned and by 1965 the proportion was 65 percent. The rising trend in coal cleaning can be expected to continue as poorer seams are worked, more stringent sulfur oxide limitations are established, and shipping costs increase.

8. Economic Impact of Control Costs

The indicated FY 1976 total annual cost of control to the coal cleaning industry will run at the rate of $5.3 million per year. For an estimated Fiscal Year 1976 production of 167 million tons, this indicates an incremental cost of $0.03 per ton. For the 256 plants in the 298 metropolitan areas, the estimated annual cost for the average plant would be $19,500. Plants of the average size indicated here (annual production of about 650,000 tons) could be expected to have no trouble absorbing a cost increase of this size. Only firms already marginal would be affected. However, because of the nature of coal as a production factor in other goods or services, and the current demand for all fuels, a price increase of $0.03 per ton could very easily be passed on to buyers.

The current open market price for coal is $4.40 per ton f.o.b. the mine. A $0.03 per ton cost is approximately one percent. This increases the price of steel not more than $0.025 per ton, which is insignificant compared to a current average price of $183.00 per ton.

D. Cement

1. Introduction

Portland cement accounts for approximately 98 percent of cement production in the United States. All portland cement is produced in either the wet or dry process, the chief difference being whether the prepared ingredients are introduced into the cement kiln as a dry mixture or as a wet slurry. The wet process is used to produce approximately 58 percent of the cement. Essentially, cement is made by quarrying cement rock, limestone, clay, shale, and/or other materials, which are finely ground and mixed. The prepared mix is burned in a long sloping kiln into cement clinker, which is then ground into a fine powder and sold in bulk or bagged.

2. Emissions and Cost of Control

Dust arising from crushing, grinding, and materials handling processes is universally controlled at quite high efficiencies because such controls recover valuable products. Kilns also emit large amounts of particulates. These are generally not fully controlled with the exception of plants built since 1960. Older plants, which account for 76 percent of the capacity of the industry, need additional control equipment to meet standards for control of particulate emissions. It is estimated that 13 percent of all cement plants will require completely new systems--either fabric filters or electrostatic precipitators--and that the remaining older plants have equipment in place that can be improved in efficiency to meet the control standard. Thus, cement plants have been grouped as follows: 24 percent for which no additional control is specified and therefore no additional cost; 63 percent now partially controlled, for which additional equipment and cost are indicated; and 13 percent for which new control systems are indicated and for which the incremental control cost will be greatest.

Particulate emissions from kilns in plants within the 298 metropolitan areas are estimated to have totalled 239,000 tons in 1967, representing an overall control level of 96 percent. This industrywide control level is based on the assumption of 95 percent control in pre-1960 plants and 99 percent control in all plants built since 1960. Expanded production in pre-1960 plants would be estimated to increase total particulate emissions to 280,000 tons by FY 1976 if the same control level were maintained. With the installation of new or more efficient fabric filters for dry process kilns and electrostatic precipitators on wet process kilns, an industry control level of 99.7 percent may be achieved, reducing total emissions for Fiscal Year 1976 to 16,100 tons of particulates.

These controls would require an investment of $110 million and Fiscal Year 1976 annual costs of $30 million.

3. Engineering Basis of the Analysis

The primary difference with respect to pollution between the wet and dry processes is the state in which the ground raw material is fed into the kiln. The major unit processes involved are: crushing and grinding, drying (dry process only), clinker production (calcining), and final grinding. Dusts from crushing and grinding operations present only minor air pollution problems as these are essentially closed systems, and the dust collected is returned to the unit from which it was collected. The same is most often true of the drier off-gases which are usually vented to either grinding or calcining control system. This study focuses on controlling particulate emissions from the calcining operation. The kiln represents the major source of particulate emissions in the cement industry, which is not well controlled at present.

Totally uncontrolled emissions from wet process kilns average 38 pounds per barrel[7/] of cement produced, while the average from dry process kilns is 46 pounds per barrel produced [Ref. 14]. The calcining operation is controlled to some degree. Table IV-13 reflects an estimate of the present status of control for the industry.

7/ A barrel of cement equals 376 pounds.

TABLE IV-13. - PRESENT CONTROL STATUS FOR THE CEMENT INDUSTRY

Year of Kiln Installation	Geographic Region	Control Level (percent)
Before 1960	Outside 298 Areas	70
After 1960	Outside 298 Areas	>99
Before 1960	Within 298 Areas	95
After 1960	Within 298 Areas	>99

Therefore, control costs were estimated on the basis of increasing the removal efficiencies on those kilns installed before 1960 to the control levels shown in Table IV-14.

TABLE IV-14. - ULTIMATE PARTICULATE REMOVAL EFFICIENCIES REQUIRED

Kiln Capacity (1000 barrels/day)	Percent Efficiency Required	
	Wet Process	Dry Process
1	97.6	97.8
2	98.2	98.4
4	99.3	99.5
6	99.4	99.6
8	99.6	99.8
10	N/A*	99.9

* Not applicable.

It was assumed that all kilns installed after 1960 were controlled to the required level. The costs of upgrading existing control equipment to the required levels are shown in Table IV-15. Existing control equipment was assumed to be electrostatic precipitators for wet process kilns and fabric filters for dry process kilns.

TABLE IV-15. - ESTIMATED COSTS OF UPGRADING EXISTING CONTROL EQUIPMENT

Kiln Capacity (1000 barrels/day)	Emission Control Costs ($1000)			
	Wet Process (high efficiency ESP)		Dry Process (fabric filter)	
	Investment	Annual	Investment	Annual
1	7.15	1.72	6.33	2.34
2	14.50	3.34	18.25	6.75
4	48.90	11.72	79.90	31.10
6	73.50	17.70	135.00	50.00
8	111.00	26.60	232.00	85.90
10	--	--	354.50	131.40

Each plant in the nation was identified by location, total capacity, and process type (wet or dry) in a current list from Rock Products [Ref. 26]. Another list from this source identified all plants installed since 1960 by total capacity, process type, number and capacity of kilns, and kiln emission control equipment [Ref. 27]. When a plant in the second list had two or more kilns, they had the same capacity. These various plant listings provided the basis for the control cost and emission estimates for the 298 metropolitan areas.

4. Scope and Limitations of Analysis

This analysis was based on data available from government, trade, and financial reporting sources. Financial data were available only for a limited number of firms; thus, the financial impact of air pollution control costs had to be stated in somewhat general terms. Many firms engage in other business activities, such as the sale of readymix concrete or cement blocks, or are part of conglomerates. Without more detailed information, it has not been possible to estimate the portion of revenues, costs, profits, or taxes attributable to cement alone in such firms. For this and similar reasons, the relationships assumed for the financial variables may be open to question.

5. Industry Structure

a. Characteristics of the Firms

The cement industry is estimated to have been represented by 58 firms and 178 plants in the United States in 1967. Of these, 50 firms and 138 plants are identified as having been in the 298 metropolitan areas. The structure of the cement industry may be described in several ways. Approximately 40 percent of the firms in the industry operate more than one plant and approximately half of those firms have productive capacity of over 10,000,000 barrels of cement per year. The purpose of multiple plant operation is, apparently, to achieve broader market coverage and, therefore, greater financial stability by lessening dependence on any one local demand pattern rather than to achieve significant economies of scale. The trend in recent years has been to larger kilns, computerized operation, and improved integration of raw mill, kiln, clinker grinding, and associated storage and materials handling equipment. These factors have produced a steady increase in efficiency of operation but have not necessarily been accomplished in larger plants. Plants built between 1960 and 1967, for instance, ranged in capacity from 1 to 8.5 million barrels per year. The range of capacities for all plants listed in operation in 1967 was from 0.4 to 16,000 million barrels per year, with the average plant having a capacity of approximately 3 million barrels per year [Ref. 26].

Since raw materials for cement production are widely distributed throughout the country, cement plants tend to be located close to major markets. Normally, cement is not shipped more than 200 to 300 miles from the plant, because transportation costs tend to price a firm out of more distant markets. In recent years, however, some firms have developed distribution terminals at locations that combine cheap water transportation with access to major urban markets. Although these firms have apparently been successful in thus extending their marketing territory, most firms continue to sell in relatively small markets. Imports and exports of cement account for less than 5 percent of the United States market and are significant only in the markets on the Atlantic Coast.

b. Operating Characteristics

The statistical summary in Chapter 2 gives United States capacity for the industry as 515 million barrels per year. The figures given indicate that the industry operated at 72.6 percent of capacity in 1967. In fact, usable capacity was probably 2-3 million barrels less and utilization slightly higher. Operation at 85-90 percent of capacity tends to produce maximum profits, but the industry has tended to operate at between 70 and 80 percent of capacity over the past ten years, due to a typical pattern of heavy investment whenever demand seems to be catching up to supply. Excess capacity and depressed profits are therefore chronic.

c. Resources

The raw materials used in manufacturing cement are abundant and widely distributed throughout the country. Most companies own their sources of supply and have ample reserves, thereby stabilizing materials costs. The costs of fuel, transportation, and labor are the other major cost variables. The rise in these costs in recent years coupled with an inability to raise prices proportionately accounts for the generally below average profit performance of this industry.

Large quantities of fuel are used in operating a cement kiln, a modern installation requiring approximately 950,000 B.t.u.'s per barrel of clinker produced. The fuel may be coal, oil, or natural gas, with gas providing a small cost advantage over the other two at present prices. Many plants burn coal and this use accounts for approximately 5 percent of industrial use of bituminous coal in the United States.

Transportation is a major cost factor as is typical of all products with a low value-to-bulk ratio. In the past, cement manufacturers maintained a basing point pricing system which tended to eliminate price competition due to freight costs from different mill-to-market distances. Since the elimination of this system as a result of Federal antitrust action, individual firms have continued to absorb transportation costs in varying degrees in order to meet competitors' prices and extend their market range. Under such conditions, transportation costs tend to place a definite limit on market size for each plant.

Labor accounts for approximately 35 percent of total cost. Rising wages in recent years have contributed to the adverse profit position of the industry.

6. Market

Portland cement is a standardized product and competition among sellers depends on quite small price differentials within a clearly defined price pattern, plus service. Most customers can choose among a number of cement producers and price shading and partial freight absorption by the producer may be necessary to clinch a sale. This competitive pressure tends to hold prices down and puts considerable emphasis on the firm's ability to deliver quantities to customers at destinations and on schedules meeting the customers' preferences. Those firms with newer equipment and most efficient operation may be able to offer marginal price concessions sufficient to keep sales at levels near optimum operation. Weaker firms may not be able to shade prices in order to keep sales volume up without reducing profit margins significantly. This competitive pressure has caused many firms to close their less efficient plants or to modernize them with new equipment and computerized controls.

Cement sales are historically closely related to construction activity, measured by the value of new construction put in place. It is anticipated, therefore, that the performance of the construction industry will set the general tone of the performance of the cement industry.

Cement purchases represent about one percent of the inputs of the construction industry based on the 1963 input/output relationship. The distribution of cement sales by purchasers for 1963 were:

Ready-mixed concrete producers	61%
Concrete product manufacturers	13%
Highway contractors	10%
Building materials dealers	8%
Other contractors	4%
Miscellaneous users (including government)	4%

7. Trends

a. Capacity and Production

Over-capacity was a chronic problem in the cement industry during the early 1960's. It appears that the industry achieved a somewhat better balance between capacity and sales in the later 1960's and this is expected to continue through the 1970's. Capacity is projected to increase at an average rate of 2 percent per year through 1976. It is anticipated that this capacity will be utilized at close to the recent average of 78 percent, implying a growth rate of 2 percent for production as well.

It is probable that the present trend toward use of more economical longer kilns and the addition of computer control systems will continue. This will lead to the closing of some older plants and remodeling of others, resulting in only a very gradual change in the industry structure.

b. Price, Sales and Profits

Prices declined slowly from a 1960 average level of $3.25 per barrel at the mill to $3.15 per barrel in 1966 but have risen gradually since then. Less than optimum operating ratios, a slowly growing market and competition with other building materials will probably keep prices rising at a slow rate through 1975. Sales are expected to increase at an average rate of 3.5 percent per year. Given the 2 percent per year increase in production indicated above, this would indicate a price increase of 1 1/2 percent per year. Profits may be expected to be stable, therefore, at or near their recent levels and somewhat below the average return for manufacturing firms.

8. Economic Impact of Control Costs

a. Industry Composite

As was noted in paragraph 2 above, plants built since 1960 have, almost without exception, been equipped with high efficiency control equipment. It is the older plants, therefore, that are a source of particulate emissions and upon which will fall the new cost of air pollution control. It is estimated that by 1967 the cement industry had already undertaken control costs equal to annual costs of $18 million.

b. Impact on Firm

The impact of the additional cost of air pollution control on the normal cost pattern of a firm can be shown by considering several "model" plants, constructed to represent typical operating patterns. The firms described here are not actual plants, but are based on known conditions in the industry.

	Plant A	Plant B
Capacity (Thousands of Barrels Per Year)	1,200	3,000
Kilns (Number & Size)	1-400 ft.	1-550 ft.
Construction Cost, 1958	$12 mil.	$12 mil.
Production, 1967 (Thousands of Barrels Per Year)	871	2,178
Average Mill Price per Bbl.	$3.17	$3.17
Sales	$2,761,000	$6,904,000
Net Income Before Tax	$ 414,000	$1,156,000
Business Income Tax	$ 179,000	$ 500,000
Net Income After Tax	$ 235,000	$ 656,000
Profit/Bbl	$ 0.2698	$ 0.3011
Annualized Air Pollution Control Cost, Total:		
If wet process	$ 90,320	$ 210,800
If dry process	$ 78,272	$ 188,680
Annualized Air Pollution Control Cost, Per Bbl:		
If wet process	$ 0.1037	$ 0.0968
If dry process	$ 0.0899	$ 0.0866

The relationships shown for Plant A and Plant B above indicate the magnitude of air pollution control costs for a small and a large plant. There are a large number of single plant firms in this industry and these figures indicate the impact which may be expected for such firms.

The costs shown are for firms or plants in the 13 percent of the industry for which completely new equipment is indicated. That is, they represent the full cost of air pollution control. Presumably, 24 percent of the plants in the industry are already absorbing equivalent costs. It appears that these plants, being newer, are more efficient in their operation and so able to sell at a competitive price.

The economies of scale appear to accrue at the plant level rather than as a result of multiple plant operation. Multiple plant firms may be approximated by multiplying individual plant costs by the number of plants.

c. Demand Elasticity and Cost Shifting

To the extent that the demand for cement is derived from the demand for public and private construction, which is not highly elastic with regard to price, the overall demand for cement would not be very sensitive to small price changes. However, in recent years cement has had a fairly advantageous price position relative to competing building materials. An industry wide increase in price by the full amount of the control cost indicated for firms that must install new equipment might be expected to change the position of cement adversely relative to substitutes.

An attempt by some firms to raise prices as a means of shifting control costs would almost certainly lead other firms to move into the market. The market for any one firm is usually small geographically. Selective price increases in some local markets will encourage large firms to expand their selling radius.

Under these circumstances, it is to be expected that those firms faced with the full additional cost of control will be unable to shift more than a small fraction of the added cost into price. Those firms faced with additional but smaller costs may, to the extent that they are larger and more efficient, be better able to raise prices, but not enough to recoup the entire increase in costs.

d. Effect on the Industry

Since it appears that the added cost of air pollution control will fall on the older, less efficient firms, it is expected that the result may be a hastening of the trend now operating in the industry to replace or rebuild older plants. In no case does it appear that these costs alone will cause a firm to fail. It is probable, however, that the growth rate of the industry may be slowed slightly and that profit margins may continue to be somewhat below the average in manufacturing through Fiscal Year 1976. Of course, a major change in demand, such as that resulting from large scale implementation of "Operation Breakthrough" housing construction using precast concrete, would stimulate production and make larger price increases more likely.

E. Elemental Phosphorus and Phosphate Fertilizer

1. Introduction

a. General

The production of elemental phosphorus and the manufacturing of phosphate fertilizer are normally considered to be two different industries. They are joined in this analysis because both products are produced from the same raw material with interrelated processes and air pollution problems. Some of the firms involved are producers of both products and the market structures are closely connected. Each industry is described and analyzed and the economic impact of control costs is evaluated in terms of the overlapping market and business structure.

All phosphorus products are derived from phosphate rock. About 40 million tons of rock were mined in the United States in 1967. Thirty million tons were processed domestically with the remainder exported. About 13 percent of the domestic output appeared as normal superphosphate, 15 percent was produced as elemental phosphorus, 39 percent was produced as wet process phosphoric acid, about 3 percent was produced in the form of animal feed, and the remaining 30 percent of the rock was treated with wet process phosphoric acid to produce triple superphosphate.

b. Elemental Phosphorus

Elemental phosphorus is produced in this country by smelting a mixture of phosphate rock, silica and a carbonaceous reducing agent (such as metallurgical coke) in an electric furnace. Submerged electric arcs in the furnace produce high temperatures which cause the reduction of the phosphate rock, releasing phosphorus, carbon monoxide and other reaction products, including fluorides. These gases emerge from the furnace and pass through electrostatic precipitators for the removal of dust. The cleaned furnace gases then discharge into a condenser, contacting sprays of water maintained at a temperature above the melting point of phosphorus (111°F). Phosphorus is condensed from the gas stream and collects below a water layer in a pump. The cooled gases, principally carbon monoxide, are recycled and burned for heat recovery.

c. Phosphate Fertilizer

The phosphate fertilizer industry as defined for this report includes all plants which produce wet process acid (both regular and concentrated), normal superphosphate, triple superphosphate, and diammonium phosphate. Fertilizer plants may produce one or all of these.

The most common process for the production of wet process acid involves the digestion of ground, calcined phosphate rock with sulfuric acid. The acid is then separated from the solids by filtration. Normal superphosphate is produced as a screened material, either as a continuous or batch process, by acidulating ground and dried phosphate rock containing 31 to 35 percent P_2O_5 with sulfuric acid. Triple superphosphate is fertilizer produced by the reaction of natural phosphates with wet process phosphoric acid. The product contains 40 percent or more of phosphoric acid. Ammonium phosphates are now the most popular form of phosphate fertilizers because of high nutrient content and low shipping cost per unit of P_2O_5. All processes for the manufacture of diammonium phosphate fertilizer from wet process phosphoric acid and ammonia are essentially the same in principle. Wet process phosphoric acid of about 40-42 percent P_2O_5 equivalent is partially neutralized by anhydrous gaseous ammonia. The resultant slurry is then fed into an ammoniator-granulator drum where final ammoniation and granulation take place simultaneously and additional water is removed. The moist granules are dried, screened, cooled, and conveyed to bulk storage.

2. Emissions and Costs of Control

Particulate or gaseous fluorides are released in almost all of the processes used in reducing phosphate rock and manufacturing products from the rock. Particulates and gaseous fluorides frequently are emitted.

a. Emissions From Phosphorus Production

There are three main sources of fluoride emissions in the production of elemental phosphorus: feed preparation, evolution of gas from the furnace, and evolution of gas from the molten slag. Fluorides evolved during the furnace operation are effectively scrubbed in the spray condensers. Emissions from the preliminary feed preparation and from the molten slag operation are also controlled to a greater or less extent in each plant by scrubbing with water. However, it is estimated that, on the average, these controls achieve only 85 percent removal efficiency. The remaining uncontrolled emission rate is 18 pounds of fluoride per ton of phosphorus. For the phosphorus plants within the 298 metropolitan areas, this results in estimated 1967 emissions of 2,400 tons of fluorides.

By applying additional scrubber capacity to the feed preparation and slag tapping off-gases, the overall control efficiency for fluoride removal can be increased to 98 percent. By Fiscal Year 1976, without additional scrubber capacity, emissions within the 298 metropolitan areas would reach 3,340 tons of fluorides. With the additional controls, these emissions would be reduced to 334 tons.

Particulate emissions occurring during feed preparation and charging of the furnace are normally controlled to 80 percent by use of dust collectors. Installation of wet scrubbers following the dust collectors can achieve a control level of 99 percent, meeting the standard adopted for this study.

The emissions of particulates in 1967 are estimated for plants in the 298 metropolitan areas as 2,400 tons. Growth of the industry would increase these emissions to 3,340 tons by FY 1976, which would be reduced to 200 tons of particulates by installation of controls.

b. Fluorides From Fertilizer Production

In the production of normal superphosphate, there are potential fluoride emissions from both handling and preparation of the rock from the acidulation and curing steps. During rock handling and preparation, fluorides are chemically bound to the dusts generated. Even during the calcining step, temperatures are too low to release gaseous fluorides. In almost every case, dusts are very well controlled, usually with fabric filters and meet established standards. During the acidulation and curing steps, gaseous fluorides are emitted. Current control practice limits these emissions to about one pound of fluoride per ton of P_2O_5 with various forms of wet scrubbers. This is approximately a 99 percent control level. The standards adopted for this analysis, however, require a final control level of 99.9 percent for production of superphosphate. Therefore, additional wet scrubbers, in series, are required. The same situation occurs in the handling and processing of rock in the production of wet process phosphoric acid which require additional controls in the same way. In addition, gaseous fluorides are evolved in the manufacture and concentration of phosphoric acid. Excluding the fluorides emitted from slime ponds, the industry presently controls fluoride emission from the digestors, vacuum coolers, and evaporators to a level of about 98 percent, resulting, on the average, in emissions of 0.2 pounds of fluoride per ton of P_2O_5. Final controls of approximately 99.8 percent are required to meet the standard for the manufacture and concentration of phosphoric acid; therefore, the installation of additional wet scrubbers is indicated.

Slime ponds serve phosphoric acid plants as storage and settling sites for solid and liquid effluents. Fluoride emissions are produced from these ponds. Emissions from the ponds are highly variable ranging from 0.08 to 0.80 pounds per ton of P_2O_5 per day. At present not enough is known of the factors contributing to the range of emissions to allow reasonable control cost estimates to be made for the ponds.

The concentration of wet phosphoric acid in vacuum concentrators does not lead to any significant fluoride emissions due to the automatic absorbtion of these gases in the process liquids. The emissions of fluoride from the submerged combustion process production of concentrated phosphoric acid are also minimal.

In the production of triple superphosphate, emission of fluoride does occur during the chemical reaction and drying steps. At the current average industrial control level of about 99 percent, an estimated 0.16 pounds of fluoride per ton of P_2O_5 are emitted. To meet the standards, a control level of 99.9 percent will be required. Additional wet scrubbers are again required to bring the emission level down to 0.016 pounds per ton of P_2O_5.

In the production of diammonium phosphate, fluoride emissions occur both during chemical reaction and during drying, although to a lesser extent than from triple superphosphate or wet process phosphoric acid. At a current estimated control level of 96 percent, emissions of about 0.10 pounds of fluoride per ton of P_2O_5 are required. Again, additional wet scrubbers will be necessary.

Total fluoride emissions in 1967 are estimated to have amounted to 612 tons for all phosphate fertilizer plants in the 298 metropolitan areas. Industrial growth would increase these emissions to 1,520 tons by FY 1976 at the same level of control. Installation of the controls specified for this analysis would reduce FY 1976 emissions to 134 tons.

In summary, for the phosphate fertilizer industry the 1967 level of fluoride control was approximately 98 percent. By implementing the controls specified, the industrywide control level will reach 99.8 percent by Fiscal Year 1976.

c. Control Costs

Total investment in the eight elemental phosphorus plants located in the 298 metropolitan areas is estimated at $6,600,000 by Fiscal Year 1976, including allowance for growth in capacity to that date. With full implementation of controls by Fiscal Year 1976, total annualized cost to the segment of this industry effected will be approximately $3,100,000 per year. Equivalent investment and annualized cost for fertilizer producers by Fiscal Year 1976 are $32,100,000 investment and $10,000,000 annually.

3. Engineering Basis of the Analysis

a. Elemental Phosphorus

Costs are available for fluoride emission control systems. These data are based on scrubbing the fumes from both the feed preparation and furnace slag tapping areas. The system for emission control during feed preparation consists of a dust collector and scrubbers. The fumes from slag tapping are collected in a hood, diluted with air, and the combined gases are scrubbed with water in a single scrubber. The scrubbed gases are exhausted through a fan and discharged through a tall stack. Water is used as the absorbant and is recirculated through the scrubber system to produce 15 percent fluorsilic acid.

The cost of the control system for a given plant is related directly to the gas flow rate through the scrubbers which in turn is a function of the plant capacity. Table IV-16 indicates the relationship between plant capacity (in terms of elementary phosphorus annual tonnages), furnace rating and gas flow rate through the scrubbers.

TABLE IV-16. - ELEMENTAL PHOSPHORUS CAPACITY, FURNACE RATING AND GAS FLOW RATE THROUGH SCRUBBERS

Phosphorus Capacity (tons per year)	Furnace Rating (KW)	Gas Flow Rates (SCFM)	
		Feed Preparation	Slag Tapping
17,000	25,000	30,000	50,000
31,000	45,000	54,000	58,000
43,500	64,000	77,000	65,000

The installed and annualized costs of control systems versus plant capacity based on these gas flows is shown in Figure IV-7. These costs represent an increase in control efficiency of 95 percent. Installated costs shown in Figure IV-7 were based on data in Reference 28. Annual operating and maintenance costs were computed on the basis of the equation [Ref. 6] $G = S\ [0.7457HK\frac{(Z+Qh)}{1980} + WHL + M]$; where:

- S = ACFM = 1.3 x SCFM,
- H = 7000 hours,
- K = 0.008 dollars per kilowatt-hour,
- L = 0.50 dollars per gallon of water,
- M = 0.06 dollars maintenance cost per ACFM,
- Z = 0.015 horsepower input per ACFM to the collector (fan + pump),
- Q = 0.02 gallons of water per ACFM required,
- h = 30 feet of head required in water circulation system,
- W = 0.0005 gallons per ACFM make up liquor required.

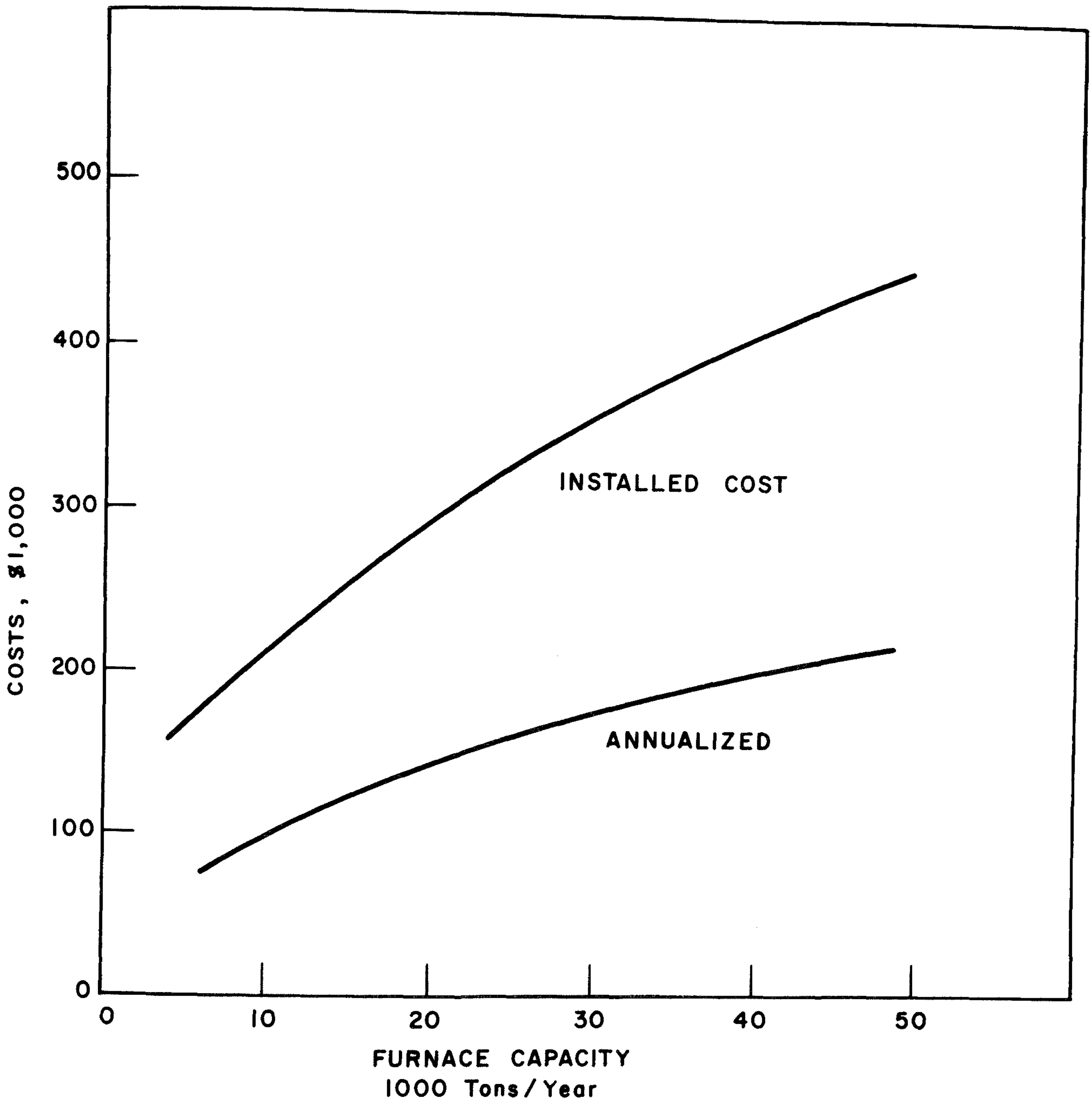


Fig. IV-7. - Investment and Annualized Costs for Phosphorus Furnaces.

b. Phosphate Fertilizer

To develop fluoride control costs for the fertilizer industry, each of the major production processes was analyzed separately. These were the production of normal superphosphate, diammonium phosphate, and wet process acid. In all cases, it can be assumed that primary scrubbing systems designed to remove fluorides existed yielding removal efficiencies of anywhere from 95 to 98 percent. However, to achieve removal efficiencies in excess of 99.5 percent, engineering analysis demonstrated that one or more control systems must be added in series to the existing equipment. Table IV-17 indicates the additional control systems required to meet the stringent removals required.

TABLE IV-17. - CONTROL SYSTEMS REQUIRED

Production Process	Control Systems Required
Wet Process Acid	Wet Cyclone + Packed Crossflow Scrubber
Normal Superphosphate	Three Stage Cyclonic Spray Scrubber
Triple Superphosphate	Wet Cyclone + Packed Crossflow Scrubber
Ammonium Phosphate	Venturi Scrubber - 15 inch w.g.

Control costs were calculated based upon data found in a draft report of an ongoing APCO study [Ref. 28]. These costs are shown in Table IV-18 as a function of capacity expressed in tons per day (tpd) of equivalent P_2O_5.

4. Scope and Limitations of Analysis

Producers of elemental phosphorus and of phosphate fertilizer have been grouped together for this analysis because all phosphorus producers are also fertilizer producers. The economic impact is, therefore, not separable. The technical and cost factors, however, are different for the two product classes and were analyzed and are reported as separate industries.

TABLE IV-18. - FERTILIZER PRODUCTION CONTROL COSTS

Capacity (tpd P_2O_5	Costs ($1,000) Wet Process Acid		Normal Superphosphate		Triple Superphosphate		Ammonium Phosphate	
	Investment	Annual	Investment	Annual	Investment	Annual	Investment	Annual
50	60	20	120	28	180	50	18	6
100	90	30	160	40	260	80	28	10
250	150	60	260	72	460	130	48	18
500	230	90	-	-	700	200	70	30
1,000	450	170	-	-	1,200	340	160	62
2,000	850	350	-	-	2,300	6,700	330	130
4,000	-	-	-	-	4,800	1,400	660	250

The larger firms in this industry produce many products and phosphorus and phosphate fertilizer contribute only a small part of their revenues. It was not possible to determine the role of these products in the overall product and cost mix of firms for which data were available. Some small firms apparently produce only fertilizer, but no published records were available for such firms. The analysis of economic impact of control costs had to be based, therefore, upon the general conditions and trends of the chemical and fertilizer industries. It does not appear that more detailed data would cause a change in the major conclusions reached in this report.

5. Industry Structure

Production of elemental phosphorus is concentrated in six private firms, with the Tennessee Valley Authority also a significant producer (approximately six percent of industry capacity). One chemical firm accounts for 35 percent of the industry and the three largest firms have 75 percent of productive capacity. Each of the producers of elemental phosphorus is also a producer of phosphoric acid and one or more of the types of finished fertilizer. All but two of them sell phosphate rock to other users. A small number of firms produce phosphate rock for sale to other users, but do not produce phosphorus products themselves. There are 80 firms, in addition to the producers of elemental phosphorus, that are producers of phosphate fertilizers, 56 of them producing normal superphosphate, 18 producing triple superphosphate, and 44 producing ammonium phosphates. The production of phosphate fertilizers is not characterized by dominance of one or two firms, although there are very great variations in firm size ranging from single-plant firms of 15,000-20,000 tons annual capacity to firms with more than 20 plants and capacity in excess of 125,000 tons per year.

Given the present pattern of industrial uses of elemental phosphorus, sales of this product appear to be stable and to provide an adequate profit to the firms producing it. Phosphate fertilizer, on the other hand, has been characterized by below average returns on investment during the past decade and has suffered from chronic over-capacity. It has attracted investment from a number of chemical and petroleum firms that had hoped fertilizer would provide a profitable outlet for materials such as sulfuric acid and at the same time provide diversification into the agricultural sector of the economy. A number of farm cooperatives also undertook phosphate fertilizer production in order to provide a stable and economic supply of one of the ingredients of the dry-mixed fertilizer they offer farmers. These farm cooperatives had rather mixed success and have not always been a stabilizing influence in the industry.

Some rationalization of the industry appears to have begun in the last year or two. Shifting demand from normal superphosphate to triple superphosphate and diammonium phosphate have induced shutdowns of some of the older normal superphosphate capacity and some smaller companies have sold out to other firms or left the industry. Also, more emphasis is being given to marketing and to solving chronic problems of storage, transportation, and distribution.

Further statistics for the two industries are shown in Tables IV-19 and IV-20.

TABLE IV-19. - 1967 STATISTICAL DATA ON THE ELEMENTAL PHOSPHORUS INDUSTRY

	United States	Metropolitan Areas
Number of Plants	13	8
Capacity (Thousands of Tons)	658	290
Production (Thousands of Tons)	587	279
Value of Shipments (Millions of Dollars)	200	140

TABLE IV-20. - 1967 STATISTICAL DATA ON THE PHOSPHATE FERTILIZER INDUSTRY

	United States	Metropolitan Areas
Number of Plants	179	147
Capacity		
Wet Process Acid (1,000 Tons P_2O_5)		
ORTHO	5,860	4,830
SUPER	316	149
Ammonium Phosphate (1,000 Tons Gross Weight)	7,430	6,430
Normal Superphosphate (1,000 Tons Gross Weight)	4,690	3,840
Triple Superphosphate (1,000 Tons Gross Weight)	3,640	3,460
Production		
Fertilizer (Thousands of Tons)	4,700	4,100
Phosphoric Acid (Thousands of Tons)	5,190	4,200
Value of Shipments (Millions of Dollars)		
Fertilizer	976	854
Phosphoric Acid	565	455

6. Market and Trends

Approximately 85 percent of the production of elemental phosphorus is sold to industry for a wide variety of uses. Almost 75 percent of phosphate output is used for fertilizer and approximately 20 percent goes to industrial purchasers. Fertilizer production, therefore, is dominant in this industry. However, industrial uses are increasingly important, as is shown by the fact that production of phosphate rock has more than doubled during the 1960's while fertilizer production, although showing a steady growth, increased only by approximately 20 percent. Until 1950, normal superphosphate was almost the exclusive source of phosphate in fertilizer. Its use, however, has declined over the years and amounts to only about 20 percent of the total phosphate market today.

The fertilizer market is quite competitive. Marketing is done by major producers serving national or regional markets, by retailers of farm and garden supplies, and by producers of mixed fertilizers who buy their ingredients from primary producers. Increasingly knowledgeable farmers operating large-scale farms have increased market influence and demand fertilizers that have analyses tailored to their individual needs. This competition tends to hold prices close to the minimum necessary to maintain adequate supplies. It also has meant that buyers of substantial quantities can negotiate significant discounts from list prices.

Average prices climbed slowly during the 1960's, but dropped in the last two years of the decade. It is expected that they will resume their upward trend in the 1970's, rising much more slowly than other industrial prices. Prices tend to be markedly higher in the Midwest than on the East Coast, primarily because of added transportation costs. This has led to extensive use of triple superphosphate and diammonium phosphate in most of the major farm areas, since these contain two to three times as much plant nutrients per ton as normal superphosphate and therefore incur lower transportation costs per unit of value. The difference is shown by comparison of the cost to the average farmer in terms of nutrients applied to the soil. Government studies have shown [Ref. 29] that a ton of P_2O_5 costs a farmer, on the average in 1969, \$163 as triple superphosphate, \$216 as normal superphosphate, and only \$149 as ammonium phosphate [Ref. 29]. Cost of production at the plant is somewhat lower for the newer triple superphosphate and diammonium phosphate processes, but not as much as this differential of applied cost. The greater share of the differences appears to result from economies in shipping the more concentrated fertilizers.

7. Economic Impact of Control Costs

a. Cost Factors

The value of investment required to achieve the desired emission control level for plants producing elemental phosphorus varies in relation to the capacity of each plant. It is estimated that the average investment per plant subject to these standards in the 298 metropolitan areas in 1967 would be $585,000. The annualized cost in 1967, including depreciation, finance, and operating charges would average $271,000 per plant in the metropolitan areas, or approximately $7.80 per ton of phosphorus produced.

Investment requirements and annual costs for fertilizer plants vary in relation not only to capacity but also to the type of product produced. The average investment in 1967 for all plants in the metropolitan areas is estimated at just under $150,000 each, and total annual costs, including the annualized investment, average approximately $47,000 per plant. The effect of varying investment and operating expenses in 1967 may be shown by comparing the range of annual cost for each production process. Annual costs per plant for production of normal superphosphate range from $18,000 per year at 12 tons per day capacity to $440,000 per year at 1,540 tons per day. For triple superphosphate producers, the annual cost per plant range is from $52,000 per year at 50 tons per day capacity to $2,000,000 per year at 10,000 tons per day capacity. Ammonium phosphate plants show annual costs from $6,000 per year at 50 tons per day capacity to $375,000 per year at 6,000 tons per day capacity. Finally, annual costs for phosphoric acid plants are estimated to range from $13,000 per year at 25 tons per day capacity to $170,000 per year at 1,000 tons per day capacity.

b. Industry Impact

It is estimated that an annual cost of $2,180,000 will be required to control facilities in operation in 1967. This will be equal to approximately $7.80 per ton of production. This is approximately two percent of the f.o.b. selling price. The annual cost estimate of $6,910,000 for control of fertilizer plants, figured on the same basis, averages approximately $1.70 per ton produced, or just over one percent of producers price. This control cost reflects, insofar as possible, the annual cost of controlling phosphoric acid production which enters into fertilizer manufacture. By Fiscal Year 1976, it is estimated that the investment requirement and annual cost for emission controls for the elemental phosphorus industry located in the 298 metropolitan areas would be $6.6 million and $3.1 million. For the phosphate fertilizer industry, the investment requirement and annual cost are estimated at $32.0 million and $10.0 million.

Data were not available to determine the share of revenue and profit attributable to phosphorus production in the seven firms in that market, or the role of fertilizer in the total operations of these fertilizer manufacturers for which financial information was known. It is believed that in most of the industrial processes using phosphorus or phosphoric acid, these inputs would be quite small relative to the total material cost. With only seven firms to buy from, and with all of them affected to some extent by the required control cost, it is expected that buyers would have to accept price increases sufficient to cover the producers' costs. Since only 44 percent of the United States production would be affected by increased control cost, prices might rise by approximately one percent, or $3.90 per ton. Sales of elemental phosphorus or phosphoric acid for industrial use would probably not be reduced by a price change of this magnitude.

The average annual control cost per ton of fertilizer produced is approximately $1.70. Annual control cost for producers of ammonium phosphate is estimated to be approximately half the average, while annual control cost for triple superphosphate is somewhat above the average.

Since most producers are affected by the increased cost and since there is no known substitute for phosphate fertilizer, virtually all of the increased cost may be expected to be reflected in price. However, the trend of substitution of high analysis triple superphosphate and diammonium phosphate for normal superphosphate may be accelerated. Delivered price on the farm of P_2O_5 may be expected to increase by approximately the same amount whether in the form of normal or triple superphosphate. This would maintain the value advantage of the concentrated superphosphate. Ammonium phosphate may be expected to increase in price by only half the increase in the other types. The average price increase for all forms combined may, therefore, be in the range of $0.70 to $1.00 per ton, depending on the eventual product mix of the industry.

For producers, this seems to indicate a hastening decline in production of normal superphosphate. Since much of the capacity for producing normal superphosphate is older than that used for the other types and may already be obsolete, producers may choose to replace it rather than invest in control equipment. Some small fertilizer producers make only normal superphosphate. The number of these firms was not determined for this study. Some of these firms may be forced to close as return on investment falls below the already poor rate normal to the industry.

F. Grain Milling and Handling

1. Introduction

Commercial grain mills process grain into flour, livestock feeds, cereals, corn syrup, and various bread and pastry mixes. Because of limited data, this study focuses on those establishments primarily engaged in manufacturing prepared feeds for livestock. Manufacture of certain feed ingredients and adjuncts, such as alfalfa meal, feed supplements, and feed concentrates is also included in these establishments. The main grain handling operations are performed at terminal and country elevators which provide storage space and serve as collection and transfer points. Terminal elevators serve as storage and distribution points and store larger quantities over a longer period of time. Country elevators are scattered over the countryside and average storage time is less than for terminal elevators. The two types of activities involved at both types of elevators are: (1) intermittent operations such as unloading and drying and (2) continuous operations such as bin aeration or turning, cleaning, and loading.

For simplicity, grain handling is assumed to proceed through the following steps: (1) after harvesting, the grain is taken to a country elevator; (2) there it is unloaded, weighed, and stored for varying periods; (3) it is then loaded into a type of conveyance and taken to a terminal elevator; and (4) it is unloaded, weighed again, given a preliminary cleaning, and again stored.

Terminal elevators are usually operated continuously, whereas country elevators are not. Certain country elevator operations, such as loading and drying, involve 2,000 hours per year or less. Other operations such as turning and loading are continuous in most cases.

2. Emissions and Costs of Control

The principal type of pollutant emitted during animal feed milling and grain handling operations is particulates. Dusts, resulting primarily from mechanical abrasion of individual grains, are generated in both the milling operations in grain mills and the handling and cleaning processes of the elevators. Terminal elevators contribute the vast majority of the particulate emissions from the grain milling and handling industry. Although country elevators are of a smaller scale, most of them perform basically the same operations as the terminal elevators; therefore, country elevators, as well as terminal elevators, require particulate controls designed for maximum materials handling capacity.

Particulate emissions from elevators in the 298 metropolitan areas are estimated to equal 1,400,000 tons in 1967. With industry growth, these would increase to 1,730,000 tons by Fiscal Year 1976 if the 1967 control level of 35 percent was maintained. Installation of controls, yielding a control level of 99 percent, would reduce emissions to 26,100 tons in Fiscal Year 1976. Similarly, feed mill particulate emissions are estimated as 274,000 tons in 1967 and would grow to 347,000 tons by 1976 if the 1967 control level of 35 percent was maintained. With controls increased to 99 percent, 1976 emissions would be reduced to 5,410 tons.

Control of dust emitted from livestock feed milling and grain handling to a required level of 99 percent can be accomplished with fabric filters. At present, only about 50 percent of terminal elevators and animal feed mills are assumed to be equipped with cyclones which remove only 70 percent of the dust conveyed to them [Ref. 30]. Costs are calculated on the basis of installing fabric filters at all mills and elevators.

With the implementation of these controls by Fiscal Year 1976 in the 298 metropolitan areas, it is estimated that the investment requirement for the grain handling and the animal feed milling industry will be $436 million and $27 million, respectively. The annual costs will amount to approximately $153 million and $11 million, respectively, for each segment of the industry.

3. Engineering Basis of the Analysis

Grain elevators are currently classified by an employment size category index ranging from one to ten. The corresponding capacity in thousands of bushels is shown in Table IV-21.

TABLE IV-21. - EMPLOYMENT SIZE INDEX VS CAPACITY

Employment Size Category	Average Capacity (1,000 bushels)
1	12.5
2	50
3	100
4	200
5	375
6	750
7	1,750
8	3,500
9	7,500
10	15,000

For the purpose of analysis, country elevators are considered to be of employment size category five or less; terminal elevators therefore are from employment size categories six through ten. At country elevators only unloading, weighing and loading was assumed to occur. At terminal elevators, the following unit operations were assumed to occur: unloading, weighing, transferring, drying, cleaning, and loading. On the basis of these unit operations, data [Ref. 31]. These are shown in Table IV-22 below.

TABLE IV-22. - ELEVATOR EMISSION FACTORS

Elevator Type	Emission Factor (pounds/year/1,000 bushels capacity)
Country	250
Terminal	1,600

These were based on terminal elevators operating 8,000 hours per year and country elevators operating at 3,000 hours per year.

Control costs were based upon installing a single baghouse system to control all unit operations. On the basis of present information [Ref. 32], a total flow rate of 90 ACFM per bushel per hour was utilized. On the basis of this factor and an estimated fabric filter installed cost factor of $3 per SCFM [Ref. 32], investment requirements were calculated. Total annual costs were estimated as 0.35 times the investment required. Table IV-23 presents the investment and annual costs as a function of employment size category.

Animal feed mill unit processes include unloading, screening and cleaning, drying and processing (milling). Based upon available data [Ref. 31] an overall emission factor of 18 pounds per ton of product was utilized. Fabric filter costs were calculated on the basis of 1.38 ACFM per hundred weight (cwt)

TABLE IV-23. - GRAIN ELEVATOR CONTROL COSTS

Size Category	Installed Cost ($1,000)	Total Annual Cost ($1,000)
1	2.70	1.00
2	5.40	1.89
3	12.40	4.34
4	22.50	7.88
5	52.00	18.20
6	84.00	29.40
7	195.00	68.20
8	420.00	147.00
9	840.00	294.00
10	1,110.00	383.00

production per day [Ref. 32]. Using the $3 per scfm installed cost factor and the 0.35 annual cost factor described above, the control cost - process size (in terms of tons per day) relationships shown in Table IV-24 were developed.

TABLE IV-24. - ANIMAL FEED MILL CONTROL COSTS

Nominal Mill Capacity (tons/day)	Installed Cost ($1,000)	Annual Cost ($1,000)
10.3	10.00	3.50
35.8	10.00	3.50
71.8	10.00	3.50
154	13.00	4.55
615	33.00	11.50
1,538	84.00	29.20
2,563	144.00	50.50

4. Scope and Limitations of Analysis

Only limited data on the operation of grain elevators and feed mills were available for this analysis. So as not to understate the problem, the estimates made of dust emissions and the control cost of reducing them to acceptable levels are considered high. These estimates should be interpreted as indicating a level that probably would not be exceeded and as an indication of the order of magnitude of the problem and the controls required.

Although the distribution of elevators and feed mills by location and size was known, data were not available showing similar information by firm. Some of the largest firms in this industry are well known publicly held corporations, but the business structure, pattern of operations and sales, and financial position of constituent firms were not available. The economic analysis included in this report is, therefore, necessarily limited to the general market impact of control costs.

5. Industry Structure

In 1967, there were 4,098 grain elevators in the 298 metropolitan areas with a storage capacity of 3.48 billion bushels and a throughput capability of an estimated 9.76 billion bushels. Of this number of grain elevators, 2,898 (71 percent) had a capacity of less than 500,000 bushels and, in most cases, would be classified as country elevators. The remaining 1,200 elevators (29 percent) are classified as terminals and provide approximately 83 percent of the storage capacity and throughput capability. These large elevators include those located at major milling plants and terminals and are normally a part of large corporate producers of livestock and poultry food, or a part of large scale shippers, in addition to large elevator operators. Many small elevator operators also do feed milling and mixing of custom feeds.

Feed mills in the 298 metropolitan areas in 1967 numbered 2,155. The capacity, production and value of shipments for these mills are estimated at 55.5 million bushels, 46.2 million bushels and $3.8 billion. Seventy percent of these feed mills have fewer than 20 employees.

Both the milling and handling sectors of the industry, therefore, are characterized by a wide range of production capacities and considerable variation of operating patterns. A relatively small number of large nationally known firms operate a substantial share of the productive capacity, but there are also a very large number of independent small- and medium-sized producers, providing a highly competitive market.

6. Market and Trends

The market for grain tends to be dominated by the demand derived from consumption of the final products made from it, with government price support and production controls setting a lower limit on prices. Grain handling costs make a relatively small contribution to the delivered cost of grain and, since these functions are essential and unavoidable to the rest of the industry, it would appear that demand for handling services would show little sensitivity to price. Similarly, demand for livestock and poultry feeds is relatively inelastic with regard to price. However, large segments of the market, such as feedlot operators, may choose to reduce the amount of feed used when a rise in feed prices does not coincide with an increase in the market price of meats. The price elasticity of demand for livestock and poultry feed, therefore, depends upon price trends and price elasticity of the demand for meat and makes it more difficult for feed mill operators than for elevator operators to shift increased cost to the buyer.

7. Economic Impact of Control Costs

The cost of installing fabric filters on elevators was based upon the distribution of plants by capacity. It was assumed that the elevators with less than 500,000 bushels capacity had no effective control in 1967. It was estimated that the required investment for these elevators would average approximately \$9,000 each. The average investment would be considerably higher for large terminal elevators as a result of their larger volume of grain handling and since it was assumed that most of the grain cleaning and drying is done there. Average investment for elevators over 500,000 bushels capacity is estimated at \$77,700. Total investment for control of the elevators in the 298 metropolitan areas is estimated as $436 million through Fiscal Year 1976, including investment for elevators built after 1967.

The investment required for fabric filters to control emissions from feed mills was estimated in relation to the normal daily production and ranged from $10,000 for 10 to 100 tons per day and up to $144,000 at 2,500 tons per day. Mills with less than 100 tons per day production predominate in the industry to such an extent that the average investment per mill is only slightly over $10,000. Total investment for all feed mills, including capacity constructed after 1967, is estimated to reach $27.4 million through Fiscal Year 1976.

Annualized control costs (operating expense plus depreciation and finance cost) show a similar pattern. Country elevator annual cost averages just under $10,000 per year and terminal elevators average approximately $78,000 per year. Total annual costs for all elevators in the 298 metropolitan areas are estimated as $153 million by Fiscal Year 1976. Annual cost for an average feed mill is estimated to be $4,000 per year and the total for all feed mills would approximate $11 million by Fiscal Year 1976.

The annual cost of controlling elevator emissions is equal to $0.0127 per bushel of grain estimated to be handled in 1976 and the annual cost per ton of feed production in 1976 is estimated as $0.187. In view of the relative insensitivity of demand for grain and feed to price changes suggested in paragraph 6, above, it appears that these costs will be largely reflected in prices. It is unlikely that an added cost of one cent per bushel for grains priced from $0.70 to $1.70 per bushel will change the market significantly. Similarly, no market effect is expected from an additional cost of 19 cents per ton when added to feed averaging in the vicinity of $85 per ton. Expressed another way, these costs of control will add approximately $164 million to the nation's annual food bill by Fiscal Year 1976 or perhaps $0.75 per person.

G. Gray Iron Foundries

1. Introduction

Gray iron foundries produce castings, such as machine and automobile parts, from gray iron, pig and scrap. To melt iron for casting, the industry utilizes three types of furnaces: electric arc, electric induction, and cupola furnaces. The electric arc and electric induction furnaces, which together account for only seven percent of all castings, emit relatively small quantities of pollutants and were not included in the analysis. This report focuses on control of pollutants from cupola furnaces.

Cupolas are vertical cylindrical furnaces in which the heat for melting is provided by burning coke in direct contact with the metal charge. Most foundry emissions emanate from this metal-melting operation.

2. Emissions and Costs of Controls

Carbon monoxide and particulates in the form of dust and smoke are the significant emissions from cupolas. Particulates arise from fines in the coke and flux charge, from metal fuming, and from dirt and grease introduced with the scrap.

In 1967, it is estimated that the industry averaged about 18 percent control of carbon monoxide and 12 percent of particulates. Emissions within the 298 metropolitan areas amounted to 2,220 thousand tons and 166 thousand tons, respectively. With industry growth, these emissions would increase to 3,420 thousand tons and 255 thousand tons, respectively, in Fiscal Year 1976. Implementation of controls would result in 209 thousand tons of carbon monoxide and 29.1 thousand tons of particulates in Fiscal Year 1976.

Carbon monoxide emissions can be reduced by the use of afterburners which oxidize carbon monoxide to carbon dioxide. Afterburners in combination with gas-cleaning equipment, such as wet scrubbers or fabric filters, can reduce emission levels of carbon monoxide and particulates from cupolas to achieve compliance with stringent process weight regulations for particulates and a 95-percent removal rate for carbon monoxide.

Of the control equipment presently capable of particulate removals in excess of 90 percent, only high-energy wet scrubbers have been used on cupolas without difficulty. Several foundries, especially in the Los Angeles area, are using fabric filter baghouses with some degree of success. Fabric filter systems, when successful, require afterburners, gas-cooling equipment, high-temperature filtration material, and decreased filtration velocities. In general, maintenance costs of fabric filters are high and the costs of using them is greater than for wet scrubbers.

The total investment required to meet the standards by Fiscal Year 1976 would be $317.3 million. The corresponding annual cost would be $108.2 million.

3. Engineering Basis of the Analysis

To date, the foundry industry has been a consistent user of high efficiency control equipment on its numerous in-plant dust problems in sand preparation, shakeout, abrasive cleaning and grinding operations. However, equipment to control the fume-laden gases from the melting operation has been installed in only a few locations.

Data on the present levels of control for particulates and carbon monoxide were obtained from a joint APCO- Department of Commerce survey. From these data, regional control level estimates on a cupola by cupola bases were made. Nationally, the overall control levels for particulates and carbon monoxide are 12 and 18 percent, respectively.

Two bodies of data were available to estimate costs of controlling emissions from cupolas in gray iron foundries. Data describing features of all gray iron foundries that operate cupolas were obtained by the Department of Commerce during 1968 via a mail survey. The information gave the location of all plants and the number of cupolas and some facts on emission controls presently installed for most plants. Cupola capacity ratings were not reported.

A representative sample of 67 foundries with cupolas was visited by APCO personnel to obtain extensive data on control systems. The collected data included information about investment and annual costs. From the sample survey, information on the sizes of cupolas in each plant was used to derive a distribution by size for the total industry. Data from the sample survey were also subjected to statistical analyses to relate costs to cupola control factors. Venturi scrubbers were selected as the particulate control device. For venturi scrubbers, costs were a function of two factors, gas volume and pressure drop. Sample data were also used to estimate gas volume as a function of melt rate. Investment and annual costs for venturi scrubbers are given in Table IV-25. Afterburners were selected as the control device for carbon monoxide. However, the data from the survey, as presented in the table, does include costs of installing and operating afterburners. Therefore, separate cost estimates were not made. By using these cost estimates and the distribution of cupolas, an average cost per control system was estimated.

TABLE IV-25. - CUPOLA EMISSION CONTROL COSTS

Cupola Size (tons/hour)	Number of Cupolas	Control Costs ($1000)	
		Investment	Annual
2.5	232	103.5	31.2
7.5	323	179.0	54.0
12.5	279	246.7	74.5
17.5	211	318.4	96.1
22.5	139	386.2	116.6
37.5	20	457.8	138.2
32.5	0	529.4	159.8
37.5	0	604.9	182.6
42.5	48	678.1	204.7
47.5	29	752.0	227.0

When a foundry operates two cupolas of approximately the same capacities one emission control system is used for the pair. It was assumed that, where possible, one system would serve two cupolas. The data on foundries in each area were screened, taking into account cupolas that could be paired, to determine the number of systems required. These estimates and the estimate of average control system costs were then used to calculate an estimate of the investment cost for each area.

Annual costs were estimated by multiplying the investment cost by 0.302. This factor was determined by statistical analysis of survey data and the estimates allow, in accordance with industry practice, about 18 percent for depreciation and other capital-related charges. Annual depreciation and capital costs for other sources in this study, except solid waste disposal, allow 20 percent.

In those cases of foundries reporting installed control systems, it was assumed that presently installed mechanical collectors would be replaced by venturi scrubbers but that fabric filters, wet scrubbers, and the one reported electrostatic precipitator would be adequate. No credit was allowed in the cost estimates for the value of mechanical collectors that would be replaced.

4. Scope and Limitations of Analysis

This report is limited to control of the melting operations. Nonmelting operations within foundries are consistently controlled with high efficiency control equipment and are not included in the analysis.

The analysis of economic impact is limited to jobbing foundries, since the financial structure of captive foundries is indistinguishable from that of their parent company. Impact on a captive foundry cannot therefore be determined and its control costs are passed on directly to the final product of the parent company.

5. Industry Structure

The gray iron foundry industry consists of 1,446 plants that are located in the United States, of which 77 percent (1,115) are located within the 298 metropolitan areas. United States capacity for the industry in 1967 was 17 million tons of castings per year. In the 298 metropolitan areas, capacity amounted to 14 million tons of castings per year. Production was 14.3 million tons per year for the United States and 11.8 million tons per year for the 298 metropolitan areas or about 83 percent of the United States production.

Numerically, the gray iron foundry industry consists predominantly of small establishments. Yet production is dominated by a few large firms. The four largest companies accounted for approximately 27 percent of the industry's value of shipments in 1967, while the eight largest accounted for 37 percent.

There is a definite trend in the foundry industry toward fewer but larger firms. From 1959 to 1967, the total number of foundries in the U. S. declined by almost 200, although the number of large foundries increased.

Many of the largest firms are "production foundries," which have the capability of economically producing large lots of closely related castings. Most of the output of these "production foundries" is captive (owned and controlled by other businesses). In fact, almost half of all gray iron production comes from captive plants which do not generally produce for the highly competitive open market.

Gray iron foundries range from primitive, unmechanized hand operations to heavily equipped plants in which operators are assisted by electrical, mechanical, and hydraulic equipment. Captive plants are more likely to be mechanized and better equipped with emission control equipment than are noncaptive plants.

The nature of the gray iron foundry industry is such that foundries can be found in almost all urban areas. The economies of scale for the industry do not prohibit the continued existence of relatively small foundries. Since many foundries are operated in conjunction with steel-making facilities, they are concentrated in the "steel" states: Pennsylvania, Ohio, Michigan, Illinois and Alabama.

6. Market

a. Competition Among Sellers

The gray iron foundry industry is characterized by intense competition among the many small jobbing foundries. This fierce price competition has spurred a drive for lower operating costs and higher productivity gains. Casting quality along with engineering design services available to the customers are other areas of increasing competition. Unfortunately, many foundries have had insufficient capital or resources to invest in cost-saving and quality improvement facilities rather than straight additional capacity. Larger foundries have a competitive advantage in that they usually can offer the services of better sales engineering staffs, are more mechanized, and have more sophisticated quality control equipment.

The net effect is that many small foundries that cannot cope with increasing needs for capital, demands for better quality and service, and rising labor costs are being forced out of business. The larger and more stable firms are, in contrast, increasing their capacities in order to reduce unit costs and absorb the additional demand. Also, an increasing number of large purchasers of castings are establishing captive foundries in order to gain a ready supply of quality castings. However, these additions to capacity have been unable to keep pace with the expansion of demand and the loss of capacity of closed foundries. As a result users are finding it increasingly difficult to obtain an adequate supply of specialty iron castings.

b. Customer Industries

The major customers of the gray iron foundry industry are also major constituents of the national economy. The health of the industry is therefore closely related to the health of the gross national product (GNP). The major industrial markets for foundry castings include motor vehicles, farm machinery, and the industries that build equipment for the construction, mining, oil, metalworking, railroad and general industry markets.

These industries are considerably larger and more powerful than the gray iron foundry industry. The individual customer firms have many times the assets of the foundries from which they buy. With their financial strength and generally greater management expertise, such firms are able to play the many small foundries against each other to maintain severe price competition even under conditions of high demand for castings.

c. Foreign Competition

Direct imports of castings as well as the castings in imported machine tools, autos, textile machinery, and internal diesel engine parts do enter the American market. However, Department of Commerce statistics indicate a volume of only $2.25 million for direct imports in 1967. This is estimated by the industry to be approximately one-quarter of the actual total. Even if a total import volume of $9 million is assumed, imported castings and component castings are equivalent to less than one percent of the $2.7 billion value of shipments in the U. S. that same year.

Imports, therefore, do not constitute a major threat to the American gray iron casting market. The high cost per ton of shipping compared to the relatively low cost per ton of production is probably the most significant barrier to imports.

7. Trends

The foundry industry expects its market to continue to grow at the average historical growth rate of its customer industries. This rate is expected to average six to seven percent per year through 1980 but may be somewhat less for the period of 1970 to Fiscal Year 1976. By 1975, total foundry production volume will have to increase by 52.9 percent over 1969 just to keep up with demand. For 1980, the projected increase is 90.2 percent over 1969 volume.

During the period from 1958 to 1967, the price of gray iron castings rose steadily at a rate of 2 percent per year. At the same time, the prices of the two major raw materials, pig iron and scrap iron, have fallen at an annual rate of 2.3 percent. However, while material costs have declined, labor costs have advanced more rapidly than the price of castings, keeping continued upward pressure on price.

8. Economic Impact of Control Costs

a. Control System Costs

Full implementation of controls on all facilities which existed in 1967 would yield a total annual cost of $69.4 million and in Fiscal Year 1976 the total annual cost would be about $108.2 million. As production volume within the 298 metropolitan areas was 11.8 million tons in 1967 and is estimated to be 18.0 million tons in Fiscal Year 1976, the average cost of control per ton would be $5.88 and $6.01, respectively.

No valuable materials, which could serve to compensate for control costs, are recoverable from foundry emissions.

Currently, air pollution control increases the cost of castings for large foundries by about 0.7 percent. With small single cupola foundries, added cost averages about 3 percent of the production cost. These added costs compare to average profit rates before tax of 6.8 percent for large foundries and 5.8 percent for small foundries. To small foundries, control costs represent a reduction in profit margins of over 50 percent, while margins for larger firms would be reduced only 11 percent if costs could not be passed on to customers. Investment in air pollution control equipment would equal approximately 5 percent of the value of capital for the largest firms and as much as 25 percent for the smallest firms. The evidence of these indicators suggests that the impact of pollution control is much greater on the small jobbing firms under a million dollars in value of shipments than on those with greater shipments. The industry generally can little afford a reduction in profit rate, as its rate of 6.8 percent return on investment is already below the all-manufacturing average of 8.1 percent.

The large investment in pollution control equipment, relative to the book value and profitablity of many foundries, presents a serious problem of financing the investment. The foundry industry generally is not an attractive investment in stock or bond markets due to its low rate of return and slow profit growth. Neither is it a good risk for commercial banks due to the high ratio of control investment to book value of many small foundries and the unprofitability of the control investment. The Small Business Administration is currently the only source of funds available to many foundries. The SBA prefers to guarantee loans made by banks but will pay out funds directly in some cases.

b. Impact on the Industry

The economic impact of pollution control costs on an industry varies with the industry's ability to pass cost on to the consumer in the form of higher prices. This ability is largely dependent upon elasticity of demand for the product, the degree to which the volume of sales declines in response to price increases. Demand for castings is relatively inelastic, since most castings are inputs for the production of more complex final products and constitute a small portion of the cost of the final product. Also, possible substitute products, such as aluminum, steel, and other metals, are somewhat more costly than gray iron and are usually subject to the same upward price pressures such as rising labor costs and pollution control costs. Thus, a small price increase due to pollution control will have little effect on the market for gray iron.

Despite inelastic demand, sharp competition among the many jobbing foundries will make price adjustments for control cost difficult for those foundries that experience higher than average costs. Large mechanized firms and those smaller firms that are located outside of the 298 metropolitan areas will incur lower control costs than will other foundries. These lower cost foundries will establish price levels that prevent the less efficient firms from raising prices sufficiently to cover their control costs. The average price of castings is expected to increase by about two percent in response to stringent air pollution control regulations. Such a price increase would leave approximately one-third of the firms in the industry with reduced profit margins. These firms would be forced into marginal or sub-marginal financial positions.

The nonuniformity of control regulations and costs, along with the lack of investment capital, will force most foundries to postpone implementation of control for as long as possible. Many firms, faced with reduced profit margins and an inability to raise capital for pollution control will be forced to merge or go out of business. Some remaining firms will continue to operate at reduced profit rates. However, the larger, more stable foundries will increase their capacity to meet expanding demand, improve efficiency and continue to operate at reduced profit rates. In effect, pollution control will accelerate the trend toward fewer and larger foundries. It is apparent that the gray iron foundry industry will be among those industries most severely affected by air pollution control.

H. Iron and Steel

1. Introduction

The iron and steel industry includes plants ranging from integrated steel making operations (blast furnaces, steel making furnaces, coke ovens, sintering plants, scarfing machines, rolling mills, etc.) to much smaller operations with a few steel making furnaces producing small quantities of specialty steels. The first step in the conversion of iron ore into steel takes place in the blast furnace. The blast furnace produces a material commonly referred to as pig iron. Steel making furnaces refine the pig iron and/or steel scrap into steel. Three types of steel making furnaces are in common use; these are the open hearth furnace, the basic oxygen furnace and the electric steel making furnace. Sintering plants are designed to convert iron ore fines into a product more acceptable for charging into the blast furnaces. Scarfing is an operation which removes surface defects from steel. Coking is an operation in which bituminous coal is converted into coke, the chief fuel used in blast furnaces. Blast furnaces are always well controlled to prevent the emissions of particulates; while the gaseous emissions are fully utilized in the production of process heat. At present, very little is known about the emissions or present control patterns for scarfing machines. The full control of coking operations, at present, is not considered to be technically and economically feasible. Therefore, this report focuses on the emissions and air pollution control costs of the sintering and steel making operations.

2. Emissions and Costs of Control

This report focuses on two air pollutants: particulates and fluorides. Carbon monoxide, a potential emission from basic oxygen furnaces and blast furnaces is usually completely controlled. Particulate emissions result from the sintering operations as well as from all the steel making furnaces. Based upon the best available data the average level of particulate control in 1967 is thought to have been about 55 percent for these unit operations. To comply with the Clean Air Act by Fiscal Year 1976, an average level of particulate control of 97 percent will be required. Therefore, particulate emissions would be reduced from a potential of 1.460 thousand tons in Fiscal Year 1976 with the same controls as in 1967 to 93 thousand tons in Fiscal Year 1976 with 97 percent control.

Fluoride emissions occur during steel making operations in all three furnace types. It is estimated that in 1967 the fluoride emissions were 26,400 tons and the average level of fluoride control for the industry was about 30 percent. By Fiscal Year 1976, to comply with the Act, an average level of control of 89 percent will be required. With these controls, fluoride emissions would be reduced from a potential of 35,200 tons to 5,200 tons.

In order to implement the required increases in air pollution control levels by Fiscal Year 1976, it is estimated that an investment of $981 million will be required, and that total annual cost will be $507 million.

3. Engineering Basis of the Analysis

The processes considered for the cost analysis in this section were the following: open hearth furnace, basic oxygen furnace, electric arc furnace, and the sintering operation.

Particulate control levels are well below technically feasible levels resulting in annual national emissions of about 1.5 million tons. On the other hand, carbon monoxide, a potentially significant emission from the basic oxygen furnace, is controlled to a great extent by burning in waste heat boilers or in nonproductive complete combustion of off-gases to convert the carbon monoxide to carbon dioxide.

Totally uncontrolled rates of particulate emissions vary from process to process. Table IV-26 presents the emission rates for each process.

No one has attempted a comprehensive analysis of the present level of particulate control levels in the iron and steel industry. However, some information [Refs. 14, 33, 34], fragmentary as it is, was used to set average nationwide control levels for the various processes. These are presented in Table IV-27. For this table and the rest of the discussion of present emission estimates, open hearth control facilities are assumed to have been installed only where oxygen lancing is practiced.

TABLE IV-26. - UNCONTROLLED PARTICULATE EMISSION RATES

Process	Emission Rate (lb/ton produced)
Open hearth (nonoxygen lanced)	12
Open hearth (oxygen lanced)	22
Basic oxygen	46
Electric furnace	11
Sintering (windbox)	20
Sintering (discharge)	22

Source: Draft report, "Air Pollutant Emission Factors." APCO, August 1970.

TABLE IV-27. - PARTICULATE CONTROL LEVELS (1967)

Process	Controlled Production (percent)	Average Control Efficiency (percent)
Open hearth furnace	27	90
Basic oxygen furnace	100	95
Electric furnace	61	90
Sintering (windbox)	90	75
Sintering (discharge)	0	--

Required particulate removal efficiencies for the various processes were calculated as a function of process size on the basis of the process weight rate standard and are presented in Table IV-28.

Only rarely are fluorides associated with the raw materials, other than fluorspar flux, used in iron and steel making. In the few instances when fluorides have been reported in the iron ores, fluoride emissions appear only in the blast furnace slag or in the sintering windbox off-gases. Since last year's costs include high energy wet scrubbing of windbox off-gases and since fluorides from sintering are a rare occurance, these sources will not be considered further.

TABLE IV-28. - REQUIRED REMOVAL EFFICIENCIES FOR EMISSION SOURCES[1/]

Emission Source	Capacity (tons/melt)	Required Efficiency (percent)
Open hearth furnace[2/]	50	89.5
	100	91.4
	150	92.3
	200	94.0
	250	94.9
	300	95.6
	350	96.1
	400	96.4
	450	96.7
	500	97.1
	550	97.3
	600	97.5
Basic oxygen furnace	50	98.0
	100	99.0
	150	99.3
	200	99.4
	250	99.5
	300	99.6
Electric arc furnace	25	84.0
	50	87.0
	100	89.0
	150	92.0
	200	94.0
	250	95.0
	(tons/day)	(percent)
Sintering machine	1000	95.0
	2000	97.0
	3000	98.0
	4000	98.3
	5000	98.6
	6000	98.8
Sintering discharge	1000	95.0
	2000	97.0
	3000	98.0
	4000	98.5
	5000	98.7
	6000	98.9

1/ Based on process weight rate standard.

2/ All open hearth furnaces are assumed in this study to be oxygen lanced prior to installation of control equipment.

However, in the manufacture of steel, evolution of fluorides as HF and SiF_4 and entrained particulates does occur in the various steel making furnaces [Ref. 28]. Significant fluoride emissions occur from the operation of three major steel making furnaces. Based upon data given in Singmaster and Breyer [Ref. 28] Table IV-29 has been developed relating furnace type, amount of fluorspar (spar) used, and uncontrolled fluoride emissions.

On the basis of very minimal information, it would seem that the form of the fluoride emissions is dependent upon furnace type. Present indications are that less than one percent of the fluorides emitted from basic oxygen furnaces and open hearth furnaces are in the form of particulates, whereas 85 percent of the fluoride emissions from electric furnaces are in the particulate matter.

TABLE IV-29. - FLUORIDES IN IRON AND STEEL MAKING

Furnace Type	Amount of Spar Used (lbs./ton steel)	Uncontrolled Fluoride Emissions (lbs./ton steel)
Open Hearth	3.75	0.65
Basic Oxygen	11.42	2.0
Electric	6.77	1.2

At present, there have been no fluoride emission standards developed specifically for any industry other than aluminum and fertilizer. The standards proposed for these two are so highly specific to these industries that no simple correspondence can be developed between them and any other industry. Therefore, on the basis of a tentative agreement between APCO and RTI personnel, the following standard is proposed:

a) Gaseous fluorides will be removed by at least 95 percent.

b) Particulate fluorides will be removed to a level consistent with total particulate removals as specified by the San Francisco Bay Area Standard. In other words, whatever fluoride removal is affected when total particulates are controlled will be acceptable. In the case of the iron and steel industry, significantly high fluoride particulate removals can be expected due to the high total particulate removals required for all steel making furnaces.

Based on these required removal efficiencies, as well as particle size distribution functions, the choice of feasible control systems was made for the various processes. From the set of feasible alternatives, industry practice and other expert opinion was used to arrive at the control system requirements shown in Table IV-30.

TABLE IV-30. - SELECTED CONTROL SYSTEMS

Process	Control System	Comments
Basic oxygen furnace	venturi scrubber	upgrade from 95%
Open hearth furnace	venturi scrubber*	50" w.g.
Electric arc furnace	fabric filter	high temperature
Sintering (windbox)	venturi scrubber	20" w.g.
Sintering (discharge)	venturi scrubber	10" w.g.

* At present, open hearth furnaces (all oxygen lanced) have a 50-50 combination of scrubbers and precipitators.

Control cost estimating relationships adopted from engineering analyses developed by the Swindell-Dressler Corporation for each process. Data were available on capacities and locations of all furnaces [Ref. 35]. Sintering machine locations were known from Reference 25, but capacities had to be estimated from the known range of capacities (2000 to 6000 tons per day) and the reported grate dimensions which were assumed to be related to capacities.

Control cost data were obtained which presented investment and operating costs for the extreme ends of the expected capacity range [Ref. 36]. Intermediate levels and capacities were calculated for each process using a cost function:

$$y = ax^b$$

where: y = control cost;

x = capacity; and a and b are parameters that depend on each process.

Cost parameters for all furnace and machine types are presented in Table IV-31.

TABLE IV-31. - COST ESTIMATING PARAMETERS*

Unit Operation	Control Equipment	Units of Capacity	Cost Estimating Parameters*			
			"a"		"b"	
			Investment	Annual	Investment	Annual
Open hearth furnace	high energy venturi scrubber	tons/melt	8,308	6,576	0.7	0.7
Basic oxygen furnace	high energy venturi scrubber	tons/melt	35,775	16,318	0.7	0.8
Electric arc furnace	fabric filter	tons/melt	12,902	8,400	0.7	0.7
Sintering (windbox)	medium energy venturi scrubber	tons of sinter/day	837	518	0.8	0.7
Sintering (discharge)	medium energy venturi scrubber	tons of sinter/day	15,835	5,541	0.3	0.3

* The cost function is $y = ax^b$, where y = control cost, x = capacity, and "a" and "b" are cost parameters that depend on the type of process. The same function was applied to the calculation of both annual and investment costs by simply using the appropriate a's and b's. To illustrate the use of the parameters, suppose that it is required to determine the investment and annual cost of controlling a basic oxygen furnace with a capacity of 400 tons per melt. The investment cost (y) is therefore \$35,775 $(400)^{0.7}$ = \$2.36 million with an annual cost(y) = \$16,318 $(400)^{0.8}$ = \$1.96 million.

All types of furnaces and machines were assumed to need some additional control. Basic oxygen furnaces were assigned high energy wet scrubbers; open hearth furnaces, high energy wet scrubbers; electric arc furnaces, fabric filters; and sintering machine windboxes and discharges, medium energy wet scrubbers.

The 1967 average levels of control and the national percentages of capacity controlled were known for all furnaces and machines; regional data were lacking, however. Accordingly, the estimated relationship between national and regional control levels for the gray iron foundry industry [Ref. 37] was applied to the iron and steel industry.

The cost relationship for electric arc furnaces was calculated using data from Reference 36, assuming two furnaces exhaust into a single control system with appropriate staggering of operations. If possible, two furnaces of equal capacity were paired; if not, furnaces with no more than a 25 percent difference were paired.

Control costs for electric arc furnaces were calculated using the $y = ax^b$ cost function; when two furnaces of different capacities were controlled, the larger capacity was assumed. Control costs for single furnaces were calculated by dividing the control cost for two furnaces (each of which has a capacity equal to the single furnace) by 1.4 to allow for a reduced ducting and blower requirement as well as reduced average load. These calculations yielded basic costs at the Swindell-Dressler efficiency level [Ref. 36]. The basic costs were then adjusted to the control efficiency required by the selected standards of this study by using a cost multiplier as described in Chapter 2, "Study Methodology." The cost multiplier was again applied to furnaces to which existing control levels had been assigned to obtain the cost for the required control efficiency. When the difference between the costs for required efficiency and current efficiency was positive, it was recorded as the net control cost; no negative costs were recorded, although they did occasionally occur where the present level of control exceeded the standard.

4. Scope and Limitations of Analysis

This analysis focuses on integrated basic steel firms. Air pollution emissions that exceed the standards assumed for this study are produced primarily by the sintering plants and open hearth or basic oxygen furnaces of basic steel producers. Electric furnaces are also emission sources to a lesser extent. However, when used by secondary steel producers making specialty high alloy steels, electric furnaces are normally controlled to a high level of efficiency to avoid loss of valuable alloying metals. Secondary steel firms, therefore, are not generally faced with additional control costs.

Data on the operation of the steel industry are more available than for most industries. Nevertheless, the steel market is complicated by the vast variety of distinct products sold and the variations of product mix from one company to another. Comparison of the impact of a change in the cost of producing raw steel as it affects different companies is very difficult. Detailed data on such aspects of financial management is depreciation policy, net value of investment, pricing policy, and tax accounting are also not available, making it especially difficult to estimate profit potential for these firms.

5. Industry Structure

In 1967 there were 142 steel plants in the United States, of which 134 were located in the 298 metropolitan areas. The capacity, production and value of shipments of these plants in the United States were 165 million tons, 127 million tons and $13.3 billion, respectively. In the metropolitan areas the capacity of the plants was 61 million tons, production was 124 million tons, and the value of shipments was approximately $13.1 billion.

There were 86 steel companies in the United States in 1967. Twenty one integrated firms accounted for more than 90 percent of the 1967 steel production in the United States. They include all of the larger firms in the industry, with outputs in 1967 ranging from just under 1 million tons to more than 30 million tons. Sales for these companies varied from approximately $85 million to more than $4 billion in that year and profits from a high of $172 million for one firm to a loss of nearly $7 million for another. The two largest firms produced approximately 40 percent of the steel produced in 1967 and eight firms produced over 75 percent of the industry output.

6. The Market

The steel industry is usually described as an oligopoly characterized by administered prices and price leadership. Typically, list prices, which are virtually the same for all firms, remain unchanged for a period of time without reacting to minor changes in market conditions. Although individual prices may be shaded through the use of special discounts or premiums, the primary adjustment of company policy to short term market changes is to vary output. When price changes do occur they are usually initiated by one of the largest firms and all other companies quickly change their price lists following the pattern set by the price leader. Competition emphasizes product quality and customer service more often than price.

Steel is sold to customers in every major industrial sector of the economy. The major purchasing industries, however, are motor vehicles, heavy equipment and machinery, containers, and appliances. These industries strongly follow the swings of the business cycle and as a result cyclical changes in the national economy tend to have a magnified effect on the market for finished steel. The basic position of steel in the economy also indicates the probability that the long run trend of the domestic market for steel will be one of steady expansion and gradually rising prices.

The steel industry is also subject to significant foreign competition. Foreign participation in the U. S. steel market increased during the 1960's and posed a real threat to the market for some products. The export market for U. S. steel did not balance imports during those years. This competitive pressure was eased by the signing of an informal agreement in December, 1968, with the Japanese Iron and Steel Exporters Association and with the association of Steel Producers of the European Coal and Steel Community to limit exports to the United States for the years 1969 to 1971. This agreement, limiting increases in shipments from the countries involved to not more than 5 percent per year, appears to be effective and may well be extended. Thus the industry is partially shielded from some foreign competition. There has been a tendency for foreign steel producers to concentrate on the sale of high priced speciality steels in this country, but the protection of the agreement has been effective for basic steel producers [Ref. 38].

7. Trends

Investment in new steel capacity has been heavy over the last decade and is predicted to continue at a high level. The trend is away from the older open hearth furnaces in favor of construction of the more efficient basic oxygen and electric furnaces.

Prices have been rising following the general inflationary trend of the economy. It is predicted that prices may rise more slowly over the years to 1976, but the upward trend is expected to continue. The trend of profits is difficult to determine because net income after taxes for these companies varies substantially from year to year. Among the factors causing these fluctuations are very heavy "start up" costs when new facilities are put into production, the impact of strikes, changes in accounting and tax practices, and the tendency of firms to change output rather than price in response to short term market changes.

8. Impact of Control Costs

The investment requirement and annual cost of air pollution control for each steel firm will vary depending on the number and size of its plants and the type and capacity of its steel making furnaces. Cost estimates are calculated on the following equipment designations: high energy wet scrubbers for basic oxygen furnaces; high energy wet scrubbers for open hearth furnaces; fabric filters for electric arc furnaces; and medium energy wet scrubbers for sintering machine windboxes and discharges. Both the investment requirement and the annual costs for each of these control devices varies in relation to the capacity of the furnace or machine and has been costed on the basis of data specifying individual capacities in place. The other major determinant of cost differences among plants and firms is the number of each type of furnace in use. For example, an open hearth furance of 180 tons per heat capacity would have an annual control cost, for operation, maintenance, and depreciation, of $249,000 per year, based on 1967 prices. The equivalent annual cost for an electric arc furnace of 180 tons per heat capacity would be $490,000 per year and for a basic oxygen furnace of the same capacity would be $1,040,000 per year. It should be noted in this comparison that the basic oxygen furnace has a much shorter heat time and therefore a higher annual capacity than the electric arc furnace, which in turn has a shorter time per heat than the open hearth furnace. Thus the cost per ton of steel produced is not in the same proportion as the annual cost, but depends upon the production rate for each furnace.

The impact of control costs on firms may be shown by comparison of three hypothetical examples designed to show the range of cost per ton of steel production. A steel company with total productive capacity of approximately 9 million tons, producing 6.4 million tons of finished steel per year in 1967, 1/3 from basic oxygen furnaces and 2/3 from open hearth furnaces, would incur estimated costs as follows: total annual cost, $8,527,000; annual cost per ton of raw steel produced, $1.14; annual cost per ton of finished steel products, $1.33. If this firm does not have to incur new costs for controlling its sintering machines, as assumed in this estimate, the cost per ton of finished steel could be as low as $0.90.

Estimated costs for a typical smaller firm having an annual capacity of 2.24 million tons and production of 1.58 million tons of finished steel produced entirely with open hearth furnaces shows a total annual cost of approximately $3,000,000, or $1.91 per ton of finished steel. Similarly, a typical firm producing 1.7 million tons of finished steel in 1967 with a capacity of 2.3 million tons, using only basic oxygen and electric arc furnaces, would have an estimated annual cost of only $623,000, or $0.37 per ton of finished steel.

Comparison of these cost estimates indicates that the impact of control costs will probably be least on firms using many relatively small electric arc furnaces and greatest for firms producing primarily with open hearth furnaces. The estimated costs are relatively small in relation to the price of finished steel of $170 per ton in 1967, but differentials of the size indicated may accelerate the existing trend in the industry to retire older open hearth furnaces.

In the light of the pricing policies of the steel industry as described in Section 6, above, it is probable that most of the indicated costs will be reflected in increased prices by 1976. The firms that normally exercise price leadership in the industry are among those with substantial open hearth capacity and will therefore tend to reflect pressure to raise prices to cover the higher range of control costs. In a period of generally rising prices, an increase of the magnitude indicated for steel prices should not produce significant changes in the market position of the firms

I. Kraft (Sulfate) Pulp

1. Introduction

The pulp industry manufactures pulp from wood and other materials for use in making paper and related products. The methods used to produce pulp from wood may be classified as chemical or mechanical, only the chemical methods causing significant air pollution problems. Two chemical pulp production methods, sulfite and sulfate (kraft), account for approximately 75 percent of the total industry output. Only kraft pulping, which accounts for approximately 64 percent of the industry output, is considered in this report. Even though sulfite pulping is a potentially serious source of sulfur dioxide, when waste liquor incineration is practiced, the control costs are more than offset. This is because the sulfur dioxide emissions from the sulfite process usually are controlled since the value of recovered heat and process chemicals offset the annual costs of control.

In the kraft process, woodchips are cooked in a liquor composed of sodium hydroxide and sodium sulfide. This separates the lignin from the cellulose. Pulp is then produced from the cellulose. The separated lignin is burned as a fuel in the recovery furnace and the chemicals in the salt cake solution are recycled.

2. Emissions and Costs of Control

In kraft pulp mills, four main processes emit significant quantities of particulates: recovery furnaces, smelt dissolving tanks, lime kilns, and bark boilers. Although there are emissions of sulfur dioxide, these almost never exceed the 500 p.p.m. standard. Since the economics of the kraft method depend upon recovery of chemicals, emissions from the first three processes are controlled to prevent the loss of these chemicals. Particulates from bark boilers are also controlled, but to an extent which falls short of the standard adopted for this study. Overall, the average industry control level for particulates in 1967 was 81 percent. To meet the standard by Fiscal Year 1976, the average industry control level would have to reach 98 percent. Without implementation of the standard, particulate emissions would reach 847,000 tons for kraft plants within the 298 metropolitan areas. Assuming implementation, this could be reduced to 120,000 tons.

By Fiscal Year 1976 an investment of $73.0 million will be required to achieve full implementation for the plants within the 298 metropolitan areas. This would result, by Fiscal Year 1976, in an annualized cost of $30.3 million.

3. Engineering Basis of the Analysis

The basic engineering approach taken to estimate air pollution control costs for the pulp and paper industry consisted of: (a) an evaluation of the various production processes commonly found within the industry, (b) an analysis of the pollutants involved, their uncontrolled emission rates, present levels of control and final levels as required by the various standards adopted for this study, and (c) an evaluation to select the most satisfactory control systems to achieve the required levels.

The three most important classes of pulp-making operations from the standpoint of potential air pollutant emissions are: (a) the sulfate (kraft) process, (b) the sulfite process, and (c) the neutral sulfite semi-chemical process. The sulfite process is a potentially serious source of SO_2; however, several factors contributed to the omission of this process from this study. First, in those plants which do not practice waste liquor incineration, SO_2 emissions are practically negligible. In those plants practicing incineration, chemical and thermal recovery is economically attractive [Refs. 39, 40]. Therefore, this report assumes that all sulfite plants have or will soon have chemical and thermal recovery systems which profitably reduce SO_2 emissions to less than the 500 ppm limit.

In neutral sulfite semichemical (NSSC) pulping, particulates are not a problem; therefore, NSSC pulping was not considered for the purposes of this study.

The kraft process, however, represents an emission source which must be considered. Particulate emissions from this pulping process are being emitted to the atmosphere in quantities exceeding the standard adopted for this study. The kraft pulping process includes the following unit processes: (a) black liquor recovery furnaces, (b) lime regeneration kilns, (c) smelt-dissolving tanks, and (d) bark boilers.[8/]

Uncontrolled rates of particulate emissions are presented in Table IV-32.

Table IV-32. - UNCONTROLLED PARTICULATE EMISSION RATES

Process	Emission Rate (lb/ton air dried pulp)
Recovery furnace	150
Lime kiln	94
Smelt-dissolving tank	20
Bark boiler	18

Source: References 14 and 41.

The emissions from the recovery furnace and lime kiln consist mainly of very fine sodium and calcium salt fumes, while those of the smelt tank are very fine mists containing carbonates and sulfides of sodium. Presently, all of the processes are, on the average, controlled to some extent. Table IV-33 presents estimated particulate control levels.

Table IV-33. - ESTIMATED PARTICULATE CONTROL LEVELS AND EMISSION RATES AFTER CONTROL

Process	Control Eff. (percent)	Emission Rate After Control (lb/ton air dry pulp)
Recovery furnace	86	21.0
Lime kiln	80	18.7
Smelt-dissolving tank	50	10.0
Bark boiler	75	4.5

Based upon the process weight rate particulate emission standard, ultimate removal efficiencies were calculated for the various processes as a function of gas volume as presented in Table IV-34.

The relationship between gas volume and production for each process is given in Table IV-35.

8/ Non-bark burning boilers are also present, but are considered under industrial boiler sources.

Table IV-34. - REQUIRED REMOVAL EFFICIENCIES FOR KRAFT PROCESSES[1/]

Process	Gas Volume (10^3 acfm)	Percent Efficiency Required
Recovery furnaces	25	95.0
	75	97.8
	125	98.5
	175	98.9
	225	99.1
	275	99.3
	325	99.4
Lime kiln	5	96.9
	15	97.8
	25	98.2
	35	98.3
	45	98.6
	55	98.8
	65	98.9
	75	99.0
	85	99.1
	95	99.2
	105	99.3
Smelt-dissolving tanks	2.5	84.0
	7.5	93.2
	12.5	95.2
	17.5	96.0
	22.5	96.4
	55.0	98.8
Bark boilers[2/]	16	93.0
	24	93.0
	32	93.0
	40	95.0
	48	95.0
	56	95.0
	64	96.0
	72	96.0
	80	97.0

1/ Gas volume data taken from a 1969 APCO summary of unpublished surveys; required efficiencies were calculated.

2/ Bark boilers were considered in this study as a process step; therefore, the more stringent process weight rate standard was applied instead of the Maryland Combustion Regulation.

Table IV-35. - GAS VOLUME VS. PRODUCTION FOR KRAFT PROCESSES

Process	Gas Volume Production (acfm/100 T/D)*
Recovery furnace	25,000
Lime kiln	3,200
Smelt-dissolving tank	3,100
Bark boiler	8,000

* 100 tons per day air-dried pulp.

Adapted from Reference 41.

To achieve the required control efficiency levels, the control systems presented in Table IV-36 were selected.

Table IV-36. - CONTROL SYSTEMS SELECTED

Process	Control System	Pressure Drop
Recovery furnace	Venturi scrubber*	30" w.g.
Lime kiln	Venturi scrubber	20" w.g.
Smelt-dissolving tank	Venturi scrubber	10" w.g.
Bark boiler	Multi-cyclone	4-5" w.g.

* Assumed to follow existing electrostatic precipitator.

Data on location and total capacity of each kraft pulp mill [Ref. 42] and on the capacity of each lime recovery kiln within each mill [Ref. 43] were available for the 298 metropolitan areas. The data on total capacity of each mill were used along with data from a APCO survey [Ref. 44] to determine the capacity of recovery furnaces, smelt-dissolving tanks, and bark-burning boilers in each mill.

All recovery furnaces were assumed to be of equal size within a plant and to have an associated smelt-dissolving tank of corresponding capacity.

For each mill, a pair of equal-sized bark boilers were assigned a total capacity appropriate to the total mill capacity and a bark factor (tons of bark per ton of pulp) was used.[9/] A complete list of lime mud recovery kilns by size was obtained from Rock Products [Ref. 43].

The type of control varied with the type of process equipment. Recovery furnaces and smelt-dissolving tanks were assigned venturi scrubbers that use a weak black liquor scrubbing medium; lime kilns were assigned venturi scrubbers; and bark boilers were assigned specially-designed multicyclone collectors.

Control costs were calculated from the data in Tables IV-37 through IV-40. Gas volume - equipment cost and gas volume - annual operating cost relationships are presented for the various required control systems in Figures IV-8 through IV-14. Installed costs are 3 times the equipment costs for the black liquor scrubbers, 2 times for the wet scrubbers, and 2 times for the multicyclones. Annual costs are operating costs plus 20 percent of the investment. The resulting costs for controlling each mill were totalled for each of the 298 metropolitan areas.

Table IV-37. - KRAFT RECOVERY FURNACE EMISSION CONTROL COSTS

Furnace Gas Volume (10^3 acfm)	Associated Capacity (tons/day)*	Investment Cost ($1000)	Annual Cost ($1000)
25.0	96	92.0	20.1
75.0	290	123.0	48.6
125.0	485	198.0	78.1
175.0	680	258.6	94.7
225.0	870	309.0	130.0
275.0	1065	375.0	158.0
325.0	1260	420.0	180.4

* Tons of air-dried pulp per day.

9/ Calculated from the Sirrine report (see Reference 41).

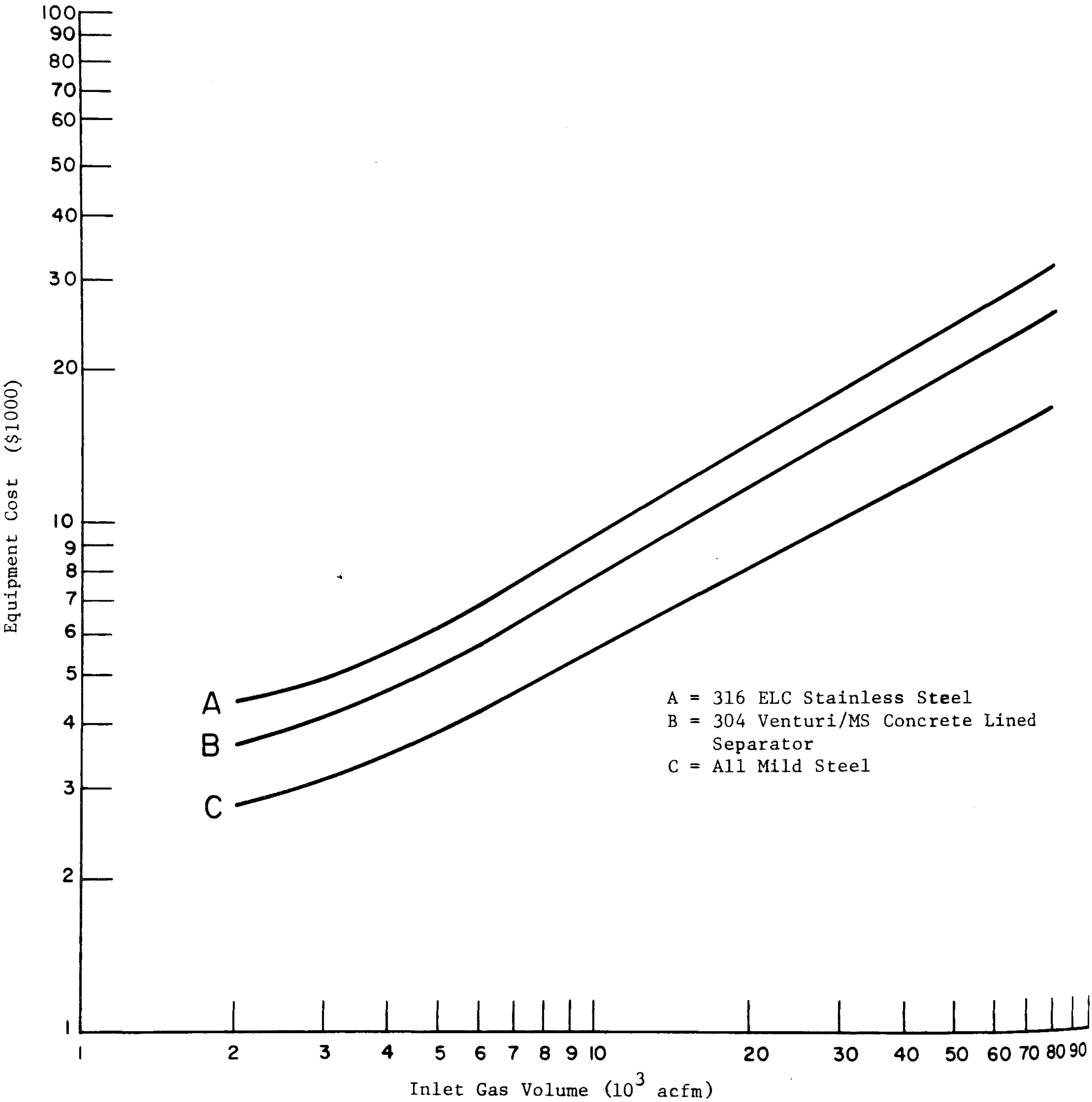
Table IV-38. - ROTARY LIME RECOVERY KILN EMISSION CONTROL COSTS

Capacity (tons/day)	Installed Cost ($1000)	Annual Cost ($1000)
100	14.0	8.8
150	17.3	12.0
200	20.0	15.0
250	22.5	17.7
300	25.0	20.5
350	26.5	23.4
400	28.0	26.5
450	29.7	29.2
500	32.0	31.4
550	34.6	34.3
600	37.8	37.6
650	40.9	41.2
700	44.0	45.2

Table IV-39. - KRAFT SMELT-DISSOLVING TANK EMISSION CONTROL COSTS

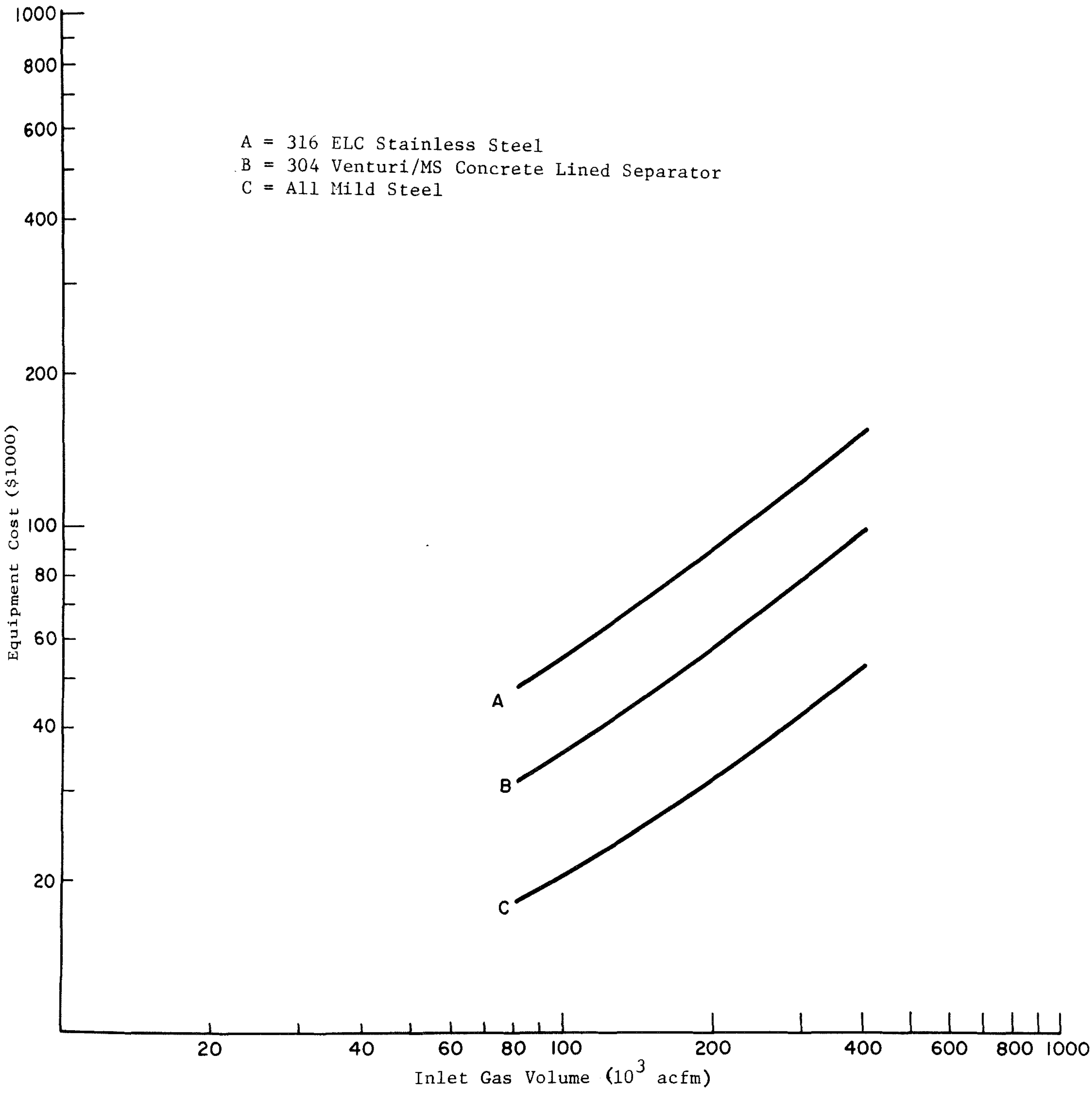
Tank Gas Volume (10^3 acfm)	Associated Capacity (tons/day)*	Investment Cost ($1000)	Annual Cost ($1000)
2.5	80	5.2	2.0
7.5	240	13.0	6.2
12.5	400	17.0	8.5
17.5	560	20.0	10.8
22.5	720	23.2	13.1
27.5	880	25.9	15.3
32.5	1040	28.7	17.6
37.5	1200	31.4	19.9
42.5	1360	34.0	22.1
47.5	1520	36.8	24.4
52.5	1680	39.6	26.7
55.0	1760	41.0	29.7

* Tons of air-dried pulp per day.



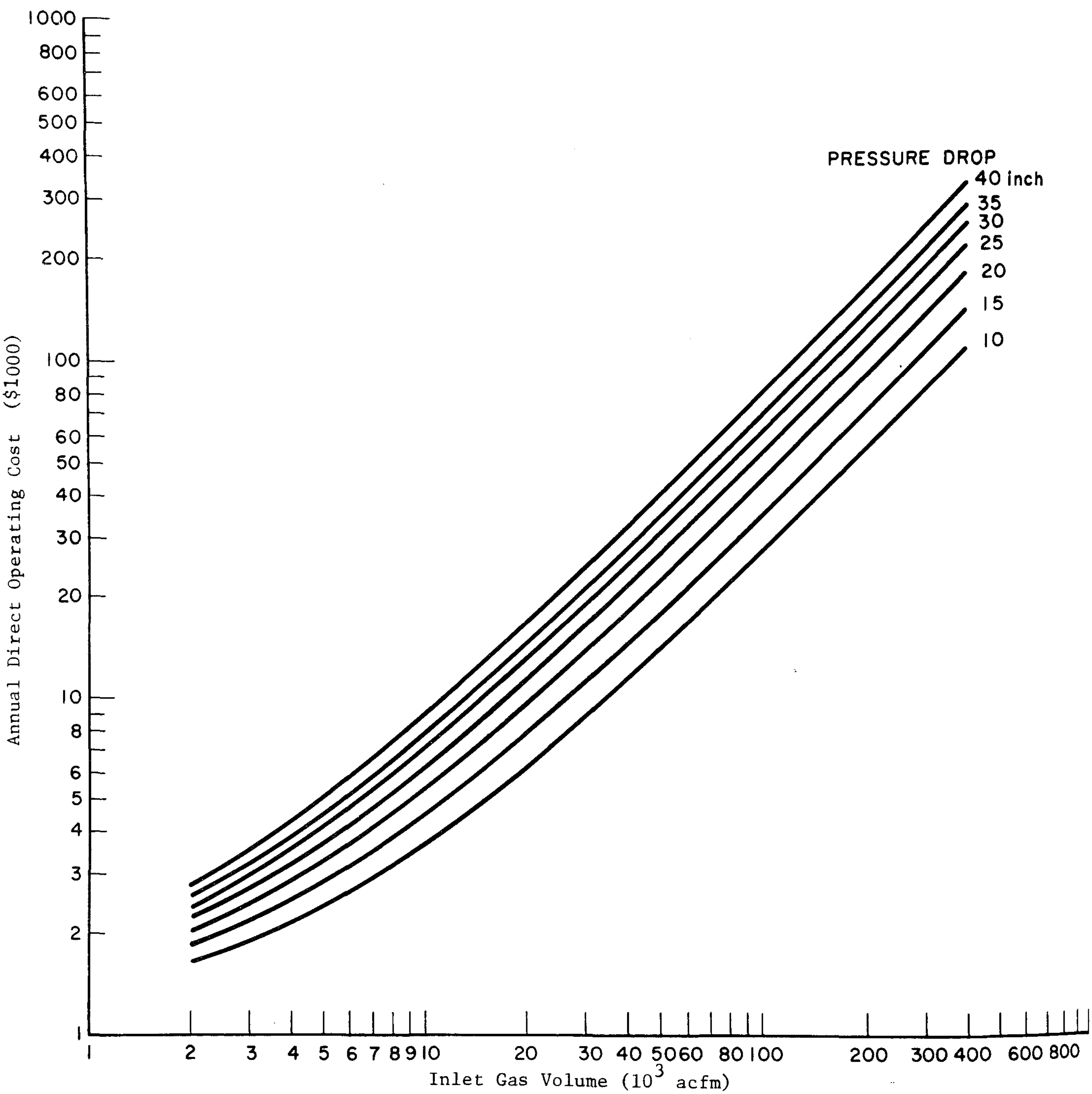
Source: Poly Con Corporation.

Fig. IV-8. Equipment Cost for Venturi Scrubbers.



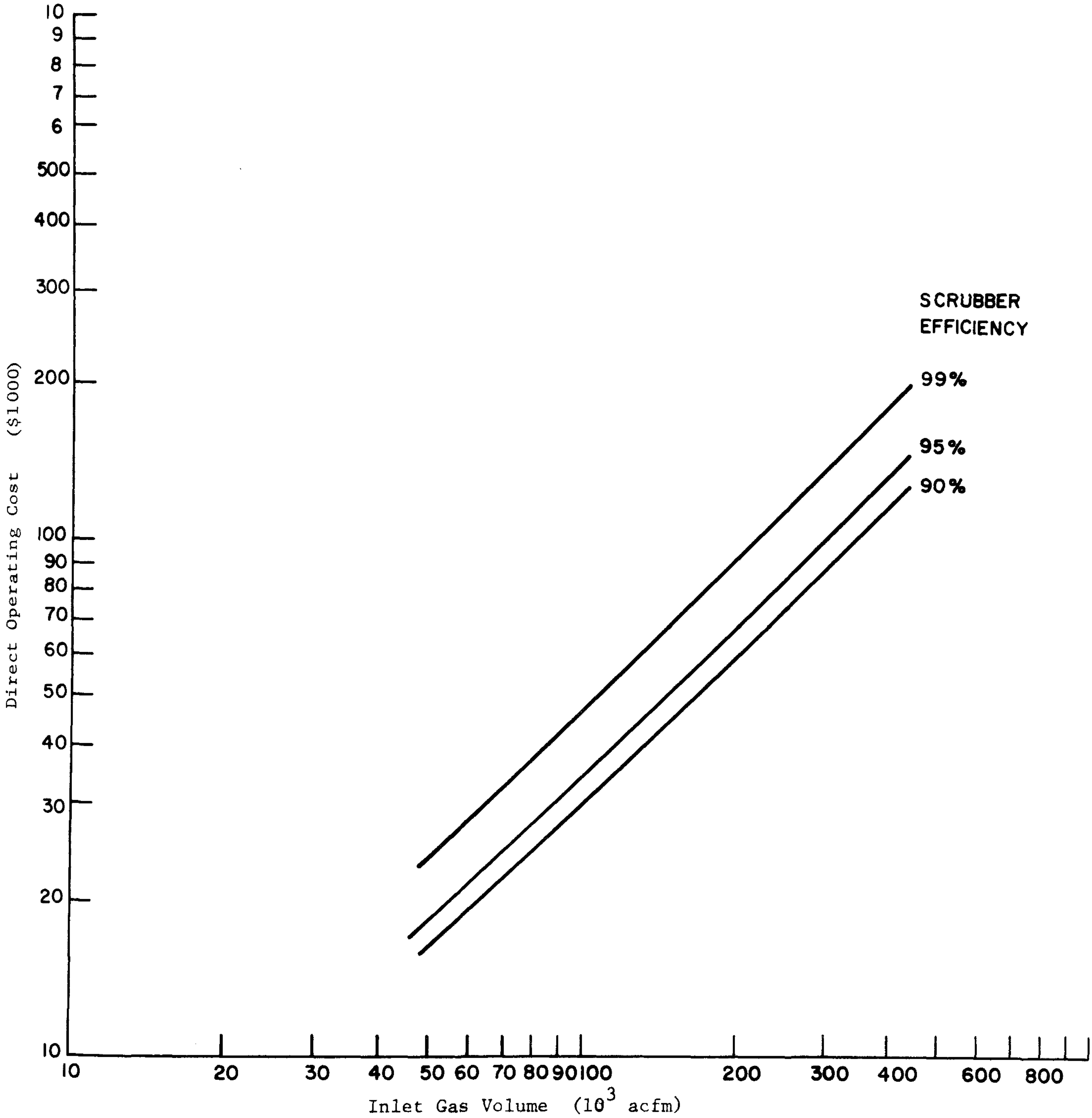
Source: Poly Con Corporation.

Fig. IV-9. Equipment Cost for Venturi Scrubbers.



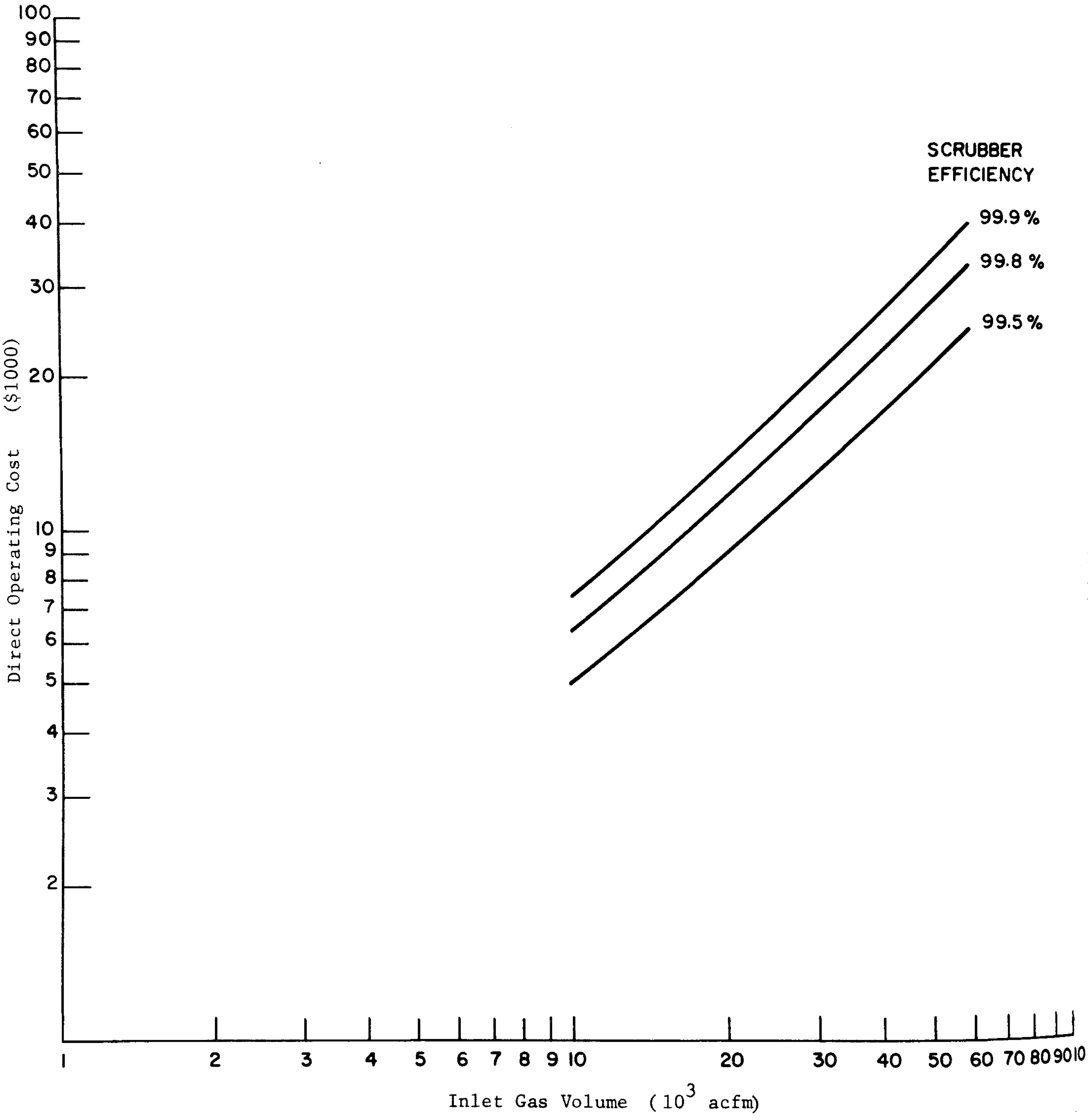
Source: Poly Con Corporation.

Fig. IV-10. Annual Direct Operating Cost for Venturi Scrubbers.



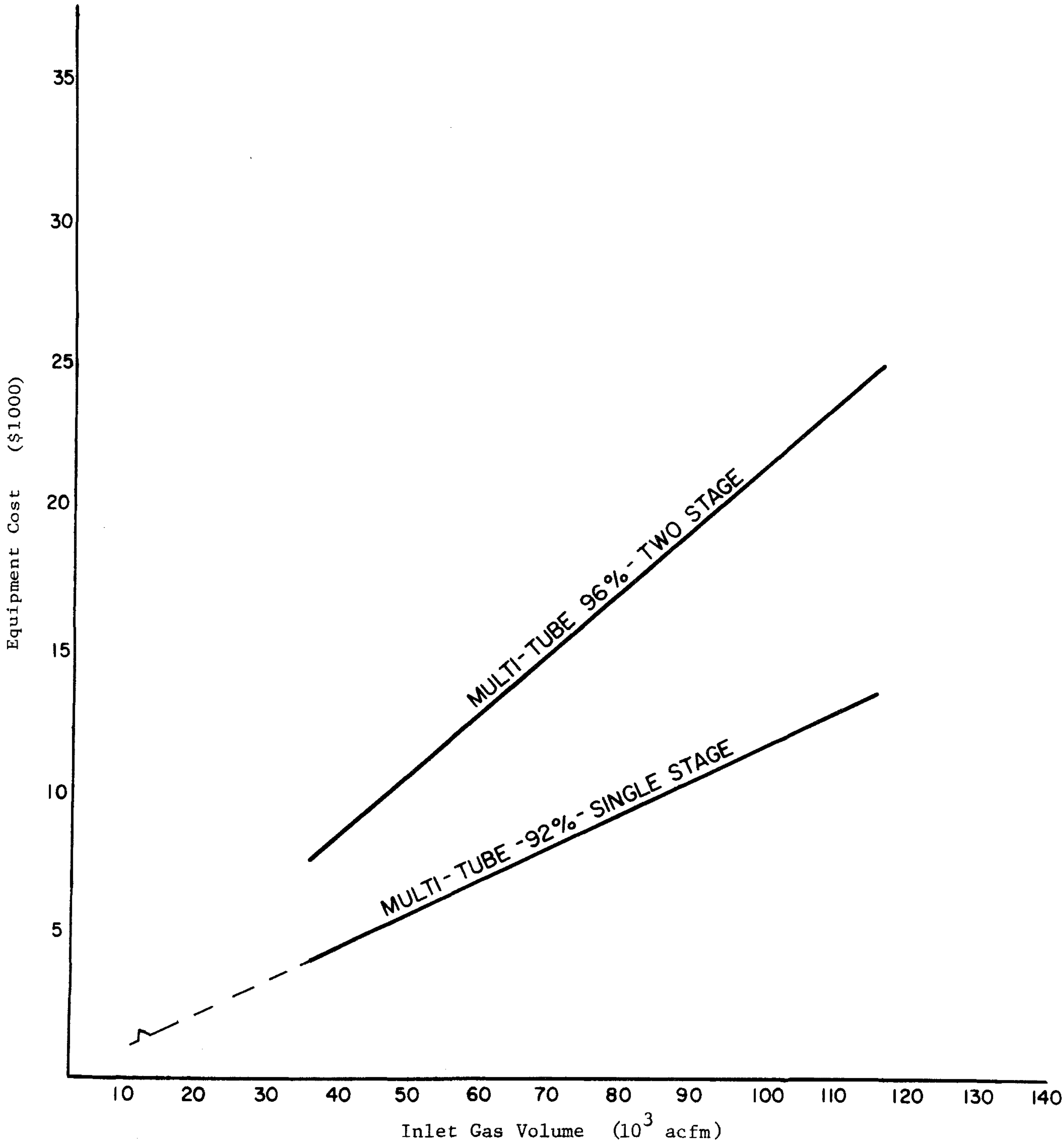
Source: Poly Con Corporation.

Fig. IV-11. Annual Direct Operating Cost for Recovery Boiler Venturi Scrubbers.



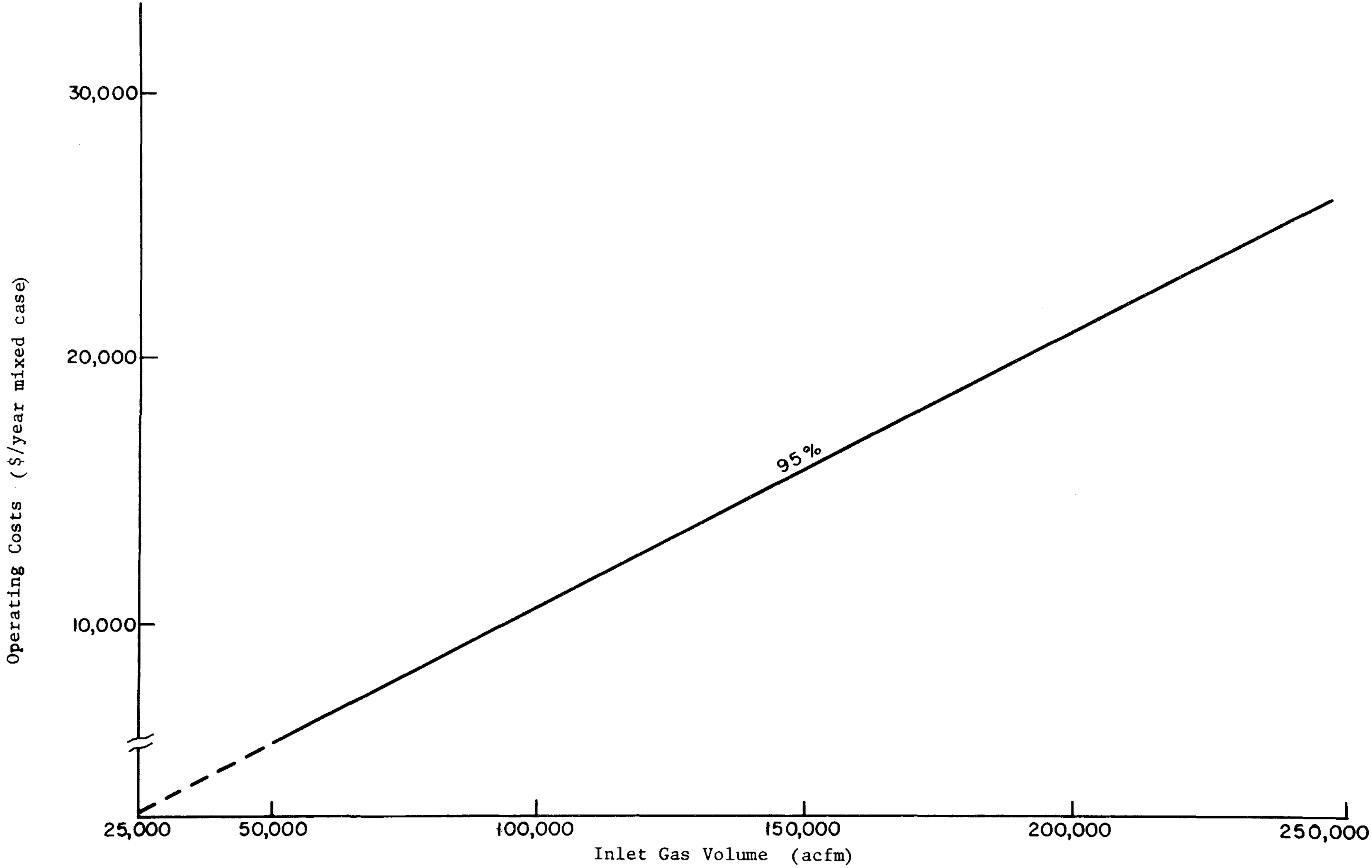
Source: Poly Con Corporation.

Fig. IV-12. Annual Direct Operating Cost for Lime Kiln Venturi Scrubbers.



Source: Poly Con Corporation.

Fig. IV-13. Equipment Cost for Multi-tube Collectors.



Source: Poly Con Corporation.

Fig. IV-14. Annual Operating Cost for Multi-tube Collectors.

Table IV-40. - KRAFT BARK BOILER EMISSION CONTROL COSTS

Boiler Gas Volume (10^3 acfm)	Associated Capacity (tons/day) *	Costs ($1000)	
		Investment	Annual
16	200	13.4	3.5
24	300	18.5	4.3
32	400	23.0	5.1
40	500	33.8	6.1
48	600	40.0	7.0
56	700	43.8	7.8
64	800	49.0	8.6
72	900	53.7	9.4
80	1000	57.5	10.1

* Tons of air-dried pulp per day.

4. Scope and Limitations of Analysis

Open market sale of kraft pulp constitutes a very small part of total production, making the open market reaction to the cost of air pollution control a less than ideal indicator of industry impact. In this case, however, it appears that the market for kraft pulp is in fact a significant supplier of the marginal resource inputs and, therefore, an integral part of the industry rather than an overflow market. On this basis it is assumed that the pulp market reflects cost changes that will affect the entire kraft paper industry.

Analysis of the impact of control costs on price and profit is clouded by the presence in the industry of many firms that produce nonpaper products, including lumber, metal containers, and other diverse products.

5. Structure of the Industry

Kraft pulping is a segment of the ninth largest manufacturing industry in the United States -- the pulp and paper industry (Table IV-41). Most pulp produced by the kraft process (and the other processes as well) is made by integrated companies and consumed by them in the production of paper and paper products. About eight percent of the kraft pulp is marketed, resulting from independent firms without paper making facilities and from integrated firms producing surplus for market.

The availability of raw materials, level of labor costs, and nearness of markets are prime determinants of plant location. The heaviest concentration of kraft plants is in the Southeastern section of the United States. Twenty-four of the 71 Southeastern plants are not, however, in air quality control regions.

Statistics concerning the kraft (sulfate) pulp industry are shown in Table IV-41.

Table IV-41. - 1967 STATISTICS ON THE KRAFT (SULFATE) PULP INDUSTRY

	United States	298 Metropolitan Areas
Number of Plants	116	81
Number of Firms	72	51*
Capacity (Millions of Tons)	32.1	22.5
Production (Millions of Tons)	23.9	16.8
Value of Shipments (Billions of Dollars)	3.6	2.5

* Forty-three firms have all their plants in the 298 metropolitan areas, 8 firms have some, and 21 firms have none.

6. The Market

a. The Competitive Pattern

Production of kraft pulp in the United States is a direct function of the market for the paper and paper products produced from it and it is this market, therefore, that is discussed in this section. A number of large firms operate in the kraft paper industry, but they do not have sufficient market power to dominate the industry. There are a large number of buyers in the market, also, from a broad spectrum of industries providing a highly diversified and competitive market. Prices tend to react freely to relative changes in supply and demand.

A large share of kraft production goes into containers and packaging materials, including wrapping paper, bags, corrugated boxes, frozen food containers, milk cartons, and other food packaging. The industry faces strong competition for these markets from makers of plastic, aluminum, and aluminum foil substitutes. The kraft industry appears to be holding a fairly constant share of this growing market through continued research and development of products adapted to the customers needs. Maintenance of its price position relative to the prices of substitutes is essential if it is to maintain its market share.

Foreign competition is primarily in the form of imported pulp, which amounts to just under 5 percent of U. S. production. Canada supplies approximately 90 percent of imported pulp and has been an important factor in the newsprint and printing paper market. Kraft pulp and paper are exported from the U. S., accounting for over half the industry exports.

b. Trends

The dominant pattern in the industry is the investment price cycle. Although demand has tended to increase fairly steadily, roughly proportional to population growth with less than the national average reflection of the general business cycle, investment in the paper industry tends to follow a five year cycle. At the beginning of the cycle the industry invests heavily and competitively to meet actual and anticipated growth in demand. When new facilities come into production, the industry as a whole is faced with overcapacity. Prices decline as firms compete for markets, profits are depressed, and investment is cut back. As demand catches up to supply, prices increase, profits improve, and new investment is undertaken. This pattern tends to keep profits generally below the average of manufacturing firms in general. The industry appears to be in the rising price phase of the cycle in 1970 and increased investment may be expected in 1971 and 1972, followed by potential excess capacity.

Another important trend of recent years has been to more highly integrated firms and inclusion of kraft paper firms in conglomerates. The small percentage of pulp entering the open market is a good indicator of the extent of vertical integration that has occured.

Paper firms have been diversifying, also, using their land and forest resources to enter the recreation, real estate, and lumber markets. Conversely, firms formerly in the lumber and plywood industries have diversified into paper products as have firms producing competing container products.

7. Economic Impact of Control Costs

a. Cost for Model Plants

In order to illustrate the varying impact of control, two plant sizes and the associated investment and annualized cost are shown below.

Mill Size (tons/day)	Investment	Total Annual Cost	Cost of Control/ton Produced 10/
145	$160,100	$ 61,420	$1.24
1,000	$862,000	$381,550	$1.14

These results assume venturi scrubbers were used to control emissions from the recovery furnaces, lime kilns, and smelt-dissolving tanks. Redesigned multicyclones were assumed to be used to control emissions from the bark boiler. The 145 tons/day mill size was assumed to have one recovery furnace, one lime kiln, one smelt-dissolving tank, and one bark boiler; the 1,000 tons/day mill size was assumed to have two of each of these units, with larger operating capacities.

The costs are not directly proportional to the number of units of equipment to be controlled, but vary according to size as well. About 45 percent of the United States plants approximate the 1,000 tons/day mill size and about 16 percent approximate the 140 ton/day mill size. The costs range from $1.14 to $1.24 per ton of sulfate pulp. These costs are relatively low when compared to the sales price of market pulp, which was about $124 per ton in 1968.

b. Impact on the Industry

Depending primarily on mill size, location, degree of vertical and horizontal integration, and financial position, impact will vary across the industry.

The most severe impact will be on the marginal nonintegrated firms that have all their plants in air quality control regions.

10/ Assuming production at 89 percent of capacity.

Most of the firms are vertically integrated and have some or all of their plants in air quality control regions. These facts, along with the increasing demand for pulp and paper exports, the upward pressure on pulp and paper prices, and the favorable economic position of customer industries, should enable nearly all industry firms to apply controls and pass the control cost on to the customer.

J. Lime

1. Introduction

The basic processes in the production of lime are quarrying limestone (high calcium or dolomitic), preparing the limestone for kilns (crushing and sizing), and calcining the stone. The lime may be processed further by additional crushing and sizing and hydration. In some cases, clam or oyster shells serve as kiln feed. The products of lime manufacturing are limestone, quicklime, and hydrated lime. The product is further classified as high-calcium or dolomitic depending on the percentage of magnesium carbonate present in the raw material. High calcium lime is produced from stone containing at least 95 percent calcium carbonate, while dolomitic lime is produced from limestone containing 30-45 percent of magnesium carbonate. Most hydrated lime is packaged in multi-wall paper bags with very little bulk shipment, while the opposite condition prevails for quicklime. Quicklime is commercially available in these forms: lump, pebble, ground, pulverized, and pelletized. Quicklime is very reactive to water and carbon dioxide and is generally manufactured as it is needed, with very little stockpiling. One hundred pounds of pure calcium carbonate limestone will calcine to 56 pounds of quicklime, which when completely reacted with 18 pounds of water will result in 74 pounds of hydrated lime. The leading uses of open market lime are as steel flux, refractory lime, in construction, and in water softening and treatment. Agricultural lime accounts for approximately 2 percent of sales.

The majority of lime is produced in rotary kilns or shaft (vertical) kilns; both are fired by coal, oil, or gas. Other types of calcinators are in use, but the production from them is considered insignificant compared to the two named above. It is estimated that rotary kilns account for 80 percent of lime produced, with the remaining production coming from vertical kilns. Rotary kilns have the advantages of high production per manhour and uniform quality production but require higher capital investment and have higher unit fuel costs than most vertical kilns. The open market industry trend is toward installation of larger capacity rotaries with a far higher capacity than vertical kilns.

2. Emissions and Costs of Control

Particulate emissions in the form of limestone and lime dust are the main source of pollution from the lime industry. At almost every step of the manufacturing process, dust is emitted. The following processes are involved: drilling holes in the quarry for explosives, blasting, loading stone for transport, transporting the stone (often over unimproved roads), crushing, pulverizing, and vibrating for sizing. At the plant site, limestone is usually moved between operations on open belt conveyors. The lime kiln is probably the major source of particulate emissions at the plant site; the estimates of emissions and control cost given here are limited to kilns, since this is the source for which control is available. Estimates for rotary kilns place the dust emissions at 5 to 15 percent of the weight of the lime produced, while vertical kiln emissions are only about 1 percent of the weight of the lime produced. Combustion of fuels for lime burning is another source of lime plant pollution.

Particulate emissions from plants in the 298 regions in 1967 are estimated to have been 181,000 tons, allowing for an average control level of 60 percent for the industry. Predicted growth of the industry would increase emissions to 253,000 tons by FY 1976 with the control level unchanged. Installation of cyclonic scrubbers on vertical kilns and venturi scrubbers on rotary kilns can achieve 97 percent control of emissions, reducing the FY 1976 emissions to 20,300 tons of particulates. For this sector of the industry, the total annual cost of control by FY 1976 is estimated to be $14.5 million and the investment requirement is estimated to be $10.6 million.

3. Engineering Basis of the Analysis

At the lime plant, the kiln operation is the major source of uncontrolled particulate emissions. Rotary kilns have been found to emit between 5 to 15 percent by weight of the lime produced. Vertical kilns emit significantly less dust, amounting to only about 1 percent of the lime produced. In addition to the emissions from kiln operations, which represent a major portion of dust generated, there are emissions from other operations. Limestone quarrying and transportation cause localized emissions for which efficient solutions are not available. Other than moderately effective dust suppression techniques at the quarry site and improvement of the road from the quarry to the lime plant, little else can be done at present. Limestone crushing and screening operations represent a potentially significant source of particulate emissions. Generally, however, plants which have well constructed buildings with adequate dust ventilation systems enclosing the crushing and screening operations may be considered satisfactorily controlled. This is the case with most modern plants. In older plants which have poorly constructed buildings and inadequate ventilation systems, the dust remains a problem only in the building and the immediate surrounding area. Lime hydrating, processing, and packaging are significant sources of noxious material; however, the use of adequate dust ventilation and control systems is quite widespread in this area of the plant.

Various types of lime kilns are presently used by the industry. Of these, rotary and vertical kilns produce the major percentage of lime and emit the major quantity of particulates. If uncontrolled, rotary kilns emit approximately 200 pounds of particulates per ton of lime produced while vertical kilns emit about 20 pounds of particulates per ton of lime [Ref. 45]. At present, rotary kilns are generally controlled with dry mechanical collectors resulting in average reductions of about 80 percent. Vertical kilns in general are presently uncontrolled. Control efficiencies were calculated to comply with the process weight rate standard. These are shown in Table IV-42.

Control systems to achieve required control limits were selected on the basis of incremental control required as well as on industry experience. For rotary kilns, medium energy (25" w.g.) venturi scrubbers were assumed as the secondary collector. For vertical kilns, cyclonic wet scrubbers (6" w.g.) were chosen as the basis for the control cost estimates. To relate process size to control equipment capacity, the estimated gas volumes shown in Table IV-43 were used.

Table IV-42. - ULTIMATE CONTROL EFFICIENCY REQUIRED

Capacity (tons/day)	Control Efficiency Required (percent)	
	Rotary Kiln	Vertical Kiln
10	N/A*	52.4
50	N/A*	78.6
100	97.8	79.8
200	98.1	83.8
300	98.8	*
400	98.9	*
500	99.2	*
600	99.3	*
700	99.4	*

*Not applicable.

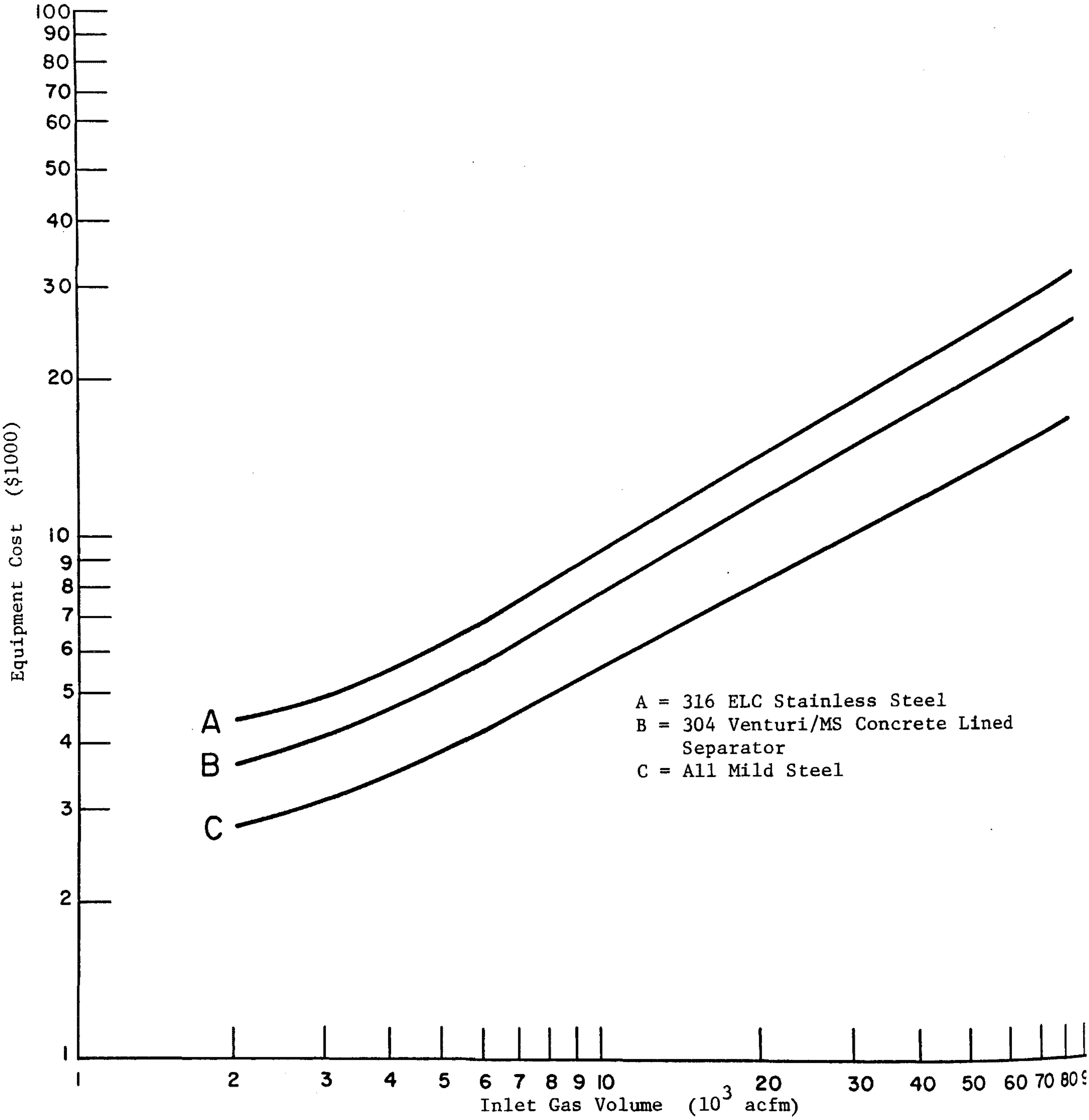
Table IV-43. - LIME KILN GAS VOLUMES

Kiln type	Unit Volume (acfm/ton/hour)
Rotary	5500
Vertical	3200

Adapted from data in A Study of the Lime Industry in the State of Missouri for the Air Conservation Commission of the State of Missouri. Reston, Virginia: Resources Research, Inc., January 1968.

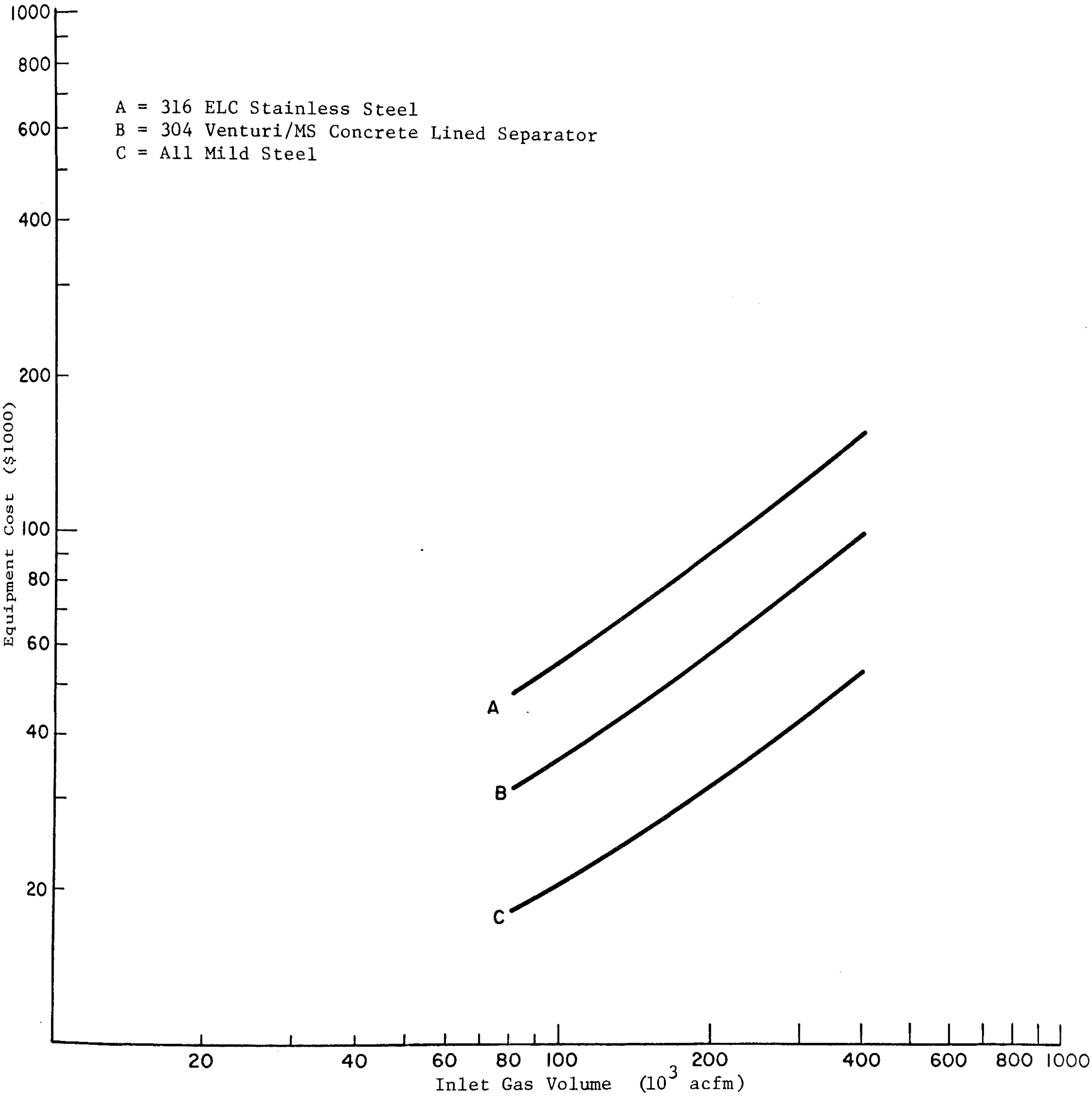
Equipment cost - process size relationships [Ref. 41] for the control equipment selected are presented in Figures IV-15 through IV-19. For both types of equipment, stainless steel was selected as the construction material with an installed cost to equipment cost ratio of two.

The distribution of capacities according to manufacturer's reports of rotary kilns and other data was used to calculate a weighted average



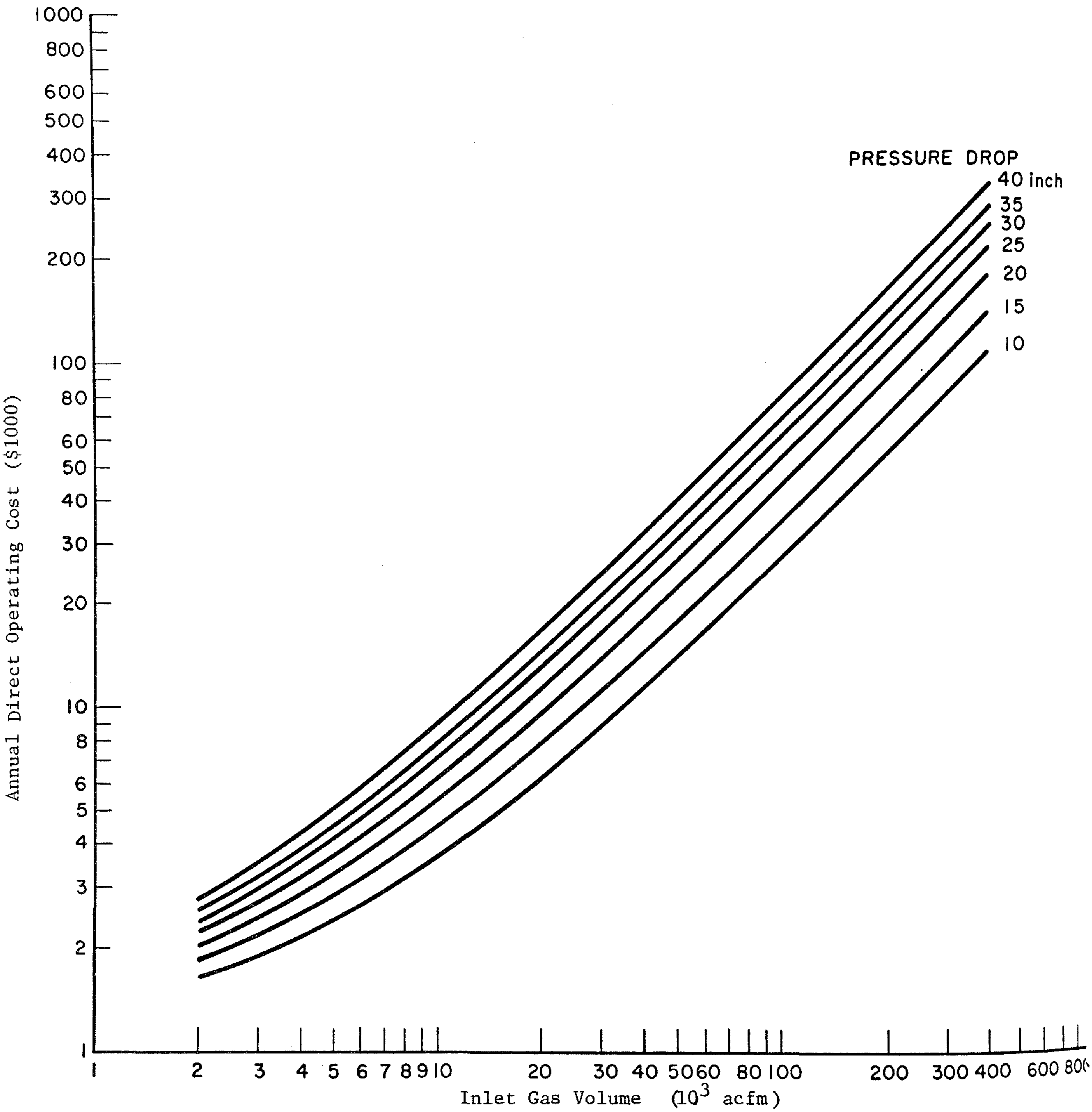
Source: Poly Con Corporation.

Fig. IV-15. Equipment Cost for Venturi Scrubber.



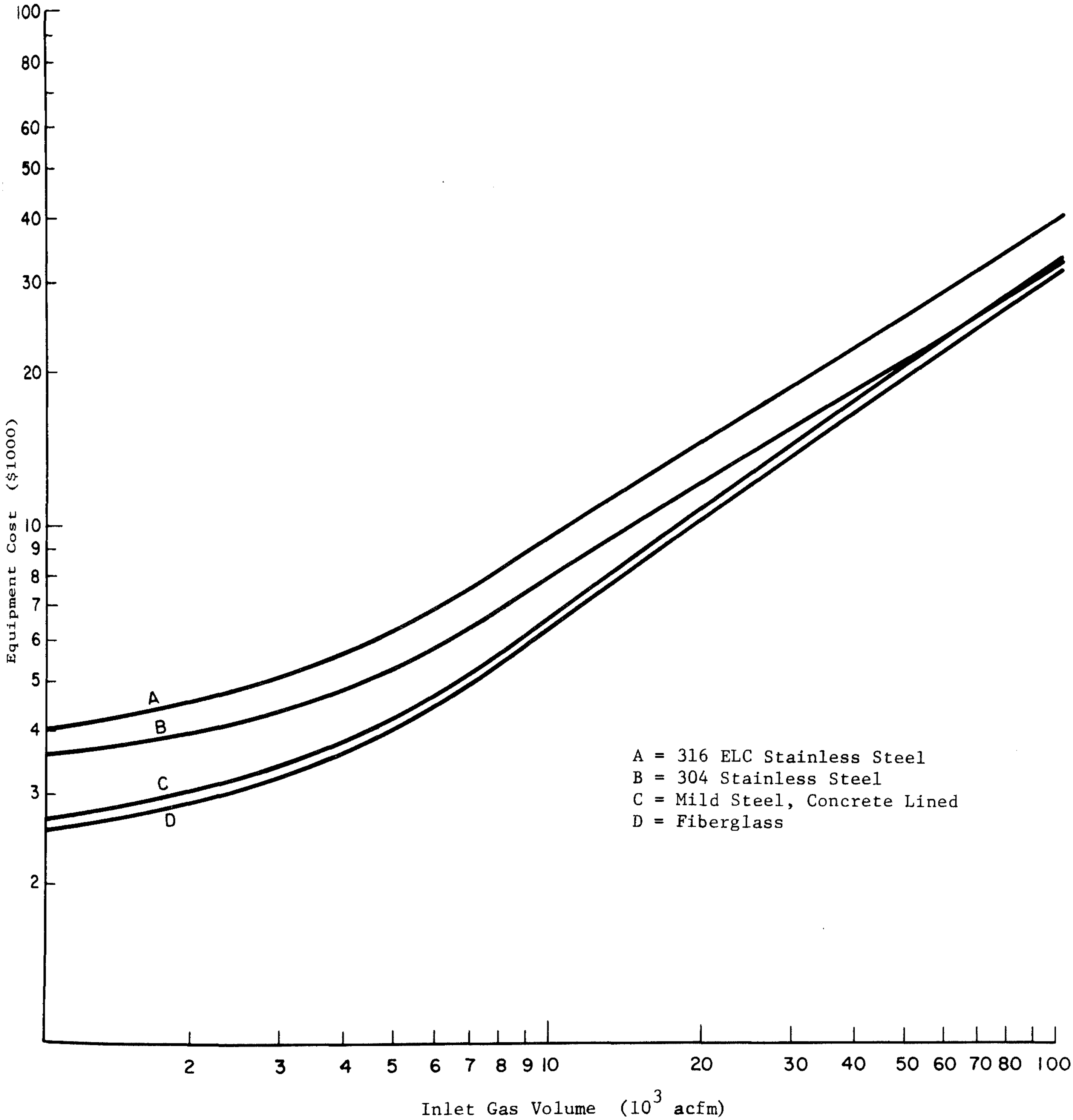
Source: Poly Con Corporation.

Fig. IV-16. Equipment Cost for Venturi Scrubber.



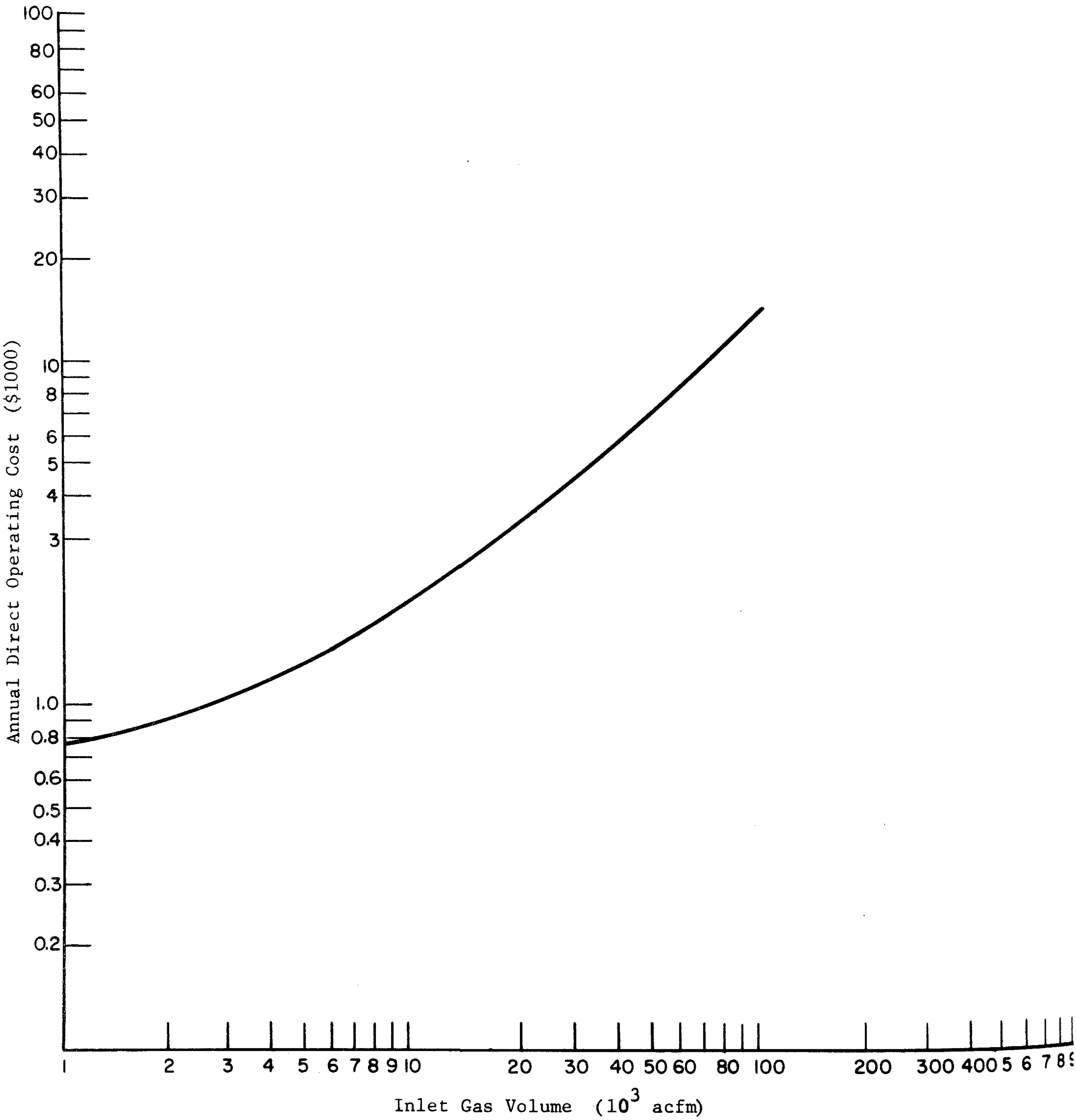
Source: Poly Con Corporation.

Fig. IV-17. Annual Direct Operating Cost for Venturi Scrubbers.



Source: Poly Con Corporation.

Fig. IV-18. Equipment Cost for Cyclonic Scrubbers.



Source: Poly Con Corporation.

Fig. IV-19. Annual Direct Operating Cost for Cyclonic Scrubbers.

cost of control per ton of capacity using the data in Table IV-44. For rotary kilns, the weighted average installed cost was $73.30 per ton of capacity per day, the weighted average annual cost was $102.00 per ton of capacity per day.

Table IV-44. - ROTARY LIME KILN EMISSION CONTROL COSTS

Capacity (tons/day)	Number of Kilns	Installed Cost ($1000)	Annual Cost ($1000)
100	4	14.0	11.8
150	3	17.3	17.6
200	16	20.0	23.2
250	8	22.5	28.5
300	10	25.0	33.9
350	9	26.5	39.4
400	14	28.0	45.1
450	4	29.7	50.4
500	18	32.0	55.2
550	6	34.6	60.7
600	2	37.8	66.6
650	4	40.9	72.7
700	2	44.0	77.2

Since data were not available on the capacity distribution for vertical kilns, the rotary kiln capacities were used to design a known distribution for vertical kilns. The weighted average cost of control per ton of capacity was then calculated using data in Table IV-45.

For vertical kilns, the weighted average installed cost was $179.20 per ton of capacity per day and the weighted average annual cost was $64.20 per ton of capacity per day.

To get the overall average cost per ton of capacity, the two average costs were combined using the known production ratio of 80 percent for rotary and 20 percent for vertical kilns. This cost was multiplied by estimated metropolitan area capacity to get the final control costs for each area.

Table IV-45. - VERTICAL LIME KILN EMISSION CONTROL COSTS

Capacity (tons/day)	Number of Kilns	Installed Cost ($1000)	Annual Cost ($1000)
10	4	5.8	2.0
26	3	7.2	2.8
42	16	9.0	3.1
58	8	11.1	3.9
74	10	13.9	4.9
90	9	17.0	6.2
106	14	20.2	7.3
122	4	22.1	8.0
138	18	23.7	8.5
154	6	24.9	9.0
170	2	26.1	9.3
186	4	27.1	9.7
200	2	28.0	10.0

4. <u>Scope and Limitations of Analysis</u>

The technical and cost analysis in this section deals with the entire lime industry except plants captive to the paper industry. The analysis of economic impact is focused on the firms in the open market, since it is there that the economic effect is most clearly defined. The incidence of the incremental cost resulting from air pollution control in captive plants depends upon the accounting conventions and the ownership form followed between captive and parent company.

For the United States, 121 firms were identified as selling lime in the open market. From the data available it was not possible to determine accurately how many of the plants included within the 298 metropolitan areas were captive, but it may be assumed that the proportion of captive to open market is approximately the same for the 298 areas as for the United States, i.e., 42 percent. Data on revenue and profit by firm or plant were not available.

5. Industry Structure

Since 1963, the United States Bureau of Mines has reported the number of active lime plants in the United States and Puerto Rico which sold lime. These can be considered the open market commercial plants. In the United States and Puerto Rico in 1967, there were 121 active plants which sold lime. There were 185 captive and open market plants in the United States and 113 in the 298 metropolitan areas.[11/] The number of plants has declined significantly since early in the century due to economic changes in the industry, but the decline has leveled off since the beginning of the 1960's, averaging about 124 plants from 1963 to 1968. There may be further slight declines as small producers find it less and less profitable to operate. The opening of new, efficient plants probably will offset the closures and some existing plants will expand their capacity.

There are no complete data on plant size for the open market producers. Examination of available data, primarily Dun and Bradstreet reports and trade journal articles, indicates that plants range in size from 1-4 employees to over 200 employees, with many plants in the 30-70 employee range. Capacity data for the open market producers are equally scarce. Some of the larger producers have been covered in articles in the trade journals and several have reported capacities in the 100-1500 tons per day category. The smallest plants are not reported in the literature but given an employment category of 1-4, it is almost certain that some plants operate with only a single, small capacity (5-20 tons per day) vertical kiln.

It is reported that open market lime is produced in 33 of the 50 states [Ref. 46]. In number of commercial plants, Ohio led the nation in 1967 with 15, followed in order by Pennsylvania with 14, Virginia and Texas each with 9, and California with 6. Sufficient data are not available to rank the states by open market production for 1967, but reports the 1963 ranking as: (1) Ohio, (2) Missouri, (3) Pennsylvania, (4) Virginia, (5) Alabama and (6) Texas. The eastern half of the United States is the location for the majority of producers apparently because of the quality of

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11/ This does not include lime kilns captive to kraft (sulfate) pulp plants.

the lime deposits found there. Open market producers are scattered sparsely throughout the western half of the nation without concentration in any one area except for the California - Southern Nevada area.

Many firms are multi-plant producers. According to a National Lime Association Map, one company had eight plants in operation in 1967 with some other firms operating from three to seven plants.

6. Market

a. Competition Among Sellers

The lime industry is reported to be intensely competitive. This condition may exist largely as a result of the threat of captive lime. Lime producers are constantly faced with the possibility that the buyers of the product may begin producing lime themselves, and many have done so in recent years. About 60 percent of captive production is the inevitable result of the producers' need for an economical source of carbon dioxide and, in some cases, the lime itself; for example, the alkali industry and sugar refineries. Also, much of the captive production is done by industries which normally would purchase lime from a commercial producer, e.g., steel producers and copper smelters.

The competitive pressure is probably most severe in those areas with a number of producers supplying essentially a uniform grade of lime. Additional competitive pressure may result from the desire of firms to attain the higher profit margins usually associated with producing nearer optimum capacity. Quicklime is reactive to atmospheric moisture and should be used quickly--within a month or two--after manufacture. Since any which has been produced and not sold is, of course, subject to becoming waste, the firm would face some pressure to dispose of it.

There may be a few plants in the Midwest which experience little competition in this immediate marketing area due to the sparseness of producers, but even these would face some competition on the outer fringes of their market.

b. Economic Position of Customer Industries

Use as steel flux is the leading single market for lime at present, with over a third of open market lime going for this one use. With the increased use of the basic oxygen furnace (BOF) in the steel industry, expectations are that as much as 40 percent of open market production may go for this use by 1975.

Refractory lime (dead-burned dolomite) for the open hearth steel furnaces, long the leading single use for open market lime, dropped from first place in the early 1960's with the steel industry's change over to the basic oxygen process. The expectation of the industry is that refractory lime will continue to decline in importance as a market for the product as the switch to the BOF continues.
Taken as an industry, construction usages are an important market for lime, with particular promise being held for the use of lime in soil stabilization in highway, parking lot and airport runway construction and in foundations for large buildings. The pulp and paper market continues in importance to the open market lime producers. Increased usage is expected in water treatment and softening and in sewage and trade waste treatment. The calcium carbide and alkalie industries have been declining markets for lime and are expected to continue to deline in importance.

The economic position of the lime consumers appears sound in the immediate future. Optimistic projections prevail for the steel industry, with estimates of 150 million net tons of steel production by 1975. This represents a growth in steel production of approximately 3.9 percent. The pulp and paper industry should also experience favorable economic conditions with new and expanded product lines.

c. Foreign Competition and Markets

United States imports of lime have been declining each year since 1965 when a decade high of 276 thousand tons were imported. In recent years virtually all of the imported lime has been from Canada. The reason for the mid 1960's high import tonnage may have been the sudden demand produced by the steel producers with the increased production of basic oxygen furnaces. Domestic producers were not able immediately to meet all the demand with existing capacity and widespread expansion in the lime industry can be seen following 1965. As United States capacity began to reach adequate levels to supply the steel industry, the need to import lime was reduced. Foreign competition in lime should not be a problem to the industry in the early 1970's since the increased capacity of United States producers appears adequate to supply the known markets. The only chance of foreign gains would be in the event of the opening of a sudden, wide market for lime. Some imports can be expected to continue since there are Canadian producers closer to certain United States markets than any United States producer. This is the case in the far Northeast, and generally along the United States Canadian border. Also, there are a number of Canadian producers in Ontario who must be considered competitors in the Ohio-Michigan-Pennsylvania marketing area.

The export market for United States lime does not appear significant. The 1968 data indicate that exports that year were 69,000 tons, about 1/2 percent of United States open market lime sold. As might be expected, most exports go to Mexico and Canada; the two countries combined receive 80-90 percent of United States export lime.

7. Trends

a. Production

The production of open market lime in the United States and Puerto Rico increased from 8,190 thousand tons in 1960 to 12,100 thousand tons in 1968, an increase of about 48 percent. This large increase in production was spurred by several new and expanded uses of the product and follows a decade of rather lacklustre performance by the industry. In 1967, open market production was 11,500 thousand tons, 40 percent above the 1960 level. The remarkable growth of the lime industry in the 1960's was a result of increased use of basic oxygen furnaces in the steel industry, with the associated higher levels of lime usage per ton of steel produced. The open hearth furnaces require about 20 pounds of lime for each ton of steel produced, while the basic oxygen process needs about 150 pounds of lime for each ton of steel produced. Increased usage of lime was also seen in soil stabilization, sewage and water treatment, and water softening. Optimism prevails in the industry and open market production is expected to continue to grow at a healthy pace into the seventies.

b. Price

Price data for open market lime are available in Bureau of Mines Reports only for 1963-68. During this period, the national average f.o.b. plant price of lime without containers declined from $14.47 per ton to $13.71 per ton, a drop of 5.3 percent. Although not certain, this depression in the price level may partially be the results of hard bargaining by steel firms for lower prices. This trend did not hold in all areas during the period, however. In Texas, the f.o.b. plant price of lime rose from $10.94 per ton in 1963 to $12.63 per ton in 1968, a 15 percent increase. The available data indicate that a declining price trend existed in a number of major producing states: Michigan, Ohio, Pennsylvania, and California. Continuation of depressed prices is unlikely in the face of rising production costs, however. The average f.o.b. plant price of lime sold increased marginally between 1967 and 1968, from $13.68 per ton to $13.71 per ton. The price trend may turn up after initial competition for the steel business.

Another contributing factor to lower prices in most areas may have been that a number of new efficient plants went on line during this period, as well as new capacity at established firms. There is a definite trend toward larger plants, and the economies acheived with the newer, higher capacity kilns may have resulted in downward pressure on prices.

c. Technology

Technological advances usually come from outside the industry proper. Sources of advancement are equipment manufacturers, industrial users of lime, and fellowships supported by the National Lime Association. In the last category there have been research fellowships dealing with lime use in soils stabilization, asphalt paving, masonry mortars, autoclaved concrete products, steel fluxing, acid neutralization, trade-waste treatment, and agricultural lining. The National Lime Association was instrumental in the market development and promotion of lime as a soils stabilization agent. This is now one of the most promising markets for the product. Continued research and development by equipment manufacturers have led to higher capacity thermally efficient kilns, both vertical and rotary. Industry spokesmen continue to stress the need for increased research, development, and marketing efforts by those in the industry, but without much effect. Even during relatively prosperous periods, the industry seems unwilling to invest in adequate research to insure continued vitality; the reluctance has been even more pronounced in the past during less prosperous periods. Low profit margins have been blamed as the reason for lack of research.

8. Economic Impact of Control Costs

a. Control Cost Factors

The investment required and the annual cost of control equipment varies according to the size and type of kiln. In 1967 a typical vertical kiln of approximately 100 tons per day capacity would require a cyclonic scrubber with an installed cost of approximately $20,000 and the annual cost, including depreciation, finance costs, and operating expenses, would be approximately $7,300 per year. A typical rotary kiln will be somewhat larger, with a capacity of approximately 400 tons per day. This would require a venturi scrubber with an installed cost, in 1967 prices, of just under $30,000 and an annual cost of approximately $45,000. Overall, for the captive and open market plants in the 298 metropolitan areas, average investment is estimated at $67,000 per plant and average annual cost at $92,000 per plant in 1967.

b. Model Firms, As Examples

Costs of controlling particulate emissions from lime kilns have been estimated for five model firms. The model firms were constructed to illustrate the costs to be encountered by firms with production solely from vertical kilns, solely from rotary kilns, and a combination of both types of kilns, with the firms spread over a wide capacity range.

Model Firm #1 - A very small single-plant lime firm with production entirely from low capacity vertical kilns.

Kilns: 4 vertical kilns rated at 15 tons/day (TPD) capacity each.

Plant capacity: 60 TPD.

Annual costs of control: $2,500.

Assuming the industry preferred operating rate of 92 percent for FY 1976, and 300 producing days per year, production of this plant would be 16,550 tons of lime.

Annual cost per ton of production = $0.15.

Model Firm #2 - A medium-sized, single-plant firm with production entirely from a rotary kiln.

Kiln: 1 rotary kiln rated at 200 TPD capacity.

Annual costs of control: $33,000.

Annual production: 55,200 tons.

Annual cost per ton of production: $0.60.

Model Firm #3 - A medium-sized, single plant firm with capacity comparable to Model Firm #2, but utilizing modern vertical kilns.

Kilns: 2 vertical kilns rated at 100 TPD capacity each.

Plant capacity: 200 TPD.

Annual costs of control: $12,600.

Annual production: 55,200 tons.

Annual cost per ton of production: $0.23

Model Firm #4 - A large, single-plant firm with production from both high capacity rotary kilns and modern vertical kilns.

Kilns: 2 rotary kilns rated at 400 TPD capacity each.
2 vertical kilns rated at 125 TPD capacity each.

Plant capacity: 1,050 TPD.

Annual costs of control: $151,800.

Annual production: 289,800 tons.

Annual cost per ton of production: $0.52.

Model Firm #5 - A large, multi-plant firm with production primarily from high capacity rotary kilns.

Kilns: Plant #1: 1 rotary kiln rated at 300 TPD capacity.
Plant #2: 1 rotary kiln rated at 350 TPD capacity.
1 rotary kiln rated at 500 TPD capacity.
2 rotary kilns rated at 250 TPD capacity each.
Plant #3: 6 vertical kilns rated at 50 TPD capacity each.
1 rotary kiln rated at 400 TPD capacity.

Firm capacity: 2,350 TPD.

Annual costs of control: $355,400.

Annual production: 648,600 tons.

Annual cost per ton of capacity = $0.55.

c. Demand Elasticity and Cost Shifting

Based on available information, there seems little reason to believe that costs of particulate emission control can be passed on to buyers of lime. The overall market for lime has been increasing in recent years and in most applications there exists no suitable substitutes at anywhere near comparable prices. Lime has faced competition or replacement from the products in a few markets, primarily agricultural and construction users, however, and price increases would almost certainly weaken lime's competitive position in these markets. The exceptions to this may be in cases of isolated producers who are not faced with competition in their immediate marketing areas. Competition in the industry is characterized as very severe, and it seems unlikely that a producer will increase his price in the face of competition from other producers in the marketing area who are not faced with control costs. This condition of forced absorption of costs is most likely to occur in those areas with a large number of producers, many of whom are not in the 298 metropolitan areas.

Lime is both a raw material input to manufacturing processes and a final product. It is possible, then, that in the latter case, some reduced demand may result from a price increase, aside from the losses due to substitute availability.

It is generally true that costs per ton of production decrease as the operating ratio increases, and that economies of scale usually insure that larger plants have lower unit costs than smaller plants. It is estimated that for 1964, the range of manufacturing costs for a short ton of quicklime is from a minimum of $6.05 to a maximum of $16.25. This would imply that the profitability range is also quite wide.

Estimates reveal that the highest annual control costs per unit of production will be experienced by plants with very small (less than 15 TPD capacity) vertical kilns, but that plants with larger vertical kilns (15 TPD and over) will experience the lowest annual control costs per unit of output. Except at the very low end of the rotary capacity scale (100-175 TPD), rotary kiln annual control cost per unit of output is almost constant.

In some marketing areas, the existing competitive structure may no longer hold, since some firms will not face control at all and others may find their competitive positions improved in relation to other controlled firms that experience higher unit control costs. A firm may find its marketing area expanded or contracted as a result of the imposition of controls.

d. Effect on the Industry

The imposition of controls on particulate emissions may have a number of short-and-long-range effects on the lime industry.

One immediate effect is likely to be a reduction in industry capacity as very small vertical kilns facing high control costs are abandoned. The number of open market firms may be further reduced by the closure of marginally operating plants of any size, which cannot absorb the costs of control equipment. To compensate for the loss of this capacity, production will be increased from the larger kilns and the industry operating ratio will increase. Firms which had been operating close to capacity may launch an expansion program as a result of lost capacity.

A second effect of control may be a renewed interest in the use of vertical kilns. The lower relative costs associated with controlling the large vertical kilns coupled with their excellent thermal properties and lower investment costs may make them more desirable in some applications. It may be that the trend toward high capacity rotary kilns will be slowed somewhat.

A third effect on the industry could be an increased emphasis on applied research in an attempt to recoup the costs of control by lowering other production costs.

The open market lime industry may benefit somewhat by the imposition of control costs. Captive lime plants have always been a problem to open market firms and each year captive production has increased, representing 35-40 percent of total lime produced. The added production cost of emission control may make captive production of lime less desirable for those industries needing large amounts of lime - most notably steel and pulp and paper. More of those firms buying open market lime may continue to do so than would have been the case before the addition of control costs. Further, a situation can be hypothesized in which a captive lime producer may, when faced with control costs, choose to reduce or discontinue entirely the manufacture of lime and begin purchasing from open market producers.

Control costs will add momentum to the current trend toward larger plants. Increased costs of labor, fuel and equipment have made it more economical to operate on a large scale, and the additional burden of controlling emissions will make economies of scale even more important.

K. Petroleum Refining and Storage

1. Introduction

Three processes in petroleum refining have been identified as sources of pollutant emissions. These are storage of crude oil or refined products, combustion processes, and catalyst regeneration. In addition, significant emissions are released by certain bulk storage tanks where petroleum products are stored for distribution. The analysis in this section is limited to the nature, control, and costs of these four sources.

2. Emissions and Costs of Control

At a refinery, both crude oil and refined products, especially gasoline, tend to give off hydrocarbon emissions due to evaporation while being held in storage tanks and in transfer. In addition, significant hydrocarbon emissions result from the operation of catalytic crackers. For the 199 refineries identified as being within the 298 metropolitan areas in 1967, it is estimated that these hydrocarbon emissions amounted to approximately 810,000 tons in that year taking into account existing carbon monoxide boilers on catalytic crackers and assuming that 75 percent of all refinery tanks were controlled by floating conservation roofs and submerged fill lines. If this level of control were maintained, it is estimated that industry growth would cause emissions from this source to increase to 996,000 tons per year in Fiscal Year 1976. Installation of floating roofs on all refinery tanks within the 298 metropolitan areas and installing carbon monoxide boilers where needed would reduce Fiscal Year 1976 emissions to 529,000 tons, the maximum control effectiveness (87 percent) feasible with present technology.

Sulfur oxide emissions from hydrogen sulfide combustion operations in refineries are best controlled by use of sulfur recovery plants. The available data indicate that 67 of the 199 refineries had sulfur plants in 1967. Thus, the 199 plants emitted 1,750,000 tons of sulfur oxides per year and it is estimated that industry growth would increase this to 2,150,000 tons by Fiscal Year 1976 with the same 37 percent level of control. Installation of sulfur plants on all refineries subject to regulation could reduce the Fiscal Year 1976 emissions of sulfur oxides to 1,270,000 tons per year, which is a 62 percent level of control. The remaining sulfur oxide emissions result from operations involving the combustion of natural gas and/or fuel oils for process purposes. These are not generally amenable to control.

Regeneration of the catalysts used in fluid catalytic cracking units results in emission of particulates and carbon monoxide. Catalyst fines are entrained in the off-gasses from the regenerator. Some of these are collected and returned by normal process equipment, but an estimated 0.10 pounds of particulates per ton of catalyst processed is emitted in the absence of air pollution control equipment. Installation of electrostatic precipitators provides the maximum control now available. In 1967, the regenerators in the refineries in the metropolitan areas emitted an estimated 80,000 tons of particulates at an average industry control level of 67 percent. Normal growth of the industry would increase this to 98,300 tons by Fiscal Year 1976. Installation of precipitators in all plants would reduce Fiscal Year 1976 emissions to 30,700 tons.

Carbon monoxide in the exit gas of regenerators was controlled by use of a carbon monoxide boiler in 70 refineries in the 298 metropolitan areas in 1967, but there was still an estimated 5,300,000 tons of carbon monoxide emissions in that year (47 percent controlled). The carbon monoxide boiler burns the carbon monoxide into carbon dioxide and provides a substantial source of heat for process use, in addition to controlling pollution. Installed in all the subject refineries they would control all but a negligible amount of carbon monoxide emissions. Without this control, it is estimated that carbon monoxide emissions would increase to 6,620,000 tons per year in FY 1976.

Within the complex system for wholesale distribution of petroleum products around the country, there are approximately 15,000 storage plants located within the 298 metropolitan areas. The storage tanks in these plants are potential sources of hydrocarbon emissions if uncontrolled. All storage tanks in California and approximately 75 percent of the remainder in the United States were controlled by use of floating roofs.

Emissions from the uncontrolled tanks in metropolitan areas were estimated at 600,000 tons of hydrocarbons in 1967, projected to grow to 738,000 tons per year by Fiscal Year 1976. Installation of floating roofs on all uncontrolled tanks could reduce the Fiscal Year 1976 emissions to approximately 320,000 tons per year.

By Fiscal Year 1976, the investment requirement for petroleum refining will be $162.0 million and the annual cost will be $7.1 million. With these expenditures, emission control levels can be expected to be about 90 percent for particulates, 62 percent for sulfur oxides, 95 percent for carbon monoxide and 87 percent for hydorcarbons.

With the installation of floating roofs that practically eliminate evaporation, the annual cost of the petroleum storage industry is considered negligible. By fiscal Year 1976, the investment requirement will be $1,082.0 million. The associated hydrocarbon emission control levels approximate 63 percent in 1967 and would be about 86 percent in Fiscal Year 1976.

3. Engineering Basis of the Analysis

a. Petroleum Refining

1) Crude Oil and Gasoline Storage

The total crude oil storage capacity for each refinery was based on a 24.4-day refinery supply, and gasoline storage capacity was based on 25 days production [Ref. 25]. A model tank size of 80 thousand barrels was selected, and the total storage capacity in each region (based on refinery capacities) was divided by 80 thousand to determine the equivalent number of model tanks in the 298 metropolitan areas. The fractional capacity remaining after accounting for all the model tanks was costed as a separate item and added to the model plant costs. Three-fourths of these tanks were assumed already to have floating roofs and submerged fill lines; therefore, no further control was required. Since the cost for converting to a floating roof tank and installing submerged filling techniques was considerably less than installing a new tank, it was assumed that all tanks would be converted and not replaced.

Figure IV-20 presents the data used to determine tank conversion costs. The tank size of 80 thousand barrels was chosen as the average based on talks with various knowledgeable people [Refs. 47 and 48] and personal observation of refinery tank farms. Operating and maintenance costs were not determined since these are low and are usually equal to or less than the value of the recovered gasoline and crude oil.

Emissions of hydrocarbons result from refinery activities including crude oil storage, gasoline storage, and gasoline transfer. The emission factors and percent control attainable with current technology is shown in Table IV-46.

Table IV-46. - PETROLEUM STORAGE EMISSION FACTORS*

Receptacle	Description and Controls	Emissions: Breathing Loss (tons/yr/1000 bbls)	Emissions: Working Loss (tons/1000 bbls)
Tank	Fixed roof, w/vapor recovery	-0-	-0-
	Fixed roof, w.o. vapor recovery, splash fill	F_a = 8.5	F_b = 0.242
	Fixed roof, w.o. vapor recovery, submerge fill	F_a = 8.5	F_e = 0.152
	Conservation, w/vapor recovery	-0-	-0-
	Conservation, w.o. vapor recovery	F_d = 0.87	-0-
Tank Vehicle	w/vapor recovery	-0-	-0-
	w.o. vapor recovery splash fill	-0-	F_c = 0.172
	w.o. vapor recovery submerge fill	-0-	F_f = 0.102

* All emission factors are from Ref. 14 except where emission factor is listed as zero (-0-), such factor is the result of independent engineering analysis.

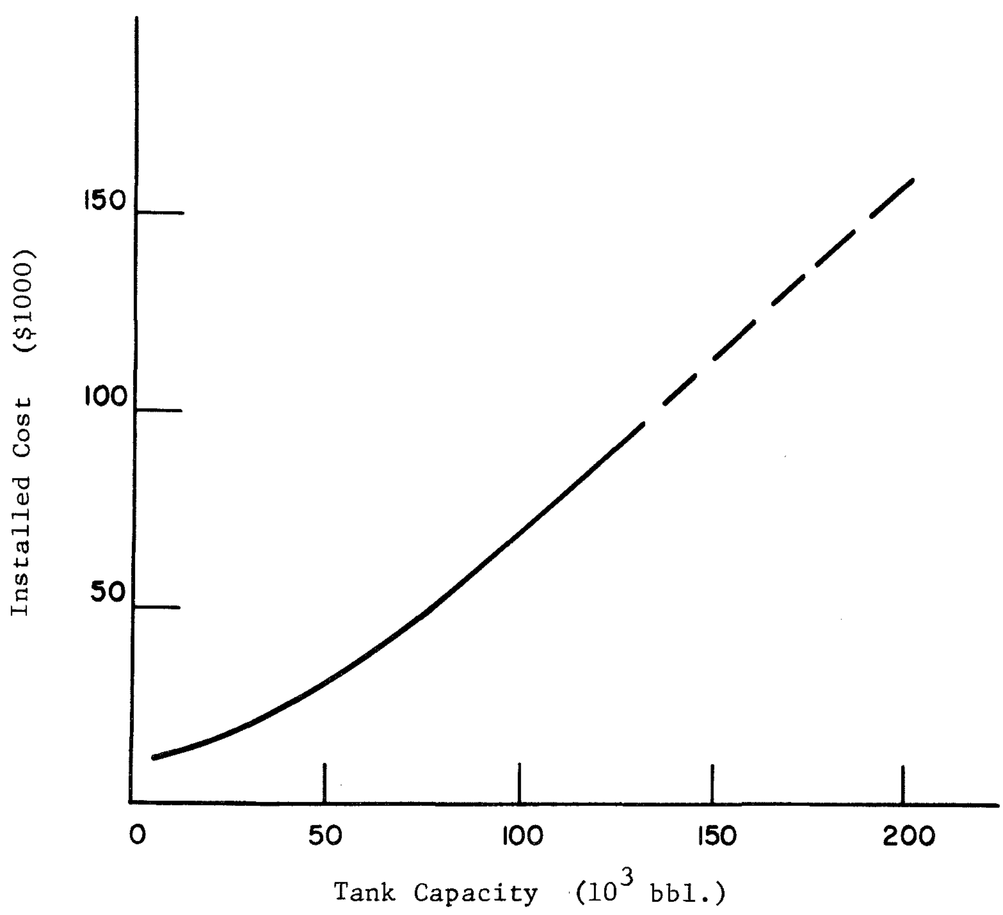


Fig. IV-20. Installed Cost of Floating Roofs on Petroleum Storage Tanks.

In determining current emissions, the following assumptions were made for each refinery:

a) Three-fourths of all crude oil storage tanks are controlled [Ref. 14].

b) Three-fourths of all gasoline storage tanks are controlled [Ref. 14].

c) One-half of all gasoline transfer operations are controlled [Ref. 14].

d) All gasoline produced is transferred to refinery storage tanks.

e) Thirteen percent of gasoline is transferred to bulk plants by pipeline.

f) All gasoline storage facilities are utilized to 60 percent of capacity.

g) Gasoline production is 51 percent of crude oil input.

h) All storage facilities in California are fully controlled.

2) Sulfur Recovery Plants

Sulfur oxide emissions were controlled by installing sulfur recovery plants at those refineries which did not already have them. The size of the sulfur recovery plants was based on each refinery's capacity and on estimated sulfur oxide emissions.

Figure IV-21 presents sulfur recovery plant costs based on information obtained from References 49,50, and 51. Existing sulfur plant locations were also obtained from these references.

Since specific data on the composition of a refinery's crude oil or its exact processing techniques were not available, a general sulfur dioxide emission factor of 50 tons per 100 thousand barrels of crude oil throughput was used [Ref. 52]. Variations in this emission factor were made based on crude oil sulfur content. Thus, in the Gulf Coast and California areas, this factor was reduced by 6 percent; on the East Coast it was increased by 42 percent; and it

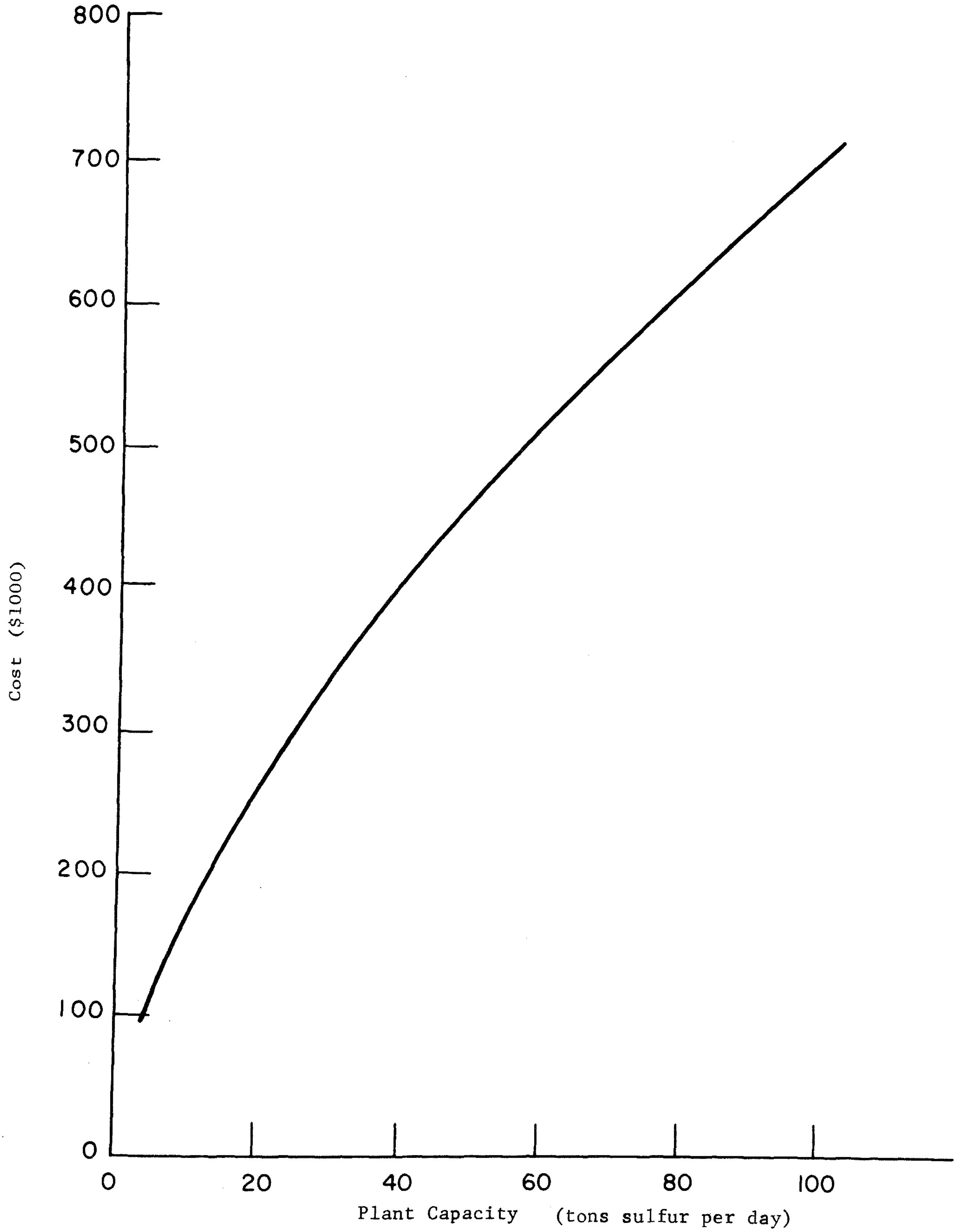


Fig. IV-21. **Sulfur Recovery Plant Costs.**

was not changed for the balance of the country. Only 58 percent of this emission is amenable to recovery in a sulfur plant [Ref. 53]. Since operation of sulfur plants smaller than 4 tons per day is not economically feasible, the smaller refineries (sulfur dioxide emissions less than 13.8 tons per day) were not included in the cost estimates.

3) Catalyst Regenerators

To meet the particulate regulation, only fluid catalytic cracking (FCC) units larger than 10 thousand barrels per day required additional controls. All smaller FCC units and all Thermofor (TCC) and Houdriflow (HCC) catalytic cracking units can meet the regulations with existing controls. In addition, all FCC units requiring control were costed separately, and the total metropolitan area cost was simply the sum of the FCC control costs within that area. Control costs were based on using a high-efficiency electrostatic precipitator; operating and maintenance costs were based on the size of the unit; and a 20 percent capital plus depreciation charge was used to derive the annual costs.

For controlling carbon monoxide and hydrocarbon emissions, the cost of a carbon monoxide (CO) boiler was estimated for each FCC unit. The HCC units located in the 298 areas already have CO boilers, and TCC units with their lower CO emissions are not generally amenable to control with a CO boiler and were not included in the cost estimate. Only 50 percent of the capital investment for these boilers was charged as an air pollution control cost since steam is generated in these units for inplant purposes [Ref. 54]. Annual charges were also not included as an air pollution cost since they are a general plant cost.

CO boiler costs were estimated according to the heat content of the exit gas stream and the available boiler cost data [Refs. 55 and 56]. Locations of existing CO boilers, when known, were taken into account. However, on a nationwide basis, approximately 25 boilers could not be located.

Sulfur dioxide is also emitted at concentrations in the 500-1000 ppm range, but these emissions are currently not controlled since it is claimed that no economical means exist for reducing this emission.

Precipitator costs were based on the gas flow rate leaving the catalyst regenerator. Based on limited data [Refs. 15, 55, and 57], the following relationship between barrels of total feed and exit gas rate was determined:

$$\text{acfm} = \frac{2830 \text{ acfm}}{1000 \text{ bbl/day}} \times \text{feed rate (in 1000 bbl/day)} + 75{,}000 \text{ acfm} .$$

With the exit gas rate known, cost functions relating cost and feed rate were prepared and used to determine total and annual charges [Ref. 6]. (See Figure IV-22.)

Emissions of particulates from FCC units with normal process controls, but without electrostatic precipitators for air pollution abatement purposes, were based on 6.25 pounds of particulate per 1000 barrels;[12/] particulate emissions from Thermofor and Houdriflow units were based on 0.52 pounds per 1000 barrels.[13/] Estimates of controlled emissions were based on an electrostatic precipitator collection efficiency of 82 percent.

CO boiler costs are shown in Figure IV-23. These costs could vary depending on the amount of supplementary fuel used to generate plant steam; however, the costs shown do represent that portion of the cost chargeable to air pollution control.

12/ FCC units emit 0.10 pounds particulate per ton of catalyst [Refs. 15 and 58].

$$\frac{0.10 \text{ lb part.}}{\text{ton catalyst}} \times \frac{62.5 \text{ ton catalyst}}{1000 \text{ bbl total feed}} = 6.25 \text{ lb part. per 1000 bbl}$$

13/ TCC and HCC units emit 0.04 pound particulate per ton of catalyst [Refs. 6 and 56].

$$\frac{0.04 \text{ lb part.}}{\text{ton catalyst}} \times \frac{13 \text{ ton catalyst}}{1000 \text{ bbl total feed}} = \text{0.52 lb part. per 1000 bbl total feed.}$$

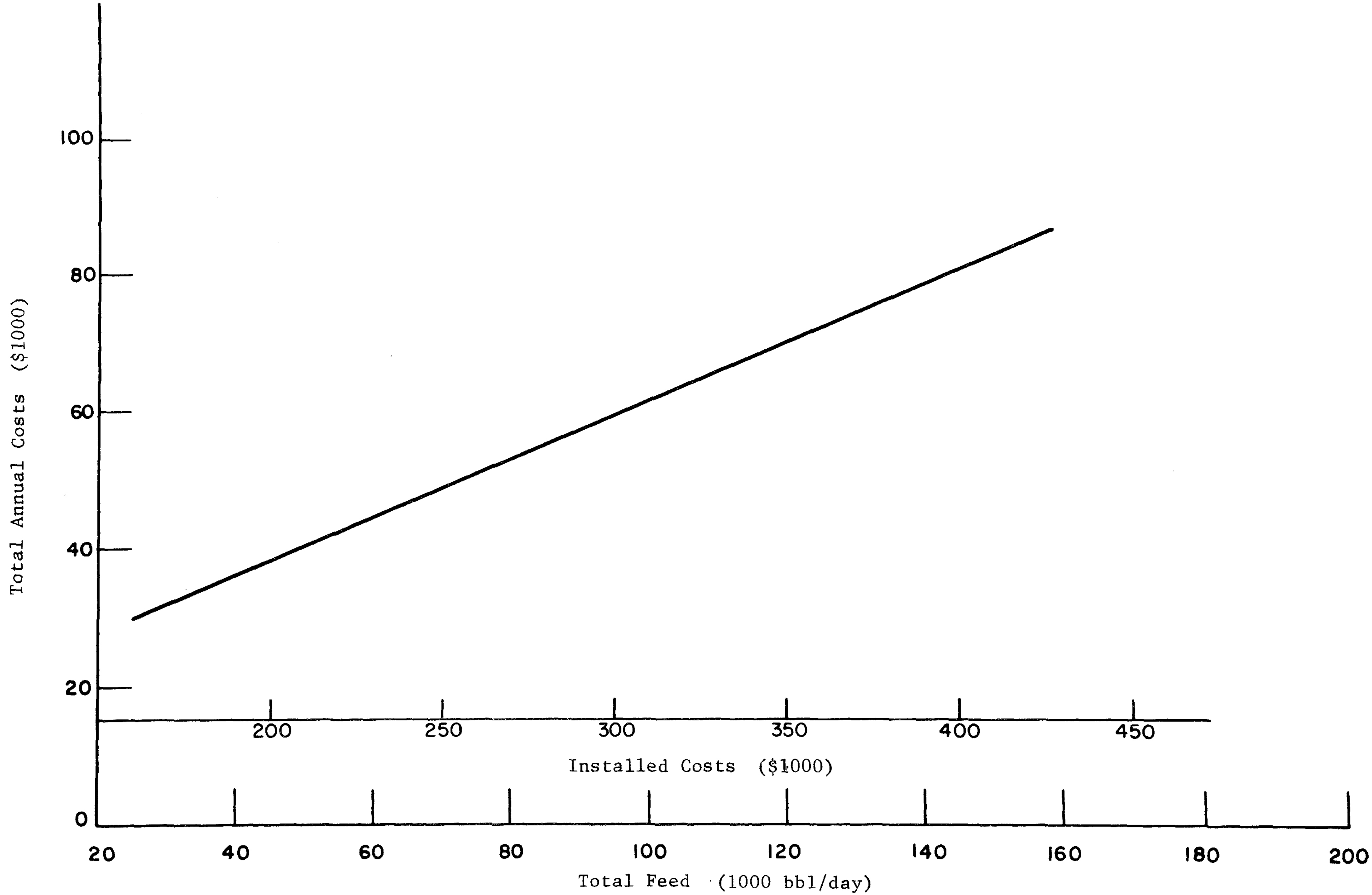


Fig. IV-22. *Annual and Installed Costs for Electrostatic Precipitators.*

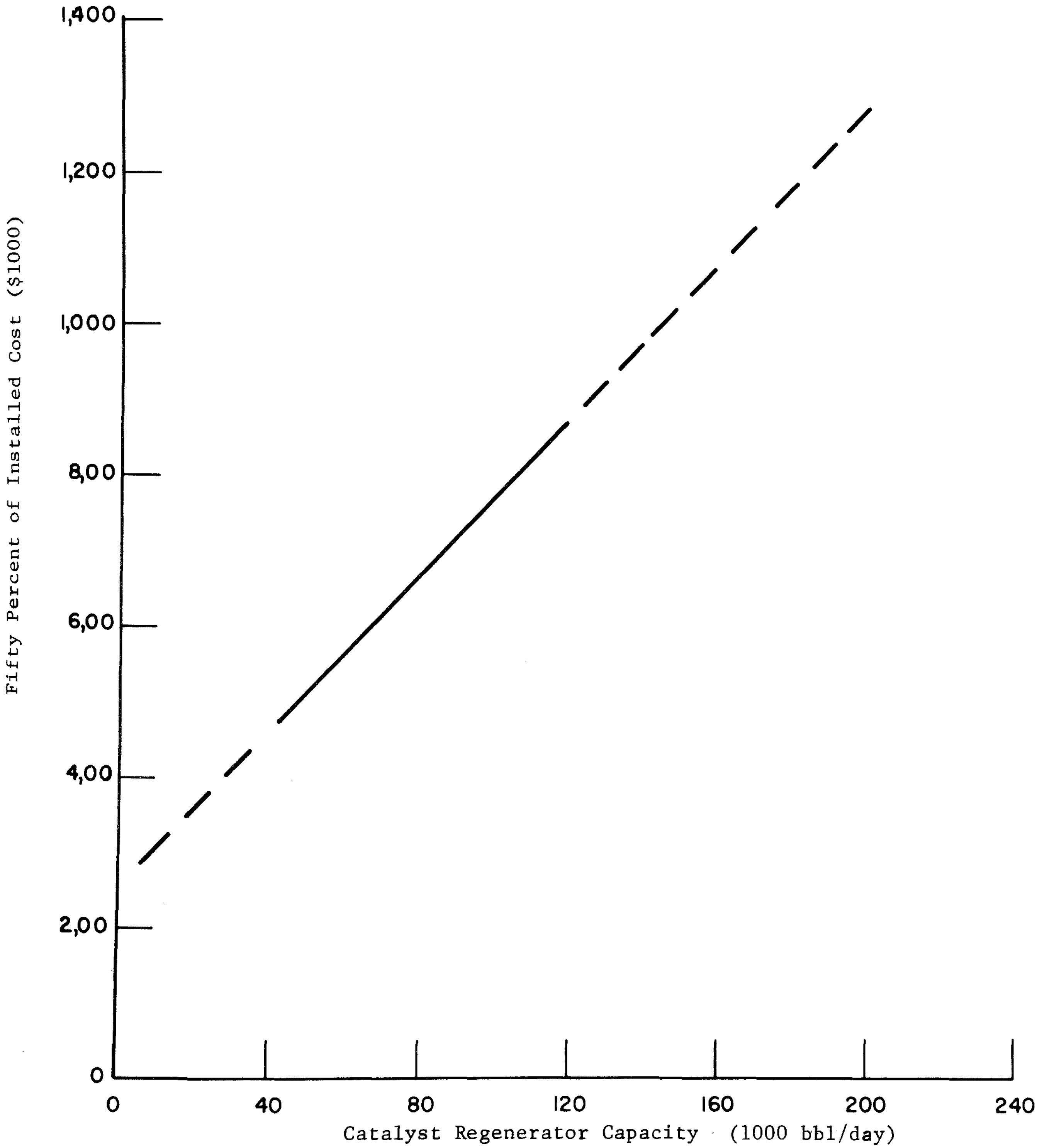


Fig. IV-23. Cost of Carbon Monoxide Boilers.

Uncontrolled emissions of CO from FCC units were based on 5.6 tons of CO per 1000 barrels total feed [Ref. 58]. Uncontrolled emissions from Thermofor units were based on 1.2 tons of CO per 1000 barrels total feed [Ref. 58]. There are no significant CO or hydrocarbon emissions from Houdriflow units since they are all presently controlled. In all cases units were assumed to operate 360 days per year. CO and hydrocarbon emissions from controlled units were assumed to be zero.

Uncontrolled HC emissions from fluid units were based on 180 pounds HC per 1000 barrels total feed and those from Thermofor units were based on 57 pounds HC per 1000 barrels total feed [Ref. 58]. These figures can be converted to 32.4 and 10.3 tons HC per year per 1000 barrels total daily feed, respectively. In all cases, emissions from controlled units were assumed to be zero.

b. Petroleum Products and Storage

Costs for converting fixed-roof storage tanks to floating roof tanks are shown in Figure IV-24. Costs for submerged fill techniques were not readily available; however, these techniques usually require only a modified nozzle on the hose used to fill tank trucks, and a length of pipe attached to the inside of the tank for submerged tank filling; the costs for such are minimal. Complete gasoline emission loading systems utilizing vapor recovery would, of course, cost much more.

The factors used to determine emission from bulk gasoline storage are presented in Table IV-46.

Transfer losses were based on ten full turnovers in tank contents per year, which was estimated by dividing total volume of gasoline sold by total gasoline storage capacity. To determine total metropolitan area emissions, three-fourths of all tanks were assumed to have floating roofs, and one-half of all transfer operations used submerged fill techniques [Ref. 14].

While the cost for converting a specific sized, fixed-roof gasoline storage tank to a floating roof tank were fairly well known, the distribution of tank sizes within any area was not

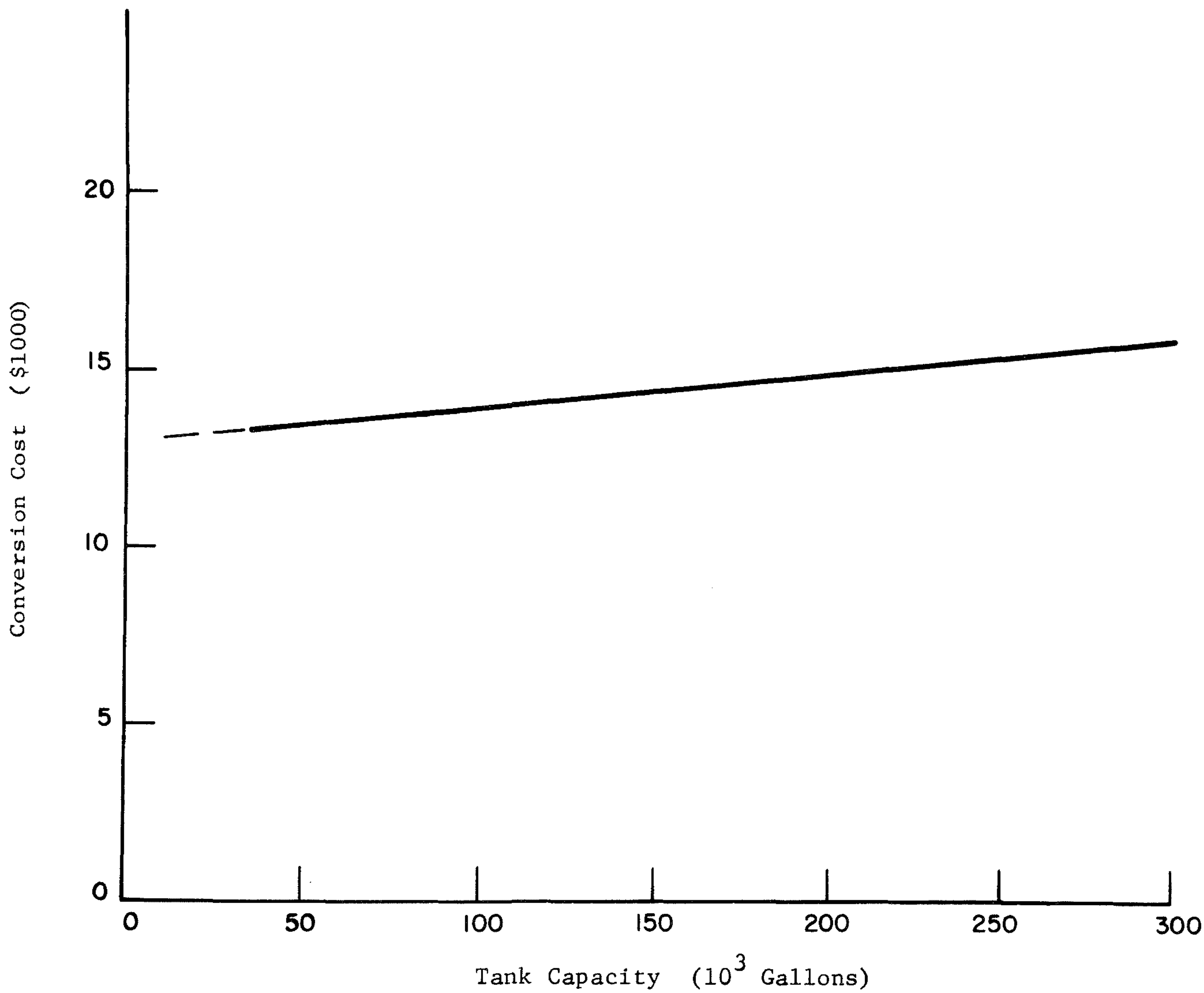


Fig. IV-24. Cost for Converting Fixed-Roof Gasoline Storage Tanks to Floating Roof Tanks.

known. A model tank approach was therefore used to estimate tank conversion costs for the various areas. The model tank size selected was 290 thousand gallons based on the fact that an average bulk gasoline storage facility has a capacity of 2.9 million gallons, assuming 10 turnovers per year. This was calculated using the present estimated national capacity of 8.8 billion gallons and approximately 30 thousand storage facilities. Seventy-five percent of all gasoline storage tanks were assumed to be presently controlled except for California which has 100 percent control.

The cost for converting a model-sized tank with a capacity of 290 thousand gallons from a fixed-roof to a floating roof unit was estimated to be $16 thousand as shown in Figure IV-24. Costs for smaller sized tanks were also taken from this figure and were used to estimate the costs for the remaining storage capacity not accounted for by an even number of model tanks. Thus, in any given area, the average capacity of each establishment was determined (total area capacity [Ref. 59] divided by number of establishments [Ref. 59]); the equivalent number of model tanks within each average establishment was then obtained (average capacity divided by 290 thousand gallons) and costed at $16 thousand each; the remaining capacity was then costed as a separate item and added to the cost of the model plants. This total cost was then multiplied by one-fourth of the number of establishments to arrive at the total area cost; this takes into account the estimate that 75 percent are already controlled.

It was assumed that all plants would prefer converting their uncontrolled tanks to floating roof units to the alternative of installing new tanks. The cost for installing submerged filling equipment was included in the cost of converting the tank.

Annualized costs were not included since the amount of gasoline saved will usually more than cover the annualized expenses incurred in converting the tank.

4. Scope and Limitations of Analysis

Analysis of refinery emissions and control equipment was, in almost all cases, based on data for each refinery involved. Control costs have been estimated on a less rigorous basis as indicated below, but are considered representative of actual cost expectations. Because the total annualized cost is not estimated to be large enough to influence prices, no analysis of market patterns is presented.

5. Industry Structure

Nearly all bulk storage plants are owned by producers of petroleum products. Although approximately 256 firms are listed as petroleum refiners, the bulk of the industry is concentrated in 30 to 35 firms. Of these, 16 are fully integrated international corporations making up the so-called "large majors" of the industry. Another eight firms may be classed as "small majors" and are also fully integrated. The remainder of the firms in the industry are somewhat smaller and either not fully integrated or operate in a limited market.

Petroleum is an oligopolistic industry characterized by sharp retail competition that usually concentrates on competitive advertising at the retail level, but experiences frequent price wars as well. In its purchases of crude oil from independent producers, it is much less likely to compete on price.

The entire industry is subject to foreign competition, but at present this is minimized through quotas under the oil import program. The effect of the quota system is to effectively set a base price higher than would probably be set were unlimited imports permitted.

Statistics concerning the petroleum industry will be found in Tables IV-47 and IV-48.

Table IV-47. - 1967 STATISTICS ON THE PETROLEUM REFINING INDUSTRY

	United States	Metropolitan Areas
Number of Plants	256	199
Capacity (Millions of bbls.)	4,210	3,620
Production (Millions of bbls.)	3,580	2,720
Value of Shipments (Billions of dollars)	20.29	15.41

Table IV-48. - 1967 STATISTICS ON THE PETROLEUM PRODUCTS AND STORAGE INDUSTRY

	United States	Metropolitan Areas
Number of Plants	29,664	14,998
Capacity (Millions of bbls.)	182	129
Production (Throughput-Millions of bbls.)	1,840 1,840	1,290 1,290
Value of Shipments (Billions of dollars)	22.50	15.80

6. Economic Impact of Control Costs

a. Cost Factors

Floating roofs for refinery tanks are estimated to require an investment of approximately $53,000 each, based on a typical tank size assumed to be 80,000 barrels capacity. Since this control reduces vapor loss by more than 90 percent, it results in preventing the loss of a valuable product. This saving more than offsets the total annualized cost of control. The same is true for distributor's storage tanks, except that the investment per tank is calculated to be only $16,000 for a typical tank of 6,900 barrels capacity.

Sulfur recovery plants vary in cost depending upon size, which is a function of the daily quantity and sulfur content of crude oil refined. For those refineries not listed as having sulfur recovery plants in 1967, this cost was calculated on the basis of plant size necessary for the listed capacity of the refinery and its estimated sulfur oxide emissions. Sulfur recovery plants of four tons per day capacity or larger were considered economically feasible, requiring investment ranging from slightly over $100,000 for four tons capacity to approximately $630,000 at 100 tons capacity. Annual cost for sulfur recovery plants was estimated as 20 percent of investment after allowance for the value of sulfur produced. The market value of sulfur is, of course, subject to change if large additional supplies are marketed. However, since it appears that the sulfur recovery plants now in use at petroleum refineries are operated at or above the breakeven point, it is assumed for this analysis that additional plants could produce revenues at least equal to annual operating costs.

Electrostatic precipitators for control of particulate emissions from catalyst regenerators on fluid catalytic cracking units vary in cost depending on size. It is estimated that the average refinery would invest approximately $565,000 for each precipitator. The total annualized cost per precipitator is estimated to average $92,500.

Carbon monoxide boilers to control carbon monoxide and hydrocarbon emissions from catalyst regenerators were estimated on the basis of the heat content of the gas stream for each affected refinery and the price of boilers. The average investment required would be approximately $3 million per boiler, of which 50 percent is charged to air pollution control, since the steam generated may also be considered a part of the normal operating process of the refinery. Similarly, the annualized cost may properly be considered to be production cost rather than cost of pollution control.

b. Aggregate Industry Costs

For the petroleum industry as a whole, installation of the controls specified in this analysis would require, by the end of Fiscal Year 1976, a total investment of approximately $1,242 million. Given the assumptions stated above, annual cost to the industry would, however, amount to only an estimated $7 million per year upon completion of installation of controls in Fiscal Year 1976.

c. Two Model Firms as Examples of Economic Impact of Control Costs

Two hypothetical petroleum companies may be used to illustrate the impact of the investment requirements and annual costs described above.

Model Firm A

Description: A fully integrated national producer, operating ten refineries, of which eight are within 298 metropolitan areas. Total crude oil refining capacity, 877,000 b/cd. Gasoline production, 52.6 percent of crude oil. Capacity utilization, 88.6 percent. Gross revenue, 1967, $7,860 million. Net income, 1967, $640 million.

Air Pollution Control:

Equipment	Number	Investment	Annual Cost
At refinery:			
Carbon monoxide boiler	4	$ 6,000,000	——
Sulfur plant	5	1,310,000	$262,000
Storage tank roofs	53	2,810,000	——
Electrostatic precipitators	4	2,260,000	370,000
At distribution points:			
Storage tank roofs	2,924	$46,800,000	——
		$59,180,000	$632,000

Model Firm B

Description: A small independent partially integrated firm, operating one refinery located in a metropolitan area. Total crude oil refining capacity, 53,000 b/cd. Gasoline production, 51 percent of crude oil Capacity utilization, 85 percent. Gross revenue 1967, $57 million. Net income, 1967, $11 million.

Air Pollution Control:

Equipment	Number	Investment	Annual Cost
At refinery:			
Carbon monoxide boiler	1	$1,500,000	——
Sulfur plant	1	140,000	$ 28,000
Storage tank roofs	18	288,000	——
Electrostatic precipitators	1	565,000	92,500
At distribution points:			
Storage tank roofs	160	$2,560,000	——
		$5,053,000	$120,500

d. Impact on the Industry

If the total annualized cost of air pollution control for the petroleum industry, as estimated here, were added to the price of the estimated gasoline production in Fiscal Year 1976, it would increase that price by approximately $0.0021 per barrel ($7 million ÷ 3,300 million barrels). Costs of this magnitude are not likely to have a visible effect upon the final prices of petroleum products, nor are they large enough to significantly reduce the profits of the 199 refiners involved. Much more significant is the magnitude of the investment involved. It appears that this industry will be required to invest \$1.2 billion by Fiscal Year 1976. At the same time, it appears that there will be a substantial excess of demand for petroleum products and producers will be under pressure to expand their exploration expenditures and increase production capacity. Some companies may find it difficult to raise the capital essential to their total investment program.

L. Primary and Secondary Nonferrous Metallurgy

1. Introduction

This section deals with firms engaged in the production of four nonferrous metals--aluminum, copper, lead, and zinc--by primary reduction from the ore and by secondary scrap processing. These might be considered as four separate industries except that many of the firms produce more than one metal and the products are directly competitive for many uses. Until recently, the primary aluminum industry has been almost entirely separate from the others, but the last few years have seen the beginning of what appears to be a trend towards further integration of the sectors of this industry group.

Engineering, market, and cost data are discussed separately where appropriate, and the economic impact of control costs on firms and the industry analyzed within the interconnected economic framework of the industry.

2. Sources of Emissions

The smelting and refining processes used in the primary production of all four metals involve emissions of particulates, sulfur oxides, and in the case of lead smelting, lead. In addition, fluorides are emitted by the electrolytic cells used to reduce alumina; control of this pollutant to the specified standard results in control of the other pollutants to levels exceeding the stipulated standards in primary aluminum production. The melting of scrap and refining and alloying processes employed by secondary producers are sources of particulate emissions. These result primarily from the various contaminants in the scrap, such as paint, insulation, oil, and dirt.

3. Emissions and Costs of Control

a. Primary Aluminum Emissions and Controls

It is estimated that emissions from primary aluminum plants at a 90 percent level of control in 1967 were 6,000 tons of particulates and 8,200 tons of fluoride, both gaseous and particulate. At the same level of controls, there would be 8,000 tons of particulates and 12,200 tons of fluorides by Fiscal Year 1976.

There are three types of electrolytic cells used in producing aluminum: prebaked, vertical spike soderberg, and horizontal spike soderberg. It has been determined that the control technique utilized by the industry in 1967 was to vent individual cell emissions to primary cyclones and simple wet scrubbers, yielding overall control efficiencies of 90 percent for both particulates and fluorides. To meet the applicable standards (Appendix II) a combination of control systems utilizing more efficient individual cell control systems plus new cell-room control systems was assumed. Engineering analysis indicates that the most effective cell control equipment would be that shown in Table IV-49 [Ref. 61].

TABLE IV-49. - CELL CONTROL EQUIPMENT

Cell Type	Control Equipment	Removal Efficiency
Prebaked	Fabric Filter-Precoated with Alumina	94 Percent; Gaseous F >99 Percent; All Particulates
Vertical Spike Soderberg	Electrostatic Precipitator + 2 Scrubbers in Series	>99 Percent; Gaseous F >99 Percent; All Particulates
Horizontal Spike Soderberg	Floating Bed Scrubbers	95 Percent; Total F 99 Percent; All Particulates

Design of the new control system assumed herein would include new and more effective hoods for each cell. Approximately 90 percent of the total pollutant emissions can be captured with improved hoods and ducted to the new control equipment specified. It is assumed that 10 percent of the emissions will still escape into the cell room and be carried by the cell room ventilation system to a wet scrubber, where 90 percent removal will be accomplished. The overall efficiency of the combined system would be 98 percent removal of both particulates and fluorides, which meets applicable standards (Appendix II). Resultant estimates of the FY 1976 annual emissions for the aluminum industry with these controls in place are 1,700 tons of particulates and 2,300 tons of fluorides.

b. Primary Copper Emissions and Controls

The 1967 level of control for sulfur oxide emissions from primary copper smelters is estimated to have been 25 percent, resulting in release of an estimated total of 2,140,000 tons of sulfur oxides for the 298 metropolitan areas. By Fiscal Year 1976, this would rise to 2,380,000 tons if no further controls were applied. Analysis indicates that the addition of an acid plant in smelters not now operating them, and the addition of lime scrubbers on the tail gas from all acid plants, would achieve the maximum removal of sulfur oxides from smelter gases practical with present technology. This would reduce emissions for Fiscal Year 1976 to an estimated 227,000 tons for the copper smelters in the metropolitan areas subject to control, equal to 94 percent removal efficiency.

c. Primary Lead Emissions and Controls

Primary lead smelters in the 298 metropolitan areas were estimated to have emitted 200,000 tons of sulfur oxides in 1967, representing control of 32 percent of potential emissions. In addition, 5,540 tons of lead was emitted with a level of control of 96 percent. Estimated growth of production would increase sulfur oxide emissions to 269,500 tons and lead emissions to 7,900 tons by Fiscal Year 1976 without further controls. Addition of acid plants at refineries not now having them and at new refineries could reduce the Fiscal Year 1976 emissions to 17,200 tons of sulfur oxides and 7,900 tons of lead, equal to 96 percent control.

d. Primary Zinc

The pattern for primary zinc smelters is similar to that of lead. As a result of high level controls effective in smelters using acid plants in 1967, it is estimated that 51 percent of the potential sulfur oxide emissions were controlled. The remaining smelters emitted an estimated 416,000 tons of sulfur oxides and this would increase to 508,000 tons by Fiscal Year 1976 if the same level of control were maintained. If all lead smelters in the metropolitan areas treated their smelter gases in acid plants, sulfur oxide emissions in Fiscal Year 1976 would be 76,700 tons, a 93 percent level of control. Further reduction of these emissions would be prohibitively expensive.

e. Secondary Nonferrous Emissions and Controls

Secondary producers of aluminum, copper, lead, and zinc in the 298 metropolitan areas are estimated to have emitted 9,800 tons of particulates and 14,500 tons of lead in 1967, with approximately half the plants controlled effectively at 95 percent, the average control for the industry therefore being about 48 percent. At this same control level, emissions would grow to 14,800 tons of particulates and 22,000 tons of lead by Fiscal Year 1976. High energy wet scrubbers, electrostatic precipitators, and fabric filters were used, where appropriate, in this industry analysis, with all three methods achieving 95 percent or better control. Installation of equivalent procedures in the uncontrolled plants would reduce emissions to 2,900 tons of particulates and 2,200 tons of lead in Fiscal Year 1976.

f. Control Costs

Implementation of the control plans discussed above would result in a total investment requirement of $393.1 million; primary aluminum, copper, lead, and zinc requirements would be 223.3, 87.0, 16.2, and 4.7 million dollars, respectively, and secondary nonferrous would be $61.9 million. Annual costs in Fiscal Year 1976 would be as follows: primary aluminum, $75.8 million; primary copper, $42.0 million; primary lead, $7.1 million; primary zinc, $2.2 million; and secondary nonferrous, $21.8 million--a total annual cost of $148.9 million.

4. Engineering Basis of the Analysis

a. Primary Nonferrous

1) Primary Aluminum

The costs of controlling the emissions from the three types of aluminum reduction cells are shown in Tables IV-50 through IV-52. Table IV-50 presents the costs of the equipment designed to control the cell emissions from prebaked and horizontal spike soderberg cells. Table IV-51 presents the costs of the scrubbers designed to control the cell room

TABLE IV-50. - COSTS OF CELL CONTROL SYSTEMS - PREBAKED AND HORIZONTAL SPIKE SODERBERG

Plant Capacity (10^3 tons Al/Year)	Prebaked Cells		Horizontal Spike Soderberg	
	Installed ($\$10^6$)	Annual ($\$10^6$)	Installed ($\$10^6$)	Annual ($\$10^6$)
50	1.3	0.4	2.0	0.7
100	2.8	0.6	3.9	1.3
150	3.6	0.9	5.8	2.0
200	5.0	1.2	7.5	2.5
250	6.0	1.6	9.6	3.4

TABLE IV-51. - COSTS OF CELL ROOM CONTROL EQUIPMENT - PREBAKED AND HORIZONTAL SPIKE SODERBERG

Plant Capacity (10^3 tons Al/Year)	Prebaked and Horizontal Spike Soderberg	
	Installed ($\$10^6$)	Annual ($\$10^6$)
50	2.5	1.0
100	4.9	1.9
150	6.4	2.9
200	9.6	3.6
250	12.4	4.7

emissions from these two cell types. Table IV-52 presents the combined costs of cell plus cell room control systems for vertical spike soderberg aluminum reduction cells [Ref. 28].

Emissions for aluminum reduction cells were based upon the uncontrolled emission rates shown in Table IV-53.

TABLE IV-52. - COSTS OF COMBINED CELL PLUS CELL ROOM CONTROL SYSTEMS - VERTICAL SPIKE SODERBERG

Plant Capacity (10^3 tons Al/Year)	Vertical Spike Soderberg	
	Installed ($\$10^6$)	Annual ($\$10^6$)
50	3.9	1.3
100	7.7	2.5
150	11.5	3.8
200	15.2	4.8
250	19.3	6.3

Table IV-53. - UNCONTROLLED EMISSION RATES FOR ALUMINUM REDUCTION CELLS

Cell Type	Total Particulates (lbs/ton Al)	Total Fluorides (lbs/ton Al)
Prebaked	55	80
Horizontal Spike Soderberg	140	80
Vertical Spike Soderberg	80	80

Source: M. J. McGraw. Draft Report, "Air Pollutant Emission Factors." NAPCA, August 1970.

2) Primary Copper, Lead, and Zinc

Obtaining and analyzing air pollution control costs for these primary metal industries was limited to the primary smelting processes only. The refining steps were not considered a problem from the point of view of particulate or SO_2 emissions [Ref. 60]. In addition, particulate emissions resulting from primary smelting operations are consistently controlled to levels in excess of 95 percent. Therefore, the resulting cost analysis focused on the control of SO_2 from primary smelting operations. The primary metallurgical processes analyzed in the smelting operations for each metal are shown in Table IV-54.

TABLE IV-54. - METALLURGICAL PROCESSES FOR COPPER, LEAD, AND ZINC

Metal	Primary Smelting Processes 1/
Copper	Roaster-reverberatory furnace - converter or Reverberatory furnace-converter
Lead	Sintering - blast furnace 2/
Zinc	Roaster 3/ or Roaster - sintering 3/

1/ The analysis was limited to these process systems because they represent the systems present in the study areas. There are other possible configurations for each metal.

2/ SO_2 emissions negligible.

3/ Followed by a usually well controlled electrolytic reduction step.

Based upon data developed in the McKee report [Ref. 61], a model plant approach was adopted as the basis of the cost analyses. The model plants are presented in Table IV-55.

TABLE IV-55. - PRIMARY SMELTING - MODEL PLANTS

Metal	Processes	Model Plants	
		Gas Volume (1,000 scfm)	SO_2 Concentration (percent by volume)
Copper	Roaster & Converter	90 1/	5.5 1/
	Converter Only	130 2/	4.0 2/
	Reverberatory Furnace	55 1/ or 180 2/	0.7 1/ or 1.5 2/
	Gas Stream to Lime Scrubbing Plant	145 1/ or 210 2/	0.4 1/ or 1.0 2/
Lead	Sinter Machine	50	5.0
Zinc	Roaster	50	8
	Roaster & Sinter Machine	20 3/	8 3/

1/ Representative when smelting operation includes roaster, reverberatory furnace and converter.

2/ Representative when smelting operation includes only reverberatory furnace and converter.

3/ It appears that when smelting process includes roasting and sintering the off-gas from the sintering operation contains less than 1,000 ppm; hence, only the off-gas from the roasting operation was considered.

The use of these models requires further explanation. Information was obtained on the presence or absence of acid conversion facilities at each plant location in the study areas [Ref. 62]. Therefore, the cost estimating methodology, which is fully discussed in the next section, was based upon the addition of acid conversion plants where none now exist plus wet lime scrubbing systems, where reasonable, to reduce

SO_2 concentration to economically feasible limits; the 500 ppm standard cannot be reasonably met.

Copper smelting plants within the study areas use either reverberatory furnace-converter smelting systems or roaster-reverberatory furnace-converter systems. With the first process, only converter off-gases are amenable to acid plant conversion of SO_2[14/] and the resulting combined gas stream from the reverberatory furnace and acid plant tail-gas must be further treated in a wet lime scrubber. In the second copper smelting configuration, combined roaster and converter off-gases are sent to an acid conversion plant and the combined tail-gas and reverberatory furnace off-gas stream must then be sent to the secondary scrubber.

In lead smelting operations, only sinter machine off-gases must be treated in an acid plant. The blast furnace operations which take place in series with the sintering step emit negligible SO_2. It is not considered reasonable to further treat the acid plant tail-gas.[15/]

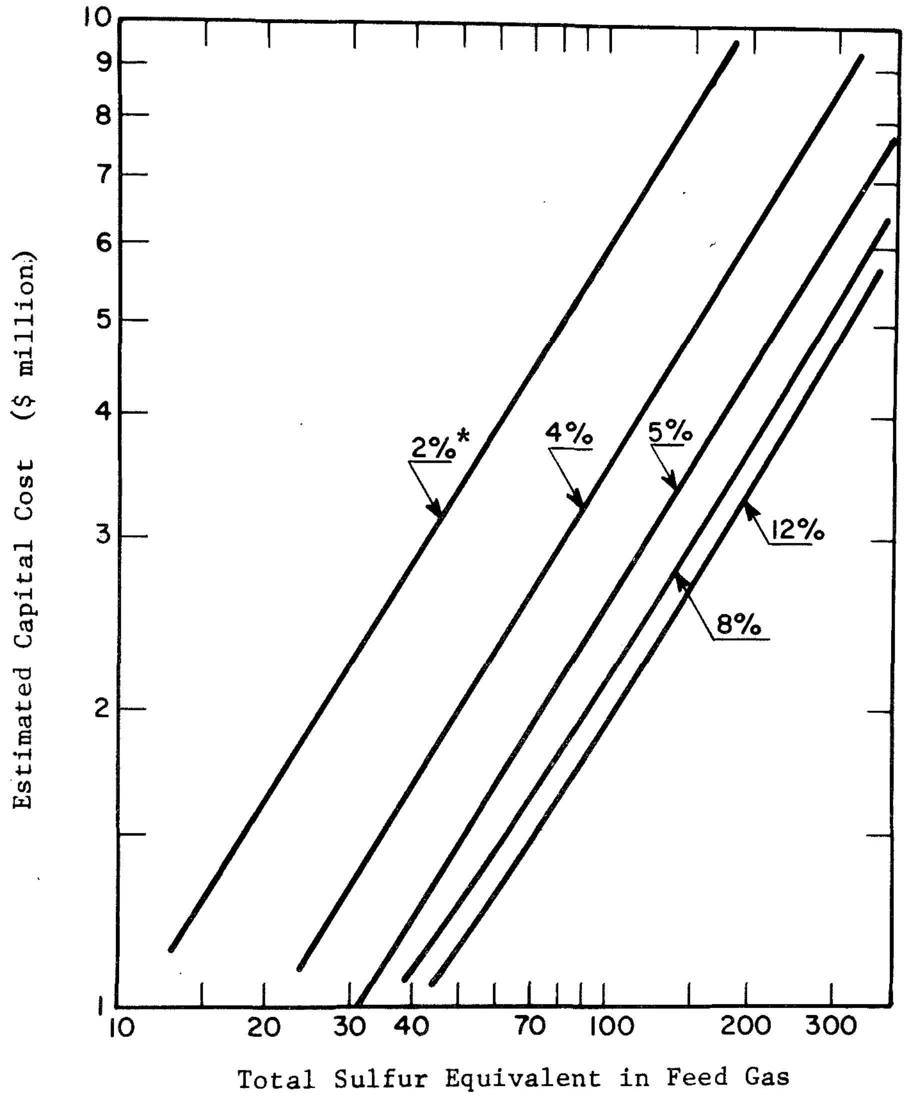
In zinc smelting operations, only the roasting process results in serious SO_2 emissions. The off-gases should be treated in an acid conversion plant to obtain effective control. Again, it is not considered reasonable to further treat the acid plant tail-gas.

Costs for copper, lead, and zinc smelters were based on the costs for building and operating acid conversion plants in locations where there were none and for building and operating wet lime scrubbing systems where applicable. Capital and operating cost relationships for these facilities were obtained from the McKee report [Ref. 61] and are presented in Figures IV-25 to IV-29.

Sulfur oxide emissions were based upon the emission factors shown in Table IV-56.

14/ The criterion is 3 percent or greater SO_2 concentration (see Table IV-55).

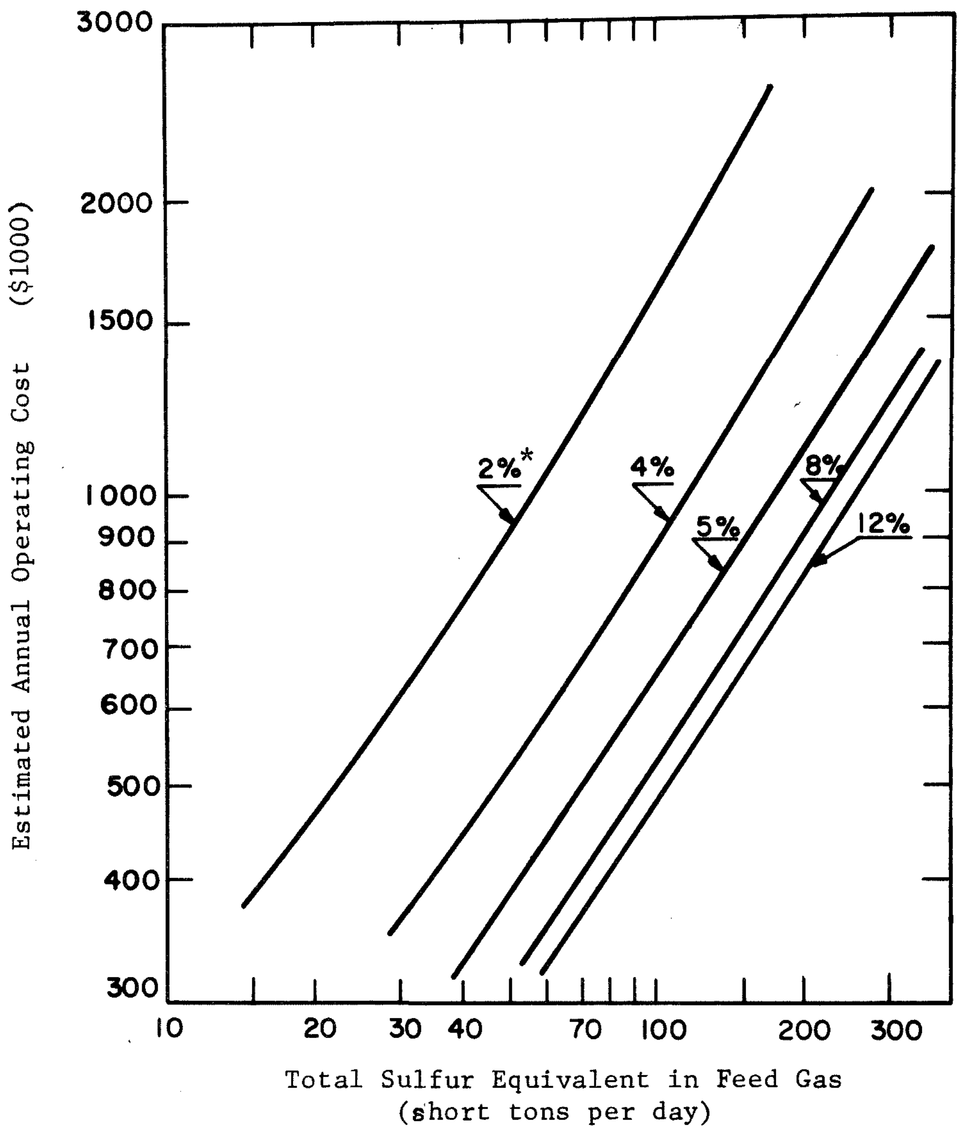
15/ The resultant SO_2 concentration should be less than 0.1 percent.



* Percent sulfur dioxide in feed gas.

Source: Systems Study for Control of Emissions in the Primary Nonferrous Smelting Industry. San Francisco, California: Arthur G. McKee and Company, June 1969.

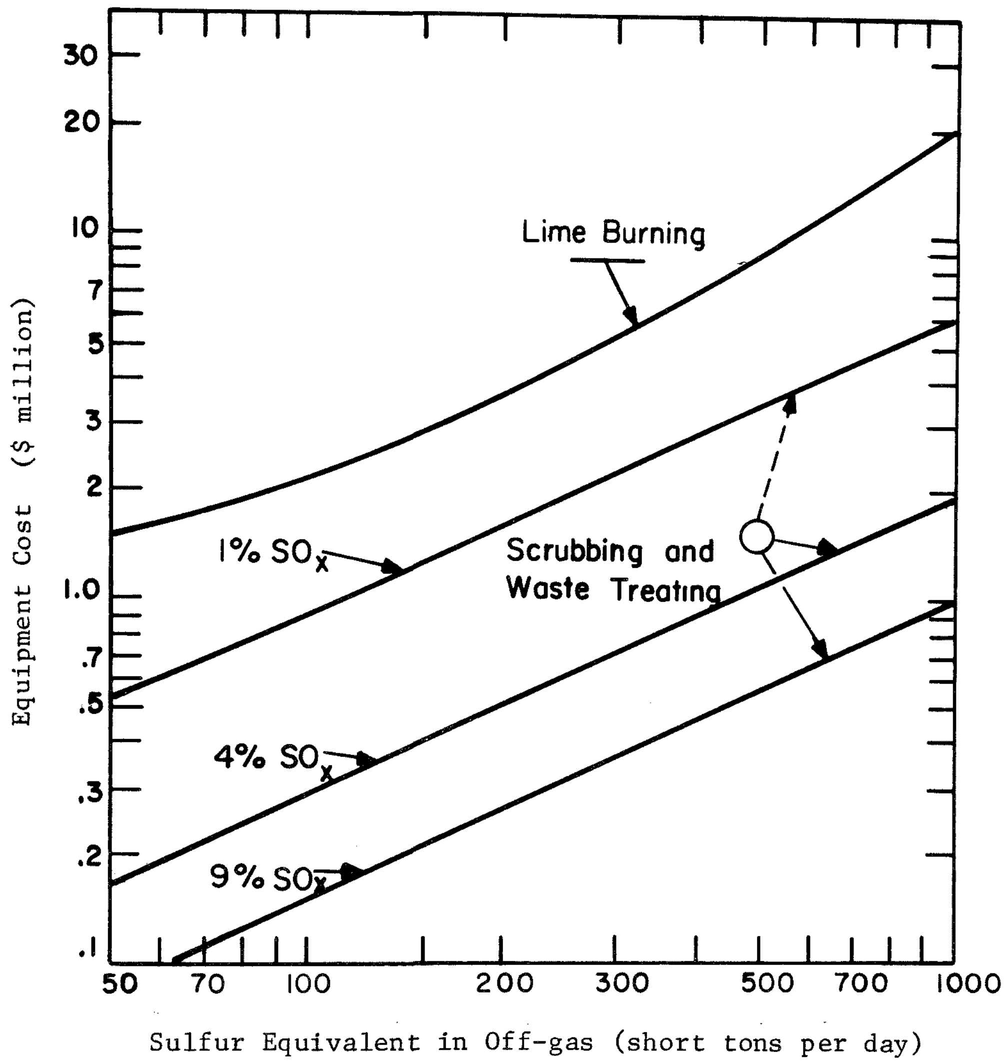
Fig. IV-25. Capital Costs for the Contact Sulfuric Acid Process.



* Percent sulfur dioxide in feed gas.

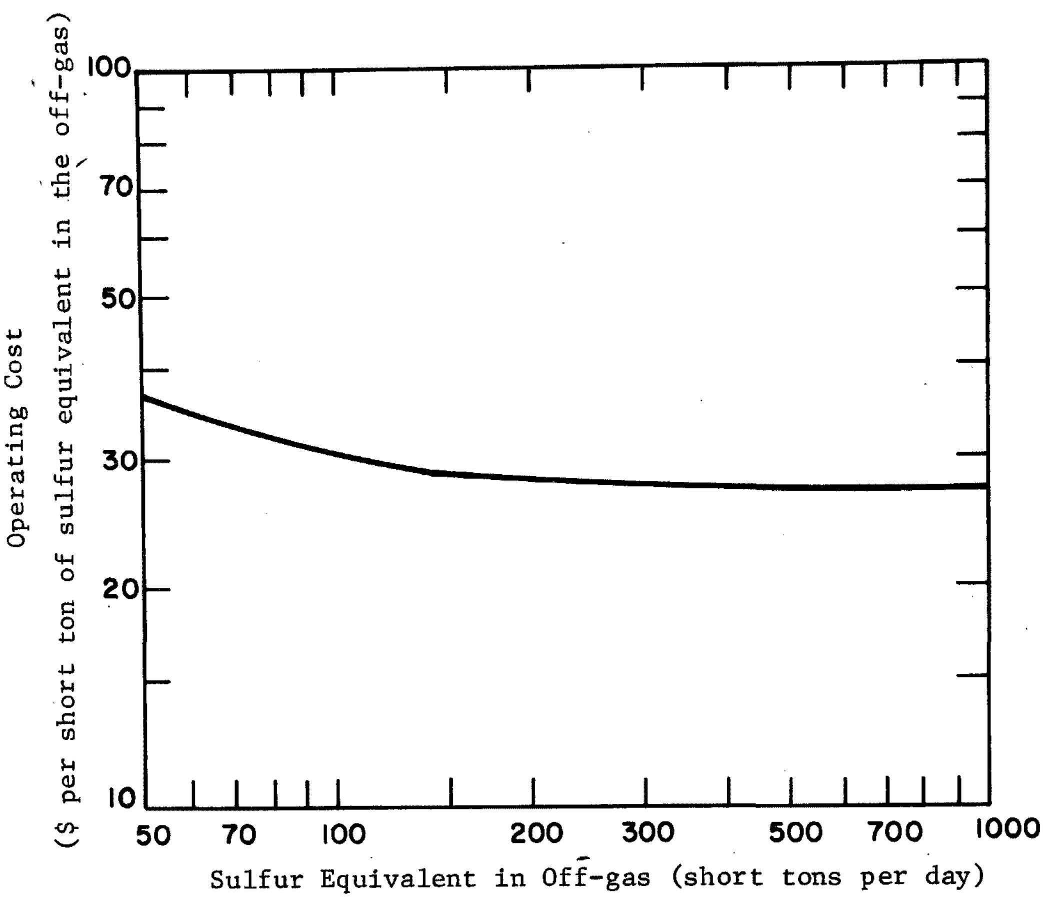
Source: Systems Study for Control of Emissions in the Primary Nonferrous Smelting Industry. San Francisco, California: Arthur G. McKee and Company, June 1969.

Fig. IV-26. Annual Operating Costs for Contact Sulfuric Acid Process.



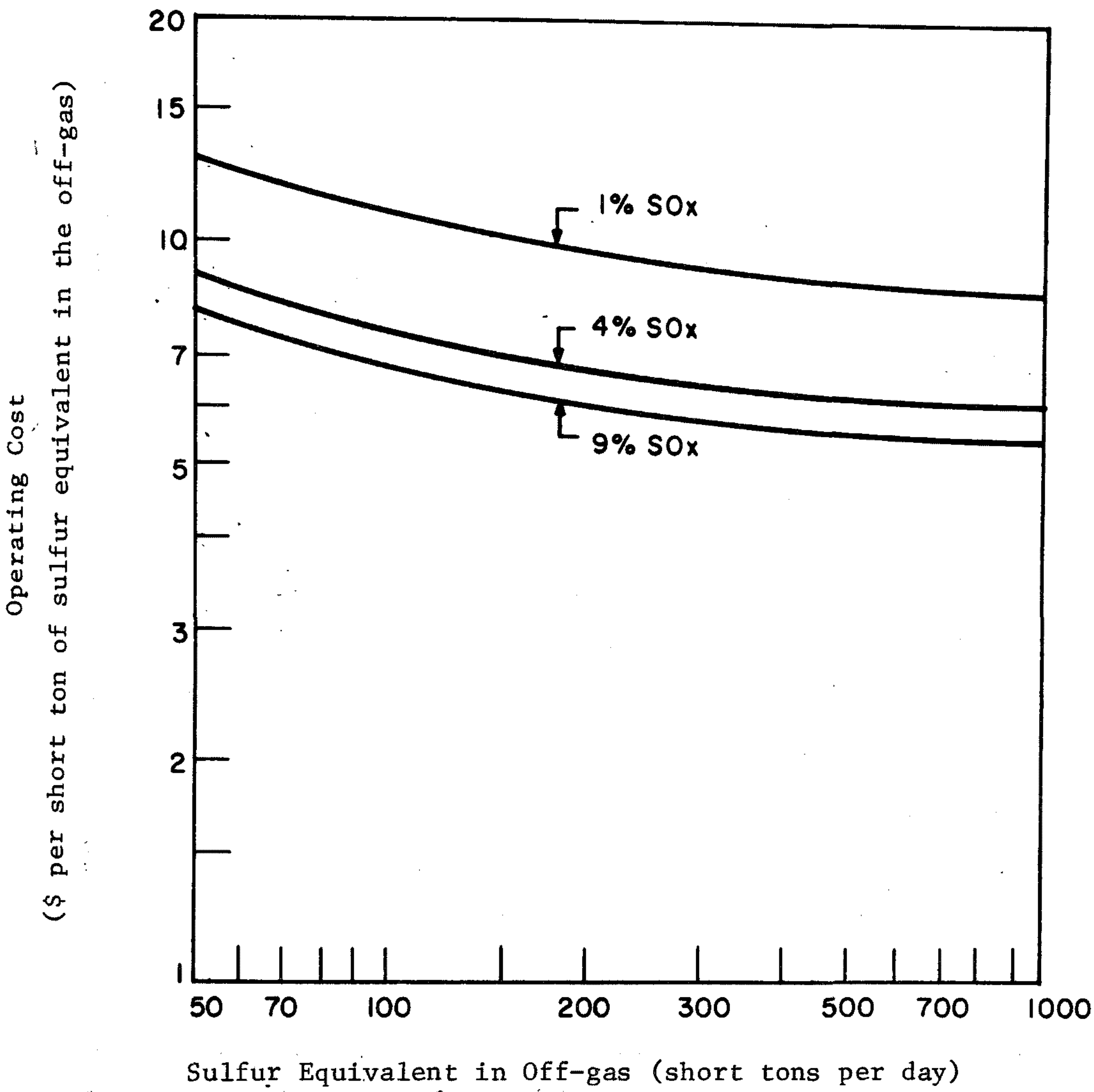
Source: Systems Study for Control of Emissions in the Primary Nonferrous Smelting Industry. San Francisco, California: Arthur G. McKee and Company, June 1969.

Fig. IV-27. Equipment Costs for Lime Wet-Scrubbing Process.



Source: Systems Study for Control of Emissions in the Primary Nonferrous Smelting Industry. San Francisco, California: Arthur G. McKee and Company, June 1969.

Fig. IV-28. Operating Costs for the Lime-Burning Section of the Lime Wet-Scrubbing Process.



Source: Systems Study for Control of Emissions in the Primary Nonferrous Smelting Industry. San Francisco, California: Arthur G. McKee and Company, June 1969.

Fig. IV-29. Operating Costs - Scrubbing and Waste-Treating Section of Lime Wet-Scrubbing Process at 100% of Capacity.

TABLE IV-56. - SULFUR OXIDE EMISSION RATES

Metal	Emission Rate (lbs/ton Charge)
Copper	1250
Lead	660
Zinc	530

Source: M. J. Mcgraw. A Draft Report, "Air Pollutant Emission Factors." NAPCA, August 1970.

b. Secondary Nonferrous

The processes of the secondary nonferrous metals industry considered in this analysis were copper, brass, and bronze melting, secondary aluminum melting, secondary zinc melting, and lead refining. Data obtained from a number of sources were used to identify secondary nonferrous metallurgical plants in the 298 metropolitan areas. Secondary aluminum plant locations were obtained [Ref. 63], and secondary zinc plants were identified [Ref. 64]. Data from Reference 64, supplemented with information from the Bureau of Mines [Ref. 25], were used to compile lists of secondary copper and lead plants in the areas. The emissions from the secondary nonferrous metals industry are particulates in the form of dust, fume, and smoke [Ref. 15]. Uncontrolled emission rates for these processes are shown in Table IV-57.

According to a recent survey [Ref. 65], 51 percent of all metal plants control pollutants; this percentage was assumed for the secondary nonferrous metals industry. Plants controlling were further assumed to control at 95 percent efficiency since the equipment normally used to control emissions in this industry includes high energy wet scrubbers, electrostatic precipitators, and fabric filters [Ref. 66]. The resulting average industry level of control was 48.5 percent.

The following data were not used in this analysis, nor were they readily available: process size, gas volume, gas stream temperature, annual hours of operation, and detailed information

TABLE IV-57. - UNCONTROLLED EMISSION RATES FROM SECONDARY NONFERROUS METALS INDUSTRY

Metal	Emission Rate (lb/ton metal produced)
Aluminum	7.5
Copper, Brass, Bronze	40
Lead	110
Zinc	15

Source: Reference 14.

on control systems. Fortunately, the approach taken in estimating the cost of emission controls in this industry did not require such data since costs per ton of production were available from a recent survey performed by the Department of Commerce [Ref. 66]. Because process size data could not be obtained, it was not possible to determine the efficiency needed to comply with the process weight rate standard. Accordingly, no assumptions as to specific types of control equipment were made, except that current practices which achieve efficiencies of approximately 95 percent will be continued.

Plant capacities for copper, lead, and zinc were estimated indirectly. Production data for the Nation were obtained [Refs. 25 and 67] and peak monthly output was assumed to approximate capacity. Because of the lack of additional information, the assumed capacity was apportioned to each area according to the number of plants in each. The average plant size for each metal was estimated by dividing national capacity by the number of plants in the Nation.

Cost data were abstracted from a publication of the Department of Commerce [Ref. 66], which included investment and annual costs per pound of production. Investment costs were given by type of metal, and annual operating costs were given as an average for all types of metals. Depreciation and capital charges were added to the annual operating cost to obtain total annual costs for each area. Unit costs are shown in Table IV-58.

TABLE IV-58. - EMISSION CONTROL COSTS FOR SECONDARY NONFERROUS METALLURGY

Metals	Average Plant Size (tons/yr)	Investment Cost ($)		Annual Operating Cost* ($)	
		Per lb/yr capacity	Per plant	Per lb/yr capacity	Per plant
Brass, bronze, & copper	7,349	0.0095	139,631	0.0012	17,638
Aluminum	4,082	0.0101	82,456	0.0012	9,797
Zinc	268	0.0097	5,199	0.0012	643
Lead	1,418	0.0051	14,464	0.0012	2,413

* Annual Operating Cost as reported does not include depreciation and capital-related expenses.

Source: Reference 66.

5. Scope and Limitations of Analysis

The engineering and control cost data summarized elsewhere in this report give a firm basis for estimating the costs of control for individual firms and the total industry. Adequate financial data on which to base the discussion of the impact of these costs on firms and the markets are also available. However, because relatively few firms are involved, hypothetical model firms have not been used to illustrate cost impact. To avoid the impression of specifying costs for actual individual firms, a procedure which may involve factors not considered in this study, such as the overall financing program of the firm and the intricacies of its tax position, the impact is discussed in relation to general trends and patterns which may be expected within the industry and the markets involved.

6. Industry Structure

The primary nonferrous metals industries are highly concentrated, with three or four firms producing more than half of the annual production of each metal. There were only eight primary aluminum, 11 primary copper, six primary lead, and seven primary zinc firms identified in the United States in 1967. The companies are large, stable, and in most years very profitable. Their market power is limited to some extent by vigorous foreign competition and, for some firms at least, by substantial competition from independent fabricators of finished industrial products and consumer goods. A large share of the market for these metals is also found among the giant manufacturing firms, such as the automobile companies, whose buying strength offsets any monopolistic power among producer firms.

The secondary nonferrous industry, on the other hand, is composed of a large number of firms, over half of them with fewer than 20 employees. It is estimated that perhaps as many as 10 percent of secondary nonferrous firms are operated very close to the breakeven level. The presence of large numbers of marginal and near-marginal firms weakens the market strength of the industry. Pricing and production, therefore, are closely related to trends in the primary nonferrous metals industry.

Tables IV-59 and IV-60 provide statistical data for these industries.

TABLE IV-59.- 1967 STATISTICS FOR PRIMARY NONFERROUS METALLURGICAL SOURCES

Aluminum	U. S.	298 Areas	Copper	U. S.	298 Areas
Number of Plants	24	14	Number of Plants	19	10
Capacity (Millions of Tons)	3.5	2.0	Capacity (Millions of Tons of Ore Concentrate)	9.3	6.5
Production (Millions of Tons)	3.3	1.9	Production (Millions of Tons)	1.2	0.9
Value of Shipments (Billions of Dollars)	1.6	0.9	Value of Shipments (Billions of Dollars)	1.1	0.8

Lead	U. S.	298 Areas	Zinc	U. S.	298 Areas
Number of Plants	6	4	Number of Plants	15	9
Capacity (Millions of Tons of Ore Concentrate	1.7	1.2	Capacity (Millions of Tons)	1.3	0.6*
Production (Millions of Tons)	0.4	0.2	Production (Millions of Tons)	0.9	0.4*
Value of Shipments (Billions of Dollars)	0.1	0.1	Value of Shipments (Billions of Dollars)	0.3	0.2*

* At this time, data are not available on two plants.

TABLE IV-60.- 1967 STATISTICS FOR SECONDARY NONFERROUS METALLURGICAL SOURCES

	UNITED STATES					TOTAL	
	Aluminum	Copper	Brass and Bronze	Lead	Zinc	U. S.	298 Areas
Number of Plants	170	117		442	159	627*	583*
Capacity (Millions of Tons)	0.90	0.50	0.52	0.63	0.08	2.63	1.93
Production (Millions of Tons)	0.82	0.40	0.48	0.55	0.07	2.32	1.71
Value of Shipments (Billions of Dollars)	0.39	0.46	0.56	0.16	0.03	1.60	1.17

* A number of plants produce more than one metal

7. Market

a. Aluminum

Market growth for aluminum has resulted from the development of new aluminum-using products and intensive competition to replace other metals in traditional uses. However, aluminum faces strong competition from various plastics in some uses. A major factor in the sales growth of aluminum has been its ability to deliver a fully satisfactory substitute for copper or steel at a significant cost reduction.

Within the industry, prices tend to be very similar from firm to firm, since four firms in the United States and Canada control approximately 65 percent of the world's output and there is only a total of eight firms in the United States.

The relationship of aluminum sales to growth in the automobile and construction industries is discussed in Chapter 5 of this volume. Also important are the electrical products, consumer durables, and container markets. In each of these industries, aluminum has significant advantages in cost and technical factors for certain uses, but seldom holds sufficient advantage to forestall effective competition from other materials. Therefore, despite its concentration, the industry faces a highly competitive market with substantial price sensitivity.

Exports account for approximately six percent of sales of aluminum and this market is not expected to grow in the next five years. Aluminum ingots are imported, but not in significantly large quantities. The tariff of one cent per pound on primary aluminum and two cents per pound on fabricated shapes appears to provide significant protection to the United States industry.

b. Copper

The market for United States copper production is very sensitive to the world's supply and demand for copper and to military use in the war in Vietnam. World capacity has been rising faster than world demand and it appears that this trend may continue, although conditions determining actual supply in any year are sufficiently unpredictable to make long range market forecasts very dependable. The effect of the industry nationalization in Zambia, completed in August, cannot be analyzed at this time, for instance. Although private management is under contract to operate Zambia's copper industry, the extent of government pressure for changed policies remains to be determined.

The other market unknown - copper demand resulting from military procurement - is estimated to decline substantially by Fiscal Year 1976. Thus, both of the factors mentioned indicate that oversupply, or at least overcapacity, may tend to affect the market over the next five years.

A very large part of copper production goes into copper wire, which is used in transmission of electricity and in electrical equipment of many kinds. In parts of these markets, copper faces sharp competition from aluminum, which also has excellent electrical properties. Substitution of aluminum wire for copper wire depends primarily on price, although aluminum may have an important weight advantage, partially offset in some uses by its greater bulk.

The copper used in automobiles, mostly for wiring and radiators, may decline. There is talk of reducing the use of copper wire so that when scrapped auto bodies are melted down the resultant scrap metal will not contain copper, which is difficult to remove. New aluminum technology seems to have overcome the difficulties in manufacturing aluminum radiators and copper may lose a part of this market as well.

The prospect, therefore, seems to be one of possible oversupply of copper and stiffer competition, which may be adjusted by changes in the relative prices of copper and aluminum. If pollution control costs ultimately prove to be significantly different for these two metals, there may be further changes in the market relationship.

c. Lead

Six firms are engaged in primary smelting of lead in the United States; four plants are in the metropolitan areas. These firms also operate refineries and produce refined lead in addition to selling lead bullion to a small number of refiners who do not mine and smelt their own supplies. Smelting is the most concentrated segment of the industry. The industry is more competitive than this number might seem to indicate, however, since smelters and refiners must deal with a larger number of mining firms and distribute semi-finished and finished products in competition with a much larger number of firms processing refined lead. Another competitive force is foreign sellers who operate extensively in the United States market. Lead prices appear to be very flexible, reacting quickly to changes in supply or demand. Supply is relatively inelastic relative to price due to the very heavy investment required in mining, smelting, and refining.

For these integrated lead producers, smelting is only one part of the productive process, contributing only a fraction of their total profit.

d. Zinc

Of the seven firms engaged in zinc smelting in the United States in 1967, six are also engaged in production of one or more of the other nonferrous metals covered in this analysis. The combination of lead and zinc is especially to be expected since the two metals frequently occur in the same ore. Unlike lead, zinc smelting is carried out through a wide variety of processing combinations and as a result production costs are more variable. Much of what has been said about the competitiveness of lead production applies to zinc as well, however. The industry is characterized by competitive pricing, moderate profit on investment, and relatively inelastic domestic supply.

8. Production and Price Trends

It is estimated that primary production of aluminum, copper, and zinc in the United States will increase at the following annual rates through Fiscal Year 1976; aluminum, 5.8 percent; copper, 1.3 percent; and zinc, 2.6 percent. This implies some increase in utilization of productive capacities, since the annual growth rates in capacity through Fiscal Year 1976 are estimated as: aluminum, 4.4 percent; copper, 0.2 percent; and zinc, 1.4 percent. The estimated rate of growth in both capacity and production of primary lead plants between 1967 and 1976 is 4.1 percent. This growth rate for the primary lead industry reflects the actual growth for the years 1967 to 1970 and assumes that they will approach zero after 1970 as the market for tetraethyl lead gasoline additives declines sharply.

Secondary producers of nonferrous metals, whose production rates depend in part on the supply of scrap and therefore on the consumption of primary production, are expected to increase production at a rate of 6.1 percent per year through Fiscal Year 1976, while increasing capacity at 6.6 percent per year.

The relative changes in the prices of metals explain in part the expected relative growth patterns. The rise of the index of copper prices from 110 in 1965 to 146 in 1968, compared to the index for aluminum prices which stood at 97 in 1965 and rose only to 102 in 1968, indicates the increased price advantage gained for aluminum over those years.

Aluminum prices should be firm through Fiscal Year 1976 as demand continues to grow, with increased growth in the container field being especially important. Even without aluminum's disadvantage of a higher control cost, copper probably will continue to lose ground to aluminum in the electrical field and in some other industries, for example automobile radiators. Most brass and bronze markets will probably change little. It is unlikely, therefore, that copper prices would continue the upward trend of the last few years.

Prices of lead and zinc may be expected to remain fairly steady through Fiscal Year 1976. Uses of lead alloys have been growing in a wide variety of applications, but lead for batteries has grown more slowly than automobile production. This reflects increased battery life, although most of the improved technology in this field appears to have been introduced and the trends of automobile and battery production may move more closely for some years. Elimination of tetraethyl lead in gasoline, however, would eliminate one-third or more of the United States lead market. If this occurs, lead prices may decline sharply and a sizeable segment of the secondary lead industry particularly may feel the impact.

The zinc market prospects are for slow steady growth and stable prices.

9. Economic Impact of Control Costs

a. Control System Costs

1) Aluminum

Annual control costs for the primary aluminum industry differ depending upon the production process with average costs as follows: (a) prebaked, $25,32/ton ($0.013/lb. of capacity); (b) horizontal spike soderberg, $31.31/ton ($0.016/lb. of capacity); (c) vertical spike soderberg, $21.14/ton ($0.011/lb. of capacity). The average prebaked process plant in the areas designated for control for purposes of this study had a capacity of just over 150,000 tons per year in 1967. The annual cost in 1967 dollars for such a plant would be approximately $4,000,000, reflecting the annualized cost of an investment of $13,000,000 plus the annual operating and maintenance cost. A similar plant using the horizontal spike soderberg process would require a total investment in control equipment of 1.2 times that for prebaked and would have total annual costs 1.2 times as great. Such a plant using the vertical spike soderberg process, on the other hand, would require only three-fourths of the investment outlay and four-fifths of the annual cost of the prebaked process plant. An adequate level of control would be achieved in all three plants.

The annual costs given above make no allowance for the recovery of materials through the control systems. Since these systems have not yet been widely employed, calculation of the value of recovered products is purely hypothetical at this time. It appears, however, that for the prebaked and, possibly, the vertical spike soderberg processes, substantial amounts of alumina and cryolite could be recovered in usable form. A conservative estimate of the value of recovered product might be $1,000,000 worth per 100,000 tons of production for the prebaked process and approximately half that for the vertical spike soderberg process. No significant recovery of materials appears possible with the floating bed scrubber indicated for the horizontal spike soderberg process. If recoveries of this magnitude prove feasible, the result would be that plants using prebaked cells would reduce total operating costs by adopting air pollution control. Plants using vertical spike soderberg cells would incur little or no net cost for control and plants using horizontal spike soderberg cells would be at a disadvantage amounting to approximately one-half cent per pound of aluminum produced. Since it appears that the vertical spike soderberg process may be the most efficient, by a small margin, of the three processes, such a cost differential could significantly affect profits for firms dependent on the horizontal spike soderberg process. Such a firm may have to absorb the added cost since its competitors would have no motivation to raise prices as a result of pollution control requirements.

Producers of secondary aluminum, in turn, face the probability of annual control costs equal to $0.0032 per pound, or $82,500 per year for a typical plant of just over 4,000 tons annual capacity installing the anticipated controls, as noted in Section 4.e. Firms operating secondary aluminum production plants sell in competition with primary producers in many markets and it is unlikely that the price of secondary aluminum could rise against an unchanged price for the primary metal. It appears that some secondary producers, now operating at a smaller scale and higher costs than the average indicated, may be forced out of aluminum by merger, shift to other metals, or by going out of business. More detailed data would be necessary to estimate how many firms may be affected in this way.

2) Copper, Lead, and Zinc

Air pollution control costs for lead and zinc smelters have been calculated as the cost of installing and operating a sulfuric acid plant in which the sulfur oxide emissions are captured and turned into a saleable by-product. In addition to adding a sulfuric acid plant, copper smelters have also been assumed to require a wet line scrubber system which does not yield a saleable by-product. Industry sources indicate that at present (1970) four of the 19 copper smelters in the United States operate acid plants, as do two of the six lead smelters and nine of the 15 zinc smelters. That these plants are generally operating acid plants in locations where they are not subject to sulfur oxide emission limitations which would make strict control mandatory is conclusive evidence that recovery and sale of sulfuric acid is economically advantageous for them.

For a copper smelting plant, it is estimated that maximum feasible control of sulfur oxide emissions will require the installation of a contact acid plant plus a lime scrubber. This would require an investment of approximately \$12,300,000 for the typical plant and total annual cost, including depreciation and interest, of \$4,500,000. Assuming that the acid plant can produce up to 180,000 tons of sulfuric acid and that this can be sold at a price of \$14 per ton, f.o.b. the smelter (a price in line with the current market), by-product revenue would approximate $2,500,000 per year. Net annual control cost would then be approximately $1,650,000 for this plant, or $23.57 per ton ($0.012/lb.) for 70,000 tons capacity.

For a copper smelting plant with an acid plant already in operation, maximum control would require the addition of a secondary scrubber. It is estimated that this would require an investment of $2,300,000 and total annual cost of $1,370,000, with no additional production of saleable by-products. For a 500,000 ton capacity plant, this would mean an estimated annual cost of $19.57 per ton ($0.0098/lb.).

Those lead and zinc smelting plants already operating acid plants would not require further control of emissions. Since they are presumably operating at or above breakeven in their acid production, there is therefore no net cost of control. Construction of a new acid plant at the smelters not now controlling sulfur oxide emissions would involve investment of approximately $5,500,000 and total annual cost of $2,500,000 for an average sized zinc plant of approximately 100,000 tons annual capacity. Sale of acid at $14 per ton would yield revenue approximately equal to annual cost, indicating zero net control cost.

The assumption has been made in estimating these net control costs for copper, lead, and zinc smelters that the sulfuric acid produced would find a market at $14 per ton. Recently published studies [Refs. 61 and 68] of the potential market for smelter acid indicate that this assumption is almost certainly not valid. The volume of smelter acid involved and its location relative to its potential market make it improbable that more than a small fraction of the potential supply could be sold at any price in Fiscal Year 1976.

The market for sulfuric acid is primarily for use in production of fertilizer with smaller amounts used for leaching copper ore and for processing uranium. It should also be noted that sulfuric acid is required in the electrolytic dissolution process for refining zinc, explaining why so many zinc plants produce sulfuric acid. The studies cited above indicated that less than 40 percent of the potential new acid production of smelters located west of the Mississippi could find a market at a price of $4 per ton, the minimum estimated production cost. The problems and cost of shipping acid to more distant markets would be prohibitive, it was indicated. It may be concluded, therefore, that primary smelters will install acid plants only to the extent that projected revenues from the sale of acid result in a net control cost less than that of alternative control systems. Assuming that the annual cost of lime scrubbing alone, without an accompanying acid plant, is approximately half the gross annual cost of the system specified in this analysis, annual cost for an average copper smelter might be approximately $3,250,000 and for a lead or zinc smelter $1,250,000 ($0.003/lb. for copper; $0.0063/lb. for zinc; $0.0018/lb. for lead).

Air pollution control costs as of 1967 for secondary copper, lead, and zinc producers have been estimated by the Department of Commerce [Ref. 69]. The cost estimate for a typical secondary copper (and brass and bronze) producer with an annual capacity of 7,340 tons was that an investment of $140,000 would be required and that total annual cost would be $54,400 or $7.41 per ton ($0.0037/lb.) of capacity. Equivalent figures for a secondary lead producer with 1,420 tons capacity were investment of $14,500 and annual cost of $5,300 or $3.74 per ton ($0.0019/lb.). For a secondary zinc plant of 268 tons capacity, the required investment was calculated as $5,200 and annual cost as $1,700 or $6.27 per ton ($0.0031/lb.).

The added costs indicated by this analysis for some primary producers of copper, lead, and zinc, and the increased costs for secondary producers suggest that some upward pressure on prices may occur. However, foreign competition, competition from plants not subject to control regulations, and those already meeting emission standards, plus the realistic possibility of excess capacity by Fiscal Year 1976, make it probable that little if any price increase will eventuate as a result of these cost pressures.

b. Impact on the Industry

The impact of net cost on any one primary producer is more difficult to determine than the aggregate annual costs. The impact depends upon the product mix, degree of horizontal and vertical integration, the amount of metal purchased from other producers, the percentage of their plants subject to control regulations, the control cost for the specific production processes used, the productivity of the processes, the firm's market and financial strength, and many other factors. No analysis of the impact on actual firms is given in this report. Any attempt to do so would imply much more detailed knowledge of the variables involved than would generally be available to an outside observer. This section is intended to suggest the range of possible effects which may be felt by some firms and the industry as a whole.

For primary producers of aluminum, it appears that the industry will be required to invest approximately $223.3 million in the years between calendar year 1967 and Fiscal Year 1976. By Fiscal Year 1976, the industry will be incurring total annual costs for control of approximately $75.8 million in addition to an estimated $7.0 million now being spent annually for control instituted before 1967. It is probable, however, that much of this cost may be offset by the recovery of valuable materials. Only the firms operating horizontal spike soderberg cells appear to face significant net control costs. The aggregate estimated annual control cost for this sector of the industry will be approximately $26.2 million in 1976. It may be expected, therefore, that use of this production process will tend to decline in the long run unless new technology can offset its economic disadvantage. Some shifting into alternative product lines or change in individual market shares may occur, but the primary aluminum industry is not expected to show any fundamental change in response to new control costs, nor is the market price likely to increase.

The impact of control costs on primary producers of copper, lead, and zinc depends primarily on the amounts of these (and other) metals they are smelting, since it is the smelting process for these three metals that will require new or additional emission controls. How many of a company's plants are already partially or completely controlled and how many are located in metropolitan areas where additional controls will be required will also affect the impact on a particular company. The other prime determinant of the cost for a firm will be the marketability of sulfuruc acid from its existing or newly required acid plants as more smelter acid enters the market.

Among them, the 23 firms smelting copper, lead, and zinc may invest an estimated $107.9 million by Fiscal Year 1976 in additional control equipment. The annualized cost of control by that year is estimated at $51.3 million. Offsets to this annual cost reflecting the value of the sulfuric acid produced could be as high as $31 million, leaving a net estimated control cost of approximately $20 million, almost entirely the cost of secondary scrubbing in copper smelters. If the value of acid output is assumed to be only half that used in these estimates and if world and domestic productive capacity remain reasonably in balance with demand, some upward pressure on price may occur. Adjustments per pound to this pressure by Fiscal Year 1976 would probably not exceed $.012 for copper, $0.001 for lead, and $0.003 for zinc. Price variations of this magnitude would not be enough to cause any significant shifts in market shares or production.

Secondary nonferrous producers face a more difficult situation. Overall, by Fiscal Year 1976, they may be required to invest a total of approximately $61.9 million and by that year annual costs for control for these firms are estimated to total approximately $21.8 million. These producers will have no saleable by-product with which to offset these costs. If the assumption is correct that the price of the secondary output cannot change significantly relative to the primary price when there are adequate supplies available in the primary market, it is probable that some marginal secondary producers will be unable to continue without change. This impact would be most severe on firms handling copper scrap and much less for lead and zinc firms. Some firms may drop out of the copper market and concentrate on handling larger volumes of other metals. Considering the expanding market for secondary metals, some very small firms may merge to gain economies of larger scale operations. This latter course is probably in line with a trend toward fewer and larger firms in the industry anyway, to which air pollution control costs will provide greater impetus.

M. Rubber (Tires)

1. Introduction

The industrial classification considered in this section includes the manufacture of tires and tubes of all types for all kinds of vehicles, the bulk of which are for automobiles, trucks, and buses. Tubes are included because no distinction is made between tires and tubes in statistical data.

2. Emissions and Costs of Control

Air pollution emissions come from only two tire manufacturing processes, i.e. the tire cord dipping operation, and the mixer which blends carbon black into the tread material.

Hydrocarbon emissions have been reported in the offgases from the tire and dipping process. The amounts of these emissions have not been determined although they are believed to be in such quantities as to require control. Controls are predicated upon industry practice and experience under the regulations of the State of California. It is reported that a direct gas-fired afterburner provides fully adequate control of these hydrocarbon emissions. These have been assumed to be required in all plants outside of California.

Approximately 80 percent of the tire plants reported use fabric filters to control emissions of carbon black particulates at a control level of better than 99 percent. Carbon black is a costly material and the plants controlling these emissions do so because the value of the material recovered more than offsets the annual cost of control. For the 20 percent of the industry which was not controlling particulate emissions in 1967, it is estimated that 1,230 tons of particulates per year were emitted. Predicted growth of the industry would increase this amount to an estimated 1,670 tons per year in Fiscal Year 1976. Installation of fabric filters in these plants would reduce the estimated Fiscal Year 1976 emissions to negligible amounts of particulates by Fiscal Year 1976.

Installation of these controls would require an investment of $1.92 million and a Fiscal Year 1976 annual cost of $1.35 million for the plants located in the 298 metropolitan areas.

3. Engineering Basis of the Analysis

At the present time, insufficient data are available to estimate hydrocarbon emissions from tire and tube production and only limited data are available for particulate emissions. However, cost estimates can be based on industry practice which is to control the carbon black with fabric filters to prevent the loss of this valuable material. These devices will enable tire and tube producers to meet the process weight rate regulation. Afterburners will readily meet the assumed standard of 90-percent hydrocarbon emission control.

In 1968 there were 53 tire manufacturing plants in metropolitan areas 1-298 with an average capacity of 20,000 units per day (UPD).[16/] It is estimated that a 20,000 UPD plant emits 114 tons of carbon black per year [Refs. 70 and 71] (uncontrolled). Estimates of particulate emissions were based on the assumptions that:

1) All California plants control both hydrocarbon and carbon black emissions.
2) No plants outside California control hydrocarbon emissions.
3) 80 percent of plants outside California control carbon black emissions.
4) Control efficiencies are 100 percent for hydrocarbon and 99 percent for carbon black.

Table IV-61 lists the controlled and uncontrolled plants based on the above assumptions.

TABLE IV-61. - STATUS OF EMISSION CONTROLS FOR RUBBER PLANTS

Contaminant	Control Status	Areas 1-298	Calif.
Hydrocarbon	Controlled	-0-	6
	Uncontrolled	52*	-0-
Carbon Black	Controlled	43*	6
	Uncontrolled	9	-0-

* Includes the California plants.

16/ Average excludes plants which manufacture off-the-road tires only. (<100 UPD capacity) However, due to great size of these tires, such plants are considered as average (20,000 UPD) plants for this study.

It was estimated that the average cord dipping operation requires a 15,000 scfm exhaust system. For direct gas-fired systems with no heat exchange, installed cost for a 15,000 scfm system equals $25 thousand ± 25 percent [Ref. 72] for the average plant.

The following equation and calculations were used in determining annual costs [Ref. 73]:

$$G = S[195.5 \times 10^{-6}\ PHK + HF + M];$$

where:

S = 15,000 acfm;

P = 1" water;

H = 2,000 hours/year (50 weeks, 40 hours/week of afterburner operation);

K = $0.011/kwh;

F = $0.00056/acfm/hr.;

M = $0.06/acfm;

thus,

G = 1.204S or:

Capital charges plus depreciation at 20 percent.

Total annual cost:	$18,100/yr
	5,000
	$23,100

Installed cost of Orlon bags with a continuous air jet cleaning system and a capacity of about 20,000 scfm is estimated to be $20 thousand [Ref. 73]. Recovery of carbon black is sufficient to cover the annualized costs of the system. The average plant requires a system rated at approximately 20,000 scfm.

4. Scope and Limitations of Analysis

The data necessary for detailed analysis of emissions and control costs were not available for this analysis. Industry experience has been used, however, to estimate the control systems appropriate to the air pollution problems associated with the production of tires and tubes. The magnitude of the costs involved appears, even after allowance for substantial possible error, not to be large enough relative to the size of the industry and its member firms to warrant more extensive analysis at this time. Therefore, the discussion is limited to the estimated cost of control. Since this cost is relatively small and is not expected to affect price or profit significantly, no analysis of the industry's market has been made.

5. Structure of the Industry

The rubber tire and the tube industry consists of 60 plants that are located in the United States and represents 16 firms. Fifty-four of the 60 plants, or 90 percent, are located within the 298 metropolitan areas--representative of 15 firms. United States capacity for the industry was 1,080,000 tires and tubes per day. In the 298 areas, capacity amounted to 1,000,000 units per day--93 percent of the United States total. Production was 213 million units per year for the United States and 196 million units per year for the 298 metropolitan areas or 92 percent of United States production. Three major firms accounted for 59 percent of United States capacity, with all but one of their plants within the designated control regions.

6. Economic Impact of Control Costs

Control costs were estimated, as of 1967, for a model plant representative of the industry. This plant was described as employing 350 persons and producing 825 thousand tires and 206 thousand tubes per year. Although many plants do not produce tubes or have a different product mix than this, it appears that costs for the model plant represent an approximate average for the industry.

Installation of only an afterburner in a model plant of this size would require an investment of $25,000, for which the total annual cost would be $23,100. Investment in the fabric filter system in addition to an afterburner for a model plant of this size would add approximately $18,000. It appears that recovery of carbon black will more than offset the annual cost of the fabric filter. Therefore, no additional annual cost has been estimated. Investment in the 80 percent of the plants adding afterburners will be approximately $25,000, and in the 20 percent adding fabric filters and afterburners it will be $43,000. The annual cost of $1,350,000 for these controls will be slightly more than $0.005 for each of the 266 million tires and tubes estimated to be produced in the metropolitan areas in Fiscal Year 1976. Investment and annual costs of the indicated magnitude can be absorbed within the normal operation of the firms.

N. Sulfuric Acid[17/]

1. Introduction

Sulfuric acid is a strong, economically priced inorganic acid that is utilized in the production of phosphate fertilizers and other industrial chemicals, in the purification of petroleum, in the dyeing of fabrics, and in the pickling of steel. Greater than 90 percent of all sulfuric acid produced is by the contact process. In this process, sulfur or pyrite is burned to form sulfur dioxide (SO_2) which is then catylyzed to sulfur trioxide (SO_3). The SO_3 is then absorbed in weak sulfuric acid to form the concentrated products.

2. Emissions and Costs-of-Control

Sulfur dioxide that remains unconverted and acid mist particulates that escape from the acid absorption tower are the pollutants for which control costs have been developed. With only a single absorption stage, approximately a 96 percent conversion of SO_2 to SO_3 can be expected. To comply with the SO_2 standard, a conversion efficiency of 99.5 percent is required. This is equivalent to an overall 86 percent removal efficiency. To accomplish this, it is assumed that plants will install a secondary absorption tower with appropriate addition of heat to facilitate more complete conversion of SO_2. Although most plants do control acid mist particulates to some extent, the average industry control level of 46 percent does not meet the particulate standard. An overall industry removal efficiency of 67 percent will be required. To meet this standard, it is assumed that more efficient acid mist eliminators will be installed. By Fiscal Year 1976, if these control measures are not adopted, emissions of sulfur oxides and particulates will reach 921 thousand tons and 90.1 thousand tons, respectively. With the specified controls, these will be reduced to 129 thousand tons and 55.1 thousand tons, respectively.

The investment required to implement the controls by Fiscal Year 1976 will reach $176 million and the annual cost is estimated as $41 million. This annual cost does not take into account the slightly increased yield of sulfuric acid which will occur.

17/ An economic impact analysis for this industry is not included in this report. A comprehensive study is currently in preparation by APCO.

3. Engineering Basis of the Analysis

The rate of emission of tail-gas from a contact sulfuric acid plant is determined by the concentration of SO_2 in the feed stream to the SO_2-to-SO_3 convertor; this concentration is subject to process control. Many plants take enough air into their sulfur burner to provide adequate excess oxygen for conversion, others add so-called "dilution air" after burning but prior to one or more stages of the convertor. To maintain plant thermal balance, it is necessary for the SO_2 concentration to be in excess of about 3 percent. As the SO_2 concentration is increased, stack losses of unconverted SO_2 also increase. Most plants vary the SO_2 concentration in order to vary production, but avoid concentrations causing conversion efficiency to fall below about 96 percent.

It was assumed that 96 percent conversion is obtained with an eight percent SO_2 concentration to the convertor and that the actual tail-gas rate is thus about 74 acfm (at 150° F) per ton-per-day (tpd) plant capacity.

The concentration of SO_2 in the tail-gas from a contact sulfuric acid plant operating at 8 percent SO_2 concentration to the convertor and 96 percent conversion efficiency is fixed at about 3500 ppm. This figure was assumed to represent average operations for the industry and agrees with literature, industrial, and APCO sources as representative of present-day operations. The assumed SO_2 standard of 500 ppm thus requires an 86-percent reduction in the present average emissions.

With the exception of oleum production (sulfuric acid containing excess SO_3), acid mist emissions from contact sulfuric acid plants are less subject to process control variation than are SO_2 emissions. Acid mists arise from two independent sources: (1) moisture-SO_3 reactions within and outside of the process equipment and (2) liquid sulfuric acid entrainment in exhaust from the SO_3 absorber. The moisture-SO_3 reactions include reactions of SO_3 with residual moisture in the dried process air, moisture arising from the oxidation of hydrocarbon impurities in the sulfur, and atmospheric moisture that contacts the tail-gas exiting the stack. The moisture-SO_3 sources depend on the operation of the drier and whether or not oleum is being manufactured. Fine acid or SO_3 mists are formed after the convertor when either moisture reacts with SO_3 or the SO_3 dew-point (50° C = 122^0 F) is reached. Both types of mists pass through the absorber with little removal and thence through the stack. If SO_3 mists are emitted, they react with atmospheric moisture to produce acid mists.

For this report, a value of 16 mg mist per scfm of tail-gas was assumed. This value is somewhat higher than the average reported in Reference 74 but is in line with the more recent data reported in Reference 17. The particulate emission standards are the process weight rate standards. Because combustion air is excluded, the weight rate factor is (32 + 18) / 98 = 0.51, i.e., 0.51 pounds of raw materials yield 1.00 pound of product. The required efficiency for particulate control ranges from 43 percent for a 50 tpd plant to 93 percent for a 5000 tpd plant.

The basis for control of SO_2 emissions was that of improving process yield, but because very high (about 99.5 percent) overall SO_2-to-SO_3 conversions were required to meet the 500 ppm standard, cost estimating was limited to the double absorption method. The basis chosen for estimating the cost of acid mist control was utilization of glass-fiber mist eliminators capable of removing 100 percent of particles greater than 3 microns and about 80 percent of particles less than 1/2 micron. Reference 74 gives limited data indicating that mist particles may be assumed to be such that adequate control will result. These devices were assumed to operate with 6" to 8" w.g. pressure drop.

Sulfuric acid plants were reported by location and capacity [Ref. 75]. The controls selected were second absorption towers in the acid-making process and additional acid mist eliminators in the exhaust streams, where necessary. Some plants need another catalyst bed; however, such would be an investment in production equipment.

Costs were calculated assuming one process stream per plant, since no plant was reported to have a capacity larger than the known maximum process stream size. The cost of adding a second tower was included in the estimated control cost, but the cost of another catalyst bed was assumed to be compensated for by the increased production efficiency. Cost parameters for a second absorption tower were based on data from Chemical Engineering Progress [Ref. 76], which gives costs for a new plant of 1000 tons per day production using either single or double absorption. The difference in costs was multiplied by 2 to allow for modification of existing equipment, and then scaled to other plant sizes based on the cost being proportional to capacity to the 0.6 power. Cost parameters for mist eliminators were based on data from the Monsanto Chemical Company (Brinks Mist Eliminators). Costs were calculated for each plant by capacity and then aggregated for the 298 metropolitan areas. These costs are presented in Tables IV-62 and IV-63.

TABLE IV-62. - SULFURIC ACID EMISSION CONTROL COSTS: DOUBLE ABSORPTION

Plant Size (100% H_2SO_4, tons/day)	Costs ($1000)	
	Investment	Annual
50	120	26.0
100	185	40.0
200	280	64.0
500	485	113.0
1000	760	191.0
5000	2080	664.0

TABLE IV-63. - SULFURIC ACID EMISSION CONTROL COSTS: MIST ELIMINATOR*

Plant Size (100% H_2SO_4, tons/day)	Costs ($1000)	
	Investment	Annual
50	4.5	0.9
100	9.5	1.9
200	19.5	3.9
500	43.8	8.8
1000	82.5	16.5
5000	375.0	75.0

* Brink Mist Eliminator, Type H-V or S-C.

4. Industry Structure

In 1967 there were 213 plants with a total capacity of 38.7 million tons of sulfuric acid in the United States. Production mounted to 28.8 million tons. Within the 298 metropolitan areas there were 180 plants with a total capacity of 32.9 million tons. These plants produced 24.5 million tons of sulfuric acid.

O. Varnish

1. Introduction

Varnish is one product group produced by the paint industry. This industry also manufactures and distributes paints (in paste and ready-mixed form), lacquers, enamels, and shellac; putties and caulking compounds; wood fillers and sealers; paint and varnish removers; paint brush cleaners, and allied paint products.

Technical and statistical literature dealing with the paint industry is often not clear as to the technical definition of "varnish" as opposed to other product classifications. Generally, varnish is an unpigmented protective coating of natural or snythetic resins dissolved in a volatile oil for use on wood or sometimes metal. Like almost all paint industry products, varnish is manufactured using a process where the proper amounts of ingredients are mixed together in a batch and then packaged. Varnish is unique in that it is cooked in the manufacturing process. However, like paint, varnish cures through polymerization by reaction of the binder with oxygen in the air after evaporation of the solvent. In contrast, lacquers cure merely by evaporation of the solvent, forming the film. While varnish is usually unpigmented, producing a clear coating, it may also be pigmented. It may also be used occasionally as a base in making paint.

2. Emissions and Costs of Control

Varnish must be cooked during production, which results in the evaporative emission of hydrocarbons. Air pollution control to 90 - 95 percent efficiency can be attained using direct-fired afterburners.

All varnish plants in California were assumed to be controlled, while only about 20 percent of the plants located elsewhere were assumed to be controlled. The overall national level of controls was estimated to be 18 percent. Emissions for 1967 were estimated by using an emission factor of four percent of throughput. Hydrocarbon emissions were thus estimated to be 2,200 tons per year for 1967 in the 298 metropolitan areas. Implementation of the Clean Air Act would require an initial investment of $790,000 and an annual cost of $0.95 million. Emissions would be reduced to approximately 300 tons per year in Fiscal Year 1976.

3. Engineering Basis of the Analysis

The cost of a direct-fired afterburner system serving two varnish cookers varies from about $2,000 to $3,000 depending on the type of venting system and the exact type of afterburner [Refs. 77-79]. Exit gas rates on the order of 350 acfm to about 1,000 acfm are normally encountered. More than one varnish cooker is usually used at a plant, and for the purposes of this report, a step-wise increase in cost was used as the manufacturing capacity of an establishment increased. This cost versus size relationship is shown in Figure IV-30.

Operation and maintenance costs, assuming gas stream input and output tempreatures of 500^{o} and 1200^{o} F, respectively, were based on the following equation [Ref. 15]:

$$G = S[195.5 \times 10^{-6} PHK + HF_i + M]$$

where: S = acfm, 600 acfm for up to 250 gal tank, and 1200 acfm for 250-1000 gal tank;

P = 1" water;

H = 2400 hours/year (240 days at 10 hrs/day);

K = \$/kwh;

F_1 = \$0.0027/acfm/hr (0.03 cfm fuel/acfm exit gas) [Ref. 15], fuel cost = \$0.0015/ft^3;

F_2 = \$0.0015/acfm/hr, fuel cost = \$.00085/ft^3;

F_3 = \$0.0009/acfm/hr, fuel cost = \$.00050/ft^3;

M = \$0.06/acfm.

The various fuel costs (F_i) were based on average gas rates for different parts of the country [Ref. 80]. Using these fuel costs, the annualized cost factors (including 20 percent depreciation and capital charges) presented in Table IV-64 were obtained.

TABLE IV-64. - CAPACITY VS. ANNUALIZED COST FACTORS

Capacity (gal)	Annualized Cost Factors ($)		
	East Coast, Northwest, Hawaii (F_1)	Midwest (F_2)	Southwest (F_3)
0-250	4390	2650	1820
250-1000	8705	5225	3365

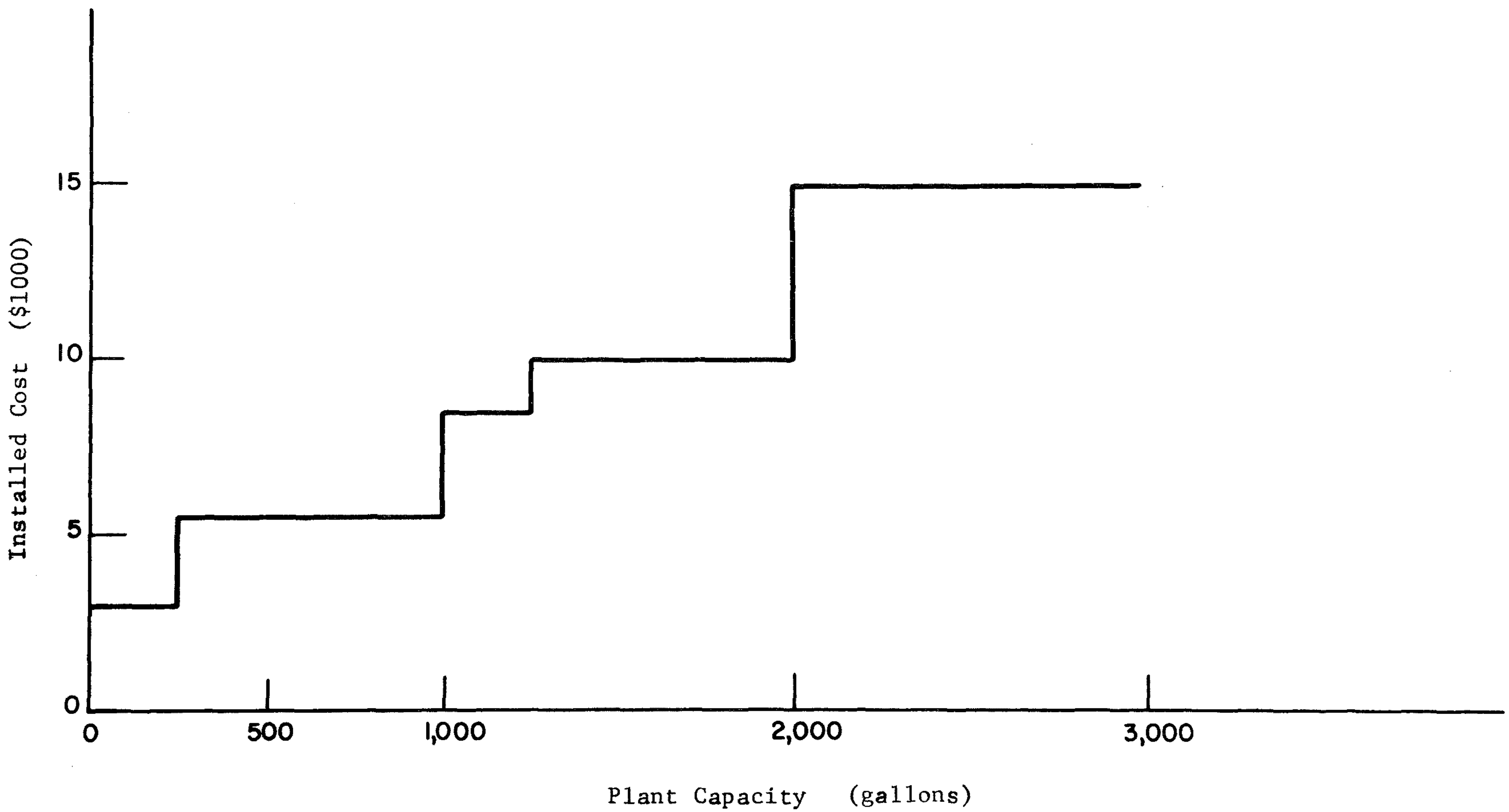


Fig. IV-30. Installed Cost for Direct-fired Afterburner for Varnish Plant.

Emissions for 1967 were estimated by using an emission factor of 4 percent of throughput [Ref. 14] and assuming 20 percent of the plants were already controlled. Fully controlled emission estimates were based on all plants being controlled with a hydrocarbon removal efficiency of 90 percent.

Due to the varied types of varnish plants, a model plant approach was used to determine control costs. Plant names, locations, and numbers of employees for plants producing varnish were extracted from a Dun and Bradstreet listing. Area varnish-making capacity was estimated by relating regional employment to the ratio of national production of varnish to national employment in the industry. The control costs for the model plant were based on a production rate of 250 gallons per cooker and on a direct-fired afterburner (without heat exchange) control system. A step-wise increase in control costs based on as many as four tanks venting into a single control system was used. Any plant larger than one thousand gallons (4 cookers at 250 gal. each), therefore, required at least two control systems.

Twenty percent of the plants throughout the country were assumed to have adequate existing controls and all plants in California were assumed to be adequately controlled.

The average size of the plants within a region was obtained by first dividing the annual regional varnish manufacturing capacity by 240 days per year and then dividing this daily capacity by the number of establishments. Where one or two plants in a region were extremely large, as indicated by their employment, they were handled separately, i.e., not averaged in with the smaller plants. Only plants with more than 2 employees were included in the cost analysis.

The cost for the average plant (indicated in Figure IV-31) was multiplied by 0.8 (eighty percent of the plants were assumed uncontrolled.) Costs for very large plants were estimated as separate items and added to the cost of the average plants.

Annualized costs included operating and maintenance costs and 20 percent of capital investment. Variation in fuel cost was taken into account as previously shown in Table IV-64.

4. Scope and Limitations of Analysis

Because of the large number of small firms producing varnish, data on plant location is incomplete. Detailed data on plant capacities and production are also incomplete and were estimated from industry totals by applying known relationships to data on employment by plant and industry totals. Statistics on varnish or resins produced by heat reaction in 1967 (or any other year) apparently do not exist either among government or industrial sources. The problem is further compounded by the fact that some products that are called varnish are not varnish (although they may have been in the past) but are more properly called lacquers. Electrical insulating varnish is an example of a major product of this type.

Financial data by plant or firm are even more fragmentary and, therefore, estimated industry costs may be somewhat in error. However, the estimates given are felt to indicate the order of magnitude of industry cost impact and to reflect a reasonable approximation of the control cost per gallon of product.

5. Industry Structure

One statistical source indicates that there were 220 plants producing varnish in the United States in 1967 and 216 of these plants were located in the 298 metropolitan areas. Estimated capacity was 23 million gallons for the U. S. and 22 million gallons for the metropolitan areas. Production by United States and metropolitan area plants was estimated at 10 million and 9.6 million gallons in 1967, respectively.

6. Markets

The market for varnish is largely a function of building and building maintenance activity; competition for sales is keen. This results from the large number of firms that produce varnishes, large unused production capacity, low investment requirements, a well-known technology, and a number of very competitive substitutes.

Varnish, like other paint industry products is distributed through two district channels; industry and trade. Industrial sales are made directly by the manufacturers to industrial users for use either in production or for maintenance. Trade sales are those made to wholesalers and other middlemen for resale to the general public, contractors, and other commercial accounts.

Industry sources indicate that varnish products move almost entirely in trade sales channels. They have been almost entirely replaced in industrial markets by other types of finishes with superior characteristics such as faster drying and greater durability. A similar trend is taking place in trade sales, where varnish is receiving stiff competition from lacquer, urethane, and epoxy finishes because of drying and durability properties. In addition, increasing use of "prefinished" products are reducing demand for on-site finishing and finishes.

Paint industry products are generally not important in world trade since they are expensive to ship and easily produced locally. International licensing agreements and foreign joint ventures are common and U.S. industries are leading participants.

In 1967, paint industry exports were 10.2 million gallons valued at $42.7 million, or 1.7 percent of all U. S. dollar shipments. Trade sales products account for about 60 percent of the total shipped on a volume basis. Imports were $1.6 million and included some distempers, water pigments, stamping foils, and dyes.

7. Trends

For the decade ending in 1967, paint sales (dollars) increased at an average annual rate of 4.7 percent as compared to 6.3 percent for GNP and 1.4 percent for population. Volume of sales (gallons) increased by an average of 3.4 percent per year. Future growth in the paint industry should approximate the volume rate.

The factors limiting long-term growth in the paint industry and sales of varnish are increasing use of products that require no paint or less paint, and the improvement of paint products themselves. Products that require no paint include such materials as stainless steel, aluminum, glass, stone and brick, Fiberglass reinforced plastics, laminates, extruded or molded plastics and such surfacing materials as wall paper, plastic films, porcelain enamels, and electroplated, phosphated or oxidized metal films. To meet such competition, the paint industry has developed more durable and easily applied coatings resulting in lower costs per unit of surface covered.

Factory finished building materials are replacing on-site painting which is becoming increasingly expensive. Labor now accounts for as much as 80 percent of the total cost of on-site finishing. Since prefinishers generally use specially formulated industrial finishes, the trend towards prefinishing in building products is at the expense of trade sales products such as varnish.

Varnish is not expected to share in the growth of paint industry sales because of the competition from substitute materials, from prefinishing, and from other coatings. Instead, varnish is expected eventually to be largely replaced by competitive finishes and materials among trade customers as it has among industrial customers. Because habits and customs are slow to change, varnish sales and production are expected to remain approximately at present levels through fiscal year 1976.

8. Economic Impact of Control Costs

Assuming approximately 220 firms producing varnish with production of 23 million gallons, this analysis indicates that for the average firm an initial capital investment of $3,600 or $0.036 per gallon of capacity would be required. Because of the large unused capacity, investment per gallon of product would be almost $0.08.

The total annual cost to control the varnish producing segment of the paint industry would be $950,000 per year by Fiscal Year 1976. This cost includes allowances for recovery of investment, interest, taxes, fuel, labor, maintenance, and other expenses of owning and operating the air pollution control equipment. For an estimated Fiscal Year 1976 production of 10 million gallons, this gives an incremental cost of almost $0.10 per gallon.

Considering the nature of competition among producers and by substitute materials, few firms can afford cost increases of this sort from profits nor will they be able to completely shift the

$0.10 per gallon increase to the consumer through price increases. It is expected that about half this increase can be shifted; thus, prices may be expected to rise by about $0.05 per gallon above the level they would otherwise achieve by 1976.

It is expected that all producers in a region or market will tend to postpone installation of control equipment as long as possible so as to avoid incurring this cost. When regulatory orders force compliance, most firms will act at the same time. The action taken by firms will depend on their evaluation of their own varnish sales, their share of the varnish market, and the firm's expectation of customers reaction to a price increase. Marginal varnish producers will discontinue production and will either drop varnish from their product line or contract to buy varnish for resale under their own label.

Any price increase will cause some buyers to switch to the wide variety of substitutes available, hastening present trends to other products. Since use of varnish is already declining and a price increase will cause a further decline, the firms that install air pollution control equipment will do so only on equipment they anticipate will be used regularly enough so that they can recover their investment. As a result, the present unused capacity may be scrapped to the maximum extent possible, and some of the currently used capacity may also be scrapped.

If this pattern occurs, there is little reason to anticipate financial difficulties except for those firms that are already marginal. The paint industry as a whole is basically healthy.

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APPENDIX V

Alternatives To The Control Of Sulfur Oxides From Stationary Combustion Processes

APPENDIX V

Alternatives to the Control of Sulfur Oxides from Stationary Combustion Processes

I. INTRODUCTION

In the second Cost of Clean Air Report [Ref. 1], it was assumed that the control of particulate and sulfur oxides emissions from stationary combustion sources during the period Fiscal Year 1971 through Fiscal Year 1975 would be achieved by a straightforward switching from high-sulfur coal and high-sulfur residual fuel oil to low-sulfur residual oils.[1/] At the time of publication of the second report, inadequate data hampered consideration of any other possible alternatives. In the intervening year, however, data and information have become available on which to view other alternatives, as well as study the reasonableness of the fuel switch alternative previously chosen. The purpose of this appendix is to summarize these new findings and to discuss the basis of the control alternatives chosen in the third Cost of Clean Air Report. Finally, although this report encompasses only 298 metropolitan areas, the concentration of population and fuel consumption makes it reasonable to broaden the discussion to the national basis. Therefore, the focus of this appendix centers upon conclusions which can be drawn for the entire United States.

II. PATTERNS OF FUEL CONSUMPTION

A. Coal

In 1967 the United States consumption of bituminous coal amounted to 520 million tons. Of this amount, only 187 million tons contained less than 1 percent sulfur. Of this 187 million tons, 48.6 million tons were exported and 91.6 million tons were used for metallurgical coking

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1/ High-sulfur coal is defined as having a sulfur content of greater than 1 percent; and high-sulfur oil greater than 1.38 percent.

purposes. Within the stationary combustion category, steam-electric generating utilities consumed 270 million tons, industrial boilers consumed 78 million tons, commercial-institutional heating plants consumed 5.2 million tons, and residential heating facilities consumed 21.9 million tons. By 1975, it is expected that in the absence of any regulations on allowable fuel usages,steam-electric generation would consume 430 million tons; industrial boilers, 63 million tons; commercial-institutional heating plants, 2 million tons; and residential heating plants, 9 million tons. It is important to notice the expected natural decline in the utilization of coal for the latter three stationary combustion categories with an equally noticeable rise in the amounts predicted for the utility steam-electric generating industry. Of course, the steam-electric industry's justification for planned increases in the utilization of coal is that coal is the only major fuel which could, by itself, meet the cumulative energy demands for the remainder of this century or beyond [Ref. 2]. A more comprehensive discussion on fuels availability will be given in Section III.

B. Oil

Fuel oils presently account for 17 percent of the nation's fuel consumption in terms of energy equivalents [Ref. 3]. Fuel oil may be considered as two types: distillate (No. 1, 2 and 4 oils) and residual (No. 5 and 6 fuel oils). All distillate oils fall within the sulfur content range of 0 - 1.0 percent.

Consumption of distillate oil for the Nation in 1967 amounted to approximately 550 million barrels. Percentage utilization for residential, commercial-institutional, and industrial users was 82 percent, 10 percent and 8 percent, respectively. However, the apparent trend is toward a greater proportion of distillate oils to be used by commercial and industrial customers.

The average sulfur content of domestic residual fuel oil is about 1.75 percent although the percentage range is very wide. Average values for domestically produced residual fuel oils (No. 6) for various regions of the country range from 1.36 percent in the Eastern Region to a high of 2.09 percent for the Rocky Mountain Region. Other values include 1.51

percent for the Western Region, 1.70 percent for the Central Region, and 1.84 percent for the Southern Region [Ref. 2]. Offsetting the recent trend of domestic producers of decreasing domestic, residual fuel oils has been an increase in the importation of this commodity from foreign countries. In the three years from 1965 through 1967, imported residual fuel oil increased from 267 to 345 million barrels per year. In general, the imported residual fuel oil has higher sulfur content than domestic due to the fact that many of the foreign crude oils have higher sulfur content.

In 1968, 620 million barrels of residual oil were consumed in this country. Of this, roughly 25 percent was consumed in each of the large commercial-institutional heating plants, industrial operations, and steam-electric utilities. The remainder was consumed by vessels, the military, oil company usage, railroads, and others [Ref. 2]. Most of the imported residual oil is received at east coast terminals. However, some is also received at the west coast ports and used in the immediate area.

C. Natural Gas

A total of nearly 18.2 trillion cubic feet of natural gas was consumed in the United States during 1967. About two-thirds of the gas is used for industrial purposes including 2.7 trillion cubic feet for steam-electric generation. Approximately 3 trillion cubic feet is consumed in residential heating units and another 2 trillion for commercial-institutional heating purposes. Current trends seem to indicate an increasing desire to increase the utilization of natural gas in all stationary combustion categories.

III. LOW-SULFUR FUEL SUPPLY PATTERNS

A. Coal

Of the 333 million tons of high-sulfur coal produced in 1967, it is estimated that only 11 percent of this quantity could be cleaned to a sulfur content of 1 percent or less by present pyrite washing techniques. The estimated cost of cleaning the coal is about 80 to 90 cents per ton. [Ref. 4]. Present methods of coal washing is limited, therefore, to reduction of pyritic sulfur, and it can be expected to yield only a moderate increase in the supplies of low-sulfur coals. In many different types of coal, the amount of sulfur is present in almost equal pyritic and organic fractions. Experiments with organic solvents, such as hexane, to remove the organic sulfur indicates that costs will be prohibitive [Ref. 4]. However, notwithstanding the sulfur content problem, coal is by far the most abundant fossil fuel resource in this country. Moreover, The Office of Coal Research indicates that proven coal reserves are roughly equivalent to a 400-year supply at present rate of production.

B. Oil

Both the Bureau of Mines and Oil Import Administration indicate that there is no appreciable surplus of residual oil production capacity in the United States today; furthermore, domestic production of residual fuel oil has been decreasing in this country. It is anticipated that refiners will continue to reduce the yield of residual oil in the future. The possibility of increased production of crude oil resulting in increased production of the various fractions is not very promising. Except for the Southern Lousiana fields, no significant increases in pumping is anticipated [Ref. 5].

Even with residual oil desulfurization techniques, domestically produced fuel oil does not appear to be a major alternative. Whatever low-sulfur oils that can be produced and/or desulfurized will be needed for commercial-institutional heating plants, and to some extent for industrial operations. Therefore, residual oils are not apt to play any major role in the solution to the sulfur dioxide problem in the steam-electric utility industry.

Residual oil may now be imported at east coast ports without limit for eastern consumption, but west coast imports are sharply limited by quota. Planning is already underway to desulfurize the foreign crude oil either at the refinery or more likely in this country. From these sources the supply of low-sulfur content residual oil can be increased tremendously. It appears unlikely, however, that the Oil Import Administration will permit, for reasons of national security, imports into any additional regions of the country that will substatially increase dependence of United States power producers on imported residual oil.

C. Natural Gas

Natural gas is an ideal fuel from the point of view of air pollution emissions. Particulate emissions are near zero and sulfur dioxide emissions are negligible. However, the Federal Power Commission reports that the supply of natural gas is diminishing to critical levels in relation to demand. On the basis of current trends, only a few years remain before demand will outrun supply [Ref. 6].

The Commission does report on several supplementary sources of gas which may prove feasible during the 1980's. The processes include high B.t.u. gasified coal, liquified natural gas (LNG) imports by ocean tanker, and Alaskan natural gas. The technical feasibility of producing pipeline quality gas from coal and lignite has been demonstrated in a recent study by Bituminous Coal Research, Inc. which is covered in Reference 6; however, the economic feasibility of producing pipeline quality gas from coal and lignite has yet to be demonstrated on a large scale in the United States [Ref. 6].

The transportation of LNG in specially designed ocean freighters could potentially relieve the U. S. gas distribution industry from complete dependence on U. S. and Canadian produced natural gas. The impact of the importation of significant quantities of LNG would not be felt for a considerable period of time. Large additions to the present ocean-going fleet must be constructed, storage facilities of significant expense and technological complexity must be constructed at various U. S. deep water ports, and additions must be made to the existing natural gas pipeline network. Finally, the net result of LNG inputs in the future may be simply to satisfy natural increases in the demand for natural gas. Therefore, it may not be reasonable to consider the use of LNG as an alternative for existing nongas-burning facilities.

The newly discovered Alaskan natural gas field will likely be one of the world's largest. However, transportation via LNG tanker or by pipeline will be costly and difficult. At present, there are no immediate prospects of exporting natural gas from Alaska to the United States. To quote the Staff Report on Natural Gas Supply and Demand, "Alaska obviously has excellent potential for petroleum resources. However, the financial and manpower drains involved in developing these far north resources could have a retarding effect on the development of our other gas areas. Money that might have gone into additional deep drilling, the development of an oil shale industry, and gasification of coal, and the exploration of our other shelf areas may now go to Alaska. The magnitude of the gas reserves will have to be enormous and the development of a transportation system will have to be timely in order to offset the possible detrimental effects."

IV. THE REMOVAL OF SULFUR OXIDES FROM STACK GASES

The preceding has dealt with the possibilities of limiting the amount of sulfur in the fuel itself; this section will discuss briefly the possibilities of achieving significantly reduced SO_2 emissions by the application of alternative hardware systems at the stack. In the past year, a great deal of information has been written concerning this area. Most of this information is concentrated on the control of emissions from utility steam-electric generating plants; however, it may be equally applicable to other large fossil fuel burning facilities. At this point whether such application will be possible in smaller facilities is unknown.

The growing problem of atmospheric pollution by sulfur oxides has promoted a large amount of research and development on processes to remove this pollutant from power plant stack gases. The purpose of this section, therefore, is to present information on each of the most promising processes paying special attention to probable commercial availability, expected removal efficiency, costs, by-products where applicable, and suitability or lack of installation in existing facilities. The processes being developed may be reasonably classified as those which yield a "throwaway" residue and those which yield a potentially salable by-product. A technical discussion of each process is limited because such material can be found elsewhere in the literature.

A. Throwaway Processes

Of the throwaway processes, sufficient work has been done suggesting that the dry limestone and wet limestone processes will soon become commercially available.

The dry limestone injection process is viewed as the process which could become the first commercially available process for sulfur oxide control. It is also applicable to older and smaller plants which have a limited life. The advantages of the process include simplicity, availability of limestone in the vicinity of many power plants, and ease of installation in existing facilities. The most significant disadvantages include substantial increases in solid waste disposal requirements in the plant, the necessity of high-efficiency, large-capacity electrostatic precipitators, very poor overall SO_2 removal (20-50 percent), and low efficiency of utilization of the limestone. Overall, the results of the work done on this process may be considered very disappointing.

The limestone injection wet scrubbing process could be applicable to new or existing power plants; however, it is best adapted for larger facilities. The process is under intensive developmental efforts at present, and successful commercial demonstrations and acceptance are anticipated within one to two years. There are two variations of the limestone wet scrubbing process. Either limestone can be injected into the power plant boiler, or limestone or more preferably lime can be injected directly into the scrubber. The latter process was developed over 30 years ago in England; however, for a variety of reasons, modern emphasis is on the former. Results of experimental work demonstrate that a high degree (in excess of 90 percent) of sulfur oxide removal can be achieved by this process. Other advantages include particulate removals in excess of 99 percent in the scrubber thus avoiding the need for an electrostatic precipitator, low investment costs in comparison with any of the by-product type systems under consideration, and significantly, the application of a well-known technology. Also noteworthy is that the total operating costs for limestone wet scrubbing may be lower than any of the by-product processes even when credit is given for the sale of the various products. Disadvantages of the process include a liquid waste sludge, a possible water pollution problem, the necessity of reheating the off-gas, and the potential formation of scale expecially in the scrubber system.

B. By-Product Recovery Systems

Several processes for recovering sulfur from the stack gas following combustion are at or near the demonstration level. These processes will remove the sulfur oxide and convert it into marketable products such as sulfuric acid and elemental sulfur. It must be noted at this point that the potential acceptability of any of these processes is dependent upon sale of the recovered products at reasonable prices.

In addition, existing power plants will probably not wish to consider installation of by-product recovery systems due to the extensive integration into total plant operation which will be required. Hence, the possible utilization of these processes would appear more suitable for plants under design. Of the by-product processes under consideration, the most promising ones are the Stone and Webster/Ionics process, the Wellman Lord process, and the Catalytic Oxidation (Cat-Ox) process.

The Stone and Webster/Ionics process will produce high purity H_2SO_4, H_2, and O_2 as products. The process, however, must be limited to those plants, either new or existing, which have large daily swings in electrical output due to the large electrical requirements of the process itself. Investment costs are projected to be about double those for wet limestone scrubbers and the annual operating costs are dependent upon the existence of long term markets for H_2SO_4, H_2 and O_2. This, of course, is dependent upon plant location as well as other market factors. In addition, a high efficiency particulate removal device will still be required prior to the process. In any case, it is expected that possible commercial availability would not occur before 1975.

The Wellman Lord process can produce concentrated sulfur dioxide from power plant flue gas. The concentrated sulfur dioxide steam can then be converted in a contact plant to sulfuric acid or in a Claus plant to elemental sulfur. The process is applicable to all boilers both old and new. It seems reasonable that the concentrated SO_2 would be converted to elemental sulfur since it is a more valuable by-product than acid. However, unless additional control systems are used on the auxiliary acid or sulfur plant, some of the original SO_2 captured from the power plant flue gas will eventually be emitted to the atmosphere. The investment cost for this process (Wellman and Lord + sulfur plant) is estimated to be approximately 1-1/2 times that for the wet limestone system. Unless a market is available for either the sulfur or sulfuric acid, operating costs could run as high as twice the wet limestone operating costs. In addition, high efficiency particulate removal is required prior to the process. Possible commercial availability cannot be expected before the middle of 1975.

The Catalytic Oxidation (Cat-O_x) process consists of two basic designs. The integrated system is to be employed with new power plants while the "reheat" system is intended as an add-on unit for older plants. The process removes SO_2 from the flue gas and converts it to a potentially salable by-product which is approximately 80-percent sulfuric acid. The process includes removal of all flyash from the flue gas. The process is exceedingly expensive--possbily running 3 times the investment cost of wet limestone scrubbing. Operating costs, assuming full credit for sale of H_2SO_4, will probably exceed that for wet limestone scrubbing. If the sulfuric acid cannot be sold at the market price, the annual costs are prohibitive. In any case, commercial availability is not expected before 1975 for the "reheat" system and the middle of 1977 for the integrated system.

V. OTHER LONGER RANGE POSSIBILITIES

At least two processes offer hope for removal of sulfur during combustion. These two, the "fluidized bed" combustion process and the "molten iron bath" combustion process, have not yet entered the development stage. It is doubtful that they can be retrofitted into existing plants since both require major boiler design modifications. The fluidized process is applicable to both high sulfur coal and oil while the molten iron bath process is applicable only for the combustion of coal. Feasibility studies for both processes are currently underway.

Somewhat related to the molten iron bath process is the so-called MHD power system which represents an entirely new concept in the production of electrical energy. Description even in the simplist terms is beyond the scope of this study; however, the process would virtually eliminate both sulfur dioxide and particulate emissions. Work is being carried out on a theoretical level for this process. No estimate can be given of the date of commercial availability.

VI. AVAILABLE ALTERNATIVES

The alternatives as well as other information which has been briefly discussed above were carefully reviewed for the purpose of arriving at a reasonable methodology by which emission reductions and control costs for stationary combustion sources could be attained. Two constraints were imposed on the decision making process: the alternative should stand a reasonable chance of being implementable by 1976, and the alternative should be consistent with longer range solutions to the problem.

A. Residential Heating

According to present trends, the usage of coal as a fuel for home heating is diminishing quite rapidly giving way somewhat to the use of distillate oil but more rapidly to the use of gas and electricity. In some regions, use of distillate oil is giving way to natural gas and electricity. For these reasons, the report assumes that coal use for residential heating will decrease by "natural attrition" with the restriction that no coal boiler could be replaced by another coal boiler; therefore, no costs to the residential component of stationary combustion sources have been assigned as resulting from the Air Quality Act. In other words, it is assumed that whatever changes have occurred or will occur in the direction of lower air pollutant emissions will have occurred without enactment of any form of air pollution legislation.

B. Commercial-Institutional Heating Plants

At present, commercial-institutional heating plants are predominantly oil and gas burning facilities with only minimal usage of coal. Furthermore, only a small fraction of these units are presently burning a high-sulfur fuel oil. It can also be reasonably assumed that no further facilities which utilize coal or high sulfur residual fuel oil will be installed. Therefore, the cost estimate developed is only for switching present coal burning facilities to a low-sulfur content oil. The utilization of hardware for the control of the sources is not considered a reasonable alternative. Finally, it was assumed that all facilities which burn natural gas would continue to do so. New facilities, it was assumed, would burn low-sulfur oil or gas without the pressure of any form of air pollution legislation. Therefore, no control costs for additional sources were computed.

C. Industrial Boilers

The choice of a reasonable alternative for the control of emissions from industrial boilers was not so straightforward. In the absence of specific legislation establishing criteria for fuel sulfur content, many existing industrial boilers can be expected to be coal-fired for the foreseeable future. In addition, many would continue to burn high-sulfur residual fuel oils. There is a trend away from building new coal burning facilities with a preference toward increasing utilization of natural gas.

The use of hardware control of SO_2 from coal and high-sulfur oil burning boilers was considered. Specifically, the use of the wet limestone injection process was under consideration. However, the adoption of this alternative would have required installation of wet limestone injection systems on a large number of relatively low B.t.u. capacity boilers. Preliminary economic analysis of the process shows that unit costs increase dramatically with the size of the boiler. Indeed preliminary calculations have shown that a reasonable cutoff point is a boiler size of 200 megawatts or the equivalent in terms of millions of B.t.u. input. Only the few largest industrial boilers fall near this size range. In addition, the large number of systems which would be required make this alternative an unlikely choice for implementation by 1976.

It finally appeared that a choice involving a switch from coal and high-sulfur residual oil to low-sulfur oil is probably the only feasible control alternative available with reasonable chance for implementation by 1976 for this source. The assumption here, of course, is that additional quantities of low-sulfur oil will become available in the near future. It does not appear too unreasonable that some easing of import restrictions on low sulfur oils or high sulfur oils allowing for desulfurizing plants to be constructed in this country will occur and permit such an alternative to be implemented. Of course, additional fuel costs on a B.t.u. basis will be involved.

D. Utility Steam-Electric Boilers

There is no question that until about the year 2000[2/] there will have to be an increasing reliance on the use of coal to supply our ever increasing power requirements [Ref. 6]. To assume the "across the board" switch-

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2/ By that time the use of nuclear energy will equal the use of coal after which the requirement for coal will start a downward trend.

ing of coal to low-sulfur residual oil without envisioning severe shortages of such fuels for other sources, specifically commercial-institutional and industrial boilers, and without considering that such a massive fuel switch might be completely unfeasible, was unacceptable.

It became fairly obvious that low-sulfur fuels, both oil and gas, are not presently available in such large quantities and quite possibly may be available to that extent. Even considering that approximately 10 percent of the available coal could be desulfurized to about 1 percent[3/], the resultant supply of low-sulfur fuel will still not be adequate. Consideration of the possibility of dramatically increased imports of residual oils into this country for power production is, at present, not consistent with stated policy to avoid a substantial increase in the dependence of U. S. power producers on imported residual oil. Therefore, it became apparent that use of several alternatives would be required to develop cost estimates of controlling steam-electric boilers by 1976.

Among the hardware alternatives, only the wet and dry limestone processes are amenable to retrofitting. Therefore, only these could be considered for existing facilities. The application of the various recovery processes for the control of coal and oil burning boilers to be built by 1976 did not seem to be an unreasonable alternative at this time for two reasons. First, expected availability of these processes will probably not occur until 1974 or 1975 at the very earliest, and second, the present and near future for marketing the various by-products does not seem to be especially bright. Therefore, recovery processes were not considered further. Of the two throwaway processes, the wet limestone process appears to be clearly superior at present.

In a comparison of the increase in annual costs of switching fuel and the application of wet limestone scrubbing systems, it was found that below a 200 megawatt plant operating at about a 17 percent load factor a switch to a low-sulfur content fuel of the same type would be cheaper [Ref. 7]. In addition, when analysis of available data showed that power plants rated less than 200 megawatts consumed only 33.3 million tons of coal,

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3/ Even this level may not be adequate with many cities and states setting limits of 0.5 percent or less. Examples are New York City and the State of New Jersey.

it was concluded that a fuel switch in these smaller plants, while assuming the application of wet limestone injection scrubbing process for larger coal and oil burning plants, would represent a reasonable choice of alternatives which could possibly be implementable by 1976. After consultation with various personnel within APCO, it was finally decided to employ this combination of alternatives as the cost estimating methodology for this report.

VII. CONCLUSION

On the basis of current information, an across-the-board switch to low-sulfur fuels for the purpose of sulfur dioxide abatement appears unfeasible. Fuel-switching can be realistically anticipated for the residential, commercial-institutional and industrial sector, with the exception of the steam-electric utility industry. For this industry, stack gas scrubbing plus some fuel substitution may be feasible. By 1976, it appears that only the wet limestone scrubbing systems meet the criteria of commercial availability, economic reasonableness, and adequate removal efficiency. In the long run, pollution abatement in the steam-electric industry will result from increased nuclear power generation and from other technological developments which may be available in the period of the 1980's.

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APPENDIX VI

IMPACT OF THE COST OF EMISSION CONTROLS ON THE PRICE LEVEL OF THE U.S. ECONOMY

Appendix VI

Impact of the Cost of Emission Controls on the Price Level of the U. S. Economy

I. INTRODUCTION

The annual costs of air pollution control are estimated for each of the 18 industrial process sources studied (Appendix IV) and increases in the prices of the output are projected (See Table VI-1).[1/] These projections are based on the structure of each industry and the demand for each industry's product. Estimates are made in this appendix of the impact of the price increases on the economy's overall price level in order to gain further insight as to the effect of air pollution control on the standard of living, as reflected in the level of prices. This appendix also examines separately the impact of those price increases on two industries, construction and automobiles, because they consume significant portions of the output of industries studied and because of their importance to the economy.

In order to develop estimates of the impact of the costs of emission control on the price level of the U. S. economy, it was assumed that the price increases projected for the industries studied will be passed along, by all firms purchasing the output of these industries, to final purchasers and that the pattern of inputs for any purchasing industry will not be affected. It was assumed also that as a result of the costs of emission control, imports are not increased nor is production outside the metropolitan areas encouraged relative to the production of the firms inside the metropolitan areas. Finally, it was assumed that the distribution of the gross national product (GNP) in Calendar Year 1975 will be similar to the historical distribution.

II. IMPACT ON THE PRICE LEVEL FOR SPECIFIC INDUSTRIES

Using input-output relationships, it is possible to estimate the impact of the projected subject industry price increases on the general level of prices and on the price level of other industries. Input-output is a method for analyzing the interdependence among the

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1/ Because of the large number of tables and figures in this appendix, they have been put at the end for ease in reading of the text.

industries or sectors of an economy. Input-output analysis uses a table or matrix which shows for a specific point in time the distribution of sales and purchases by each industry. In constructing an input-output table, the output of each industry is divided into two categories: (1) the interindustry transactions and (2) the final demand sales. The total output of any industry can be represented by the following equation:

$$\sum_{j=1}^{n} X_{ij} + C_i = X_i \quad (i = 1 . . ., n),$$

where:

X_{ij} = amount of output industry i sells to industry j,

C_i = final demand for output of industry i,

X_i = total output of industry i.

At this point, the table consists of cells containing the dollar value of the interindustry transactions (X_{ij}) or final demand sales (C_i) in each cell. The table, however, is more useful when the transactions are converted into a system of technical coefficients of production. A technical coefficient is the ratio of input to output and can be written as follows:

$$a_{ij} = \frac{X_{ij}}{X_j},$$

where:

a_{ij} = technical coefficient,

X_{ij} = amount of output of industry i purchased by industry j,

X_j = total output of industry j.

For example, in the production of $40.031 billion of motor vehicles and equipment in 1963, $3.453 billion of primary iron and steel was directly consumed. The technical coefficient expressing the direct requirement for steel by the motor vehicle industry is therefore:

$$\frac{3.453}{40.031} = 0.0863.$$

In other words, to produce $1.00 worth of output of motor vehicles required about $0.09 worth of primary iron and steel.

The final form into which the initial transactions matrix can be transformed shows both the direct and indirect inputs from one industry to another. For example, it was noted above that the motor vehicle industry's direct requirement for steel is 0.0863. However, to build a motor vehicle requires other inputs which, in turn, require steel as an input. The technical coefficient for the rubber and miscellaneous plastics products used by the motor vehicle industry is, for example, 0.0223, but to produce rubber requires a direct input of steel of 0.0051. Coefficients which represent both the direct and indirect requirements are generated by inverting the direct requirements matrix. The resulting matrix shows the direct and indirect output of industry i required for industry j to deliver a dollar's worth of output of final demand. In the case of the motor vehicle industry the direct and indirect requirements for steel are 0.2121.

Knowledge of the structure of the American economy as represented by the direct requirements and the total requirements (direct and indirect) coefficients may be used to evaluate the impact of the projected increases in the prices of products of the industries in question. This can be done because it identifies the industries which purchase the affected products and provides a basis for estimating the price increases necessary to maintain profit levels.

The U. S. Department of Commerce has published three input-output tables of the U. S. economy. The most recent table, for the year 1963, was just released. This table was expanded more than fourfold from the previous table (1958) to about 370 separate industries which permitted identification of most of the subject industries. Table VI-2 compares the identification of the subject industries, both by name and standard industrial classification (SIC) number, with the closest industry in the input-output table. In most cases the industries are the same.

The 370 sector table was, however, found to be too unwieldy in this application so it was reduced from computer tapes of the table to a smaller table based on the 1958 table's classification of industries. However, the integrity of the subject industries was preserved. What resulted, therefore, was a table which shows the industries in detail and the rest of the sectors in a more aggregated form. Finally, the major purchasers of the output of the subject industries were identified as the industries that consumed one percent or more of the intermediate output of each of the subject industries. There were 72 such industries. The final input-output table is presented in Table VI-3. Three ratios are presented in each column. The first is the portion of the output of the subject industry purchased by the consuming industry. The second number is the technical coefficient--that is, the portion of the industry's total inputs which comes from the subject industries. The third is the total requirements coefficient, reflecting the industry's direct and indirect requirement for the output of the subject industry.

Next, an estimate of the impact of the costs of emission control on the price level of each of the 72 industries, which purchase one percent of each subject industry's output, can be derived by using the estimated price increase for each subject industry adjusted downward by the percent of the industry not in the metropolitan areas, and the percent the subject industry is of the input-output industry, and multiplying it by the total requirements coefficient. Table VI-4 shows the projected increase in the price levels of the industries primarily affected by the subject industries. Due to problems in identifying the grain and petroleum storage industries in the input-output table, these industries are excluded.

In order to estimate the impact of the projected price increases on the general price level of the U. S. economy, each industry's contribution to GNP was determined based on the distribution of final demand presented in the 1963 input-output table. The values are shown toward the bottom of Table VI-4. Finally, by multiplying the contribution of each industry to GNP by the increase in the price level projected for the industry and summing the results, an estimate of the impact on the general level of prices is obtained. The estimate is expressed in terms of the increase in the implicit price deflator for gross national product, an index similar to the consumer price index. Table VI-5 shows the estimated impact by major sector.

The primary reason for the small price increase is that only nine of the study industries are projected to increase their prices over one percent, and none of the increases exceed three percent. Of these nine, four have less than 55 percent of their capacity in the 298 metropolitan areas which further reduces the impact of the price increases.

The industry most affected is construction, which accounts for 43 percent of the 0.14 percent increase. The primary contributor to the increase in construction costs is the price increase projected for steel. Nine percent of the steel output is purchased by the construction industry where it accounts for two percent of the construction industry's inputs. Also contributing to the projected increase in construction costs are price increases by the gray iron foundries, steam-electric power plants and the brick and tile industry.

Manufacturing is expected to contribute 29 percent of the 0.14 percent increase, largely as a result of price increases in the motor vehicle industry due to higher prices for steel, gray iron castings and steam-electric power; other transportation equipment industries due to higher steel and gray iron casting prices; and food and kindred products industries due to higher electric and coal prices.

Transportation, communication, electric, gas and sanitary services price increases contribute 21 percent of the projected 0.14 percent price increase as a result of higher electric and coal prices.

Services account for the smallest portion of the 0.14 percent increase - 7 percent, due to higher electricity prices.

III. KEY INDUSTRIES

Due to the interdependence of the economy and the specific interrelationships between the APCO industries and other industries as shown, for example, in the input-output table, the effects of the projected price increases tend to cluster in a few industries. Two of these industries, construction and motor vehicles, have been singled out for analysis because of their significance. These two industries consume large percentages of the output of several of the industries studied and are important contributors to the level of GNP.

A. Construction

1. Study Industries Affected

The following of the industries studied sell over one percent of their intermediate output directly to the construction industry:

Paints and allied	49%
Petroleum refining related products	7%
Paving mixtures and blocks	90%
Tires and inner tubes	4%
Cement, hydraulic	42%
Brick and structural clay tile	97%
Lime	10%
Blast furnaces and steel products	10%
Electric utilities	2%

2. Review of Industry

The value of new construction put in place in 1969 was a record $91 billion, even though new housing units started, which are a major component of construction activity, were less than 1.5 million units for the year (see Figures VI-1 and VI-2). Both the trend toward larger structures and the general increases in the cost of new construction caused by inflation contributed to the record level.

The construction industry is currently characterized by rising costs and a strong underlying demand held in check by the cost of credit.

3. Privately Owned Construction

This component of construction activity consists of residential and nonresidential building construction. Private construction represents about 70 percent of the value of new construction and 98 percent of the new housing units started.

Residential construction activity is primarily influenced by credit conditions, the existing supply of dwellings, and the formation of households.

There appears to be a strong underlying demand for residential construction that has recently been dampened by the rise in interest rates. Between 1963 and 1969 interest rates on conventional first mortgage loans rose 31 percent (see Figure VI-3). During this period, even though the annual increase in households averaged about 880,000 per year, the rate of private housing starts fell over 100,000 (see Figure VI-1).

The rise in interest rates is expected to taper off in the seventies, though most analysts do not expect any significant decline in them. The number of households is expected to increase at about 1 million per year in the seventies (see Figure VI-4). The result will be a requirement for the construction or rehabilitation of 26 million housing units within the next decade according to the Housing and Urban Development Act of 1968.

It appears, therefore, that the anticipated stabilization of interest rates, the expected increase in households, the high demolition rates of the 1960's, and the current low vacancy rates will provide a strong underlying demand for residential construction in the seventies. However, the outlook is dimmed somewhat by the inflation expected in materials, labor, and land. This situation is expected to increase the demand for lower cost housing, thereby strengthening the trend toward multi-unit construction and mobile homes. Attempts will be made to improve productivity in order to reduce price trends by using industrialized methods and less on-site labor.

4. Publicly Owned Construction

Public construction consists of: housing and redevelopment, industrial, educational and other public buildings; highways and streets; military facilities; conservation and development; and other public construction. The demand for publicly owned construction is not expected to be as strong as residential building primarily due to the tapering off of demand for additional educational buildings and the leveling off of the interstate highway program. The strongest components of public construction are expected to be at the state and local levels especially for sewer systems and water supply facilities. There is, however, a backlog of federal military projects deferred in the late 1960's.

5. Price Trends

Since 1960, construction has contributed disproportionately to rising prices as shown in Figure VI-5. For example, between 1960 and 1969 the implicit price deflator for GNP increased at an annual rate of 2.2 percent. The implicit price deflator for structures increased at an annual rate of 3.2 percent during the same period.

Rising financing and land costs have been the primary sources of the cost increase although the cost of labor has also increased, stimulating the search for alternatives to on-site labor where labor is less productive (see Table VI-6).

It appears that rising prices will continue in the construction industry during the 1970's, due not only to the inflation expected in the economy but also to the lack of productivity improvements in the construction. It is anticipated, therefore, that these conditions will stimulate the search for substitutes for any significant input to construction whose prices are rising faster than the general increases for all inputs.

6. Forecast of Construction Activity

The share of gross national product (GNP) represented by construction has been declining since the mid 1950's, when it was about 12 percent to about 10 percent in 1967. Through the 1970's, construction is expected to maintain its share of GNP at about the present 10 percent level. 2/

As Table VI-7 shows, the construction industry is expected to increase to $138.5 billion by 1975 without allowing for the impact of emission standards. However, a substantial portion of this increase ($31 billion) is expected to be in the form of price increases.

2/ U.S. Department of Commerce, Construction Review, Vol. 15, No. 7, (July 1969), p. 13.

7. Price Impact

Using input-output analysis, it was estimated that the price level in construction will be about 0.6 percent higher annually than otherwise due to price increases caused by the extra costs to the study industries for emission control. While the percentage increase is small, in dollar terms, the amount is fairly large--$600 million in 1975. Assuming approximately 25 percent of this increase was allocated to 1.5 million housing units started in calendar year 1975, the average increase per housing unit would be $100.

B. Motor Vehicles

1. Study Industries Affected

The following study industries sell one percent or more of their intermediate output directly to the motor vehicle industry:

Petroleum refining and related products	6%
Tires and inner tubes	24%
Blast furnaces and steel products	11%
Primary lead	1%
Electric utilities	1%
Iron and steel foundries	25%

2. Review of Industry

Motor vehicle production, with a combined output of all types of motor vehicles of about ten million vehicles annually currently accounts for about four percent of gross national product (GNP). This industry has a pervasive influence on the U. S. economy not only due to its share of GNP but also because of its linkages with the rest of the economy.

Figures VI-7 through VI-9 show the production and registration history of motor vehicles.

3. Automobiles

Passenger car production accounts for about 80 percent of both the value of all new motor vehicles sold and the number of units manufactured. Automobile production is related to the level of disposable income, the requirement for replacement automobiles, the increase in households, and other factors not easily quantified.

As Figure VI-10 shows there has been a fairly stable relationship between disposable income and personal consumption expenditures on new automobiles, averaging about five percent over the last 20 years. In recent years, however, the demand for new automobiles appears to be slackening somewhat although the reasons for the slowdown in the sales rate are not yet discernible.

The requirement for replacement automobiles is related to the average life of a passenger car. About eleven years is the average life of a passenger car.

In addition to the requirement for replacement vehicles, there are additions to the number of passenger cars registered. The primary sources of these additions are the increase in households and the increase in the number of families owning two or more automobiles (see Table VI-8).

The result has been a fairly steady increase in both the number of automobiles per household and per capita as shown in Figure VI-11.

4. <u>Trucks and Buses</u>

The number of truck and bus sales, after remaining fairly constant between the end of World War II and 1962, have been increasing at the rate of over seven percent per year since 1962. The value of sales has increased even faster than the number of sales due to the increases in sales of light and heavy-duty trucks (see Table VI-9).

5. <u>Price Trends</u>

Measured by the Consumer Price Index, the prices of new cars have been virtually constant since 1958 (see Figure VI-12). This index measures the changes in the prices of new cars of a fairly fixed specification and product mix. The actual average price per unit has, however, been increasing steadily due to acceptance of new equipment (e.g., air conditioning) by the customer and a shift in demand toward more expensive body styles. It appears that this upward trend in prices may be somewhat offset by the introduction of domestic compacts to compete with small imported vehicles.

6. Forecast of Motor Vehicle Production

Gross auto product as a percent of GNP and personal consumption expenditures for automobiles as a percent of disposable personal income have both been fairly constant over the last twenty years as was shown in Figure VI-10. Assuming that these historical relationships continue to 1975, the gross auto production at that time will be about $44.2 billion. (See Table VI-10 for the industry projections.)

7. Price Impact

The increase in the price level of the motor vehicle industry was estimated at 0.5 percent. If 10 million cars and trucks are produced, this percentage translates into an absolute dollar amount in 1975 of $225 million--a cost per vehicle of $22.50.

TABLE VI-1.- PROJECTED PRICE INCREASES

Industry	Unit Price	Price and Percentage Increase		Percent Capacity in Metropolitan Area
Grain milling & handling		negligible		86.30
Elemental phosphorus	$350.00/ton	$7.80/ton	2.23%	44.00
Phosphate fertilizer	$160.00/ton	$1.00/ton	0.63%	88.00
Varnish	$ 3.33/gal.	$0.05	1.50%	98.20
Petroleum refining	negligible			85.90
Asphalt batching	$ 6.00/ton	$.075/ton	1.25%	83.40
Rubber tires & tubes		negligible		92.60
Cement	negligible			76.70
Brick and tile	$ 40.00/thousand	$1.05/thousand	2.63%	71.60
Lime	negligible			67.60
Steel	$170.00/ton	$1.33/ton	0.78%	97.60
Primary copper	$ .3823/lb.	$.012/lb.	3.14%	69.00
Primary lead	$ .1410/lb.	negligible		71.50
Primary zinc	$ .1384/lb.	$.003/lb.	2.17%	52.90
Primary aluminum	$ .2498/lb.	negligible		56.60
Secondary nonferrous metals	$ .2733/lb.	$.001/lb.	0.37%	72.80
Steam-electric	$ .015/KWH	$.0003/KWH	2.00%	54.30
Kraft (sulfate) pulp	$122.50/ton	$1.26/ton	1.03%	70.10
Gray iron foundries	$189.00/ton	$4.91/ton	2.60%	82.40
Coal cleaning	$ 4.40/ton	$0.05/ton	1.14%	37.60

TABLE VI-2. COMPARISON OF APCO AND INPUT-OUTPUT INDUSTRY IDENTIFICATION

APCO Industry	SIC NO.	Input-Output Model Industry	SIC NO.
1. Grain milling and handling	2042	1. Prepared feeds for animals and fowls	2042
2. Elemental phosphorus	2819958 2819959	2. Elemental phosphorus	281 except 28195
3. Phosphate fertilizer	2871	3. Phosphate fertilizer	2871, 2872
4. Varnish		4. Paints and allied products	2851
5. Petroleum refining	2911	5. Petroleum refining and related products	2911, 299
6. Asphalt batching	2951	6. Paving mixtures and blocks	2951
7. Rubber (tires and inner tubes)	3011	7. Tires and inner tubes	3011
8. Cement	3241	8. Cement, hydraulic	3241
9. Brick and tile	3251	9. Brick and structural clay tile	3251
10. Lime	3274	10. Lime	3274
11. Iron and steel	3312	11. Blast furnaces and basic steel products	331
12. Primary copper	3331	12. Primary copper	3331
13. Primary lead	3332	13. Primary lead	3332
14. Primary zinc	3333	14. Primary zinc	3333
15. Primary aluminum reduction	3334	15. Primary aluminum	3334
16. Secondary nonferrous metallurgical	3341	16. Secondary nonferrous metals	3341
17. Steam electric power plants	4911	17. Electric utilities	491, pt. 493
18. Kraft (sulfate) pulp	2611	18. Pulp mills	2611
19. Grey iron foundry	3321	19. Iron and steel foundries	332
20. Coal cleaning	1211	20. Coal mining	11, 12
21. Petroleum products storage	5092	21. Not identified	

TABLE VI-3. - SELECTED COMPONENTS OF THE INPUT-OUTPUT TABLE OF THE U. S. ECONOMY

INDUSTRY	1. Livestock & livestock products			2. Other agricultural products			3. Coal mining		
	O	D	T	O	D	T	O	D	T
1 - prepared feeds for animals & fowls	.7634	.1106	.6823						
2 - elemental phosphorous				.0316	.0124	.2243			
3 - phosphate fertilizer				.6195	.0292	.1866			
4 - paints & allied products									
5 - petroleum refining & related products	.0158	.0064	.1221	.0885	.0355	.3021			
6 - paving mixtures & blocks									
7 - tires & inner tubes	.0161	.0011	.0140	.0605	.0040	.0329	.0159	.0108	.0139
8 - cement, hydraulic									
9 - brick & structural clay tile									
10 - lime				.0220	.0001	.0017			
11 - blast furnaces & basic steel products									
12 - primary copper									
13 - primary lead									
14 - primary zinc									
15 - primary aluminum									
16 - secondary nonferrous metals									
17 - electric utilities									
18 - pulp mills									
19 - iron & steel foundries									
20 - coal mining							.1938	.1556	1.1878

Code: O - Portion of the output of the industries in rows 1-20 sold to industries in columns 1-72.
D - Share of total inputs of each industry in a column provided by the industry in a row--direct requirements coefficient .
T - Output required directly and indirectly, from each industry in a row for each dollar of delivery to final demand for industry named at the head of the column--total requirements coefficient.

Source: U. S. Department of Commerce, Office of Business Economics.

TABLE VI-3. - SELECTED COMPONENTS OF THE INPUT-OUTPUT TABLE OF THE U. S. ECONOMY (continued)

	Crude petroleum and natural gas 4.			Stone & clay mining and quarrying 5.			New construction 6.			Maintenance and repair construction 7.			Ordance and accessories 8.		
	O	D	T	O	D	T	O	D	T	O	D	T	O	D	T
1-															
2-															
3-															
4-							.1302	.0047	.0037	.3655	.0434	.1090			
5-							.0649	.0107	.1641	.0109	.0059	.0489			
6-				.0311	.0070	.0006	.4786	.0033	.0022	.4337	.0100	.0013			
7-							.0322	.0009	.0158	.0130	.0012	.0045			
8-							.3909	.0071	.0917	.0324	.0020	.0062			
9-							.9170	.0044	.0149	.0502	.0008	.0015			
10-				.1029	.0085	.0088	.1011	.0003	.0078						
11-							.0915	.0271	.5117	.0126	.0123	.0751			
12-															
13-													.0267	.0022	.0941
14-															
15-															
16-															
17-	.0126	.0070	.0112				.0161	.0021	.0667						
18-															
19-							.1007	.0052	.0611	.0198	.0034	.0121	.0167	.0089	.1880
20-															

TABLE VI-3. - SELECTED COMPONENTS OF THE INPUT-OUTPUT TABLE OF THE U. S. ECONOMY (continued)

	9. Prepared feed for animals and fowls			10. Food & kindred products except prepared feeds for animals & fowls			11. Broad & narrow fabrics, yarn and thread mills			12. Lumber & wood products, except containers			13. Household furniture		
	O	D	T	O	D	T	O	D	T	O	D	T	O	D	T
1	.1715	.1485	1.1868	.0329	.0018	.6820									
2							.0306	.0241	.3795						
3															
4										.0218	.0046	.1491	.0385	.0214	.0731
5				.0188	.0031	.7921									
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															
16															
17				.0323	.0039	.5237	.0126	.0079	.0852						
18															
19															
20				.0181	.0006	.1136									

TABLE VI-3. - SELECTED COMPONENTS OF THE INPUT-OUTPUT TABLE OF THE U. S. ECONOMY (continued)

	14. Other furniture & fixtures			15. Pulp mills			16. Paper & allied products except containers & boxes (pulp mills)			17. Printing & publishing			18. Industrial inorganic & organic chemicals		
	O	D	T	O	D	T	O	D	T	O	D	T	O	D	T
1															
2							.0239	.0195	.2789	.0174	.0107	.2357	.1709	.1432	1.1961
3													.0690	.0069	.0095
4	.0152	.0175	.1394												
5													.0887	.0758	.1057
6															
7															
8															
9															
10				.0119	.0017	.0022	.0678	.0009	.0070				.1011	.0014	.0018
11													.0103	.0158	.0236
12															
13													.1578	.0067	.0107
14													.0485	.0014	.0030
15													.0101	.0015	.0034
16													.0100	.0007	.0072
17							.0165	.0107	.1369				.0261	.0173	.0296
18							.7943	.0595	.3816						
19															
20							.0346	.0057	.0628				.0302	.0051	.0617

TABLE VI-3. - SELECTED COMPONENTS OF THE INPUT-OUTPUT TABLE OF THE U. S. ECONOMY (continued)

	19. Fertilizers			20. Chemicals & selected chemical products except 18 & 19			21. Plastics and synthetic materials			22. Drugs, cleaning & toilet preparations			23. Paints & allied products		
	O	D	T	O	D	T	O	D	T	O	D	T	O	D	T
1															
2	.0390	.2893	.3909	.0669	.2144	.7890	.2131	.3473	1.6012	.0772	.0867	.4169	.0446	.1917	.2908
3	.1075	.0955	1.1092	.0176	.0067	.0493									
4				.0216	.0155	.0326									
5							.0103	.0170	.2501						
6															
7							.0177	.0049	.0321						
8															
9															
10															
11															
12															
13													.0408	.0088	.0137
14															
15															
16															
17															
18							.1800	.0269	.1935	.0162	.0017	.0095			
19															
20							.0114	.0037	.0425						

TABLE VI-3. - SELECTED COMPONENTS OF THE INPUT-OUTPUT TABLE OF THE U. S. ECONOMY (continued)

	24. Petroleum refining and related products			25. Paving mixtures & blocks			26. Rubber footwear			27. Glass & glass products			28. Cement, hydraulic		
	O	D	T	O	D	T	O	D	T	O	D	T	O	D	T
1															
2	.0476	.0241	.0405				.0177	.0266	.2144	.0123	.0443	.1597			
3															
4															
5	.1312	.0678	1.10866	.0106	.2468	.2881									
6				.0138	.0136	1.0155									
7							.0741	.0189	.0640						
8															
9															
10										.0214	.0012	.0039			
11															
12															
13															
14															
15															
16															
17	.0126	.0051	.0150												
18															
19															
20													.0310	.0548	.0696

TABLE VI-3. - SELECTED COMPONENTS OF THE INPUT-OUTPUT TABLE OF THE U. S. ECONOMY (continued)

	29. Stone & clay products except cement, brick, tile, and lime			30. Blast furnaces and basic steel products			31. Iron & steel foundries			32. Primary iron & steel manufacturing			33. Primary copper		
	O	D	T	O	D	T	O	D	T	O	D	T	O	D	T
1															
2				.0332	.0176	.0343									
3															
4															
5				.0123	.0066	.0203									
6	.0175	.0010	.0230												
7															
8	.5638	.0826	.5204												
9	.0196	.0008	.0401												
10	.2883	.0059	.1862	.1302	.0011	.0015									
11				.1932	.1924	1.2790	.0265	.1502	.2076	.0252	.3243	.6179			
12													.3374	.3047	1.4441
13													.0254	.0062	.0186
14				.2507	.0047	.0069									
15				.0132	.0013	.0033									
16				.0176	.0008	.0058							.2486	.1058	.1703
17				.0319	.0134	.0261									
18															
19				.0811	.0137	.0196									
20				.2192	.0232	.0377									

TABLE VI-3. - SELECTED COMPONENTS OF THE INPUT-OUTPUT TABLE OF THE U. S. ECONOMY (continued)

	34. Primary lead			35. Primary zinc			36. Primary aluminum			37. Secondary non-ferrous metals			38. Primary nonferrous metals manufacturing, except 33, 34, 35, 36 & 37		
	O	D	T	O	D	T	O	D	T	O	D	T	O	D	T
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12													.5740	.1122	.7937
13	.1669	.1728	1. 234	.0308	.0450	.0615				.0483	.0277	.0406	.2022	.0108	.1609
14	.0989	.0719	.1012	.0107	.0111	1.0191				.0507	.0204	.0255	.3115	.0116	.0732
15							.1606	.1545	1.2267	.0182	.0371	.0487	.6868	.1302	.6736
16	.2228	.3992	.5304	.0484	.1223	.1568	.2739	.1281	.1716	.0182	.0181	1.0690	.1223	.0113	.4012
17							.0137	.0580	.0851						
18															
19													.0160	.0054	.0117
20															

TABLE VI-3. - SELECTED COMPONENTS OF THE INPUT-OUTPUT TABLE OF THE U. S. ECONOMY (continued)

	39. Metal containers			40. Heating, plumbing & fabricated structural metal products			41. Screw machine products, bolts, nuts, etc. and metal stampings			42. Other fabricated metal products			43. Engines and turbines		
	O	D	T	O	D	T	O	D	T	O	D	T	O	D	T
1															
2															
3															
4	.0329	.0316	.0861	.0380	.0093	.1149	.0113	.0054	.0135	.02776	.0072	.1296			
5															
6															
7															
8															
9															
10															
11	.0512	.4030	1.0219	.1076	.2173	2.5539	.0530	.2069	.5790	.0679	.1452	2.1617			
12				.0100	.0020	.2478				.0272	.0058	.1775			
13										.0118	.0007	.1391			
14							.0150	.0011	.0074	.1665	.0068	.0805			
15				.0309	.0061	.3588									
16															
17															
18															
19				.0166	.0059	.1328				.0469	.0175	.1788	.0329	.0461	.1225
20															

TABLE VI-3. - SELECTED COMPONENTS OF THE INPUT-OUTPUT TABLE OF THE U. S. ECONOMY (continued)

	44. Farm machinery			45. Construction, mining, oil field machinery equipment			46. Materials handling machinery and equipment			47. Metalworking machinery and equipment			48. Special industry machinery & equipment		
	O	D	T	O	D	T	O	D	T	O	D	T	O	D	T
1															
2															
3															
4															
5															
6															
7	.0303	.0177	.0206	.0224	.0098	.0242									
8															
9															
10															
11	.0146	.0922	.1866	.0145	.0685	.4976				.0135	.0489	.4667	.0109	.0555	.7430
12															
13										.0231	.0023	.0119			
14															
15															
16															
17															
18															
19	.0271	.0297	.0454	.0651	.0535	.1945	.0107	.0222	.1526	.0411	.0260	.1651	.0329	.0291	.2540
20															

TABLE VI-3. - SELECTED COMPONENTS OF THE INPUT-OUTPUT TABLE OF THE U. S. ECONOMY (continued)

	49. General industrial machinery & equipment			50. Machine shop products			51. Service industry machines			52. Electric trans-mission & distri-bution equipment and electrical industrial apparatus			53. Household appliances		
	O	D	T	O	D	T	O	D	T	O	D	T	O	D	T
1															
2															
3															
4													.0174	.0033	.0716
5															
6															
7															
8															
9															
10															
11	.0179	.0644	.9177							.0173	.0523	.7950	.0160	.0659	.8881
12															
13	.0182	.0018	.0229												
14															
15										.0135	.0038	.1496			
16															
17															
18															
19	.0485	.0305	.3399	.0183	.0274	.0370	.0162	.0161	.1211	.0120	.0061	.0701			
20															

TABLE VI-3. - SELECTED COMPONENTS OF THE INPUT-OUTPUT TABLE OF THE U. S. ECONOMY (continued)

	54. Miscellaneous electrical machinery, equipment & supplies			55. Motor vehicles & equipment			56. Aircraft & parts			57. Other transportation equipment			58. Optical, ophthalmic & photographic equipment and supplies		
	O	D	T	O	D	T	O	D	T	O	D	T	O	D	T
1															
2													.0127	.0524	.1633
3															
4				.0822	.0048	.0380									
5															
6															
7				.2352	.0105	.0812				.0176	.0064	.1358			
8															
9															
10															
11				.1089	.0525	.5096				.0210	.0826	1.0753			
12															
13	.1990	.0469	.2606	.0116	.0002	.0055									
14															
15															
16															
17			.0497	.0143	.0030	.0497									
18															
19				.2500	.0210	.0793	.0145	.0031	.0458	.0527	.0362	.3000			
20															

TABLE VI-3. - SELECTED COMPONENTS OF THE INPUT-OUTPUT TABLE OF THE U. S. ECONOMY (continued)

	59. Miscellaneous manufacturing			60. Transportation and warehousing			61. Communications, except radio & television broadcasting			62. Electric, gas, water & sanitary services			63. Wholesale & retail trade		
	O	D	T	O	D	T	O	D	T	O	D	T	O	D	T
1													.0131	.0004	.0027
2															
3													.0243	.0003	.0006
4	.0235	.0077	.1378										.0137	.0003	.0027
5				.1433	.0391	.3263				.0207	.0075	.0567	.1249	.0112	.0360
6															
7				.1037	.0047	.0302							.1220	.0018	.0055
8													.0011	.0000	.0005
9															
10															
11															
12															
13															
14															
15															
16													.0147	.0001	.0009
17				.0165	.0035	.0908	.0126	.0078	.0103	.1081	.0305	1.1344	.1780	.0123	.0317
18															
19				.0330	.0028	.0184									
20										.3005	.0214	.0714			

TABLE VI-3. - SELECTED COMPONENTS OF THE INPUT-OUTPUT TABLE OF THE U. S. ECONOMY (continued)

	64. Finance & insurance			65. Real estate & rental			66. Hotels & lodging places; personal & repair services, except automobile repair			67. Business services			68. Automobile repair & services		
	O	D	T	O	D	T	O	D	T	O	D	T	O	D	T
1															
2										.0104	.0030	.0178			
3				.0961	.0015	.0057									
4													.0314	.0068	.0087
5				.0453	.0058	.0227	.0135	.0095	.0424	.0108	.0031	.0350	.0111	.0110	.0196
6															
7													.1075	.0178	.0204
8				.0018	.0000	.0004									
9															
10															
11															
12															
13															
14															
15															
16															
17	.0498	.0122	.1114	.0143	.0014	.0104	.0150	.0082	.0304	.0337	.0076	.0457			
18															
19															
20															

TABLE VI-3. - SELECTED COMPONENTS OF THE INPUT-OUTPUT TABLE OF THE U. S. ECONOMY (continued)

	69. Amusements			70. Medical, educational services & nonprofit organizations			71. Federal government enterprises			72. State & local government enterprises		
	O	D	T	O	D	T	O	D	T	O	D	T
1												
2												
3	.0169	.0028	.0065									
4												
5				.0136	.0000	.0562						
6												
7												
8												
9												
10										.0981	.0023	.0038
11												
12												
13												
14												
15												
16												
17				.0808	.0203	.1446				.0617	.0713	.3119
18												
19												
20							.0316	.0075	.1774	.0385	.0112	.0766

TABLE VI-4. - PRICE EFFECTS OF THE COSTS OF EMISSION CONTROL

Each entry represents the increase in the price level of the industries purchasing at least one percent of the output of the NAPCA industries as a result of the costs of emission control INDUSTRY	Livestock & livestock products 1.	Other agricultural products 2.	Coal mining 3.	Crude petroleum and natural gas 4.	Stone & clay mining & quarrying 5.	New construction 6.	Maintenance & repair construction 7.
1 - prepared feeds for animals & fowls							
2 - elemental phosphorus		.0000					
3 - phosphate fertilizer		.0007					
4 - paints & allied products							
5 - petroleum refining & related products							
6 - paving mixtures & blocks					.0000	.0000	.0000
7 - tires & inner tubes							
8 - cement, hydraulic							
9 - brick & structural clay tile						.0003	.0000
10 - lime							
11 - blast furnaces & basic steel products						.0035	.0005
12 - primary copper							
13 - primary lead							
14 - primary zinc							
15 - primary aluminum							
16 - secondary nonferrous metals							
17 - electric utilities				.0001		.0007	
18 - pulp mills							
19 - iron & steel foundries						.0008	.0002
20 - coal mining			.0051				
TOTAL INCREASE IN PRICE LEVEL	—	.0007	.0051	.0001	.0000	.0053	.0007
CONTRIBUTION TO GNP	.0037	.0108	.0009	.0000	.0002	.1110	.0083
IMPACT ON IMPLICIT PRICE DEFLATOR FOR GNP	—	.0000	.0000	.0000	.0000	.0006	.0000

BASED UPON 1963 INPUT-OUTPUT STRUCTURE OF THE U. S. ECONOMY - U. S. DEPARTMENT OF COMMERCE, OFFICE OF BUSINESS ECONOMICS

TABLE VI-4. - PRICE EFFECTS OF THE COSTS OF EMISSION CONTROL (continued)

	Ordnance & Accessories 8.	Prepared feed for animals & fowls 9.	Food & kindred products except prepared feeds for animals & fowls 10.	Bread & narrow fabrics, yarn & thread mills 11.	Lumber & wood products, except containers 12.	Household furniture 13.	Other furniture 14.
1 -							
2 -				.0000			
3 -							
4 -							
5 -							
6 -							
7 -							
8 -							
9 -							
10 -							
11 -							
12 -							
13 -	.0005						
14 -							
15 -							
16 -							
17 -			.0057	.0009			
18 -							
19 -	.0025						
20 -			.0005				
TOTAL INCREASE IN PRICE LEVEL	.0030	—	.0062	.0009	—	—	—
CONTRIBUTION TO GNP	.0096	.0887	.0093	.0017	.0000	.0055	.0026
IMPACT ON IMPLICIT PRICE DEFLATOR FOR GNP	.0000	.0000	.0001	.0000	—	—	—

BASED UPON 1963 INPUT-OUTPUT STRUCTURE OF THE U. S. ECONOMY - U. S. DEPARTMENT OF COMMERCE, OFFICE OF BUSINESS ECONOMICS

TABLE VI-4. - PRICE EFFECTS OF THE COSTS OF EMISSION CONTROL (continued)

	Pulp mills 15.	Paper & allied products except containers & boxes (pulp mills) 16..	Printing & Publishing 17.	Industrial inorganic & organic chemicals 18.	Fertilizers 19.	Chemicals & selected chemical products except 18 & 19 20.	Plastic & synthetic materials 21.
1 -							
2 -		.0000	.0000	.0001	.0000	.0001	.0002
3 -				.0000	.0041	.0002	
4 -							
5 -							
6 -							
7 -							
8 -							
9 -							
10 -							
11 -				.0002			
12 -							
13 -				.0001			
14 -				.0000			
15 -							
16 -				.0000			
17 -		.0015		.0003			
18 -		.0039					.0020
19 -							
20 -		.0003		.0003			.0002
TOTAL INCREASE IN PRICE LEVEL	—	.0057	.0000	.0010	.0041	.0003	
CONTRIBUTION TO GNP	.0003	.0029	.0068	.0035	.0003	.0012	
IMPACT ON IMPLICIT PRICE DEFLATOR FOR GNP	—	.0000	.0000	.0000	.0000	.0000	

TABLE VI-4. - PRICE EFFECTS OF THE COSTS OF EMISSION CONTROL (continued)

	Drugs, cleaning & toilet preparations 22.	Paints & allied products 23.	Petroleum refining & related products 24.	Paving mixtures & blocks 25.	Rubber footwear 26.	Glass & glass products 27.	Cement, hydraulic 28.
1 -							
2 -	.0000	.0000	.0000		.0000	.0000	
3 -							
4 -							
5 -							
6 -				.0106			
7 -							
8 -							
9 -							
10 -							
11 -							
12 -							
13 -		.0001					
14 -							
15 -							
16 -							
17 -			.0002				
18 -	.0001						
19 -							
20 -							
TOTAL INCREASE IN PRICE LEVEL	.0001	.0001	.0002	.0106	.0000	.0000	.0000
CONTRIBUTION TO GNP	.0108	.0002	.0171	.0000	.0021	.0008	.0010
IMPACT ON IMPLICIT PRICE DEFLATOR FOR GNP	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TABLE VI-4. - PRICE EFFECTS OF THE COSTS OF EMISSION CONTROL (continued)

	Stone & clay products except cement, brick, tile, & lime 29.	Blast furnaces & basic steel products 30.	Iron & Steel Foundries 31.	Primary iron & steel manufacturing except 30 & 31 32.	Primary copper 33.	Primary lead 34.	Primary zinc 35.
1 -							
2 -		.0000					
3 -							
4 -							
5 -							
6 -	.0002						
7 -							
8 -							
9 -	.0008						
10 -							
11 -		.0087	.0014	.0042			
12 -					.0052		
13 -					.0001	.0063	.0003
14 -		.0001				.0012	.0117
15 -							
16 -		.0000			.0001	.0004	.0001
17 -		.0003					
18 -							
19 -		.0003					
20 -		.0002					
TOTAL INCREASE IN PRICE LEVEL	.0010	.0096	.0014	.0042	.0054	.0079	.0121
CONTRIBUTION TO GNP	.0001	.0010	.0001	.0000			
IMPACT ON IMPLICIT PRICE DEFLATOR FOR GNP	.0000	.0000	.0000	.0000			

TABLE VI-4. - PRICE EFFECTS OF THE COSTS OF EMISSION CONTROL (continued)

	Primary aluminum 36.	Secondary Non-ferrous metals 37.	Primary non-ferrous metals manufacturing, except 33, 34, 35, 36, & 37 38.	Metal Containers 39.	Heating, plumbing & fabricated structural metal products 40.	Screw machine products, bolts, nuts, etc. and met metal stampings 41.	Other fabricated metal products 42.
1 -							
2 -							
3 -							
4 -							
5 -							
6 -							
7 -							
8 -							
9 -							
10 -							
11 -				.0069	.0174	.0039	.0147
12 -			.0029		.0009		.0006
13 -		.0002	.0008				.0007
14 -		.0003	.0008			.0001	.0009
15 -							
16 -	.0001	.0007	.0002				
17 -	.0009						
18 -							
19 -			.0002		.0018		.0024
20 -							
TOTAL INCREASE IN PRICE LEVEL	.0010	.0012	.0049	.0069	.0201	.0040	.0093
CONTRIBUTION TO GNP				.0001	.0017	.0007	.0021
IMPACT ON IMPLICIT PRICE DEFLATOR FOR GNP				.0000	.0000	.0000	.0000

TABLE VI-4. - PRICE EFFECTS OF THE COSTS OF EMISSION CONTROL (continued)

	43. Engines & Turbines	44. Farm Machinery	45. Construction mining, oil field machinery equipment	46. Materials handling machinery & equipment	47. Metal working machinery and equipment	48. Special industry machinery & equipment	49. General industry machinery & equipment
1 -							
2 -							
3 -							
4 -							
5 -							
6 -							
7 -							
8 -							
9 -							
10 -							
11 -		.0013	.0034		.0032	.0051	.0062
12 -							
13 -					.0001		.0001
14 -							
15 -							
16 -							
17 -							
18 -							
19 -	.0016	.0006	.0026	.0020	.0022	.0034	.0046
20 -							
TOTAL INCREASE IN PRICE LEVEL	.0016	.0019	.0060	.0020	.0055	.0085	.0109
CONTRIBUTIONS TO GNP	.0017	.0038	.0049	.0014	.0040	.0045	.0035
IMPACT ON IMPLICIT PRICE DEFLATOR FOR GNP	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TABLE VI-4. - PRICE EFFECTS OF THE COSTS OF EMISSION CONTROL (continued)

	Machine Shop Products	Service Industry Machines	Electric transmission & distribution equipment & electrical industrial apparatus.	Household appliances	Miscellaneous electrical machinery, equipment & supplies	Motor vehicles & equipment	Aircraft & Parts
	50.	51.	52.	53.	54.	55.	56.
1 -							
2 -							
3 -							
4 -							
5 -							
6 -							
7 -							
8 -							
9 -							
10 -							
11 -			.0054	.0060		.0035	
12 -							
13 -					.0013	.0000	
14 -							
15 -							
16 -							
17 -						.0005	
18 -							
19 -	.0005	.0016	.0009			.0011	.0006
20 -							
TOTAL INCREASE IN PRICE LEVEL	.0005	.0016	.0063	.0060	.0013	.0051	.0006
CONTRIBUTION TO GNP	.0002	.0031	.0046	.0056	.0013	.0413	.0156
IMPACT ON IMPLICIT PRICE DEFLATOR FOR GNP	.0000	.0000	.0000	.0000	.0000	.0002	.0000

TABLE VI-4. - PRICE EFFECTS OF THE COSTS OF EMISSION CONTROL (continued)

	Other trans-portation equipment	Optical, ophthalmic and photographic equipment and supplies	Miscellaneous Manufacturing	Transportation and Warehousing	Communications except radio & television broadcasting	Electric, gas, water and sanitary services	Wholesale & Retail Trade
	57.	58.	59.	60.	61.	62.	63.
1 -							
2 -		.0000					
3 -							.0000
4 -							
5 -							
6 -							
7 -							
8 -							
9 -							
10 -							
11 -	.0073						
12 -							
13 -							
14 -							
15 -							
16 -							.0000
17 -				.0010	.0001	.0124	.0003
18 -							
19 -	.0040			.0002			
20 -						.0003	
TOTAL INCREASE IN PRICE LEVEL	.0113	.0000	—	.0012	.0001	.0127	.0003
CONTRIBUTION TO GNP	.0064	.0022	.0071	.0249	.0114	.0212	.1500
IMPACT ON IMPLICIT PRICE DEFLATOR FOR GNP	.0001	.0000	—	.0000	.0000	.0003	.0000

TABLE VI-4. - PRICE EFFECTS OF THE COSTS OF EMISSION CONTROL (continued)

	Finance & Insurance	Real Estate & Rental	Hotels & lodging places: personal & repair services except automobile repair	Business Services	Automobile Repair & Services	Amusements	Medical, Educational Services and Non-profit Organizations
	64.	65.	66.	67.	68.	69.	70.
1 -							
2 -				.0000			
3 -		.0000					
4 -							
5 -							
6 -							
7 -							
8 -							
9 -							
10 -							
11 -							
12 -							
13 -							
14 -							
15 -							
16 -							
17 -	.0012	.0001	.0003	.0005			.0016
18 -							
19 -							
20 -							
TOTAL INCREASE IN PRICE LEVEL	.0012	.0001	.0003	.0005	—	—	.0016
CONTRIBUTION TO GNP	.0292	.0951	.0213	.0103	.0115	.0100	.0619
IMPACT ON IMPLICIT PRICE DEFLATOR FOR GNP	.0000	.0000	.0000	.0000	—	—	.0001

TABLE VI-4. - PRICE EFFECTS OF THE COSTS OF EMISSION CONTROL (continued)

	Federal Government Enterprises	State & Local Government Enterprises	
	71.	72.	
1 -			
2 -			
3 -			
4 -			
5 -			
6 -			
7 -			
8 -			
9 -			
10 -			
11 -			
12 -			
13 -			
14 -			
15 -			
16 -			
17 -		.0034	
18 -			
19 -			
20 -	.0008	.0003	
			TOTAL
TOTAL INCREASE IN PRICE LEVEL	.0008	.0037	
CONTRIBUTION TO GNP	.0022	.0015	
IMPACT ON IMPLICIT PRICE DEFLATOR FOR GNP	.0000	.0000	.0014

TABLE VI-5. - ESTIMATED IMPACT OF THE COSTS OF EMISSION CONTROL ON THE PRICE LEVEL

Industry	Estimated Increase in the Price Level*
Agriculture, Forestry and Fisheries	0.0000
Mining	0.0000
Construction	0.0006
Manufacturing	0.0004
Transportation, Communication, Electric, Gas and Sanitary Services	0.0003
Wholesale and Retail Trade	0.0000
Finance, Insurance and Real Estate	0.0000
Services	0.0001
Government Enterprises	0.0000
Total	0.0014 or 0.14%

* Implicit price deflator for GNP.

TABLE VI-6. - DISTRIBUTION OF CONSTRUCTION COST

	Percent of Cost	
	1949	1969
On-Site Labor	33	18
Materials	36	38
Land	11	21
Overhead and Profit	15	13
Financing	5	10

Source: U. S. Department of Labor, <u>Monthly Labor Review</u>. Vol. 93, No. 7 (July 1970), p. 27.

TABLE VI-7. - ACTUAL AND PROJECTED CONSTRUCTION ACTIVITY

(Billions of Dollars)

	Actual				Projected			
	Current Dollars				Current Dollars		Constant (1967 Dollars)	
	1960	1965	1967	1969	1975	1980	1975	1980
GNP	503.7	684.9	793.9	932.4	1,366.6	1,920.1	1,105.7	1,384.3
Total Value of New Construction	53.9	72.3	76.2	90.9	138.5	199.3	107.4	131.5

Source: U. S. Department of Commerce, Construction Review, Vol. 15, No. 7 (July 1969), p. 13.

TABLE VI-8. - AUTOMOBILE OWNERSHIP

	Percent of Families Owning Two or More Automobiles
1950	7
1955	10
1960	15
1964	22
1965	24
1966	25
1967	25
1968	26

Source: The University of Michigan, Survey Research Center, Ann Arbor, Michigan; "Survey of Consumer Finances."

TABLE VI-9. - TRUCK AND BUS CHASSIS FACTORY SALES
(in thousands of units)

Gross Vehicle Weight	1961	1962	1963	1964	1965	1966	1967	1968	1969*
6000 lbs. & less	647	678	836	920	1,058	1,020	900	1,136	1,085
6001 to 10,000 lbs.	180	213	247	250	294	297	290	386	404
10,001 to 14,000 lbs.	11	9	6	6	5	7	5	5	18
14,001 to 16,000 lbs.	30	27	28	24	26	21	16	17	25
16,001 to 19,500 lbs.	139	142	145	142	144	125	88	79	78
19,501 to 26,000 lbs.	65	93	110	104	110	124	124	141	143
26,001 to 33,000 lbs.	29	35	32	30	40	44	38	42	47
Over 33,000 lbs.	32	43	59	64	75	91	78	90	100
Total	1,133	1,240	1,463	1,540	1,752	1,729	1,539	1,896	1,900

* Estimated.

Source: <u>Census of Manufactures</u> and Automobile Manufacturers Association.

TABLE VI-10. - PROJECTION OF MOTOR VEHICLE SALES

	1975	1980
GNP (billions of 1967 dollars)	$1,105.7	$1,384.3
Gross Auto Product (billions of 1967 dollars)	$44.2	$55.4
Gross Auto Product as a (Percent of GNP)	4%	4%

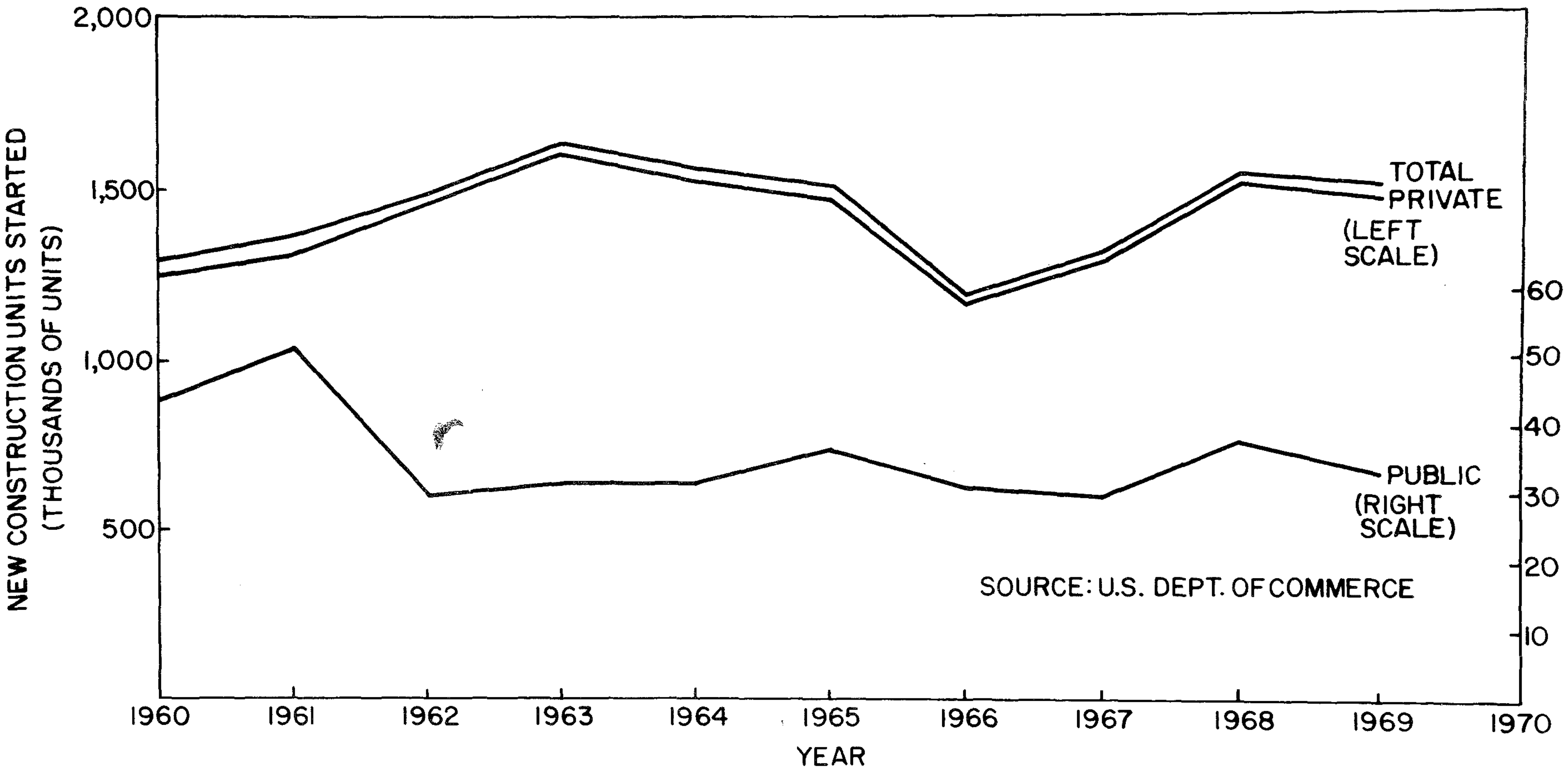

Fig. VI-1. New Construction Units Started

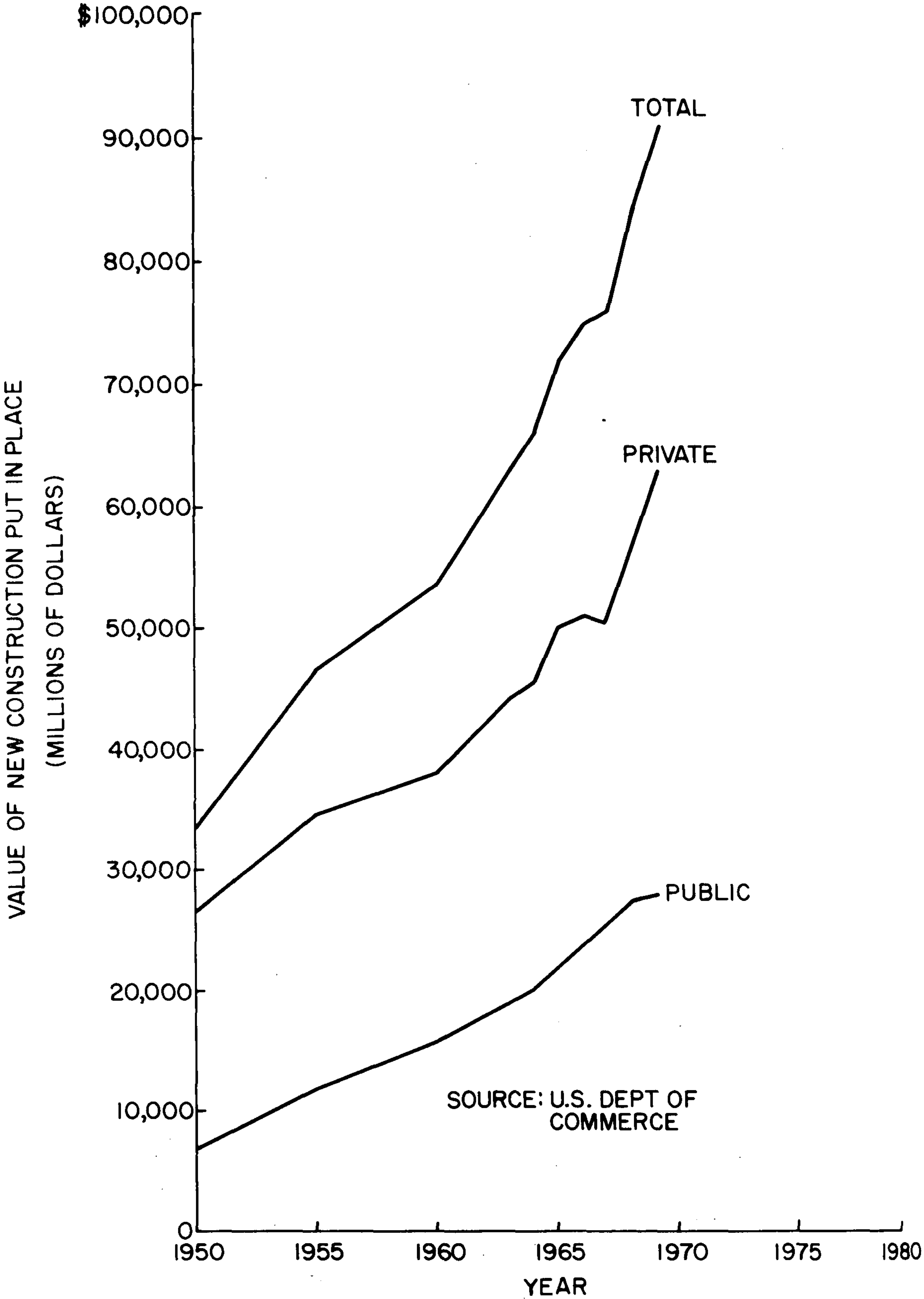

Fig. VI-2. Value of New Construction

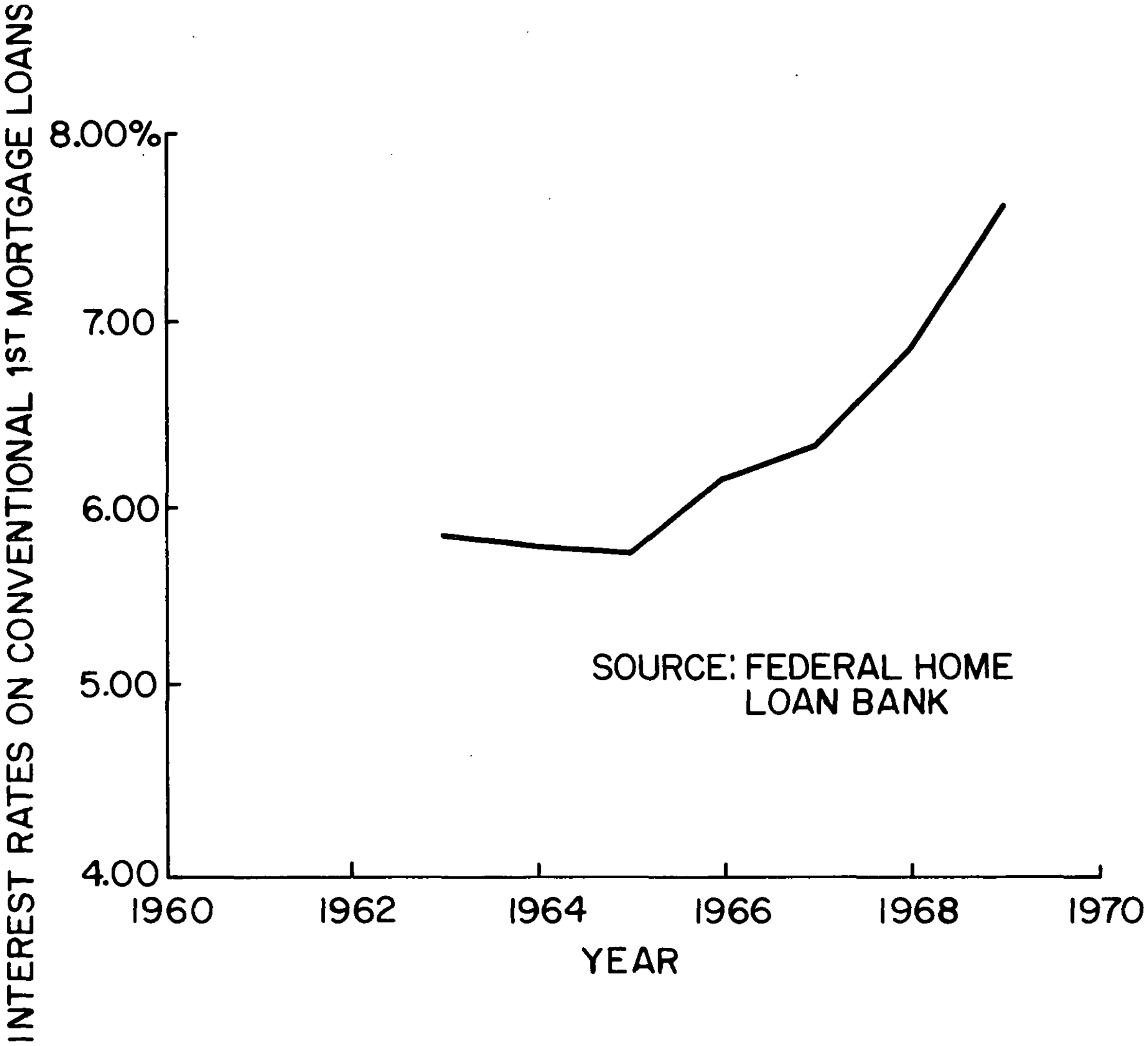

Fig. VI-3. Interest Rates

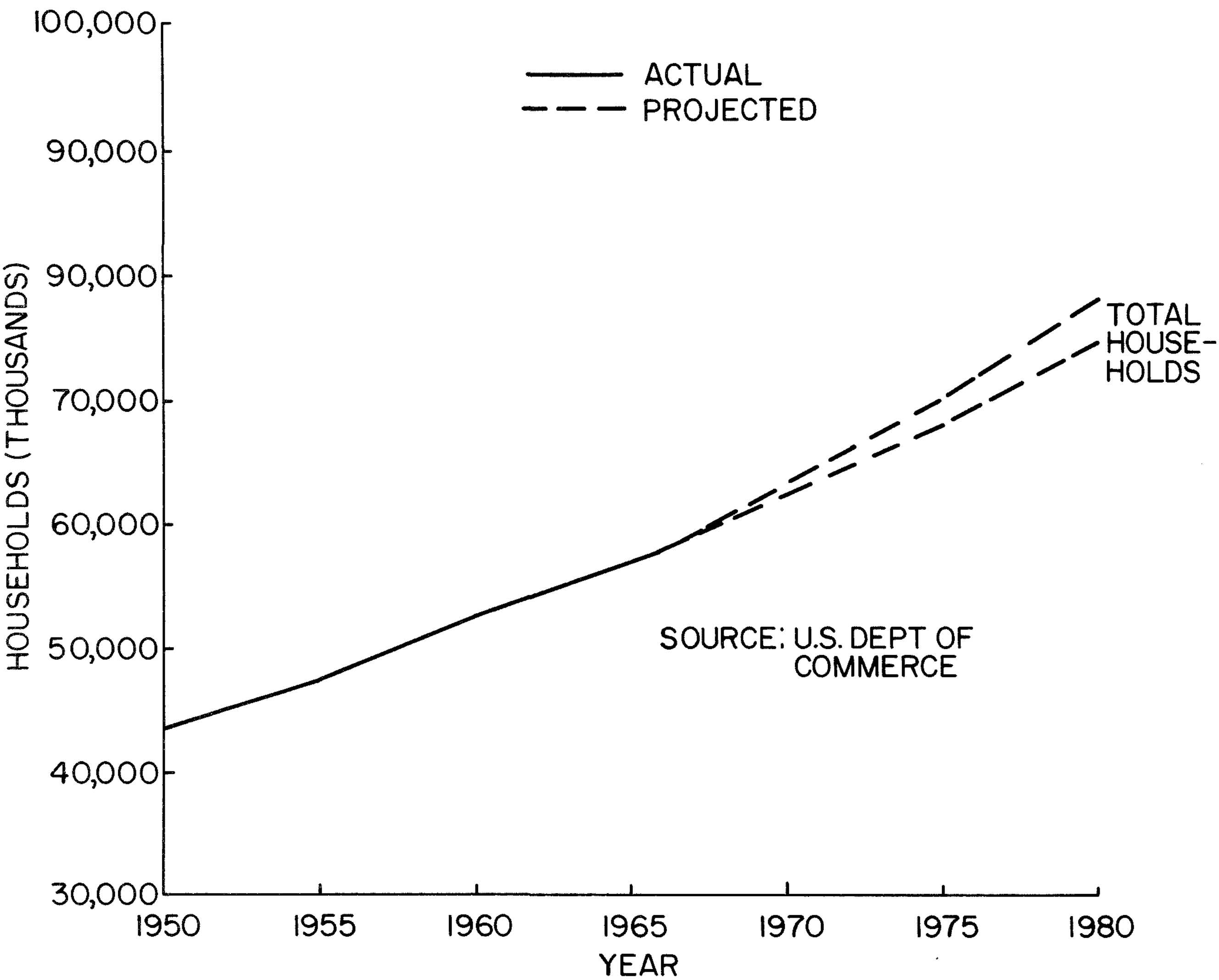

Fig. VI-4. U. S. Households

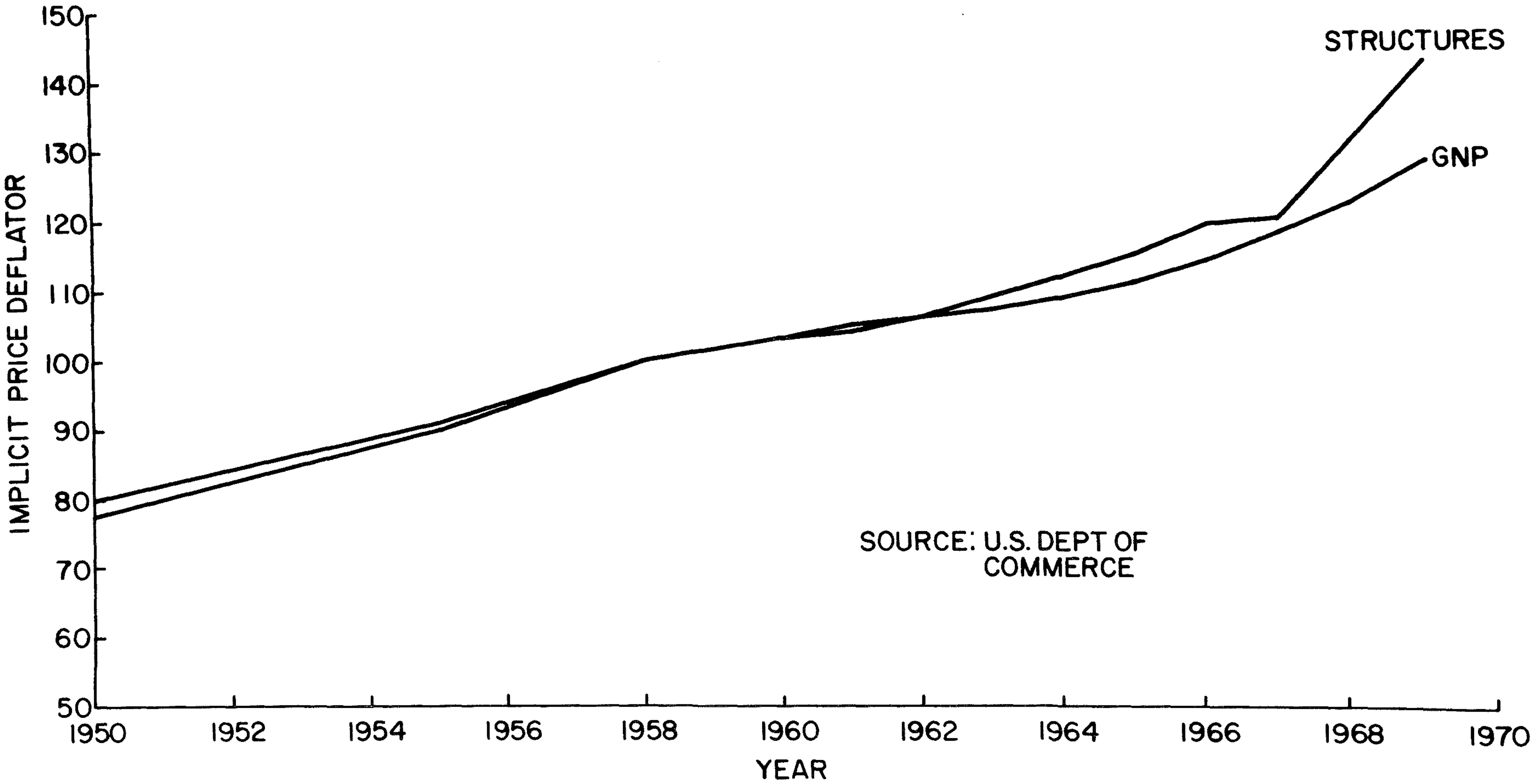

Fig. VI-5. Implicit Price Deflators (1958=100)

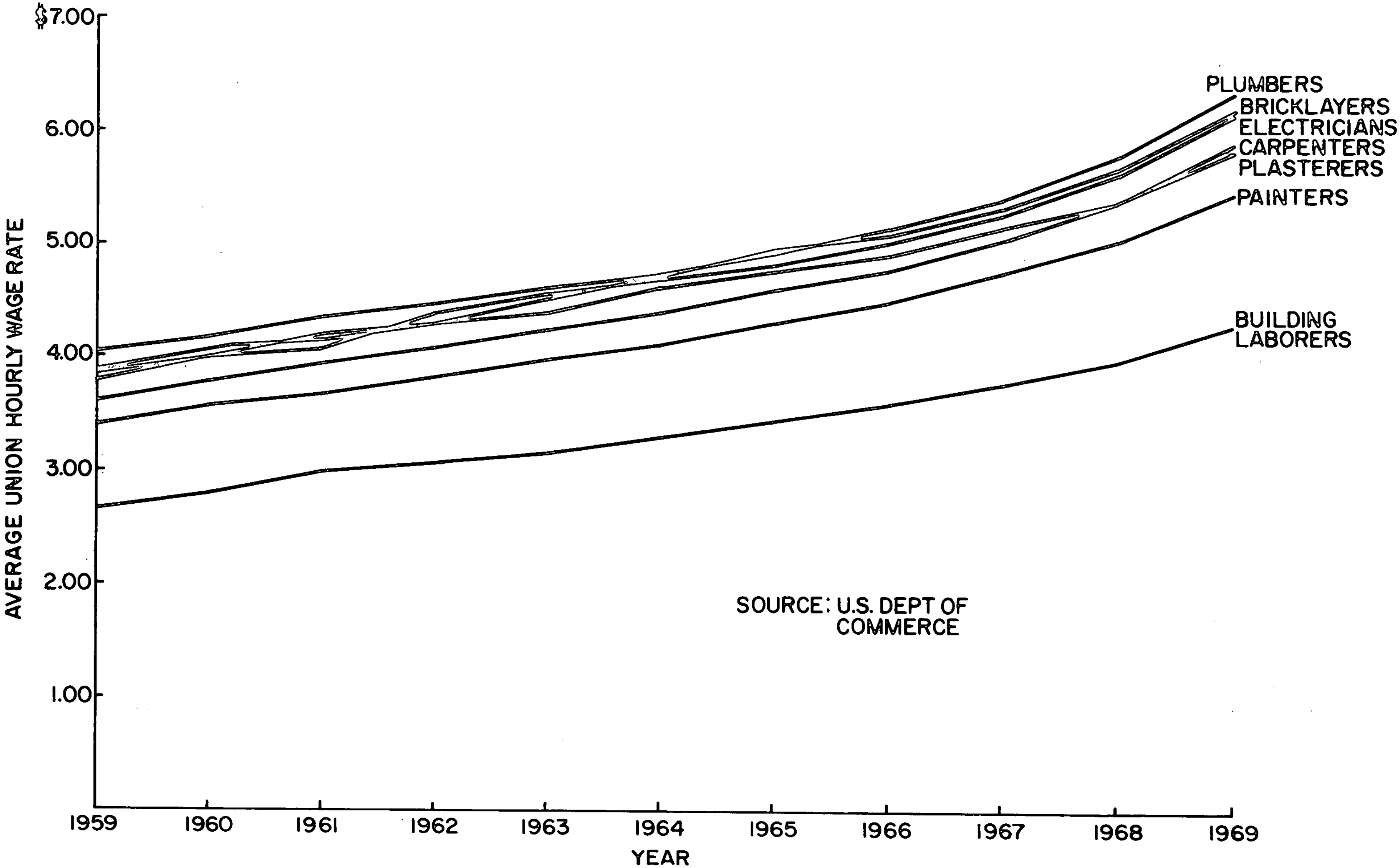

Fig. VI-6. Average Wage Rate for Selected Building Trades

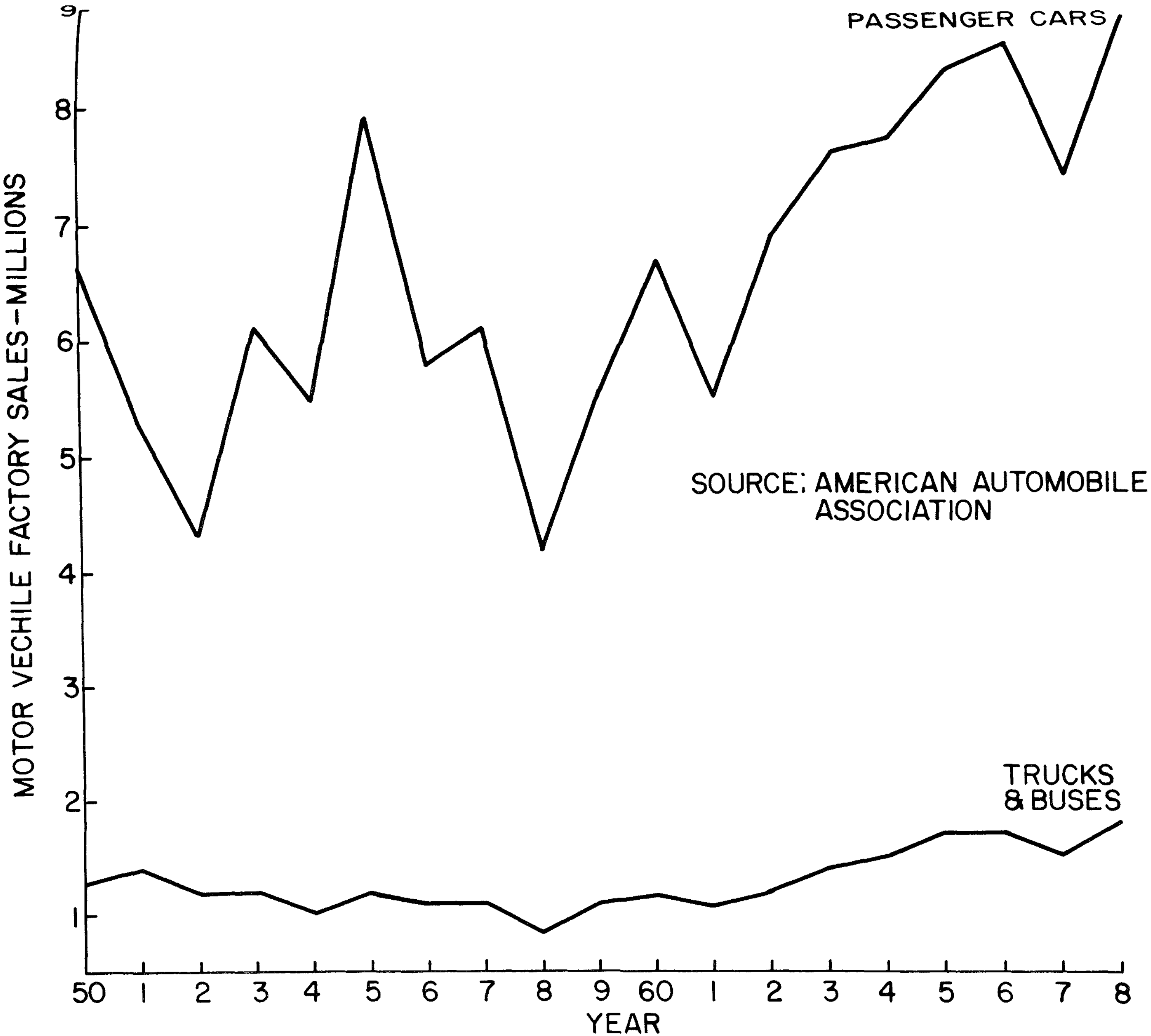

Fig. VI-7. Motor Vehicle Factory Sales-Units

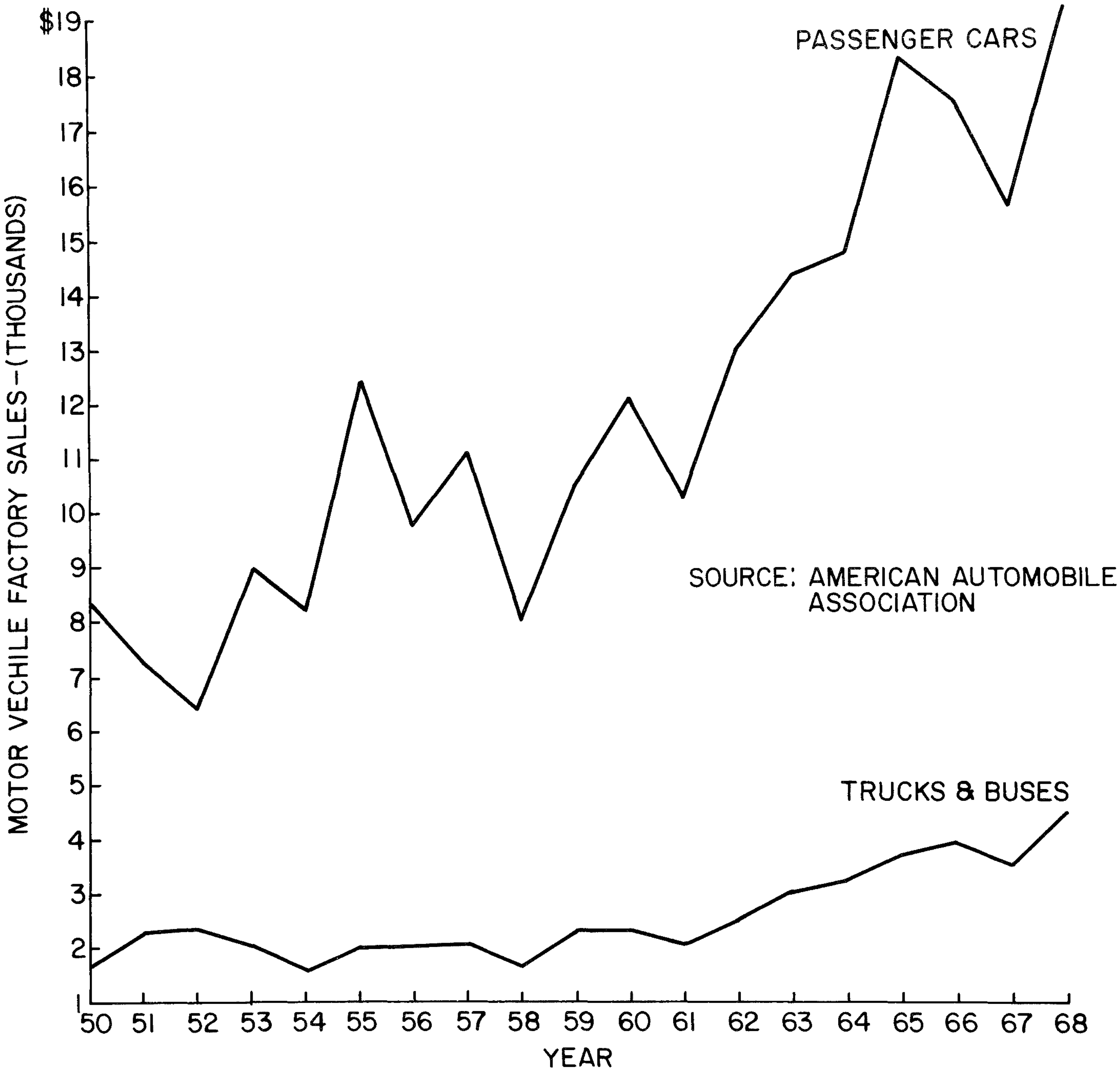

Fig. VI-8. Motor Vehicle Factory Sales-Value

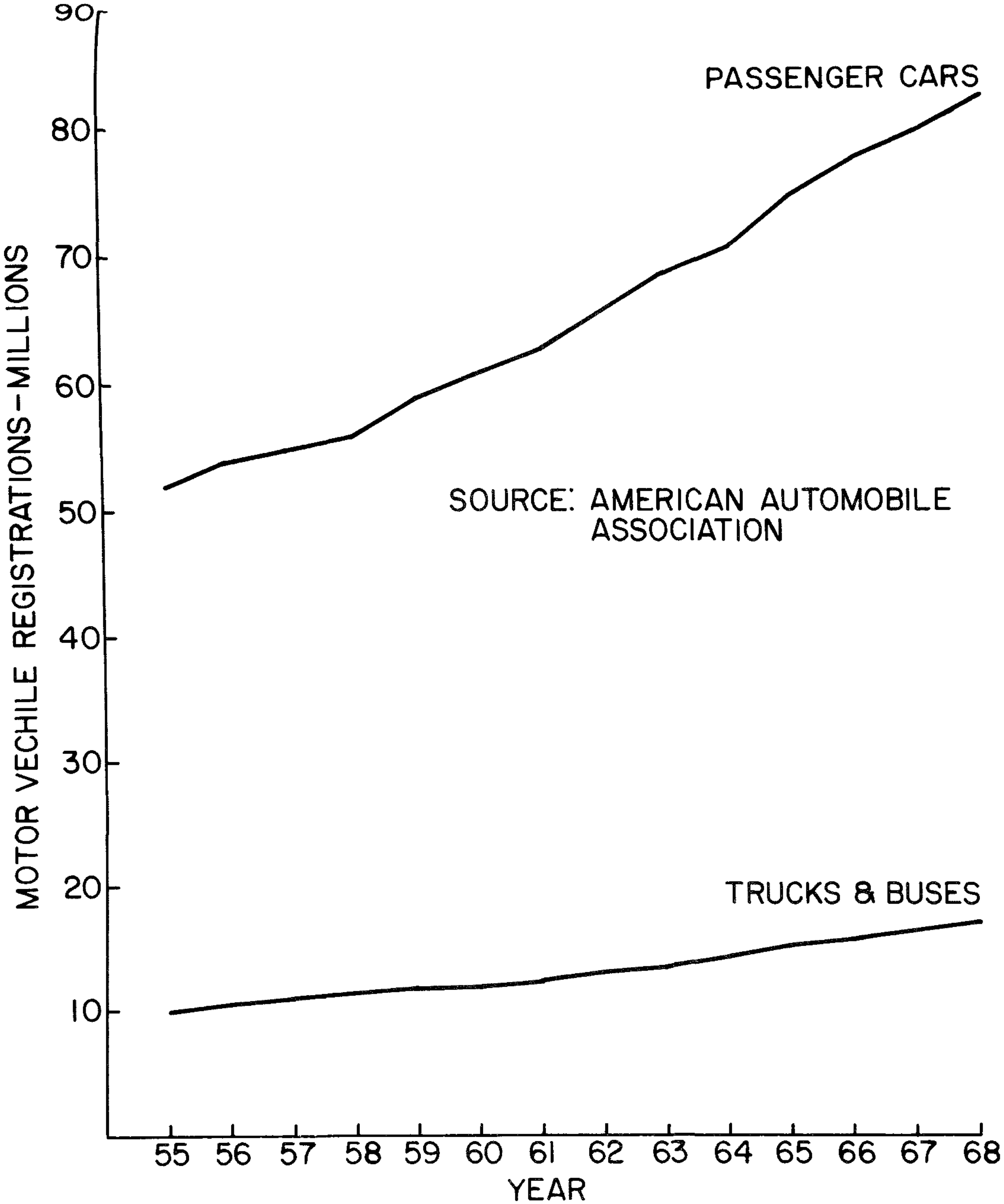

Fig. VI-9. Motor Vehicle Registrations

Fig. VI-10. Relationship of Motor Vehicle Production to GNP and Personal Income

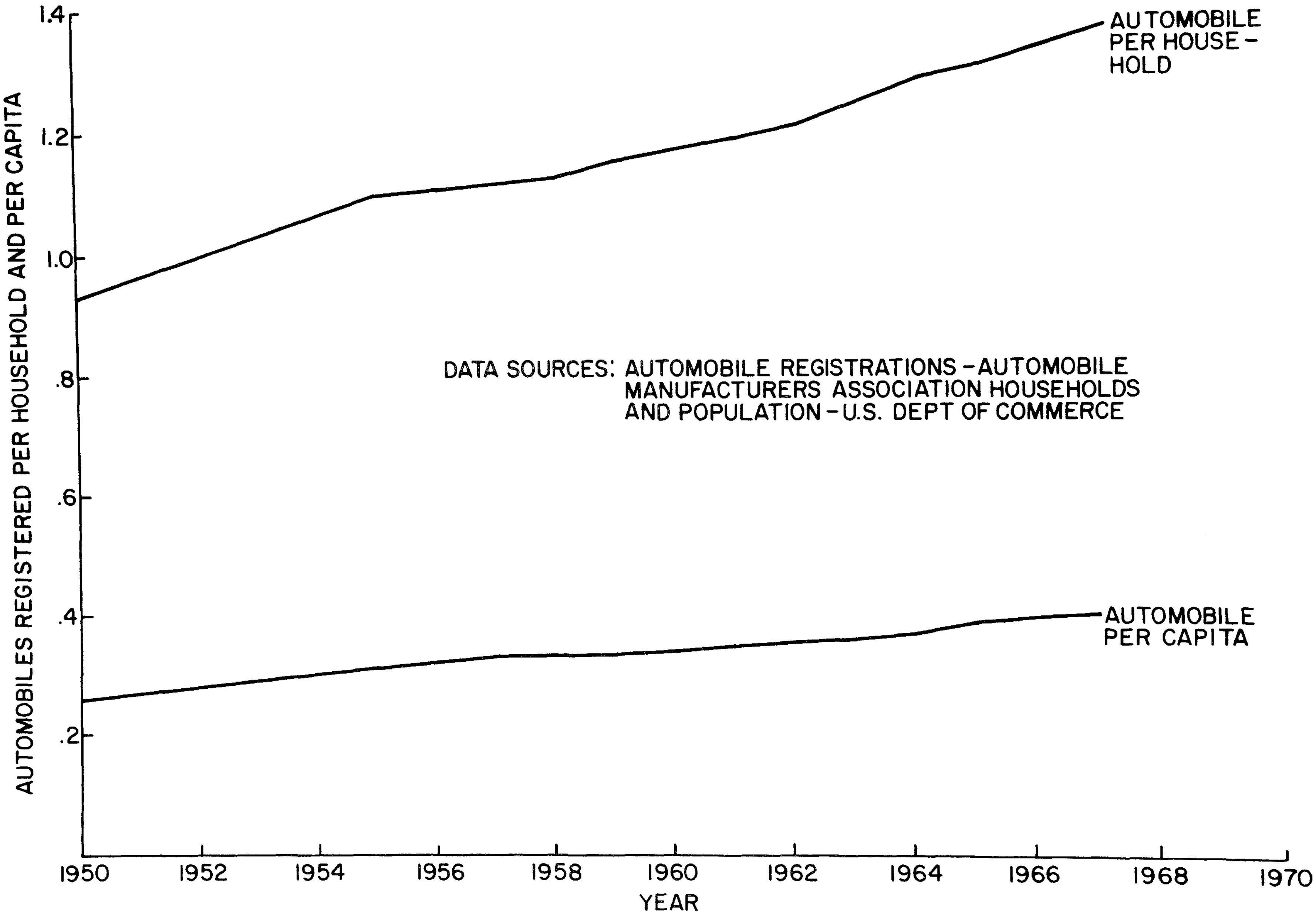

Fig. VI-11. Automobiles Per Household and Per Capita

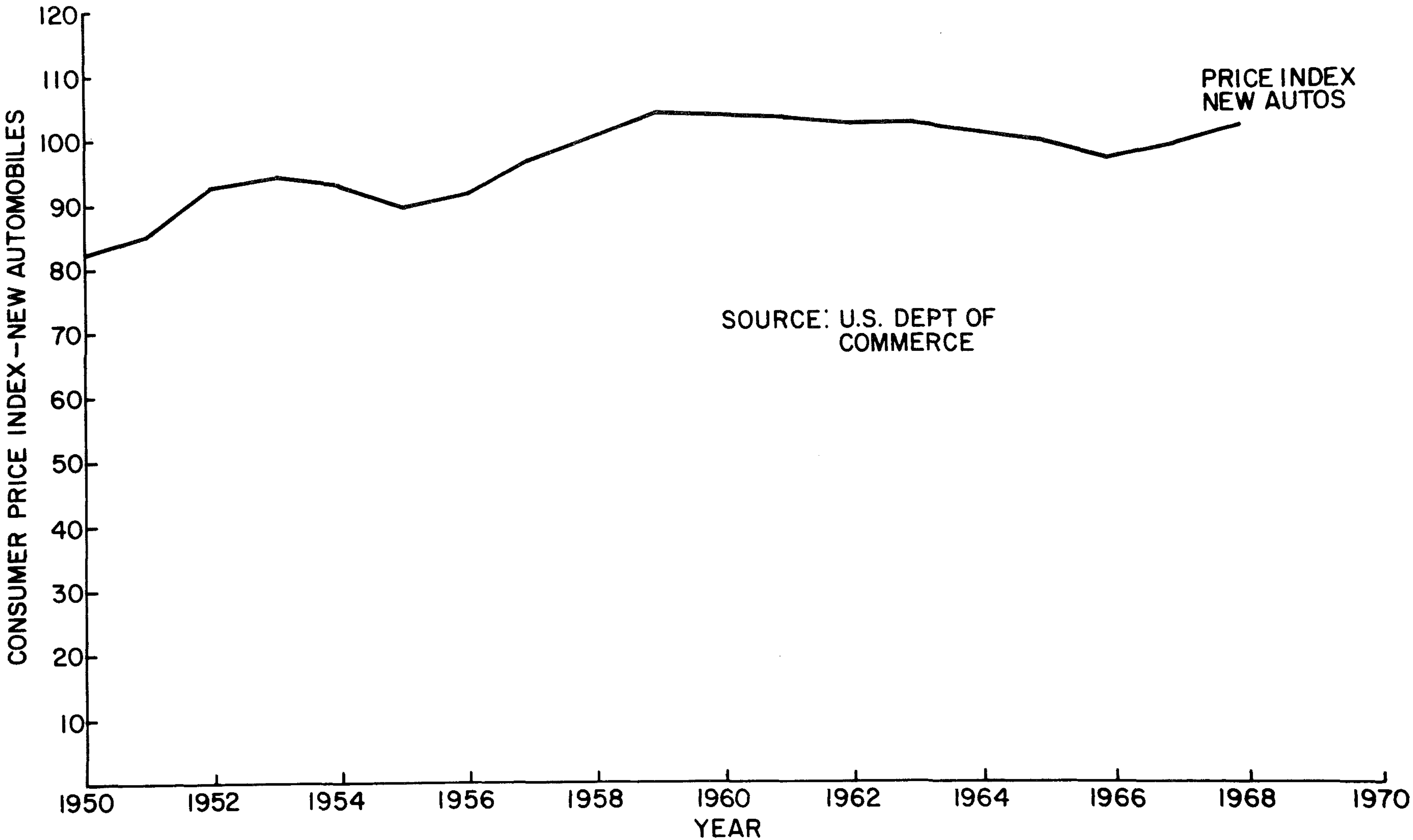

Fig. VI-12. Consumer Price Index for New Automobiles

APPENDIX VII

Bibliography

Appendix VII

Bibliography

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